REAL CORP 2025

Manfred SCHRENK, Tatiana POPOVICH, Peter ZEILE,
Pietro ELISEI, Clemens BEYER, Judith RYSER, Uwe TRATTNIG (Eds.)

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of the 30th International Conference on Urban Planning, Regional Development and Information Society

TAGUNGSBAND

URBAN INNOVATION
TO BOLDLY GO WHERE NO CITIES HAVE GONE BEFORE

MEDIUM SIZED CITIES AND TOWNS
AS A MAJOR ARENA OF GLOBAL URBANISATION

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REAL CORP 2025:
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Medium sized cities and towns as a major arena of global urbanisation

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Edited by

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PREFACE

Elke KAHR

Mayor of the City of Graz

Welcome to Graz!

As the Mayor of the City of Graz, I am very pleased that the 30th anniversary of the REAL CORP conference is taking place here in Graz, allowing us to welcome world-renowned experts from the fields of spatial planning, geoinformation, and related disciplines.

As the second largest city in Austria – in fact the largest city in the country if you count our capital city Vienna as a federal state – Graz sees itself as a medium-sized agglomeration in global terms, with just over 300,000 inhabitants, even when considering the functional urban region around Graz. We are therefore all the more pleased that this year's REAL CORP is focusing specifically on the challenges and needs of medium-sized cities. Unlike large cities, metropolitan areas, or capital cities, the framework conditions of medium-sized cities and their urban regions are unique.

This begins with their financial capacity and extends to the provision of central functions and services of general interest for the whole region. Urban morphologies are also less dense, yet the challenge under growth conditions is to make sensible and efficient use of the limited urban space available and to allow developments that improve or at least do not reduce the local quality of life.

In Graz, great emphasis is placed on ensuring a high quality of life and that the benefits of the city are accessible to all its residents. Graz is a diverse and culturally appealing city. It is crucial that living and housing costs remain affordable for the population and that social cohesion is highly valued. This commitment to inclusivity and affordability helps maintain the city's vibrant community spirit and ensures that everyone can enjoy the advantages of living in Graz.

REAL CORP participants will be exchanging knowledge and ideas on precisely these kinds of topics for the 30th time this year here in Graz. Current developments from the global to the local level will be discussed, and new ideas, partnerships, and projects will be developed. As a central science and business location in southern Austria, Graz has traditionally acted as a bridge to southern and southeastern Europe. For this reason, we are particularly pleased about event formats such as REAL CORP, which allow us to look beyond our own horizons and provide us with inspiration.

I wish you a successful conference and would be delighted if you take home a positive image of our city – and maybe come again.

PREFACE

Judith SCHWENTNER

Deputy Mayor of the City of Graz

Actively meeting the challenges of climate change

Climate change affects us all and is fundamentally changing our lives. It is essential that we respond to it in both small and large ways. A front garden with bee-friendly flowers may be a small measure, but it is just as important as international cooperation. Medium-sized cities like Graz in particular play a key role: they may not be as big as metropolises, but their large number and combined expertise means that together they can have an enormous impact. The exchange of experience and knowledge between these cities makes it possible to spread sustainable solutions globally.

Of course, the framework conditions and challenges differ from city to city. Graz holds the title of UNESCO World Heritage Site and therefore has a special responsibility to preserve its historic centre. At the same time, the city is growing rapidly, bringing new challenges in the areas of climate and health-oriented urban development, environmentally friendly mobility and the clean energy transition. However, Graz is actively facing up to these challenges and is resolutely committed to the fight against the climate crisis.

I am therefore all the more pleased that REAL CORP 2025 is taking place in Graz this year. As hosts, we have the opportunity to present our achievements while also discussing upcoming challenges with international experts from administration, science and business. I am looking forward to an inspiring exchange that will provide valuable impulses for the sustainable future of our beautiful city.

PREFACE

Harald GRIESSER

Styrian Government
Head of Provincial and Regional Development

Welcome to Styria!

Since my student years the REAL CORP conference – at that time a small event at TU Wien – has been the meeting place for discussions related to the topic of digitalisation in spatial planning. Many years later, topics such as digital planning processes, artificial intelligence in planning and the actual use of digital instruments have become part of our daily working routine.

Since the beginning REAL CORP has remained, developed and internationalized as a platform for lively scientific debates and inspiring interactions with colleagues from all over the world. At this event, you can still get a feel for the state of the art in regional planning and urban development and get a glimpse into the future "hot topics" of digital planning.

It is a special honour and pleasure for our province that REAL CORP is stopping in Styria this year. We hope that all participants will spend some interesting days in Graz. Above all, however, we hope that these days will convey to all participants the Styrian wayof life – halfway between the Alps and the Adriatic – and that this will be a reason to return, both professionally and privately.

PREFACE

Manfred SCHRENK,

Conference Director,
President CORP – Competence Center of Urban and Regional Planning

WELCOME to REAL CORP 2025, the 30th International Conference on Urban & Regional Development and Spatial Planning in the Information Society Technologies at the University of Applied Sciences Joanneum in Graz, Styria!

Not only is the world's population constantly growing, many cities around the globe are also subject to permanent growth, even in countries and regions with constant or even shrinking population numbers. Global urbanisation is not only creating new challenges in terms of infrastructure, mobility, housing and spatial planning, but especially in climate mitigation and adoption, in technological change – especially digitisation, in resilience towards multiple natural and man-made challenges and in inclusion and accessibility to improve the quality of life even under adverse conditions.

In world's megacities, such challenges have to be tackled on a large scale – with all the technical, organisational, administrative hurdles that have to be dealt with. What about medium-sized and smaller cities? Can they be faster, more flexible, more efficient than the "big tankers" when it comes to innovations? Can they lead the way to a bright future? Can they take us to solutions that help us to boldly go where no cities have gone before, especially when it comes to the criteria of sustainability, resilience and especially quality of life for the whole society? Can solutions developed on a smaller scale be upscaled to metropolises on the one hand and even trickle down to small cities and rural regions? Can measures be easily scaled up and down or do they require completely different approaches?

Traditionally we are keeping the range of topics at REAL CORP conferences very broad – as we are convinced that it is advantageous and necessary to use the conference to hear about other topics, to get inspired by similar and maybe totally different approaches and very important: getting to know experts and personalities with the same and also different professional, organisational, cultural backgrounds and networking with them – to possibly develop new ideas and – by URBAN INNOVATION help cities TO BOLDLY GO WHERE NO CITIES HAVE GONE BEFORE.

The success of the REAL CORP conferences is – clearly without doubt – the result of the efforts of participants, reviewers, and the conference organising team. We would like to acknowledge the Reviewer Team and Programme Committee members for their valueable voluntary help with the review process. Our thanks go as well to all 200 participants and authors of the submitted papers from 31 countries worldwide. The programme of this year's conference contain around 160 scientific contributions; 98 of them were selected after a double-blind, double-stage (for both abstracts and full papers) peer-review process for publication and presentation at REAL CORP 2025. The non-reviewed papers were accepted by the programme committee after a double-blind abstract review.

Welcome to Graz! Welcome to Styria! Have a great conference!

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Die Arbeiten geben die Erkenntnisse und Ansichten des jeweiligen Autors wieder
und müssen nicht mit den Ansichten der Herausgeber übereinstimmen.

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reviewed paper

A Bibliometric Analysis Mapping the Evolving Research Landscape of Homelessness and Urban Security

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1 ABSTRACT

The relationship between homelessness and urban security is a complex and multifaceted global issue. In many cities, visible homelessness can influence public perceptions of disorder and insecurity, perpetuating cycles of marginalization, criminalization, and social exclusion for those experiencing homelessness. At the same time, homelessness is often a direct consequence of insecurity, driven by factors such as violence, displacement, and economic instability. This study seeks to deepen the understanding of this intricate interplay by conducting a comprehensive bibliometric analysis of scholarly literature on homelessness and urban security. Utilizing the Scopus database and VOSviewer software, the research systematically investigates past, present, and emerging trends within this field. The analysis focuses on co-authorship networks, keyword co-occurrence patterns, and citation trajectories to achieve three primary objectives: (1) identify key research themes and trends, (2) map the intellectual structure of the field, and (3) pinpoint influential scholars and institutions shaping the discourse. The findings will offer critical insights into the current state of knowledge on homelessness and urban security, highlighting significant research gaps and underexplored areas. By uncovering the intellectual foundations and evolving priorities of this field, the study aims to inform future research directions and provide evidence-based recommendations for urban planning and policy development on a global scale. This work underscores the importance of addressing homelessness not merely as a social issue but as a critical component of urban security and sustainable urban development.

Keywords: homelessness, urban security, bibliometric analysis, Scopus database, urban planning

2 INTRODUCTION AND BACKGROUND

The relationship between homelessness and urban security is a complex and multifaceted global issue. In many cities, visible homelessness can influence public perceptions of disorder and insecurity, perpetuating cycles of marginalization, criminalization, and social exclusion for those experiencing homelessness. At the same time, homelessness is often a direct consequence of insecurity, driven by factors such as violence, displacement, and economic instability. This study seeks to deepen the understanding of this intricate interplay by conducting a comprehensive bibliometric analysis of scholarly literature on homelessness and urban security. Utilizing the Scopus database and VOSviewer software, the research systematically investigates past, present, and emerging trends within this field. The analysis focuses on co-authorship networks, keyword co-occurrence patterns, and citation trajectories to achieve three primary objectives: (1) identify key research themes and trends, (2) map the intellectual structure of the field, and (3) pinpoint influential scholars and institutions shaping the discourse. By uncovering the intellectual foundations and evolving priorities of this field, the study aims to inform future research directions and provide evidence-based recommendations for urban planning and policy development on a global scale.

This work underscores the importance of addressing homelessness not merely as a social issue but as a critical component of urban security and sustainable urban development. The significance of this study lies in its potential to provide critical insights into the intersection of homelessness and urban security, which remains an underexplored yet essential issue in contemporary urban research and policy-making. Homelessness is often perceived as a problem relegated to the margins of urban spaces, yet its impacts on both individuals and communities extend far beyond the personal hardships of those affected. By linking homelessness to urban security, this research brings attention to the broader socio-political and economic structures that contribute to urban vulnerability, marginalization, and exclusion. Furthermore, this paper aims to make a significant contribution to the field of homelessness and urban security by developing aconceptual

framework that deepens the understanding of the intricate and often underexplored relationship between these two critical urban issues.

3 GLOBAL PERSPECTIVES ON HOMELESSNESS AND URBAN SECURITY

Homelessness is a multi-dimensional problem that is deeply embedded within broader societal structures. It is often linked to issues such as poverty, unemployment, housing shortages, mental illness, substance abuse, and, crucially, urban policies that fail to address the needs of vulnerable populations (Fitzpatrick, 2018). In many cities, homelessness is seen through the lens of disorder and criminality, leading to stigmatization and the implementation of policies that criminalize homelessness rather than addressing its root causes. The dynamics of homelessness and urban security are shaped by multiple factors, including social, political, economic, and environmental influences, all of which contribute to the vulnerability and exclusion of homeless individuals (Sosin & Pollack, 2020).Globally, the challenge of homelessness is a pressing issue in both developed and developing nations. The United Nations has estimated that over 150 million people worldwide experience homelessness, with many more living in precarious housing situations (UN-Habitat, 2020). In cities across the globe, homelessness is a visible sign of urban inequality and insecurity, and it is often linked to rising levels of poverty, displacement, and conflict (Shinn & Khadduri, 2020). In the Global South, cities are grappling with rapid urbanization, slum development, and a lack of affordable housing, all of which contribute to high rates of homelessness (Afsar et al., 2020). Meanwhile, in the Global North, while homelessness rates may be lower, the visibility of homelessness in wealthy cities often exacerbates public concerns about disorder and crime, leading to more punitive measures against homeless populations (Chamberlain & MacKenzie, 2021).

For example, in the United States, homelessness is largely understood as a consequence of economic insecurity, with homelessness rates sharply rising during times of recession. The criminalization of homelessness is prevalent, with homeless individuals facing frequent arrests for “quality of life” offenses such as loitering or trespassing (Hopper, 2020). Similarly, in the United Kingdom, the rise in homelessness has been attributed to a combination of austerity policies, a lack of affordable housing, and cuts to social services (Pleace, 2019). The United Nations (2020) reports that homelessness is increasingly seen as a violation of human rights, with homeless people experiencing disproportionate levels of violence, abuse, and discrimination, further compounding their vulnerability in urban settings.In the Global South, the relationship between homelessness and urban security is particularly complex, with urban poverty and informal housing systems playing a central role. In African cities, the rapid growth of urban populations combined with inadequate urban planning has led to the proliferation of informal settlements and increased homelessness. In cities like Johannesburg and Nairobi, homelessness is often a direct result of economic displacement, lack of affordable housing, and the failure of governments to address the needs of marginalized populations (UN-Habitat, 2018). Informal settlements, which are characterized by inadequate housing, poor sanitation, and limited access to basic services, often become hotspots for insecurity and violence, further exacerbating the marginalization of homeless individuals (López-Morales, 2020).

Furthermore, in many African countries, economic instability and political violence have contributed to rising levels of displacement, both internally and across borders, creating a growing homeless population in urban centers (Hardoy et al., 2020). These conditions are compounded by the widespread criminalization of homelessness, as homeless individuals are often subjected to police harassment, forced eviction, and exclusion from public spaces, which only deepens their vulnerability (Lall, 2019). As a result, the intersection of homelessness and urban security in the Global South reflects a vicious cycle of marginalization, insecurity, and exclusion, which demands urgent attention from both policymakers and researchers. In South Africa, homelessness is a major urban challenge that reflects deep-rooted social and economic inequalities. The legacy of apartheid, which systematically excluded black South Africans from access to land, housing, and resources, has left a lasting impact on the urban landscape, particularly in major cities such as Johannesburg and Cape Town (Ntsimane, 2018). While South Africa has made significant strides in addressing housing needs through policies such as the Reconstruction and Development Programme (RDP), the country continues to face a growing homelessness crisis. This is largely due to factors such as rapid urbanization, inadequate public housing provision, and a rising unemployment rate (Statistics South Africa, 2020).

Homelessness in South African cities is also deeply intertwined with issues of urban security. In many urban areas, the presence of homeless individuals in public spaces is often viewed as a threat to security, leading to the criminalization and policing of homelessness (Olivier & Riemer, 2019). As public perceptions of insecurity rise, policymakers often resort to short-term, punitive measures such as the eviction of homeless people from public areas or the implementation of anti-loitering laws. These actions further contribute to the exclusion and stigmatization of homeless individuals, who are already vulnerable to violence and exploitation in urban spaces (Berg, 2021).Recent literature on homelessness and urban security highlights several key themes and emerging trends. One of the most prominent trends is the increasing recognition of homelessness as a human rights issue, with calls for policies that prioritize the dignity and well-being of homeless populations rather than focusing solely on criminalization (Fitzpatrick et al., 2013). Additionally, there is growing recognition of the role that urban planning and policy interventions can play in addressing homelessness, with researchers advocating for more inclusive and sustainable urban development models that prioritize affordable housing, public space access, and social services for marginalized communities (Turok, 2019).

However, despite these advancements, significant research gaps remain. There is a need for more studies that explore the relationship between homelessness and urban security in different geographical contexts, particularly in the Global South, where issues of displacement, informal settlements, and inadequate housing systems continue to drive homelessness. Moreover, the intersection of homelessness with other urban issues, such as crime, mental health, and substance abuse, remains underexplored and warrants further investigation.This is where this study intends to contribute.

4 METHODOLOGY

This study aims to deepen the understanding of the relationship between homelessness and urban security through a comprehensive bibliometric analysis of scholarly literature. The review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to ensure a rigorous and transparent process for selecting and analyzing relevant publications. A comprehensive search was conducted in the Scopus database on 11 February 2025, focusing on peer-reviewed journal articles, books, and conference papers. The key search terms used was“homelessness AND urban security". The Scopus database was selected as the primary source for this study due to its extensive coverage of peer-reviewed literature across various disciplines, including urban planning, architecture, sociology, and cultural studies (Bass et al., 2020). The process followed is detailed in the diagram below:

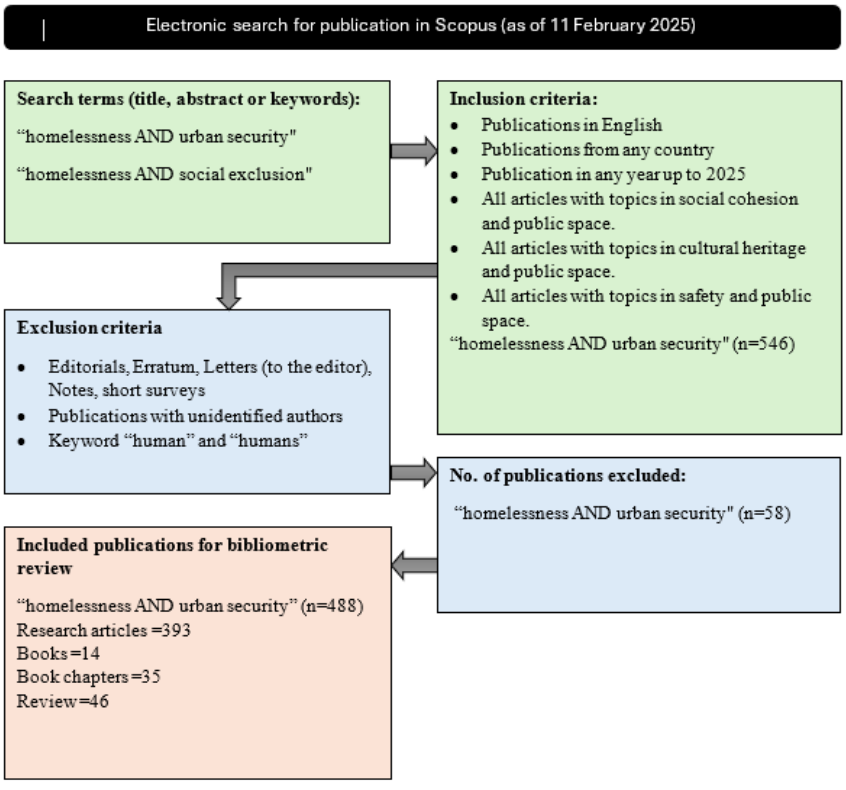


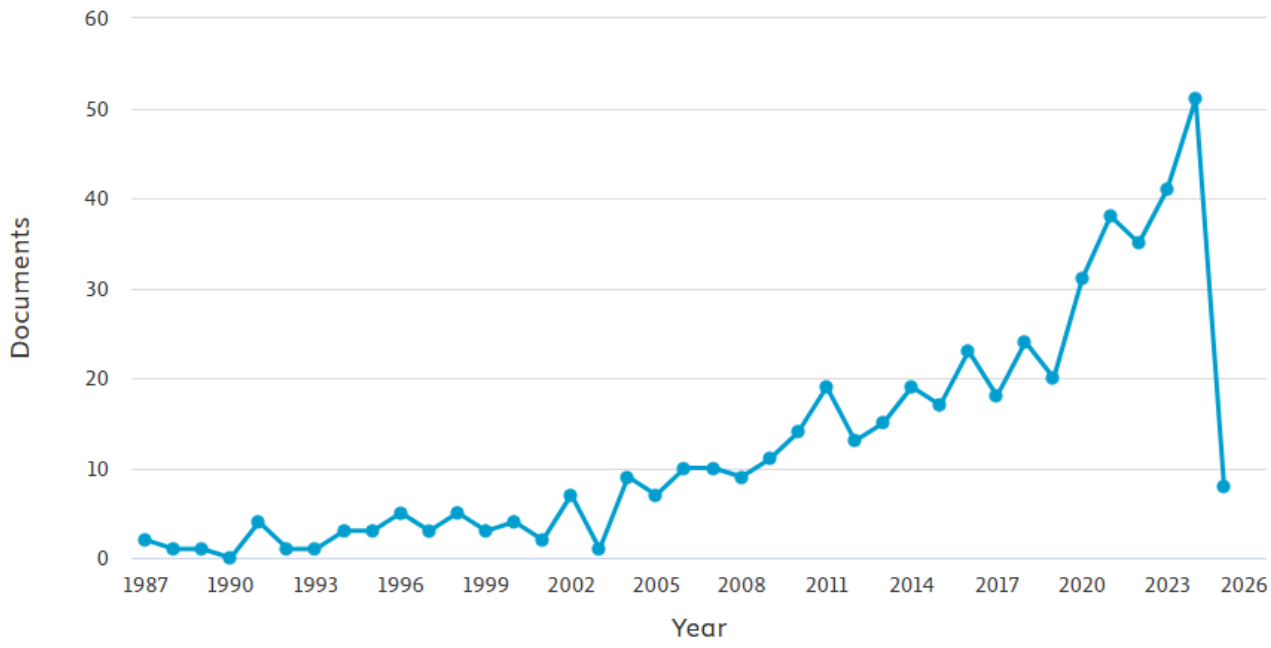
Figure 1: PRISMA flow diagram (Adapted from Moher et al. ,2016)

The initial searchyielded546publications on homelessness and urban security. After applyingtheinclusion and exclusion criteria, 58 publications were excluded, leaving a total of 488 eligible documents to beconsidered as part of the bibliometric analysis. VOSviewer was utilizedtoconductthebibliometricanalysis, as outlined in the figure below (Van Eck andWaltman, 2014).VOSvieweris a software tool that visually analyzes literature reviews, identifying trends, research foci, and key areas (Zhang et al., 2021). While other analysis tools like Citespace have been used in other studies, VOS viewer remains the preferred choice due to ist ability to handle large datasets and produce reliable results (Kalaoane et al., 2024).

5 RESULTS AND DISCUSSIONS OF THE BIBLIOMETRIC ANALYSIS

5.1 Publication trends

The graph representing publication trends on homelessness and urban security over nearly four decades reveals distinct fluctuations that warrant careful examination. From 1987 to the early 2000s, the number of publications in this field remained relatively low, indicating a nascent stage of research output. The early years of this period could reflect the challenges associated with the study of homelessness and urban security, both of which are complex, multifaceted issues often shaped by socio-economic, political, and cultural factors (Pritzker & Pascoe, 2020). During this time, homelessness was likely treated as a peripheral issue within urban studies, and research on the topic may not have been as prioritized or funded as other urban phenomena (United Nations, 2019).



However, from 2002 onwards, there is a notable surge in the number of publications, suggesting a significant shift in the research landscape. This escalation could be attributed to several factors. Firstly, an increase in research funding dedicated to urban studies and social issues, such as homelessness, likely played a significant role in this growth. Increased interest in urban security and homelessness can also be linked to technological advancements in data collection and analysis, which enabled researchers to study these issues more effectively (Fink & Freedman, 2022). For instance, the availability of satellite imagery, social media data, and geographic information systems (GIS) may have provided new insights into the spatial distribution of homelessness and urban safety, fueling academic interest (Fink & Freedman, 2022). Additionally, the early 2000s coincided with a heightened global awareness of social inequalities and urban poverty, which would have led to increased public and governmental interest in homelessness (Pritzker & Pascoe, 2020).

Moreover, international organizations such as the United Nations and the World Bank began publishing extensive reports on urbanization and poverty, contributing to a more focused academic and policy-driven dialogue on urban security and homelessness. This increased focus on policy relevance and the importance of addressing homelessness through systemic change likely spurred more researchers to engage with the

issue (United Nations, 2019). The significant rise in publications during this period is thus likely a result of a combination of institutional support, technological advancements, and a broader social agenda centered on poverty alleviation and social justice (Pritzker & Pascoe, 2020).The graph also reveals a plateau in publications after the initial surge, followed by a further escalation, reflecting the continued expansion of research in this area. This could point to an increased institutional recognition of the need for research on urban security as cities around the world faced growing challenges related to homelessness, particularly as urbanization rates soared. Researchers may have been spurred by the need for evidence-based policy solutions in the face of ongoing urbanization and the global housing crisis, as well as increasing concerns about social instability and security in metropolitan regions (Fink & Freedman, 2022).

Nevertheless, the most recent data point reveals a sharp decline in publications, which presents a critical opportunity for further inquiry into potential contributing factors. Several explanations can be posited for this downturn. One possible factor could be a shift in research priorities, where funding bodies and academic institutions may have reoriented their focus toward other pressing global issues, such as climate change, pandemics, or economic crises (Fink & Freedman, 2022). Moreover, the decline may reflect the limitations of existing funding sources, which could have been affected by global economic downturns, leading to fewer resources available for research on homelessness and urban security.A potential, albeit significant, factor in this decline could be the disruption caused by the COVID-19 pandemic. The pandemic caused widespread interruptions to academic research across all fields, with many research projects delayed, paused, or canceled entirely. Homelessness became an even more pressing issue during the pandemic as vulnerable populations were disproportionately affected by the virus, leading to an influx of governmental and NGO interventions. However, the pandemic may have also reshaped the research agenda, drawing attention away from long-standing issues and towards the immediate public health crisis, further compounding the decline in publications (Fink & Freedman, 2022).

5.2 Keyword Analysis

The network visualization presented provides a powerful tool for understanding the intricate relationships between key concepts related to homelessness and urban security. The map's structure, where nodes represent individual concepts and edges denote their co-occurrence, offers a snapshot of how these issues are interconnected. By identifying clusters of related themes, such as housing, food security, and demographic factors, the map facilitates a comprehensive view of the multifaceted nature of homelessness and urban security.

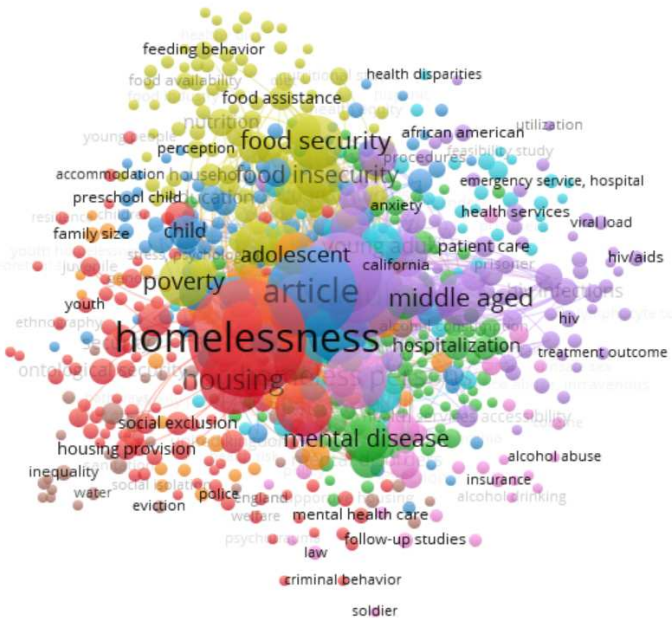


Figure 2: A co-occurrence network analysis of keywords on homelessness and urban security research.

The analysis emphasizes the prominence of central nodes such as "homelessness," "mental disease," "food security," and "poverty," noting their role as key themes that bridge multiple aspects of social vulnerability. These findings align with existing literature that highlights how homelessness, mental health issues, and

poverty form a cycle of disadvantage, reinforcing each other and exacerbating the challenges faced by vulnerable populations (Desmond & Shyr, 2014). The interconnections between these nodes are significant because they underscore the complexity of these issues. For instance, homelessness is not only a housing issue but is deeply entwined with mental health disorders and poverty, as individuals experiencing homelessness are more likely to suffer from mental health conditions and face greater barriers to economic mobility. While the centrality of these concepts is valid and reflective of current research, the network visualization may also oversimplify the intricate dynamics at play. It is crucial to consider that these relationships are not always linear or static. For example, the link between homelessness and mental health is well-established, but the nature of this relationship can vary depending on individual circumstances, such as the duration of homelessness, access to mental health services, and the presence of other social supports (Padgett et al., 2016). The visualization's inability to capture the directionality or causal pathways between nodes limits its ability to fully represent the complexity of these interactions.

The map's inclusion of food security as a central concept further illustrates the interconnectedness of social determinants. Research indicates that food insecurity is not only a consequence of poverty but also a driver of poor health outcomes, particularly for marginalized groups (Gundersen et al., 2018). The co-occurrence of food security with homelessness and mental health reflects this cyclical vulnerability, where inadequate access to nutritious food exacerbates both physical and mental health conditions, further entrenching poverty and homelessness. However, the visualization may not adequately account for the role of food assistance programs and social safety nets in mitigating these impacts. The connections in the map suggest a relationship between food security and food availability, but they do not offer insights into the effectiveness of interventions such as food banks or government programs in alleviating food insecurity. The presence of demographic factors, such as "African American," "adolescent," "child," and "middle-aged," is a critical aspect of the visualization, drawing attention to the disproportionate impact of these issues on specific populations. This aligns with extensive research on the social determinants of health, which highlights how race, age, and socio-economic status intersect to create unique vulnerabilities (Kawachi et al., 2017). For example, African Americans are more likely to experience homelessness and food insecurity, which can be attributed to historical and structural inequalities in access to resources and opportunities. The inclusion of these demographic factors is vital for informing targeted, equity-focused interventions, but the network map may not fully capture the intersectionality of these populations. A more nuanced approach might consider how overlapping identities – such as race, gender, and disability – shape individuals' experiences of homelessness and urban insecurity.

Furthermore, the visualization's focus on healthcare access and utilization is crucial for understanding how these social vulnerabilities impact health outcomes. As highlighted in the analysis, healthcare access is a key determinant of well-being for those experiencing homelessness or food insecurity. However, the map does not delve into the specific barriers to healthcare that these populations face, such as lack of insurance, transportation issues, or stigma. A more detailed examination of healthcare access could reveal important insights into how systemic barriers exacerbate health disparities among these vulnerable groups. From an urban planning perspective, this analysis is important as planners are tasked with addressing multifaceted issues, such as housing insecurity, poverty, food security, and healthcare access, all of which are interlinked and have profound implications for public health and social equity (Kawachi et al., 2017). By understanding these interconnections, planners can design more holistic and inclusive urban policies and infrastructure that address the root causes of homelessness and urban insecurity.

5.3 Top countries and scholars publishing research on homelessness and urban security

The analysis of publication trends on homelessness and urban security reveals significant variation across countries, with some nations exhibiting higher output and influence in this field. The United States stands as the dominant contributor, with 214 publications, 5243 citations, and the highest total link strength (26). This prominence can be attributed to the scale of homelessness in American cities, where the issue has been the focus of extensive academic and policy attention. The U.S. has numerous research institutions and a well-funded research environment, with government bodies like the U.S. Department of Housing and Urban Development (HUD) driving major studies on homelessness. Furthermore, the "Housing First" model has become a leading intervention, stimulating substantial academic and policy discourse (Padgett et al., 2016). Canada's rising output (78 publications, 2102 citations, and a total link strength of 19) also reflects a strong

policy focus on affordable housing, poverty reduction, and homelessness prevention. The Canadian government's National Housing Strategy, launched in 2017, further fueled interest in the issue, with scholars addressing the intersections of homelessness, mental health, and housing affordability, particularly among marginalized groups such as Indigenous communities (Gaetz et al., 2019).

Country	Documents	Citations	Total link strength
United States	214	5243	26
Canada	78	2102	19
Australia	66	749	13
United Kingdom	45	907	10
France	9	83	7
Netherlands	10	75	7
Ireland	11	65	6
Germany	7	27	5

Australia ranks third with 66 publications, 749 citations, and a total link strength of 13. In Australia, research on homelessness has gained momentum as urban areas such as Sydney and Melbourne have faced housing affordability crises. Researchers in Australia have focused on the resilience of urban areas, the impact of welfare systems, and the role of social safety nets in addressing homelessness. The increasing attention to climate change's impact on homelessness, particularly in Australian cities, has further propelled this research (Beer et al., 2011). The United Kingdom, with 45 publications, 907 citations, and a total link strength of 10, has similarly been a key player in the field. The UK's focus on housing instability, welfare reform, and austerity measures has led to significant academic contributions, exploring the link between housing policies, homelessness, and social exclusion (Pleace et al., 2019). Despite its lower citation count compared to the U.S. and Canada, the UK continues to influence international research on urban housing markets and homelessness prevention.Smaller contributors to the global research landscape include France, the Netherlands, Ireland, and Germany. France (9 publications, 83 citations, and a total link strength of 7) has a more centralized welfare approach, which may contribute to the lower visibility of homelessness in research. However, the issue has gained increasing attention in urban areas like Paris, with scholars investigating housing policies and the effectiveness of homelessness interventions (Baptista, 2015). The Netherlands (10 publications, 75 citations, and a total link strength of 7) also has a robust social safety net, leading to a relatively lower research output on homelessness, but a growing focus on housing issues in cities like Amsterdam is evident.

Similarly, Ireland's research on homelessness has intensified in response to the housing crisis, particularly following the 2008 financial crisis, which led to rising housing costs and increasing visibility of homelessness (Hennessy & Neri, 2019). Germany (7 publications, 27 citations, and a total link strength of 5) has comparatively low levels of visible homelessness due to its public housing system, but rising concerns over housing affordability in cities like Berlin have led to growing interest in urban housing and homelessness research (Wolch et al., 2014).The dominance of countries like the United States, Canada, and Australia in publications on homelessness and urban security is driven by the high visibility of homelessness in major urban centers, the scale of the problem, and significant funding directed toward social policy research. These countries are actively engaged in policy experimentation and international collaborations, contributing to the high citation counts. Conversely, countries such as France, the Netherlands, Ireland, and Germany, with lower publication outputs, have policies that have traditionally been more effective in mitigating homelessness, which may explain the more recent emergence of academic interest in these nations. However, the increasing citation counts in these countries signal a growing recognition of homelessness as a critical urban issue, and future research from these regions is expected to expand as urban vulnerabilities rise globally.

The analysis of top authors in publications on homelessness and urban security reveals diverse themes and research focuses that shape our understanding of the issue. The authors listed are contributing to the body of work that addresses the social, economic, and health-related aspects of homelessness, urban security, and vulnerability. Some of the key themes explored by these scholars include health outcomes, interventions, housing policies, and demographic disparities, all critical to urban planning and social policy.Catherine Hastings explores the social determinants of homelessness, particularly housing instability and its connection to public health, with a focus on race, gender, and economic status (Hastings, 2013). Stephen W. Hwang examines the health risks associated with homelessness, emphasizing mental health and chronic conditions, and advocating for integrated care models (Hwang, 2001). Thomas Kerr investigates policy interventions, especially housing-first strategies, and their effects on homelessness (Kerr et al., 2013), while Paula Mayock

addresses the gendered dimensions of homelessness, particularly for young people and women (Mayock et al., 2014). Cameron Parsell focuses on housing policy and the stigma surrounding homelessness, advocating for integrated services and public education (Parsell, 2018). Marc I. Rosen and Robert Rosenheck explore the relationship between homelessness, mental health, and substance abuse, with a particular focus on institutional and veteran-related issues (Rosen et al., 2012; Rosenheck et al., 2013). Chery Smith emphasizes the role of social determinants of health, including housing and healthcare access (Smith, 2010), while Wendy Stone examines the socio-legal aspects of homelessness, highlighting the importance of legal frameworks and protections for homeless individuals (Stone, 2015). These authors' work collectively informs policy and interventions aimed at addressing the multifaceted nature of homelessness.

Author	Documents	Citations
Catherine Hastings	4	19
Stephen W. Hwang	4	84
Thomas Kerr	5	135
Paula Mayock	4	14
Cameron Parsell	4	42
Marc I. Rosen	6	76
Robert Rosenheck	4	88
Chery Smith	5	199
Wendy Stone	4	27

6 CONCLUSION AND RECCOMENDATIONS: TOWARDS A HOMELESSNESS AND URBAN SECURITY CONCEPTUAL FRAMEWORK

Considering the key themes and research gaps from the bibliometric analysis. A conceptual framework is proposed in order to deepen the understanding of the intricate and often underexplored relationship between these two critical urban issues.The key components of the framework are:housing instability and security, social determinants of health and well-being, the role of policy interventions, intersectionality and vulnerable populations, urban safety and crime prevention and healthcare access and urban security. Homelessness and urban security are interconnected urban challenges that, though often studied separately, share overlapping factors. This framework explores the complex relationship between these issues, highlighting how housing instability, social determinants of health, policy interventions, and urban safety influence vulnerable populations. Housing instability is central, as inadequate housing and poor conditions contribute to both homelessness and urban insecurity (Hwang, 2001; Desmond, 2016). Social determinants like income inequality, access to healthcare, and social exclusion further exacerbate vulnerabilities, making homeless individuals more susceptible to crime and violence (Gundersen et al., 2018; Rosenheck, 2013).

Policy interventions, including housing-first models, are critical in addressing homelessness and improving security, while policies criminalizing homelessness can worsen urban insecurity (Kerr et al., 2013; Smith, 2010). Intersectionality is key in understanding how race, gender, and other factors shape experiences of homelessness and security, requiring tailored interventions for different vulnerable groups (Mayock et al., 2014; Rosenheck et al., 2013). Urban safety concerns, such as crime and stigmatization, are also intertwined with homelessness, necessitating a balanced approach that addresses both causes and effects (Rosen, 2012; Desmond & Shyr, 2014). Finally, improving healthcare access for the homeless, particularly mental health and substance abuse treatment, is essential for enhancing both individual well-being and urban security (Hwang, 2001). The framework presents these elements as interconnected components, with housing instability at the center, linked to social factors, policies, and public safety.

In conclusion, this study has explored the multifaceted nature of homelessness and urban security, proposing a comprehensive conceptual framework that incorporates various dimensions such as housing instability, mental health, poverty, policy interventions, and intersectionality. By integrating these factors, the framework highlights the complex, interconnected nature of homelessness and emphasizes the importance of a holistic, integrated approach to addressing this pressing urban issue. The findings from the bibliometric analysis underscore the critical role of health, policy, and social determinants in shaping homelessness outcomes, aligning well with the proposed framework. Furthermore, addressing homelessness requires more than just providing shelter; it demands a systemic approach that integrates housing solutions with healthcare, social services, and supportive policies. Urban planning must prioritize affordable housing, targeted interventions for vulnerable populations, and multi-agency collaboration to create supportive environments for the homeless. Research in this area should continue to explore the effectiveness of policy interventions and the lived experiences of marginalized groups to refine approaches that promote long-term solutions.By adopting the recommendations derived from this framework, cities can make meaningful strides in reducing homelessness, enhancing urban security, and ensuring that all residents have access to the resources they need for a dignified and secure life. This study contributes to a deeper understanding of the structural factors driving homelessness and offers actionable insights for both policy and practice, with the potential to influence urban planning and research directions in the future.

6.1 Practical applications of the bibliometric review and future directions

The bibliometric analysis of homelessness and urban security offers significant practical insights beyond fulfilling formal scientific publication criteria. By systematically mapping the evolution of research trends, thematic networks, and influential contributions, this analysis provides an empirical foundation for understanding the intellectual landscape of homelessness and urban security. Importantly, it highlights key knowledge gaps, emerging themes, and policy-relevant discussions that can inform future research, urban planning strategies, and governance frameworks. One of the primary contributions of this bibliometric analysis is its ability to trace the historical trajectory of research on homelessness and urban security. The identification of shifts in publication trends, particularly the surge in research output after 2002, underscores the growing recognition of homelessness as a critical urban issue influenced by policy shifts, technological advancements, and global socio-economic transformations (Pritzker & Pascoe, 2020; United Nations, 2019). These shifts are particularly relevant to urban planning, where historical insights help policymakers and planners understand how previous interventions have shaped contemporary urban challenges. For instance, neoliberal urban policies have played a crucial role in shaping homelessness through processes of gentrification, exclusionary zoning, and the privatization of public spaces (Smith, 2002; Lees, 2014). By demonstrating how these external factors shape scholarly attention, the analysis contributes to a deeper understanding of the interplay between research, policy, and urban governance. Furthermore, the observed decline in recent publications raises important questions about shifts in research funding, academic priorities, and the impact of global crises, such as the COVID-19 pandemic, on knowledge production (Fink & Freedman, 2022). This is particularly critical for urban planning, as the pandemic has exacerbated housing insecurity and challenged traditional planning paradigms. The need for resilient, inclusive, and equitable urban policies has become more pressing than ever, making continued research on homelessness and urban security a necessity rather than an academic afterthought (Bhan et al., 2020).

The keyword analysis further strengthens the practical relevance of this study by revealing thematic interconnections that are essential for evidence-based policymaking and urban planning. By identifying

dominant themes such as housing insecurity, mental health, food security, and urban crime, the analysis underscores the complexity of homelessness as a multidimensional phenomenon (Desmond & Shyr, 2014; Padgett et al., 2016). This co-occurrence mapping is particularly valuable for urban planners, who must navigate the interdependence of social, economic, and environmental factors when designing cities. Incorporating themes such as "housing insecurity" and "urban crime" into planning strategies enables the development of holistic, place-based interventions that extend beyond traditional approaches like emergency shelters or policing. For example, the rise of "Housing First" policies, which prioritize stable housing as a prerequisite for addressing other social issues, aligns with the recognition that secure, affordable, and well-integrated housing solutions are more effective than punitive or temporary measures (Tsemberis, 2010). The keyword analysis also points to the importance of mixed-use developments, public space activation, and pedestrian-friendly urban design in fostering inclusive urban environments that reduce homelessness-related vulnerabilities (Gehl, 2011).

Another critical contribution of this bibliometric review lies in its analysis of national and institutional research trends. The dominance of publications from the United States, Canada, and Australia highlights the role of national policy frameworks, research funding, and institutional capacities in shaping knowledge production (Gaetz et al., 2019; Padgett et al., 2016). This geographic mapping is crucial for urban planning because it exposes disparities in research attention and policy innovation. While cities in the Global North have implemented advanced urban design interventions – such as inclusive zoning laws, transit-oriented development, and social housing programs – many urban centers in the Global South continue to grapple with informal settlements, inadequate infrastructure, and limited research capacity (Parnell & Pieterse, 2014). Understanding these global trends is vital for urban planners, particularly in cities with high levels of informality, where conventional planning approaches may not be applicable. For example, African cities like Johannesburg and Nairobi require urban strategies that integrate informal settlements into formal planning frameworks rather than perpetuating exclusionary policies that displace vulnerable populations (Huchzermeyer, 2011). Insights from this bibliometric analysis can therefore guide comparative urban policy studies, fostering cross-regional learning and adaptive planning strategies that prioritize housing justice and inclusive urban design.

The bibliometric analysis also provides a foundation for conceptual advancements by informing the development of an integrated framework for homelessness and urban security. The proposed conceptual model, which includes dimensions such as housing instability, social determinants of health, policy interventions, and urban crime prevention, offers a structured approach for future research and policy formulation. This theoretical contribution goes beyond mere documentation of existing research trends by synthesizing fragmented knowledge into a cohesive analytical framework (Hwang, 2001; Gundersen et al., 2018). For urban planners, such a framework can serve as a tool for designing inclusive urban policies that account for the socio-spatial dynamics of homelessness. The framework emphasizes the importance of participatory planning, where affected communities are actively involved in decision-making processes related to housing and public space management (Healey, 1997). Additionally, it reinforces the role of spatial justice – ensuring that marginalized populations have equitable access to urban resources, mobility networks, and social infrastructure (Soja, 2010).

Finally, the analysis enhances knowledge translation by making complex academic trends accessible to non-academic stakeholders, including urban planners, policymakers, and community organizations. Given that planners often operate within politically charged environments, where economic interests and social justice goals may conflict, having empirically grounded insights is crucial for advocating progressive urban policies. In conclusion, while bibliometric analyses are sometimes critiqued for being purely formal exercises, this study demonstrates substantial added value in terms of content and practical relevance to urban planning. It provides a historical perspective on research evolution, identifies critical thematic linkages, maps global research contributions, proposes a conceptual framework, and enhances knowledge accessibility for urban planners and policymakers. As homelessness and urban security remain pressing global issues, such analyses are essential in guiding future research agendas, fostering interdisciplinary collaboration, and informing evidence-based urban planning interventions.

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🏆 reviewed paper

A Bibliometric Analysis of the Literature on Affordable Housing and Segregation in Johannesburg

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1 ABSTRACT

Affordable housing remains a crucial factor in addressing spatial inequality and fostering inclusive urban development in Johannesburg, a city that continues to grapple with issues rooted in its apartheid legacy, including persistent socio-economic divides, inadequate infrastructure, and entrenched spatial segregation. This paper provides a comprehensive literature analysis on the challenges and approaches to affordable housing, highlighting critical insights from existing research and the implications for social integration and spatial equity.

Utilising a mixed-methods approach, the study focuses on a thorough literature review and a bibliometric analysis to contextualise the historical and contemporary challenges of housing equity. It examines policy shortcomings and socio-economic barriers that limit access to adequate housing, particularly for marginalised communities in informal settlements and low-income areas. Programs like the Reconstruction and Development Programme (RDP) and Breaking New Ground (BNG) have sought to tackle these issues but often fall short of overcoming economic disparities and the spatial disconnect between affordable housing developments and economic opportunities. The bibliometric analysis further highlights trends and gaps in current research, underscoring the urgent need for innovative, community-driven housing solutions to effectively combat segregation and promote social cohesion in urban environments.

Keywords: Affordable Housing, Urban Segregation, Spatial Inequality, Inclusive Urban Development, Community-driven Solutions

2 INTRODUCTION

Johannesburg, South Africa's economic hub, continues to grapple with entrenched spatial inequality and urban segregation. These challenges are deeply rooted in the city's apartheid history, which established racially divided neighborhoods with stark disparities in access to resources, infrastructure, and economic opportunities (Turok, 2016). Despite post-apartheid efforts to integrate urban spaces, socio-economic divides persist, with low-income communities often relegated to the urban periphery (Charlton & Kihato, 2006). The lack of affordable housing in well-located areas exacerbates these issues, forcing many low-income residents to seek accommodation in informal settlements or overcrowded dwellings with inadequate infrastructure. This continued marginalisation limits their access to essential services, employment opportunities, and quality education, perpetuating cycles of poverty and exclusion.

Addressing these issues requires a targeted approach that provides affordable housing and ensures that these developments are integrated within the broader urban fabric, allowing for sustainable and inclusive city growth. This study serves as an analysis of the existing literature regarding affordable housing in Johannesburg, contextualising historical and contemporary challenges while exploring the systemic barriers and socio-economic factors that shape access to equitable housing. Affordable housing is a crucial mechanism for redressing historical injustices and fostering inclusive urban development. By providing low- and middle-income households with stable and well-located housing, the city can break cycles of poverty and segregation, enabling better access to employment, education, and social services (Harrison & Todes, 2015). However, achieving this requires policy innovation and sustainable urban planning efforts.

3 LITERATURE REVIEW

3.1 Historical Context: Apartheid-Era Spatial Planning and Its Legacy

Apartheid (1948–1994) fundamentally shaped Johannesburg's urban landscape through deliberate spatial segregation along racial lines. Black South Africans were systematically confined to underdeveloped townships, often far removed from economic centers and opportunities (Mabin & Smit, 1997). The

cornerstone of this segregation was the Group Areas Act (1950), which legally formalised racial zoning and led to the forced removal of millions of people. This act created a deeply entrenched spatial inequality that continues to impact Johannesburg today (Bremner, 2000). Beyond simply restricting land access, the apartheid regime implemented policies that systematically marginalised Black communities, denying them access to adequate housing, basic infrastructure like sanitation and electricity, and essential services such as healthcare and education (Parnell & Pieterse, 2010). The legacy of this exclusion is starkly visible in many former townships, which still struggle with poor connectivity to Johannesburg's economic nodes, limited access to quality education and healthcare, and persistent poverty. These historical injustices continue to shape contemporary urban planning challenges, with affordable housing recognised as a crucial tool for bridging these spatial and socio-economic divides.

The apartheid government's planning agenda was explicitly designed to prioritise the economic interests of the white minority. This resulted in the systematic neglect of the housing needs of Black South Africans, leading to severe infrastructural deficits and poor service delivery in townships like Soweto, Alexandra, and Tembisa (Christopher, 2001). The fragmentation of urban space was further compounded by policies that severely restricted homeownership and property rights for non-white citizens, further exacerbating existing socio-economic disparities. Even after the dismantling of apartheid-era legislation, the spatial and economic consequences of these policies have proven remarkably resilient. Post-apartheid urban restructuring initiatives have sought to redress these imbalances, but progress has been hampered by deeply entrenched structural inequalities, limited financial resources, and the sheer scale of the historical damage (Harrison & Todes, 2015).

3.2 Current Housing Policies and Programs: RDP, BNG, and Their Limitations

Following the transition to democracy in 1994, the South African government launched the Reconstruction and Development Programme (RDP) as a comprehensive strategy to address the massive housing backlog and provide low-cost housing for historically disadvantaged citizens (Tomlinson, 1999). While the RDP achieved significant success in delivering millions of housing units, it has also faced criticism for inadvertently reinforcing apartheid-era spatial patterns. Many RDP developments were located on the periphery of cities, far from employment opportunities and social amenities, replicating the spatial isolation of the past (Huchzermeyer, 2003). Furthermore, the standardised, low-density design of RDP housing often proved inadequate for accommodating the rapid growth of the urban population, contributing to overcrowding and the emergence of informal settlements adjacent to these developments.

In response to these shortcomings, the government introduced the Breaking New Ground (BNG) policy in 2004. BNG aimed to promote the development of integrated, sustainable human settlements by prioritising mixed-income housing developments and urban densification (Department of Human Settlements, 2004). The policy sought to move away from the mass production of standardised RDP houses and towards the creation of more integrated and sustainable communities. However, the implementation of BNG has encountered numerous challenges. Inadequate funding, persistent socio-economic inequalities, and complex bureaucratic processes have limited its overall impact (Charlton, 2009). Many BNG projects have struggled to attract middle-income residents, resulting in the continued spatial disconnection and socio-economic isolation of low-income communities. The availability of suitable urban land and the high cost of land in well-located areas have also posed significant obstacles, hindering the program's ability to develop affordable housing in prime urban locations and perpetuating urban segregation rather than reversing it. While BNG emphasises housing quality over quantity, financial and logistical barriers have hampered its large-scale implementation (Tissington, 2013).

3.3 Socio-Economic Barriers to Affordable Housing Access

Access to affordable housing in Johannesburg is constrained by a complex interplay of socio-economic factors:

- Income Disparities: A significant portion of the population, particularly low-income households, does not qualify for housing finance from banks or government subsidies, leaving them trapped in informal settlements or overcrowded and often exploitative rental housing (Napier, 2007). The wide gap between government-subsidised housing and market-rate housing creates a "missing middle" where many working-class families are excluded from accessing adequate accommodation.

- Land and Infrastructure Costs: The high cost of land in well-located urban areas, coupled with existing infrastructure deficits, makes it extremely challenging to develop affordable housing in central locations (Biermann & Van Ryneveld, 2007). This economic reality often pushes developers to construct affordable housing in peripheral areas with limited access to economic opportunities, further reinforcing spatial segregation and limiting social mobility.
- Administrative and Bureaucratic Hurdles: Lengthy and often opaque approval processes, coupled with instances of corruption and inefficiencies within housing allocation systems, significantly delay the delivery of affordable housing (Lemanski, 2011). Many low-income applicants face years of waiting lists and bureaucratic hurdles, leading to frustration and contributing to the continued growth of informal settlements.
- Lack of Effective Public-Private Collaboration: Successful affordable housing initiatives often depend on strong partnerships between government entities and private developers. However, in Johannesburg, limited collaboration, misaligned incentives, and a lack of trust between the public and private sectors have slowed the pace of development and hindered innovation in affordable housing solutions (Harrison, 2006).

3.4 The Role of Affordable Housing in Social and Economic Integration

Affordable housing plays a crucial role in reversing the spatial legacy of apartheid and fostering social and economic integration. Well-located affordable housing developments can enhance economic mobility by providing low-income residents with better access to employment opportunities, education, and other essential services. By locating affordable housing near economic hubs and transport networks, residents can reduce their commuting costs and time, freeing up resources and enabling greater participation in the city's economy. Furthermore, innovative housing solutions such as inclusionary zoning, cooperative housing models, and well-structured public-private partnerships can facilitate the integration of diverse income groups and create more socially cohesive neighborhoods (Parnell & Pieterse, 2010). Strategies such as densification, strategic urban land reform, and progressive housing policies can further support this integration, moving Johannesburg towards a more equitable and inclusive urban environment. The provision of affordable housing is not simply about providing shelter; it is about building a more just and integrated society.

4 CASE STUDIES FROM GLOBAL AND LOCAL CONTEXT

Examining successful affordable housing initiatives globally and locally provides valuable insights into how Johannesburg can improve its housing policies and programs.

4.1 Global Case Studies

4.1.1 Inclusionary Zoning Policies (United States, Canada, and the UK)

Cities such as New York, London, and Toronto have implemented inclusionary zoning policies that require private developers to allocate a percentage of new housing units for low- and moderate-income residents (Been et al., 2018; Moore & Bunce, 2009). This approach fosters social integration and ensures that affordable housing is distributed throughout the city rather than being concentrated in low-income areas (Mukhija et al., 2010).

4.1.2 Transit-Oriented Development (Singapore and Curitiba, Brazil)

In Singapore, public housing is integrated with mass transit systems, ensuring that residents have easy access to employment and social services (Yuen, 2007). Similarly, Curitiba's Bus Rapid Transit (BRT) system has helped create affordable, well-connected housing developments, demonstrating the importance of linking housing with transportation infrastructure (Cervero, 1998; Rabinovitch, 1996).

4.1.3 Cooperative Housing Models (Switzerland and Uruguay)

Switzerland's cooperative housing system provides an alternative to government-subsidised housing by encouraging community-driven development projects (Lang & Stober, 2021). Similarly, Uruguay’s self-managed housing cooperatives empower residents to participate in the design, financing, and management of their homes, leading to more sustainable and inclusive communities (Arruabarrena & Lanzaro, 2016).

4.2 Local Case Studies

4.2.1 Cosmo City, Johannesburg

One of South Africa's few successful integrated housing developments, Cosmo City combines subsidised, bonded, and rental housing within the same neighborhood (Bénit-Gbaffou, 2018). This mixed-income model has helped foster social cohesion and economic opportunities, though challenges such as infrastructure maintenance and service delivery persist (Charlton, 2018).

4.2.2 Savannah City, Gauteng

This large-scale mixed-income housing development aims to address spatial inequality by providing affordable housing options close to employment hubs and transportation networks (Turok & Borel-Saladin, 2018). The project emphasises urban densification and sustainable planning but faces financial and administrative constraints (Cirolia et al., 2021).

4.2.3 The Johannesburg Social Housing Company (JOSHCO)

JOSHCO has been instrumental in providing affordable rental housing in well-located urban areas (Tomlinson, 2017). By repurposing underutilised buildings and promoting social housing initiatives, JOSHCO demonstrates the potential of adaptive reuse strategies in addressing the city's housing crisis (Mosselson, 2019).

5 METHODOLOGY

5.1 Mixed-Methods Approach

This research utilised a mixed-methods approach, integrating a comprehensive review of existing literature with a bibliometric analysis. This combined methodology allows for a robust exploration of post-disaster housing solutions, merging qualitative insights gleaned from scholarly works with quantitative data-driven analysis (Johnson & Onwuegbuzie, 2004).

5.1.1 Literature Review

The literature review serves to contextualise the historical and contemporary challenges of housing equity in Johannesburg, South Africa. It explores systemic barriers, policy limitations, and socio-economic constraints that impact equitable access to adequate housing, particularly for marginalised communities in informal settlements and low-income areas (Turok, 2016). By analysing key policy documents, academic articles, and government reports, this review critically examines the successes and shortcomings of major housing programs such as the Reconstruction and Development Programme (RDP) and Breaking New Ground (BNG) (Department of Human Settlements, 2004). It is important to emphasise that the findings presented in this section are based on existing literature rather than new fieldwork or direct policy recommendations related to housing development.

5.1.2 Bibliometric Analysis

A bibliometric analysis, a rigorous quantitative approach for analysing large datasets, was employed to explore the knowledge structure and visually map the field of "social equity in housing" within the specific context of Johannesburg. This analysis focuses on existing scholarly publications to elucidate trends and gaps in research concerning affordable housing and social equity. The data collection process involved searching and extracting relevant publications from Scopus, a widely recognised bibliographic database. The search terms included "social equity in housing," "Johannesburg," "affordable housing Johannesburg," "housing policy," and "housing inequality Johannesburg." Publications spanning the years 2017 to 2025 were considered for inclusion in the analysis. The bibliometric analysis was conducted using a specialised tool called VOSviewer to map co-authorship networks, citation relationships, and thematic clusters, thereby illustrating the intellectual and social structures of research on affordable housing and social equity in Johannesburg. As with the literature review, it is crucial to note that the findings derived from this analysis reflect existing literature, focusing on the evolution of research rather than proposing new fieldwork or direct policy changes.

5.2 Research Questions

Guided by the overarching goal of understanding systemic barriers and potential solutions to affordable housing in Johannesburg, the study addresses the following key research questions:

(1) What are the dominant conceptual frameworks used to understand social equity in housing in this context?

(2) What constitutes the intellectual structure of this field, as evidenced by key publications and influential authors?

(3) How is the social structure of research on this topic configured, including collaborations and networks?

(4) How does the body of knowledge specifically addressing Johannesburg contribute to broader understandings of social equity in housing?

By integrating qualitative and quantitative approaches, this study aims to offer a holistic perspective on the role of affordable housing in fostering social and economic integration in Johannesburg. The mixed-methods approach ensures a nuanced understanding of both theoretical frameworks and empirical trends, enabling the formulation of evidence-based policy recommendations for more inclusive and equitable urban development.

6 RESULTS, ANALYSIS, AND DISCUSSION

6.1 Key Insights from the Literature Review

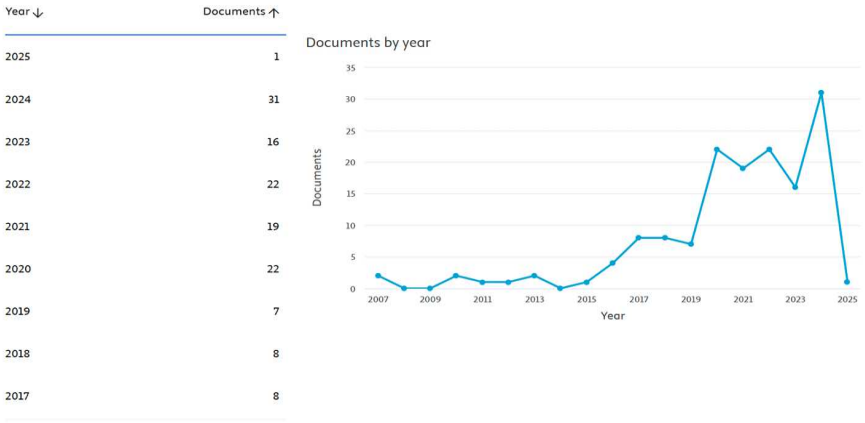
The literature review highlights several critical insights into the state of affordable housing in Johannesburg, drawing from existing scholarly work. A key theme is the persistent spatial segregation, a legacy of apartheid-era planning policies that continue to marginalise low-income communities. Despite post-apartheid housing policies such as the Reconstruction and Development Programme (RDP) and Breaking New Ground (BNG), affordable housing developments remain concentrated on the urban periphery, limiting access to economic hubs and essential services. While these policies have increased housing stock, they have not fully integrated low-income earners into mixed-income developments, reinforcing socio-economic divides. Additionally, the literature identifies structural inefficiencies such as bureaucratic delays, limited funding, and land scarcity in prime locations as major obstacles to achieving housing equity.

Another key insight is the critical role of community-driven approaches in fostering sustainable and inclusive urban development. Research suggests that active community involvement in housing initiatives leads to more sustainable outcomes better aligned with residents' needs. Collaborative urban planning, incorporating public-private partnerships and community engagement, is essential to overcoming the challenges posed by current housing models. Furthermore, the literature underscores the need for policy reforms that promote urban densification, transit-oriented development, and the integration of social services within affordable housing projects. These strategies can enhance economic mobility and social cohesion, addressing the limitations of existing housing frameworks. It is important to note that these findings stem from a comprehensive evaluation of existing research rather than new fieldwork.

6.2 Analysis of Annual Publications

The first data set focuses on the number of publications in the research field annually, illustrating how research trends have evolved significantly between 2007 and 2025. Figure 1 reveals distinct phases in the development of scholarly interest in affordable housing. The Foundational Phase (2007–2011) shows minimal activity, likely reflecting the early stages of research on affordable housing, with a focus on traditional approaches and limited exploration of complex housing challenges or sustainable housing solutions. This transitions into the Emerging Interest Phase (2012–2016), marked by a slight but steady increase, possibly driven by Johannesburg's growing urbanisation and early mixed-income housing initiatives like Cosmo City, which began shaping debates on housing integration and sustainability. The Growth Phase (2017–2019) highlights a shift toward applied studies addressing urban challenges, including housing, infrastructure, and environmental management. A Significant Surge (2020–2024) follows, with research output increasing dramatically, particularly during the COVID-19 pandemic, which exposed urban vulnerabilities and heightened interest in smart infrastructure, social inclusion, and sustainability. The peak in 2024 underscores an intensified focus on urban renewal and housing integration. This analysis, derived from existing studies, reflects prevailing scholarly trends rather than novel research outcomes, illustrating

how socio-economic shifts and a growing emphasis on sustainability have influenced the research landscape over time.



Year	Documents
2025	1
2024	31
2023	16
2022	22
2021	19
2020	22
2019	7
2018	8
2017	8

Figure 1: Graph depicting the publication trend of the topic area between 2007 and 2025.

6.3 Knowledge Evolution in the Field

The intellectual knowledge structure of the urban planning and housing integration field is reflected through

The intellectual knowledge structure of urban planning and housing integration is reflected through an analysis of research output trends, revealing the evolution of key concepts and thematic focus areas over time. By examining published documents, we can identify foundational periods of limited exploration, followed by thematic diversification and significant shifts driven by urban challenges and societal needs. Early research focused on traditional urban planning approaches, while later phases emphasised mixed-income housing integration, sustainability, smart infrastructure, and urban renewal. Key themes such as affordability, spatial inequality, and policy effectiveness have gained prominence, shaped by factors like rapid urbanisation and the COVID-19 pandemic. These shifts underscore how external influences drive scholarly focus and critical debates, shaping the field's future direction.

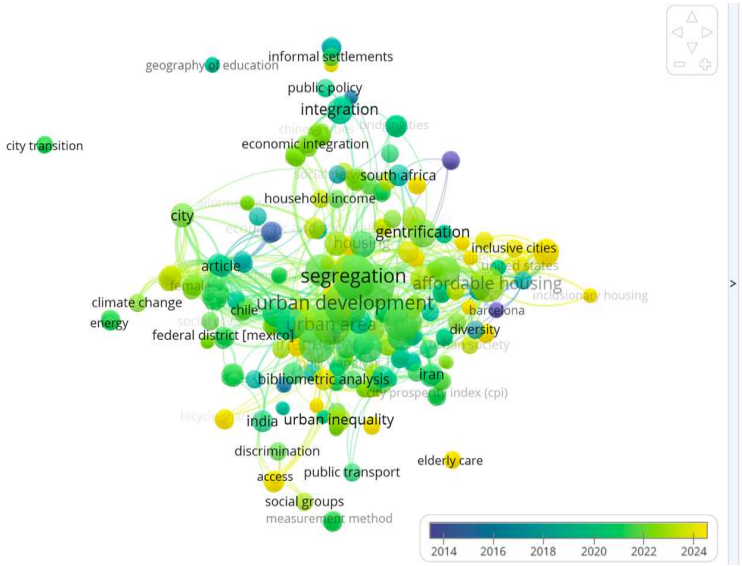


Figure 2: Visualised network map of research themes, overlay between 2014 and 2024 (10-year period) to understand the

Conceptual Structure

The dataset, which was second to be analysed for the study, focused on keyword co-occurrences. Referenced from the upward trend from the dataset, which was previously analysed and comprises research publications that were released between 2007 to 2025. It is evident that there is demand in this particular research field, and that explains the increase and upward trend over the years. There is also clear evidence that there is demand where the keyword variables are concerned. In the process of sorting the data, 540 keywords were exported from the Scopus database. For a minimum number of occurrences of a keyword being 5, of the 540

keywords, 19 met the threshold. For a minimum number of occurrences of a keyword being 4, of the 540 keywords, 26 met the threshold. For a minimum number of occurrences of a keyword being 3, of the 540 keywords, 44 met the threshold. For a minimum number of occurrences of a keyword being 2, of the 540 keywords, 115 met the threshold. All the above were insufficient as the main keywords used in this study did not all appear on the list. For a minimum number of occurrences of a keyword being 1, of the 540 keywords, all 540 keywords met the threshold. This turned out to be the best dataset to work with, as all of the required keywords appeared on the list consisting of 540 keywords.

Trajectory of research themes

540 keywords were gathered through the all keywords unit of analysis for the co-occurrence analysis type as having appeared in 66 readings which were extracted from SCOPUS. The keywords selected in this data set are they key words that are from or are closely linked to the main keywords used in this study.

KEYWORDS	OCCURRENCES	TOTAL LINK STRENGTH
Afdordable Housing	10	94
Community	1	18
Urban Segregation	1	39
Spatial Inequality	3	36
Urban Development	18	211
Inclusion	1	13

Table 1: The top 5 keywords in the research network

Intellectual Structure

To delve into the intellectual structure of affordable housing research in Johannesburg, a co-citation analysis was employed. This method, as described by Small (1973), examines the frequency with which two documents are cited together, revealing intellectual connections and mapping the knowledge structure of the field. By analysing author and document coupling, the co-citation analysis aimed to identify influential works that have shaped the discourse, discern emerging research clusters representing key thematic trends, and understand the evolution of ideas within this interdisciplinary area of study. This approach allows for a deeper understanding of how foundational research informs current investigations and highlights potential areas for future scholarly inquiry.

Document Co-Citation Analysis

A document co-citation analysis was conducted to map the intellectual landscape of affordable housing research in Johannesburg and identify influential works that have shaped the discourse. Utilising the Scopus database, 6,162 cited references were examined. A 50% threshold was applied, focusing on the 3,081 most frequently cited references to balance comprehensiveness and analytical manageability. This decision was made to include a substantial portion of highly cited works while maintaining a manageable dataset for analysis. Alternative thresholds 2, 3, and 4 were considered but were restrictive as they excluded potentially influential works and were too limiting, making analysis unwieldy. The resulting co-citation network was visualised using VOSviewer, revealing key thematic clusters that represent distinct areas of inquiry within the field.

These clusters encompassed topics such as:

- Spatial Segregation and Apartheid Legacy: Examining the historical roots of spatial inequality and the enduring impact of apartheid-era planning policies on access to affordable housing (Mabin & Smit, 1997; Turok, 2016).
- Policy Analysis and Critique: Analysing the effectiveness and limitations of post-apartheid housing policies and programs, such as the RDP and BNG, and their impact on spatial integration (Huchzermeyer, 2003; Tomlinson, 1999).
- Socio-Economic Barriers: Investigating the complex interplay of factors, including income disparities, land costs, and bureaucratic hurdles, that constrain access to affordable housing (Charlton & Kihato, 2006; Napier, 2007).
- Community-Driven Solutions: Exploring the role of community participation and collaborative planning in developing sustainable and inclusive housing initiatives (Parnell & Pieterse, 2010).

Several influential works emerged from the analysis, indicating foundational contributions that have significantly shaped the field. For instance, Turok's (2016) work on urban development in Africa suggests its

pivotal role in understanding the broader context of urban challenges and the role of affordable housing within it. Similarly, Napier (2007) underscores its enduring impact on income disparities and inequality. Harrison (2015) highlights its significance in shaping discussions around community participation and sustainable housing solutions that will indeed reduce segregation.

These frequently co-cited publications represent seminal texts and landmark studies that have significantly influenced subsequent research and practice in affordable housing in Johannesburg. By identifying these core works, thematic clusters, and the intellectual connections between them, the document co-citation analysis contributes to a deeper understanding of the evolution and current state of affordable housing research in Johannesburg, ultimately informing future research directions and policy interventions aimed at improving housing equity and integration.

Author Co-Citation Analysis

For this dataset, for a minimum number of citations of cited references being 4 and 5, out of the 6162 cited references, only 3 meet the threshold for both. This was not considered as the threshold was very limiting and would give results that are limited and not dependable. For a minimum number of citations of a cited reference being 3, out of 6162 cited references, 14 met the threshold, which was also not sufficient as that forms a mere 0.23% of the total number of cited references. For a minimum number of citations of cited references at a value of 2, 6162 cited references, 126 met the threshold. This was also not considered as this data excluded a number of documents with a high citation rate. Therefore, a minimum number of citations being 1, out of 6162 cited references, 6162 met the threshold and were considered. The chosen number of cited references was made to be 50%, which is 3081 cited references. A data set of 3081 references is large but better to work with compared to the total, which is 6162. Increasing it from 3081 to 6162 would make the analysis process very time-consuming and tedious. Out of the 3081 cited references, the top 10 of the highest citations were chosen as this is an indicator that these authors are really good or quite influential in the research area that this paper is focusing on.

Figure 3: Visualised document co-citation network map of affordable housing and segregation

Co-authorship Analysis

Co-authorship analysis is crucial for exploring the collaborative dynamics within a research field. It reveals networks and partnerships among scholars, institutions, and countries, providing valuable insights into how knowledge is co-produced and disseminated (Newman, 2001). By examining co-authorship patterns, researchers can identify key contributors, influential collaborations, and emerging research communities (Glänzel & Schubert, 2004). In this dataset, for a minimum number of documents of an author being 1 and a minimum number of citations of an author being 1, of the 172 authors, all 172 met the threshold. This was the perfect threshold as it was not limiting.

The table below shows co-authorship amongst authors. The selection of authors in this database was based on the number of citations being the determining factor of authors that were chosen.

Author	Documents	Citations	Total Link Strength
mcgranahan, gordon	1	95	2
schensul, daniel	1	95	2
singh, gayatri	1	95	2
audirac, ivonne	1	79	1
bonakdar, ahmad	1	79	1

Table 2: Co-authors with the highest citations

Analysis of Country Collaboration

Within the body of knowledge, there has to be an understanding of the impact that global collaboration has on the research area. It is also of importance to know and understand the influence of different authors on a global scale as this carries weight in terms of contribution. In this segment of the study, the top five clusters consisting of collaborations will be discussed. The highest rate of collaboration comes from 2 clusters being clusters 1 and 2. Cluster 1 has a total of 19 joint publications between Belgium, China, Erasmus University Rotterdam, Hong Kong, and the Netherlands. Clusters 1 and 2 have a tie as cluster 2 also consists of 19 joint publications between Chile, Colombia, France, Mexico, and the United States. In second place is Cluster 5, with 15 joint publications between Nigeria, South Africa, and the United Kingdom. In third place is Cluster 3, with a total of 6 joint publications between Germany and Switzerland, and in last place is Cluster 7, with a total of 4 joint publications between Estonia and Poland.

Global Network Knowledge

The analysis conducted throughout this study reveals a significant amount of global research activity in the field of affordable housing. This is evidenced by the participation of countries representing diverse continents, some of which may not have experienced severe housing crises directly. However, their engagement suggests a proactive approach to preparedness and resilience, recognising the unpredictable nature of housing challenges and the importance of a robust knowledge base. This aligns with the broader understanding of housing as a fundamental human right and a crucial component of sustainable development, as articulated by the United Nations in its Sustainable Development Goals (UN-Habitat, 2016).

This global research engagement reflects a commitment to proactive planning, with nations investing in understanding and addressing housing disparities even in the absence of immediate crises. The interconnectedness of academic networks facilitates cross-border knowledge sharing, enabling countries to learn from the experiences of others, particularly those facing persistent housing challenges (Castells, 2010). This exchange of knowledge is crucial for developing context-specific solutions and adapting best practices to local conditions. Furthermore, the growing recognition of the crucial role of adequate housing in social and economic development has driven global collaboration, as nations understand that housing issues have far-reaching societal impacts (Massey & Denton, 1993).

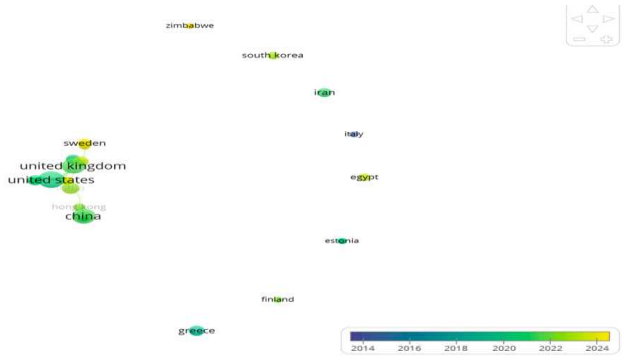


Figure 4: Visualisation of Global collaboration (country collaboration network)

This visualisation depicts international research collaborations on segregation and affordable housing, revealing a network dominated by the United States and the United Kingdom, as evidenced by their large node sizes and numerous connections. China also emerges as a significant player, indicating its growing research capacity and engagement in this field. The presence of other nations, including Sweden, Italy, Iran, South Korea, Egypt, Estonia, Finland, Greece, Hong Kong, and Zimbabwe, suggests a broadening global interest in this topic, extending beyond traditional research centers. The color gradient, spanning from 2014 to 2024, hints at the temporal evolution of these collaborations, with further analysis needed to pinpoint specific periods of increased activity or the emergence of new partnerships. This network structure facilitates

potential knowledge transfer between regions, allowing countries with varying experiences in addressing segregation and affordable housing to learn from one another. Connecting this visualisation to the previously analysed publication trends and examining the specific content of these collaborations would provide a more comprehensive understanding of the global research landscape and its relevance to the challenges faced by Johannesburg.

7 CONCLUSION

This study has explored the complex intersection of affordable housing, spatial inequality, and urban segregation in Johannesburg, utilising a mixed-methods approach encompassing a comprehensive literature review and a bibliometric analysis. The literature review contextualised the historical and contemporary challenges, tracing the roots of segregation to apartheid-era planning and examining the limitations of post-apartheid housing policies like the RDP and BNG. It highlighted the persistent socio-economic barriers hindering access to affordable housing and underscored the crucial role of community-driven approaches in fostering social and economic integration. The bibliometric analysis, including publication trend analysis, keyword co-occurrence mapping, and co-citation analysis, provided a quantitative lens through which to examine the evolution of research in this field. The analysis revealed a growing body of scholarship, with key themes emerging around spatial segregation, policy critique, socio-economic barriers, and community-driven solutions. Influential works and collaborative networks were identified, showcasing the intellectual and social structure of the research landscape. Furthermore, the analysis of country collaboration highlighted the global nature of this challenge and the importance of international knowledge exchange. Ultimately, this study reinforces the urgent need for innovative, community-driven affordable housing solutions in Johannesburg to combat segregation, promote social cohesion, and create a more equitable and inclusive urban environment. The findings presented here offer valuable insights for policymakers, urban planners, and community stakeholders working toward a future where affordable housing serves as a cornerstone for dismantling segregation and fostering sustainable urban development.

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🏆 reviewed paper

A Bibliometric Review of Global Research Trends on Designing Inclusive Public Spaces

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1 ABSTRACT

This bibliometric review examines global and international research trends on designing inclusive public spaces, with a focus on participatory approaches to improving accessibility and inclusivity in marginalized areas. Utilizing bibliometric analysis through VOSviewer, the study identifies key themes, methodologies, and conceptual frameworks shaping the discourse on inclusive urban design. It explores the influence of international guidelines, such as the United Nations' Sustainable Development Goals and Universal Design Principles, in driving innovative approaches to urban accessibility and participatory planning. The review maps collaboration networks, keyword co-occurrences, and citation trends to provide a comprehensive understanding of the global research landscape. Case studies from diverse geographical contexts illustrate how participatory practices have been adapted to address unique social, cultural, and economic challenges. By situating South African townships within this global research framework, the paper highlights opportunities and challenges in applying international best practices to local contexts. This study contributes to the broader dialogue on inclusive urban development by synthesizing global research insights and offering recommendations for future applications in marginalized areas.

Keywords: Sustainable Development Goals, Participatory Urban Design, Inclusive Public Spaces, Bibliometric review, Planning

2 INTRODUCTION AND BACKGROUND

The design of inclusive public spaces has become a critical focus in contemporary urban development, reflecting global efforts to create environments that are accessible, equitable, and responsive to diverse user needs. International frameworks such as the United Nations' Sustainable Development Goals (SDGs), particularly Goal 11, emphasize the importance of inclusive, safe, and sustainable cities. Additionally, the principles of Universal Design advocate for spaces that accommodate all individuals, ensuring social integration and spatial justice. However, despite growing international discourse on urban inclusivity, there remains a significant gap in understanding how participatory design approaches are shaping this field and how they can be effectively adapted to marginalized and historically underserved communities. A key challenge in advancing inclusive urban development lies in the fragmented understanding of global research trends on participatory urban design. While existing studies highlight the benefits of participatory planning in fostering inclusivity (Keeton, 2020), there has been no comprehensive bibliometric analysis of how research in this field has evolved over time. Furthermore, much of the scholarship on inclusive public spaces has been concentrated in high-income countries, with limited attention to low-income and informal urban settings, particularly in the Global South.

In South Africa, case studies such as Asiye eTafuleni in Durban (Lees & Dobson, 2021) and community-led placemaking initiatives in townships (Mafame & Horn, 2025) have demonstrated the transformative potential of participatory design. However, a systematic review of global research trends and how they inform local implementation remains underexplored. This study fills a critical gap by conducting a bibliometric review of global research trends on designing inclusive public spaces, focusing on participatory approaches. Unlike previous research that examines individual case studies or conceptual frameworks in isolation, this study will provide a data-driven synthesis of the dominant themes, methodologies, and collaborative networks shaping the discourse. By utilizing bibliometric tools such as VOSviewer, the study will map global research clusters, analyze key citation patterns, and explore the influence of international frameworks such as the SDGs and Universal Design Principles on scholarly output. The primary objective of this study is to conduct a bibliometric review to systematically map global research trends on participatory approaches to designing inclusive public spaces. In addition to mapping global research trends, this study intends to develop a conceptual framework based on the insights derived from the bibliometric analysis. By systematically

reviewing the dominant themes, methodologies, and theoretical underpinnings identified in the literature, the study will synthesize key principles that define participatory approaches to designing inclusive public spaces. This conceptual framework will serve as a structured lens for understanding how participatory urban design can be effectively implemented, particularly in marginalized areas such as South African townships. It will integrate global best practices with localized contextual factors, offering a model that can guide future research and policy interventions. Ultimately, the framework will provide a foundation for scholars, urban planners, and policymakers to critically engage with participatory design principles in ways that are adaptable, inclusive, and responsive to diverse urban challenges.

3 GLOBAL PERSPECTIVES ON INCLUSIVE PUBLIC SPACE DESIGN

The discourse on inclusive public spaces has gained momentum in global urban development, driven by frameworks such as the United Nations' Sustainable Development Goals (SDGs), particularly Goal 11, which calls for inclusive, safe, resilient, and sustainable cities (United Nations, 2015). The concept of universal design has also played a crucial role in shaping urban accessibility, emphasizing the need for environments that accommodate all individuals, regardless of their physical, cognitive, or social abilities (Imrie and Luck, 2021). Scholarly work highlights that participatory approaches to urban design are essential for fostering inclusivity, ensuring that public spaces reflect the needs and experiences of diverse users (Aelbrecht and Stevens, 2020). Participatory design methods, such as co-design workshops and citizen assemblies, have been increasingly integrated into urban planning processes to promote democratic engagement and social equity (Gehl, 2021). Research by Buser et al. (2021) emphasizes that participatory urbanism enhances spatial justice by allowing underrepresented groups to influence decision-making processes in public space development. Barcelona's Superblocks project is a leading global example of inclusive public space transformation. Initially implemented in response to urban congestion and pollution, this initiative reclaims street space for pedestrians, cyclists, and public activities (Rueda, 2020). The participatory planning approach involved consultations with local residents to ensure the redesigned spaces met the needs of different user groups, including people with disabilities, elderly residents, and children. The project demonstrates how inclusive urban design, combined with participatory governance, can enhance public space accessibility and social cohesion.

Despite the progress made, global studies acknowledge the challenges of sustaining participatory approaches in urban development, particularly in rapidly urbanizing regions where socio-economic disparities persist (Watson, 2020). These challenges necessitate context-specific strategies that align global best practices with local urban realities. n the African context, inclusive public space design is increasingly recognized as a key strategy for addressing spatial inequalities and historical legacies of segregation (Pieterse, 2021). Many cities across the continent face challenges related to informality, inadequate infrastructure, and exclusionary urban policies that limit access to well-designed public spaces for marginalized populations (Harrison, 2020). Participatory urban design in Africa is often linked to grassroots initiatives that empower local communities to take an active role in shaping their environments (Turok & Scheba, 2021). The concept of "placemaking" has been particularly influential in African cities, fostering collective ownership of public spaces through bottom-up interventions. The Nairobi Greenline Project, a collaborative initiative between civil society organizations and the Nairobi City Council, is an example of inclusive public space creation in Africa. The project aimed to restore and preserve green spaces in the city while providing recreational areas for diverse socio-economic groups (Mwau & Smit, 2020). By engaging local communities in tree-planting activities, design workshops, and decision-making processes, the initiative successfully integrated participatory methods into urban green space development. This case underscores the importance of community involvement in fostering inclusive and sustainable public spaces in African cities. Despite such efforts, urban development policies in many African cities remain top-down, limiting the extent to which participatory approaches can be institutionalized in formal planning processes (Parnell & Robinson, 2021). This calls for a rethinking of governance models to better incorporate local knowledge and grassroots activism in urban planning.

In the context of South Africa, urban landscape remains deeply shaped by apartheid-era spatial planning, which resulted in highly segregated and unequal cities (Todes et al., 2020). While post-apartheid policies have sought to promote spatial integration and inclusive urban development, many public spaces, particularly in townships and informal settlements, continue to suffer from neglect, poor infrastructure, and inadequate

safety measures (Landman, 2021). Participatory approaches to urban design have gained traction in South Africa as a means of addressing historical spatial injustices and fostering more inclusive city-making (Charlton & Meth, 2021). However, these efforts have often been challenged by bureaucratic inefficiencies, limited funding, and a lack of institutional support for grassroots initiatives (Bremner, 2020). A good case study of participatory urbanism that is community-centric is the example that was made reference to in earlier parts of this paper, namely Asiye eTafuleni which is a non-profit ogranisation in the City of Ethekweni, also known as Durban in the Kwa-Zulu Natal province of South Africa. The name Asiye eTafuleni is an isiZulu phrase that translates to "bringing to the table" in english. The name reflects the organization's mission of inclusivity and participation, particularly in advocating for the rights and needs of marganalized communities. The organization has successfully implemented participatory planning initiatives to improve informal trading spaces and public areas for marginalized communities. Working closely with street traders, the initiative has developed co-designed infrastructure, such as shaded trading stalls, public seating, and improved pedestrian pathways (Dobson & Skinner, 2020). By centering the voices of informal workers in the design process, Asiye eTafuleni has demonstrated the potential of participatory urbanism in fostering inclusive and economically vibrant public spaces. Despite these successes, the integration of participatory approaches into mainstream urban planning in South Africa remains inconsistent. Many township and urban areas still lack well-maintained public spaces, exacerbating social exclusion and limiting opportunities for community engagement (Mabin, 2021). This highlights the need for a more systematic approach to inclusive urban design, informed by both global best practices and locally grounded participatory frameworks.

While significant research has been conducted on participatory urban design and inclusive public spaces, there remains a gap in systematically analyzing how these approaches have evolved globally and how they can be effectively adapted to marginalized contexts such as South African townships. This study aims to address this gap by conducting a bibliometric analysis of existing literature to identify dominant themes, knowledge networks, and methodological approaches. Based on the insights gained from the bibliometric review, the study will develop a conceptual framework that integrates global best practices with localized contextual factors. This framework will serve as a guide for policymakers, urban planners, and researchers, providing structured principles for implementing participatory design in public spaces across different socio-economic and cultural settings. By bridging the gap between theory and practice, the framework will contribute to a more inclusive, evidence-based approach to urban design in marginalized communities.

4 METHODOLOGY

This study employs a bibliometric analysis to examine global research trends on inclusive public spaces and participatory urban design. Bibliometric analysis is a quantitative research method used to evaluate the intellectual structure, research impact, and knowledge networks in a particular field (Donthu et al., 2021). This approach enables the identification of key themes, influential authors, prominent publications, and collaboration patterns shaping discourse on inclusive public space design. The Scopus database was selected as the primary source of bibliographic data due to its extensive coverage of peer-reviewed journal articles, conference proceedings, and book chapters in urban studies, architecture, and social sciences (Elsevier, 2022). On 18 February 2025 a Scopus database search was conducted using the primary key search term: “Participatory AND public AND space AND design”.

The inclusion criteria focused on english-language publications from any country and any year up to 2025. The exclusion criteria eliminated editorials, errata, letters, notes, short surveys, publications with unidentified authors and books, book chapters, reviews, and conference papers not published in english. The PRISMA guidelines were followed to screen titles and abstracts and ensure eligible studies were selected. The initial search yielded 950 publications on. After applying the inclusion and exclusion criteria 98 publications were excluded, leaving a total of 852 eligible documents. VOSviewer was utilized to conduct the bibliometric analysis, as outlined in the figure below (Van Eck and Waltman, 2014). VOSviewer is a software tool that visually analyzes literature reviews, identifying trends, research foci, and key areas (Soegoto et al., 2022).

5 RESULTS AND DISCUSSIONS OF THE BIBLIOMETRIC ANALYSIS

The publication trend in participatory urban design, as depicted in the graph, highlights a significant rise in scholarly interest over the past two decades. From 1976 to the early 2000s, research output was minimal,

with fewer than 10 publications per year. However, from 2005 onwards, there is a noticeable upward trend, with research output accelerating around 2010 and experiencing exponential growth from 2015 to 2024. The highest number of publications occurs in 2024, with nearly 350 documents published. Interestingly, there is a sharp decline in 2025, which may be attributed to incomplete indexing, funding cycle shifts, or emerging research priorities.

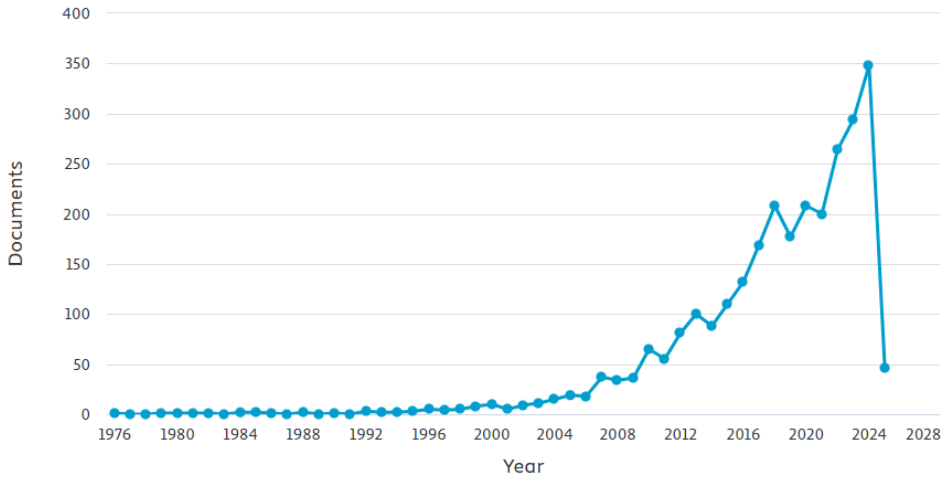

Fig. 1: Publication trend for research on participatory public space design.

This trend reflects a growing recognition of the importance of citizen engagement in urban planning and the increasing role of participatory approaches in urban governance (Frediani, 2016; Faga, 2006). The post-2010 surge aligns with global urban policies advocating for inclusive and participatory urban spaces, particularly influenced by the United Nations' Sustainable Development Goals (SDG 11) and the New Urban Agenda (2016) (UN-Habitat, 2016). Several key factors have contributed to the growth of participatory urban design research over the years. One significant driver has been the role of global urban policies. The United Nations' Sustainable Development Goals (SDGs), particularly SDG 11, emphasize making cities inclusive, safe, resilient, and sustainable (United Nations, 2015). Similarly, the New Urban Agenda (2016) promotes participatory governance and citizen-led urban design, encouraging greater scholarly interest in the field (UN-Habitat, 2016). These global frameworks have influenced both policy changes and academic research, positioning participatory urban design as a crucial component of urban planning and governance (Pieterse, 2019).

Another important factor is the rise of digital and smart city approaches, which have expanded the tools available for public participation in urban design. The increasing use of Geographic Information Systems (GIS), digital participatory mapping, and crowdsourcing has allowed for more effective citizen engagement in urban planning (McCall & Dunn, 2012). Additionally, the concept of smart cities and digital democracy has significantly shaped recent research trends, particularly in the last decade, as urban planning increasingly incorporates data-driven and technology-enabled participatory methods (Batty, 2018). The influence of social movements and the "Right to the City" discourse has also played a crucial role in shaping participatory urban design research. Inspired by Henri Lefebvre's (1996) theories, the "Right to the City" movement has gained momentum in urban discourse, advocating for citizen-centered urbanism (Harvey, 2012). Participatory urban design is increasingly viewed as a tool for spatial justice and urban equity, particularly in rapidly urbanizing cities of the Global South, where historically marginalized communities seek greater involvement in shaping their urban environments (Watson, 2014). Finally, the COVID-19 pandemic (2020–2022) had a profound impact on how cities approach public spaces, further driving research interest in participatory urban design. The pandemic underscored the need for inclusive urban design and walkability, prompting urban planners to explore innovative ways to involve citizens in shaping more resilient and adaptable urban environments (Honey-Rosés et al., 2020). The post-pandemic period (2020–2024) witnessed a surge in research on participatory urban design, as cities sought to reimagine public spaces, integrate health-conscious urban planning, and ensure equitable access to safe and inclusive spaces. This explains the sharp rise in publications in the last few years.

5.1 Keyword Analysis

The bibliometric visualization presented in the image provides an insightful mapping of key themes and conceptual linkages within the field of participatory design in urban spaces. The largest and most central node, labeled "participatory design," indicates that it is the dominant research focus, with strong connections to related concepts such as sustainability, public space, and urbanization. This suggests that participatory urban design research is deeply intertwined with broader urban sustainability and environmental planning discussions (Gehl, 2013). The color-coded clusters represent different thematic domains within participatory design research. The red cluster is strongly associated with gender and qualitative research, with prominent keywords such as "female" and "qualitative research." This signifies an increasing focus on gender-sensitive urban design and the role of women in participatory urban planning, aligning with feminist urbanism and feminist design theories (Kern, 2020). Additionally, keywords like "urban renewal" and "social aspects" suggest that researchers are exploring participatory approaches in urban regeneration projects, ensuring inclusivity and representation in urban transformation (Sandercock, 1998).

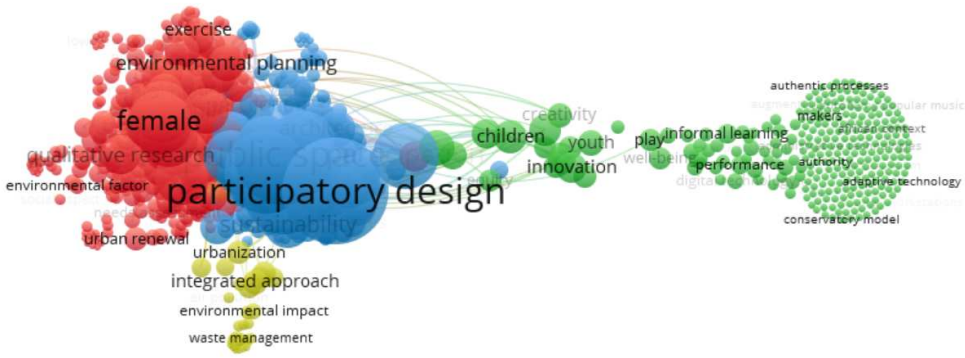

Fig. 2: Network map for keywords on research on participatory public space design.

The blue cluster is centered on sustainability, environmental planning, and integrated approaches. The strong association between "participatory design" and "sustainability" indicates that researchers are considering how inclusive design practices contribute to more resilient and adaptive urban spaces (Agyeman, 2013). Terms such as "waste management" and "environmental impact" highlight an emerging interest in ecological sustainability within participatory design frameworks, emphasizing circular economies and green urbanism (Newman et al., 2017). The green cluster focuses on youth, creativity, and innovation, highlighting participatory urban design's role in fostering child-friendly and youth-oriented urban environments. Keywords such as "children," "youth," "play," and "informal learning" suggest a growing recognition of the importance of designing public spaces that cater to younger populations, incorporating playfulness and creativity into urban design (Lester & Russell, 2010). This aligns with the shift towards child-friendly cities and participatory design methodologies that involve young people in co-creating urban spaces (Malone, 2013).

A particularly interesting aspect of the visualization is the smaller but highly connected cluster on the far right, which includes terms like "authentic processes," "makers," "digital technology," and "adaptive technology." This suggests an emerging research area where participatory design intersects with digital fabrication, maker movements, and adaptive urban technologies (Balestrini et al., 2017). The rise of digital participatory tools such as crowdsourced mapping, augmented reality, and computational design techniques is revolutionizing how urban spaces are co-created with communities (Batty, 2018).

The bibliometric network analysis reflects key contemporary debates in participatory urban design and demonstrates how the field has evolved to incorporate gender equity, sustainability, youth engagement, and digital innovation. The prominence of feminist and gender-sensitive approaches underscores the growing awareness of inclusive urbanism and the need to address historical gender biases in planning (Kern, 2020). Additionally, the strong connections between sustainability and participatory design indicate that researchers are prioritizing climate resilience, ecological planning, and community-led environmental governance (Agyeman, 2013). Moreover, the intersection of youth, play, and innovation within participatory design reveals an increasing emphasis on public spaces as sites of informal learning and creativity, which aligns with global trends in child-friendly and youth-inclusive urban planning (Malone, 2013). Lastly, the growing

presence of digital participatory tools and adaptive technologies points to the future of participatory urban design, where data-driven and technology-enhanced engagement methods will likely shape how cities involve residents in decision-making processes (Batty, 2018). Overall, the bibliometric trends indicate that participatory urban design is becoming increasingly interdisciplinary, integrating social, environmental, technological, and governance dimensions. Future research should continue exploring how these diverse elements interact, ensuring that participatory urban design remains a dynamic and inclusive framework for shaping equitable and sustainable cities.

5.2 Top countries publishing on participatory public space design

Participatory public space design is a growing area of research that intersects urban planning, architecture, environmental psychology, and social sustainability. The global distribution of research output in this field varies, with certain countries emerging as leaders in publication volume, citation impact, and collaboration networks. The table provides insight into the top ten countries contributing to this discourse, highlighting their research intensity, influence, and interconnectivity in the scholarly landscape.

Country	Documents	Citations	Total Link Strength
United Kingdom	140	1720	105
United States	164	2860	70
Spain	70	606	49
Sweden	36	1098	41
Netherlands	45	903	38
Australia	66	1050	35
Canada	54	630	35
Germany	39	766	33
Italy	83	641	33
Switzerland	12	395	33

Table 1: Top countries publishing on participatory public space design

The United States emerges as the most cited country, with 164 documents and 2860 citations, indicating its strong academic influence. The U.S. has a long history of community-based urban design initiatives, driven by movements such as New Urbanism and Tactical Urbanism (Lydon & Garcia, 2015). Scholars and institutions in the country have contributed extensively to placemaking strategies, community-led urban regeneration, and digital participation tools in urban planning (Mehta, 2019). Despite leading in citations, its total link strength of 70 suggests moderate international collaboration compared to the United Kingdom and Spain, reflecting a more nationally focused research agenda. The United Kingdom, with 140 publications and 1720 citations, stands out as a dominant contributor to participatory public space design research. Its total link strength of 105, the highest in the dataset, highlights extensive international collaboration. British research institutions focus on inclusive urban design, participatory governance, and sustainable urban spaces (Carmona, 2019). The UK's policy-driven approach, particularly through initiatives like the Town and Country Planning Association (TCPA), has contributed to a high degree of engagement with European and Global South scholars (Healey, 2010). Similarly, Spain, with 70 publications and 606 citations, has gained prominence in sustainable urbanism and citizen engagement in smart cities. Barcelona's pioneering Superblocks initiative is a globally recognized model of participatory urbanism that integrates community engagement into urban mobility and green space planning (Muñoz, 2018).

Sweden, despite having only 36 documents, has received 1098 citations, reflecting a high research impact. Swedish research is characterized by human-centered urbanism, child-friendly city planning, and social sustainability (Marcus & Colding, 2014). Scholars in Sweden contribute significantly to discussions on inclusive urban governance, green space co-creation, and participatory environmental planning (Stenberg, 2020). The Netherlands, with 45 documents and 903 citations, has also been at the forefront of living labs and experimental participatory urbanism. Cities like Amsterdam and Rotterdam are recognized for co-designing urban spaces with communities, integrating smart technologies, and testing participatory governance models (de Waal & Dignum, 2017). Australia, with 66 documents and 1050 citations, actively engages in participatory placemaking, indigenous-led urbanism, and resilient city planning (Steele & Legacy, 2017). Australian scholars emphasize bottom-up urbanism, participatory public art, and climate-adaptive design, often incorporating Indigenous knowledge systems into urban development frameworks (Porter,

2016). Similarly, Canada, with 54 documents and 630 citations, has made notable contributions to community-based public space design and participatory governance (Lehrer & Keil, 2019). Canadian research focuses on urban commons, participatory digital tools, and co-creation methods for equitable urban spaces, particularly in cities like Toronto and Vancouver.

Germany's 39 documents and 766 citations highlight a focus on participatory sustainability planning and citizen involvement in smart cities (Schäfer & Keppler, 2021). German research often explores green urban planning, digital participatory governance, and ecological urbanism, with Berlin leading in experimental participatory urban projects. Italy, with 83 publications and 641 citations, has a strong tradition of historical urbanism and participatory public space design in heritage sites (Rizzo & Thiel, 2017). Italian scholars emphasize adaptive reuse of historical urban spaces and community engagement in architectural conservation projects. Switzerland, though having only 12 publications, has 395 citations and a total link strength of 33, suggesting that its research is highly collaborative and impactful. Swiss research institutions focus on resilient urban planning, participatory environmental design, and climate-responsive public spaces (Blöchliger, 2020). Overall, the data highlights key trends in participatory public space design research. The Anglo-American dominance is evident, with the United States and the United Kingdom leading in citations and research collaboration, while European nations excel in experimental sustainability models. Australia and Canada bring strong Indigenous and community-led perspectives, and Switzerland, though smaller in volume, contributes significantly to resilient and climate-adaptive urban design. Future research should emphasize cross-regional collaboration to ensure that participatory urban design remains an inclusive and globally relevant field.

5.3 Top authors publishing on participatory public space design

The research landscape in participatory public space design is shaped by a group of scholars who contribute to critical themes such as digital participation, sustainability, and urban co-design.

Author	Documents	Citations	Total Link Strength
Olivier, Patrick	5	87	13
Boulanger, Pierre	3	56	12
Schofield, Guy	3	56	12
Shearer, John	3	56	12
Taylor, Robyn	3	56	12
Amato, Federico	3	27	9
Graziadei, Antonio	3	27	9
Murgante, Beniamino	3	27	9
Sassano, Gerardo	3	27	9
Soares, Isabelle	4	52	8

Table 2: Top countries publishing on participatory public space design

Patrick Olivier is one of the leading scholars in participatory public space design, with five publications, 87 citations, and a total link strength of 13. His work primarily focuses on human-computer interaction (HCI) and digital participation in urban design. Olivier's research investigates how digital technologies, such as smart city infrastructures, participatory mapping, and crowdsourced urban planning, can enhance community engagement in shaping public spaces (Olivier & Wright, 2015). His contributions align with smart urbanism and civic technology, emphasizing co-creation methodologies that empower local communities to influence urban planning decisions (Batty, 2018). Pierre Boulanger, Guy Schofield, John Shearer, and Robyn Taylor each have three publications, 56 citations, and a total link strength of 12. Their research collectively explores technological innovations in participatory public space design, integrating digital tools, virtual reality (VR), and augmented reality (AR) in community-driven urban planning. Their work contributes to discussions on immersive design techniques, where digital modeling and simulation are used to visualize community proposals for public space improvements (Boulanger et al., 2017). These authors are part of an emerging scholarly discourse on playable cities, a concept that integrates digital interaction and urban gamification to encourage public participation (Schofield et al., 2018).

Amato, Graziadei, Murgante, and Sassano each have three publications, 27 citations, and a total link strength of 9. Their contributions focus on sustainable urban planning, adaptive reuse of public spaces, and participatory resilience strategies. Their research examines how community engagement can shape climate-

adaptive urban spaces, particularly in European cities where historical preservation and modern sustainability principles intersect (Amato et al., 2019). Their work aligns with theories of ecological urbanism (Mostafavi & Doherty, 2016) and resilient urban governance (Ahern, 2011), emphasizing how participatory methods enhance environmental sustainability in urban design. Isabelle Soares, with four publications, 52 citations, and a total link strength of 8, focuses on gender-sensitive participatory planning, particularly in the Global South. Her research critically examines how urban spaces can be co-created to address the needs of women, children, and marginalized communities, drawing from feminist urbanism and intersectionality theory (Fainstein, 2010). Soares' work highlights how participatory approaches can challenge traditional, male-dominated urban planning paradigms, advocating for safe, inclusive, and accessible public spaces (Soares et al., 2020). Her contributions are particularly relevant to debates on feminist mobility and spatial justice, aligning with Lefebvre's (1996) concept of the Right to the City.

6 REFLECTION ON FINDINGS

While the bibliometric analysis provides a comprehensive overview of publication trends, keyword networks, and global research contributions in participatory urban design, it is essential to deepen the interpretative value by linking these findings to key theoretical and methodological developments in the field. This section critically reflects on the observed trends and their implications for participatory urban design research and practice. The observed rise in scholarly output post-2010 aligns with major global urban policy shifts, such as the adoption of the Sustainable Development Goals (SDG 11) and the New Urban Agenda (UN-Habitat, 2016). However, beyond policy alignment, the exponential increase in publications between 2015 and 2024 suggests an epistemological shift in how participation is conceptualized in urban design. The early phases of participatory design research predominantly focused on community engagement as a normative good (Arnstein, 1969; Faga, 2006). However, post-2015, there is a discernible pivot towards digital participation, data-driven co-design, and resilience-focused urbanism (Batty, 2018; Balestrini et al., 2017). This transformation reflects a broader movement from abstract participatory ideals to technology-enhanced, evidence-based urban design methodologies.

Additionally, the sudden decline in 2025 publications suggests potential research fatigue or a shift in funding and policy priorities. Analyzing the nature of recent publications can provide insights into whether participatory urban design is plateauing as a field or evolving into new sub-domains, such as AI-driven participatory planning or post-pandemic spatial justice frameworks. he keyword co-occurrence analysis reveals a strong clustering around sustainability, gender, youth engagement, and digital urbanism. This suggests that participatory urban design is no longer a singular field but an intersectional domain engaging with social equity, environmental planning, and digital governance. However, gaps remain evident such as:

- The relatively smaller presence of keywords related to informal urbanism and the Global South indicates an underrepresentation of participatory methodologies tailored to non-Western urban contexts (Watson, 2014; Parnell and Pieterse, 2014).
- Despite the prominence of gender-sensitive urban design, feminist urbanism remains a niche sub-domain, often overshadowed by broader discussions on inclusivity and social sustainability (Kern, 2020).
- Emerging research on participatory smart cities and digital co-creation points to an increasing reliance on technology in urban planning, yet critical debates on digital divide and participatory exclusion remain limited (Balestrini et al., 2017).

The bibliometric findings highlight a growing emphasis on interdisciplinary and transdisciplinary approaches in participatory urban design research. The prominence of scholars integrating geographic information systems (GIS), digital ethnography, and computational modeling suggests that methodological advancements are shaping research impact and scholarly influence (McCall and Dunn, 2012; Batty, 2018). However, the variation in citation impact across different regions indicates that methodological sophistication alone does not drive research influence – policy relevance, institutional backing, and socio-political context play critical roles in determining the uptake of participatory research outputs. For instance, the high citation count of Swedish and Dutch research correlates with strong government-university partnerships in experimental urbanism (Marcus and Colding, 2014; de Waal and Dignum, 2017). Meanwhile, research outputs from the Global South, despite their practical relevance, often remain under-cited due to limited integration into

global knowledge networks (Pieterse, 2019). This underscores the need for stronger collaborative frameworks that enhance the visibility and impact of participatory urban design research from diverse geopolitical contexts

7 CONCLUSION AND RECCOMMENDATIONS: CONCEPTUAL FRAMEWORK FOR PARTICIPATORY PUBLIC SPACE DESIGN

In conclusion, this study has demonstrated the growing significance of participatory approaches in designing inclusive public spaces, particularly in the context of urban environments that have historically been marginalized, such as townships in South Africa. The bibliometric analysis provides valuable insights into the evolution of research on participatory urban design, revealing trends that reflect a broader global shift toward inclusive, sustainable, and citizen-driven urban planning. The surge in publications, particularly after 2010, reflects increasing recognition of the role of participatory design in fostering more equitable and resilient urban environments. Despite this progress, challenges remain in adapting global research to local contexts, particularly in the Global South, where socio-economic disparities and historical legacies of exclusion continue to shape urban landscapes. This study contributes to bridging this gap by offering a conceptual framework that integrates global best practices with localized participatory approaches. The framework developed herein provides a structured lens through which urban planners, policymakers, and researchers can approach the design of inclusive public spaces, ensuring that they are accessible, equitable, and responsive to the needs of marginalized communities. Ultimately, the future of participatory urban design lies in its ability to adapt to the evolving needs of cities, particularly in addressing the intersections of social equity, environmental sustainability, and technological innovation. By fostering deeper collaboration across disciplines and geographies, and by prioritizing inclusivity in urban planning processes, cities worldwide can build public spaces that not only serve their current populations but also contribute to more just and sustainable urban futures.

Furthermore, considering the key themes that emerged from the network maps as well as the focus of the top authors in this research field and the gaps, a conceptual framework for participatory public space design is proposed. The proposed conceptual framework for participatory public space design emphasizes the integration of digital technologies, sustainability, inclusivity, and community-driven processes to create urban spaces that are adaptable, resilient, and equitable.

Fig 3: Conceptual framework for participatory public space design

The first key principle focuses on participatory digital technologies as tools for co-creation. The objective is to facilitate meaningful, real-time engagement through digital platforms that actively integrate local knowledge and community preferences into the design process. Techniques such as immersive design tools like virtual reality (VR), augmented reality (AR), and participatory mapping can allow communities to visualize potential changes and contribute to co-designing public spaces, ensuring that their voices are heard and incorporated (Zhao et al., 2021; Kitchin, 2014). The second principle, sustainability and resilience

through community-driven design, advocates for incorporating environmental sustainability and resilience strategies, particularly to adapt public spaces to the challenges posed by climate change. The objective is to foster adaptive urban spaces that are both environmentally sustainable and resilient, with the community playing a crucial role in proposing solutions. This approach draws from ecological urbanism and resilience governance, which emphasize the importance of community-led adaptations to ensure climate-resilient spaces (Pelling, 2011; Anguelovski et al., 2016). A third important aspect is the creation of gendered and inclusive urban spaces. This principle prioritizes gender-sensitive planning and intersectional approaches to urban design to ensure the inclusion of marginalized groups, particularly women and children. The objective is to create public spaces that cater to diverse needs, ensuring safety, accessibility, and inclusivity for all. By engaging marginalized communities in the design process, this approach challenges traditional urban planning structures and advocates for spatial justice, ensuring that public spaces reflect the lived experiences of those often excluded (Healey, 2004; McFarlane, 2012).

The fourth principle revolves around collaborative and playable cities, where urban spaces are designed to encourage play, interaction, and engagement through participatory methods blending both physical and digital elements. The objective here is to foster a sense of ownership and belonging among community members by enabling them to actively participate in co-creating their urban environments. The concept of "playable cities" integrates gamification and interactive digital models to promote ongoing community involvement, making the urban environment a dynamic, participatory space that evolves with its users (Bishop & Stocker, 2019). In conclusion, this framework advocates for a holistic, inclusive approach to participatory public space design that leverages digital technologies, sustainability, gender equity, and community empowerment. By ensuring that urban spaces are not only designed with community input but also remain adaptive, resilient, and equitable, the framework creates environments where all citizens – particularly marginalized groups – can thrive. This approach to urban planning supports the creation of spaces that are socially just, sustainable, and responsive to the needs of diverse communities.

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A Data Space for Accessible Multimodal Transport: Enabling Inclusive Mobility

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1 ABSTRACT

It is a long-term strategic goal of the European Union to promote multimodal mobility and thereby create a more sustainable, efficient and liveable environment. Offering travellers a wider range of choices and promoting the integration of different transport modes can help to transform the way we get around. Despite existing infrastructure, a lack of accessible and integrated information creates significant barriers for travellers. Multimodal travel is even more difficult for people with disabilities because they have more specific needs in terms of infrastructure and their itinerary. More than 8% of the population in Austria have a registered disability.

This research proposes a solution from a data perspective. We aim for a non-discriminatory low-threshold access to mobility information, especially for the group of people with disabilities or impairments and for individuals with restricted mobility. The requirements have been worked out in a participatory process with co-creation workshops and expert interviews. A use case of a person with mobility impairments has been described together with a data requirements schema. This schema of data categories covers all passenger needs from travel itinerary, change between modes of transport, and getting support. It helps to identify data specifically for similar use cases.The requirements were the starting point to design and set up the prototypical data space for mobility data. Various data sources for mobility data in Austria have been identified and analysed for their content and quality. This subsequently allowed the definition of data products with their attributes and quality measures. Data products need to satisfy consumer's needs. In the context of this work, data products are for example: disabled parking spaces in Austria, or accessible routes in and around railway stations. The actual data also includes metadata that makes it easier to find the right data product and obtain information about its origin and license terms. A specific schema was defined to fulfil the requirements for mobility data.

To successfully operate a mobility data space, suitable operator models were analysed, and the legal requirements were defined. Digital services for mobility have significant market potential. We therefore suggest establishing a dedicated task force that brings together key public and private stakeholders to create a comprehensive implementation strategy. The primary goal should be to generate practical value through improved mobility services while maintaining a sustainable operational model that promotes broad participation from current market players and fosters ongoing innovation in the accessibility sector. Well-integrated and high-quality data are a prerequisite for more usable multimodal transport. People with disabilities or individuals with restricted mobility have additional requirements in data that must be taken into account. The general public also benefits from this development as more accessible options with better information strategies is valuable for everyone.

Keywords: Mobility Data, Data Space, Multimodal Transport, Inclusion, Co-creation

2 INTRODUCTION

Most of us who work are commuters, and many of us use various forms of public transport every day. We regularly use the same and well-known route, move from one bus to another in a familiar environment. But

remember the first time you were on your own in an unfamiliar, huge, sprawling railway station, just trying to find your way out. Now imagine a blind person or someone who relies on a wheelchair to find their way to the connecting train. Things turn out to be more complicated and take much longer. The further you get away from the big cities, the less information and travel options you have – another hurdle. 8.3% (around 760,000 people) of the population in Austria have a registered disability (BMSGPK 2024). Many more struggle with mobility restrictions or other challenges such as handling a pushchair, a dog and luggage at the same time.

Mobility is of great importance for social inclusion. Research shows that people with mobility impairments face numerous additional challenges and obstacles to mobility in everyday life (Prescott et al., 2020). This can be a bad condition of pavements or the difficulty to cross a road. It is known that there are still gaps in the integration of accessibility in the field of mobility (Disabled Coalition et al., 2023). Integrated mobility services must also take extensive account of accessibility and inclusion.It is a long-term strategic goal of the European Union to promote multimodal mobility and thereby create a more sustainable, efficient and liveable environment (EC, 2021). Offering travellers a wider range of choices and promoting the integration of different transport modes can help to transform the way we get around. Despite existing infrastructure, a lack of accessible and integrated information creates significant barriers for travellers. Multimodal travel is even more difficult for people with disabilities because they have more specific needs in terms of infrastructure and their itinerary.

To enable such services, integrated and linked data is required. Data spaces are being increasingly used for decentralised, secure, and trusted data sharing within a structured governance framework. Participants in a data space establish mutual trust, agree on common standards, and maintain sovereignty over their data by defining individual policies. Unlike centralised data platforms, data sharing within data spaces occurs peer-to-peer via connectors, ensuring that data remains under the control of its original owner while enabling efficient and secure exchanges. The main advantages of data spaces include interoperability, scalability, traceability, and findability of data, making them a viable alternative to centralised data platforms. The European strategy for data aims to create a single market for data, strengthening Europe's global competitiveness and data sovereignty. A key element of this strategy is the establishment of common European data spaces, ensuring that more data is made available for economic and societal use while allowing companies and individuals to retain control over their data (EC, 2020).

In this paper, we seek for data driven solutions to solve the problems mentioned above. The question is what is needed to establish a national mobility data space and examine this issue from different perspectives by involving the community. A participatory process was applied with the help of co-creation workshops and expert interviews. The contributions in this paper range from data requirements to a prototypical implementation, to the experiences we have made with the application in practice. In detail this comprises the following: a use case of a person with mobility impairments, and a data requirements schema which helps to identify data specifically for similar use cases. From a business perspective, we propose the formation of a dedicated task force combining key public and private stakeholders to develop a detailed implementation strategy. The focus should be on creating practical value through enhanced mobility services while maintaining a sustainable operational model that encourages broad participation from existing market players and enables continuous innovation in the accessibility sector. The legal perspective addresses the use of open data and lists more complex legal issues in the implementation of data spaces. From a technical viewpoint we further propose a concrete meta data schema for the use in a mobility data space. An important benefit for data space customers is the use of data products. We implemented a set of data products for the data space to fulfil the use case and will discuss two of them in more detail in this paper.

3 RELATED WORK

To advance theinitiative of data spaces, the Data Spaces Support Centre (DSSC)[1] facilitates these data-sharing environments, enabling data reuse across sectors while respecting EU values.Furthermore, the InternationalData Spaces Association (IDSA)[2] plays a leading role in developing the technical foundation for data spaces, ensuring secure and standardised data exchange. IDSA members have been working on key technologies, leading to major achievements such as the IDS Reference Architecture Model (latest version:

[1] https://dssc.eu/
[2] https://internationaldataspaces.org/

IDS-RAM 4.0), the IDSA Rulebook, and the Dataspace Protocol, all of which define clear rules for trusted data sharing. These efforts contribute to establishing the Dataspace Protocol as an international standard, reinforcing the foundation of a fair data economy.

Several initiatives have been undertaken to advance the development of mobility data spaces, including efforts addressing the needs of persons with limited mobility, which laid the groundwork and provided impetus for the CARINA project. In Austria, the DIANA 4 CCAM project (Aichholzer et al., 2022)has contributed to this advancement. DIANA 4 CCAM has pioneered a data cycle concept that supports the integration of AI functions in the mobility sector. Internationally, the most relevant precursors for CARINA include the European Mobility Data Space (MDS)[3], a virtual marketplace for the exchange of mobility data with over 150 participants, PrepDSpace4Mobility (Bakri et al., 2024), which provided the groundwork for the MDS, the French EONA-X Data Space[4], which integrates mobility and tourism data to enhance intermodal travel experiences, and the Data Space for Multimodal Passenger Mobility (DSMPM)[5], a secure and standardized platform that enables the seamless integration and sharing of diverse mobility data for inclusive multimodal travel experiences.

Building on these foundations and among other Austrian data space initiatives, the CARINA project will contribute to the foundations for a national mobility data space in Austria. Some other current initiatives are the project Övvvi[6], which has the aim to contribute to this cause through the collection, integration, analysis and structured provision of mobility data, and the project MultiMoFusion[7] where the goal is to enable demand-driven and sustainable transportation planning through data fusion of smartphone assisted self-interviewdata, floating phone data and other data sources. The most notable current Austrian data space initiative is the KoDRM-AT[8] project. KoDRM-AT shall develop legal, organisational and technical concepts and concrete implementation steps for a national mobility data space in line with the European Data Strategy (EC, 2020) to deliver a contribution to the Austrian mobility masterplan 2030 (BMK, 2021).

There are already several platforms in Austria that collect and provide extensive mobility data (BMK, 2024). The Graph Integration Platform (GIP)[9] for example, provides a basic structure of mobility data in Austria. It is implemented as a multimodal transport graph, enables a nationwide supply of high-quality transport services in a standardized way, based on a common data standard and it is the basis for various route planners and other applications. basemap.at[10] and EVIS.AT[11] also play an important role in the mobility data landscape in Austria. They utilise data from the GIP and the Verkehrsauskunft Österreich(VAO) . basemap.at is a cartographic product that includes a simplified representation of terrain, buildings, rivers and transport routes throughout Austria. EVIS.AT provides the current traffic situation, journey times and incident reports for the Austrian road network and is available for numerous traffic information services.

Static mobility data is available, but fragmented and difficult to access (Gatzert et al., 2023). The situation is different with dynamic mobility data. There is currently no regulation on how this data must be made available. Unforeseeable temporary changes, such as defective barrier-free facilities, construction sites or short-term organisational changes pose a particular challenge for people with mobility impairments. As a result, they are unable to participate in many activities (Prescott et al., 2020) (Disabled Coalition et al., 2023).

There are many applications and services that help end users in their everyday lives when it comes to mobility. For example, VAO[12] offers a mobility information platform including an intermodal dynamic real-time route planner. This route planner is used in various mobility apps in Austria with a usage of around 590 million routing requests in 2024 (BMK, 2024). It allows users to partially customise their query, such as selecting their preferred means of transport, the maximum distance they can cover on foot or the option of

[3] https://mobility-dataspace.eu/de/
[4] https://eona-x.eu/
[5] https://i4trust.org/wp-content/uploads/DSMPM-%E2%80%93-i4Trust-Impact-Story.pdf
[6] https://projekte.ffg.at/projekt/4777251
[7] https://projekte.ffg.at/projekt/4878696
[8] https://projekte.ffg.at/projekt/4788149
[9] https://www.gip.gv.at/
[10] https://basemap.at/
[11] https://evis.at/
[12] https://www.verkehrsauskunft.at/

using escalators, stairs and lifts. There are also some customisation options for cycling and driving. Nevertheless, there is no specific consideration of accessibility. There is further potential for improvement in better linking the various modes of transport within a route. Driving, cycling and public transport are currently considered separately. In addition, information such as public transport disruptions is not fully integrated.

The mobyome mobility app[13] aims to collect mobility data and raise awareness of users' own mobility behaviour. Users can record their everyday journeys. They then get feedback on the costs and emissions of their travel behaviour and possible alternatives. Although the app does not explicitly focus on accessibility, users have the option of choosing which alternatives are suitable for them afterwards.

Wheelmap[14] is a map on whichone can find wheelchair-accessible places and rate them according to their accessibility for wheelchair users. It is based on a crowd-sourcing principle, i.e., anyone can add places to Wheelmap and rate their accessibility based on various criteria. This approach helps to easily generate data about accessibility information on a broad basis, but it is not possible to guarantee certain data quality requirements. Continuous maintenance of the database cannot be guaranteed, as the provision of data is not regulated. Nevertheless, this is an important source for many people with disabilities.

4 METHODOLOGY

It all started with the idea of using data for more sustainable multimodal mobility and responding to individual mobility needs. A key driver was also to promote the inclusion of people with mobility impairments. As an initial activity the main stakeholders of the mobility scene in Austria were identified and invited to co-creation workshops. The workshops provided a good insight into the challenges and expectations of the stakeholders. Through the participation of different representatives, important aspects from the perspective of data providers and data operators as well as inputs from representatives of people with reduced mobility could be collected. The involvement of different stakeholders is important to ensure that the largest possible group of people benefit from the results.

The co-creation activities continued with expert interviews in the area of people with disabilities. The collected information was the basis to create personas and detailed use cases. In total three use cases were developed (Russegger, 2024) one of which we will focus on in this paper. With the help of the use cases, a data schema was developed which allows to determine the data requirements for travels especially for people with disabilities. This guided the concrete implementation. First the data sources were identified, and the required data sets were collected. Automatic data transformation processes were setup which clean and prepare the datasets. The results are data products which can be re-used in various use cases. The data products are shared in a data space as new data offerings. Implementing a prototype mobility data space with real data helped us in evaluating further business- and legal foundations. A contract was setup for exchange of raw data for a data intermediary who processes data and re-sells it on the mobility data space. Finally, the business foundations for operating a mobility data space were determined.

5 REQUIREMENTS ANALYSIS

This chapter describes the co-creation activities that were carried out. It first started with co-creation workshops and then continued with expert interviews. The collected information was the basis for the use case which then led to the development of the data requirements schema.

5.1 Co-Creation Workshops

Two co-creation workshops were held as video conference sessions lasting 90 minutes. In the first co-creation workshop 9 different stakeholder organisations participated and in the second 18 different organisations. The stakeholder organisations came from following areas: organisation for people with disabilities, operator of transport data infrastructure, tourism organisation association, legal or technical counsellor, public administration, public transport provider, research institution, interest group for public transport, business development consulting, and automobile association. To make the idea of a mobility data space clearer, an exemplary use case was prepared.The workshops were transcribed and then summarised

[13] https://app.mobyome.at/gemeinde
[14] https://wheelmap.org/

and structured. This was the basis for collecting the needs and availability of data, as well as collecting the challenges and expectations of people with disabilities.

The biggest challenges include a lack of easy access and intuitive user interfaces, but also the lack of links between different transport modes, as well as barriers for people with mobility impairments despite being labelled as barrier-free. Much information is still missing, e.g., information on the options for transferring between different modes of transport, or information on alternative routes in the event of breakdowns of barrier-free infrastructure. In some cases, the data does not even exist or has to be entered manually (e.g., failure of an escalator). In addition, the lack of regulated responsibilities and competences is a major problem, as it is not always clear who has to ensure that the data is up to date. Expectations of a data space were also mentioned: barrier-free access to information, a technically intuitive solution and a coherent data space to find as much of the required information as possible in one place, and up-to-date data on the accessibility of means of transport, stops, railway stations and underground stations.

5.2 Expert Interviews

Expert interviews were conducted to further refine the use cases and the specific scenarios. Therefore, a semi-structured interview format was chosen. The invited interview partners are themselves affected by mobility impairments as well as representatives of the interests of people with reduced mobility. The expert interviews included four participants. Two of them are dependent on a wheelchair, one is from an association for the blind, and one is an employee of an organisation for people with disabilities. The aim was to ensure that the developed use cases describe realistic scenarios and provide comprehensive insight of the challenges in mobility. The lack of information and therefore the results of it were discussed, as well as possible technical assistance, the requirements of people with different impairments (e.g., physical disability, cognitive impairment), and the everyday life of a person with disabilities.

5.3 Use Case

The following exemplary use case was developed to illustrate the data needs and to show how a typical itinerary of a person with disabilities looks like. (Russegger, 2024) describes in total three personas and mobility use cases for people with mobility impairments. In this paper we address as a representative the following one:

Markus is 36 years old and is dependent on a wheelchair. He lives in the outskirts of Graz and plans to visit his aunt Erna in Klagenfurt. He then travels on to an event in Tyrol. Markus is not reliant on public transport as he has his own car. Nevertheless, he would like to use public transport for the majority of his journey and plans to use his car only as far as a suitable public transport hub, such as a specific stop or train station.

A possible itinerary would look like this: By car via Keplerstraße – car park at the main station – express bus to St. Michael – ÖBB Railjet to Westbahnhof Klagenfurt – SURAAA shuttle to intermediate destination – <PAUSE> – SURAAA shuttle Westbahnhof Klagenfurt – to Innsbruck with ÖBB – Regiobus 160x to Reutte – Regioflink to final destination.

5.4 Data Requirements Schema

A data schema was developed to identifythe requirements on data in a structured way for this use case and also for similar other use cases for people with restricted mobility. This schema is a generalisation developed from the stakeholder interviews and co-creation workshops. Its aim is to identify the required data, to categorise it, and to check for completeness.

5.4.1 Travel Planning

Description: A service for creating an itinerary that is easy to use by considering the accessibility guidelines and is configurable or automatically adaptable for specific travel needs for people with restricted mobility.

Use case: For the described use case above this would be a smartphone app with a route planner to find the optimal route from his home to Klagenfurt.

Data needs: Public transport route network and timetables, road network including current traffic situation, information on accessibility of infrastructure, etc.

5.4.2 General Information about Travel Routes

Description: Giving the opportunity to choose between different options for a travel to get the personal best option. All necessary additional information about the equipment of the stations and means of transport.

Use case: Markus should only receive suggestions for travel routes that meet his needs. This means that both the modes of transport and the routes between the modes must be suitable for wheelchair users. This can be supplemented by photos, for example. If a reservation is required for one of the means of transport, Markus needs information about whom to contact and when. He must also be told exactly where he can park his car for routes that suggest using his car.

Data needs:Travel routes at different times; equipment of the modes of transport (ramps, braille lettering, suitable seats...) including current condition and capacity utilization; current condition and availability of ramps or stairs of the routes; location and condition of sanitary facilities.

5.4.3 Transfer Navigation

Description:Information on finding connecting transportation.

Use case: Markus needs additional information for transfer navigation information, for example how to get to lifts or wheelchair lifts or wheelchair ramps.

Data needs: Location and current condition on elevators, escalators; status and location on navigation aids at stations (boards, displays); precise indoor navigation including routes to elevators or escalators.

5.4.4 Transfer Times

Description: Information on transfer times depending on the user's mobility.

Use case: Depending on the circumstances, Markus may need longer to change than a person without a mobility impairment if, for example, access via the lift takes longer than via the escalator.

Data needs: Average time a person needs to change trains; reference values for transfer times for people travelling at different speeds and different mobility; transfer times if lifts have to be used.

5.4.5 Park/Bike and Ride

Description: Information about places where it is possible to change modes of transport and where cars or bicycles can be parked and at what cost.

Use case: If parts of the proposed route are to be travelled in Markus' own car, he needs to know where he can park it. It must also be known whether there are suitable car parks with more space for Markus to get out of the car.

Data needs:Locations of park/bike and ride facilities; current utilisation; locations of disabled parking spaces, including current capacity utilisation.

5.4.6 Last Mile

Description: Information on on-demand transportation providers, taxis or similar when travelling the last leg of a journey including where to find them, how to book it and how to use these services.

Use case: In addition to the information on what options are available for the last leg of the journey to his aunt and how he can use them, Markus also needs to know whether they are wheelchair accessible.

Data needs: Options for last mile transportations; on-demand transportation providers; location, opening hours, equipment of the means of transport offered.

5.4.7 Ticket Information

Description: Information should be provided on where to buy tickets for the modes of transport. If park and ride offers are included in the itinerary, information should also be provided on how to purchase tickets.

Use case: Markus has no special requirements regarding the way in which he buys his ticket. However, if extra tickets or seats need to be booked to use public transport with a wheelchair, this should also be clearly indicated.

Data needs: Location and opening hours of ticket counters; ticket purchase at ticket machines: notes on ease of use; different modalities of ticket purchase; need for extra tickets for wheelchair spaces, including capacity utilisation.

5.4.8 Deviations and Disruptions

Description: Travelers should be informed about deviations from the planned journey and offered suitable alternatives.

Use case:In the event of short-term deviations, Markus needs alternatives that continue to meet his needs. In the event of a different platform, Markus needs information on how to get to the new platform via a wheelchair-accessible route. In the event of train cancellations or delays, new routes must be calculated that also take the aforementioned aspects into account.

Data needs: Real-time information on cancellations, platform changes, delays or non-functioning infrastructure.

5.4.9 Personal Assistance

Description: Information on where and how to get further support should also be provided.

Use case: If Markus needs additional help, such as when changing trains or with his luggage, he should be able to call up information on where and how he can get help.

Data needs: Places or telephone numbers where one can get support; location and opening hours of information centres; connecting volunteers and people seeking help.

6 IMPLEMENTATION

This chapter describes the prototypical implementation of the data space and its results. It starts with the business relevance of such a project and the various legal considerations from free and open data to complex contractual relationships. The tasks of data governance are listed to build trust and interoperability. A concrete meta data schema for the use in a mobility data space was also implemented. The end of this chapter is dedicated to the data products – the digital asset in a data space for its customers.

6.1 Business and Legal Foundations for a Sustainable Mobility Data Space

The business perspective:A sustainable mobility data space must build upon and enhance existing infrastructure and applications rather than creating parallel structures. Current mobility applications and platforms already serve millions of users daily, including essential accessibility information needs. The business value lies in augmenting these established services with standardized accessibility data and enabling new integrated solutions. With around 760,000 people (8.3% of the population) having registered disabilities in Austria in 2022 (BMSGPK, 2024) there is significant potential for both improving existing services and developing specialized mobility solutions.

Given this market potential, we propose the formation of a dedicated task force combining key public and private stakeholders to develop a detailed implementation strategy. This task force should address critical questions of governance, data monetization models, and infrastructure funding, while ensuring both economic sustainability and public benefit. The focus should be on creating practical value through enhanced mobility services while maintaining a sustainable operational model that encourages broad participation from existing market players and enables continuous innovation in the accessibility sector.

The legal perspective:Numerous valuable mobility-related datasets are provided by public sector entities. These datasets are often available as open data (e.g., GIP data in Austria or the Mobilithek in Germany) or accessible via open standard interfaces (e.g., ÖBB or Wheelmap data upon registration). These data sources, whether directly or indirectly accessible, offer a rich repository of information on mobility activities and infrastructures. Leveraging these datasets enables the development of various applications that cover a substantial portion of mobility-related processes.

From a legal perspective, the use of public datasets is generally straightforward, as broad open licensing agreements govern their reuse. Open-data licenses, such as Creative Commons or the German Data License, typically allow extensive utilization. However, restrictions exist regarding liability and warranty. When utilizing such license-free datasets, data providers generally do not assume liability for their accuracy. This

issue becomes particularly relevant when dealing with real-time or near-real-time data, which are critical for accurately reflecting current mobility dynamics. In such cases, the open-data approach reaches its limitations.

Highly relevant real-time data are often not freely licensed or are technically challenging to obtain (e.g., sensor data along roadways or IoT-generated data from municipalities). In these cases, more complex legal issues must be resolved before the data can be utilized. Another challenge arises when data are collected by a municipality but subsequently transmitted, stored, and potentially shared by third-party intermediaries acting as data service providers. This results in a legal triangular relationship or data trusteeship. Such a structure is legally more intricate because the original data provider must first transfer the data both technically and legally to the intermediary, who then becomes a secondary data provider for further distribution. While legally feasible, this setup often presents challenges for stakeholders, as it necessitates establishing multiple contractual relationships.

This sometimes complex contractual landscape among mobility stakeholders can be streamlined if a data space assumes the role of a facilitator and curator, negotiating contractual agreements in advance and, in some cases, serving as a data trustee. Clearly defining the legal framework for data access rights, monetization models, and liability provisions is essential to ensure seamless data exchange. Furthermore, mechanisms for dispute resolution and arbitration play a critical role in efficiently managing conflicts and fostering long-term trust among stakeholders.

Compliance with data protection regulations must be ensured, particularly when mobility data could indirectly enable the identification of individuals. Adherence to the General Data Protection Regulation (GDPR) is therefore imperative.

6.2 Data Space Governance and Metadata Management

Data governance refers to the comprehensive set of rules, processes, and responsibilities for managing and utilizing data within an organization. The primary objectives are to ensure data quality, data protection, interoperability, and compliance, thereby enabling efficient, secure, and legally sound data usage.

Data spaces are decentralized data ecosystems, and this project contributes to the Austrian mobility data space. While data governance in data spaces follows the same fundamental principles as in organizations, aspects such as trust, data sovereignty, and legal certainty among participants are even more critical. Within a single organization, a higher level of inherent trust exists between data providers and consumers. However, in a heterogeneous and decentralized data ecosystem like a data space, trust and interoperability must be established first. Therefore, contract-based governance mechanisms – including access policies, interoperability standards, quality assurance frameworks, and compliance regulations – are essential for enabling controlled, transparent, and efficient data sharing (Guggenberger et al., 2025).

A core principle of data governance in data spaces is data sovereignty. Each participant must retain control over their data and be able to define the conditions under which data may be shared or utilized by others. This is implemented through contractual agreements and technical mechanisms, such as access control, identity management, and policy enforcement (ref. Margoni et al., 2023). Frameworks such as the IDS-RAM (International Data Spaces Reference Architecture Model) and Mobility DCAT-AP provide well-defined structures and guidelines for these requirements.

For the planned future implementation of a national mobility data space, it is recommended to establish a strong governance structure. To make this work, a steering committee of interested organisations should bring together key stakeholders of public administration, mobility providers, research institutions, and technology experts. Everyone needs clearly defined roles: Who will be the coordinator or operator, who provides data, under which conditions and contracts, who creates and operates data services, who administrates, curates and operates the data apps and data services, who will be the final beneficiary (end-user), who ensures everything runs smoothly (business continuity)? This setup should align with existing regulations, such as the EU Data Strategy, the Data Governance Act, and Austria's Mobility Masterplan 2030. Without solid governance structures, there is no trust. And without trust, data-sharing won't work. Contracts are just as important as technology. A secure and controlled data-sharing environment requires clear rules on who can access what, under which conditions, and for what purpose. In our project we developed standardized agreements which define data usage rights, licensing terms, and compliance

measures. These templates could be used as a blueprint for future initiatives to make sure data is shared efficiently, legally, and fairly.

For the operating of data space and/or data services it is necessary to have all components for the data journey and application journey are up and running smoothly. That includes high-quality data, accurate data science components and necessary connectors and other systems. A Mobility Data Space is only useful if the information it provides is accurate and up to date. Therefore, we propose to include a Data Quality Assurance Framework from the beginning to automatically check for missing or incorrect data.

Metadata management is another crucial component of data governance in data spaces. Standardized and uniform metadata are essential for ensuring that data is discoverable, interpretable, and reusable. In this context, vocabularies such as DCAT (Data Catalog Vocabulary) play a key role, particularly in domain-specific applications like mobility. Extensions such as MobilityDCAT-AP address the unique requirements of mobility data, including infrastructure information and transportation modalities (cf. DSSC, 2024).

An established standard in this field is DCAT – the Data Catalog Vocabulary. It is an RDF-based vocabulary designed to support interoperability between data catalogs and is currently in its third version (Albertoni et al., 2024). Various application profiles have been derived from the W3C recommendation to adapt the vocabulary to domain-specific use cases. For instance, dedicated profiles exist for mobility data (Molinas Comet et al., 2025) and statistical data (Sofou and Dragan, 2016). Depending on the specific application scenario and the type of data being exchanged, it is advisable to use DCAT for a mobility data space while extending it with mobility-specific metadata. As illustrated inFigure 1, classes and properties were adopted from MobilityDCAT-AP (Molinas Comet et al., 2025) for this purpose.

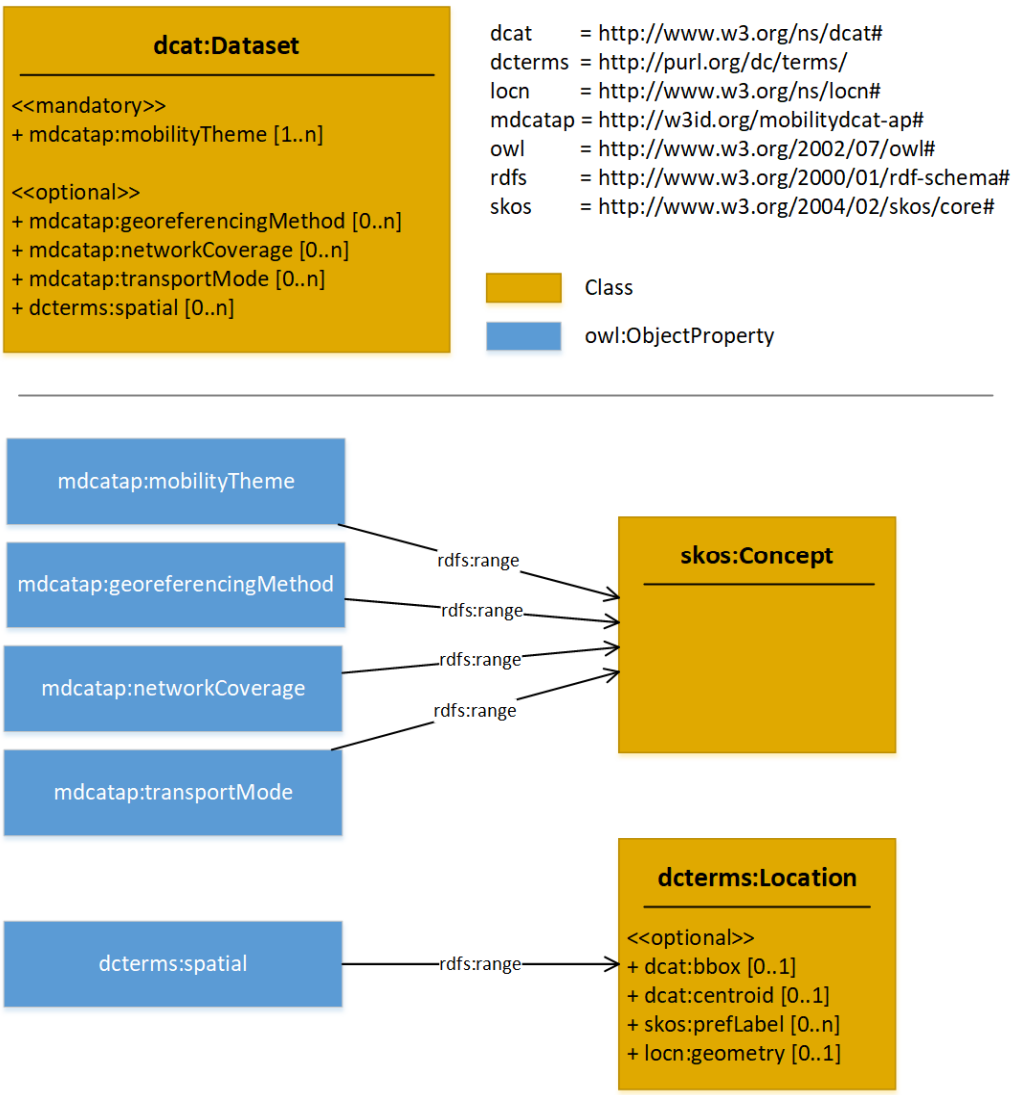

Figure 1: The proposed metadata schema builds upon the Data Catalog Vocabulary and the mobility extension for DCAT.

6.3 Data Products

Data spaces enable controlled and trusted data exchange between participants. The value creation typically begins with raw data provided by data providers. This data is processed, harmonized, and refined through specialized data processing services. The combination of relevant data and associated processing services ultimately forms a data product, which is made available to other participants in a standardized and quality-assured manner (DSSC, 2023).

Particularly valuable is that not only the final data product but also all intermediate results of the processing chain can be offered as new data assets within the data space. For example, normalized datasets, analysis results, or aggregated statistics can be made available as independent resources. This modular structure allows other participants to build upon different levels of the processing chain and develop new services or data products. This creates a dynamic ecosystem where data and services can be continuously evolved and used in new contexts.

This approach significantly reduces barriers to entry for new participants in the data space. Instead of building complete processing chains from scratch, organizations can leverage existing data products or intermediate results as building blocks for their services. This not only accelerates development but also promotes data quality through reuse of well-maintained datasets. Furthermore, the standardized description of properties and usage conditions in data productofferings creates transparency and facilitates the discovery of relevant data resources.

In the context of accessible multimodal transport, data products play a crucial role in combining various data sources into meaningful services. For instance, raw data about infrastructure accessibility, real-time vehicle locations, and service disruptions can be processed and combined into comprehensive mobility information services. Each step in this process potentially creates valuable intermediate data products that can be used for different purposes, from route planning to accessibility analysis. This flexibility is particularly important in addressing the diverse needs of people with limited mobility, as different applications may require different views or combinations of the same base data. Below we describe two exemplary data products that were implemented for the prototype.

6.3.1 Disabled Parking Spaces in Austria

This data set contains the geolocation, a corresponding address, and a description of disabled parking spaces in Austria. It combines data from Graz, Tyrol, Salzburg and Vienna, and it is updated once a day.

License: Creative Commons Attribution 4.0 International (CC BY 4.0)

Data Attributes

- provenance: origin of this record
- name: name of the parking place
- address: address name of the parking place
- municipality: municipality where this parking place belongs to
- comment: additional information for this record or parking place
- lat: latitude coordinate of this parking place
- lng: longitude coordinate of this parking place

6.3.2 Traffic Monitoring

Infrastructure based traffic monitoring data can be used in different ways to support multi-modal transport of passengers and goods. Real-time as well as long term data – or some kind of processed or post-processed set of datacreated from the original data –from specific parts of road infrastructure which are hot spots that cause delays or uncertainties for a timely arrival at the end destination of a transport mode, can be used to feed into any kind of end user application for travel planning. One kind of processed data that can be utilizedinend user travel planning applications, is long term traffic occurrence dataat said hot spots in different granularity, i.e., every minute, hour, day or month, depending on the applicationstraffic statusforecastaccuracy requirements. The main attributes forsuch data is the current time stamp (i.e., time, day or month), which

kind of road infrastructure the object is detected is on (e.g., road or sidewalk) andhow many objects are detected at a specific time stamp.

7 CONCLUSION

In more and more areas of mobility, data is being digitally recorded or even generated automatically. This ranges from train timetables and traffic monitoring systems to your own car that collects sensor data. Due to the different sources and responsibilities, this results in many heterogeneous and decentralised databases that are little or not at all linked with each other. We are in the middle of a digital transformation process that involves making these data sets available and usable. This was also taken up at the political level. Here are some examples: The European Union has released the data governance act and the data act to promote the exchange and use of data. In Austria the activities around intelligent transport systems (ITS) and the "Action Plan Digital Transformation in Mobility" (BMK, 2022) aiming to bring digital mobility services closer to users of the mobility system.

Developments in the field of data spaces in recent years are aiming at enabling homogeneous as well as trustworthy data exchange and governance within these frameworks. This is also the basis for a healthy and well-functioning data economy. Data exchange and data economy are still an unknown area for many people. As part of this implementation, we learned in interviews that people are often hesitant to take advantage of this opportunity. On the other hand, people have exaggerated expectations. They assume to generate high revenues within a short period of time. Both must be balanced, and the situation must be assessed realistically. There is some effort necessary to create substantial amount of high-quality data. Data must have integrity and a trustful framework for data exchange must be given. This includes technical and legal aspects at the same time.

Digital services for mobility have significant market potential. We therefore suggest establishing a dedicated task force that brings together key public and private stakeholders to create a comprehensive implementation strategy. The primary goal should be to generate practical value through improved mobility services while maintaining a sustainable operational model that promotes broad participation from current market players and fosters ongoing innovation in the accessibility sector.

Mobility is of great importance for all people and therefore also for social participation. Travelling multimodal faces various challenges but it is a strategic goal and has the potential to create a more sustainable, efficient and liveable environment. People with mobility impairments face numerous additional challenges and obstacles to mobility in everyday life. It is our goal to give this group the opportunity to participate in public transport on an equal basis. As a positive side effect, also other groups will benefit from a better adaptability to user needs. As a result, there is an urge for mobility services that are better tailored to individual needs. Interlinked and high-quality data provides the basis for such services.

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reviewed paper

A Participatory Planning Framework using Urban Digital Twins Supporting the Co-Creation of Flexible, Positive Energy Districts

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1 ABSTRACT

The urban socio-ecological transformation requires pathways for an urban energy transition, including the establishment of Positive Energy Districts (PEDs). Technical solutions and simulation tools for urban energy systems are needed for the planning, management and implementation of PEDs. In addition, the involvement of all societal stakeholders is needed to achieve the EU's ambitious target of 100 PEDs by 2025.[1] To this end, innovative research, information and communication strategies must be developed.The transnational funded research project DigiTwins4PEDs[2] focuses on developing an Urban Digital Twin as a dynamic digital representation of urban energy systems using advanced modelling tools. The framework facilitates the integrated energy demand-supply analysis at district scale. It enables the construction and analysis of future development scenarios to simulate the performance of PEDs.It supportsinformed decision-making by citizens and urban administration for a sustainable urban energy transition. The transnational project applies innovative methods and develops implementation strategies supported by a participatory process involving key stakeholders and citizens in co-design, co-creation and co-learning stages of research. Through the framework of living labs in four different case studies, citizens are continuously engaged throughout the project so that citizen-driven actions towards Positive Energy Districts can be considered and implemented more efficiently. New tools and methods are developed and adapted using Urban Digital Twins based on the CityGML data format to enhance public participation in advancing clean energy transition. These toolsenable citizens to actively engage in shaping the future energy transition of their communities and thus supporting informed decision-making.The developed and implemented urban digital twin framework is tested in different urban case study areas (Vienna, Stuttgart, Rotterdam, Wroclaw)within an innovative public participatory process to address the multifaceted aspects crucial for establishing PEDs together with the citizens.

This paper discusses the concept and first prototype of the developedparticipatory planning framework, a shared urban data and modelling scheme,utilizing a digital twin, as well as itsimplementation.It will show how the developed frameworkenables the simulation of urban energy systems with integrated local socio-economic and demographic parameters to identify and visualise current and future energy demand, renewable potential and different energy flexibility strategies in a district. It will discuss how the developed framework can be integrated/combined with other citizens' engagement tools, focussing on the ones used in

[1] https://setis.ec.europa.eu/working-groups/positive-energy-districts_en
[2] https://digitwins4peds.eu/

the case study sites. Furthermore, we draw conclusions on how this framework can be used to support co-design, co-creation and co-learning of community-driven solutions for energy transformation.

Keywords: Citizens Participation, Modelling and Simulation, Urban planning, Positive Energy Districts, Digital Twin

2 INTRODUCTION

Several initiatives have been started to support the clean energy transition and drive the sustainable urban transformation, like the EU SET-Plan, Action 3.2 that aims to have 100 PEDs in Europe expected to be by 2025 in concrete planning, construction, or operation1. An analysis [BOSSI et al. 2020] shows the role of stakeholder processes (citizens, urban stakeholders) as a primary factor for the success or failure of such energy transition, followed by the availability of shared information delivered by integrated technological solutions. The involvement of civil society in planning the built environment is well-established and common practice. However, little is known about their inclination towards community-based energy transition. While technological innovation is necessary to realise PEDs, the challenge is also one of societal transformation as energy transition must be accepted and pushed by citizens and not only by authorities. The participation of local communities in urban design is well-established; however, their involvement in the energy transition remains largely unexplored. While various technological solutions exist for green energy planning, achieving PEDs with strong community support continues to be a significant challenge. This ultimately presents a major obstacle to achieving ambitious targets, such as the EU's objective of deploying 100 Positive Energy Districts (PEDs) by 2025. To address this gap, DigiTwins4PEDs aims to implement an innovative public participation process using Urban Digital Twins (UDTs) embedded in a living lab concept on its four case study regions of Stuttgart, Vienna, Rotterdam, and Wroclaw.

3 CASE STUDIES

The case study in Stuttgart will focus on the neighbourhood of Nordbahnhofviertel, which is facing urban, infrastructure and societal challenges due to adjoining constructions of Stuttgart 21 and Rosensteinviertel. In addition to infrastructure and societal development, it becomes important for Nordbahnhofviertel to get itself developed in terms of energy infrastructure, together with Stuttgart 21 and Rosensteinviertel. Thus, its energetic transformation to PEDs can help Nordbahnhofviertel to ensure that it is no longer insular and ensure a sustainable basis of life for its current and future residents.

The case study in Vienna focuses on the project area "Grätzl 20 + 2" as a part of WieNeu+ urban renewal programme of the city of Vienna. Grätzl 20 + 2 is located in the neighbouring 2nd and 20th district of Vienna and was launched in early 2023 as a cross-district programme in the districts of Brigittenau and Leopoldstadt. It combines the area in the 20th district up to the Danube Canal and Stromstraße with the “Volkertviertel” and “Alliiertenviertel” neighbourhoods in the 2nd district, with Nordwestbahnstraße connecting the two areas. A special focus in these areas is to transform the currently gas-based energy supply system to alternative renewable energy sources and evaluate the implications of such conversion on the power and heat load management and related peak loads. Therefore, the intended approach within DigiTwins4PEDs is to co-design different district energy transformation scenarios with a focus on energy flexibilisation options using urban digital twins as simulation tools and co-create solutions and evaluate with residents and decision makers potentials and opportunities to transform the Grätzel 20+2 towards a PED.

The case study in Rotterdam will focus on the neighbourhoods of Prinsenland and Feijenoord. Rotterdam is committed to finding future-proof solutions to reduce its carbon footprint and become carbon-neutral by 2050. However, the city will not be able to achieve its climate action pledge alone: input from the government, province, and industries such as the port, as well as changes in city residents’ behaviour, will also be necessary. Within DigiTwins4PEDs the neighbourhoods of Prinsenland and Feijenoord will be used as a test case to experiment living labs and the development and evaluation of new IT-based tools for co-creation and community-based solutions to enable the civil society to drive energetic transformation by information exchange, visualising future energy demand for cooling, potential, flexibility scenarios and its socio-economic impact at a community level. City of Rotterdam has already established a “Digital City Rotterdam” to improve the efficiency of urban planning and management. Connecting the Digital City Rotterdam with the activities and outputs of DigiTwins4PEDs will be a very valuable opportunity to engage citizens in a co-creation process to start the transition towards PEDs.

The case study in Wroclaw focuses on the neighbourhood of Kleczków, which is facing infrastructural and societal challenges in connection with the implementation of "Nowe Kleczków" and the planned functional and spatial changes in the western and eastern parts of Kleczków. For the sustainable development of Kleczków it is important that it continues to future proof its energy infrastructure and thus its energetic transformation to PED can support in providing a sustainable living conditions for its current and future resident. Public buildings, including schools and municipal housing, often have high energy demands due to aging infrastructure. Investments in insulation, energy-efficient HVAC[3] systems, and solar panels could significantly reduce their environmental impact. Former industrial sites, repurposed into offices or cultural spaces, also present opportunities for modernization, such as renewable energy installations and smart systems to improve efficiency. Kleczków's diverse building stock, ranging from modern housing and historic churches to industrial-era tram depots, provides a solid foundation for transforming the district into a "positive energy district," where buildings not only minimize energy consumption but also generate surplus energy through renewable sources, contributing to a sustainable and self-sufficient urban environment.

4 METHODS: CONCEPTS AND FIRST PROTOTYPES

The project usesa bottom up end-use approach to model urban energy systems with focus on the district scale. The modelling methodology relays on sectoral spacio-temporal modells to conduct integrated energy demand and supply analysis,coveringselected flexibility options to balance energy demand with the volatile renewable energy supply in a timely manner. This ensures the required positive annual energy balance for the pilot PEDs.

Starting from the calibration of a base year reflecting the current district energy system, the approach allows for constructing future energydemand-supply scenarios following assumptions on the expected local demographic, socio-economic and technologicaldevelopment, the available local RES potential and the viable interaction with the neighbourhood energy system. The future development scenariosare constructed based on co-creation process involving key stakeholders and engaging citizens.

4.1 Energy flexibility analysis

PEDs represent urban energy systems relying upon variable renewable energy sources (RES) to cover district energy demand.Ensuring the timely demand-supply balance in view of such fluctuating conditions requires the provision of appropriate flexibility options to adjust demand and supply and maintain regional grid stability. Energy flexibility options involve strategies and technologies that dynamically balance energy demand and supply, ensuring optimized management for a positive annual energy balance of the PED.These options includedemand and supply sides, local energy storages, sector coupling (e.g., V2G) and smart energy management. Implementing flexibility options requires data collection and analysis to inform decision-making and develop a comprehensive implementation plan. Additionally, engaging local stakeholders is crucial to gathering qualitative insights, enhancing a data-driven approach, and promoting the benefits of utilizing local flexibility options.

Demand Response (DR) and Demand Side Management (DSM) are key measures for enhancing the flexibility of modern energy systems. It leverages the potential for temporal shifts in energy demand to better match supply fluctuations, optimizing energy use and reducing stress on the grid.Technologies such as heat pumps, thermal energy storage, and electric vehicle charging schedules can be dynamically adjusted to align with the grid conditions, contributing to more efficient and reliable energy systems. DR focuses on shifting or reducing energy consumption during peak times to off-peak periods in response to price signals or grid needs, while DSM encompasses a broader range of activities that include managing energy demand through smart devices and real-time controls. Both strategies rely heavily on advancements in information and communication technologies, allowing for seamless integration of flexible demand behaviours across residential, commercial, mobility, and industrial sectors.

DSM plays a pivotal role in enhancing the flexibility of modern energy systems, especially as the transition toward renewable energy sources accelerates. By dynamically adjusting energy consumption patterns in response to supply conditions, DSM allows for better alignment between demand and variable renewable energy options.This flexibility not only optimises energy use but also reduces strain on the grid, improves

[3] HVAC: Heating, Ventilation and Air Conditioning

system reliability, and supports the integration of clean energy resources.Furthermore, DSM and DR and advanced technologies like smart meters, empower consumers to actively participate in balancing supply and demand, fostering a more resilient and sustainable energy future. An important flexibility option is the active storage technologies like batteries and puffer tanks, but also thermal buildings inertia (concrete core activation)to capture surplus energy produced during peak renewable energy generation periodsfor using during times of low production or high consumption.

The general modelling scheme combining different tools developed in DigiTwins4PEDs enables to analyse the Demand Response and Demand Side Management for the entire district[4] and individual buildings.

4.2 General modelling scheme

The Figure 1 shows the general modelling scheme. In DigiTwins4PEDs, the CityGML 3D City Database (in short: 3DCityDB)for PostgresSQL serves as the central storage and exchange platform for CityGML-based building models enriched with Energy ADE, ensuring structured storage, retrieval, and processing of energy-related attributes. It plays a crucial role in managing complex urban datasets, allowing for efficient data exchange between simulation tools such as SimStadt and MAPED, and ensuring scalability, data consistency, and interoperability within the project's workflow.

Note: At the time of writing this article, Energy ADE 2 is in the Beta 6 stage and expected to be released in Q4 2025. To document a complete and functional workflow in this article, the Energy ADE 1 KIT profile has been used instead, as its full implementation is readily available on GitHub.[5] Once Energy ADE 2 reaches full development, it will seamlessly replace Energy ADE 1 without requiring any new modifications to the system architectures shown in Figure 1.

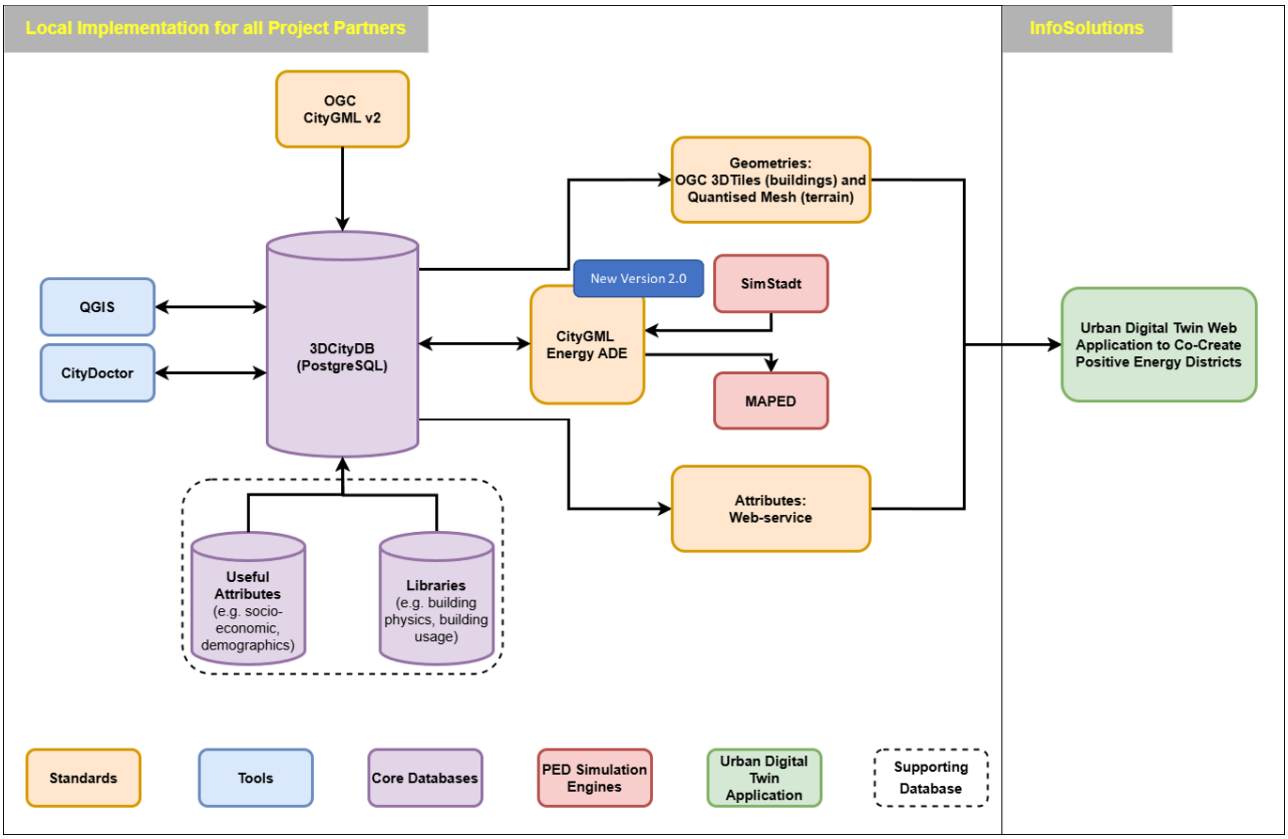

Fig. 1: DigiTwins4PEDs general modelling scheme

[4] System boundaries, not a politcal district
[5] https://github.com/3dcitydb/energy-ade-citydb

4.3 Data and Software Specifications

4.3.1 SimStadt

SimStadt is the name of an urban simulation environment developed at HFT Stuttgart and of a project of the same name, which in turn is the continuation of a project completed in 2015 (SimStadt). At its current stage, SimStadt has the capability to utilise data from real urban planning situations for energy analyses of buildings, city sectors, entire cities, and even regions. Its application scenarios encompass high-resolution simulations of building heating and cooling requirements, potential studies for photovoltaic installations on roofs, facades, and ground surfaces, as well as simulations of building refurbishment scenarios, renewable energy supply scenarios (including PV and biomass), electricity demand, load profiles, district heating networks, waterdemandand analyses of food demand and potential [1]. Thus, SimStadt can significantly assist architects, urban planners, urban energy experts and local authorities in integrated energy planning processes and the formulation of measures towards sustainable (re)design of buildings and neighbourhoods. As its primary input, SimStadt employs the open and standardised data model of CityGML to store urban objects (such as buildings, land use, trees, terrain, roads, etc.) and their associated attributes as a digital 3D city model. SimStadt processes 3D city models, enriches them with necessary attributes, and generates energy simulation results that can be seamlessly reintegrated back into the CityGML dataset. Beyond the physical shape of a building, which is derived from the input CityGML building dataset, SimStadt requires data on weather conditions and building properties, particularly to simulate the energy demand of buildings. Weather conditions are part of the weather preprocessor module of SimStadt. Based on the EPSGcode of the CityGML 3D city model, it retrieves weather data for the location of the model and creates synthetic hourly values from monthly means. Building properties are further divided into building physics properties and building usage properties. Both building physics and building usage properties are implemented as libraries and respective workflow steps in SimStadt. The buildingphysics library contains benchmarking data of building physics properties, constructions and materials, such as the U-values of the different building elements etc.With building usage, it is possible to define set-point temperatures, inner gains and occupation for different building functions (e.g. residential, office, hotel, retail ...).In the DigiTwins4PEDs project, SimStadt plays a key role in building-level energy simulations, supporting assessments of heating/cooling demand, PV potential, and different electric load profile scenarios.The simulation results are stored in 3DCityDB using Energy ADE, ensuring a structured and standardised data exchange with MAPED. The latest list of publications which use SimStadt for urban energy simulation can be found on https://simstadt.hft-stuttgart.de/about/publications/. The following figure showsan example of the Simstadt User Interfacefor a region in Stuttgart.

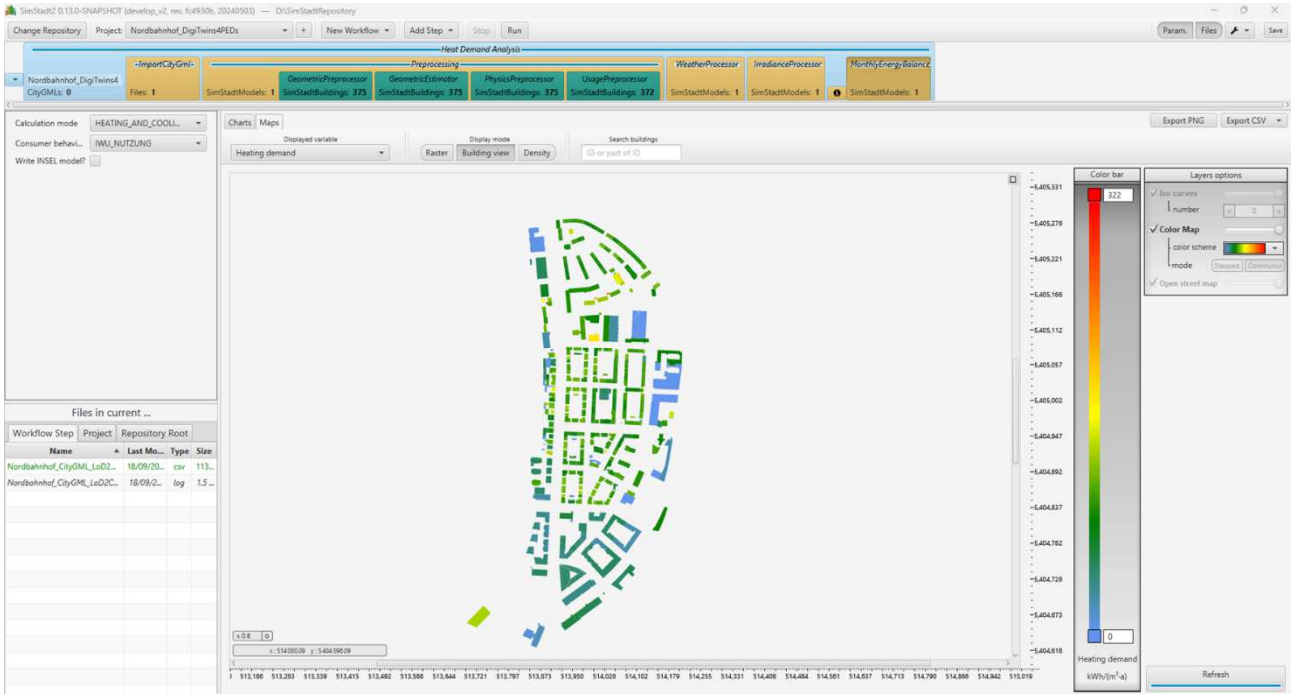

Fig. 2: Simstadt UI and heatng demand for Nordbahnhof buildings in Stuttgart ©HFT

4.3.2 MAPED

MAPED is a bottom-up rapid energy assessment tool for analysing the energy demand and supply of urban districts and assessing their qualification to reach an annual positive energy balance by exploiting local RES to cover district's electricity and heat demand. MAPED has been developed based on the proven end-use concept of the IAEA model MAED(NEUMANN et al., 2021). MAPED focuses on the evaluation of useful and final energy demand at the district scale, covering energy demand for household (residential) and service building (non-residential), urban farming, industry, and mobility. Moreover, it offers a simplified approach to evaluate and estimate the local renewable energy production to cover heat and electricity demand using photovoltaic, solar thermal energy and heat pumps. Other local supply options like biomass, waste heat and micro wind can also be considered given the prevailing boundaries, topology, social acceptance, and the applied regulations. MAPED approach evaluates final energy demand based on demographic, social, and technological data of the considered district. MAPED systematically relates the specific energy needs for providing goods and services to the social, economic and technological factors that affect the demand for a particular fuel. This implies population number and growth, number of inhabitants per dwelling, number of electrical appliances used in households and services, peoples' mobility and preferences for transport modes, evolution of the efficiency of certain types of equipment and market penetration of new technologies or energy forms. The expected future trends for these determining factors, which constitute 'scenarios' are exogenously introduced. This enables evaluating the needed measures to convert the considered district to a PED within the given demographic, social, technical and building types of specification.Since SimStadt and MAPED are integrated within the DigiTwins4PEDs workflow, building-level energy data generated by SimStadt is aggregated at the district scale using Energy ADE and then used in MAPED. This integration ensures that detailed building-level energy assessments, such as energy demand and photovoltaic potential, contribute to district-level energy flexibility strategies, includ-ing energy balancing, renewable energy integration, and demand-response measures.

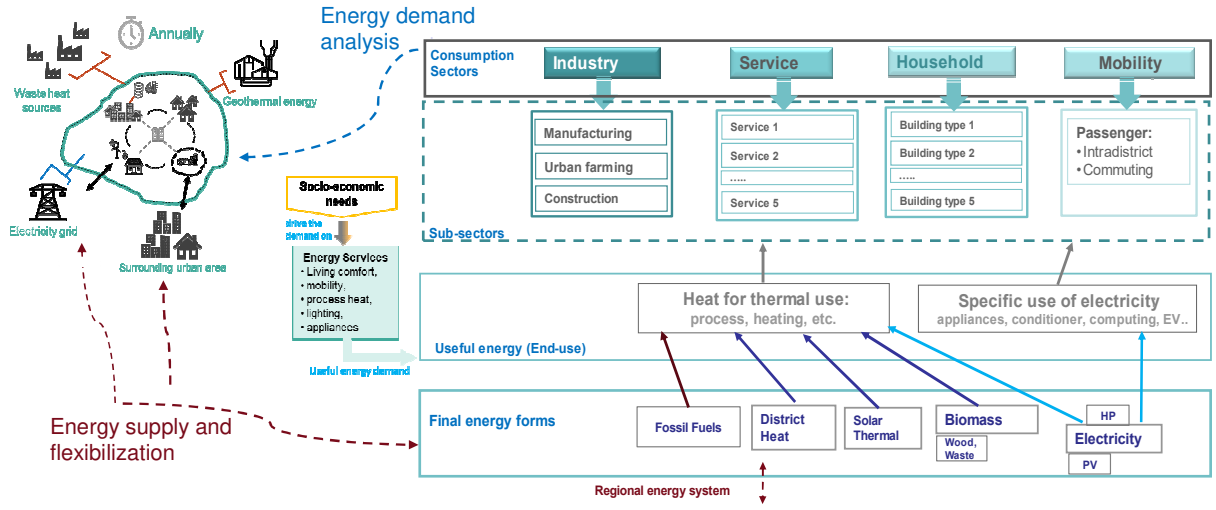

Fig.3: MAPED concept for the disaggregation of district energy demand by fuel and consumption sector, and the conceived energy supply and exchange with the neighbourhood energy system ©AIT

4.3.3 CityGML Energy ADE

The international standard City Geography Markup Language (CityGML), issued by the Open Geospatial Consortium (OGC), offers the possibility to model urban environments, including buildings, in a 3D space. CityGML defines "basic entities, attributes, and relations" of relevant urban objects, functioning both as a conceptual data model for semantically enriched 3D city models and as a storage and exchange format. Currently, the most widely used version is CityGML 2.0, which was released in 2012.CityGML has been intentionally designed to be application independent. Nevertheless, in certain cases, additional classes or attributes may be needed for specific domains. For this reason, CityGML can be extended following two approaches. The first one allows for the definition of so-called generic attributes and GenericCityObjects without the need to extend the conceptual data model. The second one, on the other hand, offers more modelling capabilities but demands an extension of the data model. This second approach is referred to as the Application Domain Extension (ADE) mechanism.

The Energy ADE[6] is such an extension for CityGML [AGUGIARO, 2018]. It builds upon the CityGML 2.0 Core and Building modules and extends them by means of additional classes and properties. As such, it has been conceived and designed as a solution to model and store relevant data needed for UBEM. It offers the possibility to model both data serving as input for energy-related applications and as output, for example from the energy simulation results. The overall goal is to foster interoperability of energy-related data between different stakeholders and different software tools to perform city-wide energy assessments based on a bottom-up approach that starts from the granularity of the building. The Energy ADE was released in 2018 through a joint effort of various international parties and stakeholders (familiar/expert with/in either CityGML or UBEM). It is mentioned in the literature as a best-practice example when it comes to ADE development due to its technical maturity and available documentation. As a result, the Energy ADE has already been used in several national and international projects.One of the outcomes of the DigiTwins4PEDs project is to improve the current version of the Energy ADE and to release a new, improved version, tentatively named simply Energy ADE 2.0.

The Energy ADE 2.0 follows the same principles and goals of the previous versions, but it also incorporates the experiences and feedback from the projects carried out since its first release. At the same time, it takes into account new developments both in terms of ADEs and CityGML itself. In the former case, for example, a source of inspiration to improve and extend the data model comes from the Food-Water-Energy ADE (PADSALA et al., 2021) and the i-Urban Revitalisation ADE (AKAHOSHIet al., 2020). In the latter case, a new version of the CityGML data model has been published in 2021, reaching version 3.0 (OGC, 2021).As a result, the development of the new Energy ADE 2.0, although still based on CityGML 2.0, is already incorporating concepts that will ease its future conversion to CityGML 3.0.

Among the most significant changes introduced in the Energy ADE 2.0 is an improved “Building physics module”, which contains classes to model objects such as thermal zones, thermal boundaries and thermal openings, i.e. objects needed to compute the heat transfer through the thermal hull of the building. The new module overcomes some limitations of the previous version, in that, for example, now multiple representations of such objects are allowed (i.e. from LoD1 to LoD3), and, at the same time, the overall modelling approach has been brought closer to the overall “logic” of CityGML.

Additionally, the newly added “Resources module” completely overhauls the previous EnergyDemandclass by introducing the more general concept of resource, i.e. a quantifiable amount of “something” (i.e. energy, but also water, food, construction materials, waste, etc.) that can be associated to any city object and that can be expressed as yearly amount, or a time-dependent variable (via time series). The classes contained in the Resources module take inspiration and further elaborate concepts from the Food-Water-Energy ADE.

Besides other minor changes and simplifications, another addition of the Energy ADE 2.0 is the possibility to create a hierarechical partion of space (e.g. according to administrative boundaries: country, region, city, district, quarter, block, ...). Each of the objects at each level can associated to aggregated values (e.g. energy demand for heating at block, district, city level, etc.). This new addition, consisting in the so called UrbanFuntionArea, takes inspiration from a nearly equal class described in the i-UR ADE.

The Energy ADE 2.0 is currently in active development and is being implemented in terms of Java libraries (needed for the existing tools for CityGML 2.0) and a database schema that extends the CityGML 3D City Database (YAO et al., 2018). Eventually, the 3DCityDB-Tools plugin for QGIS is also planned to add support for it (AGUGIARO et al., 2024).

4.3.4 Urban Digital Twin Web Application

The front-end, the UDT Web Application (Figure 4 and 5), enables to interact with the simulation results and visualises the results at different spatial resolutions. Thus building-related information, as e.g. the specific energy demand over time of a building, as well as the entire demand and energy production potentials of the district.The UDT-Web Application will be developed as an information-sharing, gathering and/or a co-development platform for citizens and stakeholders to simulate and visualise different future PED scenarios for their communities before their real-world implementations. It will be an expert tool, which shall be used by public authorities and urban planners to inform and design together with citizens scenarios to realize PEDs. The system’s architecture has been depicted in the Figure 6below, showing main components and

[6] https://www.citygmlwiki.org/index.php/CityGML_Energy_ADE

technologies utilised. In the storage layer, we mainly use NoSQL – Firebase and google cloud where we have defined user roles and permissions in the system. Spatial data are stored in dedicated containers for their specific handling. The application layer uses mechanisms of services, business logic, communication API and user interface components to support specialized views and support the geoportal tool. The system components communicate with each other using the http protocol.In the design of the Web GIS application open-source libraries were used to render geospatial data. In particular, the Cesium.js technology for generating views of the globe, as 3D perspectives in a web browser environment.

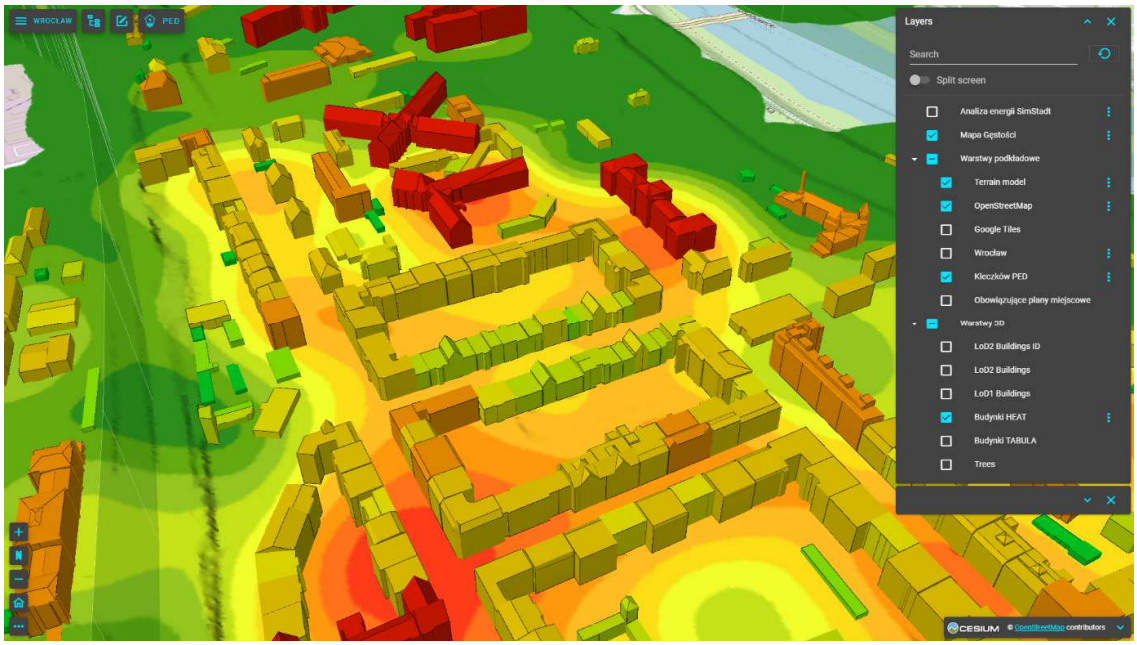

Fig. 4: UDT platform first prototype: Screenshot Wroclaw ULL: 3D Building Heat Demand ©INFOSOLUTIONS

Fig. 5: UDT platform first prototype: Screenshot WROCLAW ULL 3D Building information ©INFOSOLUTIONS

In addition, the service supports tools for generating analytical charts and static data sets. The views are presented in the form of a thematic geoportals for all the fouruse-cases (Stuttgart, Vienna, Roterdam, Wroclaw) equipped with a set of analytical and data management tools, including business intelligence dashlets to present thematic datasets. To build layouts Vue.js with the Vuetify library framework[7] was deployed as it allows building a responsive application.The data structure designed allows for flexible adaptation of the project while adhering to all rules regarding data access and project sharing with other

[7] https://vuetifyjs.com/en/

users. By "project," we refer to an isolated, thematically prepared dataset intended for presenting both general views and specific phenomena. Users can configure the project's layer settings, compositions, and dedicated documents for displaying static data. These configurations can then be incorporated into the application's layout and tools, providing a tailored user experience. Once the project is configured, the application allows presentations of 2D/3D data in formats supported by the Cesium.js API. As a standard, raster base layers such as TMS, WMS, GEJOSON, CZML, tiled 3D data are supported.

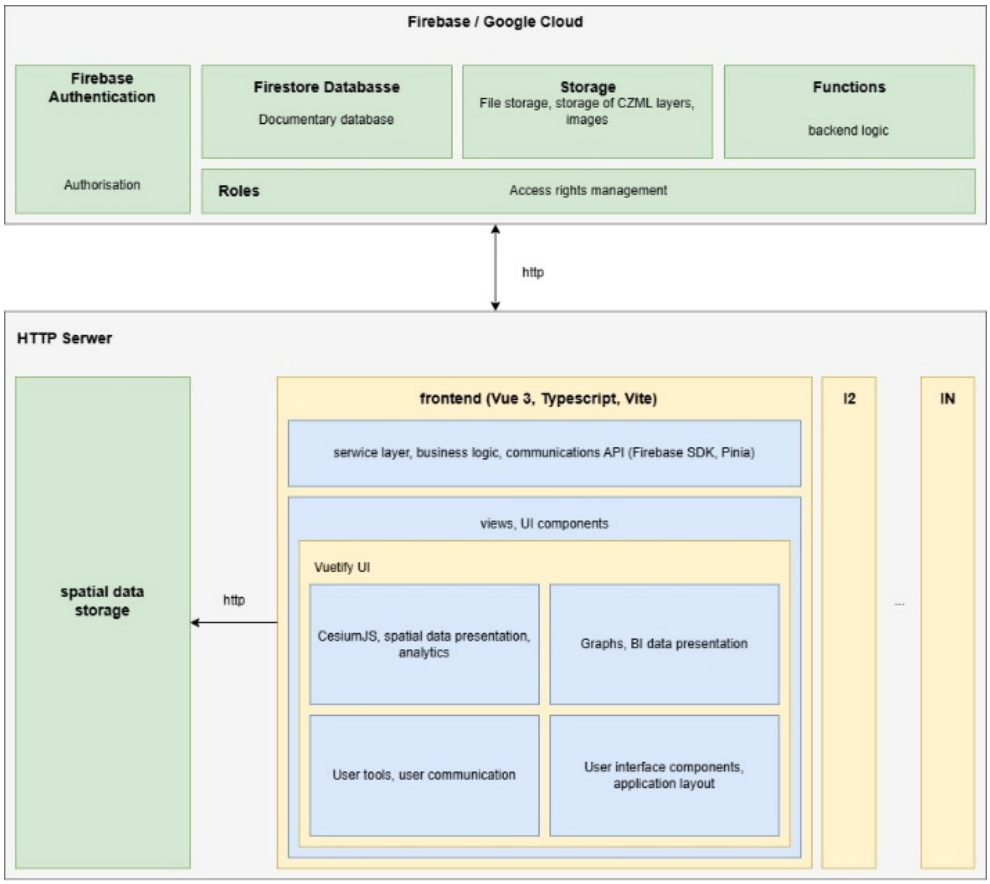

Fig. 6: Web GIS service system architecture ©INFOSOLUTIONS

5 CO-CREATION: A PARTICIPATROY PLANNING FRAMEWORK

5.1 Urban Living Labs

Urban Living Labs (ULLs) represent a dynamic approachfostering participatory community engagement by testing and evaluating small-scale interventions in collaboration with local communities [AFACAN, 2023]. These labs serve as platforms for co-creation, where citizens actively contribute to experiments and innovations, facilitating engagement and transformative change [VAN DER JAGT, 2018]. By incorporating co-design processes, ULLs enable the development of long-term partnerships between science and the community, ensuring that local needs are addressed and tailored solutions are created [MAHAJAN, 2022;ZINGRAFF-HAMED, 2020]. Through collaborative, neighbourhood-based approaches, ULLs activate urban resources and significantly contribute to resilient urban development [PETRESCU, 2022]. They provide a normative framework for guiding real-world experimental processes, aligning them with broader social and environmental goals [ZIEHL, 2021]. These experiments test and refine innovative solutions, strengthen social interaction, promote practice-based knowledge, and inspire new thinking and action [ROBAZZA, 2024]. Moreover, ULLs facilitate cross-sector collaboration, supporting urban transformation and innovation across disciplines [ZINGRAFF-HAMED, 2019]. They offer a promising opportunity to address current and future challenges by developing responsive and innovative urban solutions that enhance participatory resilience [BELFIELD, 2024]. By creating spaces for experimentation and fostering community involvement, ULLs empower cities to align with transformative goals and ensure sustainable, inclusive urban development [FRANTZESKAKI, 2018].

In the DigiTwins4PEDs project, ULLs serve as adaptive spaces for informing, experiencing and learning about everyday energy needs and PEDs, enabling the development of viable transformation pathways. DigiTwins4PEDs uses ULLs to implement a co-design, co-creation and co-learning process, where local communities actively engage in the energy transition. The ULLs bridge the gap between technological innovation and societal needs by integrating new tools and methods using UDTs to support participatory planning at neighbourhood level and make more informed decisions. These digital tools are iteratively designed, tested, and refined within ULLs, allowing communities to explore energy solutions, make informed decisions, and drive urban transformation. To maximize participation and acceptance, hybrid formats – combining digital and analogue interventions – are implemented.The IT-based solutions developed within DigiTwins4PEDs will be integrated into ULLs to assess how UDT platforms can enhance citizen acceptance and encourage active participation in urban transformation. By engaging key target groups, the project aims to explore how UDTs can contribute to enhance urban resilience and quality of life. To raise public awareness, an UDT platform will be made accessible at the citizen level, allowing individuals to explore, test, and provide feedback through interactive participation formats. This hands-on approach will raise awareness among communities of the concept of a clean energy transition and empower them to take an active role in shaping sustainable neighbourhoods. By using UDTs as a catalyst for citizen-driven action, the project seeks to identify strategies for sustaining long-term engagement and strengthening social responsibility. We plan to address three key target groups – young people, tenants, and property owners – and have developed a participatory planning framework with three targeted interventions for integrating UDTs into energy transition.

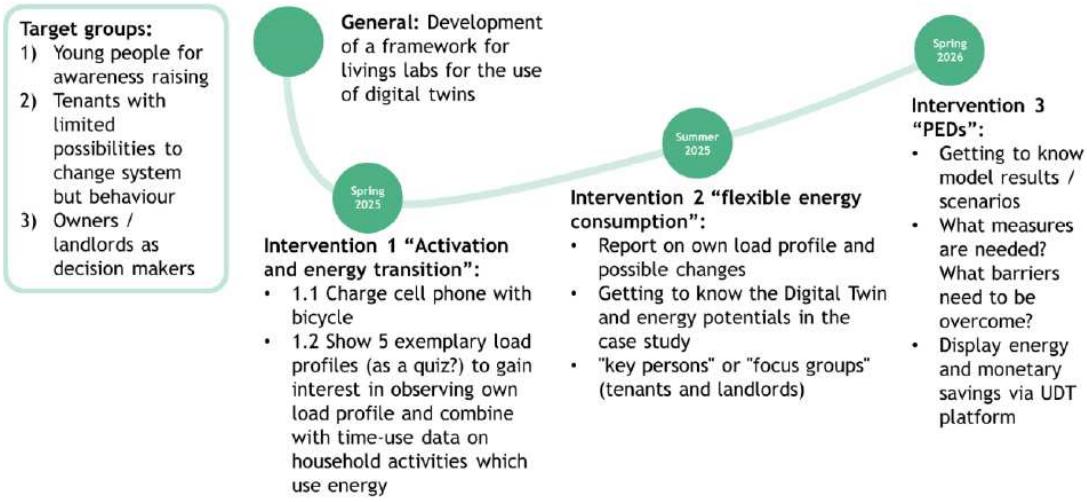

Fig. 7: Framework Idea for a cross-case study co-creation method

5.2 User "Behaviour" Stories for a Better Learning Process

The project'sresearch efforts are linked to the broader question of 1) how consumers can be empowered to become prosumers and 2) which measures are of interest and feasible for the citizens as end users.

The planned interventions will play a key role in enabling the flexibilisation necessary for the energy transition. Thus, behaviour-based scenarios will be created and implemented through the planned interventions covering activation and energy transition (intervention 1), flexible energy consumption (intervention 2) and PEDs (intervention 3). The three interventions developed in the framework focus on the following cross-sectional topics, providing end-users with insights into the impact, timing, and costs of various measures throught the UDT platform:

(1) Energy supplymeasures:such as installing photovoltaic systems, heat pumps, and district heating.

(2) Energy demand measures: actions focusing on energy-saving, including consumer behaviour, and energy efficiencymeasures, e.g., building refurbishment.

(3) Energyflexibilization measures: strategies like power and heat storage, sector coupling (like vehicle-to-grid) and demand-side management (e.g. shiftable use of appliances like washing machines).

The UDT platform will be tested using two prototypes of the UDT system: First, during the 2nd intervention, a prepared scenario will demonstrate the concept by the concept by testing 1-2 measures (e.g. PV installation and washing machine use). Second, if the system performs as expected, users of the UDT will independently formulate questions and select additional options for testing during the 3rd intervention.

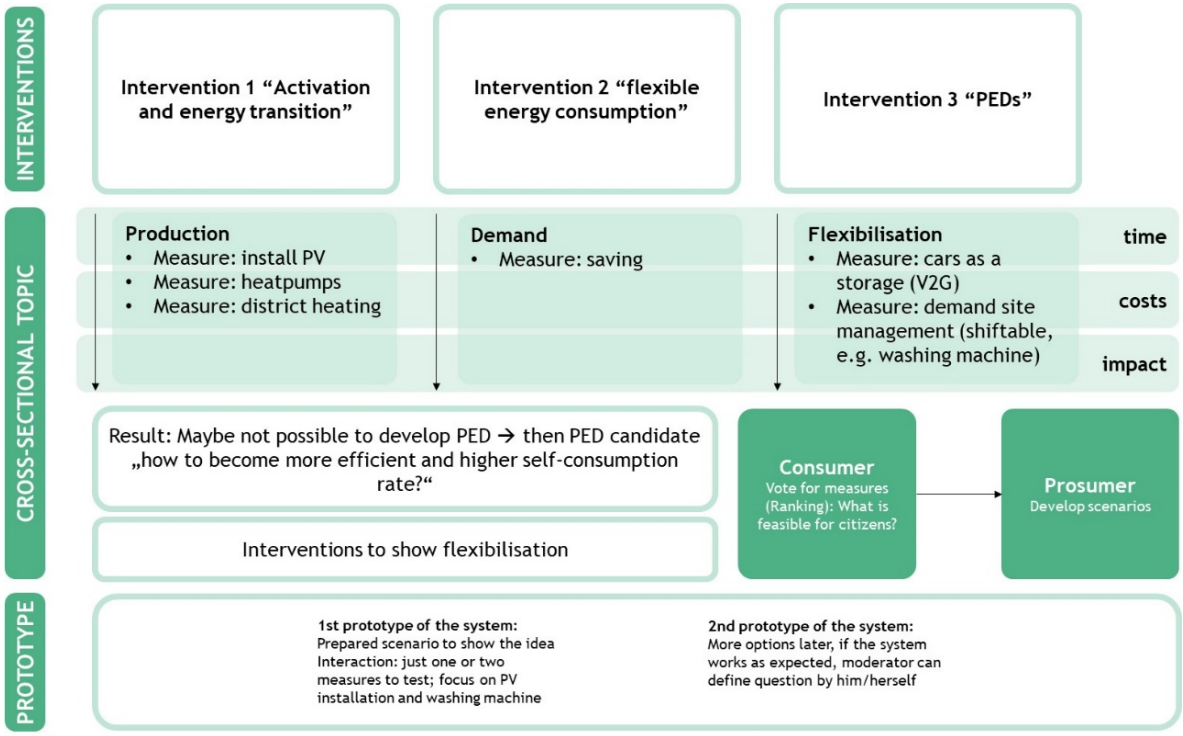

Fig. 8: Behaviour Stories to show energy flexibilisation

6 CONCLUSION AND OUTLOOK

The research project DigiTwins4PEDs develops an urban digital twin framework tested in different urban case study areas (Vienna, Stuttgart, Rotterdam, Wroclaw). Based on the 3D CityGML data format, the UDT integrates two urban energy simulation tools SimStadt and MAPED. To have a structured and standardised way of data sharing amongst the two simulation models, Energy ADE implemented in 3DCityDB PostgresSQL is used. The developed platform can be used in participatory processes to address the multifaceted aspects crucial for establishing PEDs together with the citizens.The concept and first prototypepresented above already show the potentials,e.g. how it can be used to explore behaviour stories for realizing the energy system transition, to change e.g. from pure energy consumer to become a prosumer. The first experiences also show that the UDT needs a facilitator (operator) to maximise its potential. Furthermore, that it is essential to integrate it in already existing citizens' engagement tools (platforms like Wien mitgestalten[8]) to be successful and accepted by the citizens and urban administration. Combining different Energy System Simulation tools, capable of simulating from the building level up to the district, enables us to show the broader picture for the district as well as give citizens (tenants and building owners) andpublic authorities the information to support their decisions and develop jointly sustainable scenarios for the future.The project sofar developed the Energy ADE 2.0, which is one of the major outputs of the projectneeded to enable this from a technical perspective.During the next phase of the projectwe will further improve the concept and test the prototype applied in the planned interventions in the four involved case study. The developed data-workflows in the different cities necessary to prepare the input data for the simulation tools are essential to learn how the framework can be used in other cities with their available data.For the stakeholders involved from the cities,this isan important aspect to keep the effort at minimum, whenever the UDT framework should be transferred after the project.

[8] https://mitgestalten.wien.gv.at/de-DE/

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🏆 reviewed paper

Accelerating Climate Change Adaptation in Cities with FAIR2Adapt: FAIRifying Hamburg's Risk Map

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1 ABSTRACT

As climate change intensifies, cities must develop adaptive strategies to mitigate risks and enhance resilience. The FAIR2Adapt project applies FAIR (Findable, Accessible, Interoperable, and Reusable) principles to climate adaptation data, ensuring long-term usability and interoperability across urban planning tools. This paper presents our work on identifying requirements for the FAIRification of Hamburg's Risk Map, a critical resource for urban climate adaptation.

We outline the methodological framework used to enhance data findability, accessibility, and interoperability, integrating the Risk Map with broader urban data infrastructures. The approach involves a requirements elicitation process as a pre-phase of the FDO-driven FAIRification Framework we develop in the FAIR2Adapt project. Based on the description of the city of Hamburg case study, which is one of six in the FAIR2Adapt project, we identified user stories and extracted more specific requirements. To address these requirements customized FAIR Supporting Resources will be needed, such as a FAIR metadata schema for geospatial risk maps and simulation models, improving data sharing and reusability within ArcGIS-based risk assessment tools, and applying Scientific Knowledge Graphs (specifically, the Open Research Knowledge Graph) to ensure scientific transparency and reproducibility. Additionally, we will enhance urban climate modeling workflows making the developed procedures accessible via RO-Crates that allow to package the software together with structured documentation.

By embedding these principles, we strengthen decision-making for urban climate adaptation, providing city planners and stakeholders with actionable, interoperable data. We discuss challenges in the uptake of FAIR implementation, and present an outlook on scaling our approach to other cities. Our findings contribute to the broader discourse on how FAIR principles can accelerate climate resilience efforts in urban environments.

Keywords: climate change, resilience, climate adaptation, interoperability, urban planning

2 INTRODUCTION

2.1 FAIR2Adapt for advancing Climate Adaptation

Climate adaptation efforts require reliable, accessible, and interoperable data to inform evidence-based decision-making. The FAIR2Adapt project, financed by the Horizon-INFRA-2024-EOSC-01-01 program, addresses this challenge by applying FAIR (Findable, Accessible, Interoperable, and Reusable) principles (Wilkinson et al., 2016) to climate adaptation data, ensuring that critical environmental and socio-economic datasets can be effectively utilized for urban long-term planning. The project has recently started and is currently in the process of developing an FDO-driven FAIRification Framework. This paper focuses on requirement elicitation, an initial phase within the FAIRification process that aims to identify the specific needs of stakeholders involved.

2.1.1 Why the FAIR principles matter for data management in CCA

The FAIR principles are crucial for data management in Climate Change Adaptation (CCA) due to the complex and multidisciplinary nature of climate data. Effective climate adaptation strategies depend on integrating diverse datasets, such as meteorological data, socio-demographic information, and infrastructure resilience indicators. Applying the FAIR principles ensures that these datasets are:

- Findable: Easily discovered and located by both humans and machines, enabling efficient identification and visibility of relevant data through searchable resources.
- Accessible: Reliably retrieved through standardized, open, and secure protocols, ensuring long-term accessibility of metadata even if restrictions apply.
- Interoperable: Compatible with various systems and tools, allowing seamless data integration across platforms.
- Reusable: Properly documented and standardized, promoting long-term usability and reproducibility.

By improving data FAIRness, FAIR2Adapt enhances the usability of climate risk assessments, such as Hamburg's Flood Risk Map, by integrating diverse sources, including urban flood data, socio-demographic information, and infrastructure resilience indicators.

2.1.2 Added value for the CCA communities

The added value of applying the FAIR principles to CCA data management lies in several key areas:

- Enhanced Decision-Making: With FAIR-compliant data, city planners and stakeholders have access to high-quality, actionable information, enabling informed, data-driven decisions.
- Scientific Transparency: The FAIR principles promote the sharing of well-documented and reproducible data, which is essential for scientific credibility and progress.
- Long-Term Usability: By standardizing metadata and documentation, the FAIR principles ensure that data remains usable and relevant over time, supporting ongoing adaptation efforts.
- Interdisciplinary Collaboration: FAIR-compliant data facilitates collaboration across different sectors and disciplines, fostering holistic approaches to climate resilience.

2.1.3 Key barriers and challenges

Despite the benefits, several barriers and challenges must be addressed to effectively implement the FAIR principles in CCA data management:

- Data Integration: Combining diverse datasets from different sources can be technically challenging due to varying formats, standards, and quality.
- Metadata Standardization: Establishing and maintaining consistent metadata standards across datasets is crucial for interoperability, but can be resource-intensive.
- Infrastructure Limitations: Existing data platforms may lack the necessary support for the FAIR principles, requiring upgrades or new implementations.
- Stakeholder Engagement: Ensuring that all relevant stakeholders understand and adopt the FAIR principles requires significant outreach and education efforts.

In addition to advancing climate adaptation efforts, the FAIR2Adapt project aligns with broader policy goals such as those outlined in the EU Data Act. While FAIRification is not a strict legal requirement for all datasets, the Data Act promotes data sharing, access, and reusability, reinforcing the importance of FAIR practices, particularly for publicly funded research data. By embedding these principles, FAIR2Adapt contributes to enhancing data governance and interoperability in line with EU policy objectives.

Addressing these challenges is essential for maximizing the impact of the FAIR principles on urban climate resilience. Through a structured approach that integrates user-driven needs, metadata standardization, and technology integration, FAIR2Adapt fosters collaboration among researchers, policymakers, and urban planners, creating a scalable model for cities seeking to strengthen their climate adaptation strategies.

2.2 Hamburg's Climate Risk Mapping: challenges, goals and key assets

2.2.1 Challenges and opportunities

Hamburg, a city with various climate-related risks, needs to adapt to climate change in a systematic, sustainable and cross-sectoral approach. At the organisational level, the interaction between the administration and public enterprises is crucial for the implementation of adaptation strategies and the consideration of interactions between the different actors and sectors of the urban system, which is a

prerequisite for sustainable adaptation planning. In addition, adaptation and mitigation need to be weighed against each other to assess trade-offs and avoid incompatibilities (e.g. urban densification versus adaptation to climate-induced stressors), which requires tailored state-of-the-art climate and adaptation scenarios (e.g. Representative Concentration Pathways RCPs and Shared Socioeconomic Pathways SSPs).

2.2.2 Key assets for FAIR Climate Adaptation

Hamburg faces risks from pluvial flooding due to heavy rainfall events, exacerbated by urbanization and climate change. To support decision-making and adaptation strategies, the city has developed key assets that facilitate data integration, flood risk assessment, and predictive modeling. Unlike fluvial or coastal floods, pluvial floods are localized, unpredictable, and challenging for numerical weather models. Hamburg, with its flat topography and complex flood risks (pluvial, fluvial, coastal), serves as a case study for a high-resolution risk mapping approach.

The „Pluvial Flood Risk Assessment for Hamburg“ develops a risk assessment framework for pluvial flooding in Hamburg. The study follows the IPCC 2014 risk framework, considering hazard (flood levels), exposure (people in affected areas), and vulnerability (socio-economic factors) to develop Pluvial Flood Risk Indices related to well-being (PFRWB) and mobility/accessibility (PFRMA).

To quantify social vulnerability, the study incorporates socio-economic factors, namely children under 10, elderly singles, low education levels, and social welfare recipients. Exposure is defined by differentiating between people affected by mobility restrictions (all residents in a building) and direct flood impact on residential well-being (only ground-floor residents). The hazard component is derived from high-resolution flood simulations for Hamburg, based on a 100-year rainfall event (36 mm/h). The methodology applies TOPSIS and Shannon Entropy to quantify vulnerability and integrates spatial analyses using Delaunay-Triangulation for visualization.

The results identify risk hotspots in Hamburg, where high PFRWB and PFRMA values overlap. A key finding is that social vulnerability does not correlate directly with hazard occurrence, highlighting the complex spatial nature of urban flood risk. The study underscores the need for a holistic approach to risk assessment, integrating climate science, infrastructure planning, and social policies to enhance urban resilience. The methodology developed in this study is transferable to other urban areas, making it a valuable asset for climate adaptation planning and risk-informed decision-making.

The risk map was implemented in ArcGIS using a number of different tools after external data preparation. The whole procedure will be available as a customized ArcGIS tool, which will be prepared as a shareable resource to allow its application in other urban areas. This approach will be utilized for Hamburg's Risk Assessment Framework and will be used to produce a heat risk map for the city of Hamburg, adapting procedures with different input data.

In Hamburg, the Urban Data Platform Hamburg (UDP)[1] serves as a central hub for geospatial and hydrological data, enabling municipal agencies to access and analyze critical datasets such as those used to create the risk map. However, while it consolidates data from various sources, its FAIR compliance remains limited, posing challenges for data findability and integration with external data.

Complementing the UDP, the Urban Modelling Platform (UMP) provides advanced computational capabilities to run simulations using the OGC API Processes standard for easy access of executable models. Unlike the UDP, which primarily stores and visualizes data, the UMP enables the sharing of modeling methodologies like the flood risk assessment, enabling customization for local applications. Researchers and practitioners can contribute new methods and algorithms, which municipalities can then adopt and refine based on local needs. The platform supports Python-based frameworks such as SWMM (Storm Water Management Model) and TELEMAC for hydrological simulations, while leveraging ArcGIS-based spatial analysis tools for urban flood mapping. Through the integration of UDP and UMP, Hamburg fosters a collaborative ecosystem where researchers, municipalities, and policymakers can co-develop and share methodologies to address urban risks effectively.

[1] https://www.en.urbandataplatform.hamburg/

3 METHODOLOGY

3.1 FAIR2Adapt's FDO-driven FAIRification Framework

Based on the FAIR Hourglass concept (Schultes 2023), the FAIR2Adapt project develops a FAIRification Framework to turn data into actionable knowledge to shape climate adaptation strategies.

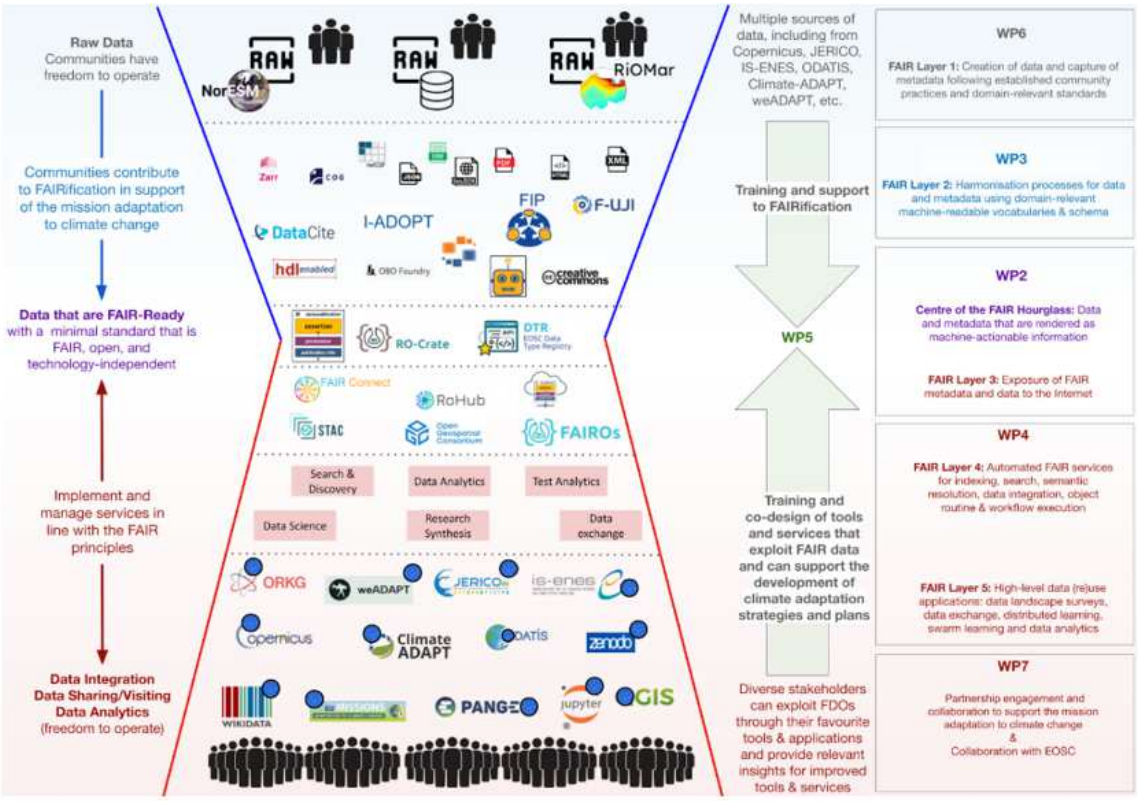

Fig. 1: The FAIR Hourglass applied to FAIR2Adapt.

The hourglass shape (Fig. 1) represents the flexibility at both the beginning and end of the process:

- The upper part focuses on FAIRifying community-provided data.
- The lower part ensures FAIR Orchestration, enabling services to act on FAIR-ready data.
- At the center, the FAIR Digital Object (FDO) ensures machine readability and interoperable reuse of digital objects.

To demonstrate the transformative impact of FAIR in advancing climate action and support the EU Mission on Adaptation, the FAIR2Adapt project engages in six case studies that address real-world challenges. The FAIR2Adapt case studies cover the six main steps defined by the Regional Adaptation Support Tool (RAST) to provide guidance to regional or local authorities during the adaptation planning process. By defining user requirements for each case study, the project develops tailored FAIR Supporting Resources to improve the FAIRness and semantic interoperability of critical CCA datasets and services. Where appropriate, these resources are transformed into FDOs using RO-Crate for packaging research data with their metadata and nanopublications for providing machine-readable metadata of FAIR Supporting Resources (FSRs). Additionally, the project provides training and support to the case study communities enhancing their awareness and capacity to effectively utilize the ecosystem of the developed and improved services.

3.2 Deriving requirements for the FAIRification process

This paper focuses on requirement elicitation, a pre-phase of the FAIRification process that aims to identify the specific needs of stakeholders. In agile software development, requirements are used to identify functions or features, constraints, rules, or other elements that must exist to satisfy user needs. A functional requirement defines what is needed, and not how it should be achieved (the solution). Non-functional requirements specify the criteria that will be used to test how well the solution meets the user's needs.

Gathering requirements to design the necessary services that the user expects is crucial, but is sometimes viewed as inefficient or overly restrictive when tried to be identified too early in the process because they can evolve over time. Thus, a more high-level requirement in the form of a user story is often used to express needs from the perspective of an end-user goal. A user story has three parts:

(1) The Who describes the user as a role (As a …)

(2) The What describes what is desired or needed, thus the goal as an activity (I want/need to …)

(3) The Why describes the reason or expected benefit (So that ..).

In FAIR2Adapt we apply user stories to identify the high-level FAIR requirements for each case study (see Fig. 2). We define a case study as a description of a real-life situation involving several users and digital objects. Hence, a case study refers to several user stories. While case studies are described by the case study provider by identifying the stakeholders involved, the addressed challenges, the goals and the aimed solutions, the user stories are extracted through interviews with stakeholders by FAIR data stewards as part of the Community Support and Engagement (WP5) activities.

From each user story, we derive specific functional requirements, identifying the necessary activities, as well as non-functional requirements, represented as constraints. Additionally, we determine the involved agents and digital objects (DOs) – some of which will be FAIRified, while others will serve as FSRs. It is crucial to keep the requirements free from concrete solutions, as these solutions should only be selected or developed after a thorough evaluation of the requirements. This ensures that the solutions align with the real needs, constraints, and goals of the stakeholders rather than being predetermined by available technologies or existing implementations.

By generalizing the requirements, we can distill reusable use cases that can be associated with potential FSRs, enabling their application in different CCA contexts. All components in the requirement elicitation process are planned to be collected via an online form. They will be represented in machine-readable format and made available within a queryable knowledge graph. A library of use cases can significantly help facilitate the uptake of FAIR implementation, allowing stakeholders to quickly adapt and apply proven solutions to their contexts ensuring consistency, scalability, and interoperability in CCA.

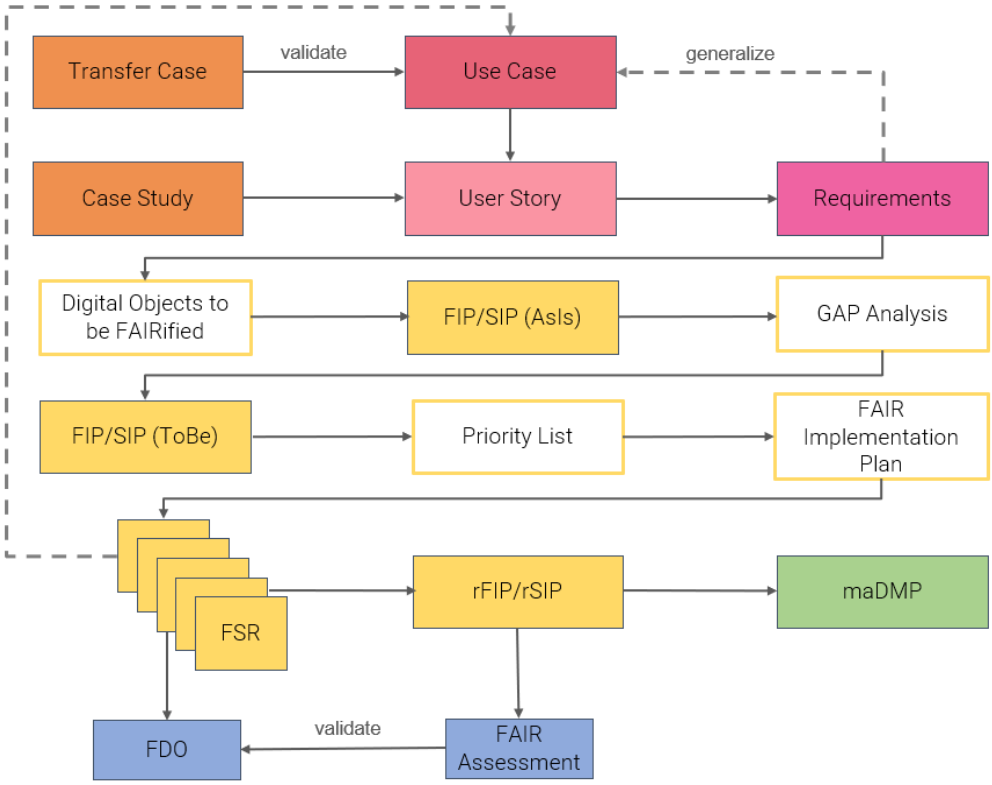

Fig. 2: Requirement elicitation process used in the FAIR2Adapt project.

To systematically address each of the FAIR Principles to enable the FAIRification of digital objects, the GO FAIR Foundation has developed the FAIR Implementation Profile (FIP) approach (Magagna et al., 2024). A

FIP is a structured questionnaire that documents relevant standards, technologies, and policies chosen by a community, made available as a collection of FDOs. In analogy, a Semantic Interoperability Profile (SIP) is a list of declared implementation choices focusing on the interoperability aspects of the FAIR principles including semantic artefacts and their supporting services. Rather than a one-size-fits-all approach, this methodology allows stakeholders from different case studies to specify the FAIR Supporting Resources best suited for their workflows. At the same time, FIPs and SIPs can serve as accelerators of FAIR convergence, as ready-made and well-tested collections of FSRs developed by trusted communities will be widely reused by other communities (Schultes et al., 2020).

In the context of FAIR2Adapt, FIPs and SIPs are used to:

- Assess the current state of the case study (AsIs)
- Identify the gaps in the profiles (Gap Analysis)
- Define the target state for a case study (ToBe)
- Prioritize and develop a FAIR implementation plan, agreeing on a reference list of FSRs (r)
- Integrate FSRs into researcher's daily workflows through machine actionable data management plans (maDMP)
- Validate FDOs via informed FAIR assessment tests

This systematic documentation helps evaluate the project's FAIR compliance decisions, ensuring the use of registries, vocabularies, and other resources that support FAIR data. We aim to assess FAIRness using specific tools, such as F-UJI or the RDA FAIR Maturity Indicators, to monitor progress. Establishing a baseline for FAIRness is essential, allowing reassessment after FAIRification of data, software, and workflows.

The FSRs listed in a rFIP may either already exist, or need to be created. In some cases, existing resources can be leveraged by FAIRifying them, while in other cases, new resources need to be developed from scratch. FAIRification begins with the provision of metadata. While there is a high degree of consensus on the use of domain-agnostic metadata standards to improve data discoverability, there is a lack of community-specific metadata schemas to enhance data reusability. Using the Metadata for Machines (M4M) approach, we will develop required metadata involving stakeholders from case studies. At the same time, we will ensure that these schemas are machine actionable by mapping them to existing standards and reusing FAIR vocabularies. The key role of M4M in the FAIRification process is to enable automated workflows for data discovery, retrieval, and integration, aligning with the FAIR principles.

3.3 Hamburg Risk Map user stories and their requirements

To demonstrate the user requirements elicitation process in FAIR2Adapt, we examine the case study of the city of Hamburg and describe three user stories that we were able to identify in a stakeholder meeting in Hamburg in early March 2025. Each user story is outlined with its corresponding requirements and thoroughly analyzed to identify the potential FAIR Supporting Resources that could be implemented to properly address the stakeholders' needs.

3.3.1 User Story 1: Sharing the ArcGIS Toolbox for Risk Mapping

User Story:

As a researcher I want to share the Hamburg Pluvial Flood Risk Map ArcGIS toolbox so that other implementers can use it to calculate risk and sensitivity maps in other urban areas.

Analysis:

FAIR2Adapt will evaluate together with the stakeholders of the case study how these requirements should be properly met. The aim of the toolbox is to create a reproducible framework, where stakeholder and flood risk managers can holistically assess flood risk providing information at building-resolving scale in order to support climate adaptation. From Table 1, it is clear that the ArcGIS toolbox needs to be FAIRified to some extent. For this a FIP will be developed to identify what is missing and what can be achieved within the timeframe of the FAIR2Adapt project. Nevertheless, here are a few preliminary thoughts on how we might FAIRify the tool:

- Requirement 1 calls for FAIR metadata about the high-resolution data needed to run the tool. A dedicated M4M workshop with the risk map developers will identify the required metadata elements to be included in the data description.
- Requirement 2 asks for the tool to be deposited in a public repository and GitHub is a good solution to make the software accessible and version controlled. ArcGIS is a proprietary and expensive tool and therefore it is recommended to transfer the code in open source systems like Python which makes geospatial workflows more efficient, scalable, and reproducible. Overall, it will be reasonable to follow the recommendations of the recommendations of the FAIR for Research Software RDA WG.
- Requirement 3 requires contextualizing the ArcGIS toolbox with a paper describing the technical procedures. The paper in preparation (Von Szombathely, 1) addressing the methodology of the Hamburg Pluvial Flood Risk Map describes the methods used and and toolbox developed, following the risk framework of the IPCC. It was tailored to high-resolution data and the assessment of two risk types (mobility/accessibility & well-being). Using RO-Crate allows to package and share the tool together with the paper in a FAIR-compliant manner, making it machine-actionable, well-documented, and interoperable.

Requirement 1	Information about the data required to run the tool.		
Activity	Provide metadata about data		
DO Name	Socio-economic data	Buildings and streets data	Modelled flood level data
DO Type	Dataset	Dataset	Dataset
Resource Type	DO to be FAIRified	DO to be FAIRified	DO to be FAIRified
Constraint	Metadata should be FAIR	Metadata should be FAIR	Metadata should be FAIR
Requirement 2	Make the ArcGIS tool accessible.		
Activity	1. Put ArcGIS toolbox in public repository	2. Transfer code in open source systems	
DO Name	ArcGIS tool	ArcGIS procedures	
DO Type	Software	Software	
Resource Type	DO to be FAIRified	DO to be FAIRified	
Constraint	Follow FAIR4RS Principles	Follow FAIR4RS Principles	
Requirement 3	Contextual information required for the ArcGIS toolbox		
Activity	Package tool together with a technical paper describing the ArcGIS toolbox.		
DO Name	Urban Pluvial Flood Risk: Methodological Framework		
DO Type	Puplication		
Resource Type	Supporting Resource		
Constraint	Increase Reusability		

Table 1: Requirements for user story 1.

3.3.2 User Story 2: Making my research paper machine-processable

User Story:

As a researcher I want to make the scientific knowledge and findings in my paper machine-processable, so that other researchers and systems can easily access, interpret, and reproduce my work.

Analysis:

Academic articles remain the primary expression of scientific knowledge. This form of knowledge recording and communication has persisted over centuries, which speaks for its usefulness for knowledge sharing among experts. However, knowledge expressed in narrative text documents is not machine readable, is hardly findable, interoperable, reusable. To integrate or synthesize scientific knowledge, for instance in

systematic reviews or meta-analysis, researchers routinely manually extract knowledge from documents and organize the extracted knowledge in databases that then support reuse. This extraction activity is time-consuming, error-prone, inaccurate, and potentially repeated, since (different) researchers may extract the same knowledge multiple times.

To address the requirement 1 (see Table 2), the Open Research Knowledge Graph (ORKG) (Stocker et al, 2023) has developed services for the production, curation, publication, and reuse of structured scientific knowledge. The ORKG's reborn article initiative (Stocker et al., 2024) has developed an approach that enables the production of high-quality and reproducible machine-readable scientific knowledge produced in (statistical) data analysis. Leveraging these systems, User Story 2 aims to FAIRify the scientific knowledge published in an upcoming article (Von Szombathely, 2) presenting the scientific findings on pluvial flood risk assessment for the city of Hamburg, Germany. By publishing a reborn article in addition to the original article we ensure that the scientific findings are published also in machine-readable format. Depending on whether the scientific findings are produced using open scripting languages (e.g. R or Python), it will also be possible to publish the findings so that they are reproducible. This is achieved by interlinking the scripts used to compute the findings. The requirement 2 can be addressed in the same way as requirement 3 of user story 1 by providing a RO-Crate.

Requirement 1	Make scientific knowledge in my paper machine-processable
Activity	Use services to extract knowledge
DO Name DO Type Resource Type Constraint	Research paper about Pluvial Flood Risk Assessment in Hamburg Puplication DO to be FAIRified
Requirement 2	Add data to the paper
Activity	Provide persistent identifier to refer to the input data.
DO Name DO Type Resource Type Constraint	Input data for deriving the risk map datasets DO to be FAIRified Increase Findability and Reusability

Table 2: Requirements for user story 2.

3.3.3 User Story 3: Improving Findability and Reusability of the Urban Data and Modelling Plattform

User Story:

As a data manager I want to make data and models more findable in Urban Data Platform (UDP) and Urban Modelling Platform (UMP) so that urban planners, climate modellers and citizens can make use of them according to defined usage licenses.

Requirement 1	Improve usability of UDP		
Activity	Provide metadata for datasets	Provide identifiers for datasets	Provide data usage license
DO Name DO Type Resource Type Constraint	UDP Datasets datasets DO to be FAIRified Increase Findability	UDP Datasets datasets DO to be FAIRified Increase Findability	UDP Datasets datasets DO to be FAIRified Increase Reusability
Requirement 2	Improve usability of UDM		
Activity	Provide metadata for models	Provide identifiers for datasets	Provide data usage license
DO Name DO Type Resource Type Constraint	UDM models models DO to be FAIRified Follow FAIR4RS Principles	UDM models models DO to be FAIRified Follow FAIR4RS Principles	UDM models models DO to be FAIRified Follow FAIR4RS Principles

Table 3: Requirements for user story 3.

Analysis:

User Story 3 focuses on FAIRifying the datasets in the Urban Data Platform (UDP) and models for Urban Modeling Platform (UMP). The goal of this FAIRification effort is to provide global unique persistent identifiers for all assets and to provide FAIR metadata, ensuring that the platform's outputs – such as climate risk predictions – are not only accessible but also findable and reusable under defined usage licenses. The key requirements include establishing a standardized metadata schema and ensuring interoperability with external models, which are essential for integrating UMP data into broader climate adaptation frameworks. A central activity involves enhancing discoverability and enabling efficient search and retrieval based on the reuse of common vocabularies. Potential measures for FAIRification include the development of a robust metadata framework based on ISO standards, as well as integration with Hamburg's Metadata Catalog. Identifying useful FAIR Supporting Resources can be best achieved by involving stakeholders in FIP workshops. Additionally, the FAIRification of models should also align with the FAIR for Research Software (FAIR4RS) approach, where not only the data but also the methods and algorithms used to generate it are made FAIR. This ensures full provenance, enabling researchers to track the inputs and parameters used in climate models. This holistic approach enhances the transparency and reusability of both the data and the underlying methods, contributing to the long-term sustainability and credibility of climate modeling efforts.

4 OUTLOOK AND UPSCALING

4.1 Overcoming Identified Barriers

One of the primary barriers to scaling the FAIRification process is the lack of convergence among existing standards, which can create challenges in ensuring interoperability across different systems, sectors, and regions. Furthermore, there is often a lack of interest from communities in adopting these standards, primarily because the added value of FAIRification may not be immediately evident. To overcome this, the FAIR2Adapt project uses real-world case studies to demonstrate the practical benefits of FAIR principles, helping to onboard key stakeholders and fostering a community-driven approach to climate adaptation. By showcasing tangible examples, we aim to highlight how FAIRification can enhance the discoverability, accessibility, and usability of data and tools, thereby driving greater engagement from the CCA (Climate Change Adaptation) community.

Another significant barrier is the lack of skills and knowledge in FAIR data management among CCA practitioners. To address this, FAIR2Adapt has developed a comprehensive capacity-building strategy, to raise FAIR awareness and embed the FAIR skills into the case study communities. Additionally, the use of AI technologies to support semi-automated FAIRification processes is a key aspect of this capacity-building effort. By integrating AI into the workflow, we aim to make the FAIRification process more efficient, reducing the burden on stakeholders and enabling them to focus on more strategic aspects of climate adaptation. Through these efforts, we not only address the barriers of interest and skills but also create a sustainable framework for scaling the adoption of FAIR principles across the CCA sector.

4.2 Vision for Future Developments (Upscaling)

To ensure a sustainable impact, comprehensive evaluation and dissemination of the project results in various formats is essential. A central component of this process is the implementation of transfer cases to validate the FAIRification framework, including the requirements elicitation process, in terms of its effectiveness and ease of adoption. These cases will showcase the process of applying FAIR principles to real-world datasets and workflows, highlighting both the challenges and opportunities in scaling across different contexts.

The concept of upscaling encompasses the scaling of the developed approaches beyond initial pilot projects with the aim of effectively addressing a larger number of users. This includes both geographical expansion and the structural development of political and administrative framework conditions in order to promote sustainable implementation. In addition, cross-sectoral dissemination of the results will be sought in order to maximise synergy effects between different areas and enable interdisciplinary application of the findings. (Guentchev et al., 2023)

The upscaling process in the FAIR2Adapt project will focus on two key aspects: the FAIRification framework and the reuse of FAIRified data, tools, and workflows.

As a pre-phase of the FAIRification framework the requirement elicitation process ensures that the real needs of stakeholders are captured in order to tailor the FAIRification of various components, including data, tools, and workflows. The goal is to enable CCA (Climate Change Adaptation) partners to independently apply this framework by the end of the project. The capacity-building effort in WP5 includes a "train the trainer" program that equips community members with the skills to teach and lead others in applying FAIR principles in their own contexts. The framework will be adaptable and scalable across diverse CCA sectors, empowering stakeholders to continuously apply FAIRification practices to new datasets and workflows.

For scaling the adoption of FAIR practices, we also aim to facilitate the reuse of identified use cases, along with their potential FAIRified datasets, tools, and workflows. The vision is to create a flexible ecosystem that allows various stakeholders to mix and match these components to support a wide range of use cases. By standardizing the FAIRification of data and tools, we create the conditions for easy reuse and adaptation to new scenarios. For example, a tool developed for Hamburg to assess pluvial flood risks could be easily adapted for other cities or regions facing similar challenges. This reuse model significantly reduces the cost of developing new solutions while enhancing the impact and scalability of the FAIR2Adapt project.

A comparison between FAIR2Adapt and other initiatives, such as VALORADO and FARCLIMATE reveals shared interests in applying FAIR principles to climate change adaptation data. Engaging with these projects can provide valuable insights and foster collaboration. Particularly, VALORADO partners involved in CLIMATE-ADAPT4EOSC, a project funded under the same EOSC topic, offer potential entry points for dialogue. Understanding these projects' approaches enriches our perspective on scaling FAIRification practices across different contexts.

The successful implementation and scaling of the FAIR principles requires coordinated efforts at various levels. The use of new technologies, targeted training measures and the promotion of international cooperation are essential building blocks for sustainably anchoring FAIR data management in climate adaptation.

5 CONCLUSION

In summary, the FAIR2Adapt project is not only focused on the technical FAIRification of data, tools, and workflows but also on ensuring that these components can be effectively scaled and reused across different case studies. Through WP3 and WP5, we aim to establish a robust FAIRification framework, preceded by a requirements elicitation process, that will enable CCA partners to integrate FAIR principles into their own work according to their needs, promoting long-term sustainability and impact. Furthermore, by fostering the reuse of FAIRified resources, we create an ecosystem that accelerates the development of new solutions, expands the reach of the project, and makes it easier to replicate successful approaches in diverse contexts.

The scaling process is thus twofold: building the capacity of stakeholders to apply FAIR practices independently and ensuring that the resources developed are flexible and adaptable enough to meet the needs of future case studies. This approach will enable the FAIR2Adapt project to have a lasting impact, offering scalable solutions that can be reused across various domains to support climate change adaptation efforts globally.

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reviewed paper

Addressing Regional Disparities in South Africa's Just Energy Transition: A Case for Green Infrastructure Planning

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1 ABSTRACT

Amidst the global push for decarbonization, solar and wind energy are rapidly gaining acceptance due to their minimal environmental impact and low carbon footprint. This global shift towards green energy transition presents both opportunities and challenges, particularly in addressing regional disparities in infrastructure investment. Using South Africa as a case study, this study employs a mixed-methods research approach, drawing on both primary and secondary data sources. It examines the historical context, governance, and regulatory framework influencing the Just Energy Transition in South Africa. The findings highlight significant spatial disparities in green infrastructure development, with limited investment observed in regions like Mpumalanga and Limpopo, which remain heavily reliant on fossil fuels. The study concludes by recommending indicators to identify priority areas for green infrastructure planning, thereby supporting a more equitable energy transition.

Keywords: Green infrastructure, regional disparities, fossil fuels, Just Energy Transition, South Africa

2 INTRODUCTION

South Africa is the largest carbon emitter in Africa, accounting for 40% of the continent's total emissions. It is also one of the most carbon-intensive developing economies in the world (Salahuddin et al. 2019; Udeagha and Breitenbach, 2023). According to World Bank (2021) South Africa is the continent's largest contributor to climate change and the world's 15th-largest producer of CO2 (making up 1.09% of global emissions). One of the most unequal countries in the world is South Africa, where the wealthiest 10 percent of the population own 86% of the nation's total wealth, over 30% of workers are unemployed, with youth unemployment exceeding 65%, and 55% of people live in poverty (IRENA, 2023). South Africa is now confronted with the urgent need to transition to cleaner power sources as a nation historically reliant on coal for its energy needs.

Globally to fight the global climate crisis, the European Union has committed to reducing its greenhouse gas emissions to net zero by 2050 (Pacesila et al., 2016). A fundamental step on that road is phasing out coal-based industry as coal has been outlined as a highly polluting energy source. In 2019, the European Commission unveiled its new development strategy, the European Green Deal (EGD), that seeks to reduce GHG emissions to net-zero and a decoupling of economic growth from resource use by 2050. The aim of this strategy was to conserve and enhance the EU's natural capital while protecting the health and well-being of its citizens from environment-related risks and impacts (Potrč et al., 2021). The EGD also stressed the need for a just and inclusive transition and presented a set of policy measures in key areas such as energy, industry, construction, transportation, agriculture, ecosystems, and pollution control. Moreover, it highlighted the need to strengthen cooperation between key stakeholders, to jointly promote just transition policies that "leave no one behind" (Musiał, et al., 2021; Brodny et al., 2021).

Germany's transition away from coal has not result in the abandonment of traditional coal industries. Rather, a focus on strengthening or upgrading these industries to make them more sustainable (Maliszewska-Nienartowicz, 2024). This process involved upgrading equipment and technology, reducing production, and adjusting product portfolios to enhance competitiveness. To facilitate this transition, Germany has implemented a targeted industrial policy that created a favourable institutional framework and market environment for industrial development (Ozkan, et al., 2024). This included providing financial subsidies and reducing land costs where necessary. The aim is to incentivize SME development, thus promoting

vitality through the redevelopment. Additionally, policies aimed at improving the local investment environment attracted a significant number of emerging companies. Statistics show that during the transition period, the fast-growing services sector absorbed 40% of the workers leaving traditional coal industries (Pata et al., 2023).

Poland's coal sector has been in a gradual but steady decline since 1990. Annual production in Poland was reduced by 50% between 1988 and 2019. This was driven by policy-led strategies aimed at reductions in hard coal. The number of operating coal mines declined from 70 in 1990 to 24 in 2021, and more are scheduled for closure in 2024 (Sokołowski et al., 2022). The Poland energy transition has been slow due to financial stresses. The industry continues to suffer from weak market conditions and elevated production costs, partly due to surplus labour, and partly due to the low quality of coal produced. In the past years, employment in the coal sector has reduced. The construction, manufacturing, and energy sectors have the highest potential to replace the coal sector jobs. These industries provide relatively good wages, are similar in terms of the required skills and competencies and are also in line with regional specializations.

One potential solution to repurpose the site would be the installation of a solar power facility (solar farm). The transitioning from a power plant to a different kind of renewable power source upon decommissioning may be perceived by the public as less risky than transitioning to a non-energy use (Idoko et al., 2024). With respect to coal-based communities, community members have expressed a desire to preserve their way of life, which had been enabled by and formed around the coal power plant (Pata, 2021). Because of this, a transition between two kinds of energy generation may feel like a natural pathway for the host community. Additionally, many former plant sites have retained critical electric power infrastructure that could make the transition to solar easier (Nakhli et al., 2022). There is already a precedent for siting large-scale solar operations on formerly contaminated sites through a process called "RE-powering" (Lin et al., 2021; King et al., 2021). A solar farm may also appeal to a utility that needs to manage risk because, apart from installation, solar farms require significantly less maintenance, which means less need for worker access to the site (Borowski, 2022). While fewer onsite workers may be seen as an advantage by the utility, it does mean that a solar farm would likely do little to mitigate the loss of skilled jobs after nuclear power plant closure.

To address climate risks, the South African government has created and is still creating extensive institutional, regulatory, policy, and governance frameworks in collaboration with important social groups (see Figure 1). Together, they provide the frameworks that make climate-related investments in adaptation, mitigation, and the just transition possible (Mirzania et al., 2023; Streimikiene et al., 2021; Heffron, 2022). They also show that South Africa is committed to fundamentally reshaping the electricity industry to address energy poverty and competitiveness, guarantee fair and inexpensive access to clean energy, and develop the human capital necessary for a new energy economy. The shift to cleaner energy sectors offers job opportunities as well (Musonda et al., 2025). The 2019 Integrated Resource Plan (IRP), the government's electricity plan, describes a strategy to diversify electricity production with a major emphasis on renewable energy sources. Twenty percent of the new capacity will come from grid-connected solar photovoltaics (PV), and about fifty percent will come from wind energy (Huang & Liu, 2021).

Nevertheless, many parts used in renewable energy are currently made outside of the country. Investing in the knowledge and equipment needed to produce these parts locally – like wind turbines – can generate long-term employment opportunities here at home and lead to more opportunities via export. It's critical to understand that jobs generated in the renewable energy sector do not always result in employment for those previously employed in coal plants (Chirisa et al., 2021). A reskilling plan is necessary for a just energy transition to guarantee that people have access to sufficient training.

Given South Africa has several power plants that are planned for decommissioning. The study assesses regional disparities in infrastructure investment using South Africa as case study. The shutting down of the old plant station will not significantly impact the national electricity grid as the remaining unit only contributed 121MW. Eskom has transferred the majority of employees from power station that have shut down to support and augment skills in other power stations and areas of the business in line with operational requirements. As of October 5, 2023, Eskom is considering delaying the decommissioning of some coal plants until 2030. This is due to appeals that could force Eskom to shut down some stations to meet minimum emissions standards. Several power plants have plans to repurpose the sites for renewable energy

projects. The Komati power station had been operating at only 125 MW capacity since 2021. This will be replaced with a combination of 220 MW of renewable energy solutions (including 150 MW solar PV solar and 70 MW wind) and 150 MW batteries, improving power supply and grid stability. The World bank funds this project to assist energy transition plans in South Africa.

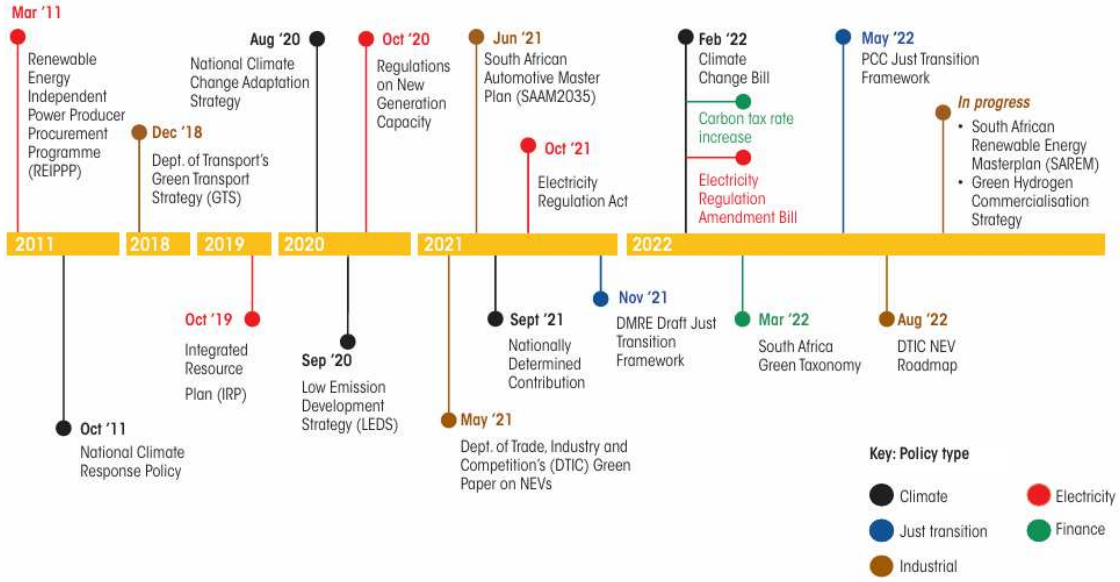

Figure 1: Key policies enabling energy transition in South Africa

3 METHODOLOGY

Using South Africa as a case study, this study employs a mixed-methods research approach, drawing on both primary and secondary data sources. Historical and current literature on governance, and regulatory framework influencing the Just Energy Transition in South Africa was reviewed. Additionally, Open source geographic information datasets were obtained from the Department of Agriculture, Land Reform and Rural Development (see table 1). The approach sheds light on the trade-offs between renewable energy plans and energy sector employment impact, while examining the distributional implications of these policy choices.

Format	Dataset
Shapefile	Location of power plants
Shapefile	Location of Green energy projects
Shapefile	Renewable Energy Development zones
Excel	Green energy projects

Table 1: Datasets

4 FINDINGS AND DISCUSSION

The corridors are important for planning the distribution and transmission of electricity infrastructure. In 2018, the Government published a notice that identifies five strategic transmission corridors and the procedures for applying for environmental authorization. There are currently five renewable energy zones which have been earmarked for the development of large-scale wind and solar projects (commonly known as RED Zones) (Figure 2).

Five existing power corridors support the RED Zones to develop large-scale electricity transmission and distribution infrastructure. These areas were chosen based on the findings of strategic environmental assessments: development is prioritised in specific geographic locations which have an abundance of resources (such as wind and sun), low environmental sensitivity, and where there is an increased need for socio-economic development, among other things. For example, the placement of RED Zones in mining areas aims to provide opportunities for rehabilitation, the re-use of existing infrastructure, and continued employment for local communities when the mines are eventually decommissioned.

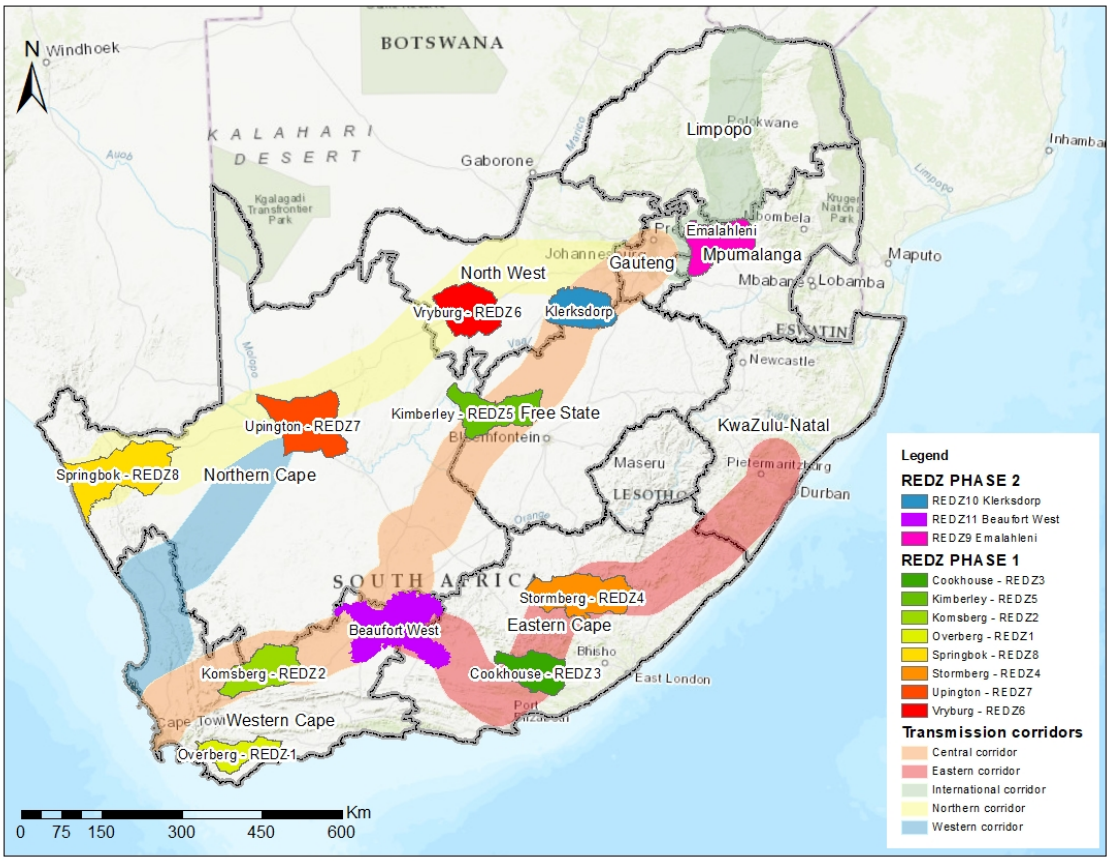

Figure 2: Renewable Energy Development zones.

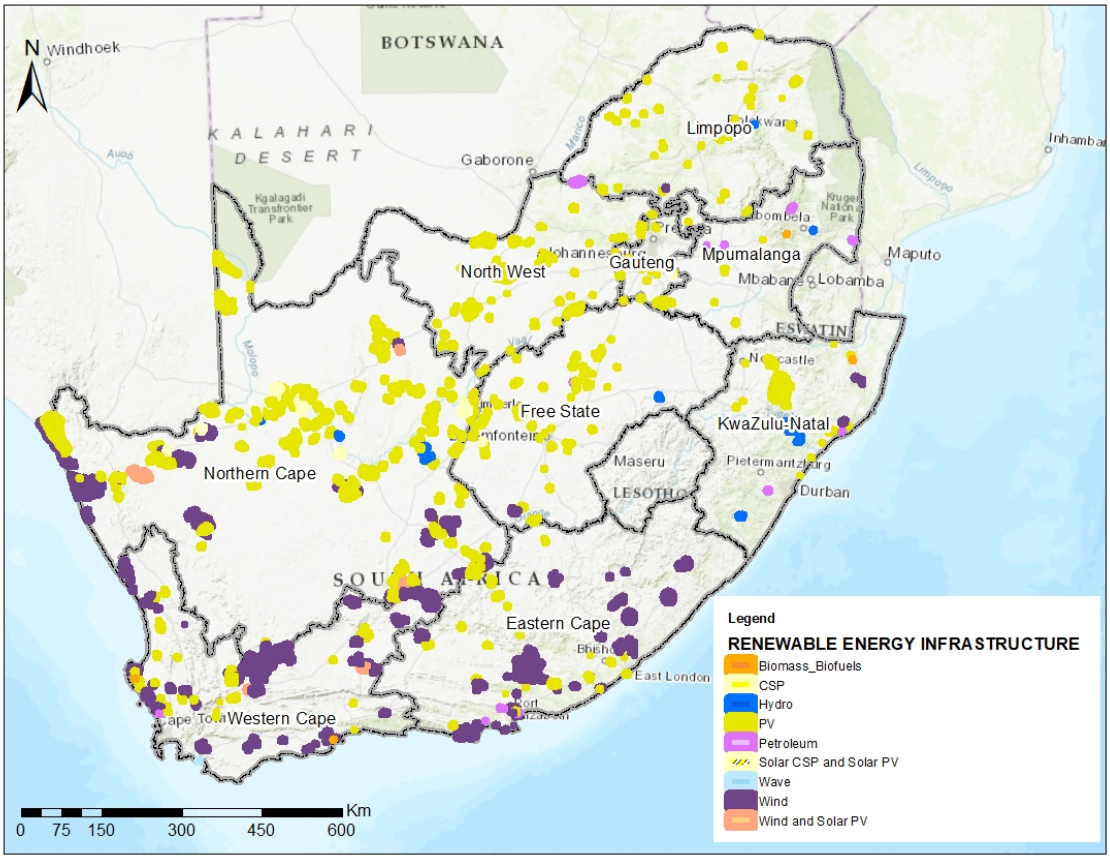

Figure 3: Spatial distribution of renewable energy projects.

The government has set goals to reduce emissions and increase the share of renewable energy in the national energy mix. To support this initiative several sites have been identified for clean energy projects, including solar, wind, and biomass (Figure 3). The South African Renewable Energy Masterplan informs these projects. Create and sustain decent employment across the value chain, from development and construction, to manufacturing and services, to operations and maintenance, to end-of-life management.

Expansion of the industrial capacity in the renewable energy and storage value chain should be supported with plans to develop the local industrial capabilities in the production of renewable energy and storage components, parts and systems to ensure the availability of supply for the domestic market as well as shield the local market from excessive price volatility.

1608 have been approved, 210 are under review, 29 projects were refused and 1 is currently under review (Figure 4). Renewable energy and battery value chains create a wide range of employment opportunities, particularly for skilled and semi-skilled workers. Over the first four bid windows, REIPPPP projects committed to the creation of 63 291 job-years (48 110 in construction and 15 182 in operations).[1] It is further estimated that about 20 000 people were directly employed in the solar energy value chain in South Africa in 2022.

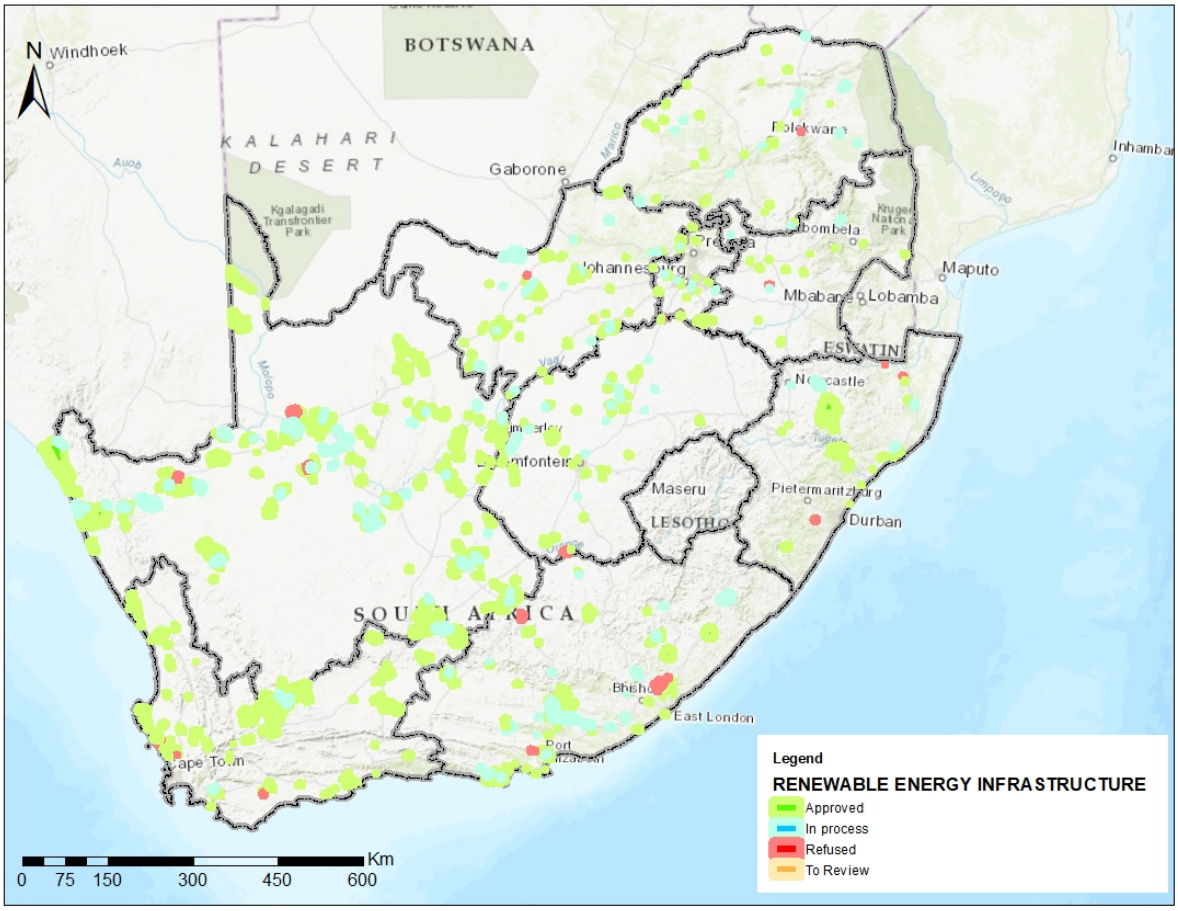

Figure 4: Status of projects.

5 LESSONS LEARNED AND IMPLICATIONS FOR POLICY

Overall, the case studies found that while many coals related jobs are at risk because of energy transition, there are available options retrain and upskill employees. Though the number of coal industry jobs is modest 4.7 million jobs globally and shrinking, the industry generates significant indirect jobs across economic sectors. Closing coal-based energy plants has implications for labour markets beyond the power plants

[1] IPPO, 2022. Independent Power Producers Procurement Programme (IPPPP): An Overview as at 31 December 2021. Independent Power Producer Office. Pretoria and Johannesburg: Department of Mineral Resources and Energy, Development Bank of Southern Africa and National Treasury.

workers. It negatively affects workers along the coal value chain, hurts local economies reliant on mine workers' earnings, fragments community well-being and social capital, and squeezes public finances.

In some communities, closing power plants can create a persistent, destabilizing demand shock as displaced workers struggle to transition to new jobs, because few alternatives are available, or workers are unwilling to accept lower-paying options or move to regions with greater labour demand. Given that coal production is concentrated in just a few countries, global coal phase-out targets could be achieved through ambitious action by a small number of key players. But, instead of phasing out, some countries are ramping up coal production for export.

Lessons from power plant closures illustrate the complexities and risks of inadequate planning, coordination and stakeholder consultation, insufficient investment, and poor policy design. A critical aspect to planning for coal transitions will be laying the foundations for attracting private investment and stimulating private-sector labour demand and business development. This calls for supportive infrastructure and institutions, education curricula aligned with the skill needs of emerging sectors, and a conducive regulatory environment. To address spatial misalignments related to employment, it was observered new jobs may be created in different communities, regions or countries than those where the principal job losses occur. This is particularly the case in locations that lack economic diversification. While sectoral misalignments rising from industries may draw more heavily on raw materials or intermediate inputs from sectors that are quite different from those that supply once prominent but now declining industries.

6 CONCLUSION

In conclusion the rise and decline of coal plant over the last century had the effect of building power-plant-dependent economies through coal-based employment, and then exposing these communities to severe negative shocks. Many of these relatively communities were already lagging in terms of socio-economic development; the sharp reduction in coal demand over the past several decades created further dislocation that undermined their economic sustainability. The magnitude of the impact across counties varies, as does the degree of economic resilience and capacity to transition to alternative industries. Some counties transitioned early, while others delayed the difficult and costly adjustment needed to diversify their local economies.

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reviewed paper

AgriVoltaics in the Wine Industry

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1 ABSTRACT

The increasing detrimental consequences of climate change and the decline in fossil fuel resources are leading to a rise in demand for food and energy. Agrivoltaics (Agri-PV) offers an opportunity to combine space-optimised photovoltaic (PV) use for sustainable agriculture. By feeding solar energy into the grid, PV is regarded a key component of renewable energy systems. Especially, the wine industry is facing increasing challenges due to climate change, particularly in regions where excessive solar radiation and rising temperatures negatively affect grape quality and yield.

In this article we have examined a cost-efficient technical solution that can also be used on a small scale. It is shown that by using mostly standardcomponents without special parts, a modular system with high photovoltaic output and the least possible disruption to agricultural use can be created. Due to bifacial solar modules, which have recently emerged on a massive scale, a cost-effective structure withoptimal use of the sun over the course of the day was realised. Initial resultsof PV utilization, especially in the winter months, with shading and rain influenceshow the technological and economic feasibility of the proposed technology.

Keywords: Sustainable Innovation, Photovoltaics, Climate Change, Food and Energy, Agriculture

2 INTRODUCTION

The synergy of agriculture and photovoltaics is reflected by the Sustainable Development Goals 2 and 7 (SDGs) of the United Nations: “Goal 2 is about creating a world free of hunger by 2030.The global issue of hunger and food insecurity has shown an alarming increase since 2015, a trend exacerbated by a combination of factors including the pandemic, conflict, climate change, and deepening inequalities” (https://www.un.org/sustainabledevelopment/hunger/); “Goal 7 is about ensuring access to clean and affordable energy, which is key to the development of agriculture, business, communications, education, healthcare and transportation(https://www.un.org/sustainabledevelopment/energy/).Sustainable innovations increasing the efficiency, resilience and profitability by cost saving and photovoltaic inspired quality improvement solutions might contribute to strike a balance to a currently prevalent existential crisis of vineyards in the Palatinate, the setting of the experiment in the South West of Germany, and the neighbouring wine region of Baden-Württemberg,which both suffer due to low wine prices and high cost burdens (Rheinpfalz, 2024; Suedkurier, 2024). A deterioration of wine quality, a ‘death’ of Winemakers and/or wine regions lying fallow will have very negative repercussions for tourism and wine and/or regional branding of the region in question (Correia Loureiro and Kaufmann, 2012; Kaufmann and Durst, 2008).

Prolonged heat stress can lead to reduced acidity and altered sugar content of grapes, as well as to an overall decline in wine quality, putting economic pressure on winemakers. Traditional shading methods offer only limited protection, and water-intensive irrigation strategies are becoming less sustainable due to increasing drought conditions.Agri-photovoltaics (agrivoltaics) presents a promising solution to mitigate these issues by integrating photovoltaic (PV) systems into vineyards. By providing partial shading, Agri-PV can help regulate microclimatic conditions, reducing heat stress while simultaneously generating renewable energy

(Zha et al. 2022; Ferrara et al., 2022). Recent advancements in bifacial PV technology further enhance this approach. Bifacial modules, which capture sunlight fromboth sides, are particularly well-suited for vineyard applications, as they can utilize light radiationthrough diffusion optimizing energy yield without significantly compromising agricultural productivity.The east-west orientation of the bifacial solar systems also offers advantages in terms of feeding electricity into the grid structure. The change in energy production during the day, with peaks in the morning and afternoon, is counteracted by conventional south-facing solar systems (Guo et al. 2013; Thomas Rosenzopf, 2022). This results in a more balanced feed-in of electricity generated by solar systems throughout the day. However, a major challenge in the widespread adoption of Agri-PV systems is the cost of implementation. Many existing Agri-PV installations rely on custom-built components, making them economically viable only in large-scale projects with high production volumes. This limits accessibility for smaller vineyards that could benefit from the technology but cannot justify the high initial investment. Therefore, this study focuses on the use of cost-effective, standardized components that enable small-scale Agri-PV installations to be financially viable even in low-volume production.

As a foundational step in this study, existing Agri-PV concepts will be examined based on the guidelines outlined in DIN SPEC 91434. The current state of technology will be analyzed through two key examples: commercially available Agri-PV solutions, such as those provided by Next2Sun, and research-based installations like the system developed by Krinner Carport GmbH as part of the HyPErFarm project. Additionally, concepts proposed by the energy provider RWE will be considered, even though they currently exist only as design renderings without real-world implementations.

Following this analysis, the advantages and disadvantages of these existing systems will be evaluated to determine which elements can be integrated into a novel prototype for a new Agri-PV concept. A key focus will be on cost-effective construction methods that enable small-scale feasibility. This includes the incorporation of standardized components, such as trusses from the event industry and steel cables as a low-cost mounting alternative. The latter offers significant structural benefits, particularly by reducing the impact of wind forces through the elimination of bending and torsional moments. These design optimizations aim to improve both economic and structural efficiency, making Agri-PV more accessible for smaller vineyards while maintaining high energy yield and agricultural productivity.

3 THEORY

The aim of agrivoltaic systems is targeted use on agricultural land that allows agricultural use to be largely unrestricted so that a wide variety of crops can continue to be grown. The photovoltaic system then offers an additional environmentally friendly way of generating electricity while protecting the plants from excessive solar radiation through shading. Intelligent irrigation systems can also be installed, allowing rainwater to be collected from unfavourable areas and used in a targeted manner on the planted areas. The dual utilisation of agriculture and electricity generation is illustrated in Figure 1. With an optimal and favourable set-up, the yield of agricultural crops can be significantly increased for the same usable area, while the electrical energy can either be sold or used for own consumption.

The system can be customised to the respective agricultural area of use. Agri-PV systems are categorised into different types of structure, which are suitable for specific areas of use and plant varieties.

The German DIN (German Institute for Standardisation) for specification 91434 distinguishes between two categories of Agri-PV: Agri-PV systems with an elevation with a clear height are designated as category one while category two systemshave an elevation close to the ground.

The design of an agricultural PV system must be such that the PV modules are evenly distributed across the height of the roof. In category 1, a minimum height of 2.10 m is required to comply with health and safety regulations and to allow agricultural use of the area. The area lost to the installation must not exceed 10% of the total usable area. In addition, it must be ensured that the area can continue to be cultivated and, depending on the crop, can be driven over if necessary. Light availability should meet the needs of the crops and be evenly distributed over the area. Potential shading should be checked. Water availability also plays a key role: either a targeted irrigation system must be integrated, or the system must be designed to allow rainwater to reach the crops unhindered. Measures must also be taken to prevent soil erosion and siltation, for example by using suitable drip edges on the PV modules, and the ability to completely disassemble and remove the modules without leaving any residue must not be the focus of the prototype. Economically, the

concept must be designed in such a way that the combination of energy production and agricultural use remains profitable for the farmer. Finally, a high level of land use efficiency should be aimed for, with the crop yield after installation of the agrivoltaic system being at least 66% of the original reference yield.

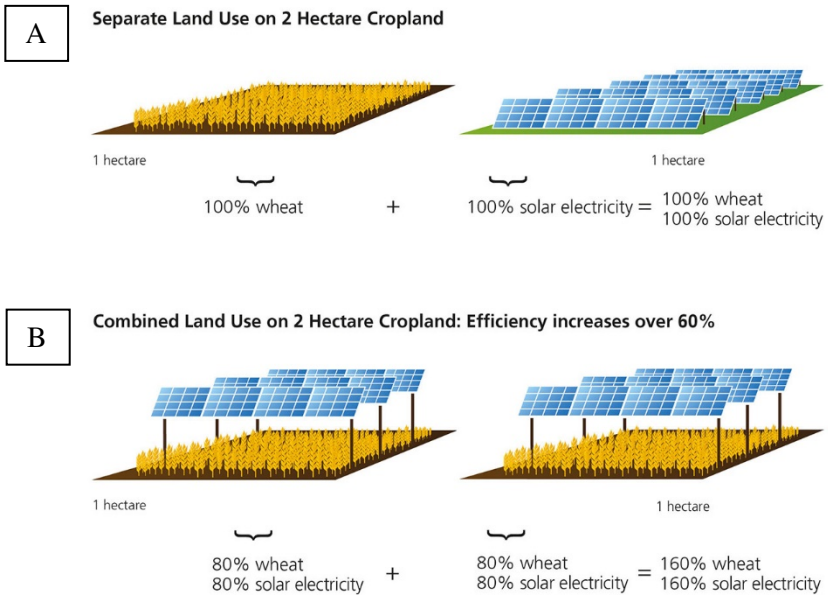

Figure 1: Theoretical benefits of agrivoltaics on an agricultural field: Separate use of agriculture and photovoltaics (A); combined use of agrivoltaics and agriculture (B)(Metsolar.eu, 2021)

The utilization area of Agri-PV systems is divided into four utilization categories based on agricultural requirements:

A: Permanent crops and perennial crops

B: Annual and perennial crops

C: Permanent grassland with cut use

D: Permanent grassland with pasture use

Permanent crops are plants that grow on agricultural land for at least five years and provide recurring yields during this time. These do not count in the crop rotation. Permanent grassland is not part of the crop rotation for at least five years and can either be used with cut grass for yield or as fodder for farm animals.

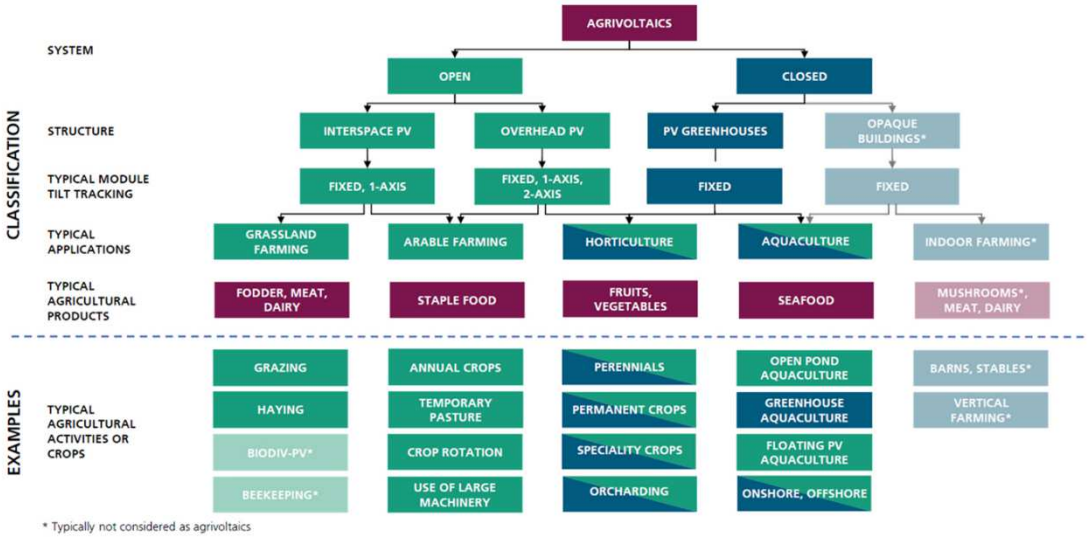

Figure 2: Classifcation of agrivoltaics system with different fields of application (Gorjian et al. 2022)

Furthermore, agrivoltaics can be categorised into two distinct systems: open and closed. Closed applications pertain to greenhouses and are classified as fixed solar systems mounted on the uppermost structure. These systems facilitate the cultivation of a diverse range of crops, including fruits, vegetables, and aquaculture. As

illustrated in Figure 2, open solar systems are further subdivided into the two previously delineated categories. Additionally, there exist various mounting variants, such as fixed and tracked configurations. The scope of application encompasses grassland and arable farming, as well as areas where closed agrivoltaics systems are employed in a complementary manner.

The current technical state of Agrivoltaics

The provider “Next2Sun” presents its ground-level agrivoltaic systems, which are placed on agricultural land like a kind of fence system. As can be seen in Figure 3, the PV modules are mounted in a frame system that provides for two transversely aligned modules one above the other, which are attached at both ends with two posts protruding vertically from the ground. According to the manufacturer, who specifies a patented mounting system, the posts are hydraulically driven into the ground. The advantage is the installation of bifacial modules, which can generate electricity on both sides of the modules through solar radiation. According to Next2Sun, the modules are optimally aligned to the east and west, which results in the highest energy yield in the morning and afternoon to early evening. According to the company, this results in significantly better power generation than with conventional south-facing PV installations. Luxor and Akcome silicon modules from China are used. The strips between two PV rows have a width of ten meters, which can be used for agricultural purposes. Next2Sun states the following about the shading: “The partial shade of the PV modules reduces the evaporation rate of the area. [...] In addition, higher crop yields can be expected in arable farming for shade-tolerant crops such as potatoes, spinach, carrots, etc.”

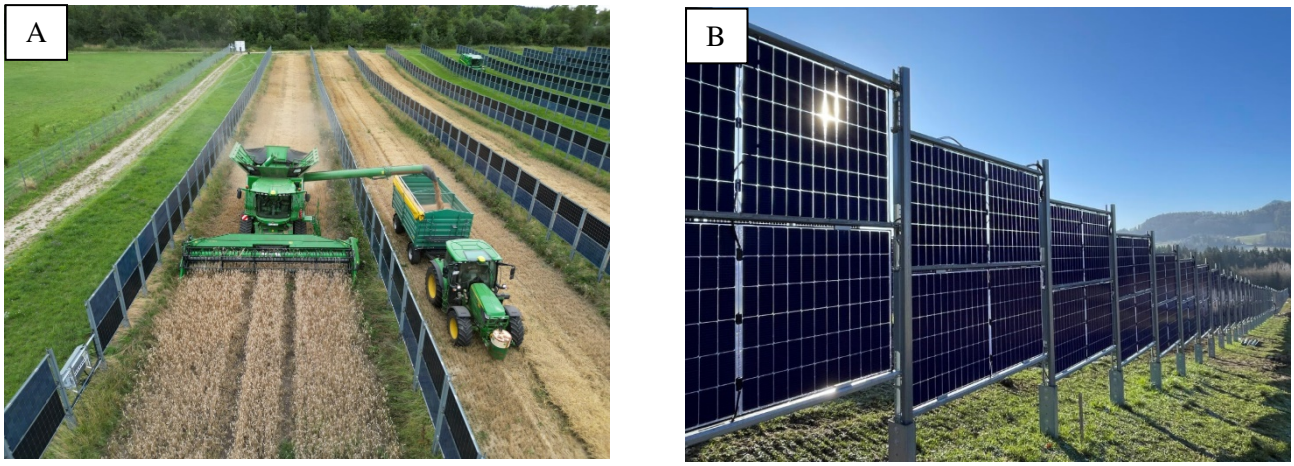

Figure 3. (A) Next2Sun agrivoltaics concept with arable farming (B) Next2Sun concept with grassland farming (Next2Sun, 2024)

The solar carport manufacturer Krinner Carport GmbH from Straßkirchen is presenting another agrivoltaic concept. Two demonstration systems have already been built here as part of the HyPErFarm research project, which involves the Fraunhofer Institute for Solar Energy Systems and a large number of other investors and companies. The publication by Asa’aet al.(2024) shows that this is a trackable PV system. As shown in Figure 4, this is a category one agrivoltaic system mounted at a clear height. The PV modules are mounted on a twelve-metre-long beam, which is mounted on two posts as a pivot axis. Galvanized steel is used as the material, and the steel beams are mounted on the posts using a custom-made suspension system. The length of the girder results in a construction on which 12 modules are installed per girder. The construction can be varied in its length by adding further cross beams and supports of the same dimensions (Figure 3B). The support pillars are inserted into a sleeve driven into the ground and braced with wire ropes at the edges of the Agri-PV system. The height of the structure is not specified, but according to Figure 4B it is large enough to ensure that the agricultural land can be driven on. The pivot axis results in a system that can be tracked. Figure 4A shows a grass strip in the line of the support pillars, which cannot be harvested by commercial vehicles. However, it is stated that these green strips, which make up 10% of the total area, can increase biodiversity as a flowering meadow by providing natural food sources for insects. Krinner Carport GmbH states that by tracking the module bridges, both the snow and wind load can be reduced and at the same time electricity generation is improved by tracking solar radiation.

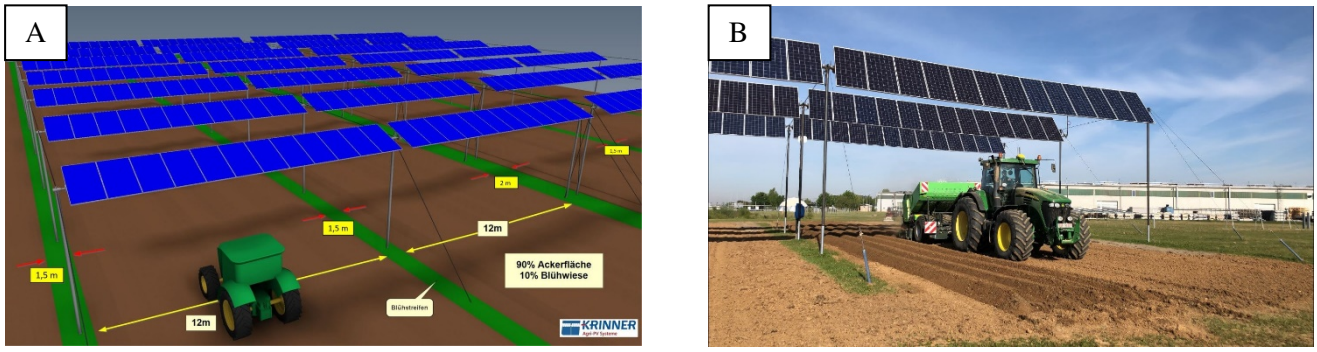

Figure 4. (A) Krinner Carport GmbH agrivoltaics concept (B)Krinner concept realization (Krinner Carport GmbH, 2024)

The RWE demonstration plant at the Garzweiler opencast mine near Bedburg is investigating the advantages of agrivoltaics in different concepts and systems. In co-operation with the Institute of Plant Sciences at the Jülich Research Center and the Fraunhofer Institute for Solar Energy Systems, a large-scale plant with 6100 modules and three different concepts was constructed. The plant has a capacity of 3.2 MWpeak and was built on an area of seven hectares. A ground-level system with a vertical module arrangement, a ground-level system with single-axis tracking and a highly elevated system constructed in a frame design with cross beams and support pillars as well as PV modules inclined at 45 degrees.

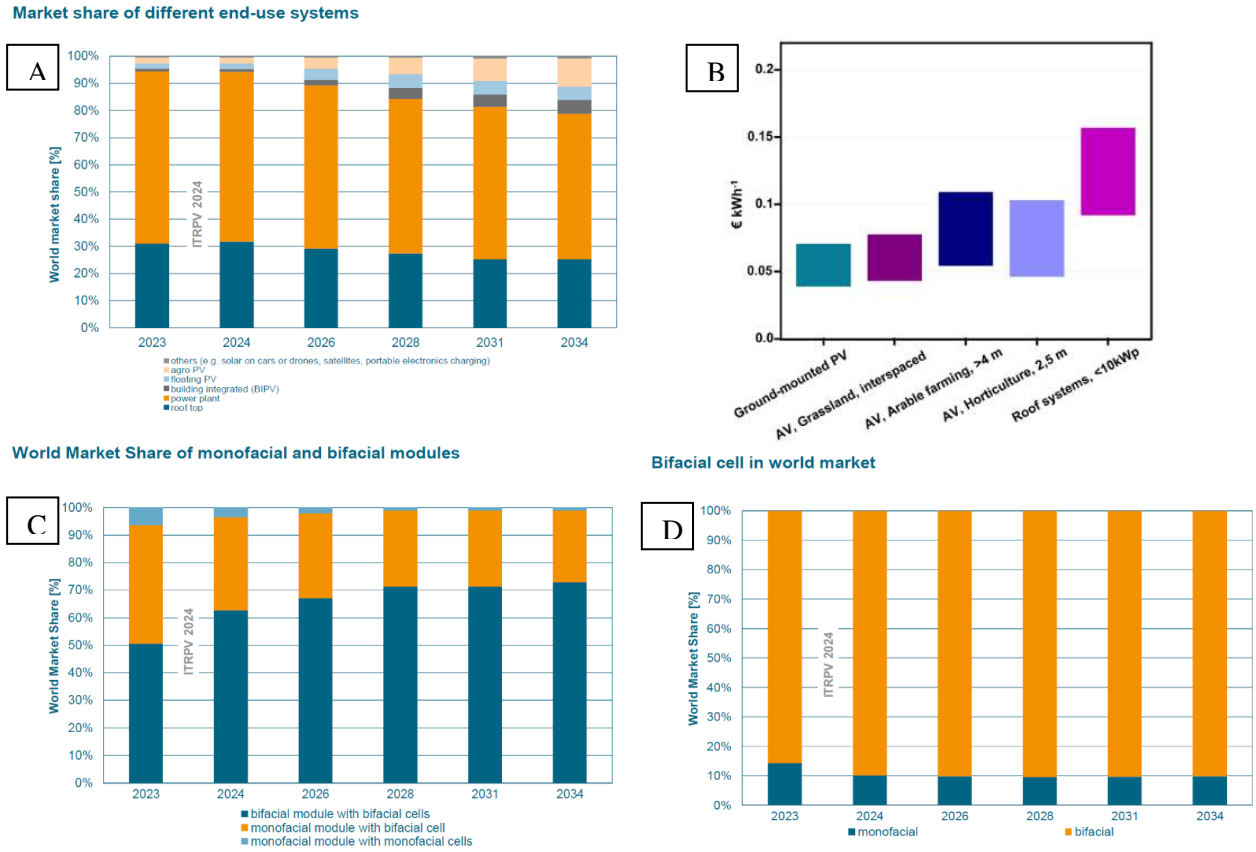

Figure 5. (A) world market share of differend end use systems (B) energy costs of different photovoltaic systems (C) world market share of monofacial and bifacial modueles (D) market share of bifacial cells(ITRPV, 2024; Trommsdorf et al., 2023)

The current market situation

Agri-photovoltaic systems that utilize bifacial PV modules offer significant advantages over traditional monofacial modules, especially when combined with an east-west orientation. Bifacial modules are capable of capturing light from both sides of the module – not only direct sunlight but also light reflected from the ground or surrounding environment. This results in higher energy production, as the reflected sunlight enhances the overall output of the modules, which is particularly beneficial in agricultural applications where reflected light from crops or the soil can be utilized. The east-west orientation maximizes energy production throughout the day and provides more consistent energy output compared to traditional south-facing

setups.In contrast, conventional monofacial silicon solar cells only capture direct sunlight, limiting their efficiency as they cannot harness reflected rays. Whilst a significant proportion of conventional monofacial c-Si cells are still being manufactured at present, Figure 5D demonstrates a favourable forecast for the escalating production of bifacial solar cells. Furthermore, an augmentation in the utilisation of bifacial modules is also predicted (Figure C).

Additionally, there are concentrating optical solar systems that rely on lenses or mirrors to focus sunlight onto small, high-performance solar cells. While these systems offer high efficiency, they are generally designed for specialized environments or large-scale installations and may be less practical for agri-PV applications, as they are not optimized for use in agricultural fields. Another emerging technology is tandem solar cells, which use multiple layers of different materials to absorb a broader spectrum of sunlight. However, tandem solar cells are still in the development phase and are currently less widespread and economically accessible compared to monofacial or bifacial systems.

By incorporating bifacial modules and an east-west orientation, the potential of agri-PV can be maximized, combining higher energy production with a more sustainable and efficient use of agricultural land.With increasing projections for renewable electricity production from agrivoltaic systems (Figure 5A), which are expected to account for over 10% of total solar electricity production by 2034, the focus must be on the price and viability of these systems. At the current stage of this work, category one open agrivoltaic systems represent the most expensive share of non-rooftop industrial electricity production (Figure 5B).Substructures for agrivoltaic systems in arable farming cost an average of 400 eurosper kWp (Landverpachten.de; 2024).

Materials and methods in the presented concept

In order to develop a cost-effective prototype, various aspects of the design were given due consideration. These included the design of the statics for weather influences, the optimal choice of solar modules for good efficiency, and the development of a construction system that is easy to assemble.

The wind pressure WD is calculated using the dimensionless pressure coefficient cp, the density ρ of the air and the wind speed v. The dimensionless pressure coefficient for vertical surfaces has a value of 1, which is assumed for simplification in the following calculations. Similarly, for wind speeds with a Mach number < 0.3, air is assumed to be an incompressible gas, which results in the density as a function of temperature and air pressure. The wind pressure is calculated as follows:

$$W_D = c_p \cdot \frac{\rho}{2} \cdot v^2$$

Free-standing solar installations must be able to withstand wind speeds of up to 151 km/h, i.e. 42 m/s, with their elevation. As the density varies with the temperature over the year and a safety margin is added for all mechanically and statically stressed components, a density at 20 °C and standard atmospheric pressure is assumed here.

$$W_D = 1 \cdot \frac{1{,}204\ kg \cdot m^{-3}}{2} \cdot \left(42\ \frac{m}{s}\right)^2 = 1058\ \frac{N}{m^2}$$

This considers a gale force wind of over 118 km/h with a safety margin for Germany, ensuring that the photovoltaic systems are stable in all weather conditions.

Agrivoltaics setup

The prototype, which was designed as part of this work, consists of two vertically aligned trusses (Global Truss F34400) with a height of 400 centimeters, which were set up eleven meters apart. These are set up on a base plate from the same manufacturer (Global Truss F34BASE). To ensure the stability of the trusses, two concrete foundations with dimensions of 50 x 50 cm and a depth of 80 cm were poured, reinforced with steel to enhance flexibility. Four ground anchors from Igel GmbH, model Spirafix, measuring 30 x 300 mm, were cast into the concrete to secure the base plates to the concrete foundations, thereby ensuring the necessary stability. To ensure the secure installation of the Agri-PV system, a system consisting of three guy ropes per truss, offset by 90° around the truss, was installed. The wire ropes for tensioning the trusses, manufactured by Drahtseile24, have a thickness of eight millimetres and a winding of 7x19 strands, with a tensile strength of 1960 N/mm2. These ropes were anchored to the ground using Spirafix ground anchors (50x1540 – AC type – M16 thread), with each anchor capable of supporting 1400 kg. Additionally, high-strength eye bolts (Igel GmbH eye bolt – M16 thread for AC type) were utilized, with each bolt possessing a tensile strength of

4000 kg. Two wire ropes, with a spacing of one meter, were attached horizontally between the trusses to suspend the solar modules. All wire ropes were mounted using wire rope clips from the manufacturer Drahtseile24, which correspond to the tensile strength of the wire ropes. Photovoltaic modules from the manufacturer Solarwatt were attached to the horizontally tensioned wire ropes with four quick-connect links each, which have a load capacity of 140 kg per bracket. The brackets are attached to the mounting holes of the module frames and then hooked into the wire ropes. Additional clips serve as spacers.To comply with safety standards for work and buildings, solar modules with appropriate overhead glazing certification were selected to prevent safety measures such as nets.

Due to pragmatic concerns, simplifications were implemented for the prototype, with the utilization of more cost-intensive materials enabling enhanced flexibility in operation and the modification of extensions. For instance, 400-centimeter trusses were procured in lieu of the originally specified 500-centimeter trusses, a decision that was made to facilitate the assembly process. However, these trusses can be extended with additional modules, thereby enhancing their functionality. Additionally, higher-priced clamps were utilized in lieu of inexpensive seals for tensioning the wire ropes, a choice that facilitates expeditious removal of the wire ropes.

Figure 6. left side:Impression during construction phase; without PV modules;right side: first preliminary installation of the first raw of modules.

Materials

- Trussing: Global Truss F34400
- Base Plate: Global Truss F34BASE
- Steel Cable: Drahtseile24 DS10103.245 8mm / 7x19 (flex)
- Wire rope clips: Drahtseile24 wire cope clips stainless steel DIN 741 DS10025.5
- Photovoltaics-Holder: Drahtseile24 Quick connectorstainless steel DIN 56927 form BDS10174.2
- Ground anchor: Igel GmbH -spirafix ground anchor – 50 x 1540mm – AC-Type – M16 thread
- Eyebolt: Igel GmbH High-strength eyebolt with M16 thread for 50mm AC anchor
- Photovoltaic module: SOLARWATT Panel vision GM 3.0 construct (370 Wp) PERC-Module

Measurement setup

- Ambient light sensor: VEML7700
- Soil moisture sensor: Seed Studio Grove – Capacitive Moisture Sensor with NE555DR Chip

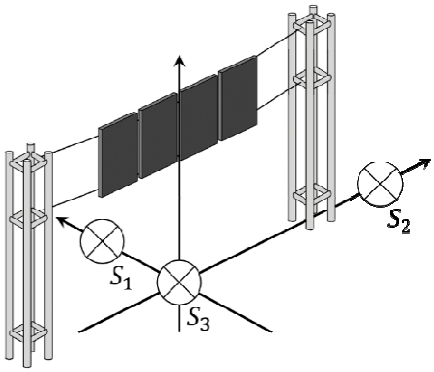

Figure 7. Sensor position diagram

4 EXPERIMENT AND UPSCALING

The prototype system developed and tested as part of this work demonstrates the suitability for upscaling to a large-scale agrivoltaics system.The chosen construction, consisting of two vertically erected trusses with three guy ropes per truss, forms a stable basis for a flexible expansion of the system (Figure 8).A key feature of this design is the ability to arrange the trusses one behind the other at a constant distance of 11 metres. This linear configuration facilitates the establishment of a route of any specified length, with the capacity to accommodate 8 to 10 solar modules between the crossbars.The total energy yield for a designated agricultural area is contingent on the parameters p (distance between the tracks) and h (height of the solar modules) (Figure 8) (Riaz et al. 2020).The ratio p/h exerts a dual influence on both the level of plant shading and the number of solar module tracks within a specific area (SOURCE). In order to optimise material efficiency and reduce the effort required to stabilise the structure, the bracing system was adapted (Figure 3): while the two end trusses of a route still need to be secured with three guy ropes, it is sufficient to fix the intermediate trusses in between with just two guy ropes. This significantly reduces the amount of material used and the installation costs per unit without compromising the structural integrity of the overall system.

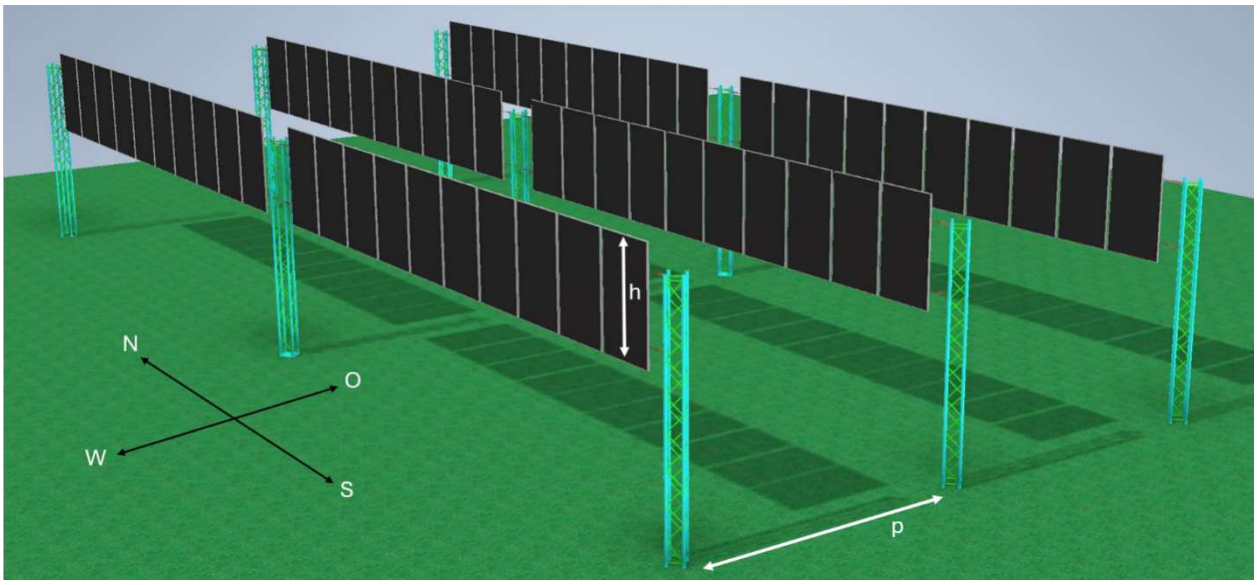

Figure 8. Visualization of the east-west oriented bifacial agrivoltaics concept in a scale up with a pitch (p) of five meters and a solar module height (h) of 1.7 meters

In the event of the agrivoltaic system being simulated within an agricultural area measuring one hectare, utilising a scale-up model, the following data is generated:Within an area of one hectare, with an edge length of 100 x 100 m, a total of 20 traverses can be configured with a pitch of five metres. Given a photovoltaic section length of 11 metres between traverses, this results in 9 sections, each with eight modules mounted on a single section. This calculation yields a total of 1455 solar modules per hectare.Utilising SOLARWATT Panel vision GM 3.0 construct solar modules with a nominal output of 370 Wp results in a total output of 538 kWp. For the test region of the prototype in the Southern Palatinate, approximately 1000 full-load hours of sunshine are estimated per year. According to current data, the sale of a kilowatt hour in Germany is

valued at 8 – 9.5 cents, with an average value of 8.75 ct, equating to a total of € 47090 for an annual yield of 538 MWh. Given the yield generated, the ROI (return on investment) of the pilot project is 10.3 years. The production costs for the prototype are €900 per kWp, and no labour hours are included in the cost breakdown, which results in pure material costs. For the real conditions of series production, the costs for labour must be taken into account, but the costs of the components are estimated to fall by two thirds in large-scale production.

The potential income for the farmer should be compared with a normal yield from wheat with up to 9 tons per hectare and a price of 300 € per ton. So the income from electricity is much higher, than the income from wheat.

The aforementioned synergistic effect of agriculture and photovoltaics is even more enhanced when the installation of photovoltaic systems on agricultural land improves ground conditions by the implicit shading effect. In these cases, the shading, while simultaneously generating energy, provides protection for crops and can lead to higher crop yields in selected regions. Such a positive combined effect is currently also occurring in wine-growing regions, where, for example, white wines are grown in areas affected by global warming. The warmer summers and autumns result in higher alcohol levels, which are not desired or expected by customers. Rain shading continues to be a key aspect in the development of Agri-PV. It can be desirable or undesirable. The different objectives lead to different proposed solutions. Last but not least, the price and the possibility of small-scale application play a role in the design decision. Often, however, current proposed agrivoltaics systems are almost exclusively associated with customised parts, which only makes large-scale production economically viable. For this reason, in the project presented, we focus on applications that can also be used on a small scale, where the sun shading effect is desired and rain shading is undesirable, and the total installation makes economic sense for the farmers or winemakers. This brings us to a solution approach that appears very simple in terms of design, but nevertheless exactly corresponds with an optimum of the required properties mentioned. An agrivoltaics prototype was designed and built, using bifacial photovoltaic modules with vertical orientation and low-cost standard components. These components are easily available everywhere and do not need an exclusive supply chain. After an analysis of current research in the agrivoltaics sector and the global market share of photovoltaic technologies (Metsolar, 2024; Asa'a et al., 2024; Ogobomo et al., 2017), the advantages of low agrivoltaics systems were combined with bifacial modules and high-mounted agrivoltaics systems. The developed system relies exclusively on standard components such as stage trusses and offers a raised height with fixed modern Passivated Emitter and Real Cell (PERC) modules, which makes the coverage of a wide range of agricultural space possible.

5 RESULTS AND DISCUSSION

The system set up on the area of the SIZ site in Neustadt/Weinstrasse currently undergoing testingallowsvarious aspects of the type of agri-PV proposed by the authors to be investigated. The yield tests to date have mainly covered the winter months, which are actually unfavorable in Germany. Nevertheless, useful energy harvests can be achieved here. The energy yields to dateextrapolated to the year as a whole is approximately 20-30% above theexpected value for monofacial PV modules. This can also be seen in the daily progression in figure 9A, which shows a long, uniform power delivery. Over the course of the month there are verystrong daily fluctuations according to varying cloud cover in the winter months.

Despite the extremely cost-saving design, the system withstood the winter storms without any problems.Several moisture sensors (figure 10) were positioned in order to be able to make statements about the rain distribution. It was found that an increased amount of water was registered directly below the vertically suspended modules. This is probably due to the oblique rainfall, which runs down the modules and drips off. Effects on the vegetation must therefore be taken into account.

From a business model perspective, the system's modular expandability ensures scalability, accommodating both small and large-scale agrivoltaics systems with efficiency. The tested prototype offers a robust foundation for upscaling, characterised by its simple expansion options, reduced guy ropes per intermediate traverse, and targeted spacing adjustments. These features position the system as a promising solution for large-scale agrivoltaics installations. The p/h ratio exerts a substantial influence on the implementation of the system as a scale-up, with a pitch of 5 metres and a solar module height h of 1.7 metres resulting in a ratio of 3 (Riaz et al. 2020). This indicates that the agrivoltaics system provides optimal shading conditions and efficient electricity production.With an estimated return on investment (ROI) of approximately 10 years, this

can be further optimised through cost reductions achieved by purchasing in larger quantities. The system's economic viability is further enhanced for small and medium-sized farmers, making it a viable option for a wide range of agricultural applications.The PERC modules in particular are notable for their rapid response to increased sunlight, achieving maximum energy yield even during the winter months, a trait that is a consequence of their inherent characteristics.

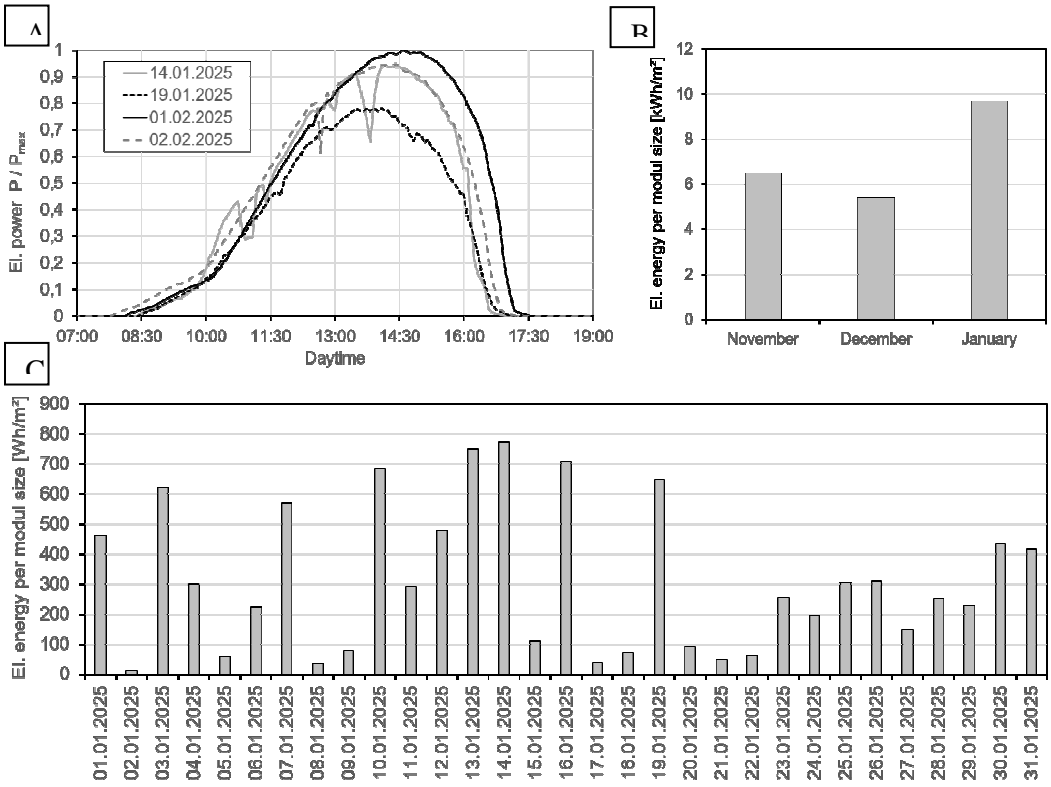

Figure 9: (A) Typical trend of electrical power on sunny days in January and February(B) Electrical Energy generated in winter months (C) daily energy generation for January

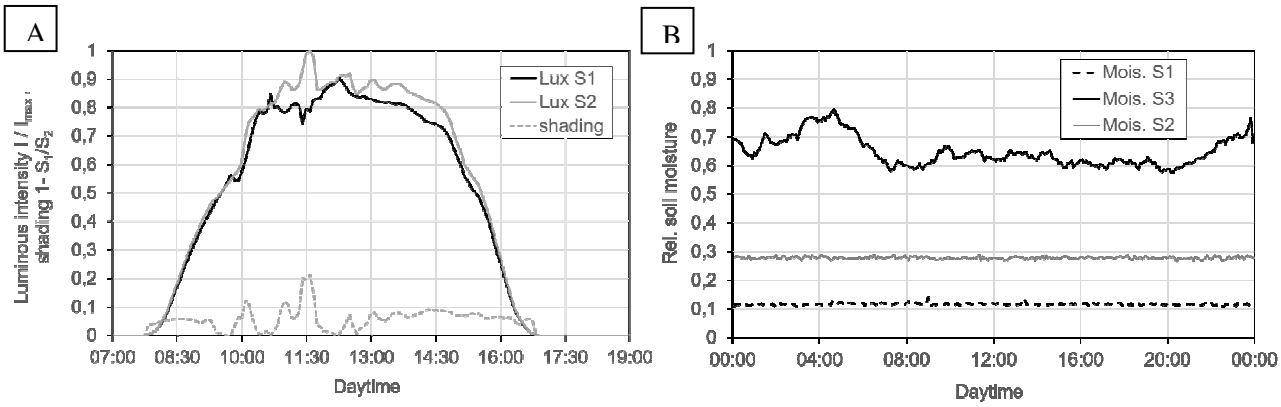

Figure 10:Measurement data according to the sensor positions fromFig. 7(A) Typical daily light intensity curve and shading in case of diffuse light (B) Exemplary course of soil moisture

In addition, a business model design of the small scale wineries whose existence is threatened, must include wine marketing, wine tourism as well as networking perspectives embracing all the stakeholders of a wine region ecosystem (Koch, Martin and Nash, 2013). In more detail, whilst a higher level of resilience against the 'heat stress'and higher level of renewable energy use to be achieved by the introduced agrivoltaics system,will positively affect the product brand(acidity and sugar content; sustainability), other organisational-level branding (i.e. family, winery, friendliness), regional branding (i.e. place of origin, regional image)and, last but not least, emotional consumer aspects (i.e. brand love) should be considered in an integrated manner (Johnson and Bruwer, 2007; Panovic, Obermayer and Kovari, 2022;Kaufmann and Durst, 2008; Correia Loureiro and Kaufmann, 2012).

6 CONCLUSIONS

This paper aims to provide an innovative albeit economical contribution for the winemaking industry by developing a prototype of a system which exploits synergistic effects of agriculture and photovoltaics for winemakers currently facing a daunting economic future. In this respect, this paper presents the results of an experiment to develop a prototype of an invention to micro scaling a developed prototype for wine makers to possibly increase their resilience and "diversify their risk by entering into the business of bioenergy production and intelligent agrivoltaics (Fiorillo, Lo Zoppo and Saputo (2023, p.54). This experiment in progress will provide detailed figures on efficiency key performance indicators, area output as well as typical geometrical positions of the developed system. The synergy effect on agricultural and energy efficiency by agrivoltaics systems are regarded a promising basis for successful sustainablebusiness models for small scale wineries including multifaceted and multi-stakeholder branding strategies.

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🏆 *reviewed paper*

Akustik im Städtebau – vom Potenzial für eine gesundheitsorientierte, nachhaltige Stadtentwicklung

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1 ABSTRACT

Ein Großteil der stetig wachsenden Weltbevölkerung lebt aktuell in Städten, die vor multiplen Herausforderungen stehen. Neben den unumgänglichen Anpassungen, die der menschengemachte Klimawandel erfordert, wird der urbane Raum maßgeblich von vielfältigen und divergierenden Stressfaktoren geprägt. Diese multiplen Stressfaktoren wirken sich auf die physische und psychologische Gesundheit der Menschen aus. Dazu zählt im urbanen Raum besonders Umgebungslärm, welcher beispielsweise auf Verkehrsemissionen basiert und laut WHO (2018) zu erheblichen gesundheitlichen Risiken bei betroffenen Personen führt. „Herz-Kreislauf-Erkrankungen, chronische Lärmbelästigung, Schlafstörungen, kognitive Beeinträchtigung sowie Tinnitus und Gehörschäden“ (UBA 19: 5) sind beispielsweise für die gesundheitlichen Auswirkungen von Umgebungslärm anzuführen. Eine nachhaltige urbane Entwicklung welche das Sustainable Development Goal (SDG) 11 adressiert,beinhaltet den zentralen Baustein für eine resiliente Quartiersentwicklung bis hin zur Gebäudeebene (Reicher at al. 2022: 71-76). Dabei spielt besonders auch eine gesundheitsorientierte Entwicklung eine zentrale Rolle.

Bisherige Forschung thematisiert vor allem den bauteilbezogenen „Lärmschutz“ beispielsweise bei Autobahnen, Gebäuden oder auch Innenräumen. Lärm tritt im urbanen Raum in Form von zahlreichen, unterschiedlichen Schallquellen auf. Herkömmliche und typische Bauweisen in Städten bedingen diese Lärmentwicklung mehr als diese zu reduzieren. Eine Adressierung gesamtheitlicher Schallreduzierung auf Stadtraum – beziehungsweise Quartiersebene ist dabei bisher wenig erforscht.

Innovative Maßnahmen, wie beispielsweise der Einsatz von schallabsorbierenden Textilfassaden, könnten allerdings einen Beitrag zur Lärmreduzierung im urbanen Raum liefern. In diesem Beitrag werden Erkenntnisse aus einem Projekt zur Untersuchung von schallabsorbierenden Textilfassaden im urbanen Raum vorgestellt. Das Projekt wird in Kooperation dreier Institute der RWTH Aachen durchgeführt, die sich mit Textiltechnik, Akustik und Städtebau beschäftigen.

Am Beispiel von Aachen wird die städtebauliche Integration der Textilfassaden im urbanen Raum untersucht. Zur Untersuchung werden verschiedene Methoden angewendet, die sich aus Material- und Eigenschaftsuntersuchungen, akustischen Simulationen und Auralisierungen sowie baulich-räumlicher Szenarienbildung der Textilfassaden zusammensetzen. In diesem Beitrag wird besonders die Perspektive des Städtebaus zur Lärmreduzierung in Stadträumen betrachtet, mit Textilfassaden als innovativen Beitrag für eine gesundheitsorientierte, nachhaltige Stadtentwicklung. Hierbei werden Erkenntnisse zur Verbesserung des „akustischen Wohlbefindens“ in Städten gewonnen.

Keywords: Innovation durch Textilfassaden, Akustisches Wohlbefinden, Gesunde Quartiersentwicklung, Akustik im Städtebau, Nachhaltige Stadtentwicklung

2 EINFÜHRUNG

Die aktuelle Debatte zur nachhaltigen Stadtentwicklung wird besonders durch die Einsparung von anthropogenen Emissionen geprägt. Dabei stehen insbesondere Luftemissionen im Betrachtungsfokus, wie beispielsweise CO_2-Emissionen und eine damit verbundene, angestrebte CO_2-Neutralität, welche beim Ziel desSustainable Development Goals (SDG) 11: „Nachhaltige Städte und Gemeinden“ (Vereinte Nationen 2022: 18) berücksichtigt wird. Parallel dazu soll auch das Sustainable Development Goal (SDG) 3: „Gesundheit und Wohlergehen“ (Vereinte Nationen 2022: 10) erreicht werden. Gerade für den urbanen Raum spielt eine nachhaltige aber auch eine gesundheitsorientierte Entwicklung eine entscheidende Rolle, da ausgestoßene Emissionen als Immissionen auf die Umwelt und die physische sowie psychologische Gesundheit der Menschen einwirken. Als Lebensraum einer immer weiter anwachsenden Weltbevölkerung,

ist besonders der urbane Raum von einer Vielzahl an Emissionen, die über die Luftemissionen hinaus gehen, betroffen und welche weitere Einsparungen für eine nachhaltige Entwicklung notwendig machen. Lärmemissionen im Stadtraum gelten als gesundheitsgefährdende Stressfaktoren, die zum Beispiel durch Verkehr emittiert werden. Zu den gesundheitlichen Gefahren gehören laut der WHO (2018) beispielsweise „Herz-Kreislauf-Erkrankungen, chronische Lärmbelästigung, Schlafstörungen, kognitive Beeinträchtigung sowie Tinnitus und Gehörschäden“ (UBA 19: 5).

Bereits 1957 hat Professor Erich Kühn mit seiner Publikation zu „medizin und städtebau“ (Vogler & Kühn: 1957) am Lehrstuhl für Städtebau an der RWTH Aachen zum Themenfeld der gesunden Stadtentwicklung in der gebauten Umwelt geforscht, zu der neben der Emissionssenkung, auch „Sicherheit“ oder „Walkability“ gehören. Es zeigt sich, dass die Aktualität dieser Forschungsbedarfe bis heute besteht und innovative Lösungen für den urbanen Raum notwendig sind.

3 VOM BAUTEILSBEZOGENEN LÄRMSCHUTZ ZUM GESAMTHEITLICHEN SCHALLSCHUTZ

Besonders der urbane Raum ist von einer Vielzahl sich immer wieder verändernder Schallemission betroffen. Diese stellen neue Bedarfe, Herausforderungen und Anforderungen an gesunde Lebensbedingungen in Städten. Neue Entwicklungen, wie beispielsweise die Einführung der neuen Gebietskategorie „Urbanes Quartier“ (BauGB: 2021), das einen höheren Grad der Nutzungsmischung sowie Dichte zwischen Arbeiten, Wohnen aber auch produzierenden Gewerbe beinhaltet, machen eine intensivere Beschäftigung mit der akustischen Qualität als gesunde Lebensräume, notwendig.

3.1 Herkömmliche Lärmschutzmaßnahmen im Städtebau

In der aktuellen Praxis finden Lärmschutzmaßnahmen im Städtebau, vor allem auf der Bauwerks- oder einer untergeordneterenBauteilsebene statt – und beziehen sich insbesondere auf den Innenraum von Gebäuden. Gängige städtebauliche Bauweisen fördern eher die Entwicklung von Lärm als diese zu reduzieren. Besonders in Gebäuden oder auch in Innenräumen eingesetzte spezielle Bauteile oder Materialien sollen Umgebungslärm reduzieren. Lärmschutzmaßnahmen, wie zum Beispiel Lärmschutzwände an Autobahnen, Flüsterasphalt auf Schnellstraßen oder auch Schallschutzfenster an Umgehungsstraßen sind diesbezüglich, als einige Beispiele zu benennen. Ziel ist es, die Einhaltung der Grenzwerte nach dem Bundes-Immissionsschutzgesetz (BImSchG), der Technischen Anleitung zum Schutz gegen Lärm (TA Lärm) oder auch der DIN 18005 zum Schallschutz im Städtebau zu gewährleisten. Diese Vorgaben orientieren sich vor allem an einzuhaltenden Grenzwerten und weniger an anzustrebenden gesamtheitlich betrachteten akustischen Umgebungen oder Qualitäten, die bei der Planung und Gestaltung unserer gebauten Umwelt zu Verbesserung der Aufenthaltsqualität führen könnten.

3.2 Gesamtheitlicher städtebaulicher Schallschutz

Die Reduzierung von Lärm in städtischen Räumen ist eine zentrale Herausforderung moderner Stadtplanung. Ein ganzheitlicher Ansatz zur Schallminderung berücksichtigt nicht nur die Reduktion von Lärmquellen, sondern auch die Gestaltung angenehmer akustischer Umgebungen, die das Wohlbefinden der Bewohnerinnen und Bewohner fördern können (Alves, 2015). Im Falle des Straßenverkehrs lässt sich neben einer Reduktion der direkten Schallpegel der Quellen, z. B. durch modernere Fahrzeugtypen, geringere Geschwindigkeiten oder der Verwendung spezieller Fahrbahnbeläge, ebenfalls eine Reduktion durch eine Veränderung des Reflexionsverhaltens der Umgebung erzielen.

Zu den allgemeinen Maßnahmen zur Verbesserung des akustischen Wohlbefindens in innerstädtischen Umgebungen gehören auch die Integration von Grünflächen, die als natürliche Schallabsorber und -Diffusoren wirken, sowie die Förderung von angenehmeren akustischen Klanglandschaft, sogenannten „Soundscapes“ (ISO 12913-1 2014), bei denen beispielsweise natürliche Klänge wie Vogelgesang oder Wasserplätschern die Schalldruckpegel nicht reduzieren, aber zu einer durch Menschen positiver bewerteten Klanglandschaft führen (Bilen & Can, 2021).

Die Betrachtung von Soundscapes ermöglicht es, akustische Umgebungen gezielt zu gestalten. Dabei wird nicht nur der Lärmpegel gemessen, sondern auch die Qualität der Klänge bewertet, um harmonische und angenehme akustische Umgebungen zu schaffen (Brown 2004). Eine ganzheitliche Lärmkontrolle in der Stadtplanung erfordert innovative Ansätze, die über die reine Lärmminderung hinausgehen. Die

Kombination von Soundscape-Design, grüner Infrastruktur und gezielten Maßnahmen zur Schaffung ruhiger Zonen kann die Lebensqualität in Städten erheblich verbessern.

Ein Teil davon sind auch alternative Fassadengestaltungen, die durch akustische Absorption und Streuung zur Lärmminderung in städtischen Umgebungen beitragen können – solche Maßnahmen sind Gegenstand der hier präsentierten Untersuchungen. Die Kombination von Absorption und Diffusion an Fassaden, insbesondere im unteren Bereich der Gebäude, kann zu einer relevanten Reduktion der Schalldruckpegel führen (Picaut 2009). Derartige Maßnahmen führen nicht nur zu einer ruhigeren Außenumgebung, sondern auch zu einer Reduktion des Innenlärms, ohne dass direkte Eingriffe in die Gebäudewände erforderlich sind (Magrini 2016).

3.3 Neue Forschungsbedarfe im städtebaulichen Kontext

Dabei bietet eine intensivere Beschäftigung mit einem umfassenden Schallschutz im Städtebau ein großes Potential Stadträume dauerhaft zu beruhigen. Der Ansatz basiert dabei nicht auf der Vermeidung von Schallemissionen, sondern auf der nachträglichen Reduzierung im gebauten Raum. Das akustische Wohlbefinden rückt dabei in den Betrachtungsfokus. Die Gestaltung und Untersuchung von Soundscapes, welche übergeordnete Verbindungen zwischen Umgebungslärm, Akustikqualität und gesundheitlicher Auswirkung im Stadtraum betrachten, stellen neue Forschungsbedarfe (Moebus et al. 2020). Erste Forschungsansätze untersuchen dazu „Klangraumgestaltung von Außenräumen“ (Sturm et al. 2019). Eine ganzheitliche Adressierung der Schallreduzierung von der Quartiers- bis zur Gebäudeebene ist wenig erforscht. Es gilt resiliente urbane Räume zu entwickeln (Reicher at al. 2022) und Emissionen durch beispielsweise innovative Maßnahmen zu senken.

4 TEXTILFASSADEN ALS INNOVATIVE MASSNAHMEN ZUR SCHALLREDUZIERUNG IM URBANEN RAUM

Als ein potentieller Ansatz zu Schallreduzierung im Städtebau wird im Folgenden das Potential für Textilfassaden interdisziplinär untersucht und vorgestellt. Textilfassaden stellen einen neuartigen Ansatz dar, die durch ihre Eigenschaften dazu beitragen können Stadtträume akustisch zu beruhigen.

4.1 Textilfassaden

Die Verkleidungselemente einer vorgehängten hinterlüfteten Fassade können aus technischen Textilien bestehen und werden in diesem Fall als Textilfassaden bezeichnet. In der Praxis bezieht sich der Begriff „Textilfassade“ jedoch überwiegend auf ein zusätzlich vorgelagertes Fassadensystem, das als Sekundärfassade fungiert. Sekundärfassaden werden als ergänzende Schicht vor die thermisch abgeschlossene Primärfassade montiert, da die durchlässige Struktur textiler Materialien die Schutzfunktionen der Verkleidungselemente nicht in vollem Umfang gewährleisten kann (FVHF 2017).

4.1.1 Materialität und Struktur

Die Konstruktion von auf dem Markt verfügbaren Textilfassaden basiert auf einer Unterkonstruktion, die in der Regel aus Aluminium oder Stahl besteht. Auf dieser Unterkonstruktion wird ein spezielles Gewebe gespannt, das aus synthetischen Fasern wie Polyester oder Glasfaser besteht und mit PVC oder PTFE beschichtet ist. Diese Beschichtungen verleihen dem Gewebe Eigenschaften wie Witterungsbeständigkeit, UV-Stabilität und eine hohe Reißfestigkeit. Die Wahl des Gewebes beeinflusst dabei maßgeblich die optische Wirkung der Fassade, von transluzenten bis hin zu opaken Erscheinungsbildern. Zudem ermöglicht die Flexibilität des Materials die Realisierung komplexer, dreidimensionaler Formen, die mit traditionellen Baustoffen schwer umzusetzen wären (König 2025.)

Aufgrund ihrer transluzenten Eigenschaften lassen sich textile Fassadenelemente auch vor Fensterflächen installieren, ohne die natürliche Belichtung vollständig zu blockieren. Dadurch wird ein effektiver Sonnen- und Blendschutz erzielt, während gleichzeitig der Sichtkontakt nach außen erhalten bleibt. Ein ausreichender Hinterlüftungsraum ermöglicht zudem die Öffnung von Fenstern und unterstützt so die natürliche Belüftung. Darüber hinaus schränken Textilfassaden den Einblick von außen in das Gebäude ein und tragen damit zur Wahrung der Privatsphäre bei. Durch die Absorption eines Großteils der solaren Einstrahlung reduziert die textile Sekundärfassade den Wärmeeintrag in das Gebäudeinnere, wodurch die thermische Gebäudehülle weniger stark aufgeheizt wird. Dies kann die Überhitzung im Sommer signifikant verringern und die

Kühllasten eines Gebäudes um bis zu 78 % senken. Angesichts der angestrebten Klimaneutralität im Gebäudesektor ist diese Einsparung von hoher Relevanz, um den Energiebedarf aktiver Kühlsysteme zu minimieren (Serode 2022).

Ein vielversprechender Ansatz zur Weiterentwicklung von Textilfassaden ist der Einsatz von 3D-Textilien. Diese mehrlagigen 3D-Gewebe bieten erweiterte funktionale und ästhetische Möglichkeiten im Fassadenbau. Durch die gezielte Variation von Materialdichte, Webtechniken und Strukturbildung lassen sich spezifische Eigenschaften wie verbesserte Schallabsorption, gesteuerte Lichtstreuung oder eine optimierte Luftzirkulation realisieren. Darüber hinaus können 3D-Textilien durch ihre dreidimensionale Formgebung die thermische Regulierung des Gebäudes unterstützen, indem sie beispielsweise als zusätzliche Verschattungselemente fungieren oder durch gezielte Luftführung den Wärmeaustausch zwischen Fassade und Umgebung steuern. Aufgrund ihrer strukturellen Vielfalt eröffnen sie zudem neue gestalterische Freiheiten, indem sie komplexe Oberflächenstrukturen ermöglichen, die mit konventionellen textilen Flächenmaterialien nicht realisierbar wären.

4.1.2 Einsatz und Verwendung

Neben funktionalen Vorteilen eröffnen Textilfassaden auch neue gestalterische Möglichkeiten. Durch eine gezielte Modulation der Unterkonstruktion können dreidimensionale Fassadenstrukturen realisiert werden. Zudem ermöglichen die transluzenten Eigenschaften des Materials in Kombination mit Lichtinszenierungen die Erzeugung ästhetischer Akzente, die das architektonische Erscheinungsbild eines Gebäudes maßgeblich prägen können.

4.2 Projekteinführung STumM

Das Projekt „STumM – Schallabsorbierende Textilfassaden im urbanen Raum – Machbarkeitsstudie“ beschäftigt sich mit der Fragestellung, welchen Beitrag Textilfassaden zu einer akustischen Schallreduzierung im Stadtraum leisten können. Ziel des Forschungsvorhabens ist es, eine Verbesserung der akustische Fassadenoberflächenwirksamkeit von Gebäuden zu erzielen, um urbane Lärmpegel, beispielsweise im öffentlichen Raum, der Stadt zu minimieren. Dazu gilt es, im urbanen Gefüge Szenarien zur Evaluierung ihrer städtebaulichen Integration von textilen Fassaden und ihrer Anwendbarkeit zu überprüfen. Aufgrund der Komplexität urbaner Räume gilt es, akustische Berechnungen und Messungen zu validieren und einen Vergleich mit simulierten Daten durchzuführen. Abschließend soll die technologische und differenzierte, funktionale Weiterentwicklung der textilen Fassaden, was beispielsweise Öffnungs- sowie Wandelemente betrifft, überprüft werden.

Innerhalb des Projekts wird eine perspektivische Betrachtung der Forschung auf drei Betrachtungsebenen vorgenommen. Auf einer übergeordneten, städtebaulichen Macro-Ebene wird eine städtebauliche Analyse der Integration von textilen Lärmschutzfassaden betrachtet. Auf der Mesoebene wird die akustische Simulation verschiedener Szenarienräume vorgesehen. Als abschließende Perspektive auf Microebene erfolgt eine Untersuchung der Ebene der Materialität. Diese zeigt, den interdisziplinären Ansatz des Projektes, vom Stadtraum bis zur bauteilsbezogenen Ebene, was die Notwenigkeit einer interdisziplinären Querschnittsbetrachtung verdeutlicht.

4.3 Urbane Szenarien

Um den methodischen Ansatz umzusetzen werden Szenarienräume aufgestellt. Diese Szenarienräume stellen drei divergierende baulich-räumliche Situationen auf dem „Campus Mitte“ der RWTH Aachen dar, welche unterschiedliche Lärmquellen aufweisen.

Gerade Universitätscampusareale werden in der aktuellen Forschung nicht mehr nur als reine „Lern – und Arbeitsorte“ angesehen sondern als „Living Lab“ (Verhoef, Bossert 2019), die sich durch eine 24h-Nutzung zu abwechslungsreichen Lebensorten (Potulski 2020; Fusi 2019) wandeln, für die eine nachhaltige aber auch gesundheitsorientierte Entwicklung von großer Bedeutung ist (Okanagan Charta 2015).

Der sogenannte „Campus Mitte“ rund um das historische Hauptgebäude der RWTH Aachen, bietet sich dabei besonders gut als Betrachtungsraum an, aufgrund der räumlichen Nähe und vorliegenden Expertise der beteiligten Institute. Gleichzeitig weist dieser eine Vielzahl an divergierenden Geräuschemissionen und Nutzungen auf, die in zentraler urbaner Innenstadtlage angrenzend an Wohnnutzungen liegen, die besonders

geräuschempfindliche Nutzungen darstellen. Die drei ausgewählten Szenarienräume setzen sich wie folgt zusammen:

Szenarienraum Mensa, dieser stellt einen zentralen Anlaufspunkt und Aufenthaltsbereich auf dem Campus Mitte dar. Besonders der Vorplatz und Außensitzbereich der Mensa ist von den hohen Geräuschemissionen der angrenzenden stark befahrenen Turmstraße betroffen.

SzenarienraumSemitemp, dieser Raum stellt eine Art Nachverdichtung im rückwertigen Campusbereich dar. Das „Semitemp“, als temporäres Seminargebäude wurde auf einen Teil der Parkplatzfläche aufgestellt, mit den angrenzenden Lärmemisssionen der verlaufenden Bahnstrecke.

Abb. 1: Foto des Szeanrienraums „Wüllnerstraße“ (Mathilda Murray, 2025)

SzenarienraumWüllnerstraße, dieser wird als Verbindungsstraße sowie als Zufahrt zu einem angrenzenden Parkplatz (Talbotparkplatz) ebenfalls maßgeblich durch verkehrliche Geräuschemissionen geprägt, ergänzt durch einzelne Schallemissionen dort ansässigen RWTH Institute.

Alle drei Szenarienräume eignen sich besonders gut, da die ausgewählten Bestandsgebäude unterschiedliche konstruktive Fassadentypen aufweisen und damit auch divergierende Umsetzbarkeiten der Fassadentypologien ermöglichen.

4.3.1 Baulich-räumliche Integration

Anhand der drei definierten und vorgestellten Szenarienräume, wird in einem Forschungsfeld mit Masterstudierenden der Architektur und Stadtplanung der RWTH Aachen untersucht, wie an den definierten Gebäuden der Szenarienräume, schallabsorbierende Textilfassaden nachträglich ergänzt werden können. In einem zweiten Schritt wird die baulich-räumliche Integration dieser neuen Fassaden in ihr Umfeld erforscht. Dazu werden nach einer ersten inhaltlichen Auseinandersetzung mit Textilfassaden, Testentwürfe durch die Studierenden erstellt. Pro Szenarienraum sollten dafür drei divergierende Varianten ausgearbeitet werden, die auf unterschiedlichen Konstruktionsweisen basieren und multiple Erscheinungen der Fassade hervorrufen. Dafür werden je nach Fassadentypus der Bestandsgebäude die bestehenden Fassaden durch Textilfassaden ersetzt oder eine neue textile Fassadenhülle additiv ergänzt. Trotz der unterschiedlichen Szenarienräume mit divergierenden Ausgangsgebäuden zeigen die Ergebnisse, dass drei Grundtypen bei der Erstellung der Fassaden immer wieder Anwendung finden. Dazu zählt die flächig, vorgespannte Fassade, eine Aufteilung in verschieb- oder verstellbare Teilelemente sowie eine panelartige Ausführung (siehe Abb. 2).

Gerade der flächig festvorgespannte Fassadentypus, lässt sich gut additiv ergänzen. Bestehende Fensterflächen werden allerdings ebenfalls mit dem Textil überspannt, was zu Einbußen oder zu

Beeinträchtigung der visuellen Sichtbezüge zwischen Innen- und Außenraum führen kann. Die verschiebbaren elementartigen Textilfassaden, weisen diesbezüglich Einschränkungen ebenfalls auf, lassen sich aber für freie Sichtbezug zur Seite verschieben, was gerade bei beispielswiese dauerhafter Büronutzung, eine große Bedeutung für die Innenraumqualität spielen könnte. Die dritte Variante der unbeweglichen elementierten Panelfassade, welche gerade Textilflächen im rechten Winkle zur Fassaden stellt, kombiniert die Gewährleistung der Freihaltung der Sichtbezüge und bietet eine größtmögliche aktivierbare textile Fläche an, die akustischen Auswirkungen dieser Fassaden gilt es im Weiteren zu erforschen.

Abb. 2: Baulich-räumliche Ausführungsvarianten von Textilfassaden im Städtebau am Beispiel des Szenarienraums „Wüllnerstraße“ – (v. l.) „fest verspannt, beweglich, panelartig“ (Judith Möhringer & Selina Pick 2024)

Im zweiten Schritt, sollten die Studierenden in selbst durchgeführten Umfragen die Akzeptanz für den Einsatz textiler Fassaden im urbanen Raum untersuchen. Als Grundlage der Integration werden dafür, die aus der Literatur abgeleiteten Integrationsparameter nach Reicher (2017: 218), die von „Einordnung“, „Unterordnung“ und „Überordnung“ sprechen, verwendet. Die Ergebnisse dieser Umfragen zu den verschiedenen Szenarienräumen zeigen querschnittsartig, dass Textilfassaden an sich als wichtige Innovation angesehen werden, allerdings visuell besonders einheitliche Fassadenerscheinungen, die weniger auffällig sind, im Stadtraum bevorzugt werden.

4.3.2 Akustische Auswirkung

Da eine Veränderung einer urbanen Umgebung, mit dem Ziel die Lärmpegel in dieser zu reduzieren, im Regelfall mit erheblichem Aufwand verbunden ist, werden bei der Planung der Veränderung üblicherweise akustische Berechnungs- und Simulationsmodelle verwendet. Durch eine Beschreibung der akustischen Charakteristik von Oberflächen (Fassaden), ist es mit verhältnismäßig einfachen Rechnungen möglich, die akustische Wirkung einer veränderten Fassade zu beschreiben, indem der Schalldruck der an der Fassade zurückgeworfenen Reflexion bestimmt wird. In der nicht-isolierten realen Situation einer urbanen Szene befinden sich jedoch eine Vielzahl von Schallquellen und Reflexionsflächen, was zu einer wesentlich komplexeren Berechnung der akustischen Auswirkung führt.

Für die Vorhersage von urbaner Schallausbreitung existieren eine Vielzahl verschiedener Normen und Richtlinien (ISO 9613-2 1996; CNOSSOS-EU 2012) sowie Berechnungsmodelle (Attenborough 1995; Pasareanu 2018). Soll jedoch nicht nur Parameter bzw. Schalldruckpegel bestimmt werden, ist die Anwendung der geometrischen Akustik ein übliches Verfahren, mit dem es möglich ist, eine definierte Situation an verschiedenen Hörpositionen auch zu auralisieren (hörbar zu machen). Die Betrachtung der geometrischen Schallausbreitung erlaubt eine effiziente Durchführung der Ausbreitungssimulation und in Kombination mit akustischer Signalverarbeitung ist so eine Auralisierung auch für interaktive Szenarien möglich (Stienen 2023).

Mit Hilfe der Simulationssoftware RAVEN (Schröder 2011) wird in diesem Projekt in einem ersten Schritt untersucht, welche Auswirkungen die Veränderung der akustischen Fassadeneigenschaften hat. Dazu wurden die Szenarien in 3D-Modelle (beispielsweise für Szenarienraum Wüllnerstraße dargestellt in Abb. 3) konvertiert, die den Anforderungen des verwendeten akustischen Simulationsmodells genügen. Durch eine Definition der akustischen Parameter der Oberflächen (Absorption und Streugrad) ist so eine kontrollierte Untersuchung des Einflusses der Fassaden möglich. Die resultierenden Impulsantworten für die in der Szene definierten Schallquellen hin zu festgelegten Hörpositionen können mit entsprechenden Signalen kombiniert werden, was zur einem plausiblen Höreindruck des definierten Szenarios führt.

Um erwartbare Effekte für verschiedene Szenarien zu bestimmen, wird für eine kontrollierten Modellsituation (Szenarienraum Wüllnerstraße) eine akustische Simulation von verschiedenen

Quellpositionen (Q1, Q2 und Q3) betrachtet. Die in Abb. 3 dargestellten Fassaden in den Farben grün und rot werden in drei Varianten in ihre akustischen Absorptionseigenschaft variiert (alle frequenzunabhängig) :

- Variante A: Absorptionsgrad von 10 % (Referenz)
- Variante B: Absorptionsgrad von 40 %
- Variante C: Absorptionsgrad von 80 %

Diese angenommenen akustischen Eigenschaften stellen stark vereinfachte eher extreme Werte dar und sind in der Realität, in Kombination mit der gewählten Großflächigkeit der angepassten Fassaden, nicht zu erwarten, sollten aber einen Eindruck von erwartbaren Auswirkungen vermitteln.

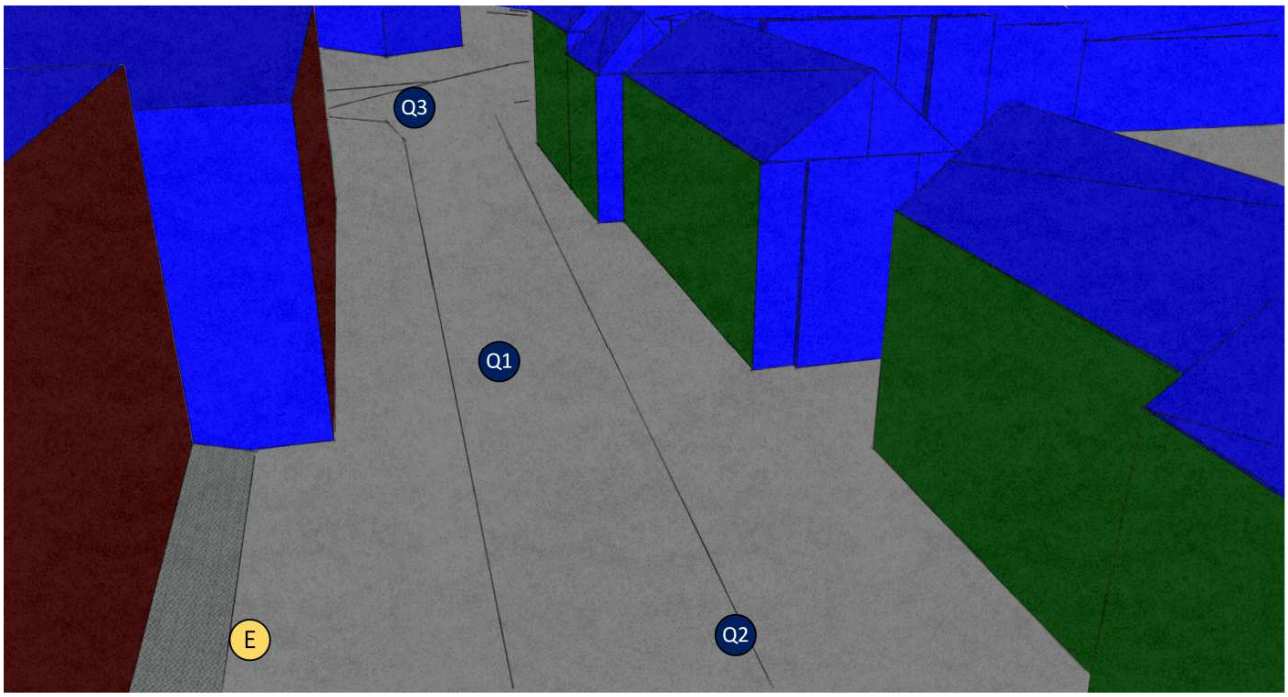

Abb. 3: Beispielhafte Untersuchung von Fassaden mit akustischen Simulationsmodell für den Szenarienraum Wüllnerstraße. (IHTA)

Variante A wird für die Ergebnisse als Referenz betrachtet. Für Quellpositionen Q1 und Q2 (ca. 26m und 18m Distanz zum Empfänger E) sind aufgrund der relativen Nähe zum Empfänger durch eine Veränderung der Fassaden in den Ergebnissen kaum Pegelreduktionen zu beobachten, sowohl für Q1 als wurden für Q2 sind -0. 2 dB und für Variante B -0. 4 dB bestimmt. Im Falle von Quellposition Q3 (Distanz ca. 95m), die keine direkte Sichtverbindung zum Empfänger besitzt und somit der Direktschall (zum Teil) durch die versetzte Fassade blockiert wird, liegen die Pegelveränderungen entsprechend höher: -1. 9 dB für Variante B und -6. 6 dB für Variante C, im Vergleich zur Referenzbedingung (Variante A).

Diese Ergebnisse zeigen, dass durch eine Veränderung der Fassaden in der betrachteten städtischen Umgebung keine extremen Änderungen des Schalldruckpegels zu erwarten sind – wenn sich die Lärmquellen in der Nähe der Hörposition befinden. Bei größeren Distanzen zu Lärmquellen und insbesondere wenn der Schall nicht direkt zum Empfänger gelangt, sind größere Pegelunterschiede möglich. Diese zeigen, dass akustische Maßnahmen bei den Fassaden eine mögliche Maßnahme zur Verbesserung der Lebensqualität im urbanen Raum darstellen kann – denn selbst geringfügige Pegelreduktionen im Bereich von 1-3 dB machen insbesondere bei ständiger bzw. dauerhafter Aussetzung einen Unterschied für Menschen und Tiere in der Umgebung aus.

Im weiteren Verlauf des Projektes sollen die angesprochenen Szenarien und die entsprechende akustische Simulation schrittweise in Richtung realitätsnahe Konzepte angepasst werden. Dazu werden sowohl die Eingabedaten (realistische Absorptions- und Streudaten für die Fassaden, detaillierte Modellierung der Lärmquellen, genaue Modellierung der möglichen Fassadenflächen) als auch das verwendete Simulationsmodell angepasst. Dabei wird auch untersucht, ob die verwendeten Simulationsmodelle auch die akustischen Eigenschaften von komplexen, dreidimensionale Fassadenstrukturen (vgl. Abb. 2 rechts) berücksichtigen können.

Neben der Bestimmung der Reduktion von Schalldruckpegeln bei verschiedenen betrachteten Fassadenvarianten, werden für die Szenarienräume typische Lärmsituationen auralisiert (hörbar gemacht). Diese Auralisierungen können zukünftig auch in Wahrnehmungs- und Soundscape-Studien eingesetzt werden.

4.3.3 Materialbezogene Bedingungen

Da Textilfassaden sich zum Teil auch vor Fenstern befinden, ist die Untersuchung der Lichtdurchlässigkeit relevant. Eine Lichtdurchlässigkeitsprüfung kann mithilfe eines Lichttisches durchgeführt werden, welcher aus einer lichtdurchlässigen Grundplatte besteht, unter der eine gleichmäßige Lichtquelle installiert ist. Diese Anordnung sorgt dafür, dass das Licht von unten auf das zu prüfende Textil strahlt. Bei jeder Messung wird ein Foto des Textils aufgenommen, bei gleichbleibender technischer Konfiguration in einem definierten und gleichbleibenden Abstand um eine Vergleichbarkeit zu gewährleisten. Nach erfolgter Aufnahme wird das Bild mit Hilfe von Software in ein reines Schwarz-Weiß-Bild konvertiert. Diese Umwandlung ermöglicht eine differenzierte Analyse der Helligkeitswerte, die durch die unterschiedlichen Textilien und deren Dichte beeinflusst werden. Anhand dessen kann die Geschlossenheit des Textils quantifiziert werden. Die Geschlossenheit ist ein entscheidender Faktor für die Bestimmung der Lichtdurchlässigkeit. Ein höherer Grad an Geschlossenheit führt typischerweise zu einer geringeren Lichtdurchlässigkeit und vice versa. Mit diesem Verfahren können sowohl 2D als auch 3D-Textilien untersucht werden. Die in Abb. 4 so erzielten Ergebnisse, beispielhaft für zwei Textilvarianten, zeigen eindeutige Unterschiede in der Lichtdurchlässigkeit (30 % vs. 51 %).

Weitere materialbezogenen relevante Faktoren sind unter anderem die Elastizität und Dauerhaftigkeit. Diese Parameter sind unter anderem von den verwendeten Fasermaterialien sowie von deren Nachbehandlung abhängig. Bei der Wahl und Herstellung von Material für Textilfassaden sollte die Dauerhaftigkeit, unter Berücksichtigung der am Einsatzort zu erwarteten üblichen Witterungsbedinungen, betrachtet werden. Die Drapierfähigkeit und Flexibilität von Textilen hat einen positiven Einfluss auf die Formgebung der Fassade. Nicht nur durch das Fasermaterial und der Textilart sondern auch durch die Einspannung kann die Optik der Fassade beeinflusst werden.

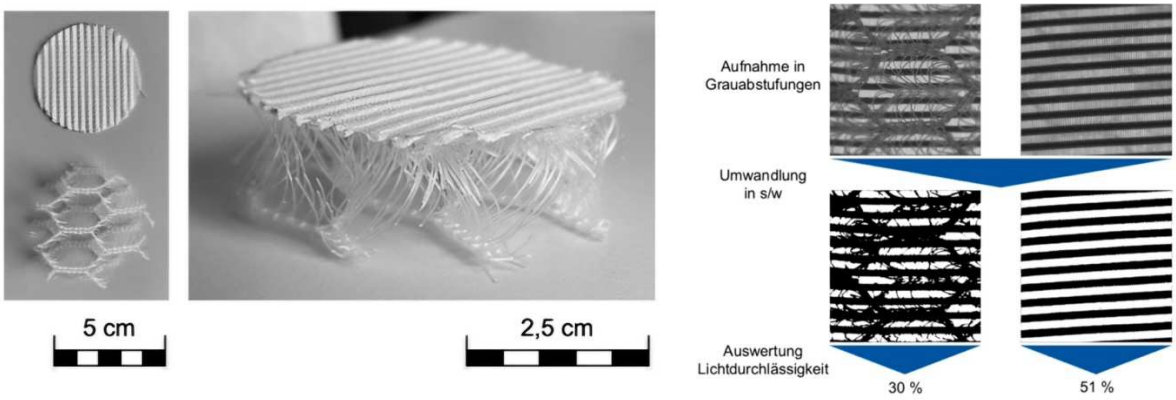

Abb. 4: Textilvarianten und Lichtdurchlässigkeitsprüfung Textilen. (ITA)

5 SCHLUSSFOLGERUNGEN

5.1 Erkenntnisse

Die Ergebnisse des vorgestellten Projektes verdeutlicht, dass durch innovative Maßnahmen, wie dem Einsatz von schallabsorbierender Textilfassaden, Umgebungslärm in urbanen Räumen reduziert werden kann. Die Höhe der Reduktion hängt dabei maßgeblich vom eingesetzten Materialumfang sowie der Materialdicke der eingesetzten Textilien ab. Durch größere Flächen und eine höhere Materialstärke kann im Regelfall eine höhere Schallabsorption erzielt werden. Vollflächig bespannte Fassaden besitzen damit den größten akustischen Effekt, mit dem Nachteil, dass die Textilien gerade in Festerbereichen zu Einschränkungen der Sichtbezüge zwischen Innen- und Außenraum sowie des Tageslichteinfalls führen können. Die Auseinandersetzung mit dieser Problematik hat zur Ausbildung verschiedenster Fassadenvarianten geführt, die neben einer Vollbespannung, kleinteiligere Formate in Form von verschiedenartigen Panelen oder Segeln

vorsehen. Gerade durch die Ausbildung vertikal aufgestellter Panele kann die Innenraumqualität bei Fensterflächen gewahrt werden. Allerdings werden diese panelartigen Fassadentypologien als deutlich dominanter im Stadtraum wahrgenommen und als weniger gut, in den urbanen Raum, integriert.

5.2 Weiterer Forschungsbedarf

Als weiteren Forschungsbedarf lässt sich die vermehrte Implementierung von schallabsorbierenden Fassaden im urbanen Raum anführen. Es gilt im Weiteren zu erforschen, wie eine Steigerung der Einsetzbarkeit und Verwendung von schallabsorbierenden Textilfassaden im Neubau, aber auch in der Bestandsentwicklung in der Stadt generiert werden kann und welche rechtlichen aber auch funktionalen Rahmenbedingungen es dafür benötigt. Dazu gilt es, die schallabsorbierende Wirkung verbunden mit einer kleinteiligeren, panelartigen Aufteilung auf ihre akustische Wirkung hin genauer zu untersuchen sowie weitere Untersuchungen auf der Konstruktions- sowie Materialebene anzustellen, die beispielsweise eine höhere Durchsichtigkeit generieren, um die Verwendbarkeit der Fassaden zu erhöhen.

5.3 Notwendigkeit interdisziplinärer Perspektiven

Abschließend zeigt sich deutlich, dass zur Adressierung und Verbesserung der akustischen Qualität im urbanen Raum ein interdisziplinärer Ansatz zur ganzheitlichen Emissionssenkung notwendig wird. Das vorgestellte Projekt „STumM“, als interdisziplinäre Schnittstelle zwischen Städtebau, Elektrotechnik und Maschinenbau, untersucht innovative Ansätze zum Umgang mit komplexen Herausforderungen um urbane Lärmemissionen und damit gesundheitsgefährdende Stressfaktoren ganzheitlich zu senken und wohltuendere Lebensumgebungen in Städten zu schaffen. Damit zeigt sich, dass die Auseinandersetzung mit Akustik im Städtebau ein hohes Potential für eine gesundheitsorientierte, nachhaltige Stadtentwicklung birgt, im Sinne des SDG 11 den urbanen Raum zu entwickeln.

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Al-Bireh Resilient City

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1 ABSTRACT

Al-Bireh city, located in the central West Bank, faces growing challenges due to climate change, Israeli occupation, and settlers. The municipality has implemented five key strategies to enhance resilience and sustainability: Adaptive urban planning, Climate change mitigation policies, Building community resilience, Enhancing food security, and Sustainable mobility. These strategies are aligned with the Sustainable Development Goals (SDGs), aiming to create a resilient, adaptive, and sustainable urban environment. The implementation of these strategies positions Al-Bireh as a model for cities facing similar challenges worldwide.

Keywords: sustainability, community, resilience, Al-Bireh, climate change

2 INTRODUCTION

Al-Bireh, a key urban center in the West Bank, faces significant challenges related to urban planning, green space reduction, environmental degradation, and political constraints stemming from the Israeli occupation. The city's rapid expansion, compounded by territorial restrictions and urban sprawl, has created a complex situation for sustainable development. Furthermore, Al-Bireh is experiencing a decline in green spaces, compounded by pressure from residential and commercial development. Environmental challenges, including climate change, air and water pollution, and limited natural resources, exacerbate these issues. This paper explores the municipality's strategies to enhance urban resilience and sustainability in the face of these challenges, while aligning with the United Nations Sustainable Development Goals (SDGs).

3 METHODS

3.1 Research Design

This study follows a qualitative research methodology to assess the resilience strategies of Al-Bireh. The research combines primary data (interviews with municipal officials, field observations) and secondary data (academic literature, municipal reports, international reports) that are aligned with global sustainability standards and the Sustainable Development Goals (SDGs). This approach helps evaluate Al-Bireh's efforts in sustainable urban planning, climate resilience, and community-building in the context of international best practices and frameworks for sustainable development.2.2 Data Collection

Primary data was collected through interviews with key municipal departments, such as the Planning and Engineering Department, the Cultural Department, and the Media and Public Relations Department, as well as field observations of the urban landscape. Secondary data sources included plans, policies, reports, and documents provided by the Al-Bireh Municipality, academic publications on urban sustainability, and international reports on climate resilience and SDG localization.

3.2 Data Analysis

The data was analyzed thematically, with a focus on identifying the collected data was analyzed using a thematic approach, focusing on identifying key themes and patterns related to the alignment of Al-Bireh's urban strategies with the Sustainable Development Goals (SDGs). The analysis aimed to assess the effectiveness of municipal strategies in fostering urban sustainability and resilience, with particular emphasis on the integration of climate action, social inclusion, and environmental stewardship.The five primary strategies evaluated in this analysis include:

Al-Bireh Urban Planning:

Current Situation and Issues:

(1) The Master Plan and Limited Green Spaces: The approved master and organizational plan for the city of Al-Bireh, which was ratified in 2003 covering an area of 10,854 dunams, suffers from shortcomings in

maintaining an environmental balance between residential areas and green spaces. This plan did not allocate enough space for green areas, leading to a significant shortage, as green spaces make up less than 1% of the city's organizational area. This deficiency negatively impacts the quality of life in the city, contributing to environmental challenges such as air pollution and rising temperatures, as well as reducing spaces dedicated to recreation and leisure.

(2) Population Growth and Migration: Al-Bireh suffers from a significant population increase due to its centrality in the West Bank, with a large influx of people migrating from the north and south of the West Bank. This population growth places additional pressure on the city's infrastructure and public services, increasing the need to allocate more space for urban expansion and sustainable growth, the currently city population around 120,000 capita.

(3) Land Restrictions under Israeli Control: The city of Al-Bireh covers an area of approximately 22,198 dunams, but 51% of this area is classified as "Area C" according to the Oslo Accords, meaning it is under Israeli civil and military control. As a result, citizens and the municipality are not allowed to invest in or utilize these lands, which restricts urban growth and development in the city.

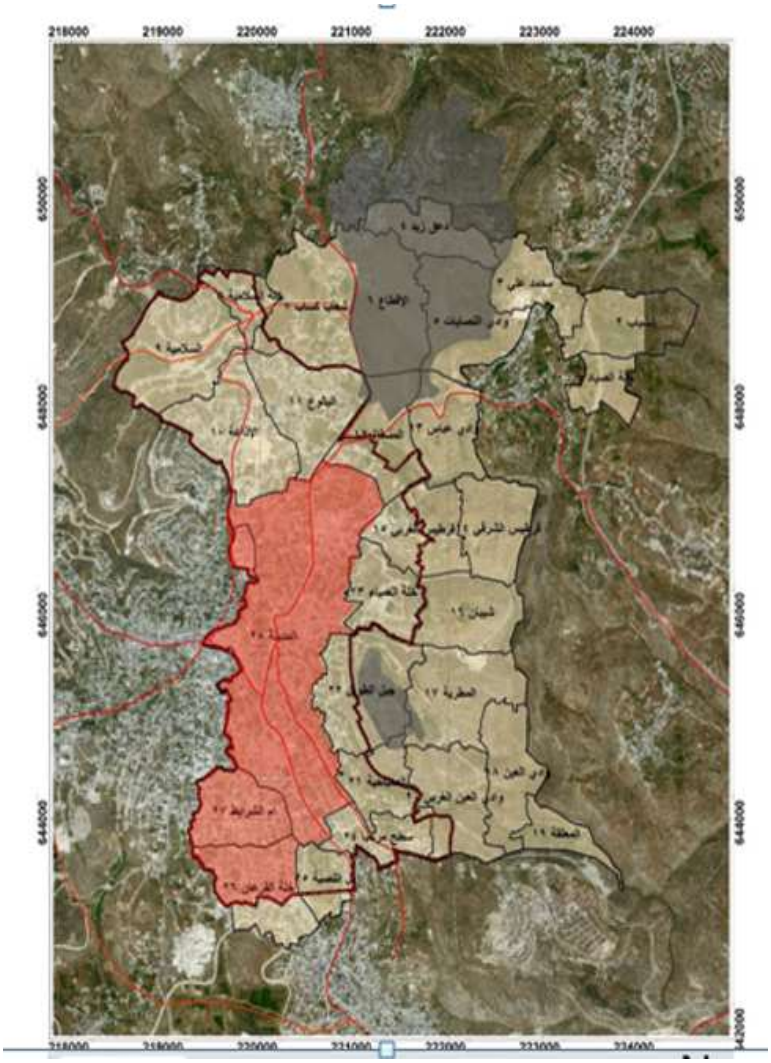

Figure 1.

(4) Israeli Settlements: Two Israeli settlements are located to the north and east of the city: the Beit El settlement (covering 1,800 dunams) and the Psagot settlement (covering 308 dunams). This distribution leads to the division of the city and limits equitable access to services across all areas of the city.

3.3 Impacts of Climate Change in Al-Bireh:

Current Situation and Issues:

Al-Bireh, like many cities around the world, is experiencing the increasing impacts of climate change. These impacts are clearly manifested through rising temperatures and decreasing rainfall, which exacerbate the

city's environmental challenges. One of the most prominent impacts is the urban heat island effect, where the city records a significant rise in temperatures due to the lack of green spaces and the increase in urban density. This leads to higher temperatures as buildings and infrastructures reflect heat.

Additionally, the lack of green spaces is a major factor contributing to the increased local temperatures. The scarcity of parks and recreational areas prevents the city from benefiting from the natural cooling effects provided by green spaces. Therefore, preserving and expanding green spaces is a crucial strategy to mitigate the effects of urban heat islands and improve the overall quality of life in the city.

Challenges Related to Water and Electricity:

In addition to the climate impacts, the residents of Al-Bireh face significant challenges concerning basic natural resources, such as water and electricity, due to the restrictions imposed by the Israeli occupation.

(2) Control over Water Resources: Water sources in the West Bank, including Al-Bireh, are under strict Israeli control. Israeli authorities prevent Palestinians from drilling new deep wells or deepening existing wells and impose restrictions on the amount of water that can be extracted, limiting the city's ability to meet the needs of its population. In contrast, Israeli settlements are permitted to use groundwater for agricultural irrigation, leading to the depletion of local water resources. For example, the drilling of deep wells in the Al-Auja settlements near Jericho has resulted in the drying up of local springs and increased water salinity, negatively affecting local agriculture.

(2) Challenges in the Electricity Sector: Al-Bireh also faces challenges in the electricity sector, as the city's electricity distribution companies do not have the license to generate or produce electricity. The city's electricity supply is limited to what is provided by the Israeli electricity company "Mekorot," which can reduce the amount of electricity allocated to Palestinians, leading to frequent power outages. Additionally, there are limited efforts to import electricity from some Arab countries, but these attempts face many obstacles due to Israeli policies and available infrastructure.

3.4 Al-Bireh City and Community

Current Situation and Issues:

Al-Bireh city is one of the central cities in the West Bank, playing a vital role in the political, economic, and social life of the region. It has around 25,000 families, with a population of approximately 120,000 people. The city also hosts numerous governmental and private institutions that contribute to promoting sustainable development, providing essential services, and supporting the local community in various fields. In this context, the institutions in Al-Bireh can be divided into the following categories: Charitable and Developmental Associations: There are around 30 associations working in various fields such as community development, health, environment, and education. These associations significantly contribute to improving the quality of life and supporting vulnerable groups in the community.

Government Ministries and Institutions: Al-Bireh hosts several government ministry offices, including the Ministry of Education, Ministry of Health, Ministry of Interior, and others. The city has about 10-15 government offices, reflecting its important role in providing services to the citizens.

Non-Governmental Organizations (NGOs): There are numerous NGOs in the city that work in the fields of human rights, sustainable development, and environmental support. The number of these organizations ranges from 30-40, reflecting active community engagement and cooperation with local and international institutions.

Consulates and Diplomatic Offices: Although Al-Bireh does not directly host consulates, it is located near Ramallah, where there are approximately 15-20 consular offices representing different countries. These offices enhance diplomatic and administrative communication with the Palestinian community.

3.5 Limited Agricultural Land and Resource Access in Al-Bireh

Current Situation and Challenges:

(1) Unused Lands in Area C:

A large portion of Al-Bireh's lands, especially in Area C (which is under full Israeli control according to the Oslo Accords) which is around 51% from Al-Bireh Area, remains unused or restricted. Area C is a vital region for both urban and agricultural expansion, but it is subject to restrictions imposed by Israeli

authorities. These restrictions prevent Palestinians from fully utilizing the land for agricultural or construction purposes, limiting the ability to expand food production or enhance food security through sustainable farming.

The lack of access to these lands makes it difficult for the municipality to implement large agricultural projects that could contribute to local food production and enhance food security.

(2) Land Classification and Uses:

As a central city, Al-Bireh experiences high demand for land for urban and commercial expansion. As a result, most of the land in the city is classified for commercial or residential use rather than agricultural purposes. This classification limits the use of available land for agriculture and makes it more challenging to increase local food production.

Additionally, land prices in the city are extremely high due to the demand for urban and commercial expansion, making it difficult for local agricultural initiatives to invest in these lands for sustainable agriculture or food security purposes.

(3) Limited Agricultural Land in the City:

The amount of land available for farming within Al-Bireh is limited due to urbanization in the area and the restrictions on land use. Therefore, agricultural activities within the city are restricted, and much of the food supply relies on external sources, which increases the challenges associated with price fluctuations and supply disruptions.

Furthermore, the city lacks sufficient space for food cultivation within urban areas, which has led to a reduction in land designated for agriculture due to the increasing demand for residential and infrastructural land.

(4) Water and Resource Scarcity:

Access to water, which is a crucial resource for agriculture, is a significant challenge in Al-Bireh due to the restrictions imposed by Israeli authorities on access to water. The city, like many other Palestinian areas, struggles to secure its water needs for both urban and agricultural use.

In addition to water scarcity, the availability of resources such as fertilizers and other agricultural inputs is often limited, hindering the ability to expand agricultural projects and sustain them.

3.6 Challenges in Sustainable Mobility and Connectivity in Al-Bireh

Current Situation and Challenges:

Al-Bireh city faces several challenges related to sustainable mobility and connectivity, highlighting the urgent need to improve the city's transportation infrastructure. Despite ongoing efforts to improve transportation means, several factors hinder the development of this sector in the city.

(1) Traffic Congestion and High Emissions

Al-Bireh suffers from severe traffic congestion, especially during peak hours, as the city is a residential and commercial hub in the West Bank. This congestion leads to increased carbon emissions from vehicles, significantly contributing to air pollution and rising temperatures in the city.

Additionally, the absence of sustainable transportation options, such as bike lanes or an effective public transportation system, exacerbates this issue, making most residents rely on private cars for daily commuting.

(2) Road and Sidewalk Infrastructure

Road Conditions: The road network in Al-Bireh is outdated and does not meet the needs of the growing population or increasing traffic. Many roads are narrow or poorly maintained and lack traffic signals or effective traffic monitoring systems, leading to accidents and decreased efficiency in road usage.

Sidewalks: Although there are some sidewalks in parts of the city, they are often incomplete or in poor condition, posing risks to pedestrians and discouraging walking. Some sidewalks are obstructed by parked cars, hindering pedestrian movement, which makes walking an uncomfortable option for residents.

(3) Lack of Effective Public Transportation

Although Al-Bireh has a network of small buses (microbuses), this network is still inefficient and disorganized. Public transportation covers some areas but lacks integration in transportation networks or proper connectivity with other parts of the city or surrounding areas. Furthermore, the bus routes are often irregular, leading to long wait times and overcrowding on public transport.

The city lacks a unified, effective public transportation system that connects urban areas with each other or coordinates with neighboring municipalities such as Ramallah and Betunia, creating significant gaps in inter-city mobility.

Limited Bicycle and Walking Infrastructure

Despite the global shift towards promoting cycling and walking as sustainable modes of transportation, Al-Bireh lacks the necessary infrastructure for these activities. There are no dedicated bike lanes, and the streets in the city are not pedestrian-friendly, making it difficult for residents to adopt these modes of transport. Furthermore, these factors hinder the move towards reducing reliance on private cars.

4 RESULTS AND MUNICIPALITY STRATEGIES

In response to the multifaceted challenges facing Al-Bireh which mentioned above, the municipality has developed a set of innovative and strategic initiatives aimed at fostering sustainable development. These efforts are designed not only to address the city's immediate challenges but also to lay the groundwork for a resilient, inclusive, and environmentally conscious future. By integrating adaptive urban planning, climate change mitigation measures, community empowerment, food security initiatives, and sustainable mobility, These strategies are aligned with global frameworks such as the Sustainable Development Goals (SDGs), ensuring that the city's progress is both locally relevant and globally impactful. The following sections present the key results and strategic actions the municipality is undertaking to navigate its challenges.

4.1 Adaptive and Sustainable Urban Planning (SDG 11: Sustainable Cities and Communities)

- Urban Growth, Environmental Sustainability, and Green Spaces Integration: The updated master plan of Al-Bireh focuses on balancing urban growth with environmental sustainability. Despite the challenges posed by political and territorial constraints, the municipality has ensured the inclusion of green spaces, environmental preservation, and resilience-building strategies in its planning. A key feature of this plan is the strategic incorporation of green spaces and open areas, which are designed to enhance the city's environmental quality, provide recreational spaces for the community, and mitigate the urban heat island effect. This integration not only promotes a healthier urban environment but also contributes to the city's overall resilience, making it more adaptable to climate challenges. The goal is to create an urban environment that respects nature while accommodating population growth and development needs.
- Service Area Redistribution: The updated plan also focuses on the equitable distribution of services across the city. By redistributing service areas, the municipality aims to promote social equity and ensure that all neighborhoods, especially underdeveloped ones, receive adequate access to essential services such as water, sanitation, and transportation.
- Incorporation of Area C Lands: The master plan also includes lands in Area C, which are subject to Israeli control. Despite the legal and territorial restrictions, the municipality has developed urban and environmental master plans for these lands to ensure comprehensive and sustainable development. The goal is to use these lands effectively for residential, commercial, and green space projects, despite the challenges posed by the occupation.

4.2 Policies for Climate Change Mitigation (SDG 13: Climate Action)

- Tree Protection Policy: Al-Bireh has implemented strict regulations to protect trees by prohibiting their removal, imposing significant fines, and requiring environmental compensation based on international standards (DBH – Diameter at Breast Height). These regulations are essential in preserving the city's green canopy and mitigating the effects of climate change.
- Rainwater Harvesting: New residential and commercial buildings are mandated to install rainwater harvesting systems. This policy aims to reduce the pressure on local water resources by collecting and utilizing rainwater, promoting water sustainability within the city.

- Renewable Energy Initiatives: The municipality has begun installing solar panels in most government schools and is exploring incentives for private homeowners and investors to adopt clean energy solutions. This initiative is being carried out in collaboration with relevant authorities. Additionally, the municipality plans to build a new school that will be a green building according to the EDGE classification, making it the first green school in Palestine. The design tender for this project will be issued soon.
- Green Spaces: Building regulations and municipality policies ensure that at least 10% of the front setback area in new developments must remain green and permeable. This initiative is designed to improve water infiltration, reduce the urban heat island effect, and promote environmental sustainability in urban areas.

This set of policies highlights Al-Bireh's commitment to adapting to climate change, enhancing resilience, and contributing to global climate action goals.

Figure 2.

4.3 Building Community Resilience

(SDG 16: Peace, Justice, and Strong Institutions)

To enhance the community's ability to adapt to challenges, the Al-Bireh Municipality has implemented several initiatives aimed at fostering resilience. These efforts focus on increasing awareness, building capacity, promoting social cohesion, and empowering vulnerable groups. The key actions taken to develop a more resilient and inclusive community include:

- Awareness Campaigns: Conducting public awareness campaigns to educate schools and the community about climate change adaptation and disaster response.
- Capacity Building: Organizing training programs for staff and community members on sustainable infrastructure, emergency management, and climate change adaptation.
- Social Cohesion: The Al-Bireh Municipality serves as the primary umbrella for charitable associations and civil society organizations in the city, working to strengthen community bonds by providing necessary logistical support and services to ensure the resilience and sustainability of these institutions. The municipality also coordinates efforts and unifies programs aimed at enhancing social cohesion and contributing to sustainable community development.
- Support for Farmers and Artisans: Allocating municipal squares and central halls weekly for farmers and artisans to display and sell their products, thereby enhancing their economic resilience and supporting local craftsmanship.
- Empowering Women: Operating a specialized center dedicated to supporting and empowering women, which currently includes approximately 200 women. The center organizes workshops and training sessions aimed at economically and socially empowering women, highlighting their pivotal role in society.
- Collaborative Approach: Establishing partnerships with local organizations and neighboring municipalities to ensure coordinated disaster response and the sharing of best practices, thereby strengthening community resilience.

Through these initiatives, the Al-Bireh Municipality aims to build a strong, cohesive community capable of effectively facing social, economic, and environmental challenges with resilience and sustainability.

4.4 Enhancing Food Security and Utilizing Unused Lands

(SDG 2: Zero Hunger, SDG 12: Responsible Consumption and Production)

Al-Bireh Municipality is committed to enhancing food security by effectively utilizing unused lands, particularly in Area C, through the establishment of community orchards. These initiatives aim to provide locally grown food and promote sustainable agricultural practices.

Community Orchards: The municipality collaborates with landowners in Area C and local institutions to develop community orchards. These efforts offer residents access to fresh, locally produced goods and strengthen community bonds.

Figure 3.

Challenges in Area C: Area C constitutes approximately 61% of the West Bank's territory and remains under full Israeli control, both administratively and militarily. Palestinians face significant obstacles in obtaining permits for construction or land development in this area, with the Israeli authorities often rejecting such applications on grounds of lacking approved master plans.

By implementing these initiatives, Al-Bireh Municipality strives to enhance food security and support sustainable agricultural practices, contributing to the well-being of the local community and reinforcing their resilience in the face of ongoing challenges.

4.5 Sustainable Mobility and Connectivity (SDG 9: Industry, Innovation, and Infrastructure)

Al-Bireh Municipality, in collaboration with the municipalities of Ramallah, Beitunia, Surda, and Abu Qash, aims to develop a sustainable transportation system that enhances mobility between these cities and reduces harmful emissions. To achieve this, a joint master plan has been prepared, encompassing short-term, medium-term, and long-term strategies developed by specialized consulting teams.

- Short-Term Transportation Plans: These include immediate solutions to improve traffic flow and reduce congestion, such as optimizing traffic signal timings and designating dedicated lanes for public transportation.
- Medium-Term Transportation Plans: These focus on developing transportation infrastructure, including expanding road networks and establishing modern public transit stations to enhance connectivity among the cities.
- Long-Term Transportation Plans: The goal here is to create a sustainable transportation system that incorporates public and smart transportation options, as well as developing pedestrian and bicycle networks to promote clean and healthy mobility.

5 DISCUSSION

Al-Bireh's resilience strategies effectively address urban growth and environmental sustainability, demonstrating alignment with several SDGs. The city's adaptive urban planning integrates green spaces, climate adaptation measures, and sustainable urban growth, which is vital given the political challenges the city faces. The municipality's climate change mitigation policies, including tree protection, renewable energy, and water conservation measures, showcase a proactive approach to reducing environmental impact.

Community resilience-building efforts, such as awareness campaigns and disaster response training, empower residents to address climate-related challenges. Local food security initiatives, such as community orchards, foster sustainable agriculture and reduce reliance on external food supplies. The city's sustainable mobility initiatives, focusing on reducing emissions and improving regional transportation connectivity, support long-term urban sustainability.

However, the political constraints imposed by the Israeli occupation, including the division of land into different zones and the expansion of Israeli settlements, present significant challenges to fully implementing these strategies. These factors limit the municipality's ability to expand green spaces, develop new infrastructure, and utilize land in Area C, highlighting the need for adaptive and flexible planning in the face of such external pressures.

6 CONCLUSION

Al-Bireh's strategies provide valuable lessons for other cities facing similar political and environmental challenges. By integrating sustainable urban planning, climate change mitigation, community resilience-building, food security initiatives, and sustainable mobility, Al-Bireh has demonstrated how cities can adapt to complex challenges while promoting long-term sustainability. Despite the constraints imposed by Israeli occupation, the city's efforts align with the SDGs, positioning Al-Bireh as a model for other cities in conflict zones seeking to enhance resilience and sustainability.

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An Interplay of Aesthetically-Urban, Aesthetically-Spiritual and Social Responsibility Aspects in Urban Regeneration

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1 ABSTRACT

The focal point of this analysis would be an attempt to evaluate the role of beauty in architecture, for example, how and to what extent it could be related to a feeling of happiness during the urban regeneration process.

One of the hypotheses concerns the importance of beauty in architecture through its significance and influence in a spiritual way. Beauty, it seems, encompasses, as an indivisible part, the notions of happiness, fulfilment, and pleasure in the widest possible sense.

Some important historical sources approach the otherwise insufficiently researched question of beauty in a spiritual way.

It started with Thomas Aquinas, back in the 13th Century. His preliminary ideas of spiritual beauty are recomposed and transposed for our modern times by the unsurpassed author Umberto Eco. They both presented an emotional and intellectual journey towards a better understanding of a model of beauty. We could say, those references should represent a role model for all of us, thoughtful architects, advanced-thinking urbanists, and city planners. Those who need primarily to think and observe to analyze, synthesize, and find a final model through harmonizing different inputs.

We are mostly exhilarated and touched by the so-called model of moral beauty (or the opposite: shaken by moral ugliness). The public could be petrified of assertive designers and architects all the way to corrupted regime(s). They could spoil one's view, happiness, etc. through their bad models: facades without proportion or even complexes without any sense, spoil the environment, but also spoil entire streets, area and therefore destroy an image, a setting of the whole city.

Moral ugliness is somehow connected not only to general poverty but also to corrupted society. Meddling with planning rules and regulations could put decent architects out of the system and unscrupulous ones push forward.

One can speculate that Investors in societies without rules (or rules and regulations are there but not being followed) have enormous greediness for profit and will do anything to achieve their goals.

Therefore, to battle moral ugliness, or to reach happiness under the frame of beauty, or moral beauty, we have to follow important steps.

Keywords: urban regeneration, moral beauty, moral ugliness, corrupt society, responsibility

2 INTRODUCTION

Urban land is one of the most important sources for countries and it is planned and controlled by the government according to the laws (Cochrane, 2006: Harvey, 2012). Furthermore, the built environment presents the "frozen history of cultural transformation" and should be treated as a valuable resource. Global environmental and political change pose huge challenges for spatial planning and urban planners deal with a lot of obstacles and face numerous problems on different levels (Hartmann, Needham,2012).

During a process of urban regeneration in not sufficiently developed democracies like Serbia, mega new developments and/or reconstructions, with not enough respect for the already built environment, cultural and architectural heritage, (let's call it the "Urban chaos"), is caused by lack of law and order, and therefore, the lack of repercussions. Mostly not civilized or better to put it: the rude behaviour of some actors of the construction industry showed their bad impact. Sometimes buildings are even collapsing without needed or sufficient building permits, for example: on the 1st of November last year a failed eaves of the rail station in Novi Sad killed 15 citizens. Terrible event. Construction and design procedures were not followed. Also, it

could be speculated that political affiliation produced a bad selection of morally suspicious and less talented individuals, selected by political groups and/or different interest groups.

2.1 Only profit-oriented urban regeneration

Wrapped in that shiny phrase "economic and urban redevelopment", only pure profit presents the most important benefit for the parties involved (Vujošević, Zeković, 2012). Since construction is one of the most lucrative branches of industry, gaining maximum profit by, for example, multiplying the same residential buildings, seems to be the constructor's only goal.

With a lack of transparency, difficult-to-track projects, etc. we suddenly wake up with a project being built up with a lack of public spaces, not enough greenery or sports and cultural facilities. In short, a massive loss to the public (Zekovic, Vujošević, 2006). There is an absence of a so-called "pyramid of responsibility".

Basic workers are not overwatched by middle managers, neither the supervisors nor the highest supervisors. Without diaries or written reports, anything could go wrong. One could speculate that the biggest weight on the scale belongs to the concentration of corruption in public offices, especially institutions dealing with urbanization. The greater amount of money is circulating, those issues will be more difficult to resolve.

So, hypothetically, if we were dealing with money laundering of so-called "grey money" or even from criminal resources (drugs, trafficking, or else), there would be hardly possible effective investigation that could lead to real success. Often, one can suspect, we could spot that some politicians and controversial businessmen proceed forward together with no regard for anyone or anything to gain more money and benefits.

We can note that corruption moved decades ago from an economically neglected Africa, all the way to Europe. This could be one of the important reasons why there is so much inequality and disharmony in the present age.

Corruption goes global. It may not be openly visible as it is in the Balkans, but the statistical facts show: That northern countries like Denmark, Finland, and Norway, rank among the least corrupt globally. Established democracy included honesty and obeying principles of order and law. Those principles have a long tradition in those countries (https://www.transparency.org/en/cpi/2024)

Eastern Europe, on the contrary, for example, Ukraine and Moldova, or the Balkans tend to score much lower, indicating higher levels of perceived corruption. It is due to several reasons, but mostly because of the fast transformation of the political system from communism to capitalism & mercantilism, but also, consequently to a huge gap between ordinary working-class citizens, small and medium enterprises owned by families, and "new money" controversial businessmen.

In the context of corruption, Serbia has faced a significant rise in recent years. Democratic changes took place in Serbia in the 2000s. But the path onwards was very rough: political battles were influenced by the direct intervention of criminal gangs and post-war paramilitary groups. As a result, the first democratically elected Prime Minister was killed by criminal gangs of, some would say, political opponents in 2003. The autocratic regime, which has been in power now for more than 12 years, split people between Urban, urban rural, and rural inhabitants through aggressive populist media. During the expulsion and migrations of the 90's of Serbs from Croatia and Bosnia to Serbia, the inhabitants' structure changed, and a feeling of stronger nationalism took place. The most brutal civil war in Europe from the Second World War took place in ex-Yugoslavia and made an ugly impact that is still in the air.

European "Transparency International", a non-governmental organization, was founded in 1993 with the purpose of monitoring, advocating and if possible, battling general corruption.

According to them, in the Perceptions Index (CPI) 2024, Serbia scored 38 out of 100, where 0 indicates high levels of perceived corruption and 100 indicates very low levels of corruption and it is placed 105 among 180 countries (https://www.transparency.org/en/cpi/2024). So, Serbia seems to be in the low to medium range of the index, reflecting ongoing concerns about corruption in public & urbanistic institutions, judiciary, health institutions, etc.

Key issues in Serbia related to corruption include:

(1) Public Sector Corruption: There are persistent reports of corruption within government agencies, state-owned enterprises, and law enforcement.

(2) Judicial Corruption: The judicial system is often criticized for inefficiency and lack of independence, which can contribute to corruption.

(3) Political Influence: Concerns about the influence of politics in business and public procurement processes are prevalent. Building and architecture design are strongly influenced by political affinity. Only selected architects and design studios close to the regime could obtain bigger lucrative jobs.

According to Transparency International's Corruption Perceptions Index (CPI) for 2024, many Western European countries tend to score higher (Denmark, Finland), indicating lower levels of perceived corruption. On the other hand, some Eastern European nations struggle more with corruption issues (OECD, 2024).

Initiatives include expert assessments and opinion surveys. This helps in the creation of awareness and advocacy for accountability. Transparency International (TI) encourages the signing and ratification of international and regional anticorruption conventions such as UNCAC (United Nations Convention against Corruption) and the OECD Anti-Bribery Convention. TI advises on how to assess and strengthen national integrity systems, including governance, accountability, and participation in the process of reducing opportunities for corruption. The agency calls for integrity pacts that forbid corrupt practices in public contracts. TI, as well, pushes for the establishment of solid whistleblower protection to encourage people to come forward without fear of retaliation. TI imparts training and resources to top governments, businesses, and civil society organizations around the world so that they develop their knowledge and build effective policies against corruption. But unfortunately, TI stays under the theoretical frame. There is also a document for combatting high-level corruption in Eastern Europe. (OECD, 2024).

3 FROM DISORDER TO MORAL UGLINESS

Back in 13th century Italy, Thomas Aquinas[1] recognized all those signals that could quite possibly be in different doses rooted in our human nature. He observed in his environment of the Middle Ages all sorts of disrespect, greed, unruliness, individual caprices, and tyranny. But, Thomas Aquinas, under all these obstacles noted, proceeds to try to observe the plain inputs as „beauty of proportion and wholeness"- the prime condition for harmony. "Splendor" was trying to reach through colours and proportion. Despite all those difficult circumstances, he tried to abandon ugliness (both moral and physical) by choosing the path of beauty, in particular, moral beauty.

For those of us, architects, with a focus on cities, his pure idea of the "arrangement of things that leads to an exact goal", could be one of the key elements to reaching true compatibility and balance. According to the initial idea, everything added by force and with no particular need and purpose is considered as excess. ("Less is more", which Loos proclaimed five centuries later).

To identify spiritual beauty, or we can say beauty in the soul of an entity, Thomas Aquinas considered the general lack of order and balance as the first element towards chaos. He was a seeker of purity.

Under the wider picture, today, life under chaos and crumbling institutions, put us from civilization down, by breaking the ancient laws from the times of the Bible. We are witnessing more and more people taking a quicker path toward success while stomping over others and that being acknowledged as a goal worthy of respect in the 21st Century. Lots of negative attributes have been raised: disorder, lack of justice, disharmony, etc.

That is why nowadays, when, and if rules are not obeyed, we do have very important doubts about the style of progress of urban regeneration, in particular concerning cultural heritage.

4 LEVELS OF MORAL BEAUTY (OR UGLINESS) AND HOW WE COULD DEFINE THEM THROUGH GRADES UNDER THE SCOPE OF URBAN REGENERATION:

To show practical case studies, we selected three case studies with different capital investment sizes in Belgrade, Serbia, upon which we will try to implement the first level of the most basic analysis of quality.

[1] Thomas Aquinas, 13th century philosopher and a Dominican monk (Castle near Aquino, 1225 – Fossanova 1274.), the greatest systematician of his age who adapted Aristotle's thinking for the needs of the Catholic church dogma. His life coincides with the awakening of the philosophic consciousness in Paris, Padua, and Bologna, where he lived. Quodvisum placet – the beauty is what we like – leads us with no doubt towards more subjective elements in questions of aesthetics.

Not to involve real names we will call them A, B, and C cases. There could be a hypothesis or a subjective view which is not easy to prove, that the mutual characteristic of all of them is that smaller or bigger corruption in the process has affected all three types of new projects.

So, when Umberto Eco says moral ugliness, transposed words of Tomas Aquinas from the 13th Century, we can conclude that greediness remains a human weakness from our biological beginnings. That is why both historical personalities introduce the word "moral" ugliness.

(1) MEGA project/state mega project with foreign partners

(2) MIDDLE project "Golden cage" system,big block project by foreign and local investors

(3) LOCAL project, suburb streets with small villas and gardens became a concentration of 7 floors infill buildings: as small and medium projects, by local investors

4.1 Mega State project with a foreign investor

Parameters to define grades of quality,unfortunately, depend among other factors, on personal subjectivity. This raises awareness and inserts a sort of relativism in these tables, but, for a primary categorisation it could be a decent start for the analysis:

1	Value of location in between focal points of the city and transport facilities	9
2	Maximum sustainability, sources: inputs of sun, wind, freshwater, and clear air	7
3	High architectural value as a whole (subjective) and affordability	3
4	High-quality residential buildings (apartments and buildings)	4
5	Affordability	2
6	Comfort: Enough greenery, public places, sports, and cultural facilities	5
7	Urban safety	10
8	Education, Culture, and entertainment nearby	5
9	Retail & shopping areas nearby	10
10	Local characteristics, integrity with context	1
		56

Table 1: 100 Points are matter maximum = (moral) beauty.

This project could tempt several observations, possibly conclusions: the project is designed as a top state project, but without transparency. Foreign architects without the implementation of local experts or public design. Therefore, the whole project started with a negative prefix. The location is the best possible, near the river Sava. The previous railway station and industrial zone were abandoned for several decades. It would not be possible without big changes in urbanistic plans, and annexes of plans. Today it is known as a most extravagant and expensive area, where only very rich people can buy apartments for EUR 10,000.- per square meter. Therefore, only a selected few can get into purchasing those, while the public can not afford it even in their dreams. So, there is no mix of different layers of population. Ghetto, although the luxury one, is already established.

Schools and sports facilities exist only in the plans. Greenery is beginning to develop; public places are refined and luxurious.

The mega luxurious shopping mall is the soul of the area, so consumerism is an important part/goal of this project. There is no, however, any link with local architecture, past or present, so the identity of the whole city is getting diminished.

It could be stated that this project represents a kind of foreign model from the Middle East, erased without any link with the continuity of local architecture and characteristics.

4.2 "Golden cage" system, big block project by foreign and local investors.

1	Value of location in between focal points of the city and transport facilities	7
2	Maximum sustainability, sources: sun, wind, fresh water, and clear air	6
3	High architectural value as a whole (subjective) and affordability	7

4	High building quality of residential (apartments and buildings)	7
5	Affordability	4
6	Comfort: Enough greenery, public places, sports and cultural facilities	5
7	Urban safety	10
8	Education, Culture, and entertainment nearby	5
9	Retail & shopping areas nearby	6
10	Local characteristic, integrity with context	3
		60

Table 2.

"Golden cage" (Gated compound) is an already known system and comes originally from Latin America. Due to a huge wealth gap between citizens, the rich are hiding "intra mures", in a "closed cage" to protect themselves from the poor. Latin American system gradually moved to new Russia and Eastern European countries, with a lot of "new money "circulating, creating a new, wealthy class. Inhabitants are only allowed to enter their compound, where there usually is a nice kids' playground in the centre, and the most needed under-terrain garage is placed under the whole location.

Some side locations are used as well for construction, but it could be stated that they are too close to the traffic system. Therefore, issues of safety, security, noise pollution, etc. could be raised. (Djukic, Brajkovic, 2025). Using the perceived benefits of a broader location compensates for the absence of schools and kindergartens, culture, or sports facilities.

Architecture is vernacular and contemporary, like in every other city in the world, without any trace of integration with local architecture. Sustainable architecture is not planned, and greenery is also shared with the neighbourhood blocks. It could be argued that the quality of apartments is average, meaning too expensive, not providing value for money.

Of course, all these notions above can be put into debate, and different opinions and arguments could be put on the table, therefore creating more transparency about these projects, so the public can be better informed about them before they start.

For some reason, this is not the case. Why? Well, we can only speculate!

4.3 Suburb Streets, small and medium projects, by local investors

1	Value of location in between focal points of the city and transport facilities	8
2	Maximum sustainability, sources: sun, wind, fresh water, and clear air	6
3	High architectural value as a whole (subjective) &affordability	5
4	High quality of residential (apartments and buildings)	3
5	Value of comfort as a neighbourhood, public places	4
6	Enough greenery and sports facilities	4
7	Urban safety	3
8	Education, Culture, and entertainment nearby	4
9	Retail & shopping areas nearby	8
10	Local characteristics, integrity	4
		49

Table 3.

One of the hypothetical case studies of hundreds of new infills is in the longest street in Belgrade called "Vojvode Stepe" street (7 km) in the area named Vozdovac. From the beginning, the street was a vernacular suburbia street without cultural legacy and value. The system was formed by small, modest individual houses with tiny gardens. Without high-quality buildings, in the 1960s, several, one can say, brutal, high-rise complexes were erected. In the late 1990s, it could be speculated that, allegedly, corruption showed up in local municipalities and both urbanistic institutions enabling small and medium companies to build, without regard to building rules and regulations. Excessively high buildings were allowed to be raised by local planning authorities (at least six, or seven floored rises).Investors themselves, hard to believe, designed some

of the buildings, without professionals being involved, namely, architects. Surprisingly, firstly built dwellings being constructed like that, influenced what followed: balconies were constructed small, with fences full of concrete to stay cheap, and the colours used were not pleasant; green and kaki, etc.

Over time, the high street changed its profile entirely. Density became high, traffic became unsustainable. Amazingly, the population gradually got used to it. One can speculate that thanks to corruption around building works, this street became ugly and chaotic (without proportion, harmony, or beauty in general) reminding some people of the eastern way, for example in some parts of Turkey or North Greece, where poor architecture could be noted in small cities and suburbs of big cities.

5 CONCLUSION

The Transformative processes dealing with land use should be more sensible and responsible. Urban transformations as fundamental, multi-dimensional changes in urban land-use patterns, should be followed by establishing sustainable and democratic values, norms, procedures, and behaviours (Banzhaf et al., 2017).

One perhaps cannot be wrong by noting that not obeying rules leads to anarchy. If we look backward in history; Japanese people are real experts in rigidness and responsibility. Therefore, under that scope corruption seems unnecessary. On the contrary, in countries where corruption is high, people die working in or under unsafe constructions, like in Turkey while an earthquake took place or in Serbia, because of lousy business dealings, low level of general morality, etc. Not very different from Tomas Aquinas's "Moral ugliness" from the Middle Ages.

Each of these case studies hypothetically shares one common trend: corruption, for example, to obtain regular building permits, or fake permits, by paying different interest groups involved, being people working on building sites, or in planning commissions and public institutions, to change or amend planning rules. Ultimately, with so much cash, allegedly, certain lawyers are paid handsome fees to fight on the side of these unscrupulous investors, with the final goal always to obtain even bigger profits.

By analyzing those three (mega, medium, and small size) examples above, perhaps one can conclude that case number 3 (small case investments starting circa from the year 1990), has the biggest bad influence on the general beauty of architecture. Projects built with, in comparison, much bigger investments look generally better, at least we can say civilized, although without any value as first-grade author's architecture. Smaller investments use context and neighbourhood for sports, greenery, or education facilities nearby. That is their advantage. Nevertheless, in those cases, general urban safety is not at a high level. So, every case looks at the end of the day with approximately similar grades. Unfortunately, the level of unclean regulations to achieve more and more, (greediness) could be spotted everywhere.

The catastrophic loss of 15 lives at Novi Sad Railway station on the 1st of November 2024 was a trigger for citizens in Belgrade and Serbia to raise against deeply embedded corruption, to try to change the system, and to make a positive difference. To obtain wider democracy. The narrative about urban regeneration in Serbia without mentioning these, biggest student protests since the year 1968,wouldn't be possible. The whole picture would not make any sense. There is hope for a better future. Future with far less corruption. In arranged country.

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https://www.transparency.org/en/cpi/2024

reviewed paper

Analysing Population Displacement and Financial Precarity Induced by Gentrification based on Social Mix Perspective

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1 ABSTRACT

This study investigates the spatial dynamics of gentrification and upward filtering in Taipei City, a metropolis characterized by Taiwan's highest population density and acute housing affordability challenges. Examining the interplay between financial precarity and population displacement, this research analyzes distinct patterns of neighborhood change within this dense urban context. Comparative analysis reveals that areas experiencing upward filtering, marked by increased real estate transaction volumes, exhibit a stronger correlation between market activity and rent prices, highlighting the direct impact of real estate dynamics on affordability. Conversely, the observed decline in high-income and highly educated residents in other areas suggests potential displacement pressures. Despite these shifts, the absence of strong spatial autocorrelation between real estate transactions and rent prices indicates the significant influence of localized factors, such as zoning policies, on rent price dynamics. Bivariate spatial autocorrelation analysis further underscores the interconnectedness of demographic changes, particularly the clustering of high-income and highly educated populations in upward-filtering areas. These findings contribute to a nuanced understanding of gentrification and upward filtering within Taipei's unique urban landscape, providing insights for policies aimed at mitigating financial precarity and fostering equitable urban development.

Keywords: Gentrification, Financial Precarity, Population Displacement, Bivariate Spatial Autocorrelation, Planning

2 INTRODUCTION

Gentrification, originally conceptualized in 1964 by British sociologist Ruth Glass, describes the process of social mobility within urban centers. Glass observed that in London, the middle class progressively encroached upon working-class neighborhoods. As rental contracts expired, deteriorated housing units were reclaimed, renovated, or even reconstructed, facilitating the redevelopment of declining urban areas. This transformation, however, led to the displacement of the proletariat, triggering significant socio-economic consequences (Glass, 1964). Gentrification is no longer confined to inner-city areas but has expanded to peripheral urban zones (Williams, 1984) and even economically abandoned spaces that were previously developed but have since been left vacant (Schaffer & Smith, 19 86). Urban shrinkage has been identified as a driver that creates new potential for gentrification (Oswalt, 2006). As a dynamic urban process, gentrification reshapes the socio-economic composition of neighborhoods, leading to class replacement and the emergence of new industries (Hamnett, 2003; Kennedy & Leonard, 2001). In the early 2000s, policy-oriented research began framing gentrification as a positive urban development strategy – one that could foster the revitalization of disadvantaged areas and promote social integration. Through infrastructure improvements, better housing conditions, and job creation, gentrification has been seen as a means to drive the redevelopment of marginalized urban areas and enhance social cohesion (Arthurson, 2010; Lees, 2008).

However, numerous studies have found that gentrification often leads to the displacement of economically vulnerable households and contributes to psychosocial stress and educational resource disparities in gentrified areas (Martin & Beck, 2018; Davidson, 2010; Wyly et al., 2010). While gentrification, as an urban renewal strategy, can promote community integration and reduce social exclusion in certain contexts, it also presents significant negative consequences in practice. For instance, the East End Regeneration Program in London aimed to revitalize impoverished communities in East London by improving infrastructure and attracting new industries to stimulate local economic development. In the short term, the program successfully enhanced housing quality and public amenities, attracting young professionals to the area (Butler & Robson, 2003). However, it simultaneously exacerbated housing affordability issues for long-term residents, forcing some low-income families to relocate (Atkinson, 2004).

The factors driving displacement can be broadly categorized into material and conceptual aspects. Material factors include direct influences such as housing prices and living conditions, while conceptual factors are primarily based on residents' perceptions and lived experiences (Phillips et al., 2021). Displacement itself can be classified into three types: direct or physical, indirect or economic, and exclusionary factors. Forced displacement refers to situations where legal policies or external forces compel residents to relocate, while "responses and impacts" describe the broader consequences of environmental change. Among these factors, indirect or economic displacement is closely linked to gentrification. For example, transportation infrastructure projects and public investments often lead to rising property values and rental costs, making housing unaffordable for existing residents and triggering migration (Zuk et al., 2017).

Original residents and tenants may be forced to relocate due to economic pressures, environmental changes, or personal development factors. This migration pattern is often characterized by "downward filtering", where displaced populations move to areas with lower living costs and standards. Conversely, "upward filtering" refers to higher-income individuals moving into city centers or well-developed neighborhoods, driving up housing prices and gradually replacing lower-income residents with an upper-middle-class demographic (Covington & Taylor, 1989).

On the other hand, the relationship between gentrification and financial precarity has increasingly become a crucial topic in urban studies (Smith, 1987; Lees et al., 2008; Zuk et al., 2018). Financial precarity is generally understood as a multidimensional phenomenon, encompassing financial stress and vulnerabilities at the individual, household, and community levels (Standing, 2012; Kalleberg, 2018). During the gentrification process, the influx of high-income groups reshapes the local economic structure, leading to rising housing costs and increasing overall living expenses, which further intensifies financial pressures on original residents (Smith, 1996; Zuk et al., 2017). This economic pressure often manifests in rising housing prices and rents, increasing costs for basic services, and overall higher daily living expenses. Previous studies indicate that financial precarity typically reduces individuals' and households' financial resources, limiting their ability to cope with economic fluctuations or unexpected crises (Desmond, 2016; Morduch & Schneider, 2017). In gentrified neighborhoods, low-income families frequently experience financial stress, including declining savings capacity, rising debt burdens, and even forced displacement from their communities (Newman & Wyly, 2006; Holme, 2002). Economic precarity in gentrification also extends to changes in the local labor market. The influx of high-income residents often drives a transformation of the regional economic structure, fostering the growth of high-end service industries while simultaneously displacing traditional service sectors and local workers, leading to labor market polarization (Hamnett, 2003). In the short term, this transition may contribute to economic growth, but for original residents, it often results in a mismatch between skill demand and income structures, exacerbating their economic vulnerability (Braveman et al., 2011).

Moreover, financial precarity induced by gentrification is often intertwined with issues of spatial inequality. While urban development policies aim to promote urban renewal, they often lead to unequal resource distribution, further widening social and economic disparities within urban spaces (Adger, 2000; Smith, 1996). For instance, the upgrading of public infrastructure and the influx of high-value commercial investments attract additional capital to gentrified areas, pushing housing costs even higher. At the same time, public service resources may be reallocated to cater to high-income groups, potentially reducing access to essential services for lower-income residents (Morduch & Schneider, 2017). This phenomenon not only weakens marginalized groups' ability to access public resources but may also reinforce financial precarity within gentrified neighborhoods (Holme, 2002). In the gentrification process, balancing economic development and social equity while mitigating the impact of financial precarity on vulnerable populations remains a key challenge for urban development policies (Standing, 2012; Newman & Wyly, 2006).

This study aims to investigate the spatial distribution characteristics and correlation between financial precarity factors and population displacement factors in the context of gentrification by examining the spatial composition characteristics of gentrification.

3 RESEARCH DESIGN

3.1 Materials

3.1.1 Study area

This study focuses on the metropolitan area of Taipei City (Fig. 1) as the research site, excluding areas such as mountains, rivers, parks (e.g., Daan Forest Park, Youth Park), and Songshan Airport. Taipei City, characterized by Taiwan's highest population density and high housing prices, is a suitable location for investigating gentrification.

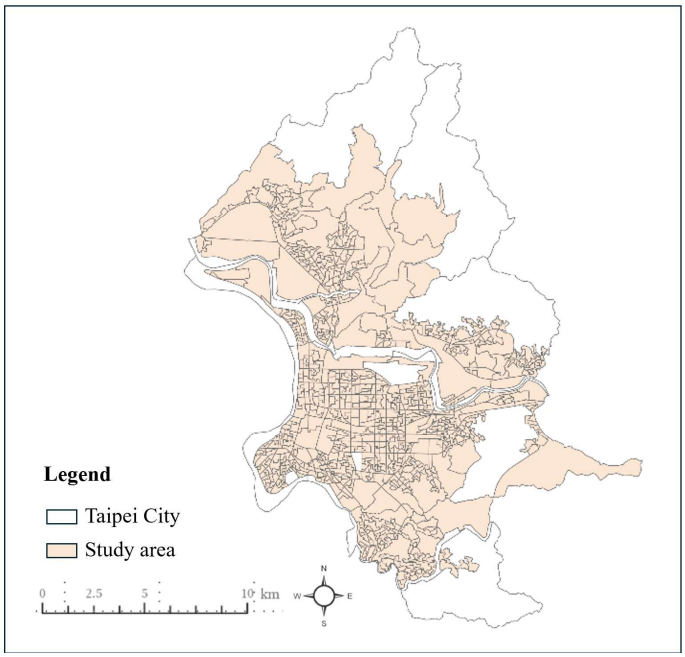

Fig. 1: Study area

3.1.2 Indicators of gentrification and financial precarity

To ensure temporal and spatial consistency in identifying gentrified displacement areas, it is important to have precise indicator years. Therefore, this study sets the data collection period from 2013 to 2019, and all data sources and years are shown in Table 1.

Subject	Indicator		Data Source (Year)
Demographic mobility	M1	Total number of immigrants	Social Economic Data Service Platform (2023)
	M2	Total number of emigrants	
	M3	Change rate of high-income population	Ministry of Finance, Executive Yuan (2022)
	M4	Change rate of low-income population	
	M5	Change rate of highly educated population	Social Economic Data Service Platform (2023)
Demographic Structure	P1	Percentage of high-income population	Ministry of Finance, Executive Yuan (2022)
	P2	Percentage of low-income population	
	P3	Percentage of highly educated population	Social Economic Data Service Platform (2023)
	P4	Percentage of young and middle-aged population	Social Economic Data Service Platform (2023)
	P5	Percentage of disabled population	Social Economic Data Service Platform (2023)
Real Estate characteristic	R1	Real estate transaction volume	Real Estate Transaction Cases – Actual Information Data Supply System, Ministry of the Interior, Executive Yuan (2023)
	R2	Housing rent price	
	R3	Change rate of housing purchases	
	R4	Change rate of housing rent	

Table 1: Indicators of gentrification

This study focuses on the phenomenon of gentrification and, specifically, examines variables related to "financial precarity" within this context. From the broader set of gentrification indicators, a selection of key variables has been identified and isolated for further analysis due to their direct relevance to financial

precarity. These selected indicators, along with their explanations and supporting academic literature, are detailed below (Table 2). This focused approach allows for a deeper investigation into the complex relationship between gentrification and the precarious economic conditions that can arise within changing neighborhoods.

Indicator	Explanation	References
M3 Change Rate of High-Income Population	Influx of high-income residents can inflate housing costs, displacing existing residents and creating financial strain. Outflow can signal declining opportunities.	Florida, R. (2002); Moretti, E. (2012)
M5 Change Rate of Highly Educated Population	Shifts in the educated population can intensify job competition, creating or worsening financial precarity for less-educated residents.	Lucas, R. E. (1988); Goldin, C. D., & Katz, L. F. (2018); Autor, D. H. (2014)
R1 Real Estate Transaction Volume	High transaction volume can signal speculation and rapid neighborhood change, leading to displacement and increased financial precarity.	Case, K. E., & Shiller, R. J. (1989); Glaeser, E. L., & Nathanson, N. (2017)
R2 Housing Rent Price	Rapid rent increases directly strain budgets and can lead to displacement, a key mechanism of gentrification-driven financial precarity.	Glaeser, E. L., & Gyourko, J. (2008); Mayer, C., & Somerville, C. T. (2000); Desmond, M. (2016)

3.2 Methods

3.2.1 Principal components analysis

Principal Component Analysis (PCA), a widely employed multivariate statistical technique, serves as a dimensionality reduction method. Initially proposed by Pearson (1901) and further developed by Hotelling (1933), PCA is primarily utilized to determine the weights of individual variables in order to construct composite indicators. The primary objective of PCA is to identify a set of linear combinations that retain the information inherent in the original variables (representativeness), ensure that the composite indicators (principal components) are uncorrelated (independence), and achieve a parsimonious representation of the original variables by a reduced number of composite indicators (parsimony).

$$\begin{cases} U_1 = l_{11}x_1 + l_{12}x_2 + \cdots + l_{1p}x_p \\ U_2 = l_{21}x_1 + l_{22}x_2 + \cdots + l_{2p}x_p \\ \cdots \\ U_m = l_{m1}x_1 + l_{m2}x_2 + \cdots + l_{mp}x_p \end{cases}$$

where m refers to the spatial units, p refers to the number of attributes, x_p refers to the original attributes, l_{mp} is the factor loading, and U_m refers to the principal components. U_1, U_2, …, U_m (with $m \leq p$) are linear combinations of x_p.

Gentrification is composed of a variety of indicators, and the appropriate indicator forms vary depending on the country, city, historical culture, and other factors. Therefore, it is crucial to determine how to calculate and combine these indicators to reflect the texture of gentrification in Taipei. In this study, the standardized indicator values of each indicator will be integrated and weighted using Principal Component Analysis (PCA) to construct "Principal Component Groups" (hereinafter referred to as composite indicators) under various measurement standards. This approach allows for the analysis of gentrification patterns under different composite indicators. Finally, the composite indicator scores will be calculated and mapped, followed by spatial analysis to identify the secondary release areas with migratory characteristics of gentrification in Taipei City.

3.2.2 Pearson's Correlation Coefficient

Pearson's Correlation Coefficient, developed by Karl Pearson, is a statistical measure that quantifies the degree of linear association between two continuous variables. It is widely used in various fields to explore the relationships between variables.

$$r(x,y) = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

The coefficient, denoted as r, ranges from -1 to +1. +1 indicates a perfect positive correlation, meaning that the two variables increase or decrease together in a perfectly linear fashion. 0 indicates no linear correlation, suggesting that the variables do not have a linear relationship.

In this study, Pearson's Correlation Coefficient will be employed to investigate the linear relationships between variables related to gentrification and financial precarity.

3.2.3 Local indicators of spatial association (LISA) and Bivariate Spatial Autocorrelation

The local index of spatial correlation can be used to identify the different spatial correlation and aggregation patterns that may exist in different spatial locations, and then find out the spatial heterogeneity between data (Anselin 2010). Also known as Local Moran's I Index. It mainly uses the spatial pattern comparison with neighboring areas to find out areas with similar or different patterns to define cluster areas and expresses them with local correlation distribution maps. Statistics calculation method:

$$I_i = \frac{n(x_i - \bar{x})\sum_j W_{ij}(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2} = \frac{nz_i \sum_j W_{ij} z_j}{z^T z} = z_i^T \sum_j W_{ij} z_j^T$$

Among them z_i^T and z_j^T Tare the average standardized observation values of the observation values. W_{ij} is the spatial adjacent weight matrix of space unit *i* and *j* area *(j=1,2,3,...,n)* within the research scope, Wij=1 means *i* and *j* are adjacent, and W_{ij}=0 means *i* and *j* are not adjacent.

In the local spatial autocorrelation analysis, when the observation value of itself and the neighboring area are both high (higher than the average), it can be represented by High-High (HH); when the observation value of itself and the neighboring area are both low, it can be Low -Low (LL) means; in addition when the own observation value is high, the surrounding low is expressed as High-Low, and when the own observation value is low, the surrounding high is expressed as Low-High.

Based on spatial correlation analysis, Anselin et al. (2010) developed a bivariate local indicator of spatial association (LISA) to measure local spatial correlation and identify the type of spatial correlation between the two variables. This method is a local bivariate Moran's I statistic and is defined as:

$$I_{kl}^i = Z_k^i \sum_{j=1}^n W_{ij} Z_j^i$$

where W_{ij} represents the spatially weighted matrix,

$Z_j^i = [x_k^i - \overline{x_k}]/\sigma_k$, $Z_l^i = [x_l^j - \overline{x_l}]/\sigma_l$,

where x_k^i is variable *k* at location *i*, x_k^i is observation *l* at location *j*, and σ_k and σ_l are the variance of x_k and x_l, respectively.

Component	1	2	3	4	5
M1	0.830*	0.129	0.346	-0.017	-0.098
M2	0.852*	0.116	0.243	-0.021	-0.073
M3	0.219	-0.105	0.491*	-0.250	-0.019
M4	-0.145	0.265	0.029	0.464*	-0.360
M5	0.047	-0.325	0.743*	0.046	0.058
P1	0.778*	0.375	-0.254	0.069	0.077
P2	0.772*	-0.249	-0.227	-0.041	0.115
P3	0.103	0.860*	-0.163	0.123	-0.040
P4	-0.044	-0.569	0.417*	0.035	-0.104
P5	-0.236	-0.723	-0.148	-0.097	0.111
R1	-0.082	0.182	0.779*	0.104	0.035
R2	-0.089	0.731*	-0.015	-0.151	0.156
R3	-0.035	0.120	0.056	0.056	0.905*
R4	0.073	-0.115	-0.006	0.857*	0.120
Sum of Squared Loadings	2.776	2.601	1.922	1.084	1.051
Explained Variance (%)	19.827*	18.575*	13.732*	7.744	7.505
Explained Variance (%)	19.827	38.402	52.134	59.878	67.383
KMO	0.576				
Bartlett's Test	Degrees of Freedom: 91, Significance: 0.000				

Table 3: Rotated Component Matrix of Gentrification

4 RESULTS

4.1 Principal Component Analysis of Gentrification Composite Indicators

This study used Principal Component Analysis (PCA) on 14 collected gentrification indicators. The results are shown in Table 15, which yielded five principal components, explaining 19.827%, 18.575%, 13.732%, 7.744%, and 7.505% of the variance, respectively (Table 3). This study used principal components with variance greater than 10% as the basis for classifying gentrification indicators. Table 16 summarizes the framework of the composite indicators. Based on the indicator properties of each group, the composite indicators are defined as "Undergoing Gentrification," "Gentrified," and "Upward-filtering Effect." The subsequent spatial analysis results will explain the common results of gentrified areas in the three composite indicators (Table 4).

Composite Indicator	Undergoing Gentrification (Component 1)	Gentrified (Component 2)	Upward-filtering Effect (Component 3)
Indicators	M1 – Total number of immigrants M2 – Total number of emigrants P1 – Percentage of high-income population P2 – Percentage of low-income population	P3 – Percentage of highly educated population R2 – Housing rent price	M3 – Change rate of high-income population M5 – Change rate of highly educated population P4 – Percentage of young and middle-aged population R1 – Real estate transaction volume
Weights	2.776	2.601	1.922

Table 4: Gentrification Composite Indicators

The indicator values of each spatial unit were multiplied by the component loadings of that indicator to perform weighting, and the 'composite indicator score' of that spatial unit in the composite indicator was obtained. Fig. 2 below shows the mapping results of the composite indicators after weighting:

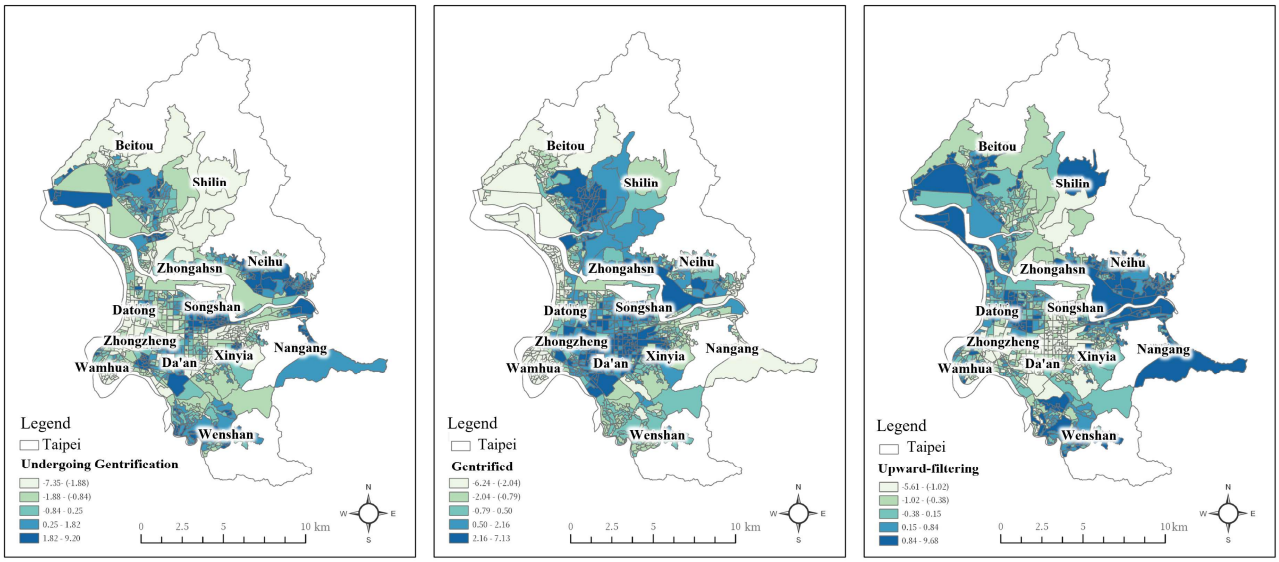

Fig. 2: Mapping of Composite Indicators – Gentrification Patterns

4.2 Spatial correlation of gentrification indicators

To verify whether the gentrification composite indicators have a global spatial autocorrelation aggregation phenomenon, Moran's I was used as the verification method, and the results are shown in Table 17 below. Among them, the P-value is 0 and the Z-scores are all greater than 1.96, which means that all three composite indicators are 'significantly clustered' in the verification results (Table 5):

	Undergoing Gentrification (Component 1)	Gentrified (Component 2)	Upward-filtering Effect (Component 3)
Moran's Index:	0.271455	0.630205	0.394249
Expected Index:	-0.001129	-0.001129	-0.001129
Variance:	0.000047	0.000047	0.000047
z-score:	39.663892*	91.791183*	57.697443*
p-value:	0.000000*	0.000000*	0.000000*

Table 5: Global Spatial Autocorrelation Results of Gentrification Composite Indicators

To use the regional spatial autocorrelation method to find the location of internal spatial clustering of each composite indicator. The results of the "Gentrification Pattern – Regional Spatial Correlation Index" calculated by LISA are as follows (Fig. 3). As can be seen from Figure 32, the High-High values of 'Undergoing Gentrification' are mainly located in the south of Beitou District, the intersection of Songshan District, Da'an District and Zhongzheng District, Neihu District, and Wenshan District; the High-High values of "Gentrified" are mainly located in large areas of Zhongzheng, Songshan, and Da'an Districts, and Shilin District; the High-High values of "Upward-filtering Effect" are located in Beitou District, along the Datong District to Shezidao line, and Neihu District.

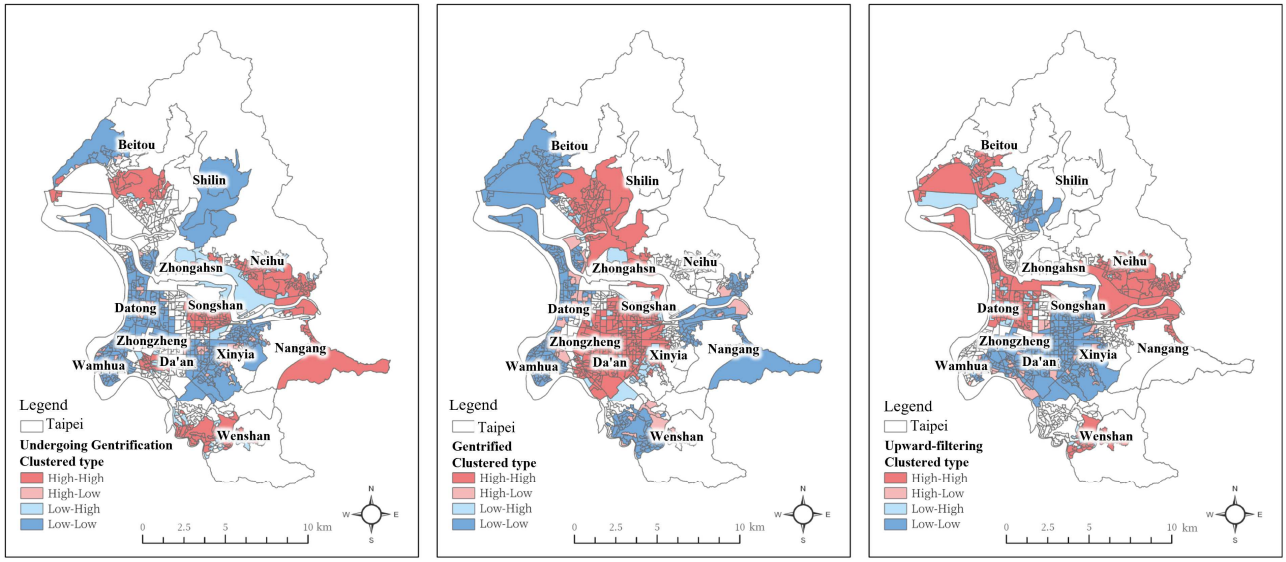

Fig. 3: Spatial Clustering Distribution of Each Gentrification Pattern

4.3 Comparative Analysis of Financial precarity in Gentrified and Upward-filtering Neighborhoods

Given that the principal components of the Upward-filtering areas did not include R2 housing rent prices, and as the figures illustrate a clear divergence in the spatial clustering distribution of the high-value areas between gentrified (Principal Component 2) and Upward-filtering effects (Principal Component 3), a subsequent analysis was conducted to examine the characteristics of financial precarity within these distinct high-value (HH) areas.

This study investigates the nuanced dynamics of financial precarity within urban areas undergoing socio-economic transformation. Specifically, we compare and contrast two distinct neighborhood types: those experiencing gentrification and those exhibiting a Upward-filtering effect. Gentrification, characterized by the influx of higher-income residents and subsequent displacement of existing populations, often leads to significant changes in the social and economic fabric of a neighborhood. The Upward-filtering effect, while also involving an influx of more affluent individuals, may not necessarily result in direct displacement but rather a gradual shift in the area's character and affordability.

The analysis focuses on key indicators of financial precarity, examining how these manifest differently in gentrified versus filtering-up neighborhoods.

4.3.1 Analysis of financial precarity variables in Gentrified HH Areas and Upward-filtering HH Areas

A comparative overview of these indicators in gentrified and Upward-filtering high-value (HH) areas reveals notable differences (Table 6).

(A) Change Rate of High-Income Population(M3):

The mean value of M3 is negative in both gentrified and Upward-filtering areas, suggesting a general trend of high-income population decrease. However, the magnitude of decrease is smaller in Upward-filtering areas (-1.29) compared to gentrified areas (-2.61). This may indicate that while both area types experience some level of high-income population loss, Upward-filtering areas are relatively more stable in attracting and retaining affluent residents. The higher standard deviation in Upward-filtering areas (1.18 vs. 1.06) suggests a greater variability in the change rate of high-income population, potentially reflecting a more dynamic economic environment.

Indicator	Gentrified HH Areas	Upward-filtering HH Areas	Remaining Areas
Mean M3	-2.61	-1.29	-2.5335
Standard Deviation M3	1.06	1.18	1.13820
Mean M5	0.79	1.7	1.1284
Standard Deviation M5	0.55	0.79	0.72114
Mean R1	124.28	184.62	113.2759
Standard Deviation R1	69.58	182.73	82.36377
Mean R2	47500.24	30218.63	28997.7741
Standard Deviation R2	12942.61	10259.75	10557.86973

Table 6: Observations of Financial Precarity Variables in Gentrified HH Areas and Upward-filtering HH Areas

(B) Change Rate of Highly Educated Population (M5):

The mean value of M5 is positive in both gentrified and Upward-filtering areas, indicating an overall increase in the highly educated population. Notably, the mean value is substantially higher in Upward-filtering areas (1.70) compared to gentrified areas (0.79). This suggests that Upward-filtering areas experience a more pronounced influx of highly educated individuals. The standard deviation is also higher in Upward-filtering areas (0.79 vs. 0.55), implying a greater range of variation in the change rate of the highly educated population.

(C) Real Estate Transaction Volume(R1):

The mean real estate transaction volume (R1) is significantly higher in Upward-filtering areas (184.62) than in gentrified areas (124.28), indicating a more active real estate market. The standard deviation is also considerably higher in Upward-filtering areas (182.73 vs. 69.58), suggesting greater volatility in real estate transactions. This may reflect increased speculative activity and rapid neighborhood change in Upward-filtering areas.

(D) Housing Rent Price(R2):

The mean housing rent price (R2) is substantially higher in gentrified areas (47500.24) than in Upward-filtering areas (30218.63). This is consistent with the conventional understanding of gentrification as a process that drives up housing costs. However, the standard deviation is also higher in gentrified areas (12942.61 vs. 10259.75), implying a wider range of rent price variation.

4.3.2 Correlation analysis of financial precarity variables between Gentrified HH Areas and Upward-filtering HH Areas

Furthermore, an examination of correlations between these variables provides insights into the interconnectedness of financial precarity factors in HH Areas(Table 7):

Indicator	Gentrified HH Areas	Upward-filtering HH Areas	Remaining Areas
Correlation between M3 and M5	0.226**	0.106	0.117*
Correlation between M3 and R1	0.123*	0.116	0.026
Correlation between M3 and R2	-0.028	0.049	0.165**
Correlation between M5 and R1	0.382**	0.393**	0.343**
Correlation between M5 and R2	0.069	0.021	-0.066
Correlation between R1 and R2	0.075	0.267**	0.035

Table 7: Correlation of Financial Precarity Variables in Gentrified HH Areas and Upward-filtering HH Areas

(A) Correlation between M3 and M5:

In both gentrified and Upward-filtering areas, there is a positive correlation between the change rate of high-income population (M3) and the change rate of highly educated population (M5). This suggests that areas experiencing an influx of high-income residents also tend to attract highly educated individuals. However, the correlation is stronger in gentrified areas (0.226**) compared to Upward-filtering areas (0.106).

(B) Correlation between M5 and R1:

A strong positive correlation between the change rate of highly educated population (M5) and real estate transaction volume (R1) is observed in both gentrified (0.382**) and Upward-filtering areas (0.393**). This indicates a close relationship between the influx of highly educated individuals and increased real estate market activity.

(C) Correlation between R1 and R2:

Notably, the correlation between real estate transaction volume (R1) and housing rent price (R2) is substantially stronger in Upward-filtering areas (0.267**) compared to gentrified areas (0.075). This suggests that in Upward-filtering areas, changes in real estate market activity have a more direct impact on rent prices.

4.3.3 Bivariate spatial autocorrelation analysis

This study further employs bivariate spatial autocorrelation analysis to investigate the spatial clustering patterns of correlated variables within Gentrified and Upward-filtering HH Areas. This approach allows for the observation of how the spatial distribution of one variable relates to the spatial distribution of another, providing insights into the geographic co-location of socio-economic changes.

The spatial autocorrelation analysis reveals distinct patterns in the relationships between key socio-economic variables across gentrified and Upward-filtering neighborhoods. The significant positive spatial autocorrelation between M3 (high-income population change) and M5 (highly educated population change) suggests a strong spatial linkage between these demographic shifts, with areas experiencing changes in one group tending to experience corresponding changes in the other. This pattern is particularly pronounced in gentrified areas (Table 8).

Furthermore, the positive spatial autocorrelation between M5 and R1 (real estate transaction volume) in both neighborhood types underscores the connection between human capital influx and real estate market activity. Areas attracting highly educated individuals also tend to experience increased real estate transactions, potentially reflecting speculative investment and development pressures.

However, while a statistically significant correlation was found between R1 and R2 (housing rent price) in earlier analysis, the lack of significant spatial autocorrelation suggests that this relationship is not uniform across space. Localized factors, such as zoning or housing policies, may play a more influential role in rent price variation, highlighting the importance of considering both correlation and spatial relationships in examining neighborhood change.

	M3 and M5	M5 and R1	R1 and R2
Moran's Index:	0.269	0.136	-0.0058
Expected Index:	-0.0011	-0.0011	-0.0011
z-score:	16.2337	8.3257	-0.3975
p-value:	0.001*	0.001*	0.37200

Table 8: Bivariate Spatial Autocorrelation Results of Financial Precarity Variables in Gentrified HH Areas and Upward-filtering HH Areas

The analysis reveals that HH areas characterized by high values of both M3 (change rate of high-income population) and M5 (change rate of highly educated population) are predominantly concentrated within Upward-filtering HH Areas (Fig. 4). This suggests that the influx of both high-income individuals and highly educated residents tends to occur in the same geographic locations, specifically within areas experiencing the filtering-up effect. Conversely, LL areas with low values for both M3 and M5 are more frequently clustered within Gentrified HH Areas. This may indicate that areas undergoing gentrification experience a relative decline in both high-income and highly educated residents, potentially due to displacement pressures and affordability challenges.

Furthermore, HH areas exhibiting high values for both M5 (change rate of highly educated population) and R1 (real estate transaction volume) are also largely concentrated within Upward-filtering HH Areas. This finding underscores the strong connection between the influx of highly educated individuals and heightened real estate market activity in these areas (Fig. 4).

5 CONCLUSION

This study examined gentrification and upward filtering dynamics in Taipei City, focusing on financial precarity and displacement. Principal component analysis identified three neighborhood change patterns: “Undergoing Gentrification”, “Gentrified”, and “Upward-filtering Effect”, each with significant spatial clustering. "Gentrified" areas saw declining high-income and highly educated residents, potentially due to displacement. “Upward-filtering Effect” areas attracted more of these groups, coupled with increased real estate transactions.

Comparative analysis revealed further distinctions. While both area types experienced demographic and real estate shifts, the strength and spatial relationships varied. The correlation between real estate transaction volume and rent prices was stronger in upward-filtering areas, indicating a more direct impact on affordability. However, the lack of significant spatial autocorrelation suggests localized factors like zoning influence rent price dynamics.

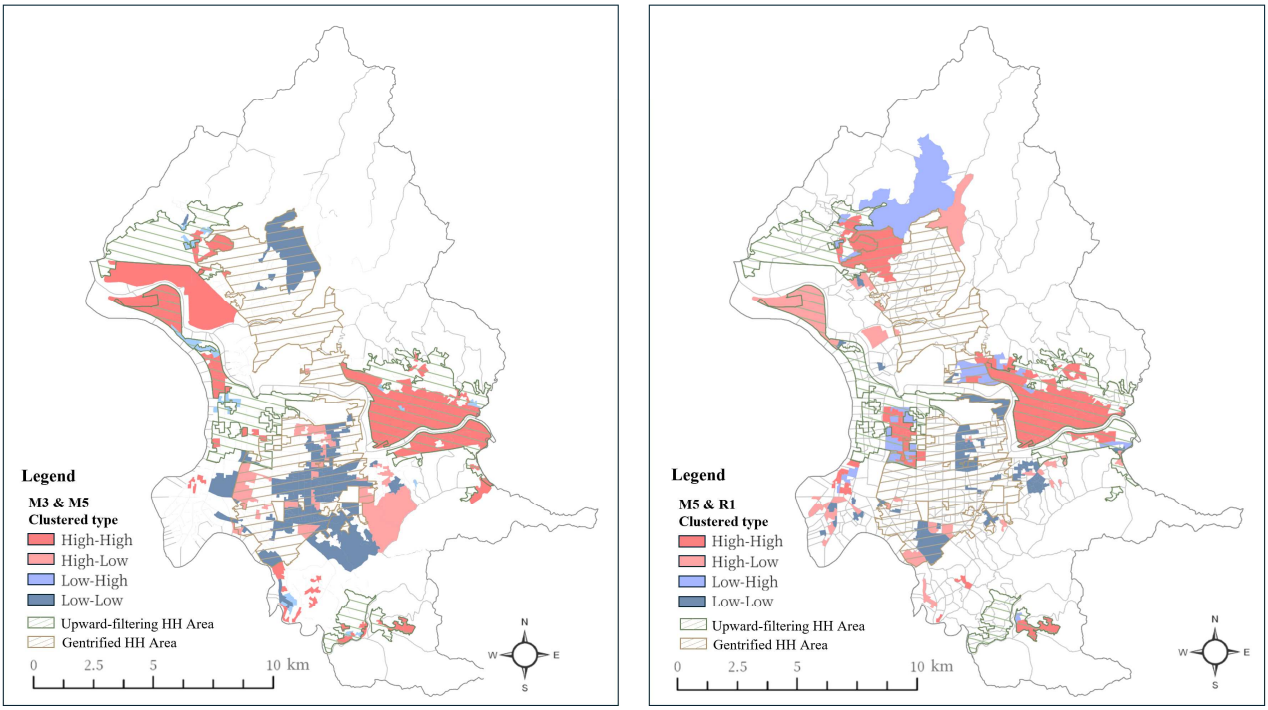

Fig. 4: Spatial Clustering Distribution of Financial Precarity Variables with Gentrified HH Areas and Upward-filtering HH Areas

Bivariate spatial autocorrelation revealed spatial linkages. The clustering of areas with high rates of change in high-income and highly educated populations in upward-filtering areas reinforces the interconnectedness of these shifts. Similarly, high rates of change in the highly educated population and real estate transaction volume highlight the connection between human capital and real estate activity. These findings contribute to a nuanced understanding of gentrification and upward filtering, emphasizing the need for policies mitigating financial precarity and displacement while promoting equiable urban development. Future research could explore targeted interventions to address these challenges.

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reviewed paper

Analysis of rSOC Systems to Support the Energy Supply of Modern Positive Energy Districts

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1 ABSTRACT

This study evaluates the integration of reversible solid oxide cell (rSOC) systems within Positive Energy Districts (PEDs) to enhance energy self-sufficiency and optimize the use of renewable energy based on seasonal energy storaging. rSOC systems are dual-mode technologies capable of operating as both electrolyzers and fuel cells, enabling seasonal energy storage by converting surplus energy, in this case from photovoltaic (PV) systems, into hydrogen during the summer months and converting it back to electricity and heat during winter. The heat generated is of a high temperature, making it suitable for both heating and hot water preparation.

For the investigation, an own simulation model was developed using Python-based tools, incorporating detailed component characteristics and operating models. The emphasis was shifted towards seasonal operation, as it became evident that there were no benefits to be gained from short-term storage in comparison to battery storages. For the saisonal operation, two operation models have been investigated: continuous operation (Scenario I) and predictive operation based on short-term forecasts (Scenario II). Results show that predictive operation reduces electricity grid dependency by aligning rSOC activity with PED energy demands and PV generation patterns. Parameter studies identified optimal configurations of rSOC power, battery capacity, and battery inverter dimensions to balance self-sufficiency and economic performance. While the system exhibits considerable technical potential, its economic integration represents a significant challenge, caused by high investment costs of rSOC systems and the comparatively low electrical efficiency for hydrogen production and subsequent reconversion into electricity. Consequently, it was not possible to identify an economically viable business model within the prevailing framework conditions, whether for Scenario I or Scenario II. Sensitive analyses taking into account the further development of the technology and the relevant framework contions however, shows, that rSOC has the potential to be an interesting option for use in PEDs in the future.

The investigation was carried out as part of the Cell4Live[1] project, focusing on technical and economic aspects of rSOC systems integrated in PEDs.

Keywords: Fuel Cell, Simulation Model, Positiv Energy District, hydrogen, rSOC-system

2 INTRODUCTION

The efficient energy supply of PED is still a major challenge. Especially when, in addition to the positive energy balance – total annual generation exceeds total annual demand – the degree of self-sufficiency is also considered. If the temporal synchronization of energy demand and energy generation is also addressed, the PED can make a significant contribution to relieving the burden on public grids and benefit from increased security of supply in the event of a power outage.

In this respect, rSOC systems are an interesting technology. They can operate in both electrolysis and fuel cell mode. Therefore, surplus electricity can be converted into green hydrogen and converted back into electricity at a later point in time. In fuel cell mode, heat is released in addition to electricity, which can be used to cover (a part of) the heat demand as well as domestic hot water demand. Thanks to the high storage capacity of hydrogen, this system makes it possible to store energy seasonally, i.e. to shift it from summer to winter. This can significantly increase the self-sufficiency rate of the PED, as photovoltaic systems (PV) are usually the main energy sources of such districts.

[1] Das Projekt wird innerhalb des Förderprogrammes „Stadt der Zukunft“ durch das Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie gefördert, Project description: https://www.4wardenergy.at/en/references/cell4life-1

Within this study, both the technical and the economic aspects of integrating a rSOC system into PED for seasonal storage of renewable electricity from a PV system, with the goal of later supplying the PED with electrical and thermal energy are examined.

3 TECHNO-ECONOMIC MODELLING APPROACH

It has been assumed that the rSOC system is integrated into a higher-level energy supply system, meaning that the rSOC system is not solely responsible for the entire energy supply of the PED. In addition, the focus was on seasonal operation. Therefore, the rSOC system operates exclusively as an electrolyzer during the summer months and as a fuel cell during the winter months. Generally, in both seasons, electricity generated by the PV is first used to meet the PED electricity demand. In electrolyzer mode (see Fig 1), any additional surplus PV electricity is used to operate the electrolyzer, storing renewable energy as hydrogen for seasonal use.

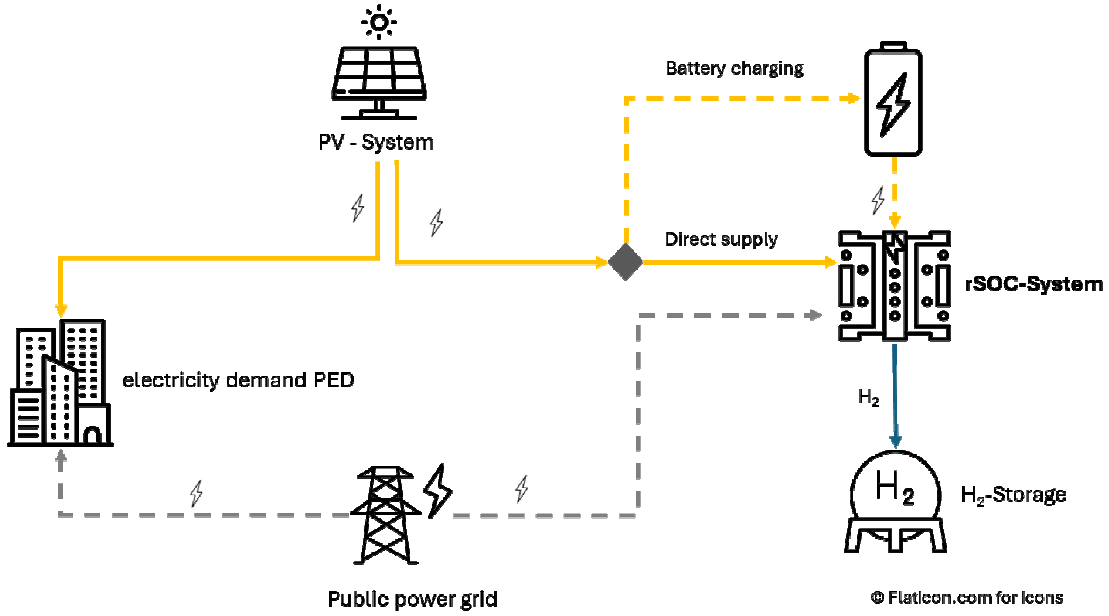

Fig. 1: Schematic diagram of the rSOC-system operating as electrolyzer (“summer operation”).

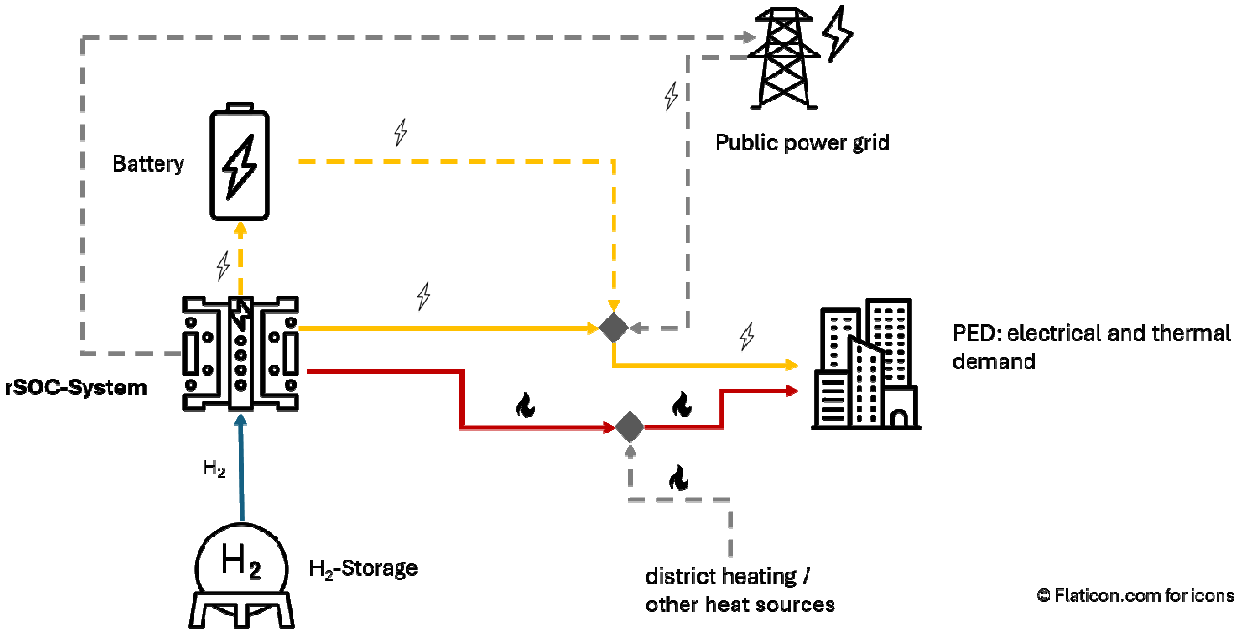

Fig. 2: Schematic diagram of the rSOC-system operating as fuell cell (“winter operation”).

During the winter months, the stored hydrogen is reconverted by the rSOC system into both electricity and heat. The generated electricity is used to cover household electricity needs, while the heat from the rSOC

system is used for heating and domestic hot water preperation (see Fig 2). Moreover, the rSOC is coupled with a battery to further optimize the operation of the system and minimize the share of grid electricity used for the operation of the rSOC system.

To calculate the energy flows between the components (rSOC system, battery, hydrogen storage, electricity grid) and to determine the optimum dimensions of the system for specific PED, a simulation model in Python was created. This model is based on the so called houshold infrastructure and building simulator "hisim" (Pflugradt, 2020). The respective models of the components were interconnected according to the PED requirements and extended regarding the technical and physical properties of real components (e.g. efficiency of the rSOC system, energy requirement for storing hydrogen in a pressurized storage tank). The operation of the rSOC system is investigated within two scenarios:

- In Scenario I, the rSOC system operates continuously, independent of PV surplus and electricity demand of the PED. The rSOC system is operated in electrolysis mode during the summer months and in fuel cell mode during winter. When the system was being dimensioned, care was taken to ensure that the hydrogen produced during the summer months is sufficient to guarantee winter operation. In order to minimise the amount of electricity purchased from the public grid for the operation of the rSOC system in electrolysis mode, the system was equipped with an additional battery storage for day/night balancing. The determination of the optimum size of the battery storage in comparison with the rSOC-system was also investigated within the project.
- In Scenario II, forecasting methods are used to optimize the operation of the rSOC system. The emphasis remains on seasonal operations. Consequently, the rSOC system is still operated in electrolysis mode during the summer months and in fuel cell mode during the winter months. However, the system is not operated constantly, but rather put into standby mode if, for instance, the forecasts indicate that no PV surplus is expected in the subsequent hours in electrolysis mode.

In standby mode, the rSOC unit consumes electrical energy, e.g., to maintain temperature, ensuring rapid reactivation. The model incorporates values from the literature (Mottaghizadeh, 2021; Tomberg, 2023), specifying that 7% of the nominal power is required for electrolysis mode and 10% for fuel cell mode.

In standby operation, the battery state of charge is evaluated against predefined minimum or maximum thresholds, depending on the rSOC mode, to minimize grid feed-in or consumption (see Table 1).

Minimum running & minimum standby time	3 h
rSOC electrolyzer mode: Minimum state of charge of the battery	50 %
rSOC fuel cell mode: Upper state of charge of the battery	90 %
rSOC electrolyzer mode: standby energy demand of nominal power	7 %
rSOC fuel cell mode: standby energy demand of nominal power	10 %

Table 1: Relevant parameters of the Standby mode.

In Scenario II the rSOC system is operated based on predictions for the electricity demand and the electricity production. For the prediction of the electricity demand, a model was developed, which was capable of generating time series forecasts based on historical load data. With this model based on a neural network, good results were achieved for the total energy demand of the PED. However, it should be noted that the aim of the project was not to develop the best possible forecast, but to find a model that is able to deliver sufficiently good results to answer the research question. To determine the energy production, weather forecasts (solar radiation, temperature) from the GeoSphere Austria (2022) were used to calculate the expected PV production for the next three hours (short-term forecasts of GeoSphere Austria).

In fuel cell mode, the activation process involves assessing whether there is an energy demand in the PED after accounting for the energy supplied by the PV system. If an energy demand which cannot be covered by the PV supply is identified, the forecasted PV power generation and PED energy demand during the minimum operational period of the rSOC system are analyzed. Subsequently, the proportion of energy from the rSOC system that can be directly utilized by the PED is determined. If more than 75% of the energy provided by the rSOC system can be consumed directly by the PED without intermediate battery storage, the system is activated. After the minimum rSOC runtime, the battery state of charge and the PED energy

demand are checked again. If the upper state of charge level is reached and no electricity power is required by the PED from the rSOC system, it is switched to standby mode.

A similar approach is applied in electrolysis mode. The forecasted PV surplus electricity and PED energy demand during the minimum operational period of the rSOC system are evaluated. If sufficient PV surplus electricity is available and the electrolysis process can operate for at least 75 % of the minimum runtime using only PV surplus electricity (without additional battery discharge), the rSOC electrolysis mode is activated. Once the minimum runtime is reached, it is checked whether the surpluce energy provided by PV or battery charge is sufficient to continue operating the rSOC system actively. If not, the rSOC system is switched back to standby mode.

The model was used to carry out a parameter study and subsequently determine the optimum dimensions of the rSOC system based on the degree of self-sufficiency achieved and the expected net present value. The results were compared with alternative technologies. In addition, a comprehensive economic sensitivity analysis was carried out using selected scenarios in order to determine which parameters have a strong influence on the economic viability of this system and which framework conditions are necessary to ensure the economic use of the rSOC system.

3.1 Input data

The simulations were carried out based on generic energy demand and supply data of a representative PED in Austria and were conducted for an entire year with an hourly resolution. The aggregated energy input data are shown in Table 2. A parameter study with more than 1000 simulations was carried out, each of them considering the operation of the rSOC system for an entire year. In the parameter study, the battery capacity, the inverter power and the electrical power of the rSOC system were varied with the goal to find an optimum between the increase of the autarky rate on the one hand and the net present value of the investment on the other hand.

		Summer	Winter	Seasonal Transition	Year
Electricity demand	in MWh	209	263	455	927
Thermal energy demand	in MWh	82	343	224	649
Photovoltaik supply	in MWh	388	78	461	927

Table 2: Energy data of the PED used for the calculations.

It was assumed that the maximum electricity power demand of the rSOC system in electrolysis mode corresponds to the PV peak power. The electricity power of the battery inverter was at least equal to the electricity power demand of the rSOC system in electrolysis mode, including the power requirement of the hydrogen compressor. The minimum capacity of the battery was sufficient to operate the electrolyser and the hydrogen storage tank for at least one hour.

In both scenarios, the battery serves as short-term energy storage for the rSOC system. The parameter space is limited upwards by the fact that the battery has a maximum capacity to operate the electrolyser and hydrogen storage for 24 hours. In general, it was assumed that the rSOS system in fuel cell mode supplies around half the power demand in electrolysis mode.

		Minimum	Maximum
Photovoltaic peak power	in kW	781	
rSOC system electricity power demand	in kW	55	781
Battery inverter power	in kW	1 x rSOC system electricity power demand	15 x rSOC system electricity power demand
Battery capacity - enables rSOC system operation	in hours	1	24

Table 3: Characteristics of the parameter space. The rSOC system's electricity demand is specified for electrolysis mode, including the hydrogen tank power demand.

4 RESULTS AND DISCUSSIONS

This chapter is divided into two main sections. On the one hand, the effects of forecast-based operation (Scenario II) were analysed in comparison with constant operation (Scenario I) and, on the other hand, the economic efficiency of the use of an rSOC system in PEDs was evaluated in general.

4.1 Comparison of the constant operation with the forecast-based operation

For the following evaluation, the configuration of Scenario I which reaches the best combination between the remaining grid consumption (to be minimized) and the net present value (to be maximized) has been selected. For Scenario II, the same configuration (size of rSOC system, battery capacity and inverter power) has been chosen to make both scenarios better comparable. The optimum configuration of Scenario II would be slightly different, this however does not influence the general findings. As main reference a scenario without rSOC-system was calculated. Meaning, the PED was modelled with the same PV-system and the same energy demand but without any kind of storage system.

It could be shown that the use of forecastes in Sceneario II reduces the the necessary consumption from the public grid by additional 5 % (see Fig. 3) in comparison to Scenario I. The predictive operating strategy ensures that the rSOC system switches from electrolysis mode to standby mode when the photovoltaic supply is expected to be low or absent, e.g. at night or when it is cloudy. Predictive operation also reduces the amount of electricity fed into the grid. If a low electricity power demand from the PED is expected, which does not justify the operation of the rSOC system in fuel cell mode, it is also switched to standby mode.

In general, the predictive operation of the rSOC system in Scenario II can be seen as to be more grid supportive. In addition to providing seasonal balancing through long-term storage of electricity energy supplied by the PV system, the predictive control of the rSOC system also compensates for daily fluctuations in PV power generation and the PED's electricity consumption.

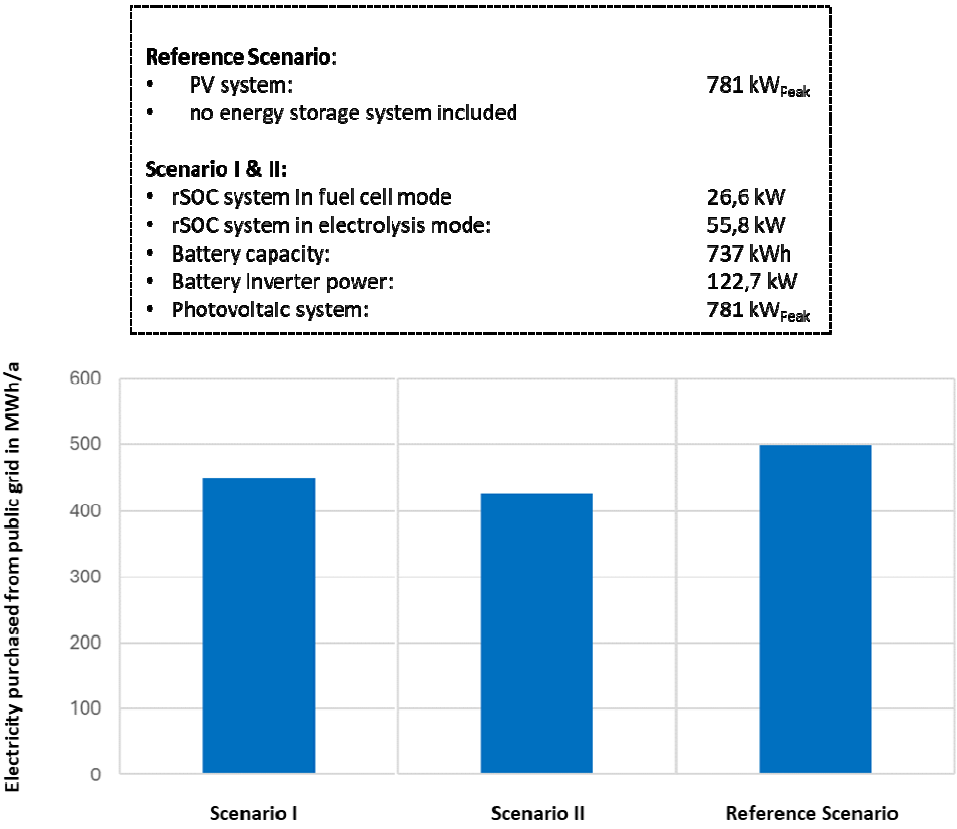

Fig. 3: Remaining share of electricity with needs to be purchages from the public grid, for Scenario I, II and the Reference Scenario.

From the technical perspective, the results of Scenario I show that with continuous operation of the rSOC system, the rSOC system power demand in electrolysis mode should be around 8 % to 12 % of peak power of the PV system to minimize electricity purchased from the public grid. The results of Scenario II show that in forecast-based operation, the rSOC system power demand can be around 10 % to 25 % of the photovoltaic

peak power to minimize electricity grid demand. These values are based on a PED where total annual electricity demand roughly meets annual electricity production.

In addition, according to the simulation results, the battery inverter power in both scenarios should be around two to three times the total electrical power of the rSOC system running in electrolysis mode feeding the hydrogen storage. The battery should have a capacity that makes it possible to operate the rSOC system in electrolysis mode for 18 to 24 hours. In continuous operation of the rSOC system (Scenario I), however, a higher battery capacity is beneficial.

4.2 Economic evaluation of the use of an rSOC system in PEDs

For the economic evaluation, the configurations which provide the best results have been chosen for Scenario I and Scenario II, resulting in different dimensions of the main components, as shown in Table 4:

		Scenario I	Scenario II	Reference Scenario	Scenario 100 % grid consumption
PV-System	kWp	781	781	781	-
rSOC System in fuel cell mode	kW	27	31	-	-
rSOC System in electrolysis mode	kW	56	65	-	-
Battery capacity	kWh	737	430	-	-
Batter inverter power	kW	122	215	-	-

Table 4: Dimensioning of main components of the overall rSOC system.

While the system exhibits considerable technical potential, its economic integration represents a significant challenge. From the economic perspective, unfortunately, no favourable configuration either for the Scenario I nor for the Scenario II could be found in comparison to the reference scenario under the current circumstances. This is mainly due to the high investment costs and the comparatively low electrical efficiency (approx. 55 % (Tokyo Gas Co, 2023)) for hydrogen production and subsequent reconversion into electricity. As shown in Fig 4 the expected net present value for both rSOC scenarios is significantly lower than in the reference scenario, which is supplied exclusively by a PV system and does have its own storage system. Both scenarios have been set in relation to a 100 % grid supply. Meaning that the investment in the PV-system would be amortised within four years, while it is evident that no amortisation occurs in the period under review for the scenario involving the rSOC system.

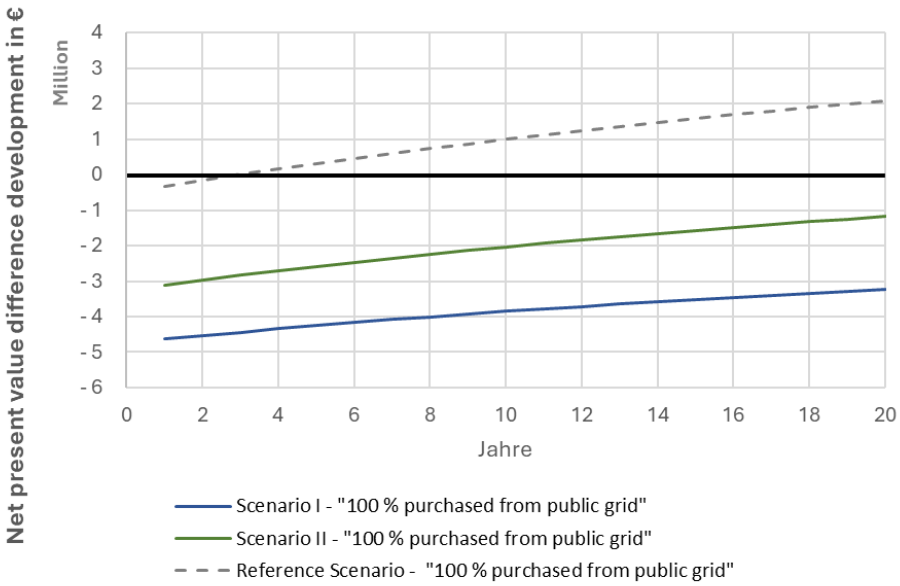

Fig. 4: Development of the net present value for the rSOC-system and the reference scenario (PV system without storage) – both in relation to 100 % grid supply – Basic Scenario.

In the absence of a positive operating model within the prevailing framework conditions, a sensitivity analysis was conducted to ascertain the impact of various parameters on economic outcomes. It has been shown that investment costs and subsidies have the most significant impact on economic efficiency. Given that rSOC systems are a young technology, it is reasonable to assume that investment costs will decrease as the market matures.

Based on these findings, further scenarios predicated on favourable development of the rSOC-technology and the related framework conditions have been defined. The assumptions underlying both the basic scenarios and the "Future Development Scenario" are outlined in Table 5:

		Basis Scenario	Future Development
Investment costs			
PV-System	in EUR/kWp	900	855
Battery Storage	in EUR/kWh	800	680
rSOC-System	in EUR/kW	5000	2000
Hydrogen Storage	in EUR/kWh	835	334
Funding options			
PV-System	%*	30	30
Battery Storage	%*	20	50
rSOC-System	%*	30	50
Hydrogen Storage	%*	30	50
Operation costs			
PV-System	%*	2	1
Inverter	%*	2	0.5
Battery	%*	2	0.5
rSOC-System	%*	3	1
Hydrogen Storage	%*	1.5	0.75
Compressor	%*	1.5	1.5
Electricity tariff	EUR/kWh	0.3	0.3
Feed-in tariff	EUR/kWh	0.08	0.08
Heat tariff	EUR/	0.13	0.13
CO_2 Price	EUR/t_{CO2}	55	55
* % of the related investment costs			

Table 5: Assumptions for the economic evaluation, for the basic scenarios and for the scenario of the future development of the rSOC technology.

The results of the scenario for the future development of the rSOC technology are shown in Fig. 5. Significant better results could be achieved with the assumptions made. Compared with an 100 % grid consumption, the Scenario II is economically viable after nine years. Scenario I is expected to reach its amortisation point after fifteen years. In comparison with the reference scenario, however, there is still no amortisation. Nevertheless, the rSOC system has a considerable future potential especially for such PEDs, where a high degree of autarky is essential.

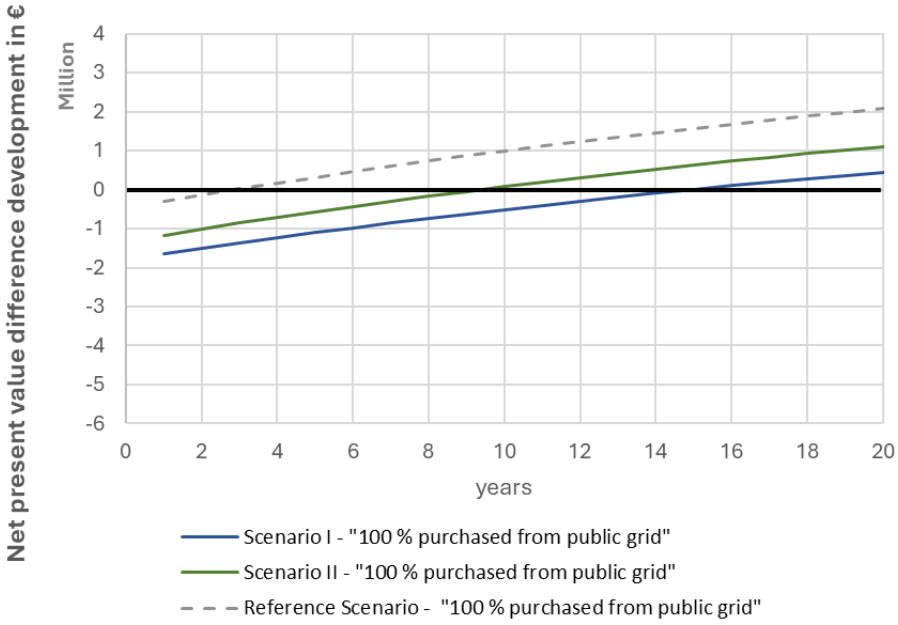

Fig. 5: Development of the net present value for the rSOC-system and the reference scenario (PV system without storage) – both in relation to 100 % grid supply –Scenario for the future development of the technology and the relevant framework conditions.

5 CONCLUSION

Although rSOC systems are an interesting technology for use in a PED from a technical point of view, it was not possible to find an economically viable use case under current conditions. However, as rSOC systems are an emerging technology, it can be assumed that there will be positive development in the coming years, both in terms of investment and achievable efficiency. Therefore, a sensitivity analysis was carried out, which shows that if investment costs and the relevant framework conditions develop favourably, rSOC technology can be an interesting option for use in PEDs in the future. The integration of rSOC systems is particularly favourable if a high degree of autarky should be achieved, as they are well suited for seasonal balancing.

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reviewed paper

Architektonische Details als Schlüssel für das kreislaufgerechte Konstruieren: Analyse von Darstellungs- und Informationsgehalten zeichnerischer Details

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1 ABSTRACT

Kreislauffähige Konstruktionen bieten erhebliche Vorteile im Hinblick auf den Klima- und Ressourcenschutz. Sie zeichnen sich durch eine hohe Ökoeffektivität[1] und Langlebigkeit aus und leisten einen wichtigen Beitrag zur Reduzierung des CO_2-Fußabdrucks, der Minimierung des Ressourcenverbrauchs und der Reduktion von Abfällen.[2] Der Schwerpunkt des kreislauffähigen Bauens liegt auf der Auswahl sortenreiner Materialien[3], die nach ihrem Gebrauch entweder erneut verwendet oder in geschlossene technische oder biologische Stoffkreisläufe überführt werden können.[4] Um eine sortenreine Trennung der eingesetzten Materialien zu ermöglichen, sind geeignete Fügetechnologien erforderlich, um die Demontage, Wiederverwendung und die materialgerechte Wiederverwertung von Bauteilen im Sinne der Kreislaufwirtschaft sicherzustellen.[5] Angesichts der globalen Notwendigkeit von Ressourcen- und Klimaschutz müssen die relevanten methodischen Konzepte des kreislauffähigen Bauens systematisch als auch informativ bis hin zur Detailzeichnung in den Planungsprozess integriert werden.

Das zeichnerische Detail ist ein zentraler Bestandteil des iterativen Entwurfsprozesses in der Architektur und dient vor allem als Medium für den Wissens- und Informationstransfer zwischen allen am Planungsprozess beteiligten Akteurinnen und Akteuren. Eine Möglichkeit, kreislauffähige Bauweisen zu fördern, ist das Hinterfragen der etablierten zeichnerischen Entwurfsgrundlagen und der Prüfung des Informationsgehalts der Detailzeichnungen auf ihre Eignung für das kreislauffähige Konstruieren. Für die folgende Ausarbeitung wurden siebzig ausgewählte zeichnerische Details von architektonischen Bauteilen mittels einer Analyse hinsichtlich ihres Darstellungs- und Informationsgehalts im Kontext der Kreislauffähigkeit evaluiert. Der Schwerpunkt lag dabei auf der Identifikation und Auswertung von Angaben zu verwendeten Materialien, Fügetechnologien sowie der potenziellen Wiederverwendbarkeit der Bauteile.

Ziel war es, zu ermitteln, inwieweit die Detailzeichnungen relevante Informationen für eine kreislaufgerechte Nachnutzung der Bauteile vermitteln und wie diese den Anforderungen der Kreislaufwirtschaft entsprechen. Durch die Untersuchung veröffentlichter Details aus Fachliteratur und Konstruktionskatalogen aus verschiedenen Zeiträumen zwischen 1965 und 2023 wurden die Darstellungen von Materialeigenschaften und Fügetechnologien sowie den Anforderungen für das kreislaufgerechte Bauen systematisch verglichen. Der Vergleich historischer und aktueller Zeichnungen liefert dabei Erkenntnisse über die Entwicklung und Potenziale zeichnerischer Details im Kontext der Kreislaufwirtschaft. Allerdings zeigt die Evaluierung auch, dass der Informationsgehalt aktueller Zeichnungen derzeit noch nicht ausreichend ist. Für die Festlegung des Informationsgehalts ist vorrangig ein methodisches Konzept erforderlich, das die relevanten Kriterien systematisch erfasst und definiert. Um eine umfassende Beurteilung zukünftiger Bauteile zu ermöglichen, ist es erforderlich, die Detailzeichnung um eine zusätzliche Schicht für die Fügetechniken zu erweitern. Zudem ist eine Betrachtung aus verschiedenen Perspektiven erforderlich, insbesondere im Hinblick auf die potenzielle Beschädigung der Materialschichten durch den Aufschluss der Fügetechnik. Durch eine

[1] Braungart, M.; McDonough, W.: Einfach intelligent produzieren. Cradle to Cradle: Die Natur zeigt, wie wir Dinge besser machen können. Berlin, 2010. S. 100 ff.
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[5] Schneider, D.: Reversible Füge- und Verbindungsmethoden. In: Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S.104-109

geänderte Sichtweise auf das Detail kann die Verfügbarkeit von Ressourcen sowie die Wiederverwendbarkeit der Bauteile in der Entwurfsphase fundierter eingeschätzt werden.

Keywords: Informations- und Darstellungsgehalt, Planung, Architektonische Details, Kreislaufgerechtes Konstruieren, Kreislaufschließung

2 ANALYSE ZEICHNERISCHER DETAILS IM KONTEXT DER KREISLAUFFÄHIGKEIT

Das zeichnerische Detail hat sich über Jahrzehnte als bewährte Methodik in der Architekturplanung etabliert, um einfache als auch komplexe Konstruktionen und deren spezifische Merkmale zu dokumentieren.[6] Besonders bei der Planung von Bauteilkonstruktionen ist das zeichnerische Detail nicht nur ein Mittel der visuellen Darstellung, sondern auch ein zentraler Faktor, der die ökonomischen, ökologischen und gestalterischen Dimensionen eines Bauprojekts maßgeblich beeinflusst. Die Betrachtung von Detailzeichnungen unter Berücksichtigung normativer und projektspezifischer Anforderungen spielt eine entscheidende Rolle im Entwurfsprozess.

Im Kontext der Kreislaufwirtschaft gewinnt die Analyse solcher zeichnerischen Details an Bedeutung, da sie einen wichtigen Beitrag zur Integration von Kreislaufprinzipien in die Entwurfsphase leisten kann. Eine präzise Untersuchung in der Entwurfsphase zeichnerischer Darstellungen ermöglicht es, Planungs- und Optimierungspotenziale für das kreislauffähige Konstruieren zu identifizieren. Dabei können sowohl die effiziente Ressourcennutzung als auch die spätere Wiederverwendbarkeit der Bauteile gezielt verbessert werden. Die wesentlichen Aspekte sind dabei die Auswahl geeigneter Materialien und Fügetechnologien, die in der Entwurfsphase in einer Detailzeichnung festgehalten werden. Die vorliegende Untersuchung widmet sich der Analyse von Detailzeichnungen, die sowohl aus historischen, traditionellen als auch aus kreislauffähigen Bauprojekten stammen. Ziel ist es, neue Erkenntnisse zur Weiterentwicklung zeichnerischer Darstellungen im Hinblick auf die Anforderungen einer nachhaltigen Bauweise zu gewinnen.

2.1 Identifizierung der Schlüsselaspekte für die Analyse

Strategische Entscheidungen zur Entwicklung einer kreislauffähigen Konstruktion und ihrer Materialien sind eng miteinander verknüpft und beeinflussen maßgeblich den Gebäudelebenszyklus sowie die zirkuläre Nachnutzung der gesamten Bauweise. Um die Kreislauffähigkeit anhand einer Detailzeichnung bewerten und Verantwortlichkeiten für deren Umsetzung definieren zu können, müssen wesentliche Schlüsselaspekte berücksichtigt werden.

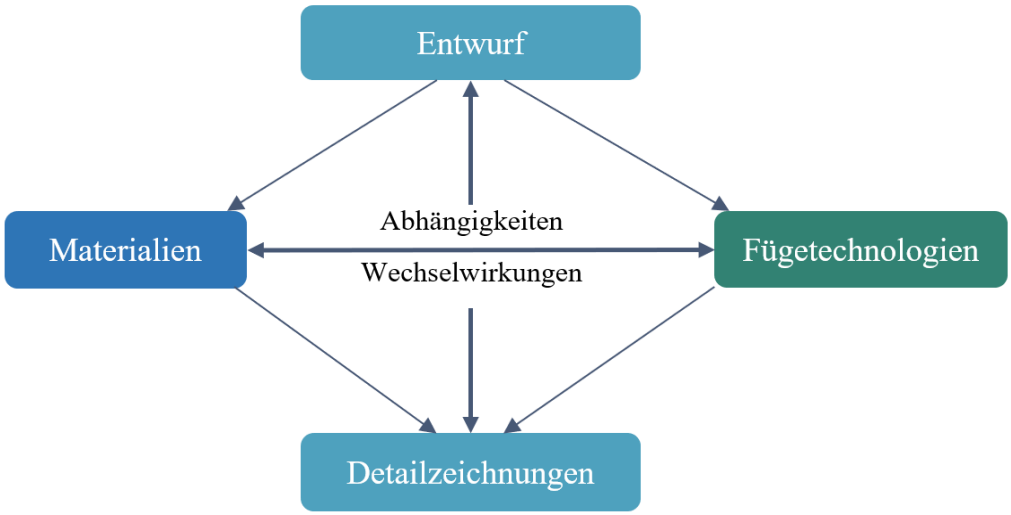


Abbildung 1: Aspekte der zeichnerischen Details im Entwurfsprozess

Abbildung 1 veranschaulicht die wesentlichen Aspekte zur Analyse der zeichnerischen Details im Entwurfsprozess. Die Ableitung und Integration dieser Faktoren sowie ihre Verankerung im zeichnerischen

[6] Schneider, D.: Die Relevanz der Bauteilanalyse. In: Nachhaltig Bauen, Ausgabe 04/2024. Berlin, 2024. S. 42-43

Detail spielen eine wesentliche Rolle bei der Auswahl geeigneter Materialien und reversibler Fügetechnologien. Im Folgenden werden diese Aspekte detaillierter erläutert.

Materialien

Die Wahl der Materialien legt die Grundlagen für das Konstruieren fest. In der Tabelle werden einzelne Faktoren aufgeschlüsselt, die für die sortenreine Materialwahl maßgeblich sind:

Aspekte	Gestaltung der Materialauswahl in der Entwurfsphase	Möglichkeiten der zeichnerischen Darstellung
Ziel	Auswahl sortenreiner Materialien, um eine Nachnutzung zu maximieren	Präzise Darstellung sortenreiner Materialien in den Zeichnungen
Kriterien	Die Auswahl erfolgt nach Kriterien: - Sortenreinheit, - Zusammensetzung, - Nachwachsende Rohstoffe, - Rezyklat - Umweltwirkungen, - Instandhaltung- und Reparatur-anfälligkeit[7] - Rücknahmemöglichkeit - Wieder- und Weiterverwendung - Recyclingverfahren	Die textlichen Beschreibungen ergänzen die dargestellten zeichnerischen Materialeigenschaften
Nachnutzung	Materialien sollen so ausgewählt werden, dass sie nach der Nutzung mit minimalem Aufwand und ohne aufwendige Aufschlussverfahren nachgenutzt werden können. Der Schwerpunkt liegt auf sortenreinen Materialien, die ohne Qualitätseinbußen wiederverwendet oder in den biologischen oder technischen Kreislauf zurückgeführt werden können	In den Detailzeichnungen werden sortenreine Materialien z.B. durch Symbole dargestellt, die den bestimmten Kreislaufansatz sicherstellen.

Tabelle 1: Auswahl und Darstellung von Materialien

Neben den oben genannten Aspekten, trägt die Reduzierung der Bauteilschichten eines Details zur Minimierung der Fügetechniken sowie zur Verringerung des Rückbau- und Demontageaufwandes bei und leistet bei der Reduzierung von Materialien gleichzeitig einen Betrag zur Reduzierung der Ressourcen und des ökologischen Fußabdrucks.

Fügetechnologien

Die Wahl der Fügetechnik sollte unter Berücksichtigung der in der Tabelle genannten Aspekte erfolgen:

Aspekte	Gestaltung und Wahl der Fügetechnik in der Entwurfsphase	Möglichkeiten der zeichnerischen Darstellung
Ziel	Die Auswahl der Fügetechnik erfolgt unter Berücksichtigung des bestimmen Kreislaufansatzes, die eine einfache Demontage und Wiederverwendbarkeit am Ende der Nutzungsphase ermöglichen	Fügetechniken werden in der zeichnerischen Darstellung durch eine eindeutige Kennzeichnung von reversiblen und demontierbaren Verbindungen dargestellt
Kriterien	Die Auswahl der Fügetechnologien wird durch Faktoren der Reversibilität, Flexibilität sowie durch die Fähigkeit zur materialgerechten Trennung und die Wiederverwendbarkeit der Bauteile bestimmt[8]	Die Verwendung von Symbolen stellt die Reversibilität der Fügetechnik sicher. Die Positionierung der Verbindungselemente wird in der Bemaßung angegeben, die Anzahl der Verbindungsmittel im textlichen Teil

[7] Schneider, D.: Die Relevanz der Bauteilanalyse. In: Nachhaltig Bauen, Ausgabe 04/2024. Berlin, 2024. S. 42-43.
[8] Schneider, D.: Reversible Füge- und Verbindungsmethoden. In: Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S.104-109

Tabelle 2: Auswahl und Darstellung von Fügetechnologien[9]

Die Darstellung von Abhängigkeiten und Wechselwirkungen von Material, Konstruktion und Flexibilität stellt sich als eine Herausforderung dar, da Materialien und Fügetechnologien in einer wechselseitigen Beziehung stehen. Ihre Kombination beeinflusst maßgeblich die Wiederverwendung und materielle Wiederverwertung baulicher Komponenten. Eine isolierte Betrachtung dieser Elemente würde potenzielle Synergien und Abhängigkeiten vernachlässigen. In der Entwurfsplanung stellt die Integration der kreislaufspezifischen Aspekte eine Herausforderung dar: das Detail entwickelt sich aus einem gesamtiterativen Prozess der übergeordneten und projektspezifischen Vorgaben an das Bauvorhaben heraus.

2.2 Definition und Eingrenzung der Untersuchungsgegenstände

Innerhalb der für das Paper durchgeführten Analyse wurde der Darstellungs- und Informationsgehalt ausgewählter Detailzeichnungen systematisch nach den in den Tabellen genannten Schlüsselkriterien evaluiert. Ziel war es, die enthaltenen Angaben in den Detailzeichnungen zu den vorgesehenen Materialien und Fügetechniken zu untersuchen und deren Relevanz für die Kreislauffähigkeit zu ermitteln.

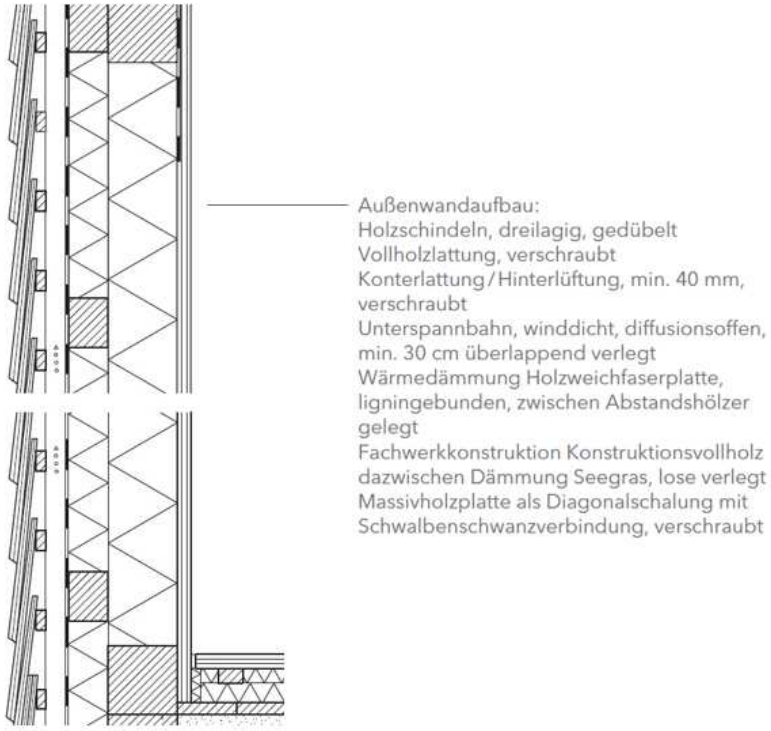


Abbildung 2: Beispiel eines analysierten Vertikalschnitts einer sortenreinen Holzständerbauweise

Die Analyse der Darstellungen zeichnerischer Details bezieht sich auch auf die Untersuchung und Interpretation grafischer Darstellungen, die in der Architekturplanung verwendet werden, um konstruktive und gestalterische Aspekte zu kommunizieren. Insgesamt wurden siebzig publizierte Detailzeichnungen untersucht, die aus historischen, traditionellen oder aktuellen nachhaltigen und kreislauffähigen Projekten entstammen. Der zeitliche Schwerpunkt umfasst Bauprojekte aus dem Jahr 1965 bis 1981 sowie im Zeitraum von 2000 bis 2023. Die untersuchten Details umfassten jeweils Konstruktionen aus der Holz-[10] [11] [12] [13] [14], Massiv- [15] [16] [17], Stahl- [18] [19] [20], Stahlbetonbauweise[21] [22] [23]. Die Datengrundlage setzte sich aus einschlägigen

[9] Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S.138-139
[10] Herzog, T.; Natterer, J. et al.: Holzbau Atlas. Berlin, 2003. S. 297, 301, 311
[11] Kaufmann, H.; Krötsch, S. et. al: Atlas mehrgeschossiger Holzbau. München, 2017. S. 179, 189,197
[12] Seggewies, J.; Riegler-Floors, P. et al.: Atlas Recycling. München, 2018. S. 167-169
[13] Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S.134-141; 146-149;
[14] Kolb, J.; Kolb, H. et al: Holzbau mit System. Basel, 2024. S. 137, 141, 155-156, 206-207, 216, 228, 250-251
[15] Achtziger, J.; Pfeifer, G.; et al.: Mauerwerk Atlas. Berlin, 2001. S. 221, 224
[16] Böttger, T.; Knauer, U.: Massives Material – Monolitisch, homogen und zirkulär Bauen. Basel, 2023. S. 30
[17] Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S.162-165

Lehr- und Grundlagenwerken zur Baukonstruktion, Konstruktionskatalogen sowie Fachartikeln zusammen. Ein besonderer Schwerpunkt lag auf der Analyse des Schichtaufbaus von Außenwänden in Neu- und Bestandsbauten, wobei die Details auf ihre zeichnerische Tiefe und die Einhaltung der kreislaufspezifischen Schlüsselaspekte geprüft wurden. Der Fokus der Untersuchung lag ausschließlich auf dem Darstellungs- und Informationsgehalt hinsichtlich der verwendeten Materialien, der eingesetzten Materialschichten und Fügetechnologien sowie den dazugehörigen textlichen Angaben. Um eine methodisch fundierte Vergleichbarkeit der analysierten Details zu gewährleisten, wurden überwiegend Zeichnungen im Maßstab M 1:20 ausgewählt. Diese Maßstabsverhältnisse entsprechen den üblichen Abmessungen, die in der Entwurfs- und Werkplanung Anwendung finden und gewährleisten eine fundierte Datengrundlage für die Analyse. Der zeichnerische Detailierungsgrad und -tiefe im gewählten Maßstab M 1:20 basiert auch auf gängigen Normen und Vorgaben, die in der Architekturpraxis und Bauplanung verwendet werden.

3 METHODIK

3.1 Beschreibung der Methodik

Im ersten Schritt der Analyse wurden Konstruktionsatlanten unterschiedlicher Jahrgänge verschiedener Materialien ausgewählt, die sowohl im Studium als auch in der praktischen Anwendung der Entwurfsplanung Verwendung finden. Es wurden standardisierte Details aus den materialspezifischen Konstruktionskataloge für Holz[24] [25] [26], Stahlbeton[27] [28], Mauerwerk[29] [30] und Stahl[31] für die Analyse des Informations- und Darstellungsgehaltes in Bezug zur Kreislauffähigkeit selektiert. Auffallend ist die gestalterische Sprache der Details in den materialspezifischen Konstruktionskatalogen. Sie ist stark auf das Wesentliche reduziert, standardisiert und vereinfacht. In der ersten Betrachtung der zeichnerischen Details wurde festgestellt, dass es stark abweichende Detailierungsgrade der zeichnerischen Darstellung und der textlichen Beschreibung im Vergleich zu einschlägigen Normen gibt. Die zeichnerische Sprache entspricht typischerweise der gestalterischen Sprache eines Verlags oder einer Autorin oder eines Autors. Die publizierten Details konzentrieren sich hauptsächlich auf die Materialschichten und deren grundlegenden Eigenschaften. Die textliche Beschreibung der Materialangaben sowie die zeichnerische Darstellung von Verbindungsmitteln der einzelnen Materialschichten und Komponenten zeigten Schwachstellen hinsichtlich der Angaben zu den dargestellten Materialien und Fügetechnologien auf. Im Allgemeinen werden in den Details keine Aussagen zu kreislaufspezifischen Eigenschaften der Materialien getroffen, da dies nicht das Ziel eines materialspezifischen Konstruktionskataloges ist. Bedingt aussagekräftige Details mit Angaben zu den verwendeten Fügetechnologien wurden insoweit publiziert, sofern es sich um ein elementares Gestaltungselement einer Sonderkonstruktion, um eine statische Anforderung oder um die Belange eines spezifischen statischen Elements handelt.

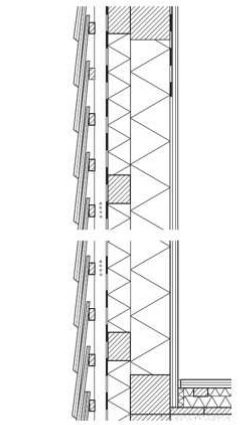
Im zweiten Schritt der Untersuchung wurden auch Details aus der weiterführenden Fachliteratur einzelner nachhaltiger und kreislauffähiger Projekte analysiert. Dazu wurde die Publikation des Aktivhauses „B10“ in Stuttgart von Architekt und Bauingenieur Werner Sobek aus dem Jahr 2015 herangezogen.[32] In seiner Publikation zum Aktivhaus „B10“ finden sich nur wenige konkrete Informationen zum kreislauffähigen Konstruieren; die vorhandenen Inhalte beschränken sich überwiegend auf Fotos und Texte, die eher implizit

[18] Bollinger, K.; Grohmann, M. et al.: Atlas moderner Stahlbau: Stahlbau im 21. Jahrhundert. Berlin, 2011. S.183-184; 197; 212
[19] Seggewies, J.; Riegler-Floors, P. et al.: Atlas Recycling. München, 2018. S. 149-151
[20] Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S. 194-201
[21] Kind-Barkauskas, F.; Kauhsen, B.; et al.: Beton Atlas. Berlin, 2002. S. 185; 189; 201; 217
[22] Schulz, J.: Sichtbeton-Atlas. Wiesebaden, 2009. S. 196, 294
[23] Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S. 182-185
[24] Herzog, T.; Natterer, J. et al.: Holzbau Atlas. Berlin, 2003
[25] Kaufmann, H.; Krötsch, S. et. al: Atlas mehrgeschossiger Holzbau. München, 2017
[26] Kolb, J.; Kolb, H. et al: Holzbau mit System. Basel, 2024
[27] Kind-Barkauskas, F.; Kauhsen, B.; et al.: Beton Atlas. Berlin, 2002
[28] Schulz, J.: Sichtbeton-Atlas. Wiesebaden, 2009
[29] Achtziger, J.; Pfeifer, G.; et al.: Mauerwerk Atlas. Berlin, 2001
[30] Böttger, T.; Knauer, U.: Massives Material – Monolitisch, homogen und zirkulär Bauen. Basel, 2023
[31] Bollinger, K.; Grohmann, M. et al.: Atlas moderner Stahlbau: Stahlbau im 21. Jahrhundert. Berlin, 2011
[32] Heinlein, F.: Residentials by Werner Sobek. Stuttgart, 2015

darauf hinweisen und entsprechend interpretiert werden können. Die zeichnerischen und textlichen Angaben bieten Potenzial zur Verbesserung, insbesondere durch die Ergänzung essenzieller Informationen zu den angewandten Fügetechnologien. Es lassen sich Angaben zu sortenrein verwendeten Materialien finden, die den Fokus auf eine kreislauffähige Bauweise betonen. Die textlichen Beschreibungen und Fotografien lassen dem Betrachtenden einen Spielraum offen, inwieweit eigens die für das Detail entwickelte Fügetechnologie nachzuplanen ist. Die Fügetechnologie spielt eine zentrale Rolle im kreislauffähigen Bauen, da sie maßgeblich die Demontierbarkeit und das Recyclingpotenzial von Bauteilen beeinflusst. Das Fehlen solcher Informationen schränkt die Anwendbarkeit der dargestellten Konzepte im Sinne einer vollständigen Kreislauffähigkeit ein. In einer weiteren Projektdokumentation der Experimentaleinheit Urban Mining und Recycling (UMAR) in Dübendorf aus dem Jahr 2019 wurden die zeichnerischen Details mit den Erläuterungen auf die von den Autoren zusammengestellten Schlüsselaspekte evaluiert. Die publizierten Details, ergänzt mit Fotografien und textlichen Angaben, konzentrieren sich auf eine vollständig kreislauffähige Konstruktion mit wiederverwertbaren und wiederverwendbaren Materialien.[33] Die Zeichnungen und Fotografien zeigen im Begleittext der Publikation, wie nachhaltige Materialien und eine kreislauffähige Planung zusammenwirken. Die von den Autoren genannten Schlüsselaspekte werden ausschließlich im erläuternden Begleittext dokumentiert und in den Detailzeichnungen nicht explizit dargestellt. Diese Zeichnungen beschränken sich auf die technische Ausführung und visualisieren keine spezifischen Hinweise zur Kreislauffähigkeit oder den zugrunde liegenden Materialstrategien.

Nachfolgend wurden in fachspezifischen Konstruktionskatalogen zum nachhaltigen oder kreislauffähigen Bauen aus den Jahren 2018 bis 2023[34] [35] weitere Details auf ihren Darstellungs- und Informationsgehalt auf die von den Autoren erstellten Schlüsselaspekte analysiert. Das nachfolgende Schaubild stellt einen Auszug aus der Analyse eines Vertikalschnitts einer sortenrein geplanten Außenwand in Holzständerbauweise dar:

Zeichnerisches Detail mit erläuterndem Text



Außenwandaufbau:
Holzschindeln, dreilagig, gedübelt
Vollholzlattung, verschraubt
Konterlattung/Hinterlüftung, min. 40 mm, verschraubt
Unterspannbahn, winddicht, diffusionsoffen, min. 30 cm überlappend verlegt
Wärmedämmung Holzweichfaserplatte, ligningebunden, zwischen Abstandshölzer gelegt
Fachwerkkonstruktion Konstruktionsvollholz dazwischen Dämmung Seegras, lose verlegt
Massivholzplatte als Diagonalschalung mit Schwalbenschwanzverbindung, verschraubt

Analyse des kreislaufspezifischen Informationsgehalts

Bauteildaten	
Quelle	Hebel, D.; Wappner, L. et al.: Sortenrein bauen - Material, Konstruktion, Methodik. München, 2023. S.138-139
Jahr der Publikation	2023
Schwerpunkt	Sortenreinheit Kreislauffähigkeit
Darstellung	Vertikalschnitt Außenwand mit textlicher Beschreibung
Maßstab	M 1:20
Maßangaben	Keine Maße und Bemaßungen
Tragende Schicht	Holzständer
Anzahl der Bauteilschichten	< 10

Zeichnerische Darstellung und Informationsgehalt	
Präzision der Zeichnung und Lesbarkeit	Ansprechende grafische Gestaltung Reduktion auf das Wesentliche Verständlichkeit und Nachvollzierbarkeit
Hierarchie	Keine Differenzierung von tragender und nicht tragender Schichten
Darstellung der Funktionen	Keine zeichnerische Darstellung von Modularität, Rückbaubarkeit und Montage-/Demontageprozesse
Archivierung/Dateigrundlage	Digitale Dokumentation

Materialkriterien	Zeichnung	Text
Sortenreinheit	↗ ✓	✓
Zusammensetzung Inhaltstoffe, Schadstoffe, Emissionen	✓	↗
Nachwachsende Rohstoffe	↗ ✓	↗ ✓
Rezyklate	✓	✓
Umweltwirkungen	✓	✓
Lebensdauer	✓	✓
Instandhaltung- und Reparaturanfälligkeit	✓	✓
Rücknahme	✓	✓
Wieder- und Weiterverwendung	✓	✓
Recyclingverfahren	✓	✓

Fügetechnologien	Zeichnung	Text
Verbindungstechnik	✓	✓
Reversibilität	✓	✓
Flexibilität	↗	↗
Materialgerechte Trennung	↗ ✓	↗ ✓
Wiederverwendbarkeit der Komponente	✓	✓
Prozess der Demontage	✓	✓
Beschädigung der Materialschichten durch Fügetechnik	✓	✓

Legende
✓ Angaben vorhanden
↗ Teilweise Angaben vorhanden / Potenzial
／ Keine Angaben vorhanden

Abbildung 3: Bewertung des Informationsgehalts eines Details hinsichtlich der Kreislauffähigkeit[36]

In den Details wurden Angaben zu den vorgesehenen Materialien und den verwendeten Fügetechniken gemacht. Im dazugehörigen Textteil wurde beschrieben, ob es sich um abbaubare, biologische oder sortenreine Materialien[37] [38] handelt. Ebenso liegt die Information vor, wie die Materialien gefügt werden z.B.

[33] Heinlein, F.: Recyclable by Werner Sobek. Stuttgart, 2019
[34] Seggewies, J.; Riegler-Floors, P. et al.: Atlas Recycling. München, 2018
[35] Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023
[36] Eigene Darstellung auf Basis von: Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S.138-139
[37] Seggewies, J.; Riegler-Floors, P. et al.: Atlas Recycling. München, 2018

ob es sich um einen losen Verbund, das Auflegen oder Klemmen handelt[39] [40]. Diese Informationen bieten eine wichtige Grundlage, um die Umsetzung kreislaufgerechter Konstruktionsmethoden zu verstehen und die Eignung der Materialien sowie ihre Verbindungstechniken im Hinblick auf Wiederverwendbarkeit und Demontierbarkeit zu interpretieren.

In einem weiteren Vergleich wurden historische Konstruktionsatlanten aus den Jahren 1960 bis 1981[41] [42] [43] herangezogen, um die dort angegebenen Materialien und verwendeten Verbindungsmittel in den Details zu analysieren. Auffallend ist die Schlichtheit der Details und auch die bewusste Einfachheit in der Materialwahl, die heute vermehrt in Projekten des „Einfachen Bauens“[44] erneut Anwendung finden. Konstruktionsweisen in Massivbau- als auch Stahlbetonbauweise halten sich in der Anzahl der Bauteilschichten reduziert. Details in Holzbauweise entsprechen dem Grundsatz der heutigen Holzrahmenbauweise. Die Untersuchung der historischen Details ergab, dass in den ausgewählten zeichnerischen Darstellungen die Materialien als auch spezifische Verbindungselemente angegeben wurden. Ein Vergleich der Details zeigt, dass sowohl die Konstruktionsweise als auch die Materialwahl auf einem sehr einheitlichen Ansatz basieren. Es lässt sich davon ausgehen, dass in den 1970er Jahren eine bewusste Sparsamkeit im Umgang mit Verbindungsmitteln herrschte. Dies ist darauf zurückzuführen, dass die Verbindungselemente zu dieser Zeit als ebenso wertvoll und ressourcenintensiv, wie die verwendeten Baumaterialien selbst angesehen wurden. Die damalige praxisorientierte Haltung reflektiert ein Verständnis der Bautechnik, das Materialeinsatz und Ressourcenschonung in den Mittelpunkt stellte, was im Kontext der Kreislaufwirtschaft auch heute zunehmend mehr von Bedeutung wird. In den Detailzeichnungen wurden teilweise Verbindungen so gestaltet, dass sie die Wiederverwendbarkeit und Flexibilität der Bauwerke unterstützten, ohne unnötige Materialressourcen zu verschwenden. Diese Herangehensweise unterstreicht die damalige Sensibilität für den sparsameren Umgang mit materiellen Ressourcen und die nachhaltige Nutzung von Materialien. Daraus kann abgeleitet werden, dass ein einfaches und ressourcenschonendes Bauen aufgrund der Knappheit der Ressourcen und der Sparsamkeit in den 1970er Jahren und in den Jahren zuvor erfolgte.

3.2 Detailierungsgrad als Herausforderung

Unterschiedliche Detailierungsgrade publizierter Detailzeichnungen in den Konstruktionskatalogen und in der Fachliterur weisen unterschiedliche Detailierungsgrade von Materialien und Fügetechnologien im Maßstab M 1:20 auf. Je kleiner der Maßstab, desto schwerer ist es, eine Aussage über die Kreislauffähigkeit des Details treffen zu können. Für die kreislaufgerechte Planung ist in der Entwurfsphase der Detailierungsgrad als Standard für die Erstellung der Detailzeichnungen sowie dessen Maßgrößen anzupassen. Eine Darstellung der Details im Maßstab M 1:100 oder kleiner kann kaum dazu beitragen, die kreislaufspezifischen Prinzipien zu verorten. Für das kreislaufgerechte Planen sollten Detailzeichnungen im Maßstab M 1:20 oder größer bereits in der frühen Entwurfsphase angefertigt werden, sofern sie in die architektonische Gestaltung einfliesen und eine Rolle spielen sollen.

Die Analyse zeigt auch, dass die in den zeichnerischen Details enthaltenen Angaben für die breite Umsetzung in der Entwurfsphase (HOAI-Leistungsphase 3 in Deutschland) für das kreislauffähige Konstruieren von Relevanz sind, jedoch nicht als verbindlicher Planungsstandard gelten. Trotz ihrer Bedeutung für die praktische Umsetzung kreislauffähiger Prinzipien wird der Detailierungsgrad nicht systematisch in den Publikationen angewendet. Dies weist darauf hin, dass die Integration kreislaufspezifischer Anforderungen in den Planungsprozess noch nicht in den Bereichen der Architekturplanung etabliert ist. Insbesondere ist es häufig so, dass solche Details in der frühen Planungsphase nicht zwangsläufig in den Standardprozess aufgenommen werden, was die Umsetzung

[38] Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023
[39] Seggewies, J.; Riegler-Floors, P. et al.: Atlas Recycling. München, 2018
[40] Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023
[41] Kemmerich, C.: Graphische Details für Architekten. Stuttgart, 1968
[42] Ahnert, R.; Krause, K.-H.: Typische Baukonstruktionen von 1860 bis 1960. Berlin, 2009
[43] Schmitt, H.: Hochbaukonstruktion. Die Bauteile und das Baugefüge. Grundlagen des heutigen Bauens. Braunschweig, 1981
[44] Technische Universität München: Einfach Bauen, 2025: https://www.einfach-bauen.net/. Online eingesehen am 28.01.2025

nachhaltiger Bauprinzipien erschwert. Die fehlende Verbindlichkeit und der unzureichende Standardisierungsgrad dieser Informationen stellen eine Herausforderung für die flächendeckende Implementierung der Schlüsselaspekte dar.

4 ERGEBNISSE

Der Darstellungs- und Informationsgehalt eines zeichnerischen Details hat direkten Einfluss auf die Kreislauffähigkeit, da diese die Grundlage für deren Präzision und Aussagekraft bildet. Der Abgleich der ausgewählten Details mit den ermittelten Schlüsselaspekten zu Materialeigenschaften und den Fügetechniken zeigten teilweise Defizite in der Darstellung auf. Dies lässt sich auf den entsprechenden Jahrgang als auch den Fokus in der Ausrichtung der Architektur sowie auf die gesetzlichen Rahmenbedingungen zurückführen. Aus den gewonnenen Erkenntnissen der Analyse lassen sich folgende Ergebnisse ableiten, die zugleich als Grundlage für konkrete Handlungsempfehlungen dienen:

4.1 Erforderliche Darstellung von Materialeigenschaften und Fügetechniken

Ein zentraler Schritt in der Förderung der Kreislauffähigkeit der Architektur besteht in der präzisen Auswahl sortenreiner Materialien und der durchdachten Definition von Fügetechnologien. Die korrekte und vollständige Angabe von Materialien und Fügetechnologien in den zeichnerischen Details ist dabei von entscheidender Bedeutung. Verbindungsmittel und Fügetechniken müssen im Detail definiert werden und eine gleichwertige Berücksichtigung im Kontext der eingesetzten Materialien erfahren. Fehlen Angaben zu den Fügetechnologien, entstehen Unsicherheiten hinsichtlich der Fügbarkeit und Trennbarkeit der Materialien. Dies stellt die ausführenden Unternehmen als auch die Bauleitung vor Herausforderungen, da sie nicht eindeutig erkennen können, welche Technologien an der entsprechenden Stelle angewandt werden sollen, und behindert so eine konsequente Umsetzung der Kreislaufwirtschaft.

Zur Vervollständigung der zweidimensionalen Zeichnung sind die Fügetechnologien als eigenständige Schicht hinzuzufügen, analog zur Materialschicht, da ihr Informationsgehalt für die Kreislauffähigkeit von Bedeutung ist.

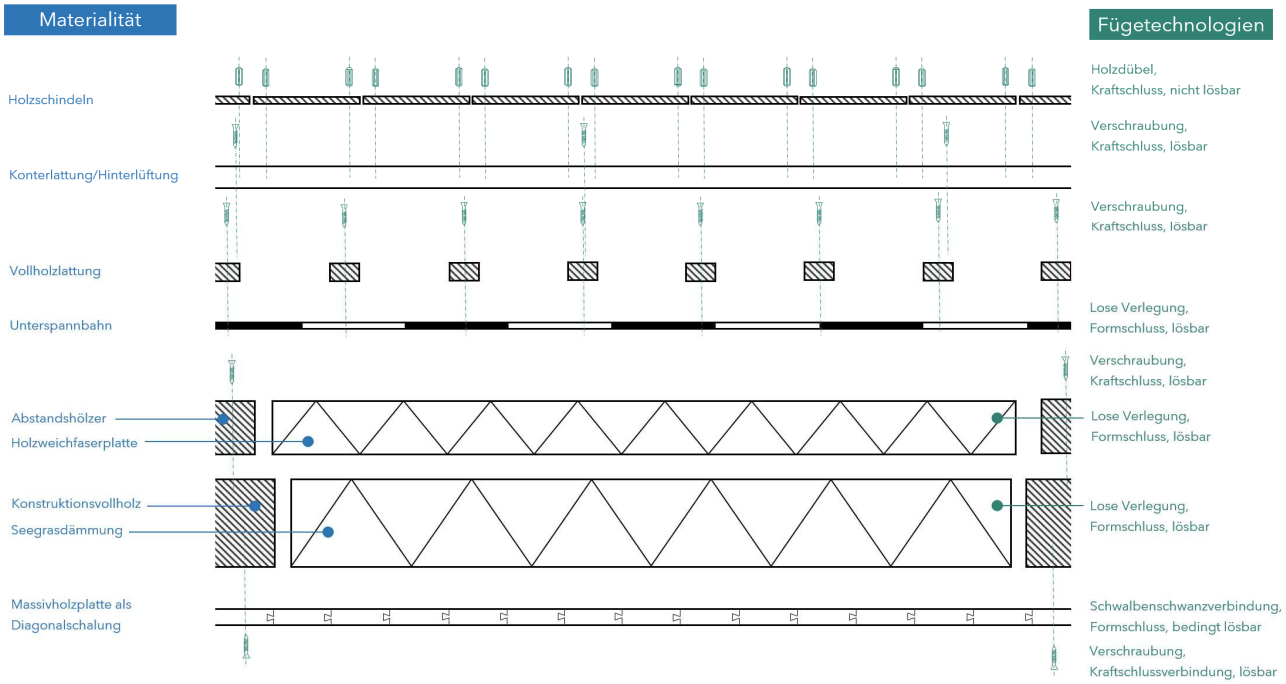


Abbildung 4: Fügetechnologien als eigenständige Informationsebene einer zweidimensionalen Horizontalzeichnung einer Außenwand[45]

Wie die Abbildung 4 zeigt, werden Fügetechnologien als eigenständige Informationsebene in der Detailzeichnung dargestellt, um ihren spezifischen Informationsgehalt in der Konstruktion deutlich

[45] Eigene Darstellung auf Basis von: Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S.138-139

hervorzuheben. Der erweiterte Informationsgehalt der Details kann eine spätere Trennung und Rückführung der Bauteile in den Materialkreislauf ermöglichen. Neben der klassischen zweidimensionalen Zeichnung bieten sich auch andere Darstellungsformen an, um die Fügetechnologien zu visualisieren. Beispielsweise kann eine dreidimensionale Zeichnung genutzt werden, um die Verbindungen und Fügetechniken in einer räumlichen Perspektive darzustellen, wodurch deren Funktion und Wechselwirkungen noch anschaulicher und greifbarer werden.

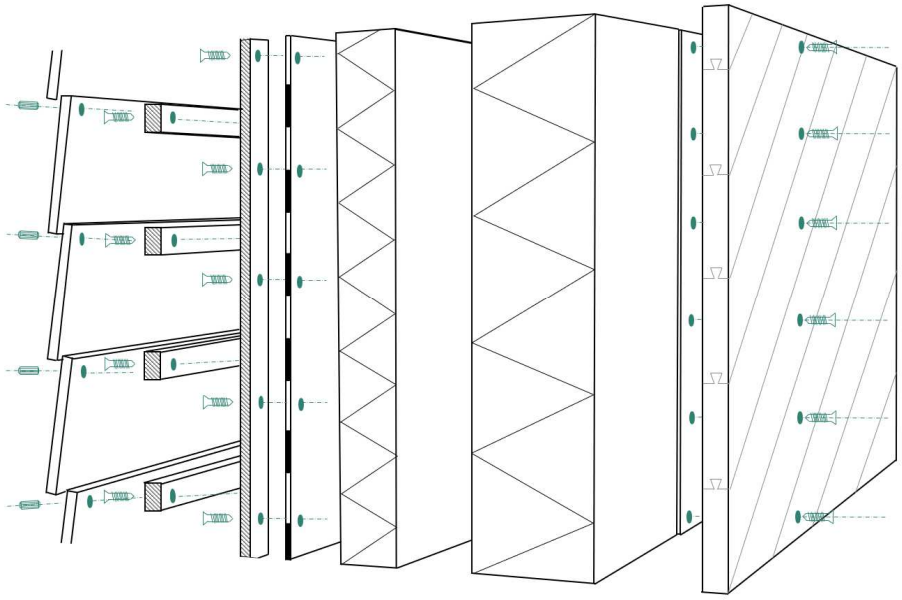


Abbildung 5: Fügetechnologien als eigenständige Informationsebene einer dreidimensionalen Detailzeichnung (maßstabslos)[46]

Eine Vorderansicht der vorgesehenen Materialschichten ermöglicht, die Schäden an den Materialien durch den potenziellen Aufschluss darzustellen und die Folgen der Demontageprozesse zu verdeutlichen. Des Weiteren verbessert diese Darstellungsweise auch den Informationsgehalt der vorgesehenen Fügetechniken.

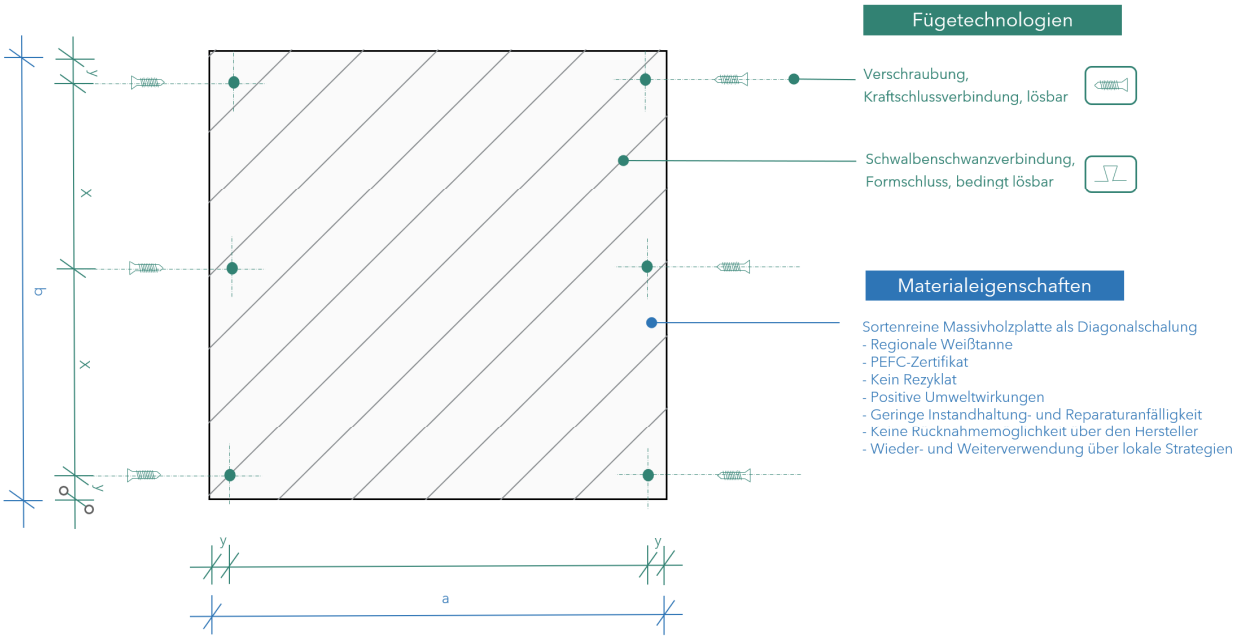


Abbildung 6: Vorderansicht einer sortenreinen Massivholzplatte als Diagonalschalung (maßstabslos)[47]

[46] Eigene Darstellung auf Basis von: Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S.138-139

Um die Auswirkungen der Demontage auf die Wiederverwendbarkeit oder Recyclingfähigkeit der Materialien besser bewerten zu können, sind zusätzliche Perspektiven auf das Detail bereits in der Entwurfsphase erforderlich. Weitere Anregungen zur zeichnerischen Detailierung sowie der Darstellung des Informationsgehaltes für Materialien und Fügetechnologien sind in den Tabellen 1 und 2 zu entnehmen.

4.2 Integration kreislaufspezifischer Aspekte in die Entwurfsplanung

Um die Kreislauffähigkeit von Materialien sicherzustellen, ist es unerlässlich, spezifische Eigenschaften der Materialien und Fügetechnologien bereits in der Entwurfsphase zu berücksichtigen. Diese Phase bietet die größte Flexibilität zur Verankerung kreislauffähiger Prinzipien in architektonischen Details, da in späteren Planungsphasen, insbesondere ab der Werkplanungsphase Änderungen an Konstruktionen oder Materialien nur bedingt umsetzbar sind. Der Grund hierfür liegt im fortgeschrittenen Planungsstand, der wenig Spielraum für grundlegende Anpassungen bietet. Die Verlagerung der konstruktiven Gestaltungselemente, die traditionell in der Werkplanung entwickelt werden, in die Entwurfsphase erfordert eine Umstrukturierung des Planungsprozesses (siehe Abbildung 3). Daher ist es erforderlich, den Anteil der konstruktiven Gestaltung, der üblicherweise in der Werkplanung (HOAI-Leistungsphase 5, Deutschland) erfolgt, in die Entwurfsphase (HOAI-Leistungsphase 3, Deutschland) vorzuverlagern.

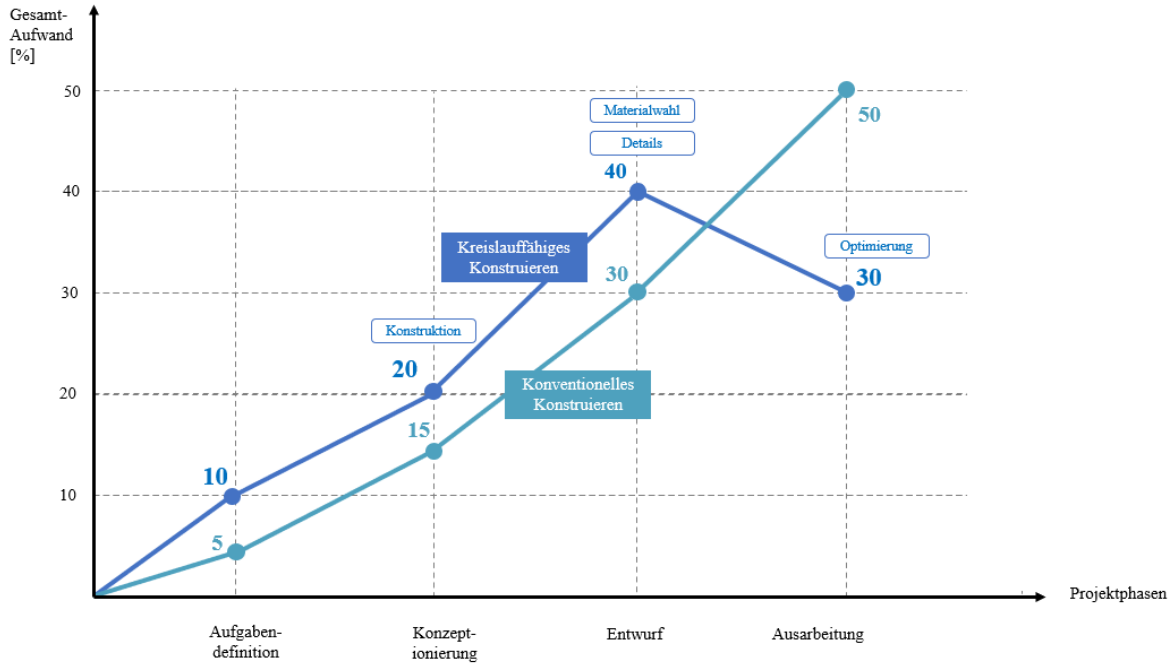


Abbildung 7: Vergleich konventionelles vs. kreislauffähiges iteratives Entwerfen

Dies ermöglicht eine frühzeitige Berücksichtigung und Optimierung von Material- und Konstruktionsentscheidungen im Hinblick auf ihre Kreislauffähigkeit. Die Verlagerung kann jedoch dazu führen, dass die Entwurfsphase verlängert wird, was im Planungsprozess entsprechend berücksichtigt werden sollte. Diese Maßnahme ermöglicht eine frühzeitige Optimierung hinsichtlich der Materialwahl, Fügetechnologien und Konstruktionstechniken, um die spätere Demontierbarkeit und Wiederverwendbarkeit der Bauteile sicherzustellen. Der verlängerte zeitliche Umfang der Entwurfsphase, der durch diese Verschiebung entstehen kann, sollte als strategische Investition in die Qualität und die Nachhaltigkeit des Bauvorhabens betrachtet werden.

4.3 Wissens- und Informationstransfer mittels kreislaufgerechter Detailzeichnung

Die Detailzeichnung stellt ein zentrales Kommunikations- und Planungsinstrument für das kreislauffähige Konstruieren dar, das über die rein dokumentarische Funktion hinausgeht. Sie ermöglicht die präzise Visualisierung der Anforderungen an die Kreislauffähigkeit eines Bauwerks und dient der übersichtlichen Darstellung technischer und gestalterischer Vorgaben. Auf diese Weise trägt sie wesentlich dazu bei, dass

[47] Eigene Darstellung auf Basis von: Hebel, D.; Wappner, L. et al.: Sortenrein bauen – Material, Konstruktion, Methodik. München, 2023. S.138-139

alle beteiligten Akteurinnen und Akteure ein gemeinsames Verständnis der Planungsziele entwickeln und Verantwortlichkeiten für die Ausführung klar definiert und nachvollziehbar festgelegt werden können. Die Schließung von Materialkreisläufen setzt voraus, dass die relevanten Informationskreisläufe vollständig und systematisch in den Planungsprozess integriert werden. Dazu gehört die Erstellung von Details im Maßstab M 1:20 während der Entwurfs- und Ausführungsplanung, die alle wesentlichen Angaben zu den verwendeten Materialien und Fügetechniken enthalten. Solche Details dienen nicht nur als Dokumentationsinstrument für eine Revisionsplanung, sondern auch als Grundlage für die spätere Nachverfolgbarkeit und Wiederverwendung von Bauteilen mittels eines Gebäuderessourcenpasses (vgl. DGNB-Ressourcenpass[48]).

Ein hoher Darstellungsgehalt in Zeichnungen mit den wesentlichen Informationen kann eine höhere Aussagekraft als ein schriftlicher Teil haben. Besonders Zeichnungen, die den Beschädigungsgrad der Materialschichten darstellen, sind von entscheidender Relevanz – sowohl für Architekten als auch für die Nutzer und spätere Rückbauunternehmen. Sie ermöglichen eine präzise Einschätzung der verfügbaren Ressourcen und helfen, die Wiederverwendbarkeit und Rezyklierbarkeit von Materialien zu beurteilen, wodurch eine fundierte Planung für zukünftige Umnutzungen oder den Rückbau ermöglicht wird.

5 SCHLUSSFOLGERUNG UND AUSBLICK

Die Analyse zeigt, dass in allgemein gültigen und materialspezifischen Konstruktionskatalogen die publizierten Bauteile weder kreislauffähig konstruiert noch nach den wesentlichen Schlüsselaspekten der Kreislauffähigkeit dargestellt worden sind. In weiterführender spezifischer Fachliteratur zum kreislauffähigen Bauen zeigt sich im Vergleich zu den Konstruktionskatalogen, eine Entwicklung im Darstellungsgrad von Informationen in der Zeichnung als auch in der textlichen Beschreibung der Details über die laufenden Jahre. Die wünschenswerten und erforderlichen Angaben in den Publikationen zur Kreislauffähigkeit haben Auswirkungen für Studium, Lehre und Praxis. Im digitalen Zeitalter gilt es, die zeichnerische Darstellungen von Materialschichten und Verbindungsmittel darzustellen und die Interaktion im zeichnerischen Entwurfsprozess aufzunehmen.

Es kann die Aussage getroffen werden, dass ein iterativer Entwurfsprozess, der die Sichtweise der Entwerfenden auf die Ansätze des kreislauforientierten Konstruierens einbezieht, ein wesentlicher Schlüssel zur Förderung der Wiederverwendung und zirkulären Nachnutzung von Konstruktionen darstellt. Idealerweise geht dem Entwurfsprozess die Gestaltung eines innovativen kreislauffähigen Konzeptes voraus, dass die Schlüsselaspekte für das kreislaufgerechte Entwerfen, die Darstellung und Dokumentation der Details beschreibt. Ein strategisches innovatives kreislauffähiges Konzept ist eine grundlegende und hilfreiche Unterstützung, dass die Entwicklung von Bauteilen definiert, die später in den jeweiligen Kreislauf für Produkte oder Materialien überführt werden können. Das Konzept umfasst übergeordnete Aspekte, um die Ziele der Kreislaufwirtschaft zu erreichen. Hierbei ist es entscheidend, dass die Materialwahl, die Konstruktionstechniken und die Fügung der Bauteile konzeptionell beschrieben werden, um eine Wiederverwendbarkeit zu fördern. Ein solches Konzept ist in der Vorentwurfsphase zu erstellen und erfordert die frühzeitige Integration in den interaktiven Design- und Entwurfsprozess. Eine erfolgreiche Implementierung eines kreislaufgerechten Konzeptes setzt eine systemische Denkweise voraus, die sowohl ökologische als auch ökonomische Potenziale der Kreislaufwirtschaft nutzt und in den gesamten Planungs- und Bauprozess integriert.

Als Ausblick kann festgehalten werden, dass die Entwicklung kreislauffähiger Bauteile einen Paradigmenwechsel in der Entwurfsplanung der Konstruktion erfordert. Durch die konsequente Berücksichtigung von Demontierbarkeit und Materialtrennung können bereits in der frühen Planungsphase sowohl ökologische als auch wirtschaftliche Vorteile erzielt werden. Eine verstärkte Fokussierung auf die Qualität der Detailplanung bietet die Möglichkeit, den Lebenszyklus von Baumaterialien zu verlängern und gleichzeitig den Ressourcenverbrauch zu minimieren. Die Umsetzung solcher Strategien erfordert eine enge Zusammenarbeit zwischen Architektinnen und Architekten, Ingenieurinnen und Ingenieuren sowie Herstellern sowie eine verstärkte Einbindung von Normen und Richtlinien, die die Prinzipien der Kreislaufwirtschaft unterstützen. Die konsequente Umsetzung solcher Strategien erfordert nicht nur eine

[48] Deutsche Gesellschaft für Nachhaltiges Bauen: Gebäuderessourcenpass, 2025: https://www.dgnb.de/de/nachhaltiges-bauen/zirkulaeres-bauen/gebaeuderessourcenpass#c2969, online eingesehen am 28.01.2025

Anpassung bestehender Planungsprozesse, sondern auch eine stärkere Schulung und Sensibilisierung der beteiligten Akteurinnen und Akteure.

6 HINWEIS

Für sprachliche Übersetzungen wurde der Onlinedienst DEEPL https://www.deepl.com/ herangezogen. Im Arbeitsprozess wurde für das Auffinden der Forschungslücke als auch nach der Recherche von Fachliteratur auch auf die Unterstützung der künstlichen Intelligenz zurückgegriffen. Dabei wurden die Chatbots CHATGPT https://chatgpt.com/ und SEMANTICSCHOLAR https://www.semanticscholar.org/ verwendet.

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Are Modular Transport Units the Answer for Tomorrow's Cities?

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1 ABSTRACT

The transformation in mobility is driven by electrification and automation. This paper examines a shared mobility system that utilizes small, driverless pods for transporting passengers and goods, assessing its efficiency, economic feasibility, and environmental impact.

We model the assignment of vehicles totrips as a Single Load Pickup and Delivery Problem with Time Windows (SLPDPTW) and present an Integer Linear Programming (ILP) formulation. Additionally, a heuristic approach is proposed to optimize trip assignments and the benefit of slipstreaming. We conduct computational experiments based on case studies from Austria to simulate various levels of adoption.

The results indicate that there could be a reduction of up to 75% in the number of vehicles required. However, increased mileage can offset some of these benefits. While slipstreaming improves efficiency, the energy savings it provides remain uncertain. The economic viability of this system depends on reducing the per-kilometer costs of the pod, which may be achievable with advancements in technology.Automated shared mobility presents significant promise but also encounters challenges realted to sustainability and cost-effectiveness. Future research should explore larger vehicles, improved routing, and market developments.

Keywords: combinatorial optimisation, fleet size and mix, automated shared fleets, planning, mobility

2 INTRODUCTION

After multiple years or even decades of almost no paradigm change in mobility, we might face a disruptive evolution in mobility culture. Two main developments contribute to this effect: electrification and automation. The breakthrough in electrification is based on developments related to chemistry and physics, i.e., increasing energy density in batteries facilitating long-range electric vehicles. Automation is closely related to developments in new and advanced sensors and the ability to process and analyze the obtained data. Ironically, the automation of the automobile might finally come to completion. According to the Oxford English Dictionary automobile refers to self-moving [1]. Current technological developments raise hopes that self-driving cars will soon be the majority on our roads. Almost all modern cars are already equipped with some kind of driver-assisting technology, which ranges from parking assistants over lane keeping assist systems and cooperative adaptive cruise control to systems supporting overtaking [6]. However, such systems are designed to be assistants. That is, the driver of the car still has to be the driver. He has to be aware of the traffic situation all the time and needs to be able to intervene at any time. In many countries, regulations are even more strict. For example, in Austria, it is required that the driver has to have at least one hand on the steering wheel all the time [7]. However, exceptions exist according to the "Automatisiertes Fahren Verordnung" [8], enabling automated mobility in exceptional cases for testing and development.

In Phoenix, San Francisco, and Los Angeles (all USA), robotaxisare already serving customers regularly [2]. In Hamburg, it is planned to introduce a fleet of 10,000 "autonomous" electric shuttles. However, please note that one has to be careful when using the word autonomous in conjunction with vehicles. Usually, it is referred to as automated mobility. I.e., vehicles that can drive along a pre-defined path according to a set of learned rules. However, no autonomous decisions can be taken in case of (major) disruptions like unforeseen roadwork or even obstacles like broken-down vehicles. One strategy to overcome this is to allow for remote control of the vehicles in case of disruptions [4]. The benefits are evident as the number of personnel needed for vehicle operations can be significantly reduced. However, there are even ideas to at least introduce AI-based methods for supporting the human tele-operators [5].

Another trend that is already state-of-the-art in mobility is car-sharing. The basic principle of car-sharing is that cars are available (either at dedicated stations or free-floating), can be pickedup by customers, used for

one (or more trips), and then are returned (either at dedicated stations or free-floating) such that the next customer can use the car. In fact, car-sharing is an extended version of car rental with way fewer bureaucratic hurdles during pick-up and return. Nevertheless, authentication during pick-up and one-time registration is still necessary.

2.1 Concepts for Automated Shared Vehicles

When combining the concepts of car-sharing and automated mobility, two possible options can be followed: First, a more evolutionary approach would be that the basic car-sharing concept is applied, which comprises of users walking to the shared cars, picking them up, and returning them at specific locations. In combination with automated mobility, the driving process would be automated. I.e., the used is only passenger and not driver.

Second, and (technologically) more advanced, the pickup and return process is transferred to the car. I.e., a car-sharing user calls a car that picks up the user. When returning the car, the user gets off the car and does not further care where and how the car is parked. Instead, the car automatically searches a parking lot.Obviously, the second approach corresponds to a classical taxiservice without taxi drivers.

2.2 Contributions of this Paper

In this paper, we focus on the assessment of the second option for combination of automated mobility and car-sharing, i.e., the driver-less taxi service. However, the following assumptions are made. We assume that

- the used vehicles, called pods in the further context, provide space for at most two persons or one pallet of goods.
- the pods can be virtually connected while driving. I.e., they can build convoys. Pods can enter or leave convoys at any time without significantly interrupting the movement of the other pods in the convoy.
- pods can be used for both passenger and freight transport. It is not possible for goods and people to be transported in a pod at the same time. However, a person can be transported first and immediately afterwards a pallet can be transported (and vice versa).
- a significant number of passengers and good transports are shifted from conventional vehicles towards pods.

We assess the impacts of this change in mobility behavior concerning to the number of vehicles needed, the economic viablity, and the environmental impact. This is done via optimizing the assignment of pods to trip demand. The underlying ILP model and a basic heuristic for solving large-sized instances are presented. Based on computational experiments conducted for three potential application areas, conclusions are drawn.

2.3 Related Works

According to the ITF (International Transport Forum) [11], it is assumed that an autonomous (shared) fleet can reduce the number of needed vehicles by 90%. However, this study does not consider concurrent trips, as this work does.In [17], the authors assume that one car-sharing vehicle might replace 5 to 20 unshared vehicles.

In [9], Alessandrini et al. investigate the potential for shared automated fleets in the urban context. While the results are quite promising with respect to the expected number of saved lifes, reductions in fuel consumption, etc., they envisage a share of 50% of automated cars in approx. 2050 and 100% in 2070. However, their assessments are based on estimations, while this work focuses on applying an optimized vehicle-to-trip assignment.

In [12], the authors adress a real-world scheduling problem of automated shuttles. The underyling problem addressed is a dynamic pick-up and delivery problem which needs to be solved with a fleet of automated vehilces. The given problem is tackled with a large neighborhood search-based approach. Challenging is the fact that vehicles on the road might influence each other as maneuvers like overtaking are not possible for the chosen automated fleet.

Related but not directly significant for this work, the authors of [10] evaluate an average occupation rate of 1.3 persons per car in Austria. It has to be kept in mind, that autonomous vehicles will significantly reduce

this number, mainly if they are employed as envisioned in this work where (empty) cars are called to pick up customers.

3 PROBLEM FORMULATION

In this work, the given road network is a directed graph $G = (V, A)$, which consists of a set of nodes $N = \{0, \dots, n\}$ and a set of arcs A, representing the road segments between a pair of nodes $a_{\{i,j\}} \in A$ and $i, j \in N$.Each arc $a_{\{i,j\}} \in A$ has travel costs $c_{\{i,j\}}$ assigned. Furthermore, we consider a set of trip demands$D$, which represents the commuting distances from a given origin to a given destination. Thus, each trip demand$d \in D$ consists of an origin and destination node pair$\{r_d, s_d\}$, with $r_d, s_d \in N$, having a maximum load of two. The set of all origin and destination nodes is defined as$R \subseteq N$. Additionally, the earliest start time for the demand at the origin is available by e_{r_d}, and the latest end time at the destination is given by l_{s_d}.Since all trip demands must be completed without combining them with other trips, we model the problem as a *single load pickup and delivery problem with time windows (SLPDPTW)* [20]. There, all load from the origin must be transported directly to its destination, which causes empty moves between the destination and the origin of the next trip demand.For directly arriving at the destination, the shortest cost path between each pair of nodes $\{i, j\} \in R$ is computed as$\hat{c}_{ij}$. Furthermore, there is a set of pods P available to serve the given the number of trip demands.Each pod $p \in P$has a maximum capacity of two units. However, the capacity constraint can be neglected in this work, since demand combination is not allowed. Although this is not allowed, pods must not take the shortest path from the origin to the destination.This allows pods to take alternative paths. To prevent excessive deviation from the shortest path, a maximum allowed detour $\hat{T}$is defined, which must not be exceeded.

The SLPDPTW formulated in this work aims to serve all trips with the minimum number of pods while considering the time constraints, such as earliest start time, latest end time, and maximum allowed detour. The second objective is tomaximize the positive effects of slipstreaming while operating the pods. In a conventional traffic system with conventional vehicles, a minimum distance must be maintained between vehicles for safety reasons. However, for the pods considered in this work, it is feasible to form convoys in which two or more pods can benefit from slipstreaming, thus reducing energy consumption. This is possible because it is assumed that the pods can communicate with each other, cf. [14].Therefore, the overall goal is to minimize the number of pods (to reduce costs) while simultanously maximizing the formation of convoys(to enhance energy efficiency).Since defining a convoy in this dynamic environment cna be complex, we opted to maximize the slipstream kilometers of all vehicles. Note, that if only one vehicle is in a convoy, no slipstream kilometers are counted. However, every vehicle from the second onward in a convoy benefits from the slipstream effect, allowing for straightforward computation of slipstream kilometers.

$$x_{pd} = \begin{cases} 1 & \text{if pod } p \text{ fulfills demand } d \\ 0 & \text{otherwise} \end{cases} \qquad \forall p \in P, d \in D$$

$$b_p = \begin{cases} 1 & \text{if pod } p \text{ is used at least once} \\ 0 & \text{otherwise} \end{cases} \qquad \forall p \in P$$

$$y_{pd}^{ta} = \begin{cases} 1 & \text{if pod } p \text{ enters arc } a \text{ at time } t \text{ to fulfill demand } d \\ 0 & \text{otherwise} \end{cases} \qquad \forall p \in P, a \in A, d \in D, t \in T$$

$$z_{pq}^{ta} = \begin{cases} 1 & \text{if pods } p \text{ and } q \text{ are entering arc } a \text{ at time } t \\ 0 & \text{otherwise} \end{cases} \qquad \forall p, q \in P, p < q, a \in A, t \in T$$

Figure 1: Variables used in the ILP model.

$$\min \sum_{p\in P} b_p - \sum_{p\in P}\sum_{q\in P}\sum_{\substack{a_{ij}\in A\\ i,j\in N}}\sum_{t\in T} z_{pq}^{ta_{ij}} \tag{1}$$

$$\text{subject to} \quad \sum_{p\in P} x_{pd} = 1, \qquad \forall d \in D \tag{2}$$

$$b_p \geq x_{pd}, \qquad \forall p \in P, d \in D \tag{3}$$

$$b_p \leq b_{p-1}, \qquad \forall p \in P \setminus \{1\} \tag{4}$$

$$\sum_{t\in T} y_{pd}^{ta_{ij}} \leq x_{pd}, \qquad \forall p \in P, d \in D, a_{ij} \in A, i, j \in N \tag{5}$$

$$\sum_{\substack{a_{ij}\in A\\ i,j\in N}} y_{pd}^{ta_{ij}} \leq x_{pd}, \qquad \forall p \in P, d \in D, t \in T \tag{6}$$

$$\sum_{p\in P}\sum_{t\in T} y_{pd}^{ta_{ij}} \leq 1, \qquad \forall a_{ij} \in A, i, j \in N, d \in D \tag{7}$$

$$\sum_{\substack{a_{ij}\in A\\ i,j\in N}}\sum_{d\in D} y_{pd}^{ta_{ij}} \leq 1, \qquad \forall p \in P, t \in T \tag{8}$$

$$\sum_{p\in P}\sum_{t\in T}\sum_{\substack{a_{ik}\in A\\ k\in N\setminus\{i\}}} y_{pd}^{ta_{ik}} = 1, \qquad \forall i = r_d \in R, d \in D \tag{9}$$

$$\sum_{p\in P}\sum_{t\in T}\sum_{\substack{a_{kj}\in A\\ k\in N\setminus\{j\}}} y_{pd}^{ta_{kj}} = 1, \qquad \forall j = s_d \in R, d \in D \tag{10}$$

$$1 - \sum_{d'\in D}\sum_{t'}^{\bar{T}} y_{pd'}^{t'a'_{ij}} \geq y_{pd}^{ta_{ij}} \qquad \forall p \in P, t \in T, d \in D, d \neq d',$$

$$a_{ij}, a'_{ij} \in A, \bar{T} = t + c_{ij}, i, j \in N \tag{11}$$

$$\sum_{p\in P}\sum_{i\in N\setminus\{s_d\}} y_{pd}^{t'a_{ik}} \geq y_{pd}^{ta_{kj}} \qquad \forall p \in P, t \in T, d \in D, a_{kj} \in A,$$

$$k \in N \setminus \{r_d, s_d\}, j \in N \setminus \{r_d\},$$
$$t' = t - c_{a_{ik}}, t' \geq 0 \tag{12}$$

$$\sum_{p\in P}\sum_{t\in T}\sum_{\substack{a_{ki}\in A\\ k\in N\setminus\{i\}}} y_{pd}^{ta_{ki}} = 0, \qquad \forall i = r_d \in R, d \in D \tag{13}$$

$$\sum_{p\in P}\sum_{t\in T}\sum_{\substack{a_{jk}\in A\\ k\in N\setminus\{j\}}} y_{pd}^{ta_{jk}} = 0, \qquad \forall j = s_d \in R, d \in D \tag{14}$$

$$1 - \sum_{d'\in D}\sum_{k\in N}\sum_{t'}^{t} y_{pd'}^{t'a_{ks_{d'}}} \geq y_{pd}^{ta_{r_dk}} \qquad \forall p \in P, t \in T, a_{r_dk} \in A,$$

$$k \in N \setminus \{r_d\}, d \in D, d \neq d',$$
$$t' = max(0, t - (\hat{c}_{s_{d'}r_d} + c_{ks_{d'}})) \tag{15}$$

$$\sum_{d\in D} y_{pd}^{ta} + \sum_{d\in D} y_{qd}^{ta} - 1 \leq z_{pq}^{ta} \qquad \forall p, q \in P, p < q, a \in A, t \in T \tag{16}$$

$$\sum_{q\in P} z_{pq}^{ta} \leq \sum_{d\in D} y_{pd}^{ta} \qquad \forall p \in P, p < q, a \in A, t \in T \tag{17}$$

$$\sum_{p\in P} z_{pq}^{ta} \leq \sum_{d\in D} y_{qd}^{ta} \qquad \forall q \in P, p < q, a \in A, t \in T \tag{18}$$

$$\sum_{p\in P}\sum_{t\in T}\sum_{a_{ik}\in A} t \cdot y_{pd}^{ta_{ik}} = f_d \qquad \forall d \in D, i = r_d \in R, k \in N \setminus \{r_d\} \tag{19}$$

$$\sum_{p\in P}\sum_{a_{kj}\in A}\sum_{t=0}^{\bar{T}} (t + c_{kj}) \cdot y_{pd}^{ta_{kj}} = g_d \qquad \forall d \in D, j = s_d \in R, k \in N \setminus \{s_d\},$$

$$t \in T, \bar{T} = l_{s_d} - c_{a_{kj}} \tag{20}$$

$$f_d \geq e_{r_d} \qquad \forall d \in D, k \in N \setminus \{r_d\} \tag{21}$$

$$g_d \leq l_{s_d} \qquad \forall d \in D, k \in N \setminus \{s_d\} \tag{22}$$

$$\hat{c}_{r_ds_d} \leq (g_d - f_d) \leq \hat{T} \qquad \forall d \in D \tag{23}$$

Figure 2: The constraints of the ILP model.

We formulate the SLPDPTW model as an integer linear program. Therefore, we introduce the variables and the ILP formulation as shown in Figures 1 and 2.The objective is to minimize the total number of used pods and maximize the number of pods using the same arc at the same time (1). Constraint (2) ensures that each trip demand is fullfilled by exactly one pod. Constraint (3) enables pod p if it fullfills at least one demand and (4) allows pod p to be only enabled if podp-1 is active (symmetry break). Constraint (5) states that for a pod and a trip demand an arc can be used only once over time. Constraint (6) determines that a pod which

fullfills a demand enters an arc exactly once at exact one time.Constraint (7) expresses that each arc is used exactly once for a demand independent of the pod and time), and (8) expresses that each pod is used exactly once at a time, independent of the arc and the demand. Constraint (9) and (10) ensure that there is exactly one outgoing arc at the origin node of a demand and exactly one ingoing arc at the destination node. Constraint (11) ensures that a pod is not used for other demands while traversing an arc.Constraint (12) ensures the consistency of a path between origin and destination node. Constraint (13) and (14) ensure that there is no ingoing arc at the origin node and no outgoing arc at the destination node of a trip demand, because only paths from origin to destination are constructed instead of tours, and (15) ensures that there is enough time (at least the shortest path costs) to get the pod from the destination node to the origin node of the next trip demand. Two pods transporting different demands entering the same arc at the same time is stated in (16), while (17) and (18)force it to zero if this is not the case. Constraint (19) determines the begin time at the origin node and (21) ensures that this is after the given earliest allowed start time. And (20) and (22) determine the begin time at the destination and ensure that this is before the latest allowed end time. Finally, constraint (23) checks if the travel cost from the origin to the destination does not exceed the maximum allowed detour.

4 ALGORITHMIC APPROACH

The solving capability of the implemented ILP approach is quite limited when it comes to the size of the instances. It is not feasible to manage a road network with a large number of trip demands and with a planning horizon of one day while achieving a timely resolution within seconds. Therefore, we have also developed a heuristic algorithm for solving the SLPDPTW.

The heuristic begins by assigning pods to the trip demands. First, it preprocesses the data to calculate the shortest cost path from the origin to the destination for all trip demands. It then sorts the list of trip demands according to their earliest start time. Next, the greedy heuristic generates a starting solution by sequentially assigning the trip demands with the shortest path costs using a first-fit insertion method, while adhering to their earliest start and latest arrival times. If no feasible insertion can be found for a trip demand, it will be assigned to a new pod.

After establishing the starting solution, it is evaluated in terms of slipstreaming, which involves calculating the total slipstreaming travel costs for all pods and trip demands. We determine for each trip demand when the edges of their respective paths must be entered to maintain a feasible solution. This results in a map that records, for each visited edge, a list of trip demands that traverse that edge, along with a time window indicating possible entry times. The entries in this list serve as potential candidates for slipstreaming. In the subsequent step, the heuristic combines trip demands for slipstreaming if their entry time windows overlap. When overlap occurs, the time windows for all affected entries in the map must be updated. This involves reassessing all edges of the paths for the trip demands, as well as for any other trip demands that are already slipstreaming with them. Once all time windows for edge entry times are updated, the number of slipstreaming pods for all edges can be computed, and this number is then multiplied by the respective travel costs.

The objective is to improve slipstreaming, even if it results in additional travel time. To achieve this, we assess alternative routes for each trip demand, ensuring that these alternatives do not exceed the maximum allowed detour costs. The heuristic method involves ten iterations, during which we randomly select alternative travel paths for all trip demands and verify whether the solution is still feasible within the constraints of the earliest start and latest end times. If a proposed solution is not feasible, we retain the shortest cost path in the solution set. Following this, we evaluate the slipstreaming costs. Ultimately, the solution that maximizes slipstreaming, along with its corresponding paths (whether they are the shortest or alternatives), is returned as the final solution.

5 EXPERIMENTAL SETUP

The computational experiments conducted in this study are based on three showcases taken from Austria: IZ NÖ Süd (an industrial area in the south of Vienna), Vienna Airport region, and the triangle Korneuburg-Floridsdorf-Gerasdorf (a suburban region in the north of Vienna). We used the traffic network, statistics on commuting behaviour [15], and land use information [16] for each of these regions to generate instances mimicing real-world characteristics.Trip demand generation involves determining an origin, a destination,

and a desired departure time for each trip. Within the study area, origins and destinations are randomly selected based on land use patterns [16]. Specifically, commuter trips originate or terminate in residential or commercial zones. For trips that begin or end outside the study area, origins or destinations are designated as access points, which include highway entrances and public transit stations. The distribution of these access points between highway entrances and transit stations is strategically designed to reflect the observed modal split, informed by statistical data [15]. Departure times are also assigned based on statistical distributions [15]. For trips based on freight transports, a similar approach was chosen, although the numbers are based on educated estimations according to experience of the authors and the project partners. We refer to Table 1 to summarize the statisticsconsidered for the further used showcases. Please note that they are named A1, A2, and A3 as they are only based on the areas as mentioned above, but the results are not representative of these areas as some assumptions (e.g., freight transport) need to be made.

Based on these statistics, the following instances have been generated: For each area A1, A2, and A3, we assume that only 5%, 10%, 20%, 30%, and 40% of the people are willing to switch to the proposed pods. For each percentage, 20 instances have been randomly generated (based on the above mentioned statistics) resulting in an overall of 300 instances, which have been solved using the described heuristic approach.

In order to compare the impact of considered pod-based system, two comparisons are made. First, the overall number of pods is compared to the overall number of vehicles needed to satisfy all the trip demands. We consider that all freight trips are done via trucks. As the load unit for freight trips is considered to be pallets, the numbers given in Table 1 need to be divided by 33, i.e., the number of pallets to be loaded on a truck. For the commuters, we need to assume that each individual traveller uses his or her own car. That is, for example, that for A1 20,900 cars are needed to satisfy the trip demands done via car.

The second comparison is on the actual costs associated with the trips. For this purpose, we calculate the costs of the individual trips in the status quo based on the Austrian statutory mileage allowance, which is 0.52€/km.

	area [km^2]	commuters	freight (pallets)	avg.MIT [%]
A1	2.7	22,000	3,800	95
A2	73.0	37,750	9,700	87
A3	70.0	125,330	14,000	88

Table 1: Basic statistical data for the considered showcases. The area corresponds to the overall area in the showcase. Commuters, as well as freight, include inbound and outbound trips per day, and avg.MIT denotes the modal split for motorized individual traffic (MIT).

6 COMPUTATIONAL RESULTS

As described in the previous section, 300 randomly generated instances have been used for our computational experiments. Each of the instances has been solved using the proposed heuristic approach, as the exact model presented is not powerful enough to solve instances of these sizes.

In Figure 3-5 the obtained results are shown. For each showcase, the number of vehicles before the switch and the number of pods afterwards are shown in the left diagram (avg #cars vs. avg #pods). In addition, the relative reduction in the number of vehicles is shown. It can be seen that for the smallest instance (A1) only 56% reduction in cars could be achieved. For the larger instances up to 75% could be achieved. That is, the potential is enormous. At the same time, this number is in line with numbers found in the literature for car-sharing concepts, cf. [17].

In addition, we show on the right side of Figure 3-5 the comparison of the vehicle travel time. The red bar indicates the travel times (of vehicles) in the current situation. Vehicles are used for only one trip before being parked. The grey bar indicates the travel times of the pods. Please note that pods need to travel with the passenger (or goods), theytravel empty to the origin of the next trip demandand in addition, might take detours during occupied travel in order to profit from slipstreams. Therefore, the overall travel time of pods is longer. At the same time, slipstream travelling can be done (indicated by the purple bar). This is not possible for individual cars due to safety reasons). The line indicates how much energy consumption (compared to conventional trips) are "allowed" during slipstream travelling such that the pods system does not consume more energy than the conventional system. It can be clearly seen that this allowed energy

consumption significantly raises with the relative share of pod users. However, values are still quite low with a maximum of about 30%.

Please note that computational times for the heuristic are up to about two hours for the largest instances which is quite low compared to the observation that these computations are needed just once when planning the introduction of such a system.

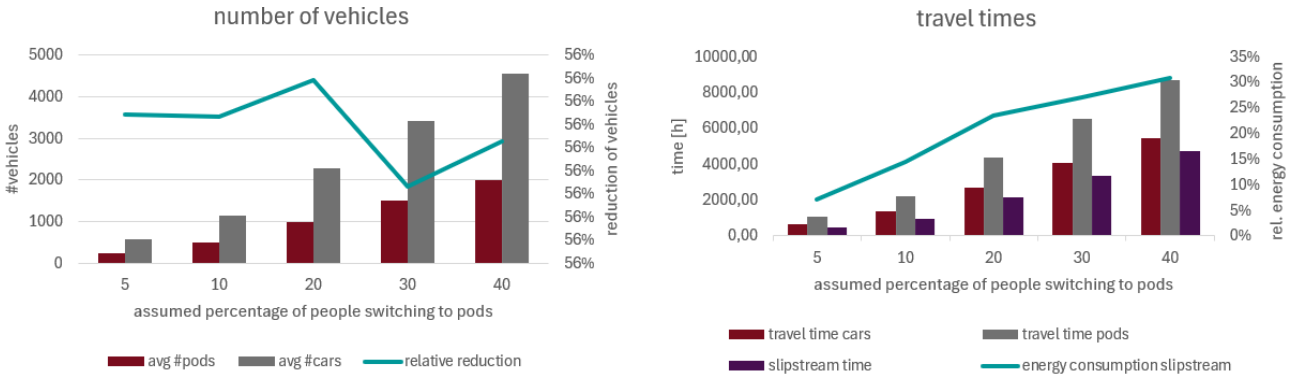

Figure 3: Showcase A1; comparison of the number of vehicles (left); comparison of the travel times (right)

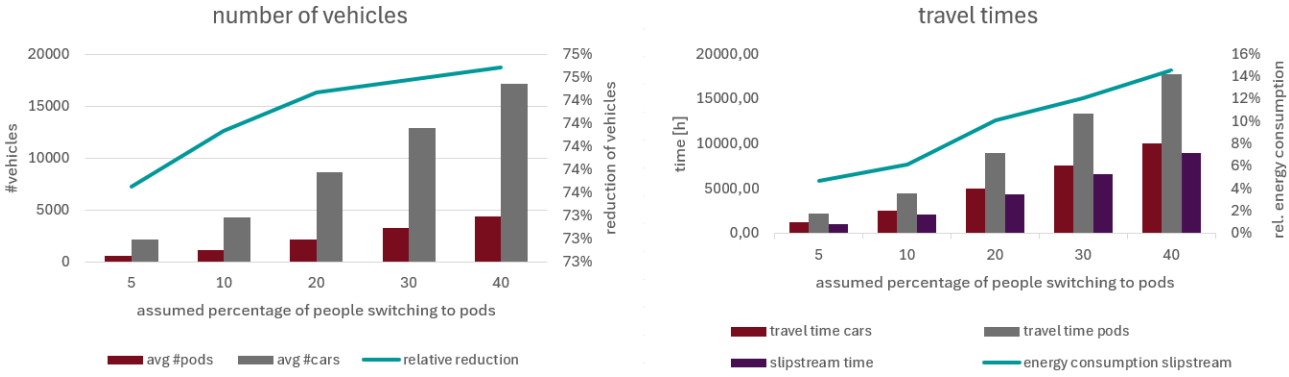

Figure 4: Showcase A2; comparison of the number of vehicles (left); comparison of the travel times (right)

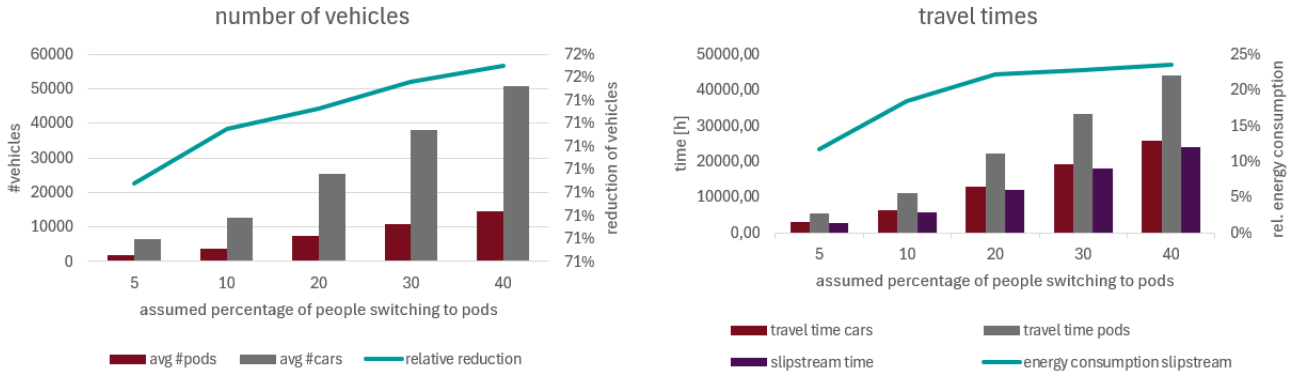

Figure 5: Showcase A3; comparison of the number of vehicles (left); comparison of the travel times (right)

7 ECONOMIC ASSESSMENT

While in Section 6 only traffic related evaluations are done, this section tries to focus on the economic part of the proposed system. A detailed assessment is quite hard, as many different options have to be considered. Therefore, a first estimate is tried within this section.

First, we compute the value for the overall travel costs according to the Austrian statutory mileage allowance, which is currently at 0.52€/km. As can be seen in Table 2, the costs range for the chosen test instances from around €9,000 to €335,000 per day on travel costs.

For the proposed pod-based mobility system, the maximum costs per kilometer such that the system is still economically viable (compared to the status quo) can be computed based on the costs of the current system divided by the distance to be traveled by the pods. As can be easily seen in Table 2, the economic viability of

the system is only given if the per-kilometer costs are far below the currently assumed costs for conventional vehicles.

Therefore, we made a short calculation trying to obtain a range of realistic cost values per kilometer for the operation of the pods. Based on a price list for renting pods [18], we obtained a range of 0.26€/km to 0.38€/km which indicates that operation at the economic break-even point might be realistic but strongly depends on the further development of the pod market.

	% of pod users	costs conventional (per day) [€]	resulting maximum costs per km for pods [€]
A1	5	8,800	0.32
	10	17,600	0.32
	20	35,300	0.32
	30	52,900	0.32
	40	70,500	0.32
A2	5	16,400	0.29
	10	32,800	0.29
	20	65,400	0.29
	30	93,100	0.29
	40	131,000	0.29
A3	5	42,000	0.30
	10	83,800	0.30
	20	167,700	0.30
	30	251,600	0.30
	40	335,300	0.30

Table 2: Estimated costs per day for trips using the conventional traffic system or the introduced pod-based mobility system.

8 SUMMARY AND CONCLUSIONS

Within this work, we proposed the introduction of a car-sharing system incorporating automated vehicles referred to as pods. These pods are considered to be rather small such that at most two persons or one pallet can be loaded. Based on three real-world motivated showcases, we assessed the traffic related as well as the economic impact. It can be easily shown that even when applying an optimized scheduling of vehicles to trip demands, additional mileage (compared to the status quo) needs to be covered by such a system. At the same time, the number of vehicles can be reduced by up to 75%. Further, it could be shown that such a system might benefit from the ability to use slipstream effects. However, due to the additional mileage, the energy consumption of the vehicles in the slipstream should be at most 30% compare to the energy consumption of vehicles not profiting from slipstreams. Although, it is necessary to evaluate whether such values can be achieved for pods, studies for trucks indicate that these values are far below realistic boundaries as for trucks energy savings in platooning are about 30% maximum [19].

The economic assessment revealed that the per-kilometer costs of conventional cars compared to the per-kilometer costs of automated pods can be much higher in order to obtain the same total system costs (related to travel). Based on prices promoted by one pod producer automated cars are much more expensive than conventional ones. Nevertheless, the first estimates show that the necessary cost reduction for per-kilometer prices could be achieved with automated pods. However, it is necessary to perform a further analysis considering costs for parking space and other effects as well. This is left for future work.

To summarize, from the current viewpoint it is very unlikely that a fully automated pod-based mobility system is ecological/traffic-related viable. From an economic point of view, the break-even point might be reached.However, it is necessary to further investigate whether different pods (e.g., larger with more bundling potential) could have a positive effect. In addition, future prices of pods might significantly drop, which could lead to more economic options.

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reviewed paper

Assessing the Effects of Road Infrastructure on Rural Mobility and Development: A Bibliometric Review

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1 ABSTRACT

A critical issue developing countries globally face is insufficient investment in road infrastructure, particularly in rural areas, where the lack of reliable road networks significantly makes development in these areas almost stagnant. Rural roads in these regions are often poorly constructed, predominantly consisting of gravel surfaces, unlike the paved roads commonly found in urban centres. This disparity creates substantial challenges in attracting private-sector funding or forming effective public-private partnerships for infrastructure development. Rural roads frequently lack proper signage and are inadequate for large-scale public transport, restricting mobility and accessibility. The absence of high-quality road networks not only limits public transport industry growth but also exacerbates transport challenges in these areas. Moreover, rural road infrastructure is often disconnected from national or regional networks, further isolating rural populations from urban centres and marginalizing them from opportunities for development. This paper explores the negative consequences of neglecting rural road infrastructure, focusing on its impact on rural development and economic growth. It also identifies key issues such as the lack of threshold densities for collective public transport and explores alternative solutions, including pilot projects implemented in developing countries. A bibliometric analysis will be conducted to uncover key research trends, identify gaps in existing literature, and highlight policy recommendations to address systemic inadequacies in rural road infrastructure. The study emphasizes the need for enhanced connectivity between rural and national/regional transport networks to support the rural economy, create development opportunities, and improve access to essential services like healthcare and education. Furthermore, the research underscores the importance of community empowerment in ensuring road development projects meet quality standards and are maintained properly.

Keywords: infrastructure neglect, transport challenges, rural road infrastructure, public transport, Community empowerment

2 INTRODUCTION

The development of any region relies heavily on well-developed road infrastructure particularly in rural areas which need frontier accessibility and connectivity as essential elements for economic expansion and social improvement (Bacior and Prus 2018). However, several obstacles exist within the scope of rural road infrastructure. Rural roads within developing countries fail to achieve basic development standards because they receive inadequate construction and maintenance services (Hemson et al., 2004). These situations worsen transportation difficulties, especially for people who reside in sparsely populated areas because they lack proper access to basic amenities such as healthcare services, educational opportunities, and economic prospects. Therefore, the paper reviews the literature of rural road infrastructure problems and the significant matter regarding inadequate threshold densities in collective public transport systems. We will examine proposed alternative solutions which have been implemented together with pilot projects developed in rural areas with local communities involved in transport planning activities.

3 DEFICIENCIES IN RURAL ROAD INFRASTRUCTURE

This section discusses the analysis of rural road infrastructure problems because road networks form the basis that determines rural transport system outcomes.

3.1 Poor Construction and Maintenance of Rural Roads

The major problems with rural road infrastructure include inadequate road construction quality and insufficient maintenance practices (Hauya, 2019). Developing countries maintain poor-quality road infrastructure, and some contain gravel surfaces which fail to support significant vehicle traffic. These paths remain exposed to all environmental hazards. Severe deterioration through erosion flooding and multiple other degradation processes that shorten their operational time and reduce their effectiveness is being experienced (Zhang and Alipour, 2020). Several regions experience premium road deterioration combined with landslides because their drainage systems are insufficient, their soil stabilization methods are weak, and their structural designs insufficient. The heavy rains of rainy seasons make unpaved roads impossible to travel, causing extensive mobility challenges. The problem runs severe in distant or mountainous areas because natural climate events, including heavy precipitation and snowy conditions, cause roads to disappear or develop deep tracking, which leads to unsafe travel conditions.

3.2 Lack of Connectivity to National and Regional Networks

The insufficient connection between rural road systems with national and regional road networks is another problem (Kanuganti et al., 2017). Rural roads face a significant problem because they do not link properly with the larger national and regional road networks. Personnel in rural areas face transportation hurdles because their roads lack connections to central transportation systems, which creates barriers to urban service access (Yu and Zhao, 2021). The absence of integration between rural road networks leads to deepening regional isolation because rural areas cannot execute economic processes or reach markets for their products (Aduda and Kalunda, 2012). The limited road connections to wider transportation networks create significant challenges to rural businesses. Farmers encounter transportation challenges when trying to move goods to urban markets because of poor road conditions, leading to price increases, wasted perishable products, and lost business prospects. This further hinders access to economic regional growth opportunities which restricts business expansion. Only limited access to extensive supply chains prevents rural industries from becoming large-scale operation.

3.3 Insufficient Infrastructure for Collective Public Transport

The transportation infrastructure shortfalls in rural regions negatively influence the implementation of public collective transportation networks (Pojani and Stead, 2015). The operation of public transport needs extensive roads that enable buses together with minibuses and alternative mass transit options. The road deficiencies, insufficient signage, and limited road capacity prevent collective transportation development, thus blocking mobility improvement and affordable public transit options for rural residents (Cervero et al., 2017). Economically sustainable public transportation becomes impossible to maintain because rural areas lack threshold densities (Hauya, 2019). Rural areas with low populations face such expensive bus and other public transit operation costs that small investments become unlikely to recover while maintaining dependable transport services remains challenging (Kanuganti et al., 2017).

3.4 Road Safety and Limited Infrastructure for Non-Motorized Transport

The absence of proper signage combined with insufficient road markings diminishes pedestrian infrastructure at rural areas thus causing severe road safety problems (Hauya, 2019). Deficiencies in road safety systems result in more accidents since pedestrians and cyclists, along with motorcycles, endure the highest risk on these roads. Lack of safety infrastructure discourages people from using present roads or public transport, which eventually restricts mobility in rural areas and deepens isolation for residents (Porter, 2014).

4 CAUSES OF THE DEFICIENCIES IN RURAL ROAD INFRASTRUCTURE

This section covers the causes of the deficits in rural road infrastructure. Once the root causes are understood, very targeted and effective solutions can be applied to overcome such problems; otherwise, most interventions will either be superficial or misdirected in nature.

4.1 Limited Investment and Budget Constraints

Budgetary constraints combined with low financial support create the main reason behind rural road infrastructure deficiencies in developing nations especially (Briceño-Garmendia et al., 2009). Governments

make budget decisions to fund urban infrastructure instead of funding rural areas because they deem urban centres to generate better direct contributions towards GDP growth. The funding dedicated to building and maintaining rural roads is usually insufficient or entirely absent which produces subpar infrastructure capability for rural growth (Magolie, 2024). However, the DRT systems in rural areas have failed to maintain financial stability as their main operational challenge. DRT systems were designed to cost less than public transportation, but the actual monetary gains are normally insufficient to cover operational expenses (Briceño-Garmendia et al., 2009). With low and unreliable rider numbers in rural areas, the fare-based revenue is inadequate to sustain the ongoing operations of the service.

4.2 Geographic and Economic Isolation of Rural Areas

Rural locations frequently exist in distant regions limiting their ability to obtain private investments. Lower population density, together with small markets in rural areas, reduces private firms' motivation to construct transport infrastructure (Hauya, F.K., 2019). Rural populations spread thinly across the land create challenges to building public transport networks because insufficient ridership numbers fail to match viability requirements.

4.3 Political and Institutional Challenges

Political mirrors, together with other factors, drive the limited growth of rural road networks. Rural regions throughout numerous nations typically receive little favours from political forces because these areas lack sufficient political power, so infrastructure development suffers as a result (Nelson, 2017). The combination of deficient institutional structures with weak governance practices and corrupt practices stops funds from reaching their intended purpose which blocks rural road development and upkeep.

5 ALTERNATIVE SOLUTIONS AND PILOT PROJECTS

Several pilot and alternative solutions across the globe were tested to overcome the perennial challenges that beset road infrastructure. These ranged from increasing road access to rural areas and other neglected niches to cutting down transportation costs and enhancing their overall quality. Many such pilot projects, therefore, focus on learning from possible ways to overcome the limitations that have traditionally dogged infrastructure development by venturing on innovative paths such as Demand- Responsive Transport, community-driven projects, Non-Motorized Transport Infrastructure, public-private partnerships and other sustainable construction methods. Therefore, this section investigates some of these initiatives.

5.1 Demand-Responsive Transport (DRT) Systems

The problem of low rural population density makes Demand-Responsive Transport systems (DRT) stand out as a flexible and budget-friendly answer. The transportation system operates using small vehicles including minibuses and shared taxis which adapt their operations based on immediate passenger requests instead of using predetermined schedules (Bacior and Prus, 2018). DRT systems provide suitable solutions for rural areas because they can operate efficiently based on inconsistent ridership patterns and the density of populations that do not support mass public transportation (Junaid and Ferretti, 2022). DRT pilot initiatives implemented in South Africa and Kenya have proven that these systems work effectively in rural areas, thus providing expanded mobility solutions to rural inhabitants.

5.2 Community-Based Transport Systems

Transport systems that rely on community management offer solutions for rural transport deficiencies. Local communities oversee systems that use minibuses, tuk-tuks, and local shuttle services for community management (Chondo, 2021). These transport systems use local insights and resources to provide rural populations with flexible but inexpensive modes of transport. Local community-based transport solutions in Tanzania and Uganda clarify that both community stakeholders and system administrators need active support from national administrators for centralized transport control to succeed (Rwigema, 2022)

5.3 Non-Motorized Transport Infrastructure

Basic walking and cycling infrastructure development constitutes an economical sustainability method for rural transportation systems. Public transport shortages lead people to choose non-motorized transport solutions to move over short distances. Rural pilot projects have installed bicycle-sharing schemes while

building pedestrian-friendly roads to increase mobility between essential services such as educational facilities and healthcare facilities.

5.4 Public-Private Partnerships

The development of rural road infrastructure receives major benefits through Public-Private Partnership (PPP) initiatives. Private investments in public programs create benefits that let governments strengthen rural roadway development programs and maintenance systems (Nallathiga, 2022). Public-private partnerships have become extensively successful in Latin America and numerous African regions through their improvements of road infrastructure and public transit systems (Kang et al., 2019). The framework elements established by rural stakeholder partnerships must include proper restrictions to ensure better services and access delivery to rural communities.

6 EFFECTIVENESS OF PILOT PROJECTS IN RURAL AREAS

Implementing pilot projects seeking rural transport improvements in developing countries has resulted in multiple outcomes, with some succeeding and others facing challenges. Two notable transport systems, Kenya's DRT system and Tanzania's shared minibus services, receive recognition because they solve problems of rural communities regarding mobility restrictions, market accessibility, and economic separation (Karema, 2021). The implemented projects activated wider access to vital public services, including healthcare facilities, medical care educational establishments and employment benefits. The transport system has produced money-making possibilities by employing drivers alongside conductors and other technical staff, which supports the local economy (Karema, 2019).

The initiatives encounter substantial barriers while trying to sustain their operations and make them scalable (Jackson, 2022). Most pilot projects survive through temporary grants and donor funding but face continued operation challenges after the external support ends. These services risk becoming unsustainable because they lack proper funding strategies and weak financial management systems. When a pilot project succeeds in a particular geographic area, expansion to new regions demands a successful resolution of logistical difficulties that include building necessary infrastructure and purchasing equipment (Siemens, 2010). Rural regions heavily depend on transportation systems that exist beyond official planning systems, including motorbike taxis and private vehicles. A new system should merge with informal networks yet maintain affordability to serve the rural population. The design of minibuses and DRT systems should focus on serving rural communities because their mobility patterns diverge substantially from urban areas (Bacior and Prus, 2018).

7 COMMUNITY INVOLVEMENT IN TRANSPORT PLANNING

Various experts claim that rural transport infrastructure failed due to the absence of rural community participation during planning decisions (Hauya, 2019). Rural populations receive inadequate participation in transport project planning steps, which leads to their development without proper consultation. When communities are not involved in the decision-making process, the infrastructure does not fulfil genuine rural needs; therefore, adoption levels decrease, and services become ineffective.

The complete involvement of local communities proves essential to creating transport solutions that fit population requirements, sustain them over time, and earn their acceptance (Roseland, 2012). Community participation in rural transport system planning and management demonstrated its effectiveness based on Ugandan and Ghanaian pilot experience. Transport system delivery becomes more successful through community involvement because people help shape services according to regional requirements while developing community ownership and commitment to lasting outcomes.

8 METHODOLOGY

This research investigates literature development through bibliometric review based on academic data from web of science databases. The research depends on organized methodologies for collecting data that involves both analysis of networks and data processing to reveal details about road infrastructure academic work (Donthu et al., 2021).

The authors starts by doing a database search for academic articles through Web of Science. The field identification uses multiple keywords that include "road infrastructure," "rural development," "transport

challenges," and "public transport." The data processing stage involves cleaning irrelevant items such as editorials and book reviews and non-academic articles after obtaining relevant article lists. The final collection includes 1496 publications. The noted bibliometric elements containing titles and authors and citations and keywords become eligible for subsequent research analysis.

The author uses VOSviewer for network visualization to show interactions between authors and publications and research themes. The software platform enables researchers to detect network patterns for co-authored, co-occurrences and co-citation networks and their spatial connections. Study findings revealed core aspects that appeared multiple times in these academic papers as well as key figures in the field of transportation.

9 PRESENTATION OF RESULTS

This section will present the findings of the study.

9.1 Publication and Citation Trend

The bibliometric review regarding road infrastructure and rural mobility grows more important due to its rising significance for developing areas. The scholarly interest during 1993 to 2013 rose significantly which led to higher publication rates and increased citations because research became theoretically grounded and interdisciplinary relevant. Overall expansion in the research field occurred despite temporarily fluctuating publication numbers between 2014 and 2019 because of changing priorities and novel transportation trends. 2020 marked the revival of rising trends that could have been triggered by extended research periods created by the COVID-19 pandemic. The steady increase in research citations demonstrates wider adoption of rural mobility findings by policymakers for developing transportation policies and resolving economic and sustainability problems. Road access plays an essential role in delivering linkages between rural settlements and enhances their economic bases while enhancing the standard of living for citizens in underdeveloped regions.

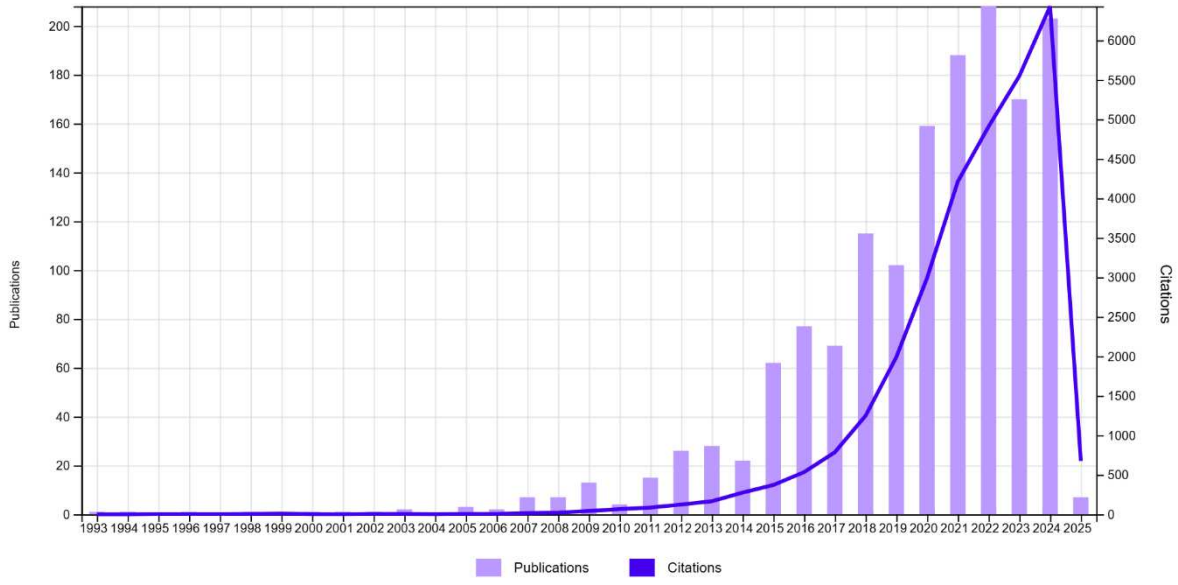

Figure 1: Publication and citation trend

9.2 Author Co-citation Analysis

The authors also focused on co-citation analysis to establish key research directions and contributions of the main authors in the field by the authors. Understanding the intellectual structure of knowledge demands the evaluation of influential authors and their network connections in this field (Song, Wu & Ma, 2021). The authors performed their analysis through co-citation methods while analysing cited authors as the basic units. The authors chose a minimum number of citations in this study of 5. The research included 1694 authors while meeting the criterion of 60 publications minimum. The obtained results present different levels of academic influence together with network connections between authors.

Research within the framework of co-citation network analysis is outlined into separate research clusters which correspond to rural road infrastructure and development topics studied in this paper. Studies on rural

transport accessibility challenges to marginalized communities are represented by the red cluster, which centres on De Vos and Ettema, along with additional authors. Research pertaining to transport planning and behavioural studies by Bamberg alongside Axhausen appears in the green cluster. Researchers Currie and Hickman operate within the blue cluster that investigates public transportation viability in low-density rural areas to address threshold density issues directly. Research on rural region economic development following infrastructure investment is represented by the studies conducted by Guzman and Borjesson who make up the purple cluster. Through this interpretation, the paper gains access to multiple intellectual structures, which enables it to conduct an all-encompassing analysis of rural road infrastructure betterment and development needs. These research fronts found in these clusters provide essential knowledge about community transportation solutions as well as community participation which help solve fundamental problems in the paper. This paper merges various theoretical approaches to advance a sophisticated comprehension of rural development challenges that can offer specific policy recommendations for sustainability.

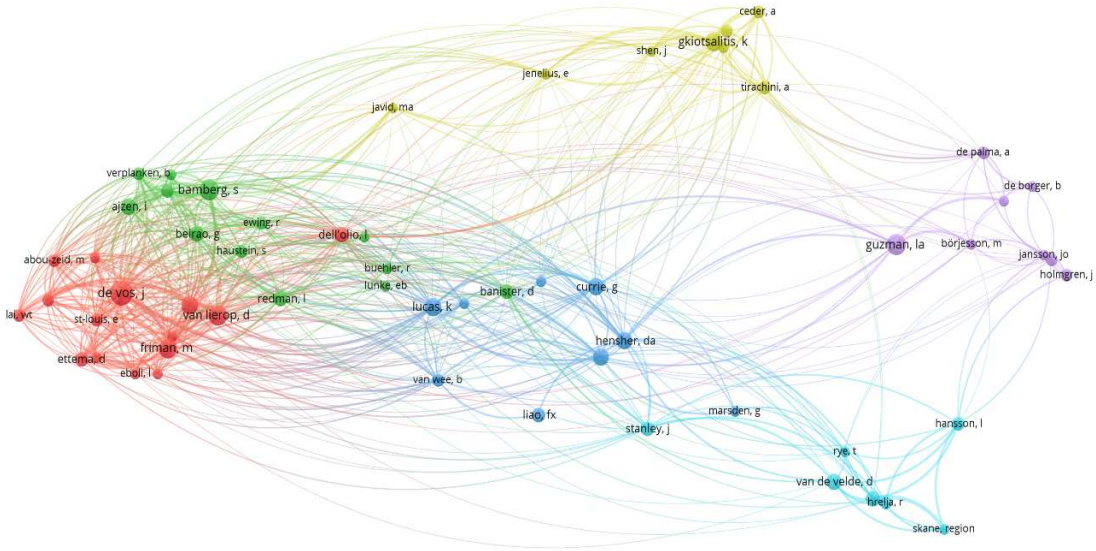

Figure 2: Author Co-citation Analysis

9.3 Co-citation of documents

Publication nodes possess a colour marking which identifies their assigned cluster affiliation, as indicated in Figure 3, which indicates the co-citation of document references. VOS viewer analysis shows that publications sharing identical colours in the network are co-cited frequently because they research related topics. VOS viewer implements computational methods to separate network items by analyzing how often they co-cite each other. The seven publications in Cluster 1 include AJZEN I, de Oña J, Dell'Olio I, Lai, W T, St-Louis E, Van Lierop D, and Ye, R. Cluster 2 features five publications with Beirão G, Ewing R, Lucas K, Redman I and Steg I. Cluster 3 comprises of three publications with Bamberg S, Shen J and Tirachini A.

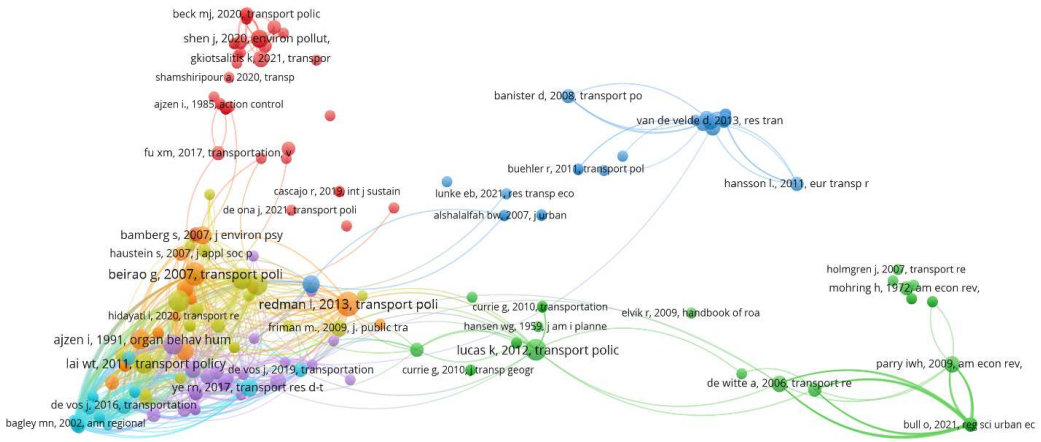

Figure 3: Co-citation of documents references

The co- document network analysis shows intellectual structures in the provided table that focus on public transport and travel behaviour within the rural road infrastructure development context of the paper. The total link strength between Beirão and Cabral (2007) and De Oña et al. (2013) indicates strong focus on investigating public transport attitudes and service quality perceptions because these elements are essential for addressing rural public transport challenges. Research from Van Lierop et al. (2018) and Dell'Olio et al. (2011) demonstrates how public transport service quality, together with the customer satisfaction factors, strongly influences public transport usage behaviour as well as addresses low threshold density problems. Research on behavioural intentions (Lai & Chen, 2011) and travel behaviour (Ye & Titheridge, 2017; Steg, 2005) offers valuable insights into how people make decisions because this knowledge is essential for developing suitable transport answers in rural areas. The paper reinforces its argument about rural population marginalization through an examination of social exclusion (Lucas, 2012) as well as the COVID-19 effects on public transportation systems (Shen et al., 2020). Therefore, the paper demonstrates its ability to utilize these theoretical frameworks to study the complex rural road infrastructure problems and develop solutions that evaluate user conduct together with wider economic effects. Such a combination of research areas within the paper will enable a wide-ranging examination of the issue followed by specific sustainability-oriented policies for rural development.

Article	Tot Link Strength
Beirão, G. and Cabral, J.S., 2007. Understanding attitudes towards public transport and private car: A qualitative study. Transport policy, 14(6), pp.478-489.	38
De Oña, J., De Oña, R., Eboli, L. and Mazzulla, G., 2013. Perceived service quality in bus transit service: a structural equation approach. Transport Policy, 29, pp.219-226.	37
St-Louis, E., Manaugh, K., van Lierop, D. and El-Geneidy, A., 2014. The happy commuter: A comparison of commuter satisfaction across modes. Transportation research part F: traffic psychology and behaviour, 26, pp.160-170.	34
Van Lierop, D., Badami, M.G. and El-Geneidy, A.M., 2018. What influences satisfaction and loyalty in public transport? A review of the literature. Transport Reviews, 38(1), pp.52-72.	34
Dell'Olio, L., Ibeas, A. and Cecin, P., 2011. The quality of service desired by public transport users. Transport Policy, 18(1), pp.217-227.	33
AJZEN, I., 1991. ORGAN BEHAV HUM DEC, V50, P179. DOI 10.1016/0749-5978 (91) 90020-T.	32
Lai, W.T. and Chen, C.F., 2011. Behavioral intentions of public transit passengers – The roles of service quality, perceived value, satisfaction and involvement. Transport policy, 18(2), pp.318-325.	32
Redman, L., Friman, M., Gärling, T. and Hartig, T., 2013. Quality attributes of public transport that attract car users: A research review. Transport policy, 25, pp.119-127.	31
Ye, R. and Titheridge, H., 2017. Satisfaction with the commute: The role of travel mode choice, built environment and attitudes. Transportation Research Part D: Transport and Environment, 52, pp.535-547.	29
Steg, L., 2005. Car use: lust and must. Instrumental, symbolic and affective motives for car use. Transportation Research Part A: Policy and Practice, 39(2-3), pp.147-162.	25
Bamberg, S., Hunecke, M. and Blöbaum, A., 2007. Social context, personal norms and the use of public transportation: Two field studies. Journal of environmental psychology, 27(3), pp.190-203.	21
Ewing, R. and Cervero, R., 2010. Travel and the built environment: A meta-analysis. Journal of the American planning association, 76(3), pp.265-294.	18
Lucas, K., 2012. Transport and social exclusion: Where are we now?. Transport policy, 20, pp.105-113.	10
Shen, J., Duan, H., Zhang, B., Wang, J., Ji, J.S., Wang, J., Pan, L., Wang, X., Zhao, K., Ying, B. and Tang, S., 2020. Prevention and control of COVID-19 in public transportation: Experience from China. Environmental pollution, 266, p.115291.	8
Tirachini, A., 2020. Ride-hailing, travel behaviour and sustainable mobility: an international review. Transportation, 47(4), pp.2011-2047.	8

Table 1: Co- document citation

9.4 Country collaboration analysis

Extended research on road infrastructure along with rural mobility development makes Sweden and England the leading powers in transportation studies as developed countries. The scholarly research reveals that Sweden has 10 documents and 192 citations and a total link strength of 14, following Canadian research composed of 4 documents with 460 citations and a total link strength of 12. The Netherlands became third with 7 documents, 376 citations and a total link strength of 11. There are 9 documents in England with a total of 155 citations and a link strength measurement of 8. Norway ranks fifth with 4 documents that accumulate 156 citations, while the total ink strength reaches 7.

The country collaboration network traces its primary connections to European countries which include Sweden together with Germany and Belgium along with the Netherlands. This intellectual framework demonstrates proven research connections among European nations that focus on transportation development regarding infrastructure development. The strong partnership among these countries demonstrates their mutual dedication to solving transportation problems which may include the rural road infrastructure issues evaluated in the paper. This international interest in the field extends beyond Europe since researchers from

Canada and Australia and China maintain relationships with their European counterparts. The paper would enhance its findings by studying European rural road infrastructure through case studies and policy analysis because these nations potentially achieved more sophisticated or delicate approaches in this field. The research demonstrates gaps in partnership alongside knowledge exchange with developing nations through its emphasis on European entities. The paper could enhance its value by studying and reporting regional linkages and knowledge transfer activities with developing world entities dealing with rural road infrastructure problems. Such an expanded knowledge base would enable better solutions that fit the specific requirements of developing nations.

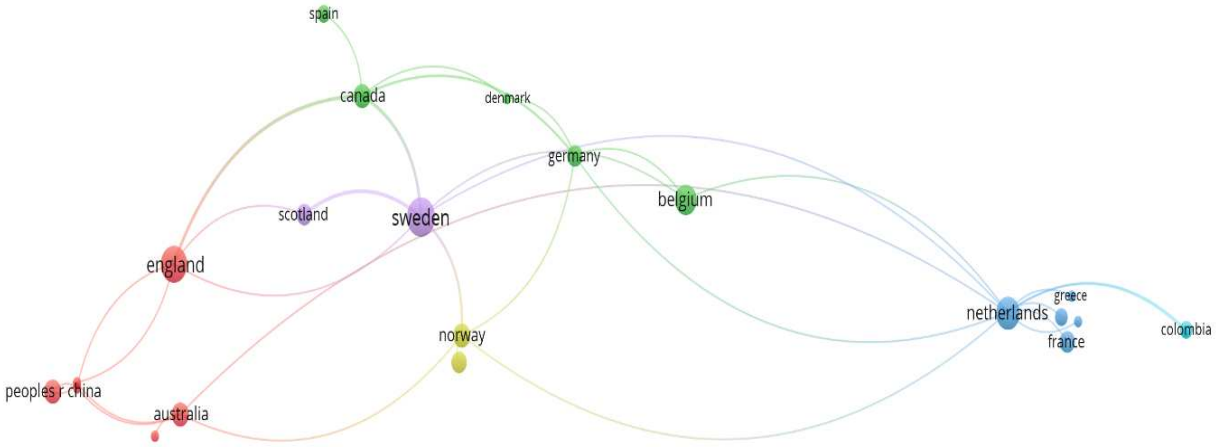

Figure 4: Country collaboration analysis

10 CONCLUSION

The poor condition of rural roads functions as an enormous obstacle for both mobility and regional economic expansion throughout rural developing regions. The lack of investment in construction and maintenance, poor connectivity to national and regional networks, and the absence of proper infrastructure for collective public transport all contribute to the isolation of rural populations. The effectiveness of alternative solutions like Demand-Responsive Transport and community-based systems and non-motorized transport infrastructure for rural areas depends on their local conditions as well as sustainability and proper implementation standards.

Rural testing projects achieve modest results but these initiatives do not deliver broad effects across many locations because services receive insufficient funding and designers fail to develop sound plans while rural inhabitants remain outside implementation stages. Community involvement at every stage of rural transport project planning and execution determines the success of new transport initiatives. Project design that includes rural populations from the start leads to better results in improving rural accessibility along with mobility options and communitywide development progress.

11 RECOMMENDATIONS

The recommendations for this study are discussed below.

11.1 Integrated Rural Transport Infrastructure Investment

National and regional budgets must establish highway development and restoration for rural areas as their top expenditure priority. The budget should contain designated funds for rural road maintenance which both maintains their condition and extends their longevity. The use of materials and technologies that demonstrate resistance to climate change should be applied during road building activities to minimize environmental threats. Local communities should take part in road condition monitoring alongside reporting activities to establish local ownership allowing timely response interventions.

11.2 Capacity Building and Technical Assistance for Local Transport Stakeholders

The government should invest resources toward establishing local expertise for proper rural transport system planning and management operations.A training program should be created to improve local government abilities alongside transport operator and community knowledge in transport planning with additional skills

in management and maintenance. Platform development aimed at distributing rural transport best practices to local situations while finding purposes of localized adaptations. Technical support should assist governmental entities by helping them deploy and expand observed prototype programs especially in data gathering and budget control operations.

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reviewed paper

Best Practises of PEDs and its Replication Potential

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1 ABSTRACT

An important sector that contributes significantly towards climate change and global warming is the building sector. Buildings account for 30–40% of global final energy consumption [1] and nearly 40% of the global CO_2 emissions. In the last decade, policies such as the Directive on Energy Performance of Buildings (EPBD) have been introduced to address this issue, aiming to decarbonize the building stock by 2050 and to reach nearly zero energy buildings (NZEBs) [2].

The 2015 Paris Agreement has put more emphasis on international efforts to reduce CO_2 emissions, where urban areas with a 70% share of global emissions have a key role. Accordingly, the United Nations (UN) Sustainable Development Goals include as goal 11 "sustainable cities and communities" with the aim of supporting the transition towards low-carbon cities, in a general framework which also points towards, e.g., climate action, affordability, and clean energy. In 2015, when the Paris agreement was signed, the EU planned to move further ahead and reduce greenhouse gas emissions by 40% by 2030.

In order to tackle this challenge and to lead the global energy transition, the EU Commission proposed in 2016 a set of new and ambitious rules known as the Clean Energy Package for all Europeans [1]. Therefore, to reach the emission reduction goals it is important to focus both at the energy systems level and at the buildings or district level. At a global level, the need for energy efficiency and an increased share of renewable energy sources is evident, as is the crucial role of cities due to the rapid urbanization rate. As a consequence of this, the research work related to Positive Energy Districts (PED) has accelerated in recent years.

This paper is based on work in a 4 years research on positive energy districts (PED), the planning and implementation of them in various markets. It summarizes the findings on replication potential of the concept. First, the concept is explained and the key performance factors are discussed. Then, it analyses almost 100 PED projects that were collected during the research duration. The PED examples were classified into 3 categories and spread in different climatic, social, and political systems. Finally, the key success factors were derived from this analysis and the findings are highlighted in best practices. By addressing these aspects comprehensively, PEDs can create more sustainable, resilient, and equitable communities that are well-prepared for the challenges of the 21st century. They move beyond simply generating clean energy to fostering a holistic transformation of how we live and interact with our environment.

Keywords: Planning, districts, energy, positive, PED

2 INTRODUCTION

The systematic use of data, the collection of information about enabling factors, barriers and frameworks (regulatory and governmental) are fundamental to supporting the planning of urban interventions towards climate-neutral transition of our cities. Tackling the challenges of climate neutrality at an urban level, the European Commission set out the SET Plan 3.2. which contained several ambitions – i.e. 100 pioneer zero-emissions cities by 2030 [1] and 100 pilot PEDs by 2025 [2] by focusing on implementation and testing of solutions on district-scale and in an efficient, resilient and climate-neutral manner.

In this perspective, there are several international research activities ongoing that try to collect these ambitions, e.g. COST Action (CA) 'PED-EU-NET' [3] in connection with further international initiatives working on PEDs concept; PED initiative, coordinated by JPI UE [4], aims to develop 'Positive Energy Districts and Neighborhoods for Sustainable Urban Development'; 'IEA EBC Annex 83 – Positive Energy Districts' coordinated by IEA EBC [5] – with the aim of mapping PED relevant experiences and collecting key parameters to characterize these districts and support their uptake around Europe and beyond; the European Energy Research Alliance Joint Program on Smart Cities (EERA JPSC) [https://www.eera-sc.eu/],

whose mission is to contribute to research and innovation in smart cities by promoting actions, at building, district and city level, that facilitate the transformation of the European built environment towards climate neutrality. In this process, a PED Database (PED DB) (https://pedeu.net/map/) is the outcome of this collaborative research.

2.1 PED database

Studies highlight the need for integrated approaches to planning green, healthy, efficient, livable, and resilient districts, aligning with local plans and addressing stakeholder needs [6-10]. Existing tools for characterizing Positive Energy Districts (PEDs) are limited. JPI Urbana Europe's PED Booklet [11] categorizes PEDs as “Projects” (achieving positive energy balance) or “Towards Projects” (adopting innovative solutions). Zhang et al. [12] analyzed these cases, developing a matrix for comparing PED models and defining archetypes. Soutullo et al. [13] mapped PED Labs, identifying strengths, weaknesses, opportunities, and threats through SWOT analysis, emphasizing real-world testing for replicability.

Focusing on Energy Communities (ECs), similar to PEDs [26, 27], the European Commission's JRC [28, 29] reported on 24 communities [30] and is developing an "Energy Communities Repository" [31, 32] with detailed case studies. These resources inform the conceptualization of a PED database. Further PED research includes cataloguing: (1) technologies and solutions [15-17], (2) financing and business models [18, 19], (3) social and community engagement tools [20, 21], and (4) Key Performance Indicators (KPIs) for impact monitoring [22-25].

Several international initiatives promote efficient urbanization and sustainable urban development, including the EU's Strategic Energy Technology (SET) Plan [4], which inspired the goal of deploying 100 Positive Energy Districts (PEDs) in Europe by 2025. A recent publication (Haase et al. 2025) lists initiatives collaborating on a 'PED Database'. Key promoters include COST Action "PED-EU-NET", JPI Urban Europe, IEA EBC Annex 83, and EERA JP Smart Cities. The PED database aims to map, filter, sort, and compare PED experiences, providing an overview of technological and non-technological solutions in various PED projects and case studies. This collaborative effort led to the PED Database, with international PED projects listed in Haase et al.’s recent publication (Clima paper).

The International Energy Agency (IEA) Annexes are collaborative Research and Development (R&D) projects under the IEA's Technology Collaboration Programmes (TCPs). These structured frameworks address specific energy challenges or opportunities, such as renewable energy, energy efficiency, or urban energy systems.

This paper focuses on the crucial internationalization of the PED model by comparing it with other community or district-scale transformation projects. Building on previous research, the PED DB disseminates PED practices via a comprehensive tool which aggregates case studies, projects, solutions, KPIs, policies, and strategies. This supports large-scale development of innovative pilot districts, both new and renovated. This international perspective is essential to identify challenges and key success factors for PED planning and implementation.

3 METHODOLOGY

For this desktop research 98 PEDs from 33 projects were analysed. Fig.1 illustrates the life cycle stages of the PEDs. Among the 98 PEDs recorded in the PED database [7], 40 are in the planning phase, 22 are under implementation, 18 have been completed, and 18 are in operation. Of these, 42 are classified as PED case studies, 18 as PED Labs, and 38 as PED-relevant case studies (see Fig.2).

The database evaluates the effectiveness of strategies and solutions in mapped Positive Energy District (PED) case studies. It is dynamically updatable with new sources and ontologies, maintaining relevance and utility as projects evolve, and enabling the generation of archetypes or "library concepts" for scenario evaluations.

The methodology used to structure the PED database fostered data field harmonization and standardization, resulting in a glossary that ensures PED data interoperability across systems. Detailed case analysis, based on project experiences and insights from PED publications and the EU Energy Community, facilitated the identification of core components, facilitating elements, challenges, and barriers.

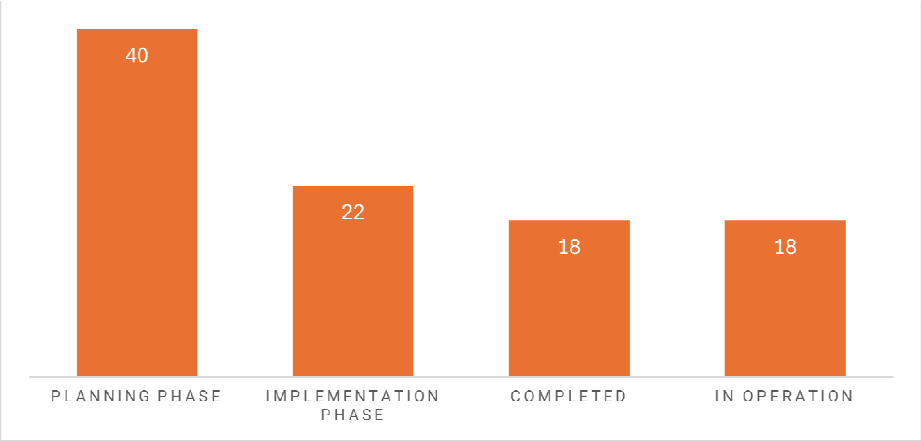

Fig. 1: PEDs from PED database [7].

By capturing detailed parameters and in-depth information, the database provides PED stakeholders with a comprehensive view of prior projects. This comprehensive approach supports the replication of effective practices in future initiatives, as it offers significant insights for deeper PED analysis.

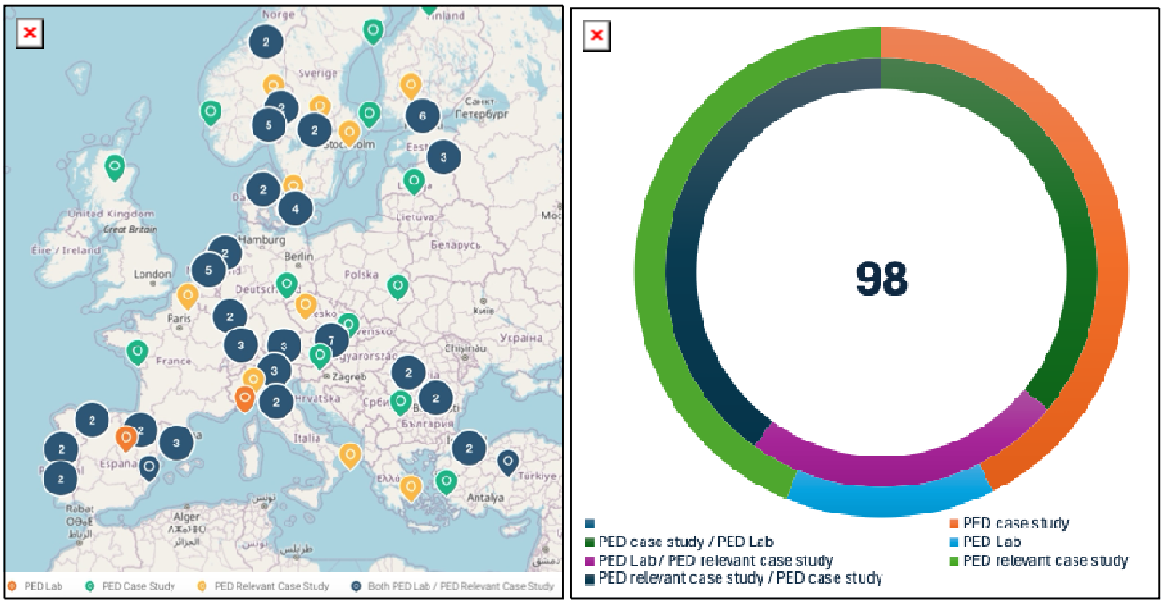

Fig. 2: PED case studies, PED relevant case studies and PED Labs in the PED database (status: Dec 2024).

4 RESULTS

Building on existing frameworks like the Annexes on energy-efficient communities, computational tools, and low-carbon heating, this initiative aims to standardize definitions and develop planning solutions. It collaborates with projects such as the EU Smart Cities Information System, Horizon 2020, and JPI Urban Europe. Annex 83 provides guidance on urban planning, impact assessments, and the economic and social implications of Positive Energy Districts (PEDs). As Annex 83 is ongoing, an evaluation framework is still in development. This framework supports cities, policymakers, and researchers in transitioning to carbon-neutral urban environments, contributing to global energy transition and sustainability goals. Annex 83 partnered with PED EU NET and Urban Europe for the PED DATABASE [26].

The PED database offers comprehensive information on new and refurbished urban environments designed to produce more energy than they consume. Its modular design and online platform enable data, in the form of PED Key Performance Indicators (KPIs), to be sourced from reliable and verified information. Developed through a database development life cycle (DDLC), it began with a scoping phase defining requirements for data collection from demo cases. Following a testing phase, the main conclusions are:

(1) There is no one-fits-all solution for PED implementation. Overall PED framework definitions require further detailing in the local context [27]. The PED Database provides an overview of not only different implementation strategies but also existing different conceptualizations and approaches for the PED concept.

(2) PEDs are still a relatively new concept, but they are gaining traction around the world. As PEDs become more popular, they are likely to play an increasingly important role in the global transition to a clean and sustainable energy future. Overall, PEDs offer a number of advantages over building-level and city-level approaches to sustainable development [28].

(3) PEDs take a holistic approach that considers the needs of the entire community [29].

4.1 PED implementation

Creating a PED is not simply a technical exercise but a complex socio-technical undertaking that requires a holistic and context-specific approach. The PED Database recognizes this diversity and aims to provide a platform for sharing knowledge and experiences across different projects and contexts, enabling stakeholders to learn from each other and adapt best practices to their own unique circumstances. With regard to diverse local contexts these aresummarized in Table 1, while Table 2 provides on averview of varied conceptualizations and approaches and Table 3 summarises the dynamic and evolving nature of PEDs.

Climate	A PED in a hot, sunny climate will have vastly different strategies for achieving positive energy balance compared to one in a cold, cloudy climate. Solar potential, heating/cooling needs, and building design will vary significantly.
Urban Form and Density	Densely populated urban areas may rely on district-level energy solutions and innovative building integration, while suburban or rural PEDs might focus on individual building generation and microgrids.
Existing Infrastructure	The availability and condition of existing energy infrastructure (grids, heating/cooling networks) will influence the feasibility and cost-effectiveness of different PED solutions.
Resources and Industry	Local availability of renewable energy resources (solar, wind, geothermal, biomass) and industrial capabilities will shape the choice of technologies and strategies.
Socioeconomic Factors	Community demographics, energy affordability, and local priorities will influence the acceptance and implementation of PED projects.

Table 1: PED implemantion results with regard to diverse local contexts

Definition of “Positive Energy”	The precise definition of "positive energy" can vary. Some PEDs might aim for net-zero energy annually, while others might focus on specific energy carriers or consider embodied energy.
Scope of the District	The scale of a PED can range from a single building to a neighborhood or even a larger district, each with its own set of challenges and opportunities.
Technology Choices	The mix of renewable energy technologies, energy storage solutions, and energy efficiency measures will depend on the local context and the specific goals of the PED.
Governance and Ownership	PED projects can involve a range of stakeholders, including public authorities, private developers, energy utilities, and community members, each with their own interests and priorities.

Table 2: PED implemantion results with regard to varied conceptualizations and approaches

Technological Advancements	Rapid innovation in renewable energy, energy storage, and smart grid technologies means that PED solutions need to be adaptable and future-proof.
Policy and Regulatory Landscape	Changes in energy policies, regulations, and incentives can significantly impact the feasibility and economic viability of PED projects.
Data and Monitoring	Effective PED implementation requires robust data collection and monitoring to track performance, identify areas for improvement, and adapt strategies over time.

Table 3: PED implemantion results with regard to dynamic and evolving nature of PEDs

4.2 PED concept

Positive Energy Districts (PEDs), while still a relatively new concept, are gaining global momentum and are poised to play a crucial role in the transition to a clean and sustainable energy future. PEDs also offer advantages over building-level and city-level approaches to sustainable development. Table 4 summarises the PED concept results with regard to gaining traction and importantance, Table 5 focuses on advantages of PEDs over Building-Level approaches and Table 6 focuses on advantages of PEDs over City-Level approaches.

Addressing Climate Change	PEDs directly contribute to reducing greenhouse gas emissions by promoting renewable energy generation and energy efficiency at a district level. This aligns with global efforts to combat climate change.
Energy Security and Independence	By generating energy locally, PEDs can reduce reliance on fossil fuels and centralized energy systems, enhancing energy security and independence for communities and nations.
Sustainable Urban Development	PEDs offer a framework for sustainable urban development by integrating energy considerations into planning and design at the district level, leading to more livable and resource-efficient communities.
Economic Benefits	PEDs can stimulate local economies by creating jobs in renewable energy, energy efficiency, and related sectors. They can also reduce energy costs for residents and businesses.
Social Benefits	PEDs can foster community engagement and ownership in the energy transition, promoting social equity and inclusivity.

Table 4: PED concept results with regard to gaining traction and importantance

Economies of Scale	PEDs can achieve economies of scale by implementing energy solutions at a district level, such as shared renewable energy systems, district heating and cooling networks, and smart grids. This can lead to lower costs and greater efficiency compared to individual buildings trying to achieve positive energy balance on their own.
Integrated Planning and Design	PEDs allow for integrated planning and design of energy systems and infrastructure across multiple buildings and land uses, optimizing energy performance and resource utilization.
Flexibility and Resilience	PEDs can create more flexible and resilient energy systems by diversifying energy sources, incorporating energy storage, and enabling peer-to-peer energy trading within the district.

Table 5: PED concept results with regard to advantages of PEDs over Building-Level approaches

Granularity and Focus	PEDs provide a more granular and focused approach to sustainable development compared to city-level initiatives. They allow for tailored solutions that address the specific needs and characteristics of different districts within a city.
Measurable Impact	PEDs make it easier to measure and track progress towards sustainability goals at a district level, providing valuable data and feedback for adaptive management.
Scalability and Replicability	Successful PED projects can serve as models for replication and scaling up to other districts and cities, accelerating the transition to a sustainable energy future.

Table 6: PED concept results with regard to advantages of PEDs over City-Level approaches

4.3 PED approach

Social Equity and Inclusion	PEDs aim to benefit everyone in the community, not just a select few. This means considering factors like affordability of energy, access to clean energy solutions, and potential impacts on vulnerable populations.
Environmental Justice	A holistic approach addresses potential environmental injustices by ensuring that PEDs do not disproportionately burden certain communities with pollution or negative environmental impacts.
Community Ownership and Engagement	Successful PEDs often involve active participation and ownership from community members. This ensures that the projects align with local needs, values, and priorities, fostering long-term support and sustainability.

Table 7: PED approach results with regard to beyond technology

Energy Systems and Infrastructure	PEDs require integrated planning and design of energy systems, including renewable energy generation, energy storage, distribution networks, and smart grids. A holistic approach optimizes these systems for efficiency, reliability, and resilience.
Built Environment and Urban Planning	PEDs consider the built environment as a whole, including building design, energy efficiency measures, land use planning, transportation, and green spaces. This integrated perspective maximizes energy performance and creates more sustainable and livable communities.
Economic Development and Job Creation	PEDs can stimulate local economies by creating jobs in renewable energy, energy efficiency, and related sectors. A holistic approach considers these economic opportunities and ensures that they benefit the entire community.

Table 8: PED approach results with regard to integrate multiple dimensions

PEDs represent a strategic middle ground between individual building efforts and broader city-level plans. They offer a tangible and manageable scale for implementing integrated energy solutions, maximizing benefits while minimizing complexity. It emphasizes a key characteristic of Positive Energy Districts (PEDs) why they are designed in a holistic way. Table 7 summarises the PED approach results with regard to beyond technology, Table 8 focuses on integrate multiple dimensions and Table 9 focuses on long-term sustainability.

Resource Efficiency	PEDs strive to minimize resource consumption and waste generation through strategies like circular economy principles, efficient use of water and materials, and sustainable waste management practices.
Resilience to Climate Change	A holistic approach considers the potential impacts of climate change, such as extreme weather events, and designs PEDs to be resilient and adaptable.
Behavioral Change and Awareness	PEDs often incorporate initiatives to raise awareness about energy consumption and promote sustainable behaviors among community members.

Table 9: PED approach results with regard to long-term sustainability

5 DISCUSSION

The holistic approach to PEDs (Positive Energy Districts) mentioned in the resutls (Table 1 – 9) focus on resource efficiency, resilience to climate change, and behavioral change and awareness:

PED and Resource Efficiency:

- Minimizing Consumption: PEDs prioritize reducing the overall consumption of resources, including energy, water, and materials. This involves strategies like energy efficiency in buildings, promoting sustainable transportation, and reducing waste generation.
- Circular Economy Principles: PEDs can incorporate circular economy principles by designing buildings for disassembly and reuse, using recycled and sustainable materials, and minimizing waste through composting and recycling programs.
- Efficient Resource Management: Smart technologies and data analytics can optimize resource management in PEDs. For example, smart grids can improve energy distribution and reduce losses, while smart water meters can help conserve water.
- Life Cycle Assessment: PEDs can benefit from life cycle assessments that evaluate the environmental impacts of materials and processes throughout their entire life cycle, from extraction to disposal. This helps identify opportunities for resource efficiency improvements.

PED and resilience to Climate Change:

- Risk Assessment and Adaptation: PEDs should conduct thorough risk assessments to identify potential climate change impacts, such as increased temperatures, extreme weather events, and sea-level rise. Based on these assessments, they can develop adaptation strategies to enhance resilience.
- Diversification of Energy Sources: PEDs can diversify their energy sources to reduce reliance on any single technology or fuel. This can include a mix of solar, wind, geothermal, biomass, and other renewable energy options.
- Decentralized Energy Systems: Decentralized energy systems in PEDs can enhance resilience by reducing vulnerability to disruptions in centralized grids. Microgrids and distributed energy resources can provide backup power during emergencies.
- Green Infrastructure: Integrating green infrastructure, such as green roofs, permeable pavements, and urban forests, can help mitigate the impacts of climate change by reducing urban heat island effect, managing stormwater runoff, and improving air quality.

PED and behavioral change and awareness:

- Education and Outreach: PEDs can implement education and outreach programs to raise awareness about energy consumption, climate change, and sustainable practices. This can involve workshops, community events, and online resources.

- Incentives and Rewards: PEDs can offer incentives and rewards for residents and businesses that adopt sustainable behaviors, such as energy conservation, waste reduction, and use of public transportation.
- Citizen Engagement and Participation: Engaging citizens in the planning and implementation of PED projects can foster a sense of ownership and encourage behavior change. Participatory processes can empower communities to take an active role in the transition to a sustainable future.
- Data Transparency and Feedback: Providing residents with transparent data on their energy consumption and environmental impact can motivate them to adopt more sustainable behaviors. Smart meters and energy management platforms can provide valuable feedback and enable real-time monitoring.

6 CONCLUSION

In conclusion, creating a PED is not simply a technical exercise but a complex socio-technical undertaking that requires a holistic and context-specific approach. The PED Database recognizes this diversity and aims to provide a platform for sharing knowledge and experiences across different projects and contexts, enabling stakeholders to learn from each other and adapt best practices to their own unique circumstances.

We found that a holistic approach to PEDs recognizes that energy is not just a technical issue but is deeply intertwined with social, economic, and environmental dimensions. By considering the needs of the entire community and integrating multiple perspectives, PEDs can achieve greater sustainability, resilience, and social equity. This comprehensive view is what distinguishes PEDs from more narrow, technology-focused approaches to sustainable development.

Further, PEDs represent a strategic middle ground between individual building efforts and broader city-level plans. They offer a tangible and manageable scale for implementing integrated energy solutions, maximizing benefits while minimizing complexity.

By addressing these aspects comprehensively, PEDs can create more sustainable, resilient, and equitable communities that are well-prepared for the challenges of the 21st century. They move beyond simply generating clean energy to fostering a holistic transformation of how we live and interact with our environment.

Regarding replication potential we can state that community-centricity can be both a challenge and an opportunity for replication. Because PEDs are designed to meet the specific needs of a community, a direct, cookie-cutter replication might be difficult. Each community has unique characteristics (climate, resources, social structures, etc.) that will influence the PED design. However, the principles of community engagement and a holistic approach are replicable. The process of understanding community needs and tailoring solutions can be replicated even if the specific technologies or designs are different.

Further, the holistic approach suggests a framework that can be adapted. While the specifics will vary, the idea of integrating various aspects (energy, social, economic, environmental) into a PED project provides a replicable framework. Other communities can adopt this integrated planning approach, even if the details of their PEDs are different.

The focus on community needs implies scalability through modularity. If PEDs are designed with a modular approach, where smaller units can be combined or adapted, this improves the potential for scaling up successful elements. This modularity could be replicated in other communities, even if the overall scale of the project is different.

Replication of PED is possible, but it will likely involve adapting the core principles and framework rather than simply copying a PED design from one location to another. The process of community-centered design is replicable; the specific solutions will likely need to be tailored. Information on the availability of resources and technologies needed for PEDs can be found in the PED database. Replication depends on access to necessary resources. To understand the true replication potential, more information is needed, such as:

- Case studies of successful PEDs and attempts at replication. These would provide concrete examples of successful implementation We gathered this information where we could, but more work is needed to better understand what worked and what didn't and why

- Analysis of the costs and benefits of PEDs in different contexts. Economic viability is a key factor in replication potential. This information is very difficult to get and to digest it so that it can become comparable.
- We need more work that focuses on policy and regulatory frameworks that support or hinder PED development. Supportive policies can encourage replication.

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reviewed paper

Beyond The Blueprint: Revitalising Active Travel amid African Realities

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1 ABSTRACT

In the face of escalating mobility challenges, active travel is a fundamental and sustainable mode of transport. However, despite its benefits, active travel is often overshadowed by the prioritization of motorized transportation creating continued car dependency.This approach creates environments that are not conducive to active travel. Notably, while Infrastructure is crucial for viable active travel, this paper argues that social realities in most African cities present additional, often overlooked challenges that hinder active travel adoption. Using a mixed method approach, including surveys and secondary data from literature and government reports, this paper investigates these linked dimensions, revealing that just developing infrastructure does not guarantee efficient travel and that the adoption of truly effective solutions is frequently impeded by a failure to address these broader issues. Additionally, policy reforms that regulate the transport planning process and provide incentives are equally important to increase active travel adoption.Ultimately, this study advocates for an integrated and holistic approach considering the broader context of active travel, which is crucial for the future of travel in African cities.

Keywords: Socio-cultural dynamics, Sustainable Development Goals, Non Motorised Transport, African realites, Urban planning

2 INTRODUCTION

Active travel is usually used interchangeably with Non-Motorised Transport (NMT) often including walking and cycling (Prince et al .2022). In this paper, active travel is examined through the lenses ofNMT, precisely walking and cycling. NMT is widely recognized as a cornerstone of physical and health benefits, accessibility, and inclusivity (Litman, 2012; Hunter et al. 2025), Additionally given the current climate crisis, active transport has also been associated with decarbonization initiatives (Moosburger et al. 2024). Although NMT is recognized in policy, the majority of countries in particular, African countries barely include NMT plans in their infrastructural projects (Uzondu and Etika, 2022). In many countries, the majority of the poor rely on walking as their primary mode of transportation. Due to urban design, they often reside on the outskirts of cities and must commute daily to access economic opportunities.

Moreover, many places still lack the required infrastructure, even though there have been major attempts to revive non-motorized transportation (NMT) in cities since the turn of the twenty-first century, and this development has been well documented in the literature. In particular, SDG 11.2, focuses on sustainable cities and communities, SDG 3 focuses on good health &well-being, and SDG 13's call for climate actionall support the use of NMT (Singhai, et al. 2021; Kalaoane et al; 2022; Mulibana et al. 2023; Mahadevia et al. 2023; 2024). The majority of African cities have signed the SDGs agreement and incorporated it into their local plans, but over time, little to no implementation has been done to accommodate these goals (Kalaoane et al; 2022). Therefore this paper investigates the dynamics of NMT adoption in South Africa.

3 NON-MOTORISED TRANSPORT IN AN AFRICAN CONTEXT

A complex and diverse landscape influenced by historical, physical, social, and economic elements may be seen in African cities' Non-Motorized Transportation (NMT). Various factors influence NMT adoption, with social issues playing a significant role. One key obstacle is demographics, where older people are often reluctant to use NMT for traveling (Longar, et al. 2024). Additionally, in most African cultures, walking remains a symbol of poverty(Acheampong et al. 2022) while buying a private motor vehicle is often a symbol of wealth (Jeske, 2016). Even in modern times, people celebrate buying a car through various cultural rituals, while using NMT typically goes uncelebrated. In contrast, many countries from the Global North, specifically European countries offer incentives for either cycling or walking, both in society and the

workplace (Buehler and Pucher, 2023; Karolemeas et al. 2023; Longar, et al. 2024), highlighting a key cultural difference toward NMT adoption. Furthermore, demographics and affordability influence NMT adoption (O'Reilly, et al. 2024). It is estimated that about 68% of people in Africa fall under the poverty line (African Development Group, 2024), forcing the majority to use walking as their primary mode of transport.Because of this contextual variability, one-size-fits-all approaches to NMT policy framework and implementation fail, requiring localized policies that take into consideration the potential and challenges that NMT poses in various cities across the African continent.

4 RESEARCH METHODOLOGY

A combination of qualitative and quantitative methodologies is utilized to create a well-rounded analysis. 300 surveys were administered to analyze the preferred mode of transport among people from different demographics. This study followed a multi-stage sampling technique which did not require a sampling frame (Sharma, 2017). Using this sampling technique, transportation stations in Braamfontein, Johannesburg were divided into different clusters. The commuters from different stations (clusters) were randomly selected to voluntarily participate, a sample size of 300 provided valuable insights while balancing practical considerations and statistical rigor.In addition to survey data, photography and observations were utilized in Johannesburg Central Business District (CBD) to understand mobility patterns. This study also employs secondary data; government reports, journal articles, policies, and legislative frameworks for a broader context of the study focus area. The gathered data from observations, and surveys were coded to identify reoccurring themes, and secondary data was cross-referenced with the survey findings to validate results and provide further insights into NMT adoption.

5 FINDINGS AND DISCUSSIONS

The data analyzed yielded several key findings on NMT adoption in Johannesburg, South Africa highlighting both cultural, policy, and economic challenges.

5.1 NMT Principles

Globally, there is a growing consensus that creating efficient NMT is a fundamental right for all. Efficient NMT is mirrored in global initiatives, specifically, the SDGs and it has been integrated into South African national legislation and policy frameworks, committed to creating a sustainable NMT. The common key principle in these policy initiatives (the Integrated Transport Master Plan (ITMP25) for Gauteng and Johannesburg Master Plan City of Johannesburg integrated Development Plan 2021-2026) and across the literature (Lefevre et al. 2021; Foley et al. 2022; Hunter et al. 2025) are depicted in Figure 1. These principles are intended to guide the planning and integration of NMT in cities.

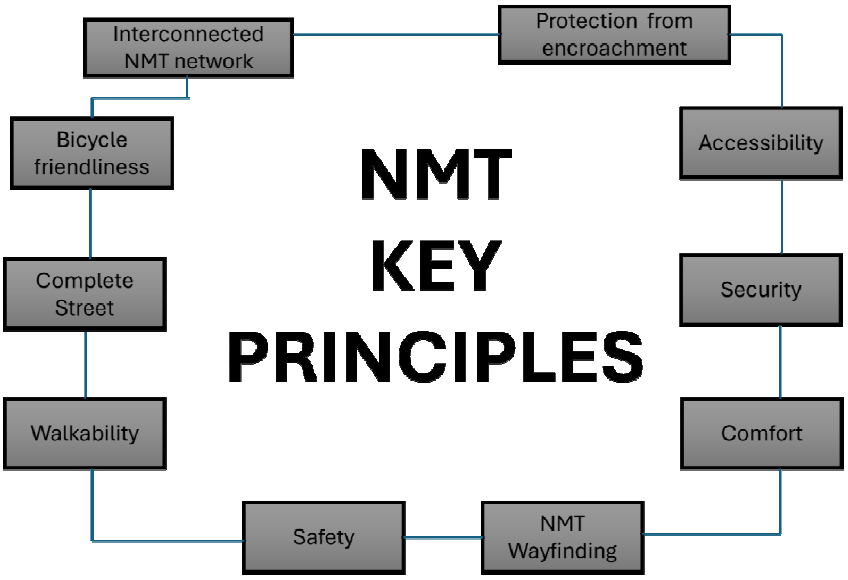

Figure 1: Key principles of NMT. Adopted by Author (2025)

However, the practical implementation of the Integrated Transport Master Plan (ITMP25) for Gauteng and Johannesburg Master Plan City of Johannesburg integrated Development Plan 2021-2026 falls short of the

intended vision. Residents of poorly integrated townships face significant financial burdens due to transportation costs, which can accountfor a significant portion of their monthly expenses (30 percent or more), given the statistics (Development Bank Group, 2024). To mitigate these challenges, the Development Bank established an initiative to construct infrastructure for NMT in South African cities focusing on Johannesburg; Soweto (Figure 2), Durban, and Polokwane.

Figure 2: Soweto NMT infrastructure. Source: Authors (2025)

Figure 2 shows the NMT infrastructure in Soweto that is often not utilized by NMT users attributed to a lack of trees for shade, safety, and security. The underutilization of non-motorized transportation (NMT) infrastructure frequently poses a serious obstacle to its wider adoption. In most cases like the Soweto initiative, NMT implementation partially focuses on one aspect of NMT often infrastructure. Therefore this raises a question; can we truly say that NMT policies are efficient or effective If the full spectrum of needs such as safety, complete streets and interconnectness is not taken into consideration leading to reluctant NMT adoption? These further support the idea that a key issue in many African countries, South Africa included, is the narrow focus on providing infrastructure, yet this focus on transport neglects other crucial elements that are essential for true sustainability and inclusion (Shinde et al. 2023).

5.2 Cultural shifts towards NMT adoption

The majority of the respondents (80%) reported walking due to financial difficulties, however, there is a desire to own a private vehicle. One respondent was quoted as saying;

As soon as I have money, the first thing I will do is to buy a car, so that everyone sees that my status has changed and that I am no longer poor.

Cultural perception also has a big impact on NMT's adoption. Many of these renters expressed frustration, as carownership is culturally regarded as a symbol of wealth and success in Africa. Walking and bicycling are stigmatized, especially among the respondents that identify these forms of transportation with poverty or a lower social standing. Even in cases where NMT is economically advantageous, this cultural view may deter people from implementing it. Walking and bicycling are frequently viewed as less desirable or inferior to motorized transportation.The widespread desire to own a motor vehicle expressed by many respondents suggests that efforts to increase NMT adoption are not having the intended impact, highlighting a critical weakness in the current Soweto initiative and other initiatives across the city of Johannesburg. Even among the respondents interested in cycling, the high cost of bicycles presents a significant barrier, making it difficult to use NMT. This demonstrates that despite people's desire to own a motor vehicle, financial limitations force them to walk or use public transport. Although high-speed rail and Bus Rapid Transit (BRT) systems were designed to solve transportation issues, they are often not accessible to communities. This scenario predicts a potential large rise in car ownership, reflecting South Africa's future mobility.

5.3 Safety and Encroachment

In South Africa, 29% of collisions are caused by cars, with infrastructure and pedestrians walking being two of the main causes, accounting for 22.3% (Road Traffic Report South Africa, 2024).This implies that enhancing safety requires a multifaceted strategy that takes into account not only driving behaviour but also the layout and upkeep of roads and walkways. Additionally, street vendors' invasion of NMT routes, frequently with little consideration for the safety of cyclists and pedestrians, jeopardizes the safety of NMT users (Figure 3). The situation is made worse by the pervasive issue of littering, which makes the NMT infrastructure less usable and creates dangerous conditions. The difficulties in developing accessible and safe transport services for all South Africans are highlighted by these coupled factors (Kalaoane et al. 2023).

Figure 3: Encroachment & littering on the NMT infrastructure in Johannesburg. SOurce: Authors (2025)

Informal trade has also encroached on NMT spaces (Figure 3), with the majority of this encroachment occurring around official business institutions such as offices and universities that are most valued for their convenience.

The significant demand for public space in Johannesburg city, particularly among low-income households that have limited access to formal business spaces, is reflected in the widespread use of NMT spaces. However, this also causes bicycles and pedestrians to compete for space, which lowers the functionality of NMT infrastructure and raises the possibility of accidents. Vendors in these areas frequently push cyclists and pedestrians into the roadway, increasing traffic hazards and decreasing the usefulness of the roads for NMT.

6 IMPLICATIONS FOR POLICY AND PRACTICE

Despite ongoing efforts, there are still many obstacles to overcome to enhance non-motorized transportation (NMT) in African cities. Walking is the most common form of transportation, especially for the underprivileged, which emphasizes the necessity of significant investment in NMT adoption. When combined with current urban planning, the restricted reach of public transport choices like BRT and high-speed rail points to a future rise in automobile ownership, which could exacerbate already-existing traffic and environmental issues. Policymakers are faced with cultural issues as they seek to change public perceptions and increase knowledge of NMT's advantages as a workable solution as well as a sustainable and healthful one. Campaigns for social change, educational programs, and the marketing of cycling as a pastime could all aid in dispelling these myths.

Additionally, road safety is a major concern, these safety hazards are made worse by the presence of litter and the encroachment of street sellers into NMT paths, which also make it more difficult to use NMT amenities. This draws attention to the necessity of integrated urban plans that take informal economic activity and mobility into account. While maintaining the safety and functionality of NMT infrastructure for bikes and pedestrians, urban planners must take into consideration the space needed by street vendors. There are numerous significant ramifications for these findings. First of all, they emphasize the pressing necessity

for thorough transport planning that incorporates NMT with other forms of transit and socio-economic activities. In addition to building infrastructure, this calls for addressing the cultural dynamics in cities and integrating cultural approaches to NMT adoption.

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Circular Economy Concepts: A Smart Solution for Communities in European Towns

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1 ABSTRACT

The paper debates the concept of circular economy in cities through introduction of circular communities composed by materials providers, developers, producers, services, distributors and consumers which all must adopt a holistic and collaborative approach. Therefore, circular development necessitates the socio-ecological transformation of our urban systems. It requires that wasted resources are looped, the ecological regenerative capacity and adaptive capacity of urban systems developed. Therefore, spatial planning potentially has a crucial role to play in the delivery of circular development. The challenge is to integrate a circularity-based approaches into spatial planning practice, and vice versa, and to go beyond the search for temporary solutions, which in spatial terms means temporary spaces for circular experimentation, and to lay the foundations for circular spatial planning thinking and action.

Keywords: spatial planning, circular communities, circular thinking, circular development, circular economy

2 INTRODUCTION

This paper is a discussion based on theoretical knowledge and experiences obtained in many years in spatial and urban planning, built environment development, industrial product design, management and enterpreneurship, and observation of social dynamics. It is encouraging that these observations seem to be finally inline with at least some directions of environmental and socio-economic thinking and recomendations of internationally acnowledged bodies (e.g. UNEP, 2024) and such reasonings are slowly, but not surely, penetrating even into the various EU documents (e.g. EC, 2020; IEB, 2020; Directive (EU) 2024/1799). Discouraging, however, is the fact that a transformation towards global sustainable resource consumption and production is urgently necessary, however, society does still not seem to feel it.

The history of civilisation follows the logic of goods exploitation. People are used to use/exploit resources and when they are exhausted, move on to new teritories to explot and exhaust again. Thus this history shows, that the collapse of settlements and cities coincides with the depletion of resources. These are usually exhausted with the help of a current technology – usually developed at the time and recognized as modern. The current civilisation is also facing the problems of resources exploitation (reflecting the way of the exploitation) as well as with the polution that goes hand in hand with it. Therefore, the UNEP (2024) calls for not merrely a transformation towards global sustainable resource consumption and production as being necessary, but for how to urgently make it happen. Further, the UNEP (2024) document points to insatiable use of resources, which has tripled over the last fifty years, and worrns if we do not change, we could see resource use up by 60% from 2020 levels by 2060.

The pursuit of individual and material profit, which has been extrapolated over the last century, has marginalised the general well-being of our society over the profit-oriented economic activities. It is seen as one of the key elements that has caused the disintegration of local communities. The benefits and well-being of the community were not looked at, but the material gain (profit) of the individual. This paper explores the establishment and strengthening of the circular economy in local communities, as a means of transition towards resource-efficient and sustainable consumption and production, as one of the leverages that may help to revers the process of wellbeing decoupling. Hence, the key to success is a system that links the consumer and the producer – a responsible consumer (user) and a responsible producer (provider). Therefore, both need to be caught in the loop of being mutually dependent and therefore responsible.

The aim of the paper is to pave the way to the cicular community through its logical structure. The logic of the community is presented, based on the logic of economics that takes into account all stakeholders in a balanced way and does not favor or neglect the well-being of any of them, instead of being based on institutions that have become entrenched in society through the implementation of the linear economy model. We will show how certain specific directions/industries/products can be realized with such logic.

The paper firstly elucidates the circular economy concept and introduces accordingly the circular community as a solution that enables systemic socio-ecological transformation (of urban systems) with a special attention to a product as a service business model, where a responsoible consumption is motivated. True, the responsibility and motivation of the consumer (user) towards the product changes the flow of the material, and that is exactly what circular economy is all about, the economy where the value of products, materials and resources is maintained for as long as possible in the economy, and the generation of waste is minimized. The discussion is further elaborated upon DIPSTOR's definition of fully circular product (FCP) and its circular design approach Evolutionary Design (DIPSTOR, 2019), a resource efficiency approach in furniture development and design. These approaches reflect the values and principles of the New European Bauhaus Compas (NEB, 2022; EC, 2019) and are further illustrated with two circularity-based implementations, the slender revitalisation and the circular landscaping. They both are based on the cascaded use approach, such as R-ladder (e.g. Kurilova-Palisaitiene, 2023) and can in the context of urban planning and development contribute to compact, balanced and parhaps quite self-sustained neighbourhoods.

3 CIRCULAR ECONOMY CONCEPT AND CIRCULAR COMMUNITY

Historically speaking, circular economy is a traditional economy of cities and communities. Today, the circular economy is recognised as an innovative model designed to eliminate waste and avoid the contstant use and exploatation resources. Unlike the currently prevailing linear economy, which follows a 'take, make, dispose' approach, the circular economy strives to create a closed-loop system where products and materials are reused, repaired, refurbished, and recycled (even upcycled) for as long as possible. At the heart of the circular economy lie three fundamental principles, designing out waste and pollution, keeping products and materials in use, and regenerating natural systems, being also a fundamental tenant to sustainable urban planning and development. Therefore, this shift not only reduces waste and conserves resources but also fosters sustainable economic growth and resilient communities with quality living environments, and responds by this to United Nations Sustainable Development Goals SDG11 – Sustainable cities and communities and SDG12 – responsible consumption and production, simultanoeusly (UN SDGs, 2017)

3.1 City as a community

"What is the city but the people? True, the people are the city." (Shakespeare, Coriolanus, act 3, scene 1). However, people always act in an environment, therefore the environment matters, and the relation between people and the environment is in reciprocal continuity (Goličnik Marušić and Marušić, 2024). Cities are places of many activities and are their representation, from economic, cultural to criminal, etc., but above all, they are society (Šimunović, 2007). These references call for a reasoning, that people in cities is about communities and networking. However, a community is successful when it works together and complements each other, and so the goods and knowledge start to circulate.

This paper is based on the premise that environments with strong communities having clearly identified and connected activities, adequate capacity and networking, have a better chance of being sustained and having potential for further sustainable development. Historically, in general there are two approaches of city emergence: bottom up and top down. Bottom-up approach reflects evolutionary process of networking of people with complementary interests, including exchange of goods and knowledge; manifested with marketplace and its further organic growth towards towns and cities. Top-down approach usually reflects the intention of the authorities to protect or expand their territories. The key to keeping such territories alive and well is to introduce, build and maintain communities that are socially and economically interconnected. However, the breakdown of socio-economic ties leads to the collapse of communities and, consequently, to the collapse of towns or cities. This was recorded many times in the history of civilisation already, from the very past until today.

Today, with unbridled and extraordinary technological development and society's often uncritical dependence on this technology and its development, we are faced with the breakdown of mutual social and economic ties between the inhabitants of local communities and the consequent disintegration of traditional ways of living and living environments. The concerns already identified decades ago became reality (Mumford, 1961). The narrow specialisation of particular urban areas for certain activities and the loss of the diversity of activities in them has also contributed to this, which is particularly evident in the historical centres of the cities.

Some parts of cities are losing, or have lost, the ability to offer a suitable living environment or a setting for the service and production activities that have traditionally inhabited such environments. These environments are losing their local population and are either emptying and decaying or are being gentrified. This interrupts continuity for many activities and, with it, the flow and transfer of knowledge. The strong point here is that the inhabitants of the city are not socio-economically connected to the city. To illustrate, the people who would traditionally represent the actors in the economic cycles of such a community have largely turned into intermediaries between globally available goods and services and domestic consumers. Some, however, have become merely intermediaries between external goods and services and even external consumers. Production/consumption cycles in the local community thus begin and progress to the break-up of the self-sustaining community. Re-establishing production cycles, especially in the absence of knowledge (crafts, local trade) is usually difficult.

Over the past century, and especially in recent decades, the linear economic model based on resource exploitation and depletion on the one hand, and profit and waste accumulation on the other, has been more intensively transferred from the elites to the general population through globalisation. In doing so, local economy systems that were often based on circular concepts died down. Local cycles also died out as local rural settlements began to empty (after World War II). This process has led to a point where material, energy and cheap labour resources are exhausted, and we are faced with a surplus of waste and a high concentration of wealth among a narrow elite, an unbalanced distribution of goods.

The migration that escalated after the Second World War, which in the rural-urban context meant a shift of the population to the cities for the jobs that were available there, and thus also for the new forms of living in the newly built residential neighbourhoods. Working and living on a farm was considered regressive, while working in industry and in administration was considered better and desirable. On the other hand, as society and technology developed, the educational level of the population rose and the mentality that people with higher education were not destined to live in the countryside, but to work in the cities, in administrative work, took hold. The educated were not returning to rural areas, which, again contributed to the impoverishment of the local community from which they came. Industrialisation has also had an impact on the agrarian community, so that production has increased without maintaining the workforce, even by reducing the workforce.

The process of globalisation that followed seemingly reduced the need for self-sufficiency by offering cheaper products from the global market. All these processes have also had an impact on the demographic picture. Globalisation has led to the drying up of the production that used to attract people to cities. The urban population, however, is at a very low level of self-sufficiency and even faces the problem of securing financial resources. Individuals or some parts of the population (including the highly educated) are emerging to reverse this process. They are returning to the countryside, also moving towards self-sufficiency, and trying to establish different models that have the characteristics of circularity. They are able to do this because today's technology allows them to develop, act and network in their areas of expertise wherever they live. This trend points to the potential for the concept of circularity to become more generally applicable and to become part of the planning and development of cities and their linkages with their rural and peri-urban hinterlands.

However, the process of globalisation has physically emptied villages and impoverished cities in terms of diversity of contents and activities taking place there, and these call for the creation of a model that can improve that situation. Setting up of circular economy models in such environments create the need for different professional profiles, and thus the possibility of introducing a balanced distribution and diversification of the population there. This enables the development of healthy communities and increases their capacity for self-sustainability.

3.2 Circular community model

Although several circular economy business models and related value add via production of goods and services as well as value chain which addresses the activities that provide or receive a value from the activity in a cycle (e.g. developing, producing, distributing, consuming), the current discussion is mostly limited to the physical processes and business models including the way products are developed, promoted or offered to consumers, and there is basically no talk about a community that runs or enables these cycles. This section focusses on setting up of a circular community and showing step by step its possible shaping and

development through its key development phases. A sequence of diagrammatic schemata helps to represent and discuss the circular community model composed by materials providers, developers, producers, services, distributors and consumers; and elucidats the basic relations among them.

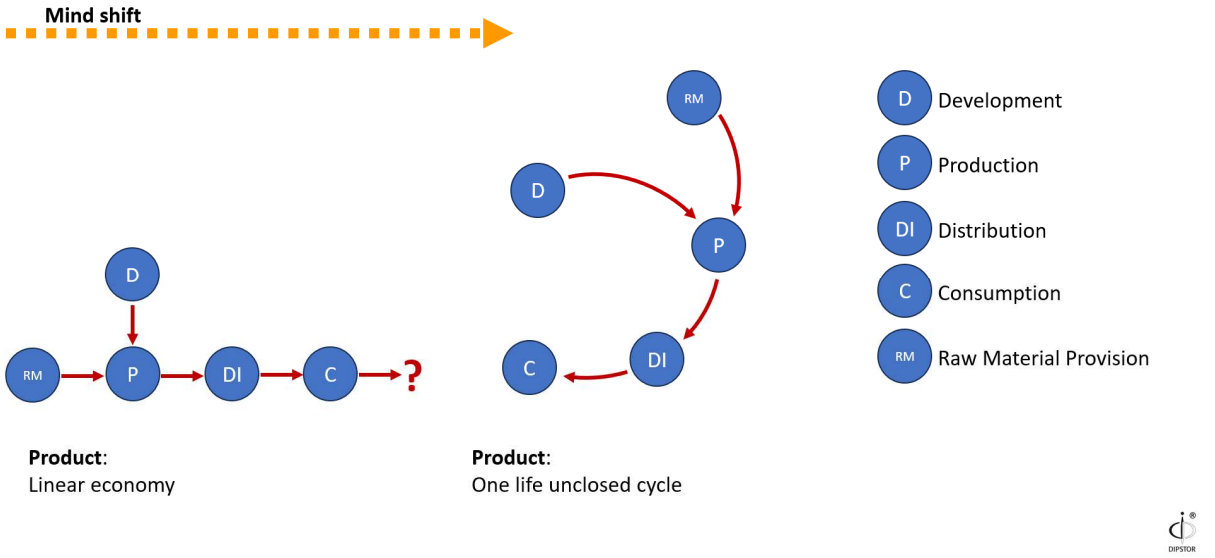

Fig. 1: From linear to basic circular economy model (illustration: authors).

Linear model in general paves the path of raw material through product production, distribution, and consumption toward waste. Development is predominantly in the function of production to serve a consumer's demand for new products. All mentioned cells have no particular need to be physically/territorially close or connected and socially or otherwise interconnected. Basically, the only goal is a profit. The consequences are dislocated production, excessive waste deposition and logistics requirements, only profit-oriented marketing and development and estranged consumption-oriented user having no real influence on quality or affordability of the product or service. The result is excessive need for transportation and waste deposition infrastructure, unbalanced jobs distribution with gravitation towards the lower-cost environments not close or even within the local environment of consumption of products or services. Spatial manifestation is either development of excessive transportation and waste deposition infrastructure requiring large amounts of valuable space or overloaded existing infrastructure or both with constantly growing spatial demand. Since available space is limited, the mind shift that could turn around such trend is essential and inevitable. Figure 1 shows the importance of readiness for as shift away from linear economy concept.

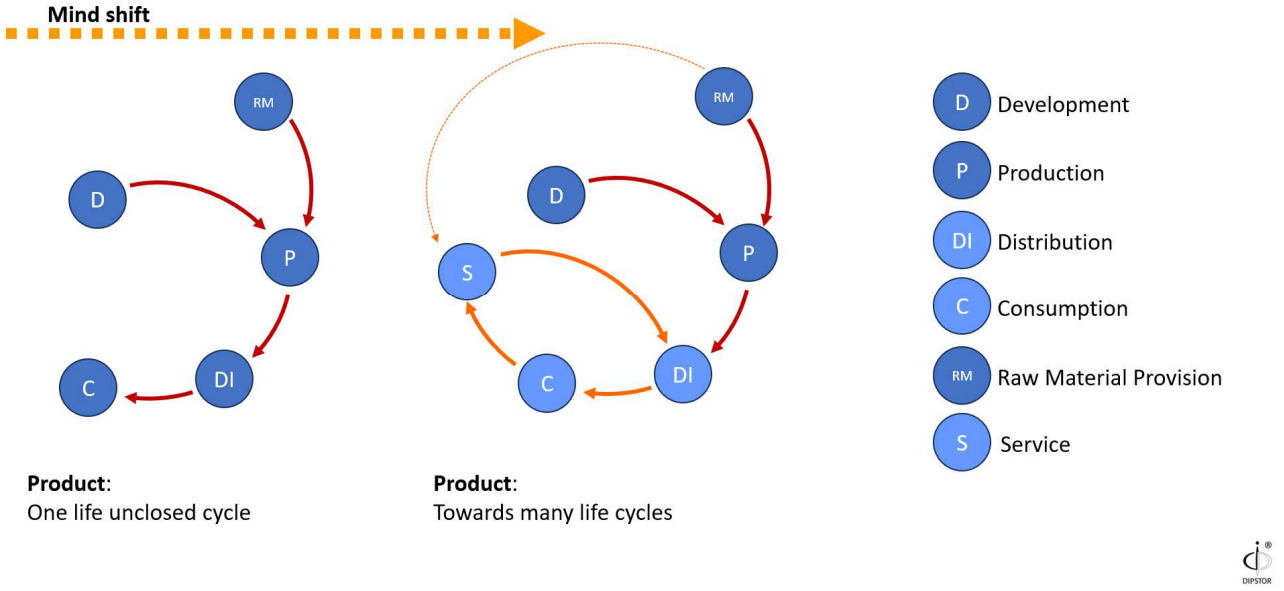

Fig. 2: From linear to basic circular economy model – stakeholders' relations (illustration: authors).

There is a challenge how to "bend the linear process" and which unit of the community could play the crucial role in that. Figure 2 shows that when adding the service in the function of repair, refurbish, or redistribute the used items to be reused, the life of products is prolonged, the need for disposal reduced as well as demand for the raw materials. Service close to consumption reduces logistics demand and provides professional employment in the local environment. Such service in general and certainly in long-term requires less space as it does not accumulate disposed products but circulate them. It also improves professional level and job-diversity in the local environment.

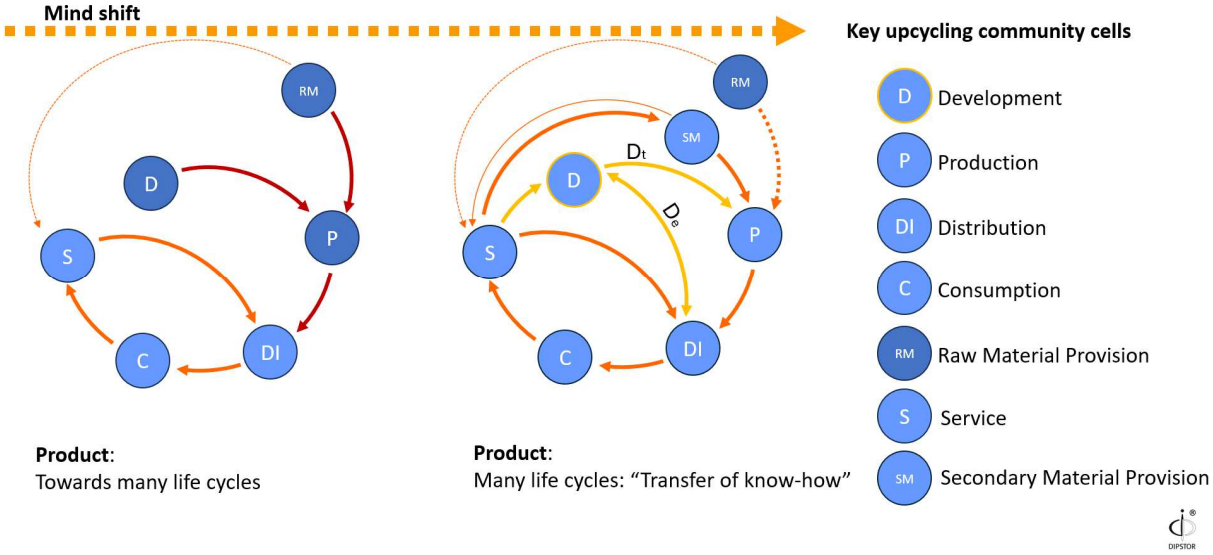

Fig. 3: From basic to advanced circular economy model – development & knowledge transfer as driving forces (illustration: authors).

However, without appropriate development that would follow and fit the contemporary economical and technological needs of consumers the products in the loop after some time (i.e. several loops) exhaust their potential and find the end in disposal. Avoiding such situation and prolongation the life of useful material as long as possible demands further development of this circular community model. As illustrated in Figure 3, Development (D) has to further develop, and interconnect with service (S) and distribution (DI) to offer along with technological development (Dt) also economical development (De) with financial products (e.g. renting, leasing, loans etc.) for both, consumer (C) as well as supplier (e.g. distributer (DI), producer (P)). Such development opens the door to wide spectra of specialisation and jobs within a local community. The products of such model are not any more merely repaired or refurbished old products, but also completely new products, which were developed from the materials of old products entering the cycle as worn-out products from various levels of the value hill R-ladder. Such an approach enables substantial metamorphoses or remanufacture of mass of worn-out products avoiding their substantial degradation (i.e. downcycling) but rather upcycling them into new potentially serial products. Methodology of development and design of industrial products that are able of metamorphosis into new generation of products in the next cycle opens new aspects in development of industrial production with fully circular products (see Section 3.3.1). A vast majority of raw material demand is replaced by secondary material. The space required for disposal of waste material is further diminished. Service (S) takes over another important task such as sorting of collected products or materials according to the value hill and their distribution to relevant units of the model.

This model also addresses the responsibility of final user. Consumer (C) which is involved in such circular process is motivated to act as responsible user as the product he/she is using is perceived as his/her currency, the value he/she will exchange in the next cycle for at least partly covering the costs of the new goods and services, respectively. This whole process suggests the introduction of evidencing and tracking of products and their parts, which can be introduced via digital passport using blockchain technology, especially in larger systems. Such approach not only improves the consumption (C) and distribution (DI) aspects, but also contributes to environmental considerations, such as carbon footprint tracking.

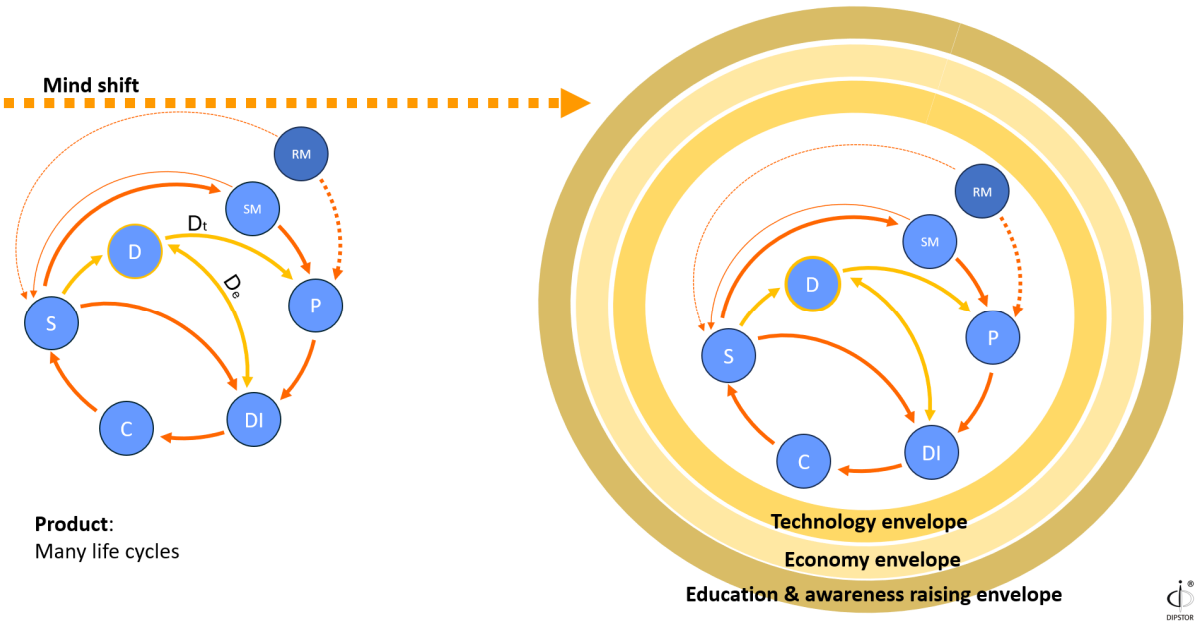

Fig. 4: Circular community model (illustration: authors).

Besides technological knowledge and technical support that every production process needs, a smart circular community to function, must be also supported by adequate economic knowledge and environment. That includes for example, appropriate financial services, presence of adequate individual and collective consumers. However, for community to sustain, it is essential to develop knowledge environment with continuous systematic education and awareness rising programmes for both community members and general public (see Figure 4). Such community is rational and people- and environment-friendly and therefore can be considered a smart community, where high technology is used only to support implementation of these values.

Each such local niche community may consist of several production (P), development (D), distribution (DI), or any other identified units as long as they are supporting each other and looking for synergies in common and shared activities. This means that a local circular community consists of a conglomerate or network of local niche circular communities specialised e.g. for furniture, tourism, gastronomy, fashion, and the like, where each entity/stakeholder can play different roles in different niches, e.g. being producer (P) in one and consumer (C) in another. Such conglomerate can support its members by sharing some common services and even more efficiently circulating the goods.

The market area that may be considered as a local often depends on product or service specifics. The circular model does not imply to extinct the interregional cooperation. On the contrary, development of knowledge network is very important for development of circular economy. Also overlapping and cooperation of neighbouring communities and their markets is important for their sustainability. Therefore, emergence of regional and even global societies and networks supporting circular economy by sharing knowledge is essential. It implies only to reduction of negative environmental impacts and developing sustainable socio-economical local environments. By reduction of transport demand the logistic infrastructure expansion may decrease and its spatial and energetic demand along as well as societal expenses for all that. That would be nice.

3.2.1 Circular product as a service

In the context of fast consumption society, the affordability of high-quality or good-quality products and services is often low. Also, in many fields, it can be observed that the quality of products and services at affordable prices is decreasing. In order to optimize the user experience and use of products, their affordability, material flows and added value in products, the model in which the consumer becomes the owner of a physical product seems not always the most successful. A product-as-a-service (PaaS) business model can offer optimal performance from multiple perspectives in many areas or for many product groups, provided that it is managed in an appropriate environment, such as a functional circular community. Such a service gives the user the opportunity and permission to use, but not the ownership of the object of use.

Responsible consumption is motivated because a responsible consumer benefits from lower service costs. Affordable and incentivized financing options can be developed, including e.g. rental, sharing, leasing, membership, etc. A wide range of products can be included in such services, especially if blockchain technology is introduced to keep records and track products. In practice, this means that one can rent a high-quality product, e.g. furniture, computer, car, etc., for an affordable initial cost and maintain the quality of service for a long time. Such a model supports local niche communities and can be well harmonised with compact neighbourhoods and a city of short distances.

3.3 The material flows

In the linear economy model the raw material extracted from a (natural) source is used in the product and after this use is exhausted, it ends as a waste expanding the infrastructural demand. Often logistic of such product life path is rather demanding as the costs of labour and input (raw) material are reduced by migration into low-cost environments. Disposing of worn-out products takes space and logistics. In somewhat improved economic models, the worn-out products are disassembled and degraded to the level that can be used in the products again. Such process is circular regarding the material flow as the primary material sources are preserved. However, it transforms the product to a very low level at the value hill (downcycling) which often requires substantial energy and the whole production process. Some materials degraded to such a low level cannot be fully recovered. As material is degraded, return to the basic production is required, often not in the local environment. Logistics for that is required, however no jobs for local community growth and reinforcement. In the case of circular models that more intensely include local community capacities and target the higher level of the value hill, efficiency of circular process may be much higher and cover multiple aspects including environmental and social ones, as they seem to be the two sides of the same coin.

Strictly speaking the story of material flows physically starts at the material origins (resources), however it arises by the consumer's need. How this need is developed and does it have a real basis is another story, however, also important in the context of sustainable circular economy. Anyhow, since we are talking about circular economy, we can basically start anywhere to get further and around in the loop. Assume a potential consumer (C) have a need for a certain product. He/she can get it (buy, rent, etc.) at the circular community distribution centre (DI). After some time, for some reason, the product is of no use any more for the given consumer (C). Perhaps it is broke, used up, do not serve the new needs, not attractive to the user anymore, etc. So, consumer (C) brings the product to the circular community service centre (S), reception of which may be at the same spot as distribution centre (DI). Regarding the condition of the used product and the needs/requirements of consumer (C), service (S) and distribution (DI) consult/offer possible solutions to consumer (C) to fulfil his/her new needs. The product brought to the service (S) is assessed and subjected to the treatment according to its condition and market requirements. It can be basically maintained and sent directly from service (S) to distribution (DI) to be reused. If necessary and possible, it can be repaired or even refurbished, if the procedures to do so are simple enough to manage them in the service workshop. Then repaired and simply refurbished products are sent from service (S) to distribution (DI). If more demanding operations are needed for refurbishment, however it is still reasonable to do so, the product is sent to one of the production centres (P). If none of above procedures are appropriate, the product is sent to the secondary material collection centre (SM) to be further treated (probably at least partly decomposed), sorted and redistributed for remanufacture, repurpose or recycle. Some products or their parts are useless for further processing in the form they are due to excessive degradation or inappropriate design, however material stored in them is useful and valuable. For material to be used again, these products have to be severely degraded first and then recycled into some kind of basic material – downcycled in the recycling plant (PRECY). To avoid such situations as much as possible, an introduction of fully circular product (FCP) development/design is needed and applied already in the production phase. Some material from old products is too decayed to be even recycled, however it might be useful for a kind of recovery production (PRECO). However, there might be some leftovers of the worn-out products that are completely useless or even toxic and have to be disposed at the appropriate waste-disposal centres (W). To avoid these situations FCP should be applied in the production of new generations of products. Some products from secondary material collection centre (SM) may be designated for repurpose (PREPU), so they may enter another circular system/loop. Circular production centres (C) get material (products or products' parts) mainly from secondary material collection centre (SM), however, also some from raw material centre (RM). They may

use also some material from recycling plant (PRECY) and other sources (e.g. other circular system/loop). They supply distribution centres with refurbished and remanufactured products. The new generation products may be based on secondary material, but also on new (raw) material, provided that these products are FCP. They also supply circular community service centres (S) with spare parts. The brain of the whole community is development centre or network (D) supporting two important components: technology (Dt) and economy (De). It is responsible for rethink solutions (e.g. FCP), refuse materials and processes harmful to environment and reduce consumption of natural resources within any products, processes and activities in community. Figure 5 shows the material flow in circular community and illustrates the community as a holder of activities which reflects the so-called R-ladder strategies (e.g. Kurilova-Palisaitiene et al., 2023) that can help to readdress concept of waste, and accordingly rethink the consumption patterns and redesign of products, which all finally affect the spatial logistics, uses and activities distribution, and therefore can represent a bottom up circular economy approach to cities and towns planning and development.

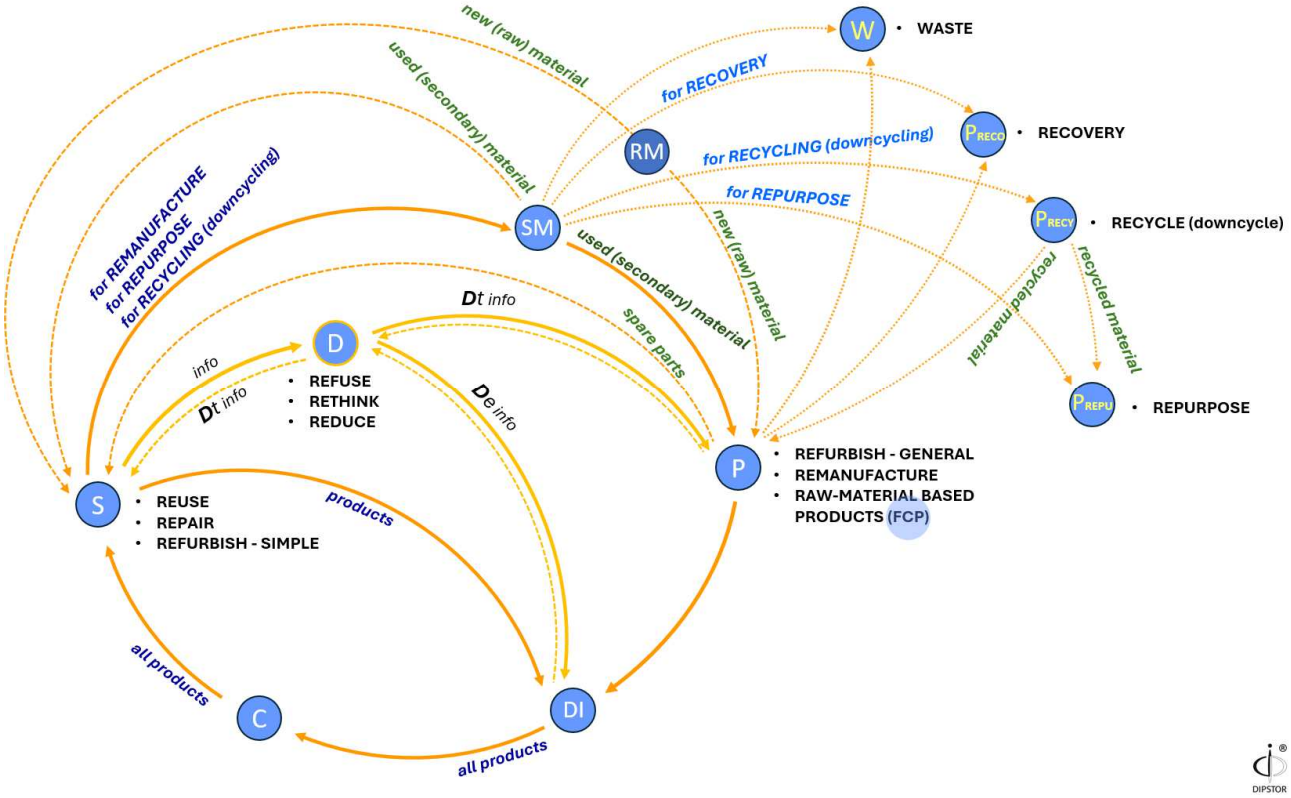

Fig. 5: Material flows in the advanced circular community model (illustration: authors).

3.3.1 Fully Circular Product – Evolutionaty Design

The implementation of circular economy models requires a rethinking of the processes with which the products are managed throughout their life cycle from design to recycle. The methodological approach of evolutionary planning represents a relevant potential for its implementation. This approach is characteristic for not to focus on just one phase of the process but throughout the entire life cycle of a product in each phase of the life cycle (maintain, repair, reuse, refurbish, remanufacture, repurpose, recycle).

Evolutionary Design is an advanced product design-development approach (DIPSTOR, 2019) that continuously generates upgrades or improvements of existing designs and generates new ones, based on success and lessons learnt from parental/related designs simultaneously considering environmental, economic, user experience and societal aspects. It is a concept of development of modular systems that are easy to maintain, repair (e.g. possibility of disassembling and changing parts) and remanufacture (modularity), following the iterative choice of the best characteristics of a product to achieve the best performance, and where each product generates the next development phase and opens new questions and possibilities for further design.

The aim is to adopt a product design-development planning process resulting with Fully Circular Product (FCP), which will, following the Evolutionary Design, move the focus of design process from deterministic

product design of a single product to possibilistic development of product evolution. In such a process the usability readiness of product or its parts for further new designs is prepared. An initial product is subject to an assessment of possible metamorphoses of the initial product via cascades of a product's life cycles.

As well as perpetuum mobile, also a FCP is an ideal, not entirely realistic to achieve. Yet, the bright goal should be to make cities Fully Circular Products (FCP) or as close as possible.

3.3.2 Slender revitalization

An illustrative example of circular process in the urban an environemnt such as a historical city is revitalisation approach where the old building material is treated with care and respect. With careful decomposition and separation of old building materials and parts a substantial share of material can be reused in the new project of revitalization and introduction of some new material is reduced. Due to disposal reduced to the minimum, transportation cost is reduced as well as demand for the landfill. However, some more qualified and careful work is required for such "slender revitalization". Such approach is easier or even possible in the case of built with simple materials rather than with the composite ones, where decomposition and reuse is problematic or even impossible. The natural materials are also often easier to be reused and their decay less harmful to environment than of the synthetic ones. DIPSTOR is currently involved in such a project. Most materials (wood, bricks, roofing tiles, stones, plaster, etc.) are being reused. Some wooden parts that are unable to be used for construction anymore, are used for furniture design, which will be included in furnishing of the renovated building. Such an approach of slender revitalisation also refers to aspects of FCP.

4 CONCLUSION

The presented concept of circular community and a community as a foundation of a city reflects circular economy concept from a bottom-up perspective. It starts on the other end as infrastructural concerns and conceptualisation of industrial symbiosis, water waste or all sorts of waste management, to complement these bigger systems and solutions. The presented model addresses rather small scale and strives towards the shift from product maximisation to provision of human needs, reflecting users' dimensions of circular economy as an instrument for delivering decoupling of economic growth from resource use (waste production) and environmental impacts in practice, as well as a part of the bigger picture of economic, societal, environmental and cultural transformation needed to deliver truly liveable cities.

In the circular model understanding and considering the user needs is addressed by how the material embedded in any product circulates through the product's life cycles or generations of products and their creators. These creators of one generation do not know who and how will create the next generation of products. All they can do is to make their design as wide as possible for the next generation, thus allowing the most probable and/or possible products to be implemented. Unlike linear models, which are deterministic, as the next generation of creators responding to the needs of the community is not actually foreseen, the challenge in designing fully circular products is to cover the needs of the present while allowing for the widest possible possibilities of the future. Thus, products created with circular models are more complex compared to those of a linear model, whether it is the design of a chair or the renovation of a house.

Circular community model discussed in this paper reflects relationships among many actors in it (representative units: P, D, S, DI, C etc.) and when considering them spatially, they all express certain demands about a place but most of all they perform a sort of behaviour pattern which reflects their optimal spatial-temporal relations, and can lay crucial bottom up foundations for optimal locations, spatial dimensions needed for their successful manifestation and the like.

The reasoning in the paper paves the way towards new conceptions of spatial planning in which circularity approach could help spatial planning to move from sectors to systems to address and find solutions for urban systemic inefficiencies and imbalances.

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reviewed paper

Cities for All: Urban Equity and Cultural Inclusivity in Cosmopolitan Cities: A Case Study of Wadi Hanifa, Riyadh

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1 ABSTRACT

The concept of “Cities for All” has become a necessity for addressing the challenges of urbanization, multiculturalism, and social equity in the 21st century. As cities are rapidly evolving anddeveloping increasingly diverse multicultural layers, it became crucial to foster inclusive environments that promote equity, equality, and justice. Yet, challenges persist in developing truly inclusive urban spaces, thisacquires a deep understanding of the interlocking complex relationship between social community needs and urban design parameters.This research explores the dynamics of the multicultural societies in urban spaces.It highlights the challenges faced in accessing equitable public spaces. It examines the role of urban design in fostering social cohesion and reducing spatial inequalities. The research aims to studythe capacity of the outdoor public spaces to accommodate people needs with cultural diversity, including individuals of different nationalities, genders, age groups, and cultural backgrounds, enabling them to practice their activities and express themselves in public without conflict, while fostering mutual acceptance.The research employs a mixed-methods approach, combining qualitative analysisof spatial data with user experiences and perceptions. The study incorporates observational research, annotated mapping techniques, photographing, and looking for traces to provide a comprehensive understanding of space utilization and cultural dynamics. The research conducts systematic observations of public behavior and space usage patterns across different times of the day. This method supported the documentation of how various cultural groups interact with the urban public space, providing insights into the effectiveness of designelements in promoting inclusivity and equity in multicultural settings.The study utilizes annotated maps to visually represent spatial data, and uses qualitative observations topresent the distribution of amenities and facilities across the urban public space to identify the patterns of use by different cultural groups. Theoverlapping between the observational data with the annotated maps creates a powerful tool for analyzing the relationship between urban design of public spaces and social equity in multicultural environments. The study proposes a robust framework for assessing and improving urban equity in diverse public spaces.The research applies its methodology to analyze a case study within the context of Riyadh city (an evolving cosmopolitan city as the capital of Saudi Arabia) with a specific focus on Wadi Hanifa as a study area. This case study concentrates on understanding the concept of urban equity in designing public spaces to promotesocial cohesion, especially in multiculture communities.The research explores the impact of Wadi Hanifa redevelopment project in promoting spatial justice and equity in public spaces, taking into account the varied requirements of the multicultural community in Riyadh. It examines the project's strategy for establishing welcoming public areas that honor local cultural practices while encouraging intercultural harmony, which provide fair access to parks and recreational areas for all groups.The case study analysis of Wadi Hanifa, demonstrates that its strategyaligns with the macro-movement towards creating “Cities for All”. It emphasizes how important it is to accommodate a comprehensive approach that considers culturally-sensitive design. The public spaces of Wadi Hanifa has a flexible design qualities that serve the whole community. The research shows that the Wadi Hanifa project successfully integrates principles of equity and urban justice, resulting in increased public use and improved quality of life for diverse multi-cultural groups. The study concludes its findings by highlighting the importance of such successful projects in promoting social cohesion in cosmopolitan cities that embrace diversity as well as harmony. This approach is aligned with the kingdom 2030’s vision for Sustainable Development, to create safe, inclusive, and resilient communities.

Keywords: Multi-cultural, Equity, Inclusion, Cosmopolitan cities, Public space

2 INTRODUCTION

The significant increasing in populations with the rapid urbanization growth in the 21st century created multicultural communities with challenging needs and unique characteristics. It has become an urgent need

for designing spaces that understand their demands and address their requirements (Gehl, 2010). Urban planning and design guidelines in many countries regulate the concept of "Cities for All" (Alkhresheh, 2012) which was developed to tackle these new challenges of multiculturalism, seeking to achieve social cohesion public spaces (Sinha et al., 2024). This research focuses on the dynamics of the multicultural communities in cosmopolitan cities. It studies the challenges and opportunities of creating public spaces for all (Harris et al., 2023). By examining the relationship between urban design parameters and the needs of diverse cultural groups, the study aims to develop a framework to understand the phenomena, consider the inputs of variables, aided by the case study-based approach for analysis and understanding (Carmona, 2021).The research support the idea that public spaces should be accessible and welcoming to all, regardless of nationality, gender, age, or cultural background, enabling users to engage in communal activities without conflict, and to express themselves freely (Harris et al., 2023).To study the role of urban design in fostering urban equity, an integration of multiple qualitative tools were implemented as observation, documentation, photographing, tracing, and looking for traces (N. Groat & Wang, 2013). On site observations through multiple field trips to examine the inclusivity of public spaces. Focusing on Riyadh, as a rapidly evolving cosmopolitan city (Elsheshtawy, 2021), the research studies Wadi Hanifa project as a case study for a public space. Wadi Hanifa, represents the principles of equity, equality and justice, aligning with the main goal of "Cities for All" (The Royal Commission for Riyadh City, 2025). The study highlights how urban design can promote social cohesion, and enhance quality of life for diverse communities. The study aims to develop a framework for assessing and improving urban equity in multicultural cities, fostering equitable access to public spaces.

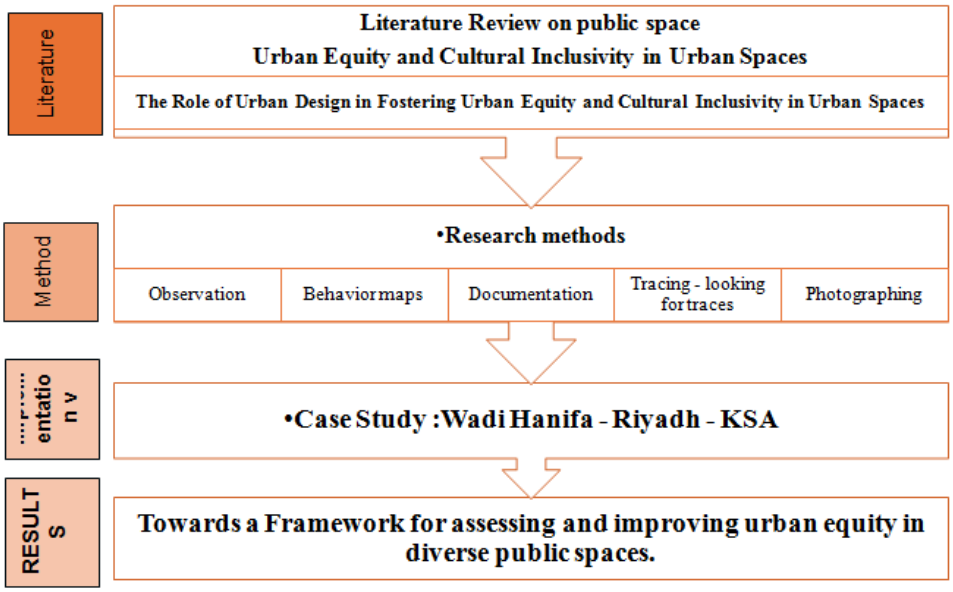

Figure 1: Research Methodology-Source: Author

3 CITIES FOR ALL

For the past decades, Cities have continued to follow a dynamic path of growth and change (Gehl, 2010). It is noticeable that cities become hubs for diversity, as a result of urban populations growth, such differences as language, and gender (Kihato & Massoumi, 2010).Despite the growing emphasis on inclusivity, many cities face substantial challenges in creating equitable and culturally sensitive public spaces (Sevincer et al., 2017). A significant consideration has been dedicated to the concept of "Cities for All" from the urban development perspective, emphasizing the need for inclusive, equitable, and culturally diverse urban spaces, addressing challenges as rapid urbanization, multiculturalism, and social equity (Harris et al., 2023). This research explores the key themes of urban equity, cultural inclusivity, and the role of urban design in fostering social cohesion, with a particular focus on public spaces in multicultural cities (Carmona, 2021). As public spaces play a crucial role in promoting social cohesion and reducing spatial inequalities (Sinha et al., 2024). The research examines the theoretical foundations and practical applications of inclusive urban design. As the implementation of public spaces should consider accessibility for all community members (Abdelfattah & Nasreldin, 2019), cultural sensitivity in design features, and chances for diverse groups to

interact and engage (Harris et al., 2023). Successful public spaces can perform as catalysts for broader urban transformation, positioning cities as models for embracing diversity although maintaining cultural authenticity (Carmona, 2021).

3.1 Urban Equity and Cultural Inclusivity in Urban Spaces

Urban equity is a crucial aspect of creating inclusive cities. The UN Habitat's urban planning principles emphasizes the importance of integrating social equity into urban development to create inclusive, sustainable cities (UN-Habitat, 2013). It defines social equity as the fair distribution of resources, opportunities, and services, addressing differences caused by socioeconomic factors (UN-Habitat, 2013).As, Pratt (2014) explores the evolving role of culture in urban development, highlighting major shifts, he identifies main aspects of differences, including education, technology, and governance, emphasizing cultural inclusivity and equity (Pratt, 2014). He highlights the importance of integrating diverse cultural practices to foster social cohesion and economic growth, aligning with the broader discourse on creating inclusive, equitable cities for multicultural communities. As cultural inclusivity in urban spaces involves creating communities that respect and cherish cultural diversity while fostering mutual understanding and acceptance among different groups. According to (Uitermark, 2012)the pursuit of urban equity is essential to achieving social justice in cities. (Sandercock, 2009) highlights the role of public spaces as sites of cultural exchange and interaction, where diverse communities can coexist and thrive. (Okano & Samson, 2010)highlights the importance of urban cultural diversity in metropolitan cities, suggesting that successful cities should recognize the value of diversity. Correspondingly, Marcuse (2009) discusses that spatial justice and urban equity requires the equitable distribution of public services including green spaces, recreational facilities, and cultural amenities. However, as (Madanipour, 2003) notes, many urban spaces fail to accommodate the multicultural community needs, which might lead to social fragmentation. This highlights the importance to have flexible and adoptable public spaces that consider the values, and preferences of diverse cultural groups, allowing them to practice their culture habits without being judged (Sinha et al., 2024). These sensitive public spaces align with the concept of “Cities for Life”, which places people at the centre of development based on principles of equity and justice (Abdelfattah & Nayer, 2023), and promoting social cohesion (Marcuse, 2009).This research is proposing urban design as a tool to approach more equitable and inclusive open spaces (UN-Habitat, 2014).

3.2 The Role of Urban Design in Fostering Urban Equity and Cultural Inclusivity in Urban Spaces

Urban design plays a critical role to approach equity and justice in public spaces. (Gehl, 2010) highlights the significance of human-centered design principles to create vibrant public spaces. He asserts that well-designed public spaces foster social interaction, and promote cohesion communities. (Carmona, 2010)supports the argument by highlighting the necessity for adaptable and flexible design solutions that can accommodate the changing needs of the multicultural communities of public spaces. Ensuring that their needs and preferences are adequately addressed (Carmona, 2021). In order to foster equitable and resilient communities to create inclusive urban spaces that address social, and economic challenges (Harris et al., 2023) highlights the importance of integrating accessibility into urban design to promote social equity and urban resilience, offers a model for inclusive urban design, aligning with the goals of creating equitable, sustainable cities. On the other hand (Sinha et al., 2024) focuses on how inclusive design and participatory approaches can strengthen social cohesion, ensuring urban spaces benefit all residents and promote equitable, sustainable cities (Nasreldin & Abdelfattah, 2020).

4 THE METHOD

Towards investigating urban equity and cultural inclusivity in public spaces, several scientific methods were adopted. An integration of multiple qualitative tools were implemented, in order to study the role of urban design in fostering urban equity, as observation, documentation, photographing, tracing, and looking for traces (N. Groat & Wang, 2013). On site observations through twelve field trips were applied to examine the inclusivity of public spaces. Six trips were completed on weekends (three trips in the day time and three trips at evening time). The other six trips were conducted on the weekdays (two trips in the day time and two trips at evening time), distributed among the four sessions (summer, winter, autumn and spring).Annotated maps and behavioural analysis were adopted to study the interaction of diverse cultural groups within the public spaces. During the field trips, the research conducted semi-structured interviews (Aboubakr et al., 2020) with

the users and visitors. The interviews tackled criteria related to the frequency of visits, activities conducted during the visits, and their sense of safety and comfort. Information were collected regarding the availability of services and facilities, quality of the set-up, vegetation and shadings, lighting during night visits, availability of parking spaces. Discussions were raised about the ability of the space to accommodate multi-culture communities from different nationalities and their overall sense of comfort, equity and cultural inclusivity in the Wadi Hanifa platform.

4.1 Framework for Inclusive Design: Improving urban equity in diverse public spaces.

The study proposes a robust framework for assessing urban equity and inclusive design to improve the interaction of diverse cultural groups within the public spaces. The framework reviewed the literature related to multiculture societies, urbanization of cosmopolitan cities and culture inclusivity, in order to develop a clear understanding of urban equity, urban equality and urban justice (Norman-Major, 2011). Equality means that everyone is provided with the same opportunities or identical resources, regardless of their individual circumstances or needs. It is based on the premise that everybody is in the same position and needs the same level of support (Minow, 2021). In equality, individuals and groups receive equal resources, regardless of their unique situations. Though, this approach does not take into consider the variations of outcomes, as everyone get advantage from the same level of support, although their different needs (Chu, 2019).On the other hand, Equity focuses on fairness rather than on equality. It takes into account that individuals are different. As Equity as a concept is trying to provide the resources or opportunities necessary to achieve equal outcomes. Equity recognizes these differences and provides unique support to individuals or groups, ensuring that every person receives the needed support to succeed (Lewis et al., 2021). Unlike equality, equity addressing individual needs for fairness, which means that some may require more support than others to achieve the same outcome (Norman-Major, 2011).Justice goes one step further from support, by tackling the fundamental causes of inequality (Lewis et al., 2021). It ensures that everyone's needs are met by removing any barriers and challenges. Justice is all about creating conditions where fairness is integrated and implemented (Minow, 2021). A model that incorporates equity, equality, and justice enhances wellbeing, social cohesion, and finally leads to the creation of inclusive public spaces (Lewis et al., 2021).

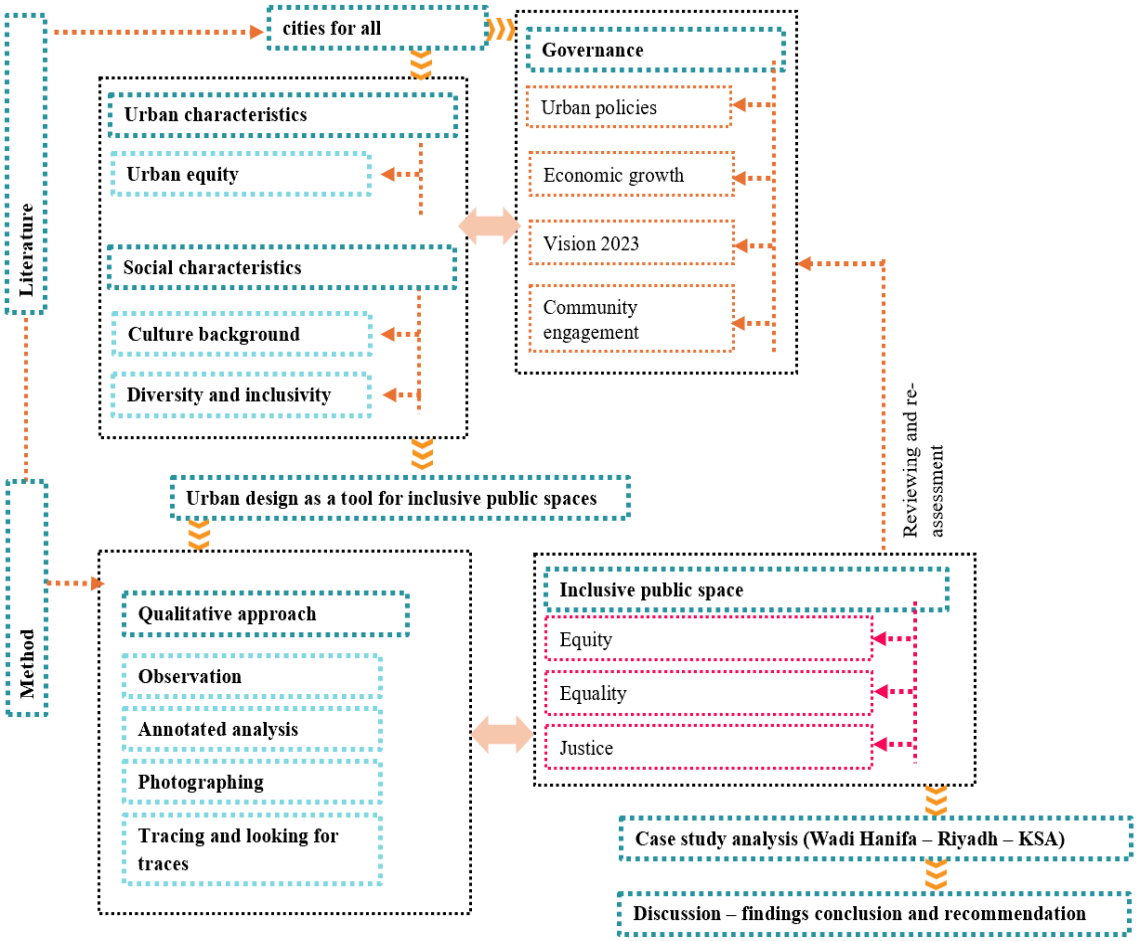

Figure 2: Urban design framework for inclusive public space – Source: Author

5 CASE STUDY: WADI HANIFA, RIYADH:

Throughout its history, Saudi Arabia has developed a cosmopolitan society, due to the free movement of traders and pilgrims, fostering cross-cultural and environmental diversity. Saudi Arabia is known for its multiculturalism, rooted in the coexistence of various national cultures (Al-Hathloul, 2017). This multicultural community includes Muslim Arabs and numerous other groups who have moved to the country for employment, bringing with them their unique cultures and languages. Saudi Arabia's population, exceeding 35 million people, diverse in terms of gender, class, and country of origin, with an estimated 10 million non-Saudis residing in the country (Ahmad Taha & Abdelfattah, 2023).Riyadh city (capital of Saudi Arabia) is considered one of the rapid growing cosmopolitan cities in the middle east and Asia within the past decade (Elsheshtawy, 2021). It is characterized by culture diversity that emphasize values such as equality, and mutual respect. It is becoming a hub for scientific and economic innovation allowing cultural expression and diversity. (Al-Naim, 2008) highlights the importance of preserving cultural identity while accommodating the needs of a diverse population in Riyadh. The concept of multiculturalism in Riyadh city can be recognized on various levels, starting from the top down urban policies that support inclusion, bottom to the daily practice of equity, equality and justice (Al-Hathloul, 2017).Wadi Hanifah represents a natural watershed for the floods and rainwater in an area of 4000 m² in the Najd region, located at the Riyadh Province, in central Saudi Arabia (Fahad & Sulaiman, 2017). The valley runs for a length of 120 km (75 mi) from northwest to southeast, cutting through the city of Riyadh, the capital of Saudi Arabia (Philby, 1920).

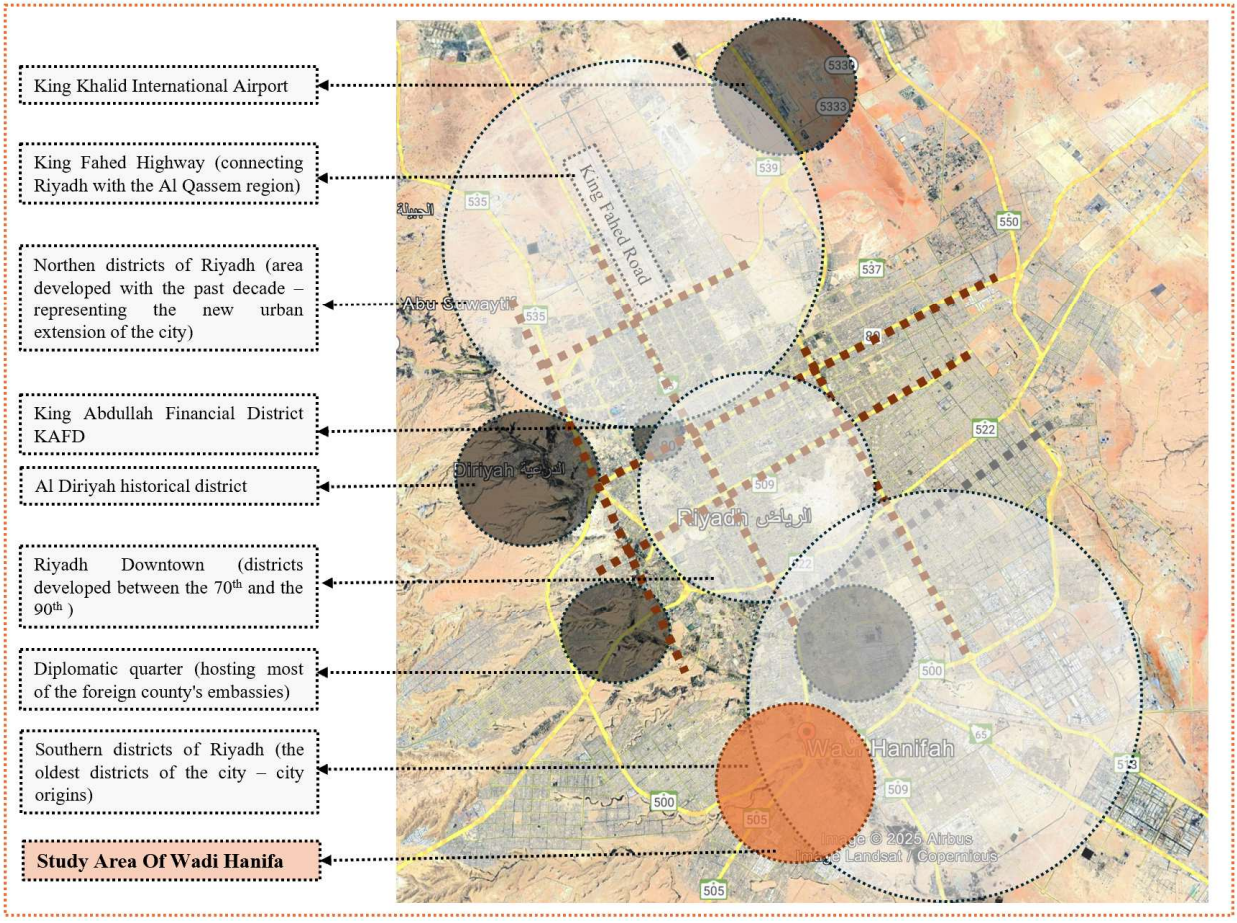

Figure 3: Riyadh City – Source: Google Earth with Author's annotation

The renovation of Wadi Hanifa serves as an example of creating spaces that are inclusive and accommodate accessibility while paying attention to cultural respect and environmental sustainability (Alhathloul, 2022). The Royal Commission for Riyadh City prioritized the conservation and renovation of Wadi Hanifa due to its strategic location and potential investment for Riyadh and its residents (The Royal Commission for Riyadh City, 2025).Back in 1987, Wadi Hanifa was declared as a development area under the direct supervision of the Commission. By 1994, an active renovation plan developed to a comprehensive action

plan. By 2002 Wadi Hanifa comprehensive development plan was approved as the master plan encompassing water resource management, environmental categorization, and land use (The Royal Commission for Riyadh City, 2025).The valley landscapes 47 kilometres of pedestrian walkways, complemented by 7.4 kilometres of rock-paved pathways overlooking rock formations, green spaces, and water canals. The pathways are built to cater to pedestrians as individuals, with strollers and wheelchairs; they also feature seating areas for relaxation and comfort purposes. A two kilometre waterfront promenade runs parallel, to the paths and provides views of the lake dam equipped with palm trees and public amenities. This promenade includes sections where pedestrians and families to picnic and appreciate the lakes beauty, with entry points connecting it to the lake. By incorporating principles of fairness into the design process the initiative has enhanced accessibility. The Royal Commission, for Riyadh City in 2025 provides a blueprint for developing areas in fast growing cities. It shows how careful planning can promote accessibility, to all individuals and communities while also embracing diversity and supporting preservation (The Royal Commission for Riyadh City, 2025).

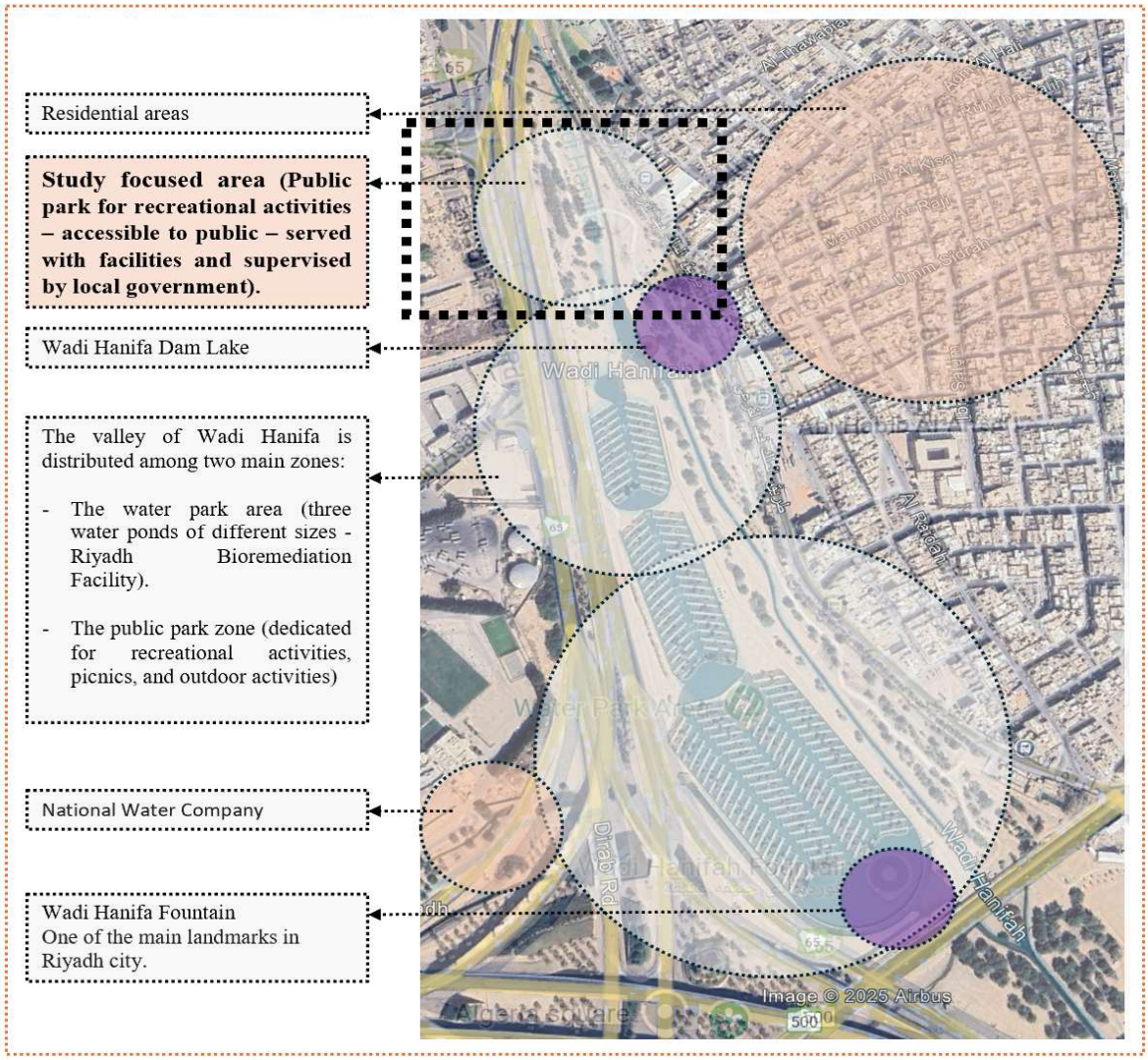

Figure 4: Wadi Hanifa – Source: Google Earth with Author's annotation

5.1 Wadi Hanifa existing conditions documentations and analysis

Documenting the existing conditions contributes a deeper understanding of the layout with insights into the facilities and functions. A layer of analysis has been added in the form of the Annotated maps and behavioural analysis, to explore the potential and determine its variables as an approach for developing a set of guidelines and framework for assessing urban equity in diverse public spaces, targeting further enhancement and improvement. The valley of Wadi Hanifa has One of the main landmarks in Riyadh city, which is the Wadi Hanifa Fountain, located directly before the water parks. The valley of Wadi Hanifa is distributed among two main zones: The water park area (three water ponds of different sizes – Riyadh

Bioremediation Facility), with direct connection to National Water Company, and The public park zone (dedicated for recreational activities, picnics, and outdoor activities). The study focuses on the northern zone of the valley, above the area of the Dam Lake. The area is designed as an urban space for public park and recreational area, where services are allocated, such as toilets and praying areas for both genders, in addition to barbecue area for outdoor cooking activities).

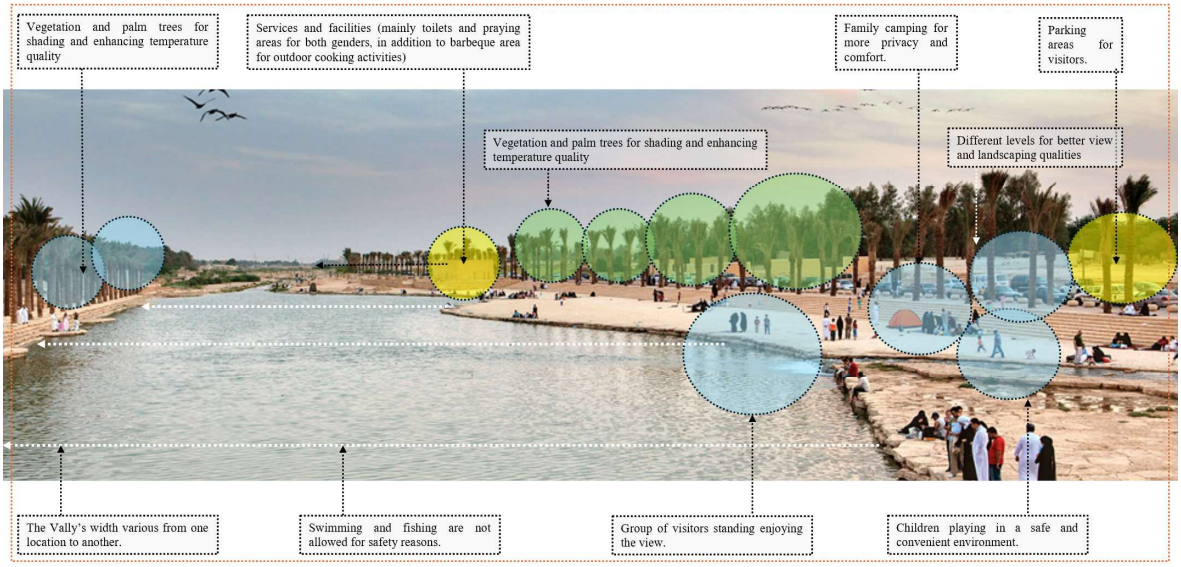

Figure 5: Wadi Hanifa – Source: Royal Commission for Riyadh City, https://www.rcrc.gov.sa/en/projects/wadi-hanifah/ with author's annotation

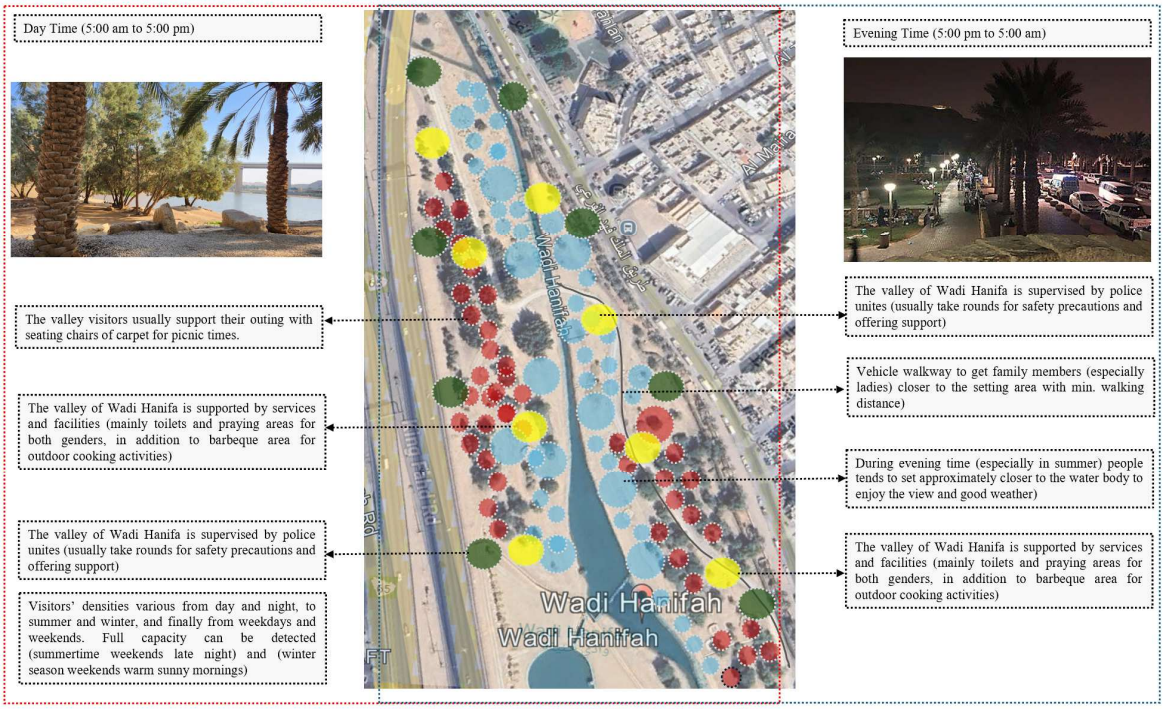

Figure 6: Wadi Hanifa – Source: Royal Commission for Riyadh City, https://www.rcrc.gov.sa/en/projects/wadi-hanifah/ and Google Earth with author's annotation

Figure 7: Wadi Hanifa – Source: Author

6 DISCUSSION:

The research has investigated Wadi Hanifa as a case study to learn more about public spaces, and its resilience to accommodate various users from multiculture backgrounds. As per the case study documentation of the existing condition, the valley of Wadi Hanifa consists of two main zones: zone one, The water park area (Riyadh Bioremediation Facility) with direct connection to National Water Company, and zone two, the public park zone (dedicated for recreational events, picnics, and outdoor activities). The

research focuses on zone two, where the area is dedicated for public use as park and recreational space. It covered the northern part of the valley, above the area of the Dam Lake. The findings of this research demonstrate the important role of urban design is in the implementation of equity and justice in the use of public spaces, particularly in the growing cosmopolitan city of Riyadh. Studying the case of Wadi Hanifa in Riyadh, the analysis demonstrates how the space is capable of fostering cultural inclusiveness and overcome the challenges of multiculturalism. The semi-structured interviews conducted during field trips to Wadi Hanifa's public park zone (Zone Two) provided valuable insights into how this public space serves a multicultural platform for local community and visitors. The users' feedback stated that the Wadi serves as a public space that promote inclusive community to accommodate different cultural groups, support social cohesion and environmental sustainability. The public space of Wadi Hanifa integrates the specific needs of the multicultural community of Riyadh, the visitors stressed on the ability of the space to provide various amenities and facilities that meet various cultural practices, age, and gender specific needs. Also, they noticed that the design of the public space provides zones or like clusters which are enclosed within rock formations. The use of contextual natural materials promotes the sustainability approaches aligning with the vision 2030. In addition, the majority of women during the interviews focused on the importance of the clusters created to provide a semi-private spots for families especially women to enjoy some freedom, free of restrictions, without being visually exposed to others. Moreover, the space provides prayer areas and water closets for both genders, providing praying carpets, in the outdoor for men, and others in private rooms for ladies. Regarding other activities, the interviews spotted that the Wadi Hanifa visitors usually enjoy outdoor cooking within the picnic areas, using the pre-installed built-in barbeque unites. The space is designed to reflect a deep understanding of the cultural and social dynamics of the community. The direct access to such facilities is directly aligns with the principles of urban equity, which emphasize the fair distribution of resources and opportunities, so that everyone, regardless of their background, can access and benefit from Wadi Hanifa public amenities. The public spaces of Wadi Hanifa contributes to accommodate a wide range of activities, from walking and social gatherings to recreational activities and cultural expressions.

This adaptability ensures the public space design flexibility to be accessible to diverse user groups over time, raising a sense of belonging and mutual acceptance among individuals. This design flexibility can be clearly detected through features like pedestrian walkways, wheelchair-friendly pathways, and seating areas located strategically. These design qualities is emphasizing that the space is inclusive for all, including elderly and individuals with disabilities. This aligns with the core principle of the urban justice, and the right for everyone to enjoy the space freely, with equitable access to outdoor spaces and recreational facilities.

Wadi Hanifa usually hosts one of the important cultural events in Riyadh (the festival of Noor Riyadh: a group of art pieces created by light shades, shiny installations and illuminated pillars). Wadi Hanifah has been one of the significant spots of Noor Riyadh Festival, representing a unique dynamic hub for art and culture. These installations was designed and implemented by both international and Saudi artists. Where Wadi Hanifah has become a shared space for connection and culture interactions, encouraging the dialogue among different culture groups. They highlight the valley's unique role as a bridge between Riyadh's natural heritage and its evolving multiculture urbanism.

The Wadi Hanifa success in encouraging social cohesion proves the significance of urban design in developing the common platform to be accommodated by divers users. It promotes a sense of community. This is remarkably in a cosmopolitan city like Riyadh, where the population includes a combination of locals and expats from diverse cultural backgrounds.

7 CONCLUSION

Urban design contributes to fostering social equity and cultural diversity. The literature emphasizes the importance of urban design in promoting social cohesion, and enhancing the quality of life for diverse individuals. In terms of how urban design can address the challenges of multiculturalism, urban justice, and social equity in rapidly growing cosmopolitan cities. This research aims to study the role of urban design as a tool to enhance inclusive public spaces. Wadi Hanifa's documentation provides a valuable opportunity to explore these principles in practice, highlighting the potential of inclusive urban design to transform public spaces and promote social equity in rapidly developing cities. The semi-structured interviews showed a great integration between the multiculture users and the facilities that meet their requirements. The public spaces provide a pleasant environment with waterfront presence. Offering opportunities for multiple activities,

sufficient to accommodate all age groups and achieve urban inclusivity to all social and culture classes. The space is well designed with a flexibility to accommodate various activities over time, that changes from walking, playing, outdoor cooking, and social gathering activities. One main thing can be highlighted, that sense of nature integration between the multiculture communities to coexistence in harmony, where every group can express his culture freely and enjoy the space.

In conclusion, based on the literature review, the semi-structured interviews and the case study analysis, the research suggests that Wadi Hanifa has been successful in creating a welcoming and attractive environment that promotes a strong sense of place. The observations and annotated maps analysis indicate that Wadi Hanifa has the key factors to become a successful public space. As cities continue to evolve and diversify, the main outcome from Wadi Hanifa to collaborate efforts to create 'Cities for All' where everyone, regardless of their background, can live and flourish.

These results could be utilize in future studies to create recommendations for improving inclusivity in diversity-focused open space. A range of innovative tools could be considered to evaluate public open space inclusivity.

7.1 Limitations and Future Research

This research sheds light and gives valuable insights on the role of urban design in promoting urban equity, and how it can foster cultural inclusivity, however, there might be some limitations. The study focuses mostly on a single case study, which might restrict the generalization of the findings and its applicability to other spaces. Future research could benefit from examining multiple case studies across various cultural and contextual locations, to enrich the understanding of the phenomena. Moreover, the current study mainly utilize the qualitative methods, such as observation, semi-structured interviews and annotated maps. By integrating quantitative approaches, such as user surveys or statistical analyses, researchers could gain a comprehensive understanding of the dynamics of equity, equality and justice in public spaces.

7.2 Declaration

During the preparation of this research, the author used plagiarism checker and Grammarly in order to check grammar and proof reading, After using this tool, the author reviewed and edited the content as needed and take full responsibility for the content of the publication.

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reviewed paper

Competitive Cities: An Exploration of Location and Human Capital in South African Cities

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1 ABSTRACT

Cities drive the economic growth of any country. In a fast globalising and urbanising world, cities are competing not only to attract investment and lure skilled labour but also to provide solutions to urban and social challenges, as well as create spaces that are liveable for its citizens. The global south has experienced an exponential increase in the number of people living in cities, making it the fastest urbanising region in the world. This presents both challenges and opportunities for the cities. South African cities are not excluded from the current realities of urbanisation and globalisation in that the cities must also position themselves to be global players but also having to deal with past spatial injustices at the same time. Cities are pushed to ensure that they enhance and maintain their unique city advantages to contest in the global arena. This study investigates factors that contribute to city competitiveness within Gqeberha aiming to position the city for global competitiveness. The study examines geographical location, human capital and urban planning as contributing factors to global competitiveness. The research provides insights into the city's strengths and challenges. A comprehensive competitive cities framework for developmental states was developed through this research, that Gqeberha and other developing states can use to set their cities on a path to global competition.

The qualitative research approach was used in the study, and primary data was gathered through semi-structured interviews with nine key informants who are professionals working with land use management, spatial planning and economic development. Furthermore, the study collected secondary data that includes documents, maps and literature. A combination of qualitative data analysis tools that includes, thematic, document and triangulation analysis was employed in the study to analyse collected data. The key findings show that Gqeberha has strategic assets, such as two seaports and Special Economic Zones, but that their influence is hampered by underutilization and a disconnected location. The city also has a human capital shortage, which results from a mismatch between industrial demands and educational attainment and a reliance on foreign expertise. Deficits in urban planning, such as old MSDF and problems with internal collaboration, further hinder development. In addressing these challenges, the study proposes a framework for enhancing competitiveness in Gqeberha and other developing states. The framework highlights that emphasis and priority needs to be placed on infrastructure development, effective urban governance, strategic spatial planning and human capital development. The implication of this study is that by implementing these recommendations Gqeberha can position itself to be globally competitive. In addition, future research should investigate other developing cities' examples of successful urban planning, assess how SEZs affect social and spatial inclusion, identify skills gaps that exist between industry demands and education, and investigate best practices for port management for developing nations.

Keywords: location, human capital, city competitiveness, urban planning, urbanisation

2 INTRODUCTION

2.1 Background

In the rapidly changing landscape of the 21st century, cities have become crucial drivers of the global economy. Economically agile and entrepreneurial people are drawn to the promises and opportunities that cities offer. As a result, many cities are experiencing rapid urbanisation and globalisation (SACN, 2016). It is estimated that Africa, the fastest urbanizing region, has an annual urbanization rate of 3.6%, with some cities growing at an average rate of 5% per year, faster than other global regions. This rapid growth has led to a significant increase in the demand for housing, infrastructure, and basic services (Korah et al., 2019).

Cities are now faced with the challenge of competing for investment and attracting talent while also addressing urban and social issues (Ghahremani et al., 2021). South African cities, including Gqeberha,

formerly known as Port Elizabeth, are not immune to these trends; they must deal with the past consequences of apartheid planning while also dealing with current realities brought about by urbanisation and globalisation.

The State of South African CitiesReport (2016) highlights the following as issues currently faced by South African cities and towns: 'demographic changes, relative strength of metro economies, basic service provision, increasing inequality and exclusivity of cities, understanding of and support for local government' To address these challenges, cities like Gqeberha must focus on enhancing their competitiveness, wherein the city should exploit or create a competitive advantage resulting in sustainable urban environments and economic growth relative to its competitors (Van Noorloos& Kloosterboer, 2018; Porter,2015).

The European Commission defines competitiveness as the "ability of a region to offer an attractive and sustainable environment for firms and residents to live and work" (Rand, 2017). Factors influencing city competition are multifaceted and context-specific, indicating that it's not a one-size-fits-all. This paper investigates factors contributing to city competitiveness in Gqeberha focusing on geographical location, urban planning, and human capital. These aspects have not been thouroughly investigated in previous studies of Gqeberha, which is essential for positioning the city for global competitiveness. The aim of the study is to develop a framework to enhance competitiveness in Gqeberha and other cities in developing countries of the Global South.

3 LITERATURE REVIEW

3.1 Defining city competitiveness

Over the past three decades, cities and urban centres have been increasingly focused on the competitiveness of their economies, firms and labour. This has been motivated by globalisation, which has integrated world economies and created mutual dependence (Jovović, 2017). For cities to be active participants in the global economy, they should adapt to technological advancements that enable interconnectivity and communication among all actors (Porter,2000). Furthermore, cities must reshape their urban spaces to accommodate a new labour force with specialised skills, mobility needs, and demands for lifestyle and social amenities (Guaraldi et al., 2020). The World Economic Forum's Global Competitiveness Report (2016) describes the competitiveness of cities as "'the set of factors – policies, institutions, strategies and processes – that determines the level of a city's sustainable productivity". Sustainability refers to a balance of economic, social, and environmental issues. Productivity is about utilising resources effectively to fuel economic development. According to Villamejor-Mendoza (2020), almost everything matters for competitiveness: schools, roads, financial markets, and citizens.

Although competition is context-specific to a country or city, general factors influence competition across the spectrum (Momaya, 2016). According to Ferreira and Ratten (2017), factors that also influence competitiveness are the resource endowments of a city. These resource endowments are tangible and intangible, including locations near major economic points such as major transportation routes, human capital, and knowledge in a region. The argument is that even if a city is geographically disconnected from other major cities, it can still be attractive and competitive based on its intangible assets, such as good urban planning strategies and policies, skills and knowledge. Baker et al. (2017) state that some of these factors that influence city competitiveness are outside the control of the city government and, by nature, are the mandate of the national government. However, a city's ability to be competitive may be hindered by urban policies that fail to address land management issues, poor business environment, weak infrastructure, low labour skills, and weak governance.

3.2 The Role of location

According to Ferreira and Ratten (2017), location is defined as a place or city with a distinct geographic space. However, it is argued that the determinants influencing location are not solely geographic; they also encompass infrastructure provision and service delivery. The competitive advantage of cities and locations presents a paradox: one might assume that, in an increasingly globalized world with open international markets and the free exchange of ideas and knowledge, location would be less significant. Therefore, when economic activity is carried out in a specific location, it is done with reason (Snowdon & Stonehouse, 2006). Some of those reasons may include soft location factors that a city offers, such as attractive landscapes,

recreational and shopping facilities, universities, and libraries. Such location factors are essential for firms and people who want to move and stay in a city (Gremm et al., 2018).

Gugler (2019), referring to Porter's diamond of four interrelated components of competitiveness, mentions that location comprises inherited and created factors. Inherited factors consist of natural resources found in a specific area, while created factors include efficient infrastructure, such as communication, transport, and energy infrastructure. Bam et al. (2020), elaborate on this by noting that location-related considerations also include natural advantages that comprises geography and climate, as well as the cost of capital, which includes physical capital, financial capital, and land costs.

Additionally, the quality and reliability of infrastructure play a critical role in location decisions. Infrastructure affects competitiveness in two ways. First, businesses depend on global access points such as airports, ports and digital infrastructure, to sell their goods and services both domestically and internationally. Second, a city's competitiveness is influenced by its ability to efficiently connect its people and physical assets for optimal usage (Parilla & Trujiilo, 2018). This indicates that industries tend to conform to pre-existing patterns of people and the resources on the land. Therefore, for cities to attract businesess, they must implement a development and beneficiation policy framework that accurately assesses and addresses the location determinants affecting firms' decisions on where to establish themselves (Bam et al., 2020).

3.3 Human Capital impact of city competitiveness

High levels of human capital provide cities with a competitive advantage. Human capital encompasses various education levels, including primary, secondary, college, and higher education. Universities and colleges serve as key reservoirs of human capital (Debra et al., 2018). The concept of human capital is rooted in the endogenous growth theory, which Paul Romer first advocated in the 1980s. It is defined as the skill sets and abilities of individuals, and can also include labor, skills, talents, and knowledge as forms of productive wealth. This expertise is developed through both formal and informal education (Osiobe, 2019). According to Antonenko (2021, p. 526), cities such as London, New York, Singapore, and San Francisco – considered among the world's most competitive – have achieved their success through clear municipal policies that prioritize human capital, strategic investments, and technological development. This emphasis has transformed them into global economic, social, and cultural hubs, attracting residents and businesses alike. To attract investments and foster a safe environment for all, other cities aiming for growth should prioritize human capital. Albach et al. (2018) argue that for a city to enhance its performance, it must be open to change, continuous improvement, and the adoption of new technologies. Additionally, the accumulation of knowledge is crucial for driving sustainable long-term growth in cities (Jones, 2019; Schilirò, 2019). This is why cities in developed countries tend to grow faster than their less affluent counterparts; they often act as custodians of innovation and technology (Chirwa & Odhiambo, 2018).

In addition to developing its own human capital, a city can also attract and retain talent from outside by offering a high quality of life and diverse opportunities. This concept is supported by Royuela (2014, p. 927), who emphasizes that a city's amenities and lifestyle options play a significant role in influencing the location choices of a highly skilled workforce. According to Katz and Wagner (2014), curriculum modifications that consider industry demands also draw talent and investments, boosting city competitiveness and growth.

Some scholars argue that for cities to effectively harness human capital through innovation and knowledge, they must promote the development of clusters. Clusters consist of interconnected businesses, universities, research institutions, and skilled individuals, serving as vital drivers of economic growth and societal progress. Nurturing and supporting these clusters has become a strategic necessity for cities aiming to succeed in today's dynamic and disruptive environment (Florida et al., 2018). To foster cluster development, cities need to ensure that their educational systems align with industry needs. This alignment helps create a workforce equipped with the critical knowledge and skills necessary for these industries to flourish (Porter, 1998). By facilitating partnerships between industry and educational institutions, cities can enhance workforce readiness and stimulate innovation (Bathelt & Henn, 2014). Additionally, Katz and Wagner (2014) suggest that adjusting curricula to meet industry demands can attract talent and investments, ultimately boosting city competitiveness and growth.

3.4 Urban planning and its influence on competitiveness

Urban planning and related spatial policies are essential tools for cities striving to succeed in an increasingly competitive global environment. The dynamic and transformative demands of the global economy have pushed cities to adopt strategic approaches to enhance their competitive edge. Consequently, urban planning and development have become important frameworks for improving city competitiveness (Yigitcanlar & Bulu, 2015). Urban planning involves the strategic organization of land use, transportation, infrastructure, and public spaces to achieve sustainable and equitable development within urban areas (Bibri et al., 2020). When combined with spatial policies that guide the distribution of resources, investments, and economic activities across a city or region, urban planning can shape both the physical and economic landscape, influencing a city's competitiveness and livability (Todes & Turok, 2018).

Effective urban planning can increase a city's competitiveness by creating efficient and attractive urban environments. This includes promoting compact, mixed-use development that reduces commuting distances and encourages walking, cycling, and the use of public transportation. By prioritizing pedestrian-friendly streets, well-connected public spaces, and diverse mixed-use neighborhoods, cities can attract more residents, businesses, and visitors (Buck et al., 2017). Moreover, cities should adopt spatial policy approaches that enhance urban conditions by leveraging their unique assets, knowledge, and human capital (Todes & Turok, 2018). However, to effectively improve competitiveness through urban planning and spatial policies, strong urban governance is essential. Good urban governance encompasses "the many ways individuals and institutions, both public and private, plan and manage the common affairs of the city. It is an ongoing process that allows for the accommodation of conflicting or diverse interests and facilitates cooperative action" (Nissen, 2021). The collaboration among various urban governance actors can have a positive impact on a city's competitiveness (Parilla & Trujillo, 2018).

Map 1: Gqeberha locality Map. Source: (AfriGIS,2023)

4 CASE STUDY: GQEBERHA

Gqeberha is a port city situated in the Nelson Mandela Bay Metropolitan Municipality. Formerly known as Port Elizabeth, the city has an estimated population of 1.26 million and encompasses a land area of 1,959 km², making it the largest metropolitan municipality in the Eastern Cape province (Cogta, 2020). Gqeberha is home to two significant ports that play a vital economic role in the province: the Port of Port Elizabeth and the Port of Ngura (Nelson Mandela Bay, 2022). Additionally, the city is recognized as South Africa's hub for automobile manufacturing (SACN, 2021). The city hosts major automotive companies such as Volkswagen,

ISUZU, FAW, and BAIC, which play a significant role in its economic growth. Additionally, the city has designated the Coega Special Economic Zone (SEZ) as a hub for industrial development. The SEZ features two ports and a cluster of heavy, medium, and light industries (COGTA, 2020; NMBM, 2021). This advantageous location provides a strong industrial cluster along the coast and key trade routes (see Map 2). Furthermore, the Automotive Industry Development Center (AIDC) offers skills development training and incubation programs for the automotive sector. In 2018, Gqeberha contributed 2.63% to South Africa's Gross Domestic Product (GDP) and was the largest contributor to the GDP of the Eastern Cape Province, accounting for 34.07% of the province's GDP in that same year (COGTA, 2020). The city's economy is primarily driven by four key sectors: manufacturing, community services, agriculture, and finance. The manufacturing industry is particularly diverse, encompassing automobile manufacturing, clothing and textiles, renewable energy, and chemicals (NMBM, 2021). A significant portion of the city's workforce is employed in this sector.

5 RESEARCH METHODOLOGY

This study employed a qualitative research approach to explore the factors that contribute to city competitiveness in Gqeberha and to develop a framework for enhancing that competitiveness. Both primary and secondary data were utilized for data collection. Primary data was gathered through semi-structured interviews with key informants, including professionals in land use management, spatial planning, and economic development. These interviews offered valuable insights into the city's strengths, challenges, and opportunities. Additionally, secondary data was collected from relevant documents, maps, and literature. To analyze the qualitative data, a variety of tools were employed, including thematic analysis, document analysis, and triangulation. This comprehensive set of analytical tools was used to ensure the credibility and validity of the results.

6 RESEARCH FINDINGS & DISCUSSION

6.1 Gqeberha fragmented cluster development

The study results indicated that Gqeberha has substantially developed clusters in Special Economic Zones (SEZs), attracting multinational corporations and foreign direct investment (FDI). These clusters are primarily manufacturing oriented. However, this has not translated into improved socio-economic conditions for local residents, revealing a disparity between corporate benefits and citizen welfare. The geographical isolation of SEZs and inadequate municipal integration contribute to this inequality, leaving surrounding areas underdeveloped.

To tackle these challenges and encourage inclusive prosperity, Gqeberha requires urban transformation. This means the city should become a central hub for addressing current urban issues. Initiatives must focus on incorporating the urban poor into the economic and social framework of the city, ensuring that all residents benefit from its prosperity.

6.2 Strategic location and assets underutilization

Gqeberha, the largest city in the Eastern Cape, boasts a strategic location with two seaports – Port Elizabeth and Ngqura – enhancing trade potential. However, these ports are underutilized due to infrastructure and management issues, limiting the city's urban development and international competitiveness. The city also has an airport in need of significant upgrades to meet global standards. While Gqeberha offers various social amenities, challenges such as high crime rates, housing backlogs, and informal settlements negatively impact liveability, particularly for economically disadvantaged residents.

Rapid urban growth is further straining ageing infrastructure, including power, water, and sanitation systems. Additionally, political instability hampers effective decision-making and development initiatives. Addressing these challenges through targeted strategies and ensuring political stability is essential for Gqeberha to capitalize on its strengths and enhance its standing as a sustainable, competitive city on the global stage.

6.3 Human Capital Deficiencies

The paper investigates the crucial components of human capital necessary for Gqeberha's development as a competitive city, emphasizing the significance of investing in education. It highlights that cities prioritizing education are better equipped to handle global competition. With only 8% of the population holding higher education degrees, and a substantial portion having only primary (69%) or secondary education (25%), Gqeberha faces significant educational challenges (SACN, 2021).

Despite a public university and several educational institutions, the city has launched various workforce development initiatives to address skill gaps, such as internships and community training (Mativenga et al., 2021). Gqeberha boasts a rich heritage and quality of life but struggles with branding and global visibility.

The university plays a role in addressing urban issues and skill development, yet its impact remains unclear. Gqeberha faces hurdles in creating a knowledge-driven economy despite its status as Africa's automotive hub, primarily due to inadequate tailored education programs and reliance on imported skills.

A deficiency in vocational training is evident, exemplified by a local boat manufacturing company that had to import skilled labor from Cape Town, indicating missed opportunities for local workforce development. The city's current initiatives to upgrade skills are insufficient, highlighting the need for enhanced training strategies and closer industry collaboration.

To remain competitive, Gqeberha must invest in human capital, focusing on education and vocational training to build resilience against global competition and ensure sustainable growth.

6.4 Urban planning Challenges

Urban planning is essential for shaping cities and integrating governance, social well-being, economic growth, and environmental sustainability. The findings indicates that Gqeberha's urban governance framework lacks internal collaboration, hindering cohesive development initiatives among various departments. This disconnection limits the city’s ability to enhance competitive advantages and address urban challenges effectively.

In Gqeberha, there is growing demand for densification, evidenced by numerous rezoning applications. However, the city struggles with this demand due to inadequate physical infrastructure and relies on an outdated Municipal Spatial Development Framework (MSDF). The MSDF, crucial for guiding development and investment priorities, needs updating to align with current and future urban needs.

To realize the potential for densification and sustainable development, Gqeberha must enhance its infrastructure and revise its MSDF. The findings highlight both opportunities and challenges for the city, emphasizing the need for proactive strategies and a collaborative approach to foster growth and resilience in Gqeberha.

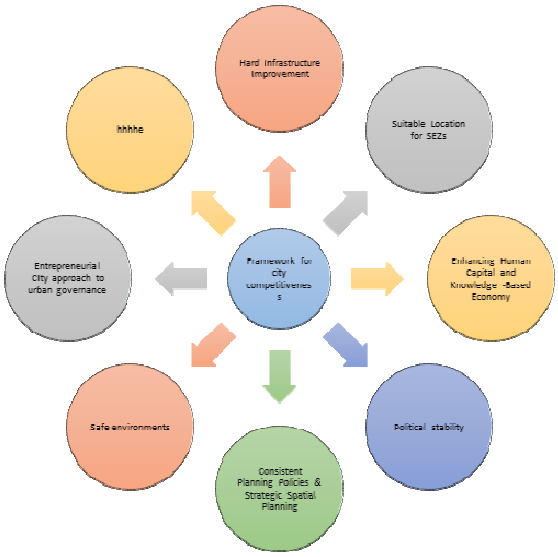

Figure 1: Competitive cities framework for developmental cities. Source: Author.

7 A FRAMEWORK FOR ENHANCING COMPETITIVENESS

Based on the findings, this study proposes a comprehensive framework for enhancing the competitiveness of Gqeberha and other developing cities. The framework focuses on seven key areas: hard infrastructure improvement, consistent planning policies & strategic spatial planning, enhancing human capital and knowledge- based economy, suitable location for SEZ development, entrepreneurial city approach to urban governance, safe environments, and political stability.

7.1 Hard Infrastructure Improvement

According to Eide's (2014) report for the World Economic Forum on the Competitiveness of Cities, urban planning is essential for providing hard infrastructure. Planners must be mindful of how they plan cities, avoiding overplanning or underplanning, which can lead to unpredictable, uneven growth. A balance between planning and organic growth is needed. Additionally, cities should increase their spending on infrastructure to accommodate urbanization demands. Without this, cities may face obstacles to sustainable growth, resulting in sprawl, congestion, pollution, and inadequate public services. However, cities must take a demand driven approach to infrastructure projects that respond to the demands of their local economies rather than a supply side approach that does not consider demand. The Successful implementation of these projects requires careful planning, budgeting, and financial support (Choe and Roberts, 2011).

7.2 Consistent Planning Policies & Strategic Spatial Planning

To thrive competitively, emerging cities must adopt a cohesive approach to development that shapes both public and private investment choices Consistent planning policies are crucial for enhancing city competitiveness for several interconnected reasons. Firstly, such policies establish a stable framework for long-term investment and development, which fosters confidence among businesses and investors. When regulations and zoning laws remain consistent over time, companies can confidently make decisions about where to locate and how to expand, without fear of encountering sudden regulatory obstacles or changes in land use. This stability not only supports local entrepreneurship but also attracts external investment, ultimately driving economic growth and job creation (Kamana et al., 2023).

In addition, a transition needs to be made from conservative spatial planning, which is concerned with preserving order, to strategic spatial planning which is more concerned with dealing with challenges and transformation. Furthermore, this approach is a breakaway from conservative spatial planning that is project orientated rather than being goal orientated. In essence emerging cities need to adopt a strategy that effects change and set good strategic goals instead of the implementation of spatial projects that are effective today and ineffective tomorrow (Albrechts, 2015; Olsen, 2014). Key to strategic spatial planning is the setting out of objectives and the formulation and implementation of strategies to meet those objectives. cities should have a vision for the future assuming that current trends will continue (Salet and Faludi, 2000). Public and private sector coordination and public participation is fundamental in the successful implementation of a strategic spatial plan (Oliveira and Hersperger, 2018). Furthermore, strategic spatial planning appreciates the fact that challenges that are faced by cities that cannot be tackled only by local authorities, as some fall outside the scope of local government, therefore intergovernmental co-ordination is needed (RTPI, 2015).

7.3 Enhancing Human Capital and Knowledge -Based Economy

Cities must acknowledge the growing influence of technologies like AI, big data, and robotics. Thompson and Curella (2021) emphasize the importance of adaptation to these emerging trends. For emerging cities, aligning processes with factors outlined in the Knowledge Economy concept, such as skills development, global competitiveness, and entrepreneurship, is essential (Amo et al., 2017). The initial step for these cities is formulating appropriate policies and strategies. Although specifics may vary, the World Bank's Knowledge Economy Index suggests focusing on themes like education, economic incentives, institutional frameworks, and ICT infrastructure. Additionally, cities should consider factors like Research and Development(R&D), vocational training, government accountability, quality education and investment in innovation and technology as enhancing measure towards their goal (Asongu and Odhiambo, 2020).

The next crucial stage in improving their knowledge economy involves developing partnerships among various stakeholders. These stakeholders include the city government, businesses, research institutions, emerging entrepreneurs, creative individuals, innovators, and residents. Such partnerships serve as platforms

for mutual learning and knowledge exchange, facilitating the pooling of resources for collective advancement (Praharaj et al, 2018).

7.4 Suitable location for SEZ development

The geographical positioning of SEZs plays a crucial role in ensuring broader inclusivity and maximizing their positive impact on local economies and communities. Therefore, a comprehensive approach to SEZ development must incorporate considerations of both regulatory frameworks and spatial planning to foster holistic socio-economic growth which gives a city a competitive edge (Ahmed, 2020; Frick et al, 2019). Thus, the location of SEZs in emerging cities should be orchestrated to serve the collective interests of various stakeholders, including governmental bodies, investors, local enterprises, residents, and workers. The primary objective should be to address pressing socio-economic challenges such as unemployment and poverty. By situating SEZs strategically, cities can harness their potential to stimulate job creation, enhance economic opportunities, and alleviate poverty rates (Ali, 2020).

Cities and national governments need to undertake comprehensive feasibility studies where SEZs are to be located to determine the best suited location that is well connected and has the ability to convert a particular area from rural to urban. Furthermore, the location choice for an SEZ should look at the potential of developing other land uses around the SEZ, such as commercial or residential (Janjua, 2017).

7.5 Entrepreneurial City approach to urban governance

Both theory and practice demonstrate that for a city to be competitive and attract investment, an entrepreneurial approach to city governance is essential. This approach advocates for treating city governance like a business, with the government acting as an entrepreneur to market the city and foster its growth. This involves ensuring fiscal stability and access to financial markets to attract investment and boost investor confidence (Lauermann, 2018).

At the core of this governance approach lies the establishment of Public-Private Partnerships (PPPs) for local government to secure external funding, create employment opportunities, and attract new direct investment (Delmon, 2017). Olsson et al. (2020) refer to these local government initiatives as "entrepreneurial governance," wherein opportunities are identified and assessed, resources are gathered and utilized, and opportunities are exploited.

Furthermore, this city governance model emphasizes the creation of institutions or municipal entities tasked with revenue collection and public service delivery on behalf of the municipality. These entities operate independently from the municipality and mitigate the bureaucratic constraints faced by public entities by adopting private sector delivery models. Although these entities maintain public accountability and transparency, they do not represent full-scale privatization. In addition to revenue collection, these entities are responsible for generating job opportunities across various skill levels (Mabalane, 2019).

7.6 Safe Environments

The UNODC (2016) highlights various factors that contribute to urban crime. Key among these is unregulated urban growth, large income disparities, and inadequate governance. To tackle these issues, cities, particularly those in developing nations undergoing rapid urbanization, need to establish robust regulatory frameworks and enforcement mechanisms. It's essential that these efforts involve active engagement with local communities. Additionally, prioritizing socio-economic inclusion is crucial. This means integrating crime prevention strategies into a range of social and economic policies and programs, including those addressing employment, education, healthcare, housing, and urban planning. By doing so, cities can work towards creating safer and more inclusive urban environments.

Lastly, urban planning approaches in developing cities need to be re-evaluated to ensure the establishment of safe urban spaces. For example, mixed land uses should be encouraged in city development as well a strengthened pedestrian traffic movement. This strategy not only increases the vibrancy of urban areas but also reduces the need for long commutes, which can contribute to safety by decreasing congestion and potential areas for criminal activity. Street layouts design should be in such a way that they deter criminals. This involves careful consideration of factors such as visibility, access points, and lighting to minimize opportunities for crime, while ensuring that housing density standards provide adequate space for community

facilities, natural light, ventilation, and open spaces for residents (Abdul-Kadhum Al-Ghiyadh and Neamah Al-Khafaji, 2021).

7.7 Political stability

Grøn and Salomonsen (2019) contend that the reputation of a city can be adversely affected by political instability. Consequently, it is crucial to proactively address potential conflicts between administrative and political entities. Public managers should also be mindful of their organization's historical reputation, as it could impede their ability to coordinate an effective and unified response when faced with threats to the organization's image. Furthermore, effective management of the discord between politics and administration in Gqeberha is essential to uphold a positive public image and foster collaboration between all actors.

8 IMPLICATIONS OF THE STUDY

The study's findings have important implications for the future of Gqeberha. By adopting the suggested framework, the city can position itself to compete globally while tackling the urgent issues of urbanization and spatial injustice. The framework focuses on key elements related to location, human capital, and urban planning, which are essential for creating a sustainable and competitive city.

Furthermore, the study emphasizes the potential for Gqeberha to become a model for other developing cities that are dealing with similar challenges. By sharing best practices and lessons learned, Gqeberha can contribute to a wider discussion on urban competitiveness in the Global South. The framework outlined in this study provides a flexible blueprint that can be customized to address the distinct challenges faced by different cities.

9 FUTURE RESEARCH DIRECTIONS

Expanding on the findings from Gqeberha, future studies on city competitiveness in developing nations can further explore these several areas:

(1) Assessing the effects of SEZ: Investigate whether the current SEZ model promotes economic inclusion or perpetuates existing disparities.

(2) Enhancing port operations: Study effective port management strategies from prosperous developing countries to identify adaptable solutions for Gqeberha.

(3) Aligning Education Curricula with industry needs: Conduct a skills gap analysis to identify specific mismatches between current educational offerings and industry requirements in Gqeberha.

(4) International promotion: Investigate the impact of global promotion on driving economic growth and competitiveness for Gqeberha.

(5) Urban Governance Collaboration and Spatial Planning: Identify successful instances of collaborative urban planning from other developing cities and evaluate their applicability to Gqeberha.

(6) Contextualizing the competitiveness framework: Refine the proposed competitiveness framework by incorporating specific data and best practices relevant to the South African context.

10 CONCLUSION

In conclusion, the dynamics of competitive cities are shaped by various factors that influence the economic, social, and environmental landscapes. Cities that emphasize knowledge and innovation, allocate resources towards infrastructure, and utilize effective urban planning strategies are more likely to thrive in the global arena. As urban areas face changes in demographics and rapid technological progress, embracing sustainable practices will be crucial for long-term viability. cities must evolve, experiment, and engage in collaboration to create lively and competitive environments that satisfy the needs of their inhabitants.

11 DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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reviewed paper

Creating Inclusive Community for the Elderly and Children: Spatio-Temporal Behaviour, Influence Mechanism and Space Optimisation

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1 ABSTRACT

Intergenerational childcare, meaning the grandparents helping to take care of the grandchildren, is a common phenomenon in China since we are going through aging population, as well as increasing work pressure on parents. Therefore, the elderly and children, who spend the longest time in the community and use the space and facilities the most frequently, are the group of people that should be prioritized to be satisfied and guaranteed in communities. Considering the physiological and psychological characteristics of the elderly and children, they have special needs for community space and facilities, such as higher demands for diversified service facilities within walking distance and higher demands for safety. However, the community design do not takes their needs into full consideration yet, in terms of inappropriate structural scale, mismatch between service facilities supply and demands, and lacking of engaging and playful space. Therefore, it's urgently needed to have a better undesrstanding of the activity patterns and needs of the elderly and children, as well as the influence mechnism of community space and environment, so as to creat a more inclusive community.

In this regard, this study adopts a human-centered perspective under the guidance of Time Geography and Environmental Behavior theories, focuing on five issuses: (1) what's the spatio-temporal activity patterns of the elderly and children; (2) what's the influence mechanism of the community environment on such activity patterns; (3) what's the differences of the activity patterns and influences mechnisms considering socio-economic property and community catergories; (4) cofiguration and approaches to inclusive community; (5) design and renewal suggestions to creat inclusive community for the elderly and children.

Firstly, 12 typical communities in Tianjin are selected including different house types and geographic location. Spatio-temporal activity of the elderly and children are collected through questionnaire, interview and unmanned aerial photograph, and are imported to ArcGIS for spatio-temporal distribution visualization. Different activity patterns are summarized using cluster analysis. For communities closer to city center, multi-time activities in the community for the elderly with infants, multi-destination activities for the elderly with infants and young children, and afternoon activities for the elderly with young children are typical types. For communities in the suburbs, multi-time activities in the community are more common.

Secondly, a community space index system is establised to calculate the density, scale, accessibility and coverage rate of service facilities and public space within the 15-minute community. Then, correlation and regression are used to analyze the influence of community space index on different activity patterns separately. In general, floor area ratio, road network density, green ratio, accessibility to amenities and education facilities,distance to subway station make a significant impact on the outdoor activity duration, distance and destination of the elderly and children.

Thirdly, heterogeneous mechnisms of space index on different activity patterns are identified. (1) To communities with high floor area ratio, road network density and green ratio, whatever they are located near the city center or in the suburb, the elderly and children spends more time outdoor, and most of their activities are within the community. (2) To communities with high accessibility to education facilities, their activiy reach increases. To communities near the city center with diversified service facilities, the destination of the elderly and children are more varied and the walking distance is longer compared to communities located in the suburb.

Finally, with the aim to promote more diverse and convenient outdoor activities for the elderly and children, three spatial planning and renewal strategies are proposed. (1) The first path is driven by the densification of service facilities within walking distance, which is suitable for newly built communities in suburbs. (2) The second path is driven by the improvement of landscape design of the community's public space, as well as the optimization of the community's space structure and walking routes, which is suitable for older

communities. (3) The third path is driven by increasing the accessibilities of education and recreation facilities within 15-minute community, which is suitable for communities especially in suburbs.

Keywords: space optimization, influence mechanism, spatio-temporal behavior, the elderly and children, inclusive community

2 INTRODUCTION

Against the background of China's aging population and the generalization of dual-income families, the proportion of intergenerational childcare is gradually increasing. Studies show that more than 40% of families with young children between the ages of 1 and 5 years have grandparents involved in childcare, making intergenerational childcare one of the most dominant forms of childcare in China at present1-2. “The 14th Five-Year Plan and the 2035 Vision and Goals Outline clearly propose the implementation of a national strategy to actively address population ageing, and the improvement of the daily life service facilities with a focus on “the elderly and children”. As communities are the basic units of urban governance and residents' lives where they spend approximately 70% of the day, it has become an important issue to optimize community living space with a focus on serving “the elderly and children”, and to solve the mismatch between the demand for integrational childcare and the supply of community living space and service facilities. In the face of the rapidly changing demographic structure and the special physical and mental development needs and activity characteristics of the elderly and children, community living spaces are faced with difficulties as an inappropriate structural scale, a lack of recreational and playing space, and a mismatch of service facilities, making it difficult to effectively satisfy the needs of the “elderly and children” for a shared and inclusive community living space3-4.

To optimize and adjust community living space for the intergenerational childcare, the initail task is to master the daily activity characteristics and patterns of the elderly and children within the community, followed by identifying the elements and mechanisms of community living space on different activity patterns of the elderly and children5. On this basis, targeted spatial design strategies such as spatial index control, service facility configuration, and environment upgrading can be proposed to improve the accessibility of the service facilities, as well as to provide safe and diversified places for recreational and educational activities for the elderly and children.

This study makes comprehensive use of interdisciplinary research paradigms as environmental behavior analysis, spatio-temporal geography, as well as space planning and design, and builds a three-dimensional analysis framework composed of “subject-the elderly and children, object-community space and service facilities, and the link between them-daily activities of the elderly and children within the community”. For the subject, the research focuses on the socio-economic characteristics and demand of the elderly and children for community space and service facilities. For the object, 15-minute walking distance from home is used as the community where most daily activities of the elderly and children take place. 8 categories of POI data are collected and calculated in terms of density, diversity and distance, to analyze and assess the built environment of the community. For the activity, which presents specific patterns in a given community setting, the research focuses on studying the daily activity patterns of the elderly and children, including the activity time, location and events, and whether the patterns vary with their socio-economic characteristics. On this basis, the influence mechanism of the community built environment on the activity patterns is analyzed. So as to identify the key spatial influencing elements and the influencing path, as well as mismatches between the supply of community living space and the demand of the elderly and children. Then more precise space optimization design strategies can be proposed to provide theoretical reference and policy inspiration for the creation of inclusive community for the elderly and children.

3 RESEARCH REVIEW

3.1 Research Theory of Adaptation between Intergenerational Integration and Community Living Space

3.1.1 The theoretical perspective of intergenerational integration wihtin the community

Relevant theories include pluralistic welfarism, social support network, etc., aiming to explain the necessity and feasibility of the integration of the elderly and children from multi-dimensional perspectives of

individual physical and mental development, community governance, and so on. Research has shown that the needs of the elderly and children are common, and the advantages are complementary. Through appropriate environmental design and activity organization, it can help to enhance the communication and interaction between the elderly and children and realize mutual help and assistance.Cohn-Schwartz (2023)6 analyzed under the guidence of Contact theory and concluded that the interaction between the elderly and children can help to promote the elderly group to have more diversified cognitions and attitudes toward aging, and the contact with optimistic people can help to promote more positive attitudes toward aging among older adults. Using the strengths perspective and social support theory, Ta Na and Zhang et al. (2023)7 indicated that the interaction between the elderly and children is not only conducive to providing diversified help and support for the elderly, but also helps to realize mutual assistance and reciprocity between the elderly and children, which is an important way for community cohesion and optimization of community self-governance.

3.1.2 Research paradigm on the adaptation of community living spaces for intergenerational integration

These researches take environmental behavior and hierarchy of needs as the theoretical basis, and takes the interaction behavior of the elderly and children as the starting point to analyze the demand, use, and evaluation of the elderly and children on community living space. Li Han (2021)8 and Lv Yuan (2021)9 take the interaction behavior patterns of the elderly and children as the starting point and analyze the supportive and hindering roles of community space. Other scholars combine social psychology research methods to analyze the relationship between the community physical environment and the subjective feelings of the elderly and children. Jiang Xiaoyan (2022)10 adopts the “anchor point theory” of spatial cognition, pointing out that spatial cognition is a multi-staged and gradual process, and the first to be noticed are the “anchor points” with high relevance and symbolism to the elderly and children, so attention should be paid to pocket parks, Therefore, attention should be paid to the environmental design of community anchors such as pocket parks, community convenience stores, etc., and use them to guide and connect other activity sites.

3.2 Research on the Needs and Interactive Activities of the Elderly and Children in the Community

3.2.1 Needs and activity characteristics of the elderly and children

These researches mainly use on-site observation, questionnaire survey, participatory interviews, etc., to conduct research on the spatio-temporal behavior and the interaction between the elderly and children within the community. Tang et al. (2023)11 pointed out that the activity space of the elderly and children has a high level of residential proximity, which is mainly concentrated in the five-minute walking range, including community public space, service facilities, walking paths, and green space next to the house, and so on. Another study pointed out that to children at different ages, the contents of the interaction between the elderly and children are different, so as their needs to community space. Xu Shuning (2023)12 indicated that for infants within 3 years of age, the interaction between the elderly and children is mainly concentrated within the 5-minute walking range around the house, and the content of the interaction is mainly caregiving and accompanying, with a higher demand for sitting and resting facilities, greening, and safe play facilities; for children aged 4-7, the elderly and children can participate in activities together, including fitness, play, and socialization, with a higher demand for the safety and diversification of the overall community environment.

3.2.2 The influence mechanism of community on the activity and integration of the elderly and children

These researches mainly focus on analyzing the influence of community living space components and spatial organization on the outdoor activities of the elderly and children within the community. Davern et al. (2020)13 pointed out that community land use, population density, and elderly's awareness of community space have a significant effect on the frequency of interaction between the elderly and children.Canedo-García (2021)14 pointed out that face-to-face interactions between the elderly and children have a positive effect on the physical, psychological, and social skills of both age group, yet differences in individual characteristics affect the frequency and satisfaction of interaction. Oetzel (2023)15 pointed out that stable interaction partners and frequency of interaction are crucial, especially when the elderly and children have a higher sense of autonomy of organizing and taking part in the interaction activities, the more conducive to the improvement of interaction satisfaction. Xu Shuning (2023)12 pointed out that the level of interaction between the elderly and children is affected by individual factors and community space. At the individual

level, the extraversion of grandparents and children, more willingness and initiative to interact, as well as higher degree of trust to neighbors have a significant positive correlation with the level of interaction between the elderly and children. In addition, at the community space level, the design and set-up of community center open-space, which can accommodate a variety of activities and residents of different ages, has a positive impact on the interaction and satisfaction of the elderly and children.

3.3 Research on Design Strategies for Elderly and Children-Friendly Community Spaces

3.3.1 Overall design of community space for the integration of the elderly and children

Considering the physiological and psychological characteristics of the elderly and children, safety and composability of community living space are the most important keywords. Zheng Yu (2021)16 proposed the design of all-age parks that can accommodate to resting and playing, delicate pocket parks, and children-friendly parks which are fun and explorable to meet the diversified recreational needs of the elderly and children. Washington et al. (2019)17 suggested transforming vacant spaces and facilities into shared kitchens, vegetable gardens, art spaces, etc. to accomodate diversified activities and promote interaction for the elderly and children. Zhong et al. (2020)18 pointed out that, in addition to the design of community physical spaces such as safe and convenient walking environment and sufficient public activity venues, the organization of coherent activities also has a positive effect on the interaction between the elderly and children.

3.3.2 Refined design of community public activity space for the integration of the elderly and children

Based on the psychology of design, Ma Zhuyi (2022)19 adopted an affective design methodology and proposed that the design of community spaces should be based on three dimensions: form and scale, function and utility, and symbolism and metaphor, to enhance the sense of pleasure and self-identity during the interaction between the elderly and children.Washington et al. (2019) 17 analyzed the interactive activities of the elderly and children in the parks and found that, as children grow older, the interaction between the elderly and children decreased accordingly, but the effective interaction between the elderly and children plays an important role in the development of children's social interaction ability. So it is proposed that the parks should be supplemented with challenging playing facilities, which need the guidance of the elderly to enhance the interaction between the elderly and children.

In conclusion, a large number of researches have been carried out on various aspects of the design of elderly and child-friendly community. Yet the following issues remain to be further explored. Firstly, the outdoor activity patterns and heterogeneity of the elderly and children in different community environments need to be supplemented. Existing researches mainly focus on the elderly and children in a single community or community public space, and few studies have systematically compared and summarized the similarities and differences in the activities and patterns of the elderly and children in different community environments. Secondly, the influence mechanisms of the community space on the elderly and children under different community environments need to be further explored. Existing studies have mainly explored the influence of community public activity space on the integration of the elderly and children, and few studies have systematically considered the influence of the whole elements of community living space at multiple scales. Thirdly, the optimization path of community living space for the integration of the elderly and children needs to be further clarified. Existing researches focus on the elderly and children-friendly space design within a single community, and few studies have clearly proposed different space optimization paths based on differences in community environments for the integration of the elderly and children.

4 METHODOLOGY

4.1 Study area

Tianjin is a mega-city and is planned as a national central city. According to the “Tianjin Urban Renewal Planning Guidelines (2023-2027)”, the core area of Tianjin is densely populated, the quality of living space is in urgent need of renovation and upgrading, and the shortcomings of public service facilities, such as elderly care, childcare and other public facilities, are yet to be replenished. In this background, seven typical communities with different locations, different construction years and complete age structures are selected as the study area (Fig. 1)(Table 1).

Fig. 1: Study Area

Number	Community name	Construction year	Community size (ha)	Population size
1	Ying Jiangli	1985	7.18	4374
2	Hong Shengli	1986	5.13	3306
3	Jia xinli	1995	5.89	3789
4	You Ai Nanli	1988	7.29	7346
5	Bi huali	1997	9.55	4238
6	Han jingyuan	2008	7.3	4638
7	Sunshine 100 International New Town	2004	10.34	6249

Table 1: Overview of the study area

4.2 Data collection

The built environment data of the community is obtained by POI data mining and remote sensing image maps. POI data is obtained from Gaode-map mining in June,2024. According to <Urban Residential Planning and Design Standards> initiated by Ministry of Housing and Urban-Rural Development of China, as well as the spatio-temporal activity characteristics of the elderly and children, 8 categories of POI data are included, namely, commercial services, educational services, health care services, public sports services, public cultural services, elderly care services, public transport station and parks. The image map is obtained through google map and is used to extract the green space and analyze the green ratio.

The daily activities of the elderly and children within the community are obtained by questionnaire, semi-structured interview and on-site observation. The questionnaire consisted of four parts: individual socio-economic characteristics, daily activity time, daily activity space, and activity content. The socio-economic characteristics include age, gender, and educational level of the elderly and children, etc. Activity time includes period, average duration, and frequency of outdoor activities. Activity space includes average walking distance to activity space, and type of activity venues. Activity content includes purpose of the activity, and interaction between the elderly and children (Table 2). The questionnaires were distributed and collected from April to July 2024 in the study area from the elderly and children who were active in the public space during different times of the weekdays and weekends.

4.3 Data processing and analysis

Hierarchical analysis and factor analysis are used to establish a community space index system including density and floor area ratio of residence and service facilities, accessibility of service facilities, green coverage and road network density (Table 3). In these indices, green coverage ratio is calculated using SegNet, the other space indices are calculated within 15-minute walking range, and are normalized and visualized in ArcGIS. The spatio-temporal activity patterns of the elderly and children within the community are analysed using TwoStep Cluster algorithm since the spatio-temporal activity data of the elderly and children includes both categorical variables and continuous variables. In this model, 13 variables as shown in Table 2, which represent the spatio-temporal activity characteristics of the elderly and children, such as outdoor activity period and frequency, activity distance and venues, as well as activity types, etc. were imported to check their contributions to the categorization results (Fig. 2).

Content of the questionnaire				Options
Socio-economic attributes	Gender			Male/Femal
	Age			40-50/50-60/60-70/ 70 years and over
	Education background of the elderly			Elementary school/Junior high school/middle school/ /college/Bachelor's degree and above
	Education background of the grandchild			Infant/kindergarten/elementary school
	Family structure			Live alone/ Cohabitation with spouse/ Co-habitation of elderly and children/ Co-habitation of elderly, middle aged parents and children
Spatio-temporal activity data	Activity time	Period (multiple choices)		6：00-9：00/9：00-12：00/12：00-15：00/15：00-18：00/18：00-21：00
		Duration		0.5h and below/0.5-1h/1-1.5h/1.5-2h/2h and above
		Frequency		Almost daily/ at least 2-3 times a week/1 time a week/barely
		Days		Weekday/weekend/weekday and weekend
	Activity space	Distance (multiple choices)		0-300m(from home)/300-500m/500m-1000m/1000m and above
		Venues (multiple choices)	Within the community	space in front of the house/community path/square and green space/community service center/commercial service facilities/education service facilities
			Outside the community	commercial service facilities/education service facilities/catering service facilities/square/park/public transport station
	Activity content	Purpose (multiple choices)		Leisure/exercise/education/shopping
		Interaction (multiple choices)		Walk with a stroller/ play with children/take care of the children/chat/take exercise

Table 2: Spatio-temporal activity data acquisition of the elderly and children

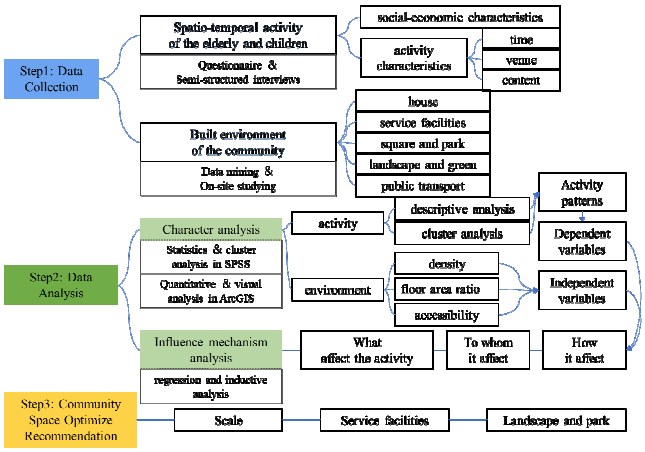


Fig. 2: Analysis Process

Primary indicators	Secondary indicator
housing	density
	floor area ratio
commercial services	density
	floor area ratio
	Accessibility (walking distance from the house)
educational services	density
	floor area ratio
	accessibility
health care services	density
	floor area ratio
	accessibility
public sports services	density
	floor area ratio
	accessibility
public cultural services	density
	floor area ratio
	accessibility
elderly care services	density
	floor area ratio
	accessibility
public transport station	density
	accessibility
parks	accessibility
green coverage ratio	–
road network density	–

Table 3: Community Space Indicator System

5 RESULT

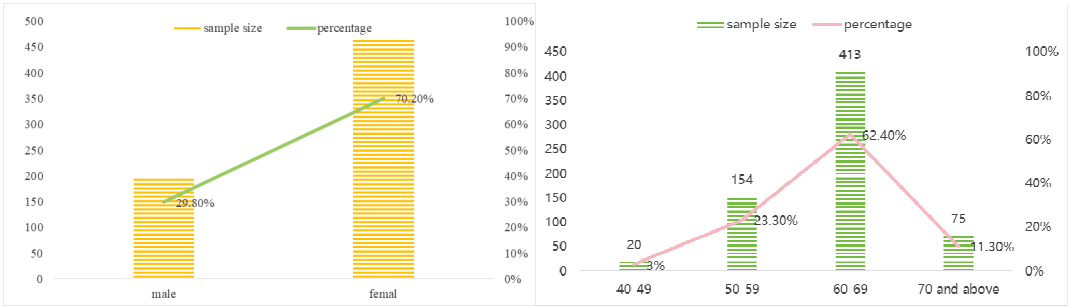
5.1 Descriptive statistics of the elderly and children surveyed

5.1.1 Socio-economic attributes of the survey sample

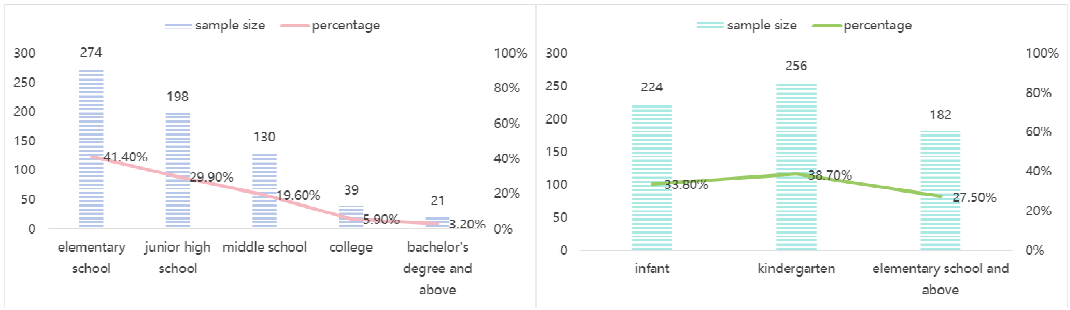
According to statistical analysis of the returned questionnaires on spatio-temporal behavior of the elderly and children in SPSS 26.0, female elderly accounts for 70.2% of the sample. In the analysis of age structure, the respondent group is mainly concentrated in 60-69 years old, accounting for 62.4%, followed by 50-59 years old, accounting for 23.3%, and there are fewer people over 70 years old and 40-49 years old, accounting for 11.3% and 3% respectively.

In the analysis of the educational background of the elderly interviewed, 41.4% has an educational background of elementary school and below, 29.9% has junior high school, 19.6% has senior high school and middle school, 5.9% has college, and 3.2% has a bachelor's degree or above.

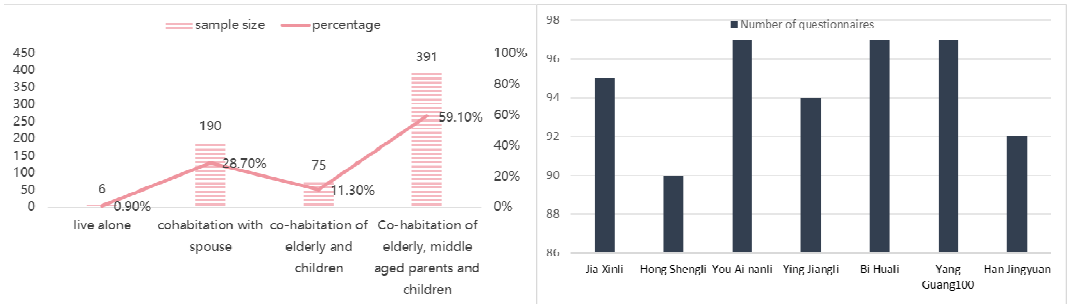
In the analysis of the education level of the children carried, children who had been enrolled in kindergarten and the younger children who are not enrolled in kindergarten are the largestest group, accounting for 38.7% and 33.8% respectively. While elementary school children account for 27.5%. In the analysis of family structure, the respondent group mostly has three generations living together, accounting for 59.1% of all samples, followed by those living with their spouses (28.7%). The group that the elderly and children living together and those living alone account for a small percentage of the sample, which is 11.3% and 0.9% respectively (Fig. 3).



Gender distribution of the sample/Age distribution of the sample



Educational background of the elderly/Educational background of the children



Family structure of the sample/Number of questionnaire of each community

Fig. 3: Socio-economic attributes of the survey sample.

5.1.2 Descriptive statistics of spatio-temporal activities of the elderly and children

(1) Characteristics of the activity time

In terms of time period of activity, the elderly and children are more active between 15:00 and 18:00, accounting for 78.1% of the total number of respondents. The second largestest group are those who chose to be active between 9:00 and 12:00, accounting for 44.1%. Those who chose to be active between 18:00 and 21:00, and between 6:00 and 9:00 are fewer, accounting for 13.4% and 9.8% respectively. While only 1.4% chose to be active between 12:00 and 15:00.

In terms of activity duration, the mostly chosen are 1-1.5h and 0.5-1h, which accounts for 32.2% and 22.5% of the surveyed sample. The proportion of the elderly and children's activity duration as 1.5-2h, and 2h and above are 22.1% and 22.2% respectively. And only 1.1% of the elderly and children usually takes outdoor activities for less than 0.5h. The average activity duration of the old and young population was 1.606h, with a maximum value of 4h, a minimum value of 0.4h, a median value of 1.5h, and a standard deviation of 0.647.

Regarding the frequency of activities, the proportion of elderly and children declines as the frequency of activities decreased. 54.4% of elderly and children are active almost every day, 29.9% are active 3-4 times a week, 15.1% are active 1-2 times a week, and only 0.6% choose the "hardly go" option.

(2) Characteristics of the activity space

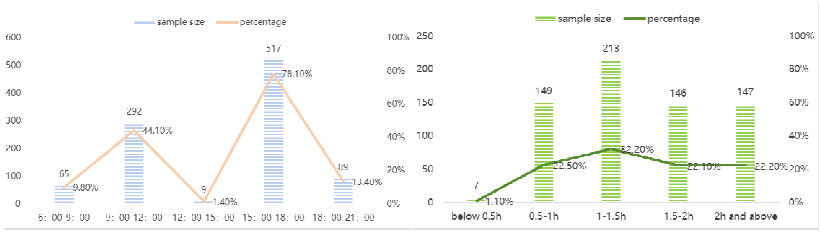
In terms of activity distance, the elderly and children prefer to take activites within short-distance. 93.8% of the surveyed sample choose to take activities within 300 meters from their homes, and the proportion who choose 300-500 meters and 500-1,000 meters from their homes are 41.2% and 24.8% respectively, with only 5.7% choose to take activities at places beyond 1,000 meters from their homes.

In terms of activity venues, the squares and parks within the community are the most chosen option, accounting for 73.3% of the surveyed sample. This is followed by parks and squares outside the community, educational facilities and downstairs space in front of the house, accounting for 59.7%, 58.2% and 55.3% respectively. Catering facilities and shopping facilities were chosen by 33.4% and 20.5% of the surveyed sample respectively. Fewer group choose community stores and canteens, as well as subway stations, accounting for 13%, 4.2% and 0.9% respectively. It is worth noting that 27.5% of the activity venues for the elderly and children involved roads within the community.

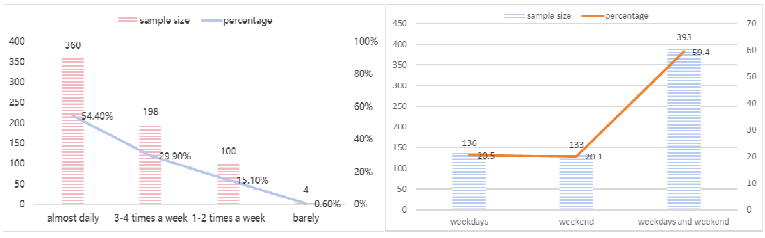
(3) Characteristics of the activity contents

In terms of activity types, those who choose recreational activities, accounting for 95.3% of the total sample. Educational and shopping activities are chosen by 58.9% and 34% respectively.

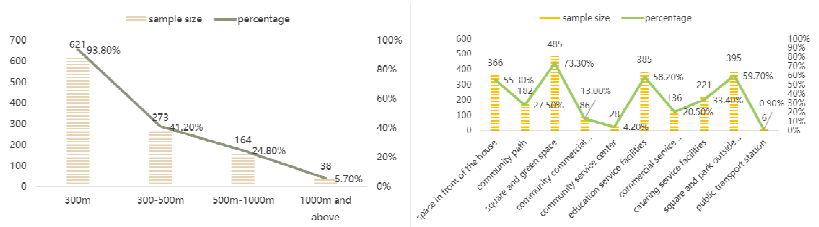
In terms of the interaction between elderly and children, a great portion of elderly choose "looking after children", which accounts for 91.8%. The next most common activity was "chatting and communicating", accounting for 48.3% of the total sample. The proportions of those who choose to "play together with children" and "do fitness activities" are 28.2% and 23.1% respectively, while the proportion of those who chose to "take a walk with a stroller" is 17.8%(Fig.4).



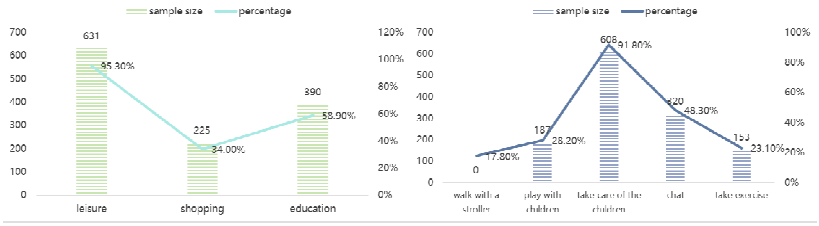
Activity time period/Activity time duration



Activity frequency/Activity days



Activity distance/Activity venue

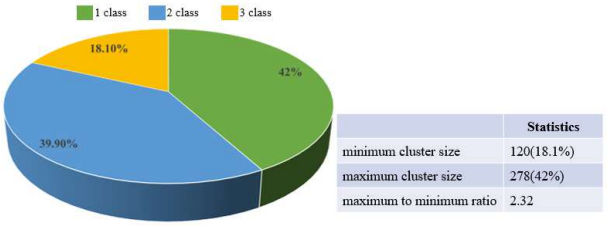


Activity purpose/Interaction between the elderly and children

Fig. 4: Spatio-temporal activity characteristics of the elderly and children

5.2 Portraits of the elderly and children

The results showed that when three clusters were generated, the centers of each category differed significantly, and the clustering result was significant (Fig.5). According to the variable significance diagram, variables such as activity period, activity frequency, educational activities, activity duration, and activity distance of 500m to 1000m from home are the important variables to distinguish the three categories (Fig.6).



	Statistics
minimum cluster size	120(18.1%)
maximum cluster size	278(42%)
maximum to minimum ratio	2.32

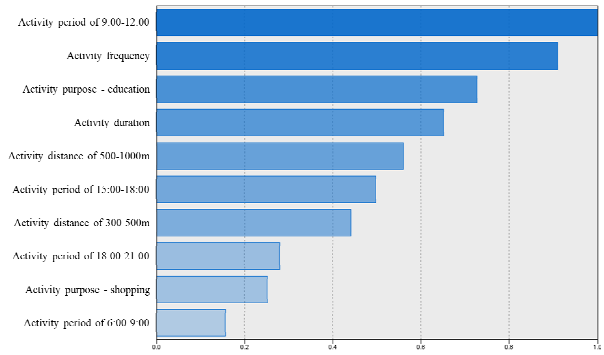


Fig. 5 (left): Cluster size and percentage. Fig. 6 (right): Importance of predictor variables.

5.2.1 The multi-time period and short-distance active group

This group is the most numerous in this research, accounting for 42% of the total research sample. In this group, children are younger, mostly not enrolled in kindergarten. The average outdoor activity duration is 2.01h a day. The activity time is more flexible compared to the other two groups, involving different time period of the day, with a higher concentration in 9:00-12:00 and 15:00-18:00. The weekly outdoor activity frequency is high, as shown in the interviews, the frequency is basically daily if there is no rain or snow. In terms of activity space, the space within five-minute walking distance around home are visited the most frequently, including the park, square and road within the community. Besides, the convenience store, supermarket, shopping mall and parks within 10 to 15-minutes of walking are also frequently visited destinations. The primary purpose of outdoor activity is recreation, followed by shopping and education.

5.2.2 The afternoon short-distance activity group

This is the second largest type of research population, accounting for 39.9% of the whole research sample. In this group, children are mostly in the kindergarten and elementary school enrollment stage, and the elderly mostly pick up the children after school and take outdoor activities on the way back home or around the neighborhood. The frequency of activities is basically once a day, which takes place from 15:00 to 18:00 in general, and the average activity time duration is 1.29h a day. The outdoor activities taks place around the neighborhoods mostly, and there are also some activities that are a little further from home, which mainly

depends on the distance between the school and home. In terms of the type of activity, it's mainly playful and educational.

5.2.3 Low-frequency and multi-purpose activity group

This group accounts for 18.1% of the total research sample, which is the smallest proportion. This group is mostly elderly people with elementary school and kindergarten-aged children. The outdoor activity time is not fixed, which takes place mostly at weekends around 9:00-12:00 and 15:00-18:00 and lasts 1.38h in average. In comparison with the other two groups, this group has a wider outdoor activities range, with both long-distance and short-distance activities involved. The type of activity is mainly amusement, followed by education and shopping.

5.3 Community space influencing factors of elderly and children's spatio-temporal activity

To the multi-time period and short-distance active group, in terms of activity duration, the higher the community greening rate, the longer the activity duration for people especially with infants, while the higher the community floor area ratio and the closer the community is to the subway station, the shorter the activity duration. In terms of activity distance, the higher the educational stage of children, the higher density of the road network and the higher the community floor area ratio, the more medium-distance activities of the baby-carrying population compared to those of the proximity population. In terms of the type of activity, the higher the greening rate, road network density and floor area ratio, the higher the probability that the elderly and children choose to play within the community. The higher the accessibility of play and leisure facilities, and the closer the community is to the subway station, the more diverse types of activities of the elderly and children.

To the afternoon short-distance activity group, in terms of activity duration, the higher the community greening rate and the higher the accessibility of educational and cultural facilities, the longer the activity duration to the elderly especially with school-age children, while the higher the community floor area ratio, the shorter the activity duration. In terms of active distance, the lower the accessibility of community educational and cultural facilities, the lower the community greening rate, and the higher the accessibility of amusement and recreational facilities, the higher the probability of choosing destinations at a greater distance. Regarding the type of activity, the higher the density of the road network, greening rate and community floor area ratio, the higher the probability that the elderly and children choose to play within the community. The closer the subway station, the diverse the type of activities.

To the low-frequency and multi-purpose activity group, in terms of activity duration, the higher the density of the community road network and more diverse the community play and leisure facilities, the longer the activity duration. As regards activity distance, the higher the accessibility of community amusement and recreation facilities, the higher the probability of taking activities within the community. In terms of activity types, the higher the accessibility of amusement and leisure facilities, the diverse the activity types (Table 4).

3 clusters of the elderly and children	Characteristics of spatio-temporal activities	Floor area ratio	Accessibility to education services	Accessibility to recreation services	Road density	Green ratio	Distance to public transport station
multi-time period and short-distance active group	Activity duration	-0.36	–	–	–	0.749	-0.278
	Activity distance	1.578	–	–	2.263	–	–
	Activity type	-3.535	–	3.945	-4.559	-5.615	3.543
afternoon short-distance activity group	Activity duration	-0.167	0.167	–	–	0.321	–
	Activity distance	–	-3.111	2.258	–	-2.158	–
	Activity type	-2.203	–	–	-4.329	-3.076	3.566
Low-frequency and multi-purpose activity group	Activity duration	–	–	0.368	0.424	–	–
	Activity distance	–	–	-5.206	–	–	–
	Activity type	–	–	4.363	–	–	–

Table 4: Influencing factors on spatio-temporal activities within the community of the elderly and children

6 DESIGN STRATEGIES FOR ELDERLY AND CHILDREN-FRIENDLY COMMUNITIES

6.1 Establishing fine-scale and multi-level community outdoor activity space for the elderly and children

According to the analysis of the activity distance and preferred space of the elderly and children, it can be seen that the activity range of the elderly and children is mainly 0-500 meters away from their homes, especially within the range of 300m, and the high green ratio and high road connectivity within this scale have a positive effect on the outdoor activity duration of the elderly and children. In addition, besides parks and squares within the community, the space in front of the house, pathway and corner space in the community are also important parts of the daily activity space, which need to be renovated in terms of safety and enjoyability for the elderly and children. Therefore, on one hand, a finer layers of community scale should be made at the macroscopic level, and the design criteria and key features of each level ought to be proposed. On the other hand, a more refined design of the space in front of the house, as well as the landscape of the community green space and corner space should be carried out at the microscopic level, so as to improve the safety and connectivity of the community roads (Table 5).

Scale level	Service radius (m)	Design specification
residential neighborhood	300	Safety road, diversified playgrounds and rest facilities, versatile landscape, high green ratio
5-minute living area	500	Diversified and accessible recreational, educational and shopping services
10-15minute living area	1000-1500	Safety road, high accessibility to diversified service facilities and public transport

Table 5: Design strategies and specifications for fine-scale community

6.2 Improving the diversity of service facilities for the elderly and children in and around the community

According to the factors influencing the community activities of the elderly and children, the higher the accessibility of playgrounds, educational services and public transport stations, the longer the outdoor activity durations and the more diversified of their activities. Therefore, on the one hand, play and rest facilities can be supplemented to the public activity space in the community, for example, revitalizing vacant and inactive public rooms in the community and transforming them into drawing rooms, chess and cards rooms, reading spaces where the elderly and children can participate and interact together, and making use of the community's marginal space to improve landscape or add play and fitness facilities, in order to provide diversified places for the elderly and children to play and rest.

7 CONCLUSION

In generall, with regard to the characteristics of temporal and spatial activities, the activity time preferred by the elderly and children are 9:00-12:00 and 15:00-18:00, among which, for the elderly with school-age children, they are more inclined to be active from 15:00 to 18:00. The duration of their activities mostly lasts 1-2 hours. The scope of daily activities is mainly within the community, usually within 500 meters from home, especially within 300 meters. Public squares, parks and green spaces within the community are the most important activity places for the elderly and children, followed by parks and squares as well as educational service facilities outside the community, and then dining and shopping service facilities outside the community. For children of school age, public spaces around the school, as well as the path between school and home are also the main activity areas. In addition, it should be noted that the space in front of the house and the community roads are also the main activity places for the elderly and children. In terms of activity content, play and leisure are the main activities, followed by education and shopping. In terms of the interaction between the elderly and children, when the children are at younger ages, the elderly mainly take care of the children, chat and communicate with each other, and take a walk with the baby carriage. As the children grow older, the proportion of the elderly and children taking exercises and playing games together increases.

With regard to the portraits of the community activities of the elderly and children, based on the results of the cluster analysis, they can be summarized into three categories, namely the multi-time period and short-distance active group, the afternoon short-distance activity group, the low-frequency and multi-purpose activity group, which account for 42%, 39.9% and 18.1% of the total research sample respectively. According to the order of importance of the predictor variables, it can be seen that the variables of 9:00-

12:00 activity period, activity frequency, activity duration, educational activities, and 500m to 1000m activity distance are important variables to distinguish the three groups.

Regarding the influencing factors, road network density, green ratio, floor area ratio, distance to subway stations, and accessibility of recreational facilities as well as science and education facilities have a significant impact on the daily spatial and temporal activities of the elderly and children within the community. Specifically, for outdoor activity duration, the higher the green ratio, road network density, and accessibility of recreational facilities, the longer the duration of outdoor activities. In terms of the differences in influencing factors among the three groups, the green ratio of the community has a greater positive influence on the activity duration of the elderly and children who are active in short-distance from home; the density of the road network and the accessibility of recreational facilities have a greater positive influence on the activity duration of the low-frequency and multi-purpose elderly and children; whille the floor area ratio has a negative influence on the outdoor activity duration of the elderly and children who take activities within a short-distance from home, but the level of influence is not high.

For activity distance, high road network density, high accessibility of recreational facilities, and high floor area ratio are associated with a greater activity range and longer distance for the elderly and children, while high accessibility of science and education facilities and high green ratio are associated with a greater tendency for the elderly and children to engage in activities within the community.

As for the types of activities, the higher the accessibility of recreational facilities and the closer the subway station, the more diversified the activities of the elderly and children are, including not only playing in the community, but also carrying out activities outside the community in educational, shopping, catering and other service facilities; whereas, with a high green ratio, a high density of the road network, and a high floor area ratio, the probability that the elderly and children carry out outdoor activities within the community is higher.

8 DISCUSSION

This research focuses on promoting inclusive community sapce for the elderly and children. By taking typical communities in Tianjin as examples, the research follows the analytical steps of “categorizing spatial and temporal behavior patterns of the elderly and children – analyzing spatial influence mechanisms – proposing spatial design strategies”, which provides a science-based method to realize the construction of human-oriented and inclusive community for the elderly and children. However, this study has only considered the spatial elements of the community when analyzing the influencing factors on the community spatial and temporal activities of the elderly and children, and has not given enough consideration to the non-spatial elements of the community such as community governance and interpersonal relationships20. At the same time, the combination of variables affecting the spatio-temporal activities of the elderly and children has not been analyzed in depth, and the path of building an inclusive community for the elderly and children under different environmental and socio-economic conditions is not yet clear.

In future researches, on one hand, non-spatial elements, such as socio-economic and cultural environment, community governance, as well as neighborhood relations have yet to be incorporated into a unified analysis system, so as to comprehensively analyze the effects of the relevant elements on the community activities of the elderly and children in terms of their direct, indirect, and interactive influences. On the other hand, on the basis of analyzing the influencing mechanisms on the activities of the elderly and children in different types of communities, Qualitative Comparative Analysis (QCA) can be used to identify and refine typical paths for the integration of the elderly and children in different community environments, so as to provide more targeted and operational guidence for creating communities that better serve the elderly and children.

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reviewed paper

Critical Analysis of Net Zero Pathways for Affordable Housing in India

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1 ABSTRACT

The residential floor area in India is expected to more than double by 2040. Ninety-nine percentof this growth is in Low Income Group segment, proving that affordable housing is the future of residential development. This will lead to high energy consumption and carbon emissions. In 2023-24, the building sector accounted for 13% of the total energy consumption in India, of which 82% came from the residential sector. It is thus crucial to ensure that all new residential building stock, expected to last for the next 5 decades, is built in a climate-conscious manner to reduce energy consumption and carbon footprint of the built environment. However, this can only happen if the needs of the affordable housing segment are addressed.

This paper examines the applicability of India's two of four net zero pathways in affordable housing – energy-efficiency, sustainable materials and construction technologies. It analyses regulatory instruments, policies and schemes, and market instruments through the Availability-Affordability-Quality framework, examining if solutions are available, if solutions are affordable, and if solution favours emission reduction.

Findings show that most instruments are designed for an overall built environment, with no specific focus on low-income groups. Of the specific affordable housing policies, recommendations for achieving affordability is found to compromise with quality, particularly considering GHG emissions. Based on the findings, the paper provides three recommendations – (i) developing a unified definition of green, (ii) consolidating policy implementation through unified regulatory mechanisms, and (iii) procurement reforms to unlock potential of sustainable materials/technologies use, to ensure an affordable net zero future for India.

Keywords: Policy implementation, Operational emissions, Net zero built environment, Embodied emissions, Affordable housing

2 INTRODUCTION

India is at a critical juncture where urbanization and its impact on climate are converging. India's urban population is expected to rise from 31% in 2011 to 38.2% in 2036, accounting for an additional 218 million population(National Commission on Population, 2020). This is expected to lead to an increased demand in infrastructure to house and service the additional urban population, with the highest demand expected to be in residential floor space. The urban residential sector was adding 0.52 billion sqm floor space annually in 2020.By 2050, this is expected to go up by 82%, adding 0.95 billion sqm annually(National Institute of Urban Affairs & RMI, 2022). In a business as usual scenario, energy consumption from this will increase threefold, and carbon emissions will quadruple. Therefore, it is crucial to ensure that all new building stock, expected to last for the next five decades, is built in a climate-conscious manner to reduce energy consumption and carbon footprint of the built environment, especially residential buildings.

Additionally, this has to predominantly address the economically weaker sections (EWS) and low-income groups (LIG). Roy & ML, (2020) estimated the urban housing shortage to be 50 million in 2018, of which 99% belonged to EWS and LIG segments. This implies that the bulk of residential development in Indian cities are required to be affordable in nature. Furthermore, considering that 50% of GHG emissions from the residential sector comes from heating and cooling needs, this segment is also impacted disproportionately by rising energy demands. Dong et al. (2021), highlights that Heating, Ventilation, and Air Conditioning (HVAC) systems are energy and carbon intensive, andunaffordable for low-income households. Studies also show that poorly insulatedaffordable housing units pose a higher risk of exposing inhabitants to prolonged energy poverty (Chen & Feng, 2022).

This paper thus hypothesizes that ensuring sustainable development for all new building stock, and achieving India's target of reducing 45% GHG emissions by 2030 and Net Zero by 2070 (Ministry of Environment, 2024)is only possible if the needs of the affordable housing segment are addressed.

2.1 Net zero pathways in India

Currently the building and construction sector contributes to nearly 40% of annual GHG emissions globally. In India, this number stands at 32% (India Third Biennial Update Report to UNFCCC, 2021). Within this, 60-65% comes from operational emissions – primarily from energy use for heating and cooling needs (National Institute of Urban Affairs & RMI, 2022). Of the 35-40% embodied emissions, the most significant portion comes from using energy-intensive building materials and construction processes. This paper identifies fourpathways of emission reduction in the built environment – reducing operational emissions through (i) clean energy transition, and (ii) energy-efficiency; reducing embodied emissions through (iii) incorporating sustainable materials and construction technologies, and (iv) building retrofit.

While the larger research reviews all four pathways, this paper focuses on the following two pathways.

2.1.1 Pathway 1 – Energy Efficiency

The International Energy Agency (IEA) highlights that energy efficiency is the single largest measure in reducing energy demand at source, leading to significant cost savings for consumers (Energy Efficiency – Energy System – IEA, n.d.). 28% of households in urban India are energy poor. (Khandker et al., 2010). In an affordable housing landscape, energy efficiency, especially through adaptive thermal comfort, supersedes other methods of emission reduction.

2.1.2 Pathway 2 – Sustainable materials and construction technologies

From the 35-40% embodied emissions, 23-34% comes from the product stage, accounting for raw material extraction, transportation to site, and manufacturing. Two-to-four percent comes from the construction process stage accounting for transportation to construction site and installation process. Three-to-six percent comes for the building use stage, with the remaining one-to-six percent coming from the end of life stage (Godrej Design Lab, 2024). This paper thus focuses on the product and construction process stage, accounting for 25-38% of overall embodied emissions.

3 APPROACH AND METHOD

This paper hypothesizes that while numerous solutions exist to mitigate operational and embodied emissions in the built environment in India, none are tailored specifically for the affordable housing sector. The study examines existing the identified pathways for emission reduction through a threefold lens – (a) Availability of existing solutions and policy/regulations/instruments through which solution is made available at scale, (b) Affordability of the solution, including incentivisation for LIG segment, and (c) Quality of solution with respect to emission reduction over complete life-cycle.

The following instruments are reviewed to critically examine the net zero landscape in India, cross examining them with respect to affordable housing policies and national and subnational levels.

Instrument category	Description of instrument	Title of policy instrument	Target sector
National net zero targets	National level climate targets and strategies	Fourth Annual Communication and Initial Adaptation Communication, 2024 National Mission for Sustainable Habitat (NMSH) India Cooling Action Plan	Net zero pathways
Regulatory instruments	Legal tools/regulatory frameworks that guide built environment development	Energy Conservation Act Model Building Bye Laws 2016 Development Control Regulations (state wise) Delhi Schedule of Rates 2021	Built environment Net zero pathways
Building codes	National instruments for regulating building design and construction across the country	National Building Code 2016 Energy Conservation and Sustainable Building Code 2024 Eco Niwas Samhita 2024	Built environment Net zero pathways
Policies and schemes	Guidelines on policy/scheme overview, focus, implementation, and impact	Pradhan Mantri Awas Yojana State Affordable Housing schemes	Affordable Housing
Policy support	Design guidelines and compendiums supporting policies	Innovative Construction Technologies & Thermal Comfort in Affordable Housing (RACHNA) Handbook BMTPC Compendium of Emerging Construction Technologies for Housing & Infrastructure	Built Environment Affordable Housing

Green Building Rating System	Rating and certification systems for greening of projects in the built environment	Indian Green Building Council (IGBC) – Green Affordable Housing IGBC NEST and NEST Plus GRIHA framework Green Pro Ecolabeling	Affordable Housing Net zero pathways

Table 1: Description of policy instruments reviewed

3.1 The Availability – Affordability – Quality (AAQ) framework

The Availability-Affordability-Quality (AAQ) framework is used to analyse regulatory and policy instruments across built environment, affordable housing, and net zero pathways. The AAQ framework was developed to review the efficacy of existing solutions in the context of affordable housing, and exploring if affordability comes at the expense of quality. The study applies a mixed method approach of analysis applied against the AAQ framework. Specific research questions for the AAQ framework along with the type and method of analysis applied to explore those questions are described below.

Framework	Research questions	Type of analysis	Method of analysis
Availability	Is a solution available for a specific pathway? If yes, then how is it made available at scale?	Qualitative	Identification and mapping of regulations, policies, schemes, guidelines, market instruments that solve for the identified pathway
	Does the implementation mechanism of identied solutions converge with affordable housing policies/implementation?	Qualitative	Comprehensive flowchart of implementation mechanisms of the policy/scheme/code/rating system co-examined against implementation of affordable housing policies, schemes, and building byelaws; outlining key stakeholder groups, roles and responsibilities, and existing communication channels between parties.
Affordability	Is the solution affordable to EWS and LIG consumers?	Quantitative	Bill of Quantities comparison of a conventional affordable housing unit vs an affordable housing unit incorporating solutions and strategies recommended in solution pathways. Materials reviewed have been taken from RACHNA handbook.
Quality	What is the quality of the solution with respect to emission reduction?	Quantitative	Comparative analysis of impact metrics for all pathways to identify conflicts in quality of output.
	Does achieving affordability impact the quality of the solution?		

Table 2: The methodology framework

3.2 Boundary conditions for analysis

Establishing boundary conditions was necessary in order to measure the efficacy of existing pathways. The following boundary conditions were identified and applied – housing affordability, typical size and scale of affordable housing unit, and scenarios for analysis. These boundary conditions are primarily applied when comparing Affordability Index with respect to solution pathways, and in determining Quality of solution with respect to emission reduction.

3.2.1 Housing affordability

Housing affordability is a key determinant when reviewing the impact of design recommendations, material, and construction techniques on the overall construction cost.

Affordable housing in India targets three specific income groups, with annual household income as stated (Ministry of Housing and Urban Affairs, 2024)

(1) EWS –up to 3,00,000 INR (3450 USD)

(2) LIG –between 3,00,001 – 6,00,000 INR (3451 – 6900 USD)

(3) Middle Income Group (MIG) –between 6,00,000 – 9,00,000 INR (6901 – 10300 USD)

The scope of this paper is limited to EWS and LIG.

As per the Task Force Report on Promoting Affordable Housing, (Ministry of Housing & Urban Poverty Alleviation, 2012), the desirable housing price to income multiple for affordable housing should not be more than 5. However, housing price is dependent on land price and construction cost. Since land prices are highly variable based on geography, and outside the purview of this paper, this study focuses on affordability of construction cost. The study applies a Bill of Quantities comparison, considering a conventional affordable housing unit of 30 sqm carpet area, with an RCC frame construction, with burnt clay brick walls of 250mm thickness, and unplastered RCC slab roofing. The construction cost for the base case is 1101190 INR (12500

USD) overall, or 25700 INR (300 USD) per sqm. This corresponds with the average cost of construction for a 30 sqm basic unit across India (Construction Cost Calculator for House, n.d.). A construction price to income ratio is also presented as a partial measure of housing affordability, primarily considering capital expenditure for materials and construction.

3.2.2 Scenarios for analysis

As per Ministry of Housing and Urban Affairs, (2024), an affordable housing unit is defined as a unit with carpet area not more than 30 sqm. For analysing efficacy of net zero pathways, we consider two scenarios

(1) An independent housing unit of 30 sqm carpet area; 42.86 sqm of total built-up area (considering carpet area is 70% of built up area (Ministry of Housing and Urban Affairs, 2016))

(2) A mass affordable housing complex of 100 units, 10 units each of 30 sqm carpet area across 10 floors; 4286 of total built up area.

4 RESULTS

4.1 Overall findings for pathway 1 – Energy Efficiency

India's Fourth Biennial Update Report (BUR-4) to UNFCCC, a comprehensive review of India's commitments and progress in terms of it's Nationally Determined Contributions, reveals that Energy Efficiency in the built environment has been a priority focus area of the Union Government (Ministry of Environment, 2024). Initiatives such as ENS has resulted in collective energy savings of 4.84 MU between 2021 and 2023. This section further explores the applicability of such measures in the affordable housing segment.

4.1.1 Availability of Energy Efficiency solutions

In affordable housing, thermal comfort and energy efficiency is primarily solved through four interventions

(1) Change in walling materials and technologies

(2) Change in roofing materials and technologies

(3) Passive design techniques such as natural ventilation, shading, daylighting, building orientation.

(4) Energy efficient appliances

This study critically examines intervention 1-3; energy efficient appliances are outside the purview of this research owing to its limited scope in architecture, design, and planning.

In the overall built-environment, interventions are made available at scale through the following instruments

Instrument category	Title of instrument	Description of instrument
National net zero targets	National Mission for Sustainable Habitat (NMSH) India Cooling Action Plan	National level mission on promoting low-carbon urban growth, achieving India's NDCs through built environment interventions, and building resilient cities. National level cooling action plan identifying strategies and cooling pathways for key sectors including built environment.
Regulatory instruments	Energy Conservation Act Model Building Bye Laws 2016	A law that aims to reduce energy intensity of the Indian economy. A model regulatory framework regulating coverage, height, building bulk, and architectural design and construction aspects of buildings, to ensure orderly urban development.
Building codes	National Building Code 2016 Eco Niwas Samhita 2024	National instrument regulating building construction activities across the country. National level energy-conservation building code for residential buildings.
Policy support	Innovative Construction Technologies & Thermal Comfort in Affordable Housing (RACHNA) Handbook	Thermal comfort design guidelines for affordable housing construction.
Green Building Rating System	Indian Green Building Council (IGBC) – Green Affordable Housing IGBC NEST and NEST Plus	Green building rating systems for affordable housing.

Table 3: Energy efficiency instruments in India

However, only the RACHNA handbook and IGBC green affordable housing, NEST and NEST plus rating systems specifically provides recommendations for the affordable housing segment. All other policy and regulatory target the built environment as a whole – with no targeted recommendations for the affordable housing segment.

Eco Niwas Samhita, a national building code on energy efficiency, is applicable only for residential development with an area of 3000 sqm or above, or with a connected load of 100kw (Bureau of Energy Efficiency, 2024). This renders independent affordable housing units ineligible for the code.

Figure 1shows the implementation mechanisms for energy-efficiency solutions, outlining actors, roles and responsibilities, and existing communication channels.

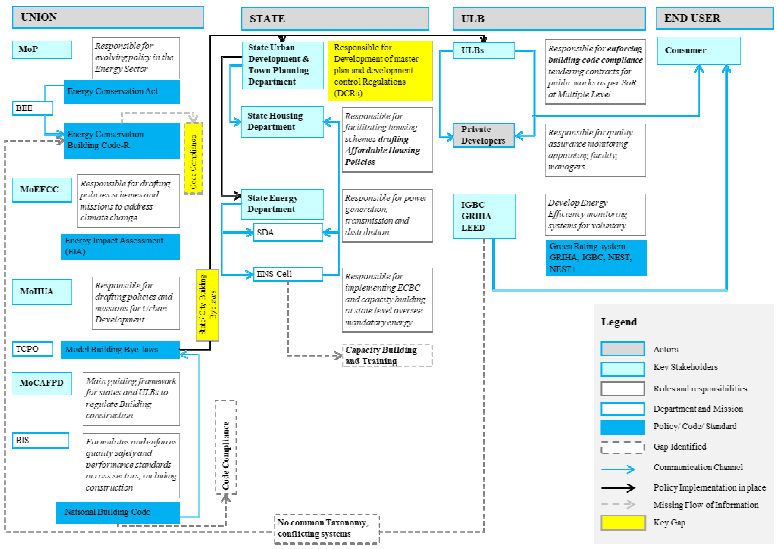

Figure 1: Implementation mechanism for energy efficiency and affordable housing policies

The comparative implementation mechanisms framework of energy efficiency and affordable housing policies reveal that there is currently no convergence between energy efficiency and affordable housing policies directly. Only the parts of the ENS that are incorporated in Model Building Bye Laws (Ministry of Housing and Urban Affairs, 2016, pp. 115-120) are legally applicable to all affordable housing units. ENS itself is not a legally mandated tool; individual state governments are authorised to mandate it across the state. To date, 17 out of 28 Indian states have initiated the notification of ENS (Bureau of Energy Efficiency & Alliance for an Energy Efficient Economy, 2023).

The PMAYhas drafted the RACHNA guidelines focusing on thermal comfort for affordable housing. However, there is limited evidence on its application, currentlyimplemented in only 6 lighthouse projects across India (Ministry of Housing & Urban Affairs, 2022).

4.1.2 Affordability of Energy Efficiency solutions

Based on calculations for standard cost of construction, it is found that walling and roofing materials constitute nearly 60% of the total construction cost. This assessment thus focuses on affordability of these two categories specifically.

In order to measure if existing recommendations are affordable, walling and roofing materials recommended in the RACHNA handbook (Ministry of Housing and Urban Affairs, 2022) or widely used in built construction across India are analysed.Table 2 presents the cost of different walling materials against this base case of an RCC frame structure with burnt clay brick walls and unplastered RCC roof slab.

The comparative construction cost assessment reveals thatmaterials that satisfy the ECBC benchmark of <15W/m2cost significantly higher than the base unit (Case 4 in Table 2). An AAC block with an RCC filler slab that satisfy all thermal comfort benchmarks, cost 31% higher than the baseline.

The construction cost of a unit with AAC walling, and RCC filler slab is 2.8 times the annual income of a EWS consumer, and 0.14 times that of an LIG consumer.

4.1.3 Quality of Energy Efficiency Solutions

The mandatory energy conservation recommendations under ENS consider Openable Window to Floor Area Ratio (WFRop), Visible Light Transmittance (VLT), Thermal Transmittance of Roof (Uroof), Residential Envelope Transmittance Value (RETV) for walls. These mandatory recommendations do not consider thermal emittance as a key criteria; it is provided as an incremental condition in both cases.

Mandatory recommendations for the IGBC green affordable rating system state only U value of roofs ≤ 1.8 W/m2K and glazing ≤ 5.7 W/m2K. The NEST and NEST plus ratings are further relaxed to provide a benchmark of U-value 2.5 W/m2K for walling assemblies. This raises the question of whether the quality of recommendations specifically aimed at the affordable housing sector differs.

Wall ↓	Case – Wall	Case 1 – Base case	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
		250 mm	200 mm	220 mm	300 mm	220 mm	200 mm	150 mm	250 mm
		Burnt clay brick + cement plaster	**CSEB**	**Fly Ash block + cement plaster**	**AAC block**	**Solid concrete block + cement plaster**	**Coffer**	**Reinforced EPS**	**Rat Trap + cement plaster**
	Overall construction cost	*1101189.13*	*1080835.86*	*1051954.16*	*1220512.19*	*1218579.33*	*1091380.94*	*1137820.94*	*1127500.94*
	Difference in construction cost	₹0.00	₹-20,353.27	₹-49,234.97	₹119,323.06	₹117,390.21	₹-9,808.18	₹36,631.82	₹26,311.82
	RETV	*16.62*	*14.35*	*16.34*	*12.35*	*25.48*	*N/A*	*N/A*	*N/A*
	Difference in RETV	0.00	2.27	-0.28	-4.27	8.86	N/A	N/A	N/A
Roof ↑	U value	*1.58*	*1.58*	*1.58*	*1.2*				
	Difference in U value	0.00	0.00	0.00	-0.38				
	SRI	*41.00*	*100.00*	*90.00*	*41.00*				
	Difference in SRI	0.00	59.00	49.00	0.00				
	Overall construction cost	*1101189.13*	*1117180.94*	*1139847.68*	*1089730.87*				
	Difference in cost	₹0.00	₹15,991.82	₹38,658.55	₹-11,458.26				
	Case – Roof	**RCC slab – unplastered**	**RCC slab + white coating – 1 coat**	**RCC slab + white cement tile**	**RCC filler slab – unplastered**				
		150 mm	150 mm	170 mm	150 mm				
		Case A – Base case	Case B	Case C	Case D				

Table 4: Construction cost and quality comparison for recommended materials – energy efficiency

This is further exemplified by the fact that there is no direct correlation between the multiple metrics of achieving thermal comfort, and measuring operational energy consumption or emissions. Operational energy is typically measured through Energy Performance Index (EPI), which represents the annual energy consumption per unit area. However, this includes the performance of appliances, in addition to efficiency through materials and passive design. In the lack of an equivalent metric between individual thermal comfort indices and operational energy, it is difficult to isolate the efficacy of each solution. This could potentially lead to difference in quality of output, as seen in the IGBC affordable housing recommendations.

4.2 Overall findings for pathway 2 – sustainable materials and construction technologies

Embodied emissions contribute to 35-40% of overall built environment emissions in India (National Institute of Urban Affairs & RMI, 2022). This share is expected to rise to 50%, as the share of operational emissions decline over time (Jain et al., 2023). A large part of this shifting balance between embodied and operational emissions is due to policy focus skewed largely in favour of operational emissions. Studies show that weightage given to the use of green materials in green building rating systems and building codes is 8-9% (Jain et al., 2023).

4.2.1 Availability of solutions for sustainable materials and construction techniques

This paper explores the availability of solutions across three areas

(1) Market innovation and availability of products and technologies

(2) Regulatory instruments enabling scaling of innovations

(3) Policies and schemes enabling higher market penetration

The following instruments curate and enable the availability of sustainable materials and construction technologies at scale.

The Compendium of Emerging Construction Technologies (Building Materials & Technology Promotion Council, 2023), presents a list of 69 materials and technologies analysed and curated through a third-party assurance system that evaluates materials and technologies based on (a) Structural performance against vertical & lateral loads, (b) Fire resistance, (c) Protection against rain & moisture, (d) Thermal &acoustic behaviour, (e) Ease of fixing services, (f) Quality assurance, (g) Durability /Service Life. The Compendium is prepared under the ambit of the PMAY scheme, implying economic viability of materials to be a key assessment criteria. The Green Pro Ecolabeling adopts an LCA approach to analyse and curate materials(Greenpro | Home, n.d.). NBC 2016 also includes a chapter on sustainable materials, providing alternatives to carbon intensive materials(Bureau of Indian Standards, 2016). However, there is no standard method of impact measurement and reporting in all three documents. Embodied energy calculation and reduction as a specific target is not addressed in any of these documents.

Instrument category	Title of instrument	Description of instrument
Materials compendium	Compendium of Emerging Construction Technologies for Housing & Infrastructure, BMTPC	List of 69 emerging materials and construction technologies
Ecolabeling	Green Pro Ecolabel Directory – 2025 (5th edition)	Ecolabel certification and directory of 9500 green materials
Building codes	National Building Code 2016 Eco Niwas Samhita 2024	*Refer* **Fehler! Verweisquelle konnte nicht gefunden werden.**
Regulatory mechanisms	Schedule of Rates	Standardized rate document for materials, construction technologies prepared for all public works projects

Table 5: Sustainable materials and construction technology instruments in India

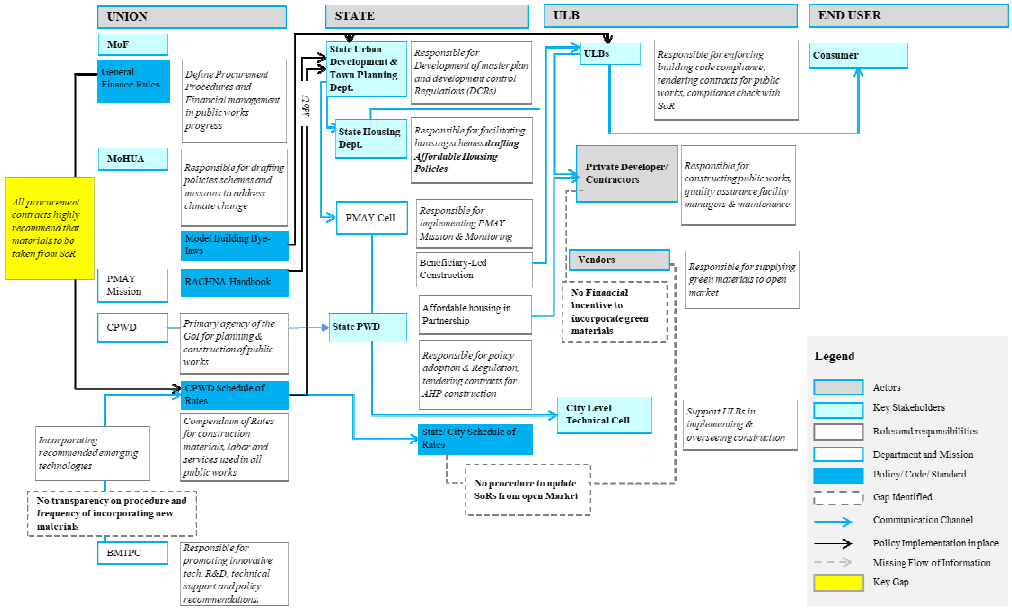

Figure 2: Implementation mechanism for sustainable materials and construction technologies in affordable housing

Finally, none of this instruments serve as mandates to include sustainable materials and construction technologies in the built environment. As per India's procurement regulations, all public works projects,including affordable housing, is recommended to use materials specified in the State Schedule of Rates, adapted from the Delhi Schedule of Rates (DSR) drafted by Central Public Works Department (CPWD). Currently the process of incorporation of sustainable materials and technologies available in the market into the SoR, as well as regular updation, is unknown. In the absence of a regulated system of including recommendations by BMTPC, BIS, and ENS into the CPWD DSR, the process of ensuring the use of sustainable materials and techniques in affordable housing remains arbitrary (refer Figure 2).

4.2.2 Affordability of solutions for sustainable materials and construction techniques

The lack of a standard method of impact measurementpresents a constraint in identifying and thereby measuring affordability of high impact materials.

This paper thus extends the exercise of reviewing recommended/highly used walling and roofing materials to also measure Embodied Energy Value (EEV). The comparative analysis, shown in Table 3, reveals

contradictions when concurrently reviewing cost, thermal comfort, and EEV. CSEB has a lower construction cost as well as significantly lower EEV. However, its RETV values are higher compared to both AAC and Fly Ash blocks. AAC blocks, which are superior in terms of RETV values, cost significantly higher and has a significantly high EEV.

	Case – Wall	Case 1 – Base case	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
		Burnt clay brick + cement plaster	**CSEB**	**Fly Ash block + cement plaster**	**AAC block**	**Solid concrete block + cement plaster**	**Coffer**	**Reinforced EPS**	**Rat Trap + cement plaster**
	Difference in const. cost	₹0.00	₹-20,353.27	₹-49,234.97	₹119,323.06	₹117,390.21	₹-9,808.18	₹36,631.82	₹26,311.82
	Difference in RETV	0.00	2.27	-0.28	-4.27	8.86	N/A	N/A	N/A
	EEV	*20931.24*	*5893.78*	*10721.33*	*20171.29*	*10446.32*	*N/A*	*12292.50*	*17791.55*
Wall	**Difference in EEV**	**0.00**	**-15037.46**	**-10209.91**	**-759.95**	**-10484.92**	N/A	**-8638.74**	**-3139.69**
Roof	**EEV**	*785.35*	*803.06*	*811.53*	*346.48*				
	Difference in EEV	**0.00**	**17.71**	**26.18**	**-438.87**				
	Difference in U value	0.00	0.00	0.00	-0.38				
	Difference in SRI	0.00	59.00	49.00	0.00				
	Difference in cost	₹0.00	₹15,991.82	₹38,658.55	₹-11,458.26				
		RCC slab – unplastered	**RCC slab + white coating – 1 coat**	**RCC slab + white cement tile**	**RCC filler slab – unplastered**				
	Case – Roof	Case A – Base case	Case B	Case C	Case D				

Table 6: Construction cost and quality comparison of recommended materials – embodied energy

4.2.3 Quality of solutions for sustainable materials and construction techniques

Table 3 reveals that most recommendations for materials and construction techniques enabling thermal comfort are done without due consideration of embodied energy values. Given that EEV is a measure of energy consumption and thus is strongly linked to energy efficiency in the overall life cycle of a building, not considering EEV while recommending materials aimed at energy efficiency is a significant gap in the current instruments.

Furthermore, measuring the quality of materials against a specific standard become difficult in the absence of a specific target. The Green Pro Ecolabel (Confederation of Indian Industry, 2025), presents the most comprehensive database of more than 9500 products, materials, and technologies from 450+ companies. The ecolabel however uses an 8 part analysis, using a credit system for scoring and selecting green materials. Life cycle assessment is one of the 8 parts, wherein credits are assigned based on performance improvement in emission reduction, and not against a standard benchmark(Confederation of Indian Industry, 2016).

4.3 Synthesis of gaps in the overall ecosystem

The findings reveal the following gaps in the current ecosystem

4.3.1 Lack of a unified/standard method of outcome measurement

The study reveals that currently all net zero pathways operate in isolation. Extensive solutions exist for both energy efficiency and sustainable materials and construction technologies. However, considering the lack of a unified metric of outcome measurement – such as reduction in GHG emissions or energy consumption across the life cycle, it is difficult to measure the overall efficacy of existing solutions. The lack of unified outcome parameter also leads to quality dilution in the case of affordable housing, implying that affordability comes at the cost of quality.

4.3.2 Lack of a comprehensive implementation mechanism for all net zero pathways

The implementation mechanisms for pathway 1 and 2 revealmultiple gaps in communication between actors at the Union, State and City. Multiple solutions exists for both pathways, with no communication between parties, and overlapping roles and responsibilities. The implementation mechanisms also reveal the lack of robust regulatory mechanisms – building codes are not legally mandated in most Indian states and cities. The ENS policy is not mandated but notification is initiated in 17 states. However, this is also not specifically attuned for the affordable housing sector. The applicability of the code rules out independent affordable homes. The limited implementation of RACHNA guidelines in affordable homes built under PMAY further reveals a gap in robust implementation mechanisms of energy efficiency pathways in affordable housing.

4.3.3 Lack of regulatory mechanisms for incorporation/usage of sustainable materials and construction techniques

While solutions exist for pathway 2, implementation of solutions across scale is impacted by the current procurement system, mandating that only materials incorporated in Schedule of Rates be used for public work projects, including affordable housing (refer Figure 2). This implies that most sustainable materials that currently exist in the market are not used in affordable housing projects, unless specifically incentivised.

5 RECOMMENDATIONS

5.1 A unified definition of Green

Multiple recommendations currently exist for categorically reducing operational and embodied emissions in the built environment. However, the lack of a comparative unit of measurement reveals contradictions in recommendations, and subsequently in quality of output.

This paper proposes that there needs to be a unified definition of "Green" that combines operational and embodied emissions of materials and construction techniques, but one that also factors in construction cost. Such a definition will eliminate contradictions in cost, energy efficiency (reducing operational emissions), and embodied emissions. However, considering that units are not equivalent across the three factors, we propose a normalised scoring method, such that

$$Green\ score = -1 * \left(\frac{c_1 - \bar{c}}{\bar{c}} + \frac{o_1 - \bar{o}}{\bar{o}} + \frac{e_1 - \bar{e}}{\bar{e}}\right)$$

Wherein, c_1 = cost of material in consideration;$\bar{c}$ = mean national cost of material
o_1 = operational emission of material in consideration; $\bar{o}$ = mean operational emission of building materials
e = embodied emission of material in consideration; $\bar{e}$ = mean embodied emission of building materials

Considering that the aim is to achieve lower cost of construction and lower emissions, the normalised calculation will provide results wherein lower the score, better the performance. However, for the sake of readability and ease of understanding, the calculations are multiplied by a factor of -1 to lead to a scoring system where higher the green score, better the overall performance and affordability.

This method requires establishing a national mean for operational and embodied emission of materials. This also enables setting standard targets for the building sector in terms of emission reduction.

5.1.1 Considerations for unified measurement metric for operational and embodied emissions

Currently, operational energy is measured through the EPI, representing annual energy consumption per unit area. However, since this also considers the emissions from active cooling systems and appliances, it is imperative to isolate the energy consumption from heat gain through building envelope, and roof, to impart a green score to specific materials, technologies, and passive design techniques.

Bhanware et al., (2020) reveals a strong correlation between the sensible cooling load of a building and ReTV. This enables the extrapolation of cooling load for each climate zone based on ReTV (Qsensible in kWhth/m2). Considering the method of cooling (natural or air conditioning) can provide a comprehensive scenario of electrical units consumed. Multiplying this value with average emissions factor for electricity in India, stated to be 0.716 kg CO_2 per kWh(Central Electricity Authority, 2023), may give the operational emissions from heating/cooling needs for the specific material. Similar methods can be applied for measuring heat gain, and subsequently GHG emissions of roofing materials using U-value. When considering the Green Score of the whole building, EPI is a better metric, but has to be calculated over time and in a consistent manner.

Embodied emissions may be calculated in the same manner from Embodied Energy Value.

5.2 Consolidating policy implementation through unified regulatory mechanisms

Section 4.3.2 highlights the conflicts in the current ecosystem stemming from a lack of convergence in roles, responsibilities, and communication channels in various policies, schemes, guidelines, and market instruments. The gap in implementation mechanisms can be addressed through two regulatory mechanisms

5.2.1 Mandating recommendations through Building Byelaws

Building codes, policies, and schemes are not legally binding. While ENS can be notified state-vide, for implementation the compliance and mandate is integrated into the building permission process through the Building Byelaws (Government of Karnataka, 2018). This paper thus recommends the development of a streamlined process of integrating key clauses of the Eco Niwas Samhita into the Building Byelaws, specifically addressing the low-income housing segment. The latest edition of the Model Building Byelaws gives specific recommendations for Low Income housing in terms of minimum plot area, minimum dimensions for room sizes and layouts, structural requirements, and regulations for land development(Ministry of Housing and Urban Affairs, 2016). However, a specific chapter on "Green Buildings and Sustainability Provisions", incorporating recommendations from ECBC 2007, do not provide targeted recommendations for the Low Income housing segment. This leads to blanket regulations, rendering all plots up to 100 sqm ineligible for any sustainability provisions, and mandating all plots above 3000 sqm (including mass affordable housing) to comply with all 10 provisions (Ministry of Housing and Urban Affairs, 2016, pp. 115-120). This paper recommends a specific segment for affordable housing in the"Green Buildings and Sustainability Provisions", tailored to the recommendations and approach discussed in this paper – to mandate net zero pathways in affordable housing.

5.2.2 Incentivising solutions through Development Control Regulations (DCRs)

DCRs are planning regulations that govern the development of a city through zoning regulations, Floor Area Ratios (FAR), height limitations, set-backs, parking requirements, plot sizes etc. In terms of legal mandates, DCRs supersede Building Byelaws, but are typically implemented in tandem with the later by city governments to guide and regulate development. The provisions in a DCR have been shown to impact housing affordability and influence sustainable development (Niti Aayog, 2021). This paper thus recommends the integration of non-fiscal incentives such as free of cost FAR for mass affordable housing projects that integrate net zero measures, or fiscal incentives such as reduced development fees for projects that meet green building criteria. While this is currently practised through a range of instruments in multiple states across India, there is a need to consolidate these incentives under city-specific regulations to ensure successful implementation on ground.

5.3 Procurement reforms to unlock potential of sustainable materials/technologies use

The findings of this study highlights the procurement challenges in the current landscape of building construction in India – including affordable housing. In order to ensure a sustained integration of sustainable materials/technology in all affordable housing construction, this paper recommends the following

5.3.1 Building a consolidated database of sustainable materials and construction techniques applying a unified measurement metric

Building a consolidated database with a unified measurementmetric is the first step towards procurement reform for sustainable materials/construction technologies. Rawal et al., (2024), and International Finance Corporation, (2017) discuss the development of an embodied energy database for commonly used construction materials using the LCA approach. Such a database provides a clear comparative assessment of all building materials against a unified benchmark. Supplementing this with specific embodied emission reduction targets for the building sector would further strengthen the assessment of building materials/technologies.

The consolidated database of materials should also enable the mapping and curation of manufacturers and suppliers that provide detailed technical specifications of the materials to be used in preparation of construction drawings, tendering, and estimation.

5.3.2 Developing a Green Schedule of Rates (SoR)and Analysis of Rates (AoR)for affordable housing

Such a database can be used to identify cost-effective, high impact materials for affordable housing. This paper recommends the preparation of a Green Schedule of Rates providing standardised rates of materials, technologies, and construction processes/services. The Green SoR should further provide the following information to ensure holistic decision-making in selecting green materials/technologies for construction

- What is the embodied carbon savings of the material?
- What is the operational emissions/utility cost savings over the lifetime of the material?
- How is its overall performance over life time compared to a conventional material it aims to replace?

The Green SoR should be supplemented with a detailed Analysis of Rates of items and services, providing a comprehensive cost analysis for each item. This ensures transparency and accuracy in the costing process. The AoR should further provide a rate comparison between sustainable and conventional materials, to further enable data driven decision making in selection of materials.

Developing a Green SoR that serves as a standardised rate document ensures all public works projects including affordable housing are built using sustainable materials and technologies.

6 DISCUSSION

This paper first examines the applicability of two net-zero pathwaysin the affordable housing segment. The Availability-Affordability-Quality framework applied here aims to comprehensively capture the gaps in the current ecosystem with respect to the affordable housing segment. The analysis reveals gaps that are addressed through three recommendations – 1) having a unified definition of "Green", (2) consolidating multiple instruments and ensuring implementation on ground through two regulatory instruments, building byelaws and development control regulations, and (3) addressing the building construction procurement system through having a consolidated database of low embodied energy materials and preparing a standardised rate document for the same. The implications of this study are discussed further

6.1 Critically considering the affordable housing segment in designing and implementing net-zero pathways

This study highlights that current net-zero pathways do not necessarily consider the needs for the affordable housing segment. Most instruments examined in this study are designed for an overall built environment, with no specific focus on low-income groups. Of the specific affordable housing policies, recommendations for achieving affordability is found to compromise with quality, particularly in terms of overall emission impact. Given that the significant proportion of new building stock is estimated to house EWS and LIG segments, it is crucial to examine and ensure the affordability of recommendations and solutions.

A framework is needed for comprehensively measuring affordability and quality of solutions, which ensures that achieving affordabity does not compromise quality. The study thus draws focus on the process of identifying and developing pathways, proposing that the needs for this segment are considered from the onset of policymaking, and not as an afterthought.

6.2 Developing a unified metric for measuring impact

The comparative analysis of recommendations analysed highlights inconsistencies in the output due to differing objectives. A material that achieves high thermal comfort may have significantly high EEV and construction cost. This thus highlights the need for a unified objective and method of measuring impact.

One potential metric is introduced. A method of developing a green score that combines operational and embodied emissions, and construction cost is discussed. However, the authors acknowledge that there may be other optimal ways of measuring impact that combines different objectives into a unified output. Furthermore, the unified metric method discussed here needs to be developed in collaboration with a wider quorum of technical experts and stakeholders – to ensure that differing objectives and needs are addressed at the onset.

6.3 Developing a consolidated implementation framework

Numerous solutions exist for each pathway discussed. While that implies a strong focus on addressing the issue, the intent may not always result in effective implementation and success on ground. The comprehensive implementation framework reveals that there are significant gaps in policy framing and policy implementation on ground. Actors responsible for drafting and implementing the multitude solutions be aligned. The intent of one policy/regulation can negate the impact of another – ultimately lessening the impact on ground. Thus, a consolidated framework of implementation, new communication channels between actors, and identification of streamlined pathways for on-ground implementation are necessary.

The paper presents an examination of two net zero pathways in the context of affordable housing in India, identifies critical gaps, and provides recommendations to ensure an affordable net zero future for India.

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reviewed paper

Das Konzept des 15-Minuten-Stadtquartiers in städtischen Randlagen – zwischen Traum und Wirklichkeit

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1 ABSTRACT

Das DREAMS-Projekt (finanziert durch das Forschungsprogramm Driving Urban Transitions to a sustainable future, https://dutpartnership.eu/) untersucht Entwicklungspfade zu barrierefreien, nachhaltigen und integrativen 15-Minuten-Quartieren in urbanen Randlagen in europäischen Städten und Regionen. Dabei werden 6 europäische Stadtquartiere außerhalb der dichten Stadtzentren als Living Labs herangezogen (Budapest, Brüssel, München, Paris, Utrecht und Wien). In einem ersten Schritt wurde die Ausgangslage untersucht, inwieweit die Mobilität der Einwohnerinnen und Einwohner schon heute dem Konzept der 15 Minuten-Stadt entspricht und wo die Defizite zu Tage treten. Hierbei wird nach verschiedenen Bevölkerungsgruppen und Verkehrszwecken unterschieden. Analysen des Mobilitätsverhaltens in den 6 Living Labs zeigen, dass der höchste Anteil an Wegen innerhalb von 15 Minuten bei Einkaufswegen (45%-81%) besteht, gefolgt von Freizeit (33%-58%) und Ausbildung (32%-49%). Im Vergleich zu Zentren nahen Quartieren sind die Ausbildungswege länger (wegen der geringeren Dichte an Ausbildungseinrichtungen), die Wege zur Freizeit hingegen kürzer (wegen dem besseren Naherholungsangebot bei den Quartieren an den Stadträndern). Von einem ausreichend hohen Anteil kann man im Ist-Zustand jedoch bei keinem Verkehrszweck sprechen. Auch bei unterschiedlichen Bevölkerungsgruppen (z.B. Alter, Geschlecht, Bildungsstand, Einkommen) gibt es Unterschiede und erreicht in keiner der untersuchten Gruppen einen Idealzustand.

Es zeigt sich außerdem, dass die Stadtstruktur bei vielen Verkehrszwecken eine wesentliche Rolle spielt. Wenn die Stadt sehr monozentristisch aufgebaut ist, sind viele Bewohnerinnen und Bewohner der Randlagen gezwungen, Wege in die Stadtzentren zu unternehmen, um ihre grundlegenden Bedürfnisse befriedigen zu können. Ähnlich verhält es sich, wenn Städte monofunktional aufgebaut sind, also Wohnquartiere weit von Einkaufsmöglichkeiten, Arbeitsplätzen, medizinischen und Ausbildungseinrichtungen entfernt sind (auch wenn sich diese in den Randlagen befinden). In diesen Fällen wird es schwierig, Wege mit aktiven Mobilitätsformen (primär zu Fuß oder Fahrrad) innerhalb von 15 Minuten zurückzulegen.

Einerseits kann man nun die Definition der 15-Minuten-Stadt aufweichen. Vielleicht reicht auch eine 20 oder 30 oder x Minuten Stadt an den Stadträndern? Sollen (umweltverträgliche) motorisierte Verkehrsmittel (Mikro-ÖV, E-Bike, Car-Sharing, etc.) miteinbezogen werden, um die Reichweiten innerhalb der 15-Minuten-Grenze zu vergrößern? Andererseits können Stadtstrukturen analysiert werden und Defizite bei Angeboten im Stadtquartier erkannt und verringert werden (auch durch finanzielle Beiträge des öffentlichen Sektors, wenn aufgrund der geringeren Nachfrage Angebote nicht marktwirtschaftlich betrieben werden können). Realistischerweise wird es wohl ein Mix aus diesen Ansätzen für Stadtquartiere in Randlagen geben, eventuell auch abgestuft nach den Verkehrszwecken.

Ausgehend von den vorliegenden Analysen werden daher in diesem Projekt auch neue Geschäftsmodelle und Governance-Ansätze für Mobilitätsdienste (einschließlich Mikromobilität, Carsharing, bedarfsgesteuerter Verkehre) und mit Mobilität in Zusammenhang stehenden Aktivitäten und Angeboten (z. B. Pop-Up Stores, kulturelle Aktivitäten im Stadtteil) in diesen Gebieten mit geringer/mittlerer Dichte entwickelt und getestet. Es wird analysiert, inwieweit diese Interventionen geeignet sind, sich dem Konzept einer 15-Minuten Stadt anzunähern.

Keywords: Mobilitätsverhalten, Stadtrand, 15-Minuten-Stadt, Planung, Städtebau

2 EINLEITUNG

Das DREAMS-Projekt fokussiert sich darauf, wie Co-Creation von Angeboten im Stadtteil und nutzerzentrierte Shared-Mobilitätsdienste zu barrierefreien, nachhaltigen und integrativen 15-Minuten-Quartieren in urbanen Randlagen in europäischen Städten und Regionen beitragen können. Für das Projekt DREAMS werden dazu sechs Stadtteile beforscht, jeweils in Budapest, Brüssel, München, Paris, Utrecht und Wien. Zunächst wird für DREAMS eine umfassende und vergleichende Analyse des 15-Minuten Lebensstils in diesen Städten und Stadtteilen durchgeführt. Die Ergebnisse dieses Arbeitsschritts werden im folgenden Paper diskutiert. Im Gegensatz zu den angebotsbezogenen Erreichbarkeitsanalysen (Moreno 2016, 2021) wird in diesem Paper die Nachfrageseite beleuchtet, also wie weit Individuen tatsächlich unterwegs sind um ihre Ziele für Arbeit, Bildung, Einkaufen oder Freizeit zu erreichen, ungeachtet davon, welche Möglichkeiten es im 15 Minuten-Umfeld gegeben hätte. Das bedeutet, es werden hier die Präferenzen der Individuen mitberücksichtigt, welche eine Mischung aus dem tatsächlichen räumlichen Angebot an Möglichkeiten und den bevorzugten Zielen aus einer Auswahl von Möglichkeiten darstellt, z.B., wenn eine Person lieber auf einem Markt statt im Supermarkt einkauft oder lieber die Staatsoper als in eine lokale Kultureinrichtung bevorzugt.

In weiterer Folge wird im Projekt DREAMS neue Geschäftsmodelle und Governance-Ansätze für Mobilitätsdienste (einschließlich Mikromobilität, Carsharing, bedarfsgesteuerter Verkehre) und mit Mobilität in Zusammenhang stehenden Aktivitäten in Gebieten mit geringer/mittlerer Dichte entwickelt und getestet, um die Autoabhängigkeit zu verringern. Im Projekt DREAMS werden die Effekte auf Mobilität, Erreichbarkeit und die weitergehenden gesellschaftlichen Aspekte der neuen Mobilitätsdienste und damit in Zusammenhang stehende Dienstleistungen untersucht. Final wird es politische Empfehlungen für Wege zur Schaffung einer nachhaltigen und integrativen städtischen Mobilität in 15-(oder X-)Minuten-Quartieren in städtischen Randlagen durch die Nutzung von durch Co-Creation geschaffenen und benutzerzentrierten neuen Mobilitätsdiensten und damit in Zusammenhang stehende Dienstleistungen sowie für neue Governance-Geschäftsmodelle geben.

3 METHODE

Für die vorliegende Analyse wurden vorhandene Mobilitätserhebungen von den sechs Fallstädten verwendet. Dabei wurde die Stadt in ihrer Gesamtheit und ein konkretes Gebiet am Stadtrand ausgewertet. Dadurch ist es möglich, nicht nur die Unterschiede zwischen den sechs Städten und Stadtteilen, sondern auch jene zwischen dem Stadtteil in Randlage und der Stadt im Gesamten zu vergleichen. Dafür wurden nationale oder regionale Mobilitätserhebungen herangezogen. Um die Daten vergleichbar zu machen wurde vorab Informationen zu den Erhebungen gesammelt: (1.) Allgemeine Informationen zur Erhebung (z. B. Name, Jahr, Stichprobengröße, Beschreibung der Verkehrszwecke, Definition eines Weges); (2.) Datensatzinformationen (z. B. Verfügbarkeit, Formattyp, Sprache); (3.) Informationen zu den Attributen von Haushalten und Personen; (4.) Informationen zu den Attributen der berichteten Wege. Darauf aufbauend wurden die Datensätze in einem weiteren Schritt harmonisiert. Das Ziel der vergleichenden Analyse besteht darin, die bestehenden Mobilitätsmuster und -verhaltensweisen von Personen zu vergleichen und zu verstehen. Daher konzentrierte sich die Analyse auf das Mobilitätsverhalten von Personen in ihrer lokalen Umgebung. Dementsprechend wurde eine spezifische Methode implementiert. Jede Datenbank wurde nach folgenden Kriterien gefiltert: (1.) Alle berichteten Wege haben als Ausgangspunkt den Wohnbezirk des Befragten. (2.) Alle berichteten Wege haben als Ziel dasselbe Land, um lange Wege zu vermeiden, die das Endergebnis der Analyse beeinflussen könnten. (3.) Der Zweck der berichteten Wege ist Arbeit, Bildung, Einkaufen oder Freizeit. (4.) Das Fortbewegungsmittel der gemeldeten Fahrten ist zu Fuß, mit dem Fahrrad, mit dem Auto (Fahrer oder Beifahrer) oder mit öffentlichen Verkehrsmitteln. Aufgrund des Seitenlimits für dieses Paper werden die detaillierten Ergebnisse exemplarisch für den Verkehrszweck Einkaufen dargestellt. Im Arbeitsbericht des Projekts sind auch die Ergebnisse für die anderen Verkehrszwecke dargestellt, siehe https://www.dreams15mc.eu/publications.

4 WIEN

Aus dem Datensatz „Österreich Unterwegs 2013/14“ wurde eine Liste von Variablen ausgewählt, die dabei helfen sollen, die Merkmale der Bewohner sowohl auf Stadtebene als auch auf Bezirksebene abzubilden und

zu verstehen. Die für diesen Teil der Analyse verwendete Stichprobe ist die gesamte Wohnbevölkerung innerhalb des Gebiets (Wien oder Liesing).

4.1 Die Gesamtstadt

Die Wiener Wohnbevölkerung legt im Durchschnitt kurze Wege (16,5 Minuten) zurück, um ihre Einkäufe zu erledigen. 70% der Einkaufswege werden innerhalb von 15 Minuten erledigt, was auf ein dichtes Netz an Einkaufsmöglichkeiten in ganz Wien hindeutet. Zu Fuß wird am häufigsten eingekauft (47,2%), mit einer durchschnittlichen Dauer von 13 Minuten, während über 80% der Wege bis zu 15 Minuten dauern. Darüber hinaus sind Einkaufswege mit dem Auto (20,7%) oder öffentlichen Verkehrsmitteln (20,6%) in der Stichprobe etwa gleich stark vertreten, mit einer durchschnittlichen Fahrtdauer von 16 bzw. 26 Minuten (siehe Tabelle 1, Abbildung 1).

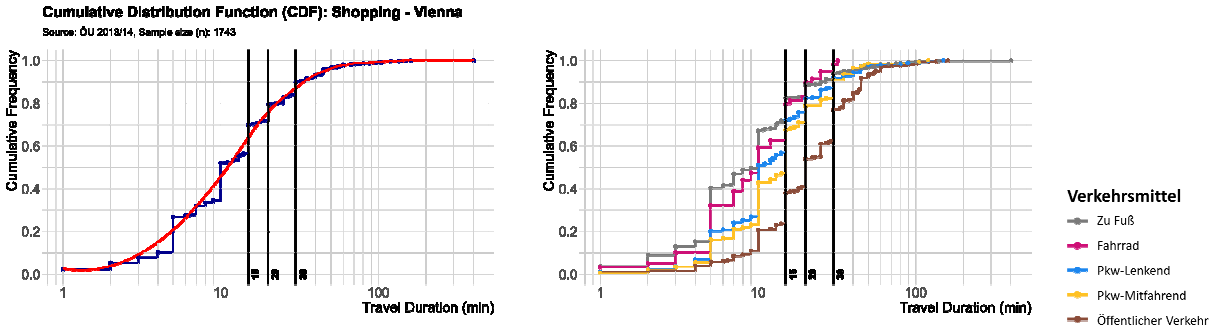

Abbildung 1: Kumulative Verteilung der Einkaufswege nach Dauer – Wien. Links: Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**52,1%**	**69,9%**	**79,5%**	**90,1%**
Zu Fuß	**67,3%**	**82,5%**	**88,7%**	**94,2%**
Fahrrad	**59,3%**	**79,7%**	**89,8%**	**98,3%**
Pkw-Lenkend	**51,1%**	**72,2%**	**82,5%**	**91,9%**
Pkw-Mitfahrend	**43,0%**	**67,6%**	**78,9%**	**90,8%**
Öffentlicher Verkehr	**20,6%**	**38,2%**	**54,0%**	**77,2%**

Tabelle 1: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Wien

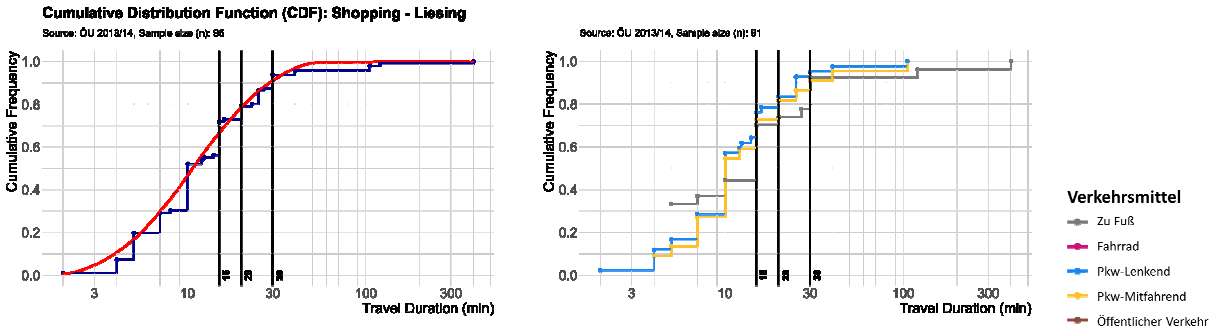

Abbildung 2: Kumulative Verteilung der Einkaufswege nach Dauer– Stadtteil Liesing. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**52,1%**	**71,9%**	**79,2%**	**93,8%**
Zu Fuß	**44,4%**	**70,4%**	**74,1%**	**92,6%**
Fahrrad	**Zu geringe Fallzahl**			
Pkw-Lenkend	**57,1%**	**76,2%**	**83,3%**	**95,2%**
Pkw-Mitfahrend	**54,5%**	**72,7%**	**81,8%**	**90,9%**
Öffentlicher Verkehr	**Zu geringe Fallzahl**			

Tabelle 2: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Stadtteil Liesing

4.2 Der Stadtrand: Liesing

In Liesing beträgt die durchschnittliche Wegedauer 21 Minuten, wobei im Gegensatz zur gesamten Stadt das Auto das am häufigsten gewählte Verkehrsmittel ist (43,8%). Zu Fuß zu gehen ist für diesen Fahrtzweck mit einem Anteil von 28,1% vertreten. Allerdings sind Gehwege deutlich länger als in Wien gesamt (32 Minuten gegenüber 16,5 Minuten). Die Kombination aus Verkehrsmittelwahl und Fahrtmerkmalen lässt darauf schließen, dass die Nähe zu Einzelhandelseinrichtungen in Liesing geringer ist, was wiederum die Nutzung motorisierter Fahrzeuge begünstigt (siehe Tabelle 2, Abbildung 2). Wenn bei der Auswertung bei den Verkehrsmittelklassen weniger als 20 Datensätze (Wege) vorhanden waren, wurden diese nicht ausgewertet.

5 UTRECHT

Für die deskriptive statistische Analyse für die Stadt Utrecht und die Region Overvecht wurde der Datensatz „Onderweg in Nederland 2021“ verwendet. Die für diesen Teil der Analyse verwendete Stichprobe ist die gesamte Wohnbevölkerung innerhalb des Gebiets (Utrecht bzw. Overvecht).

5.1 Die Gesamtstadt

Im Durchschnitt fahren die Einwohner von Utrecht etwa 12 Minuten und 3,4 Kilometer zum Einkaufen. Das beliebteste Transportmittel ist das Fahrrad (33,2%), gefolgt vom Auto (29,5%) und dann zu Fuß (28,9%). Einkaufswege mit dem Fahrrad dauern im Durchschnitt 11 Minuten und fast 87% davon bis maximal 15 Minuten. Wie erwartet dauern Fahrten mit dem Auto etwas länger (13 Minuten) und es werden viel größere Entfernungen zurückgelegt als zu Fuß oder mit dem Fahrrad. Personen, die sich für den Einkauf mit dem Auto entscheiden, suchen tendenziell Einkaufszentren außerhalb des Stadtzentrums auf. Im Allgemeinen sind Einkaufswege in Utrecht meist kurz und 84% von ihnen dauern bis maximal 15 Minuten. Dieses Ergebnis zeigt eine gute Ausstattung mit Einkaufsmöglichkeiten (siehe Tabelle 3, Abbildung 3).

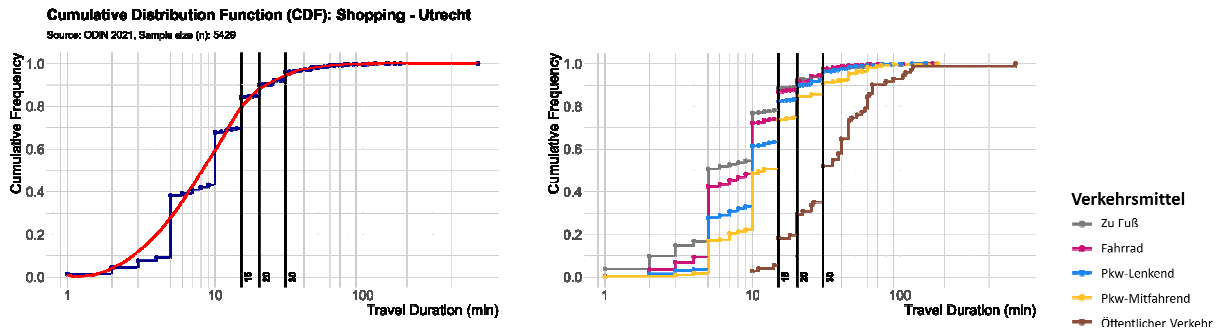

Abbildung 3: Kumulative Verteilung der Einkaufswege nach Dauer– Utrecht. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**67,8%**	**84,1%**	**90,0%**	**96,1%**
Zu Fuß	**76,9%**	**88,4%**	**92,5%**	**97,3%**
Fahrrad	**72,2%**	**86,8%**	**91,8%**	**97,6%**
Pkw-Lenkend	**61,5%**	**82,4%**	**89,6%**	**96,4%**
Pkw-Mitfahrend	**48,6%**	**73,6%**	**84,8%**	**91,2%**
Öffentlicher Verkehr	**2,8%**	**18,3%**	**29,6%**	**52,1%**

Tabelle 3: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Utrecht

5.2 Der Stadtrand: Overvecht

In Overvecht dauern Einkaufswege durchschnittlich 11 Minuten. Das beliebteste Transportmittel zum Einkaufen ist das Gehen (40,3%), gefolgt vom Fahrrad (31,9%). Einkaufswege zu Fuß oder mit dem Fahrrad dauern ungefähr 10 Minuten, während der Anteil der Wege, die bis zu 15 Minuten dauern, 89% bzw. 78% beträgt. Insgesamt werden mehr als 80% der Einkaufswege in Overvecht in weniger als 15 Minuten erledigt. Diese Zahlen zeigen, dass die Menschen in Overvecht im Gegensatz zur Gesamtstadt eher lokal einkaufen und nachhaltigere Verkehrsmittel bevorzugen (siehe Tabelle 4, Abbildung 4). Wenn bei der Auswertung bei den Verkehrsmittelklassen weniger als 20 Datensätze (Wege) vorhanden waren, wurden diese nicht ausgewertet.

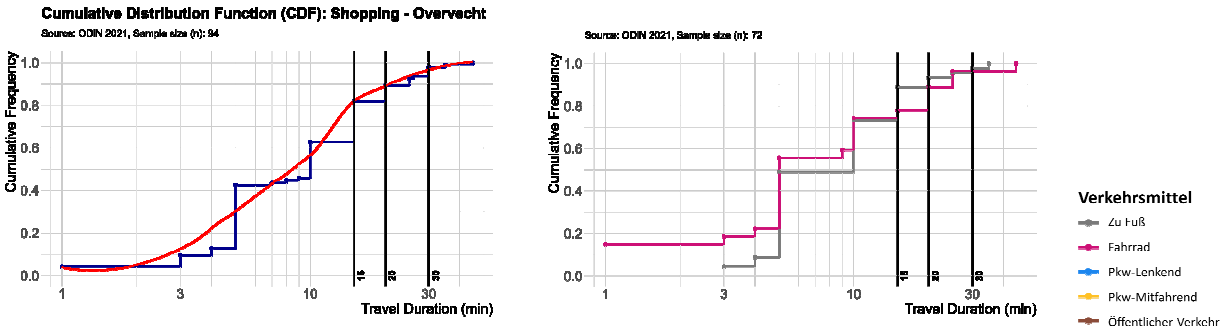

Abbildung 4: Kumulative Verteilung der Einkaufswege nach Dauer– Stadtteil Overvecht. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**62,8%**	**81.9%**	**89.4%**	**97.9%**
Zu Fuß	**73,3%**	**88.9%**	**93.3%**	**97.8%**
Fahrrad	**74,1%**	**77.8%**	**88.9%**	**88.9%**
Pkw-Lenkend	**Zu geringe Fallzahl**			
Pkw-Mitfahrend				
Öffentlicher Verkehr				

Tabelle 4: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Stadtteil Overvecht

6 BRÜSSEL

Für die deskriptive statistische Analyse für die Stadt Brüssel und die Region Brüssel-Stadt wurde der Datensatz „Onderzoek Verplaatsingsgedrag (OVG) 2021“ verwendet. Die für diesen Teil der Analyse verwendete Stichprobe ist die gesamte Wohnbevölkerung innerhalb des Gebiets (Brüssel bzw. Heembeek und Haren). Die deskriptive statistische Analyse liefert eine wertvolle Perspektive auf die demografischen Merkmale der Bevölkerung von Brüssel und der Stadt Brüssel. Was den Autobesitz betrifft, besitzt die Mehrheit der Haushalte in beiden Regionen mindestens ein Auto.

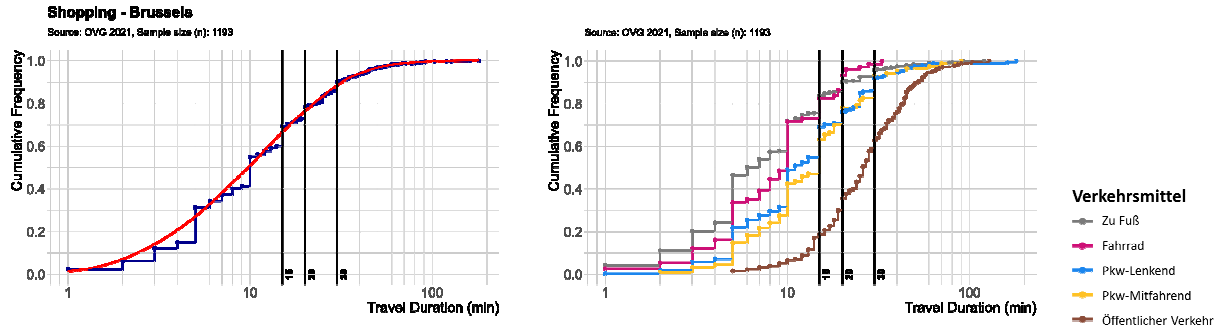

Abbildung 5: Kumulative Verteilung der Einkaufswege nach Dauer – Brüssel. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**55,0%**	**69,3%**	**78,3%**	**90,0%**
Zu Fuß	**72,0%**	**84,0%**	**90,4%**	**96,0%**
Fahrrad	**71,6%**	**82,4%**	**93,2%**	**98,6%**
Pkw-Lenkend	**49,0%**	**69,1%**	**76,1%**	**91,9%**
Pkw-Mitfahrend	**42,5%**	**63,2%**	**78,2%**	**93,1%**
Öffentlicher Verkehr	**6,7%**	**18,9%**	**35,6%**	**62,8%**

Tabelle 5: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Brüssel

6.1 Die Gesamtstadt

Einkaufswege in Brüssel dauern im Durchschnitt 15,4 Minuten, wobei fast 70% davon bis maximal 15 Minuten dauern, was auf gute Einkaufsmöglichkeiten im Umfeld hindeutet. Das beliebteste Transportmittel zum Einkaufen ist zu Fuß (49,7%), gefolgt vom Auto (21,7%) und dann den öffentlichen Verkehrsmitteln (15,1%). Im Durchschnitt gehen die Brüsseler 11 Minuten zu Fuß zum Einkaufen. Darüber hinaus dauern 84% dieser Fußwege weniger als 15 Minuten. Einkaufswege mit dem Auto dauern im Durchschnitt etwas

länger als Fußwege und es werden dabei längere Distanzen zurückgelegt. Fahrten mit öffentlichen Verkehrsmitteln dauern im Durchschnitt am längsten (30 Minuten), nur ein kleiner Prozentsatz (19%) davon dauert weniger als 15 Minuten (siehe Tabelle 5, Abbildung 5).

6.2 Der Stadtrand: Heembeek und Haren

Im Durchschnitt dauern Einkaufswege in den Stadtteilen Heembeek und Haren etwa 17 Minuten und umfassen fast 2,9 Kilometer. Das Gehen ist das vorherrschende Transportmittel für Einkaufswege (62,8%). Fußwege sind kurz und ein großer Teil davon (80%) wird innerhalb von 15 Minuten zurückgelegt. Dies zeigt, dass die Menschen die meisten ihrer Einkäufe vor Ort erledigen können. Einkaufswege mit öffentlichen Verkehrsmitteln (Anteil von 17,4%) sind sowohl in Bezug auf die Entfernung als auch die Zeit viel länger als Fußwege. Insgesamt zeigen die Ergebnisse, dass Einkaufswege in der Brüsseler Stadtteilen Heembeek und Haren mit nachhaltigeren Verkehrsmitteln wie zu Fuß und mit öffentlichen Verkehrsmitteln unternommen werden als in der Gesamtstadt (siehe Tabelle 6, Abbildung 6). Wenn bei der Auswertung bei den Verkehrsmittelklassen weniger als 20 Datensätze (Wege) vorhanden waren, wurden diese nicht ausgewertet.

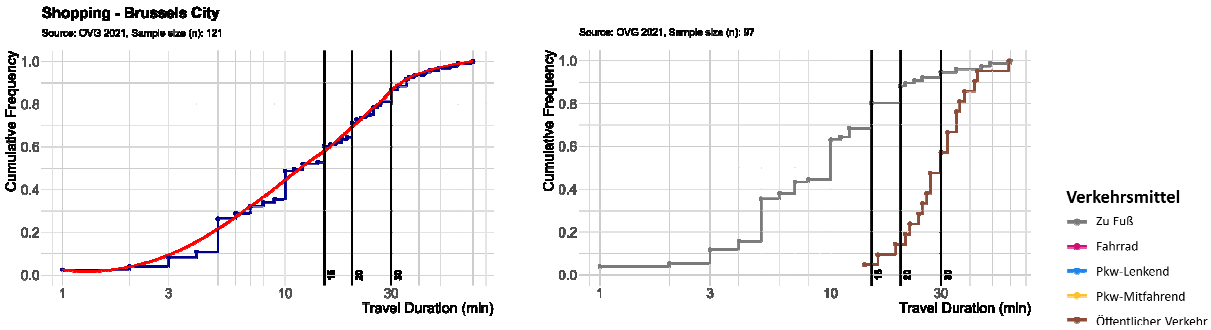

Abbildung 6: Kumulative Verteilung der Einkaufswege nach Dauer – Stadtteile Heembeek und Haren. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**48,8%**	**60,3%**	**71,1%**	**86,8%**
Zu Fuß	**63,2%**	**80,3%**	**88,2%**	**94,7%**
Fahrrad	**Zu geringe Fallzahl**			
Pkw-Lenkend				
Pkw-Mitfahrend				
Öffentlicher Verkehr	**-**	**4,8%**	**14,3%**	**57,1%**

Tabelle 6: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Stadtteile Heembeek und Haren

7 BUDAPEST

Für die deskriptive statistische Analyse der Stadt Budapest wurde der Datensatz „Unified Macroscopic Modelling Household Survey 2019“ verwendet. Die für diesen Teil der Analyse verwendete Stichprobe ist die gesamte Wohnbevölkerung innerhalb des Gebiets.

7.1 Die Gesamtstadt

Einkaufswege in Budapest dauern durchschnittlich 20 Minuten, wobei 55% davon innerhalb von 15 Minuten erledigt sind. Das am häufigsten genutzte Verkehrsmittel für Einkaufswege in Budapest ist zu Fuß (36,6%), gefolgt vom Auto (29,6%) und öffentlichen Verkehrsmitteln (27,2%). Fußwege zu Einkaufsmöglichkeiten dauern durchschnittlich 11,8 Minuten und fast 82% davon maximal 15 Minuten. Darüber hinaus sind Autofahrten zu Einkaufsmöglichkeiten im Durchschnitt länger als Fußwege, und die hohe Varianz in der Stichprobe zeigt, dass Autofahrten für Einkaufsziele bevorzugt werden, die weit vom Wohnort entfernt sind. Gleiches gilt für Einkaufswege mit öffentlichen Verkehrsmitteln. Allerdings werden nur 24% der Fahrten mit öffentlichen Verkehrsmitteln innerhalb von 15 Minuten erledigt, verglichen mit 48% der Autofahrten (siehe Tabelle 7, Abbildung 7).

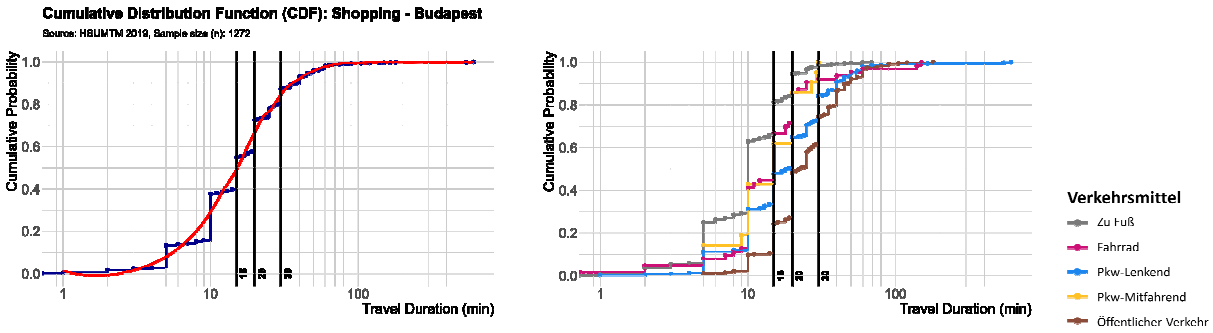

Abbildung 7: Kumulative Verteilung der Einkaufswege nach Dauer – Budapest. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**37,7%**	**55,0%**	**72,6%**	**87,4%**
Zu Fuß	**62,9%**	**81,5%**	**94,4%**	**98,5%**
Fahrrad	**41,3%**	**66,7%**	**85,7%**	**92,1%**
Pkw-Lenkend	**31,1%**	**47,9%**	**64,9%**	**84,3%**
Pkw-Mitfahrend	**42,9%**	**61,9%**	**85,7%**	**100,0%**
Öffentlicher Verkehr	**9,8%**	**24,3%**	**48,3%**	**74,3%**

Tabelle 7: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Budapest

7.2 Der Stadtrand: 16. and 17. Bezirk

Die durchschnittliche Dauer von Einkaufsfahrten im 16. und 17. Bezirk von Budapest beträgt 22 Minuten, und fast 45% dieser Fahrten werden innerhalb von 15 Minuten erledigt. Bewohner der Bezirke 16 und 17 verbringen einen größeren Teil ihrer Zeit damit, zum Einkaufen zu gelangen, als Bewohner des gesamten Stadt Budapest. Die Analyse zeigt, dass das Auto das vorherrschende Verkehrsmittel für Einkaufsfahrten ist (41,4%), was auf eine hohe Abhängigkeit von motorisierten Verkehrsmitteln hindeutet (siehe Tabelle 8, Abbildung 8). Wenn bei der Auswertung bei den Verkehrsmittelklassen weniger als 20 Datensätze (Wege) vorhanden waren, wurden diese nicht ausgewertet.

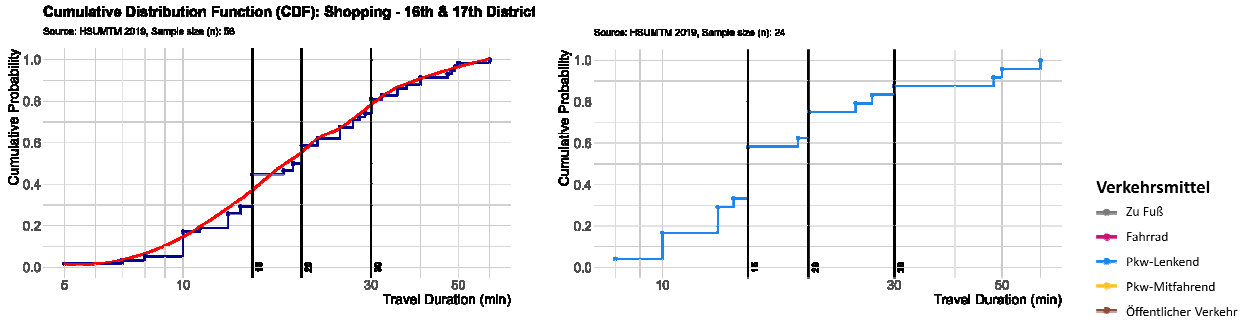

Abbildung 8: Kumulative Verteilung der Einkaufswege nach Dauer – Budapester Stadtteil 16. & 17. Bezirk. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**17,2%**	**44.8%**	**58.6%**	**81.0%**
Zu Fuß	**Zu geringe Fallzahl**			
Fahrrad				
Pkw-Lenkend	**16,7%**	**58.3%**	**75.0%**	**87.5%**
Pkw-Mitfahrend	**Zu geringe Fallzahl**			
Öffentlicher Verkehr				

Tabelle 8: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Stadtteil 16. & 17. Bezirk

8 PARIS

Für die deskriptive statistische Analyse der Regionen Paris, Île-de-France und Essonne wurde der Datensatz „Enquête Globale Transport (EGT) 2020“ verwendet. Die für diesen Teil der Analyse verwendete Stichprobe ist die gesamte Wohnbevölkerung innerhalb des Gebiets (Paris, Île-de-France bzw. Stadtteil Essonne).

8.1 Die Gesamtstadt

Im Durchschnitt dauern Einkaufswege in der Region Île-de-France etwa 16 Minuten, wobei eine Distanz von 3 Kilometern zurückgelegt wird. Das vorherrschende Fortbewegungsmittel ist das Gehen (47,6%), gefolgt vom Auto, lenkend (31,4%) und öffentlichen Verkehrsmitteln (12,2%). Im Durchschnitt gehen die Menschen in der Region Paris, Île-de-France 10 Minuten zu Fuß, um zu Einkaufsmöglichkeiten zu gelangen, wobei fast 90% dieser Fahrten bis maximal 15 Minuten dauern. Autofahrten hingegen sind vergleichsweise lang, wobei auch größere Distanzen zurückgelegt werden. Der hohe Anteil an Fahrten, die innerhalb von 15 Minuten erledigt werden, unterstreicht die gute Ausstattung an Einkaufsmöglichkeiten in der Region Paris, Île-de-France (siehe Tabelle 9, Abbildung 9).

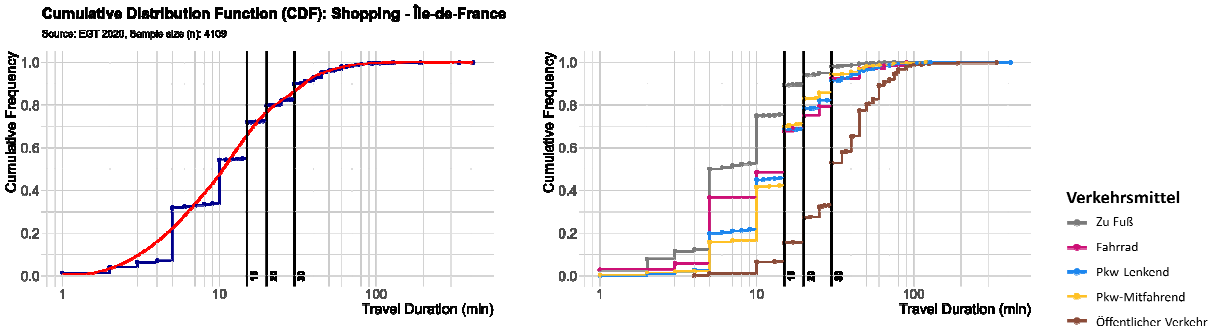

Abbildung 9: Kumulative Verteilung der Einkaufswege nach Dauer– Paris Île-de-France. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**54,4%**	**72,0%**	**79,9%**	**90,1%**
Zu Fuß	**75,0%**	**89,4%**	**94,1%**	**98,1%**
Fahrrad	**48,5%**	**67,6%**	**75,0%**	**92,6%**
Pkw-Lenkend	**45,0%**	**68,2%**	**78,5%**	**91,4%**
Pkw-Mitfahrend	**41,7%**	**69,8%**	**83,1%**	**94,2%**
Öffentlicher Verkehr	**6,6%**	**15,6%**	**27,3%**	**52,9%**

Tabelle 9: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Paris Île-de-France

8.2 Der Stadtrand: Essone

Die durchschnittliche Dauer von Einkaufsfahrten in der Region Essonne beträgt etwa 17 Minuten, wobei eine Entfernung von fast 4 Kilometern zurückgelegt wird. Das vorherrschende Verkehrsmittel für Einkaufsfahrten ist das Auto lenkend (52,9%), gefolgt vom Gehen (28,3%). Im Vergleich dazu sind zu Fuß zurückgelegte Wege kurz, wobei ein erheblicher Anteil (83%) innerhalb eines Zeitrahmens von 15 Minuten zurückgelegt wird. Im Gegensatz dazu sind Einkaufsfahrten mit dem Auto durch eine längere Dauer und größere zurückgelegte Entfernung gekennzeichnet. Die Analyse zeigt, dass die Mehrheit der Einkaufswege in der Region Essonne innerhalb von 15 Minuten zurückgelegt wird (69,3%), was auf eine ebenfalls auf eine gute Ausstattung mit Einkaufsmöglichkeiten hindeutet (siehe Tabelle 10, Abbildung 10). Wenn bei der Auswertung bei den Verkehrsmittelklassen weniger als 20 Datensätze (Wege) vorhanden waren, wurden diese nicht ausgewertet.

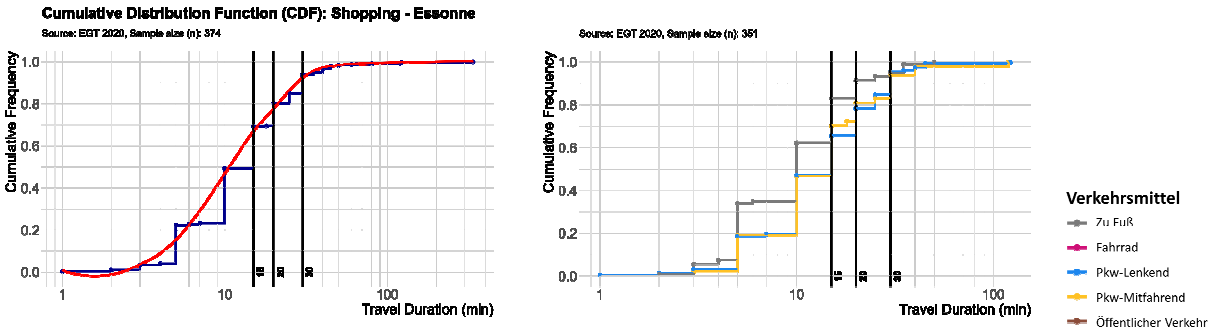

Abbildung 10: Kumulative Verteilung der Einkaufswege nach Dauer– Stadtteil Essonne. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**49,5%**	**69.3%**	**80.2%**	**93.9%**
Zu Fuß	**62,3%**	**83.0%**	**91.5%**	**95.3%**
Fahrrad	**Zu geringe Fallzahl**			
Pkw-Lenkend	**47,0%**	**65.7%**	**78.3%**	**95.5%**
Pkw-Mitfahrend	**46,8%**	**70.2%**	**80.9%**	**93.6%**
Öffentlicher Verkehr	**Zu geringe Fallzahl**			

Tabelle 10: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Stadtteil Essonne

9 MÜNCHEN

Für die deskriptive statistische Analyse für München wurde der Datensatz „infas, DLR, IVT und infas 360 (2018), Mobilität in Deutschland (im Auftrag des BMVI)“ verwendet. Die für diesen Teil der Analyse verwendete Stichprobe ist die gesamte Wohnbevölkerung innerhalb des Gebiets.

9.1 Die Gesamtstadt

Im Durchschnitt dauern Einkaufswege in München etwa 17 Minuten, wobei eine Distanz von 3,7 Kilometern zurückgelegt wird. Das vorherrschende Fortbewegungsmittel ist das Gehen mit 35%, gefolgt vom Auto lenkend (26%) und Fahrrad (20%). Im Durchschnitt gehen die Menschen in München 14 Minuten zu Fuß, um zu Einkaufsmöglichkeiten zu gelangen, wobei fast 80% dieser Wege maximal 15 Minuten dauern. Autofahrten (lenkend) hingegen sind vergleichsweise lang, wobei dabei größere Distanzen zurückgelegt werden (siehe Tabelle 11, Abbildung 11).

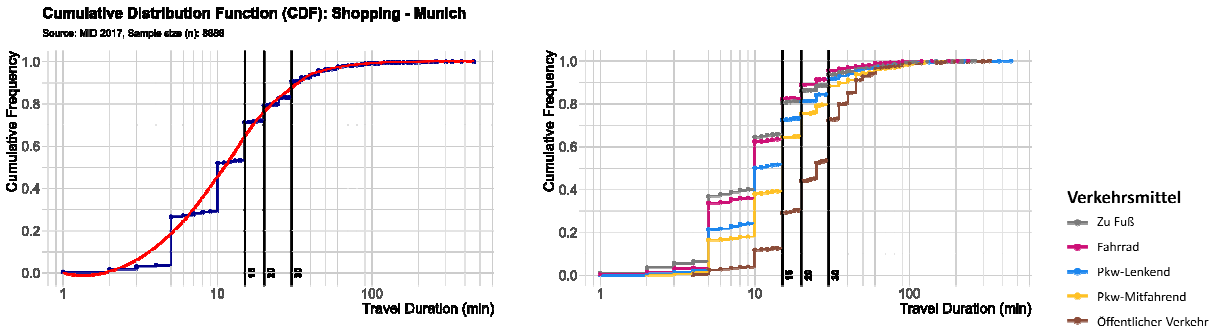

Abbildung 11: Kumulative Verteilung der Einkaufswege nach Dauer– München. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**52,1%**	**71,3%**	**79,4%**	**90,6%**
Zu Fuß	**64,6%**	**80,4%**	**86,1%**	**93,7%**
Fahrrad	**62,4%**	**82,4%**	**88,8%**	**95,5%**
Pkw-Lenkend	**50,1%**	**72,4%**	**80,9%**	**91,7%**
Pkw-Mitfahrend	**38,1%**	**64,4%**	**75,5%**	**88,4%**
Öffentlicher Verkehr	**11,8%**	**29,0%**	**43,8%**	**72,5%**

Tabelle 11: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – München

9.2 Der Stadtrand: periphere Stadtregionen Münchens

Im Gegensatz zu den anderen Fallstädten wurden aufgrund der Rahmenbedingungen der Stichprobe nicht ein konkreter Stadtteil ausgewählt, sondern anhand von räumlichen Rahmenbedingungen die Teilstichprobe gefiltert. Die durchschnittliche Dauer von Einkaufsfahrten in dieser Region beträgt etwa 15 Minuten, wobei eine Entfernung von 5 Kilometern zurückgelegt wird. Das vorherrschende Verkehrsmittel für Einkaufswege ist das Auto, lenkend (53%), gefolgt vom Fahrrad (19%). Im Vergleich dazu sind zu Fuß zurückgelegte Wege kurz, wobei ein Anteil von 68% innerhalb eines Zeitrahmens von 15 Minuten zurückgelegt wird. Im Gegensatz dazu sind Einkaufsfahrten mit dem Auto durch eine längere Dauer und größere zurückgelegte Entfernung gekennzeichnet. Die Analyse zeigt, dass ein Anteil von 77,3% der Einkaufswege in periphere Stadtregionen Münchens innerhalb von 15 Minuten zurückgelegt wird (siehe Tabelle 12, Abbildung 12). Wenn bei der Auswertung bei den Verkehrsmittelklassen weniger als 20 Datensätze (Wege) vorhanden waren, wurden diese nicht ausgewertet.

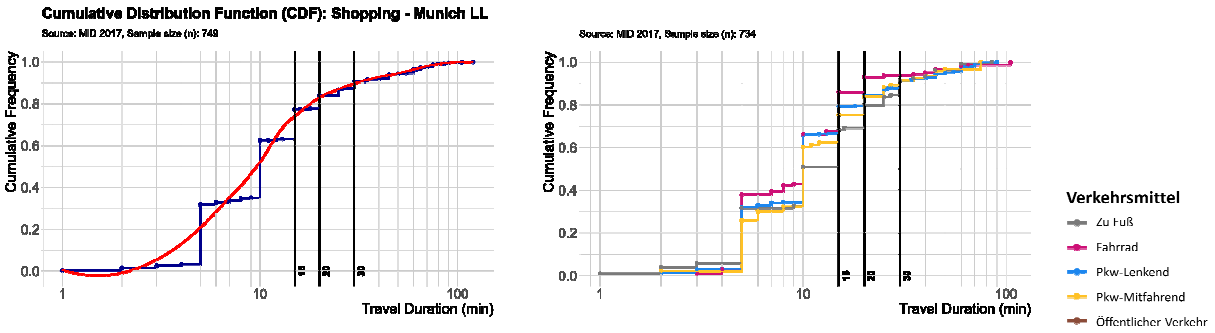

Abbildung 12: Kumulative Verteilung der Einkaufswege nach Dauer– Stadtteil periphere Stadtregionen Münchens. Links: Summenlinie Wegedauer, alle Verkehrsmittel, rechts: Summenlinie Wegedauer je Verkehrsmittel.

Verkehrsmittel	Anteil der Wege mit weniger als x Minuten			
	10	15	20	30
Alle Verkehrsmittel	**62,3%**	**77,3%**	**83,9%**	**90,7%**
Zu Fuß	**50,9%**	**68,3%**	**79,8%**	**91,3%**
Fahrrad	**66,2%**	**85,9%**	**92,9%**	**93,7%**
Pkw-Lenkend	**66,1%**	**79,2%**	**84,3%**	**91,4%**
Pkw-Mitfahrend	**60,2%**	**75,3%**	**83,9%**	**91,4%**
Öffentlicher Verkehr	**Zu geringe Fallzahl**			

Tabelle 12: Anteil (%) der Einkaufswege innerhalb einer definierten Wegedauer je Verkehrsmittel – Stadtteil periphere Stadtregionen Münchens

Zu Fuß												
Wege-zweck	Wien		Utrecht		Brüssel		Budapest		Paris		München	
	M	F	M	F	M	F	M	F	M	F	M	F
Arbeit	12,37	11,44	12,8	9,4	10,2	11,8	11,4	12,2	10,1	10,0	16,1	17,8
Ausbildung	11,07	10,28	8,8	9,1	12,1	10,6	-	-	9,7	10,3	13,2	15,1
Einkauf	13,21	12,75	10,1	10,2	9,7	11,4	12,0	11,7	9,5	9,9	13,8	14,7
Freizeit	34,06	35,32	41,3	42,1	32,9	27,1	12,5	13,0	15,8	15,3	35,1	35,2
Fahrrad												
Arbeit	19,10	17,60	20,0	20,1	19,6	17,5	23,7	32,3	26,2	25,3	23,7	21,6
Ausbildung	-	-	18,5	16,9	-	-	-	-	19,8	-	15,9	16,2
Einkauf	12,12	10,42	11,0	10,6	10,8	9,4	18,8	20,3	15,4	17,7	13,2	13,5
Freizeit	43,83	29,00	36,7	34,8	25,6	29,9	19,5	-	31,9	37,6	29,7	26,0
Pkw-Lenkend												
Arbeit	26,45	23,22	27,5	27,0	28,3	26,8	36,1	35,0	33,1	30,0	29,7	28,6
Ausbildung	23,15	-	35,0	28,4	-	-	-	-	-	-	46,1	42,5
Einkauf	17,12	14,77	12,8	13,1	18,1	15,6	20,6	31,4	18,0	16,8	18,2	16,0
Freizeit	31,09	25,57	31,3	26,3	35,0	24,1	32,4	32,4	26,8	23,0	39,0	36,7
Pkw-Mitfahrend												
Arbeit	-	21,57	29,3	24,5	-	-	40,0	-	20,3	18,4	38,7	38,1
Ausbildung	17,60	12,41	17,1	18,3	21,3	15,5	-	-	13,7	11,3	16,4	17,3
Einkauf	19,61	16,59	16,2	16,9	-	15,1	-	-	16,6	16,5	19,5	20,5
Freizeit	24,08	31,56	34,2	35,1	34,3	21,7	-	33,2	20,0	23,1	36,6	41,3
Öffentlicher Verkehr												
Arbeit	38,08	36,53	60,6	51,5	37,6	40,4	44,4	43,5	57,1	53,4	44,5	40,3
Ausbildung	31,43	31,94	53,1	58,2	40,3	38,5	-	33,5	41,9	43,6	36,5	37,0
Einkauf	26,17	25,39	-	49,4	27,0	32,0	27,4	28,2	41,0	36,4	29,0	29,5
Freizeit	34,42	34,49	69,9	73,9	37,5	37,5	32,7	39,3	48,8	44,1	45,9	49,6

Tabelle 13: Vergleich der Wegzeiten in Minuten nach Zweck und Geschlecht (M=Männer, F=Frauen) auf Stadtebene

	Zu Fuß											
	Liesing (Wien)		Overecht (Utrecht)		Heembeek und Haren (Brüssel)		16. & 17. Bezirk (Budapest)		Esonne (Paris)		Periphere Regionen (München)	
	M	F	M	F	M	F	M	F	M	F	M	F
Alle Zwecke	23,03	49,05	40,46	32,39	16,34	13,69	12,63	-	15,14	13,47	30,16	25.75
	Fahrrad											
Alle Zwecke	-		26,73	22,83	13,80	-	-		-		21,06	17,14
	Pkw-Lenkend											
Alle Zwecke	23,54	18,93	21,64	-	29,50	-	35,98	31,84	25,41	24,18	25,16	22.14
	Pkw-Mitfahrend											
Alle Zwecke	-	24,31	-		-		-		15,73	16,26	22,11	19,86
	Öffentlicher Verkehr											
Alle Zwecke	36,25	40,10	-		34,94	35,34	38,21	40,45	62,39	58,32	58,66	53,87

Tabelle 14: Vergleich der Wegzeiten in Minuten nach Geschlecht (M=Männer, F=Frauen) auf Stadtteilebene

10 VERGLEICH DER STÄDTE

Tabelle 13 zeigt den Vergleich der durchschnittlichen Wegzeiten nach Geschlecht, Verkehrsmittel und Wegezweck aller Fallstädte. Für jeden Wegzweck je Verkehrsmittel wurde jeweils der Minimalwert (blau) und Maximalwert (orange) farblich hervorgehoben. Bei der bloßen Betrachtung der durchschnittlichen Wegzeiten erkennt man, dass bei den Fußwegen der Mittelwert innerhalb von 15 Minuten liegt. Einzige Ausnahme bilden Freizeitwege, da hier in den meisten Städten auch Wege ohne Ziel (also einfaches "im Kreis" Spazierengehen) mitabgebildet sind. Wege mit dem Fahrrad liegen im Mittelwert bereits etwas über der 15 Minuten Schranke (auch hier der Effekt bei den Freizeitwegen, dass auch das Radfahren zum Selbstzweck im Datensatz erhalten ist). Bei den Pkw-Wegen und öffentlichen Verkehrsmitteln liegen die Mittelwerte deutlich über der 15-Minuten-Dauer. Frauen weisen tendenziell kürzere Wegdauern auf als Männer. Tabelle 14 zeigt diese Werte für die Stadtteilebene, wobei wegen der geringeren Stichprobengröße die Verkehrszwecke nicht mehr ausgekreuzt werden konnten. Wenn bei der Auswertung bei den Verkehrsmittelklassen weniger als 20 Datensätze (Wege) vorhanden waren, wurden diese nicht ausgewertet. Wie erwartet weisen die Wege auf Stadtteilebene größere Fahrtdauern auf als auf Gesamtstadtebene, wobei dies stärker bei Fußwegen und Radwegen durchschlägt. Pkw-Wege, lenkend und Wege mit öffentlichen Verkehrsmitteln dauern nur geringfügig länger im Vergleich zur Gesamtstadt. Die Unterschiede zwischen Männern und Frauen auf Stadtteilebene ergeben ein sehr heterogenes Bild, es ist kein Trend ablesbar, ob Frauen oder Männer tendenziell längere Wegzeiten aufweisen.

11 SCHLUSSFOLGERUNGEN

Die Ergebnisse zeigen, dass sowohl auf Gesamtstadtebene als auch auf Stadtteilebene in den gewählten Fallstädten die 15-Minuten-Stadt bei Analyse des Mobilitätsverhaltens nicht realisiert ist. Es besteht also Handlungsbedarf, die planerischen Ziele mit dem Verkehrsverhalten der Einwohnerinnen und Einwohner in Gleichklang zu bringen. Prinzipiell gibt es dazu 2 Hebeln, die Verdichtung der Ausstattung und Gelegenheiten, Ziele in einem näheren Umfeld zu erreichen und das Umdenken der Personen, ihr Verkehrsverhalten zu ändern, auch wenn dies eventuell ihren hedonistischen Präferenzen (bezügliche Verkehrsmittel und gewähltem Ziel) entgegensprechen. Im Rahmen des Projekt DREAMS möchte man in den Living Labs entsprechende Aktivitäten setzen. Parallel dazu ist für Stadtränder zu diskutieren, inwieweit die planerischen Ziele etwas weiter gefasst werden müssen, zum Beispiel bezüglich der Zielvorgaben der Wegzeiten oder auch der Hereinnahme (nachhaltiger) motorisierter Verkehrsmittel in den Verkehrsmittelmix. Die Ursprungsidee der 15-Minuten-Stadt war ja die ausschließliche Verwendung von nicht motorisierten Verkehrsmitteln. Im Rahmen des Projekt DREAMS werden wir prüfen, inwieweit Verkehrsmittel wie Mikro-Mobilität, Car-Sharing oder bedarfsgesteuerte Verkehre wie Anrufsammeltaxis) für die Erreichung einer 15-Minuten-Stadt – besonders in den Randlagen – zulässig und erstrebenswert ist.

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🏆 reviewed paper

Das Schutzgut Fläche der Umweltprüfung – Beitrag zur Reduzierung des quantitativen „Flächenverbrauchs“ und zur Stärkung eines qualitativen Freiraumschutzes

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1 ABSTRACT

Schutz und Entwicklung unbesiedelter/unbebauter Freiräume innerhalb und außerhalb von Siedlungsbereichen werden als fundamentale Handlungsfelder des natürlichen Klimaschutzes und der Anpassung an den Klimawandel betrachtet. Zugleich gilt der Freiraum als multifunktionaler Träger von Biodiversität und Ökosystemleistungen. In der Raumplanung werden mit Unterstützung des Instruments der Umweltprüfung bereits bisher für Klima und Umwelt wertvolle Freiräume gesichert sowie raumbeanspruchende Vorhaben auf ihre Klima- und Umweltverträglichkeit geprüft und optimiert. Mit der UVP-Änderungsrichtlinie der EU von 2014 wurde das „Schutzgut Fläche” in den Schutzgüterkatalog der Umweltprüfung zusätzlich aufgenommen. Damit sollen weitergehende Fortschritte bei der Reduzierung des sog. „Flächenverbrauchs“ für Siedlung und Infrastruktur erreicht und entsprechende Freiraumverluste begrenzt werden. In diesem Kontext geht der Beitrag der Frage nach, inwiefern das Schutzgut Fläche als Impuls und Unterstützung für die Eindämmung des Flächenverbrauchs und zugleich für einen multifunktional begründeten Freiraumschutz genutzt werden kann. Eine Analyse der aktuellen Praxis der Umweltprüfung zeigt im Hinblick auf die Bearbeitung des Schutzgutes Fläche im Ganzen erhebliche Defizite, in einzelnen Fällen aber auch innovative, über das Thema des quantitativen Flächenverbrauchs hinausgehende Ansätze eines qualitativen Freiraumschutzes auf. Bisher werden die Auswirkungen auf das Umweltschutzgut Fläche aufgrund fachlicher Unsicherheiten wie auch fehlender Bewertungsmaßstäbe nur selten einer fundierten Bewertung unterzogen. Verbindliche Flächenkontingente und Dichtewerte einerseits sowie planerische Festlegungen zu einer stärker multifunktional begründeten Freiraumsicherung und -entwicklung andererseits werden deshalb als Umweltziele für die Umweltprüfung mehr als bisher benötigt.

Keywords: Flächenverbrauch, Raumplanung, Umweltprüfung, Freiraumschutz, Planung

2 FLÄCHENVERBRAUCH UND FREIRAUMVERLUST ALS PERSISTENTE PROBLEME DER RAUM- UND UMWELTENTWICKLUNG

Siedlungs- und Verkehrsflächen in Deutschland, in Österreich wie auch darüber hinaus in ganz Europa haben sich in den letzten Jahrzehnten zu Lasten ökologisch wertvoller Freiräume und nicht zuletzt auch von landwirtschaftlich genutzten Flächen kontinuierlich ausgedehnt (Destatis 2023; EEA 2023; ÖROK 2023). Das Erfordernis eines Gegensteuerns gegenüber diesem sog. „Flächenverbrauch“ war offensichtlich, eine um den Faktor vier verbesserte Flächeneffizienz erschien erstrebenswert und zumindest längerfristig machbar. In Deutschland wurde mit der 2002 erstmals herausgegebenen Deutschen Nachhaltigkeitsstrategie der Bundesregierung (DNS) das sogenannte 30-ha-Flächensparziel, bezogen auf das Jahr 2020, etabliert (BReg 2002, S. 99 f.).

In den letzten 20 Jahren ist zwar die Flächenneuinanspruchnahme für Siedlungs- und Verkehrszwecke, also der Flächenverbrauch, in Deutschland kontinuierlich zurückgegangen, jedoch mit Werten zwischen 50 und 60 ha pro Tag erheblich über der definierten Zielmarke geblieben und zuletzt sogar wieder leicht angestiegen (Destatis 2023). Mit der Aktualisierung der Nachhaltigkeitsstrategie der Bundesregierung Ende 2016 wurde das Flächensparziel um 10 Jahre „gestreckt“ und als „30 ha pro Tag minus X“ für das Zieljahr 2030 proklamiert (BReg DE 2017). Die „Weiterentwicklung 2021“ der DNS bekräftig dieses fortgeschriebene „30 ha-Ziel“ und ergänzt: „Bis zum Jahr 2050 wird eine Flächenkreislaufwirtschaft angestrebt. Das heißt, es sollen netto keine weiteren Flächen für Siedlungs- und Verkehrszwecke beansprucht werden“ (BReg DE 2021, S. 269).

Auch in Österreich haben sich Bund, Länder, Städte und Gemeinden im Rahmen der Österreichischen Raumordnungskonferenz auf das Ziel verständigt, „die Zunahme der Flächeninanspruchnahme durch

Siedlungs- und Verkehrsflächen und das Ausmaß neu versiegelter Flächen bis 2030 substanziell zu verringern“ (ÖROK 2023, S. 6).

Die Europäische Union (EU) hat sich der Problematik des Flächenverbrauchs ebenfalls in vielfältiger Weise angenommen und mit ihrem „Fachplan für ein ressourcenschonendes Europa“ (EU KOM 2011) „Land und Böden“ als zu schonende Ressourcen herausgestellt. Landverbrauch und Land- bzw. Bodenversiegelung sollen weiter reduziert werden; bis 2050 soll netto kein Land mehr verbraucht werden (ebd., S. 18). Neuste Montoringergebnisse der Europäischen Umweltagentur (European Environment Agency – EEA) zeigen, dass die Mitgliedstaaten der EU in Sachen Netto-Null-Flächenverbrauch in den letzten Jahren eher nicht auf der Spur sind („likely off track“) (EEA 2025, S. 82-83).

Flächenverbrauch im Kontext der DNS bezeichnet die Umnutzung von freien, bisher unbesiedelten Flächen in Siedlungs- und Verkehrsflächen. Er wird über die jährliche Zunahme der statistisch erfassten Siedlungs- und Verkehrsflächen berechnet. Da diese in beachtlichem Umfang auch Grün- und Freiflächen umfassen, ist der Flächenverbrauch nicht mit Bodenversiegelung gleichzusetzen (Bay LfU 2019, S. 59). In Österreich sind beim Flächenmonitoring darüber hinaus auch Ver- und Entsorgungsflächen, die nicht zu den Siedlungsflächen zählen, miterfasst (ÖROK 2023, S. 77).

Die Fläche ist eine knappe, grundsätzlich nicht vermehrbare natürliche Ressource. Sie hat damit im Kontext der Ressourcenschutzpolitik eine im wörtlichen und übertragenen Sinne „tragende“ Bedeutung: Denn die Fläche übernimmt eine „Trägerfunktion“ nicht nur für die Siedlungs- und Infrastruktur, sondern auch für die natürlichen Ressourcen im Freiraum. Auf unbesiedelten, insbesondere unversiegelten Flächen außerhalb der Siedlungsbereiche wie auch in urbanen Freiräumen innerhalb der Siedlungsbereiche entfalten sich ihre ökologischen Funktionen und freiraumbezogenen Nutzungen. Die Raumplanung ist seit Langem der Umweltvorsorge und insbesondere dem Ressourcenschutz verpflichtet.

Abb. 1: Fläche im Kontext aktueller flächenrelevanter Umweltpolitiken (Eigene Darstellung)

Wie Abbildung 1 veranschaulicht, nimmt die Fläche als Träger von Flächen- bzw. Freiraumfunktionen und -nutzungen eine zentrale Rolle innerhalb aktueller Umweltpolitiken ein. Im breiteren Kontext flächenrelevanter Umweltpolitiken ist die Reduzierung von Flächenverbrauch und Freiraumverlust (im Folgenden auch als Flächen- und Freiraumschutz bezeichnet) nicht allein zur Umsetzung des quantitative definierten 30-ha-Flächensparzieles der DNS zu verstehen, sondern wesentlich umfassender im Kontext der immer vielfältiger werdenden umweltpolitischen Ziele, welche Flächen- und Freiraumqualitäten adressieren:

- Energiewende und Klimaschutz (insbes. energieeffiziente Siedlungsstrukturen, Flächeneffizienz bei Erzeugung, Speicherung und Transport erneuerbarer Energien),
- Anpassung an die Folgen des Klimawandels (insbes. Flächenvorsorge und -steuerung zur Wasserretention in der Fläche und zum Schutz vulnerabler Siedlungs- und Infrastrukturen vor Hochwasser, Sturzfluten und Massenbewegungen, aber auch Flächenvorsorge für klimaökologisch und lufthygienisch bedeutsame Frei- und Ausgleichsflächen),
- Urbaner Umweltschutz (insbes. durch kompakte und gemischt genutzte Siedlungsstrukturen mit attraktiven Wohnumfeldern und grüner Infrastruktur, Förderung einer „doppelten" bzw. „dreifachen" Innenentwicklung),
- Nachhaltige Mobilitätsentwicklung (insbes. durch Ansätze „Stadt/Region der kurzen Wege" bzw. „15 Minuten-Stadt" und integrative, den Verkehrsaufwand reduzierende und Flächen sparende Mobilitätskonzepte; im urbanen Raum als dritte Komponente einer „dreifachen Innenentwicklung"),
- Erhalt und Entwicklung der Biodiversität (insbes. Flächenvorsorge für Schutz, Pflege, Entwicklung und Wiederherstellung von Natur und Landschaft, Kompensationsflächenmanagement).

Bei alledem sind die Wechselbeziehungen zwischen den verschiedenen Raumstrukturen und Flächennutzungen, insbesondere die vielfach thematisierten Flächennutzungskonkurrenzen, als Hintergrund bzw. Auslöser vielfältiger direkter und indirekter Flächeninanspruchnahmen zu berücksichtigen.

3 FLÄCHEN SPAREN UND FREIRAUM SCHÜTZEN MIT DEM INSTRUMENT DER UMWELTPRÜFUNG

Ein wichtiges Instrument einer ressourcenschonenden, vorsorgenden Umweltpolitik ist seit den 80-er Jahren die Umweltprüfung (Töpfer 1989). Mit ihr werden mögliche Umweltauswirkungen von Planungen und Vorhaben einschließlich der Inanspruchnahme der natürlichen Ressourcen vor ihrer Verwirklichung ermittelt, beschrieben, bewertet und im Zuge ihrer Annahme bzw. Genehmigung gemäß bestehender Umweltziele und -standards berücksichtigt (grundlegend Bunge 2008).

Nach ersten, rechtlich unverbindlichen Anfängen in Deutschland und anderen Ländern wurde die Umweltverträglichkeitsprüfung für Projekte (UVP) in 1985 (UVP-RL vom 27.06.1985) und die Strategische Umweltprüfung für Programme und Pläne (SUP) in 2001 (SUP-RL vom 27.06.2001) europaweit eingeführt. Mit zunehmendem Flächenverbrauch und Freiraumverlust in dem Territorium der EU war es nicht überraschend, dass die EU-Kommission auch die Umweltprüfung als Instrument der Umweltvorsorge dazu einsetzen würde, den weiteren Flächenverbrauch und Freiraumverlust einzudämmen. Entsprechend wurde mit der sog. UVP-Änderungsrichtlinie von 2014 (UVP-Änd-RL vom 16.04.2014) die Fläche in den Schutzgüterkatalog der Umweltprüfung aufgenommen.

Die Umsetzung der UVP-Änderungsrichtlinie erfolgte in den Mitgliedstaaten der EU auch im Bezug auf das hinzugekommene Schutzgut Fläche vor dem Hintergrund der jeweiligen nationalen Besonderheiten des Planungs-, Zulassungs- und Umweltrechts unterschiedlich. Dieser Beitrag fokussiert im Folgenden auf die Umsetzung in Deutschland, die sich in rechtlicher Hinsicht drei Jahre später durch Gesetzesnovellierungen im UVP-Recht wie auch im Raumordnungs- und Bauplanungsrecht (BauÄndG vom 4.05.2017; ROÄndG vom 23.05.2017; UVP-ModG vom 20.07.2017) manifestierte.

In der Umweltprüfung, die mit der europaweiten Einführung der Strategischen Umweltprüfung (SUP) nicht zuletzt auch für Raumordnungs- und Bauleitpläne durchzuführen ist (Jacoby 2000), sind nun also neben den bisher bereits offensichtlich flächenrelevanten Schutzgütern auch die Umweltauswirkungen auf das Schutzgut Fläche zu prüfen (siehe Abbildung 2). Der Freiraum ist zwar nicht als eigenständiges Schutzgut der Umweltprüfung benannt, nimmt aber selbstverständlich im Umweltbezug als der Raum mit den ökologisch besonders wertvollen und schützenswerten Flächen eine hervorgehobene Bedeutung bei der Durchführung von Umweltprüfungen ein.

Die Einführung des neuen Schutzgutes Fläche wirft zahlreiche rechtliche und vor allem fachlich-methodische Fragen für die Umsetzung in der Praxis der Umweltprüfung auf. Dies hat nicht zuletzt mit der Begrifflichkeit „Fläche" zu tun, die in der bisherigen Praxis der Umweltprüfung als einer der wichtigsten Indikatoren mit unterschiedlichen Begriffsderivaten (Flächeninanspruchnahme, Flächenverlust u. a.) bei der Ermittlung der Umweltauswirkungen für den Großteil der Schutzgüter verwendet wurde. Auch enthalten

weder die UVP-Änderungsrichtlinie von 2014 noch die diesbezüglichen rechtlichen Anpassungen des deutschen Planungs- und Umweltrechts in 2017 klare und aussagekräftige Hinweise zum Bedeutungsgehalt des Schutzgutes Fläche und seiner Bearbeitung bei der Erstellung von UVP- bzw. Umweltberichten.

Abb. 2: Schutzgüter im Sinne des deutschen UVP-Gesetzes (Stand 2023) (eigene Darstellung).

Neben der Hinzunahme von „Fläche“ in die Auflistung der maßgeblichen Schutzgüter (siehe insbesondere § 2 Abs. 1 Nr. 3 UVPG) wird im UVP-Gesetz nur an einer Stelle der Bedeutungsgehalt des Schutzgutes Fläche angesprochen, wenn auch nach Auffassung der Verfasser sehr verkürzt. So ist in der Anlage 4 UVPG in einer Tabelle die „mögliche Art der Betroffenheit“ ausgewählter Schutzgüter beschrieben. Zum Schutzgut Fläche wird dabei als mögliche Art der Betroffenheit lediglich das Schlagwort „Flächenverbrauch“ genannt.

Nun ist der Aussagegehalt der genannten Tabelle nicht überzubewerten, da zum einen die Auflistung keinen Anspruch auf Vollständigkeit hat und zum anderen bei weiteren Schutzgütern die Beschreibung der möglichen Art der Betroffenheit ebenfalls begrenzt und wenig aussagekräftig ist. Dennoch hat die eingeschränkte Sicht auf den Flächenverbrauch im Kontext der DNS, die sich auch in den Begründungstexten der Umsetzung der EU-Änderungsrichtlinie in das deutsche Recht zeigt, dazu geführt, dass die rechtliche Auslegung und praktisch Handhabung des Schutzgutes Fläche in der Umweltprüfung bisher vor allem und häufig nur auf den Wirkungsbereich Flächenverbrauch bezogen wird. So heißt es in einem Kommentar zum UVPG: „Eine eigene Legaldefinition zu der Frage, was genau unter dem Begriff „Fläche“ zu verstehen sein soll, enthält das UVPG nicht“ (Hamacher 2018, Rn. 17). Und weiter: „Sein Bedeutungsgehalt erschließt sich jedoch ohne Weiteres aus seinem natürlichen Wortsinn und vor dem Hintergrund der aktuell geführten umweltpolitischen Diskussionen“ (ebd.). Das Schutzgut Fläche erweise sich „gewissermaßen als „spin off“ aus dem bereits zuvor in den Schutzgutkatalog aufgenommenen Schutzgut „Boden“ […]“ und fokussiere sich auf die Problematik des „Flächenverbrauchs“ (ebd.).

Wie allerdings „Flächenverbrauch“ rechtlich auszulegen sei und in der Praxis der Umweltprüfung zu handhaben wäre, bleibt an dieser Stelle offen. Insbesondere muss auch hinterfragt werden, ob das von der EU über die UVP-Änderungsrichtlinie von 2014 neu eingeführte Schutzgut Fläche vom Sinngehalt her mit der Fläche im Kontext des Flächensparziels der DNS vollständig übereinstimmt. Schließlich bezieht sich die EU-Richtlinie mit dem Schutzgut Fläche nicht auf ein einzelnes nationales Flächensparziel, sondern vor allem auf die europäische Perspektive des Flächenressourcenschutzes. In den bisherigen Ausgaben der DNS spielt zudem das Instrument der Umweltprüfung und ihr neues Schutzgut Fläche keine Rolle. Eine Verknüpfung von Flächensparziel der DNS und Schutzgut Fläche der Umweltprüfung fehlt.

Zum Schutzgut Fläche in der Umweltprüfung sind bisher neben der Aufnahme in Gesetzeskommentaren nur vereinzelt wissenschaftliche Untersuchungen durchgeführt worden (Kuhlmann; Lintzmeyer und Wilts 2014;

Alsleben 2015; Repp und Dickhaut 2017; Karrenstein 2019; Jacoby und Binder 2023). Arbeitshilfen oder Leitfäden für die Bearbeitung des Schutzgutes Fläche liegen in Deutschland bisher nicht vor. In Österreich hat das Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (2023) einen „Leitfaden für die Schutzgüter Fläche und Boden in der Einzelfallprüfung und in der Umweltverträglichkeitsprüfung“ herausgegeben, der nach Auffassung der Autoren noch zu eng an dem rein quantitativen Flächensparziel orientiert ist. Was die Praxis der Umweltprüfung und die hierbei verfolgten Ansätze zur Behandlung des Schutzgutes Fläche angeht, fehlt es bisher an einer umfassenden Analyse. Vor diesem Hintergrund hat das deutsche Umweltbundesamt (UBA) das mit Bundesmitteln finanzierte Forschungsvorhaben „Fläche als Schutzgut des Gesetzes über die Umweltverträglichkeitsprüfung – Erarbeitung von Praxisempfehlungen“ beauftragt. Die Forschungsergebnisse sollen 2025 publiziert werden.

Ergeben nun die UVP-Änderungsrichtlinie von 2014 und das entsprechend novellierte deutsche UVPG keine näheren Hinweise, was unter dem Schutzgut Fläche im Einzelnen zu verstehen ist und welche möglichen Umweltauswirkungen diesbezüglich zu ermitteln, zu beschreiben, zu bewerten und bei Planungsentscheidungen und Vorhabengenehmigungen zu berücksichtigen sind, so kann ein Blick in die Entstehungsgeschichte und Begründung der UVP-Änderungsrichtlinie der EU weiterhelfen. Die den Artikeln der EU-Richtlinie vorangestellten Erwägungsgründe geben hier bereits einen etwas besseren Einblick in die mögliche inhaltliche Bedeutung des Schutzgutes Fläche. So wird im neunten Absatz dieser Erwägungsgründe auf die Mitteilung der Kommission vom 22. September 2006 „Thematische Strategie für den Bodenschutz“ und den „Fahrplan für ein ressourcenschonendes Europa“ verwiesen, mit denen gegen die „nichtnachhaltige fortschreitende Ausweitung von Siedlungsflächen (Flächenverbrauch)“ vorgegangen werden soll. Darüber hinaus wird auf die Abschlusserklärung der UN-Konferenz über nachhaltige Entwicklung im Juni 2012 in Rio de Janeiro abgestellt. Damit zeigt sich einerseits die fachliche Nähe des Schutzgutes Fläche zur natürlichen Ressource Boden, andererseits ein klarer Zusammenhang mit dem internationalen Nachhaltigkeitsprinzip. Und der in der Richtlinie angesprochene „Flächenverbrauch“ wird bei diesem Erwägungsgrund als „nichtnachhaltige fortschreitende Ausweitung von Siedlungsflächen“ näher beschrieben, was allerdings nicht als normative Eingrenzung des Schutzgutes Fläche auf das Siedlungsflächenwachstum, sondern lediglich als eine beispielhafte bzw. bedeutsame Form des Flächenverbrauchs zu interpretieren ist („insbesondere“).

In der Begründung des Gesetzes zur Modernisierung des Rechts der Umweltverträglichkeitsprüfung vom 13.03.2017 (BTag 2017) finden sich weitergehende Hinweise auf den Bedeutungsgehalt des Schutzgutes Fläche. Zunächst heißt es: „Als eigenständiges Schutzgut wurde auch „Fläche“ aufgenommen“ (ebd., S. 57). Damit wurde Diskussionsbeiträgen, welche Fläche nicht als ein eigenständiges Schutzgut betrachten wollten, entgegengetreten.

Unter der Zwischenüberschrift „Nachhaltigkeitsaspekte“ wird in der Begründung ausgeführt, dass der Gesetzentwurf die Verwirklichung der Ziele der Deutschen Nachhaltigkeitsstrategie 2016 fördere und die positive Wirkung der UVP für die Förderung einer nachhaltigen Entwicklung weiter verbessere (ebd. 2017, S. 62). Auch mit Blick auf die in der Nachhaltigkeitsstrategie definierten Indikatoren zu den Nachhaltigkeitszielen, die sich in ihrer Systematik an den Sustainable Development Goals der Vereinten Nationen orientieren, sei der Gesetzentwurf für die Zielerreichung förderlich, unter anderem auch in Bezug auf den „Anstieg der Siedlungs- und Verkehrsfläche (Flächenverbrauch)“ (ebd.).

Und weiter heißt es in diesem Abschnitt der Gesetzesbegründung: „Dem Aspekt der nachhaltigen Flächeninanspruchnahme (Indikator Nummer 11.1.a -11.1.c) wird in dem Entwurf dadurch in besonderer Weise Rechnung getragen, dass das Schutzgut Fläche ausdrücklich in den Katalog der Schutzgüter des § 2 Absatz 1 aufgenommen wird. Damit wird deutlich, dass auch quantitative Aspekte des Flächenverbrauchs in der UVP zu betrachten sind. Der besonderen Bedeutung von unbebauten, unzersiedelten und unzerschnittenen Freiflächen für die ökologische Dimension einer nachhaltigen Entwicklung wird auf diese Weise Rechnung getragen“ (ebd., S. 63). Als ein Beispiel für eine umwelterhebliche Inanspruchnahme der Ressource Fläche durch ein Vorhaben wird an anderer Stelle der Gesetzesbegründung „eine extensive Flächeninanspruchnahme“ (ebd., S. 112) genannt, welches die Art der Inanspruchnahme (baulich oder anderweitig) offen lässt.

Hiermit wird zunächst klargestellt, dass Fläche nicht nur (wie bisher) ein Indikator für andere Schutzgüter wie insbesondere Boden, Wasser; Klima, Tier- und Pflanzenwelt darstellt (Verlust von diesbezüglich

schutzwürdigen Flächen), sondern als quantitatives Merkmal im Hinblick auf eine nachhaltige Entwicklung insbesondere von Siedlungs- und Verkehrsflächen eine eigenständige Bedeutung erhält. Dass es allerdings nicht nur um den quantitativen Flächenverbrauch gehen kann, zeigt allein die Vorgabe in Anlage 3 Nr. 2.2 UVPG, wonach bei der Beurteilung der Qualität und Schutzwürdigkeit eines von einem Vorhaben betroffenen Gebietes „Qualitätskriterien“ wie „Reichtum, Verfügbarkeit, Qualität und Regenerationsfähigkeit der natürlichen Ressourcen“ heranzuziehen sind und dabei auch die Ressource Fläche explizit genannt wird.

Betrachtet man das 30-ha-Flächensparziel der DNS genauer, so wird unter der weit gefassten Zielsetzung des Sustainable Development Goals (SDG) Nr. 11 „Städte und Siedlungen inklusiv, sicher, widerstandsfähig und nachhaltig gestalten“ als Indikator (Nr. 11.1.a) die „Flächeninanspruchnahme“ mit drei verschiedenen Teil-Indikatoren und Zielgrößen definiert:

- Anstieg der Siedlungs- und Verkehrsfläche in ha pro Tag – Zielgröße: Senkung auf durchschnittlich unter 30 ha pro Tag bis 2030 (also das weit bekannte „30-ha-Flächensparziel“),
- Freiraumverlust – Zielgröße: Verringerung des einwohnerbezogenen Freiflächenverlustes,
- Siedlungsdichte – Zielgröße: keine Verringerung der Siedlungsdichte.

Die Indikatoren Freiraumverlust und Siedlungsdichte waren in der ersten Fassung der DNS noch nicht enthalten, jedoch waren im Kapitel 3 unter dem Titel „Flächeninanspruchnahme – Freiräume erhalten“ neben dem konkreten, quantitativen 30-ha-Ziel auch die Erfordernisse des Freiraumschutzes aufgrund seiner wertvollen Funktionen und Nutzungen herausgestellt (BReg 2002, S. 99 ff.). Die Forderung nach kompakten Siedlungsstrukturen und damit einer flächensparenden Siedlungsdichte weist bereits auf Nachhaltigkeitsprinzipien der Flächeneffizienz und -suffizienz hin.

Trotz dieser verschiedenen begrifflichen und fachlichen Annäherungen an das Schutzgut Fläche sollte mit einem grundlegenden Verständnis für den erforderlichen Flächenschutz deutlich sein, worum es bei dem Schutzgut Fläche im Wesentlichen geht, das heißt, welche Umweltqualitäten überhaupt unter dem Stichwort „Fläche“ zu schützen sind: unbebaute bzw. unbesiedelte, unzersiedelte und unzerschnittene Freiräume/Freiflächen (als nicht anthropogen geprägte, naturnahe Freiräume und -flächen) als knappe natürliche Ressourcen, die insbesondere für die ökologische Dimension einer nachhaltigen Entwicklung von besonderer Bedeutung sind. In der bundesdeutschen Raumordnung ist in diesem Kontext die Flächenkategorie „großräumig zusammenhängender Freiraum“ und insbesondere die entsprechende Ausweisung von „Regionalen Grünzügen“ bekannt, den es aufgrund seiner multifunktionalen Nutzbarkeit und vor allem ökologischen Qualitäten vor Besiedlung zu schützen gilt. Die Sicherung und Entwicklung großräumig regionaler, stadtregionaler und nicht zuletzt urbaner Freiräume gewinnt gerade auch vor dem Hintergrund des Klimawandels und seiner Folgen immer mehr an Bedeutung (Domhardt et al. 2025; Jacoby et al. 2025).

Auf der Ebene der EU wurde bisher keine Arbeitshilfe oder Erläuterung zum Schutzgut Fläche veröffentlicht. Mit den neueren Leitfäden der Europäischen Kommission für das Screening und Scoping bei der UVP werden allerdings auch Fragestellungen in Bezug auf das Schutzgut Fläche formuliert, welche – über das in Deutschland fokussierte Problemfeld „Flächenverbrauch“ hinausgehend – weitere Betrachtungsperspektiven aufzeigen (EU COM 2017b, 2017c):

- Werden durch den Bau, den Betrieb oder den Rückbau eines Projektes physische Veränderungen der Flächennutzungen ausgelöst?
- Werden durch den Bau und den Betrieb eines Projektes natürliche Ressourcen wie die Fläche, insbesondere Fläche als nichterneuerbare begrenzte (knappe) Ressource, in Anspruch genommen?
- Verursacht ein Projekt einen Verlust an unbesiedeltem Freiraum (Freiraumverlust)?
- Werden durch ein Projekt vorhandene oder geplante Flächennutzungen (Wohnflächen, Grünflächen etc.) unmittelbar (durch Umnutzung der Fläche) oder mittelbar (randlich/im räumlichen Umfeld) beeinträchtigt?
- Werden durch ein Projekt besonders empfindliche Flächennutzungen (z.B. Krankenhäuser, Schulen etc.) beeinträchtigt?

Ein Teil dieser Fragestellungen lässt sich sicherlich schwerpunktmäßig anderen Schutzgütern wie Menschliche Gesundheit, Boden, Wasser, Tier- und Pflanzenwelt etc. zuordnen, ein anderer Teil, nämlich Fläche als knappe Ressource und als unbesiedelter Freiraum, wäre demgegenüber unter dem Schutzgut Fläche vertiefend zu betrachten. Fläche als eine (natürliche) Ressource soll demnach nicht nur geschützt werden im Sinne einer Nichtinanspruchnahme der Ressource, sondern soll in ihrer Verfügbarkeit für die Aktivitäten bzw. Nutzungen des Menschen möglichst erhalten bleiben, in dem neue Projekte so weit wie möglich nachhaltig und flächeneffizient geplant und realisiert werden (EU Com 2017a, S. 46). Der Nachhaltigkeitsindikator Siedlungsdichte ist von wesentlicher Bedeutung, da er sowohl direkte als auch indirekte Flächeninanspruchnahmen adressiert und neben der Effizienz der Flächennutzung auch die Suffizienz inkludiert.

4 FACHLICHE KONKRETISIERUNG DES SCHUTZGUTES FLÄCHE

Fasst man UVP-Änderungsrichtlinie der EU und das in Deutschland entsprechend novellierte UVPG einschließlich der Begründungstexte sowie aktuelle Dokumente der EU-Kommission und Ansätze aus der Fachdiskussion und -literatur zusammen, so lassen sich erste inhaltliche Konturen des Schutzgutes Fläche erkennen. Drei umweltbezogene Zieldimensionen des Schutzgutes Fläche wurden herausgearbeitet: das „quantitative Flächensparen“ (Reduktion des Flächenverbrauchs und damit des Freiraumverlusts), der „qualitative Freiraumschutz“ und eine „nachhaltige Flächenressourcennutzung“:

Abb. 3: Inhaltliche Konturen des Schutzgutes Fläche in der Umweltprüfung in Form von drei Zieldimensionen (Eigene Darstellung).

- „Quantitatives Flächensparen“: Klarer, aber nicht ausschließlicher Bezug zum Nachhaltigkeitsziel „Reduzierung der Flächenneuinanspruchnahme für Siedlungs- und Verkehrszwecke auf 30 ha minus X bis 2030“. Dieser sog. „Flächenverbrauch“ wird insbesondere in Anlage 4 Nr. 4 lit. b UVPG explizit angesprochen.
- „Qualitativer Freiraumschutz“: Deutlicher Bezug zum korrespondierenden Nachhaltigkeitsziel, unbebaute bzw. unbesiedelte, unzersiedelte und unzerschnittene Freiflächen bzw. -räume mit hohen funktionalen Qualitäten und Leistungen, die für die ökologische Dimension einer nachhaltigen Entwicklung von besonderer Bedeutung sind, von Bebauung bzw. Besiedlung freizuhalten.
- „Nachhaltige Flächenressourcennutzung“: Möglicher weitergehender Bezug zum allgemeinen umweltpolitischen Ziel des Ressourcenschutzes, nachdem die Fläche als begrenzte natürliche Ressource für alle Arten von Flächennutzungen sparsam und schonend zu nutzen bzw. zu

bewirtschaften und nach den Prinzipien der nachhaltigen Entwicklung (Effizienz, Konsistenz, Suffizienz) auch als dauerhaft und umweltverträglich nutzbar zu erhalten ist.

Mit dieser Konturierung wird auch erkennbar, dass das Schutzgut Fläche nicht von vorneherein auf das Thema „Flächenverbrauch“ im Sinne von Flächenneuinanspruchnahme für Siedlungs- und Verkehrszwecke reduziert werden kann. Sowohl UVP-Änderungsrichtlinie als auch UVPG weisen einen umfassenderen Begründungszusammenhang (Ressourcenschutz und Freiraumschutz im Sinne einer ökologisch orientierten nachhaltigen Entwicklung) auf. Schließlich verlangt das UVPG in Anlage 4 Nr. 4 lit a) auch eine (umfassende) Beschreibung nicht nur der direkten, sondern auch der „etwaigen indirekten, sekundären, kumulativen, grenzüberschreitenden, kurzfristigen, mittelfristigen und langfristigen, ständigen und vorübergehenden, positiven und negativen Auswirkungen des Vorhabens“. Auch temporäre Flächennutzungen, die Wiederherstellung des ursprünglichen Zustands temporär genutzter Flächen oder ihre mögliche andere Nachnutzung sind in der UVP zu behandeln (EU COM 2017a, S. 91).

5 ZUR PRAXIS DER UMWELTPRÜFUNG IN BEZUG AUF DAS SCHUTZGUT FLÄCHE

In der Planungs- und Gutachterpraxis herrscht bisher eine weit verbreitete Unsicherheit bezüglich der fachlichen Bearbeitung des Schutzguts Fläche vor allem aufgrund einer fehlenden, allgemein anerkannten Schutzgutdefinition, fehlender Arbeitshilfen/Leitfäden und Schwierigkeiten in der Abgrenzung von anderen bereits zuvor zu berücksichtigenden Schutzgütern (insbesondere Boden und Landschaft). Die bisher vorherrschende, weiter oben beschriebene eingeschränkte Auslegung des Bedeutungsgehalts des Schutzgutes Fläche (Prüfung des „Flächenverbrauchs“) führt in Verbindung mit weitgehend fehlenden fachgesetzlichen Standards zum Schutzgut Fläche im engeren Sinne dazu, dass in der Praxis seit 2017 zunächst vielfach das Schutzgut Fläche bei der Bearbeitung von UVP- bzw. Umweltberichten entweder ganz „vergessen“ wurde, nur randlich beim Schutzgut Boden mit erwähnt wurde und häufig auch nicht durchgängig zusammen mit den anderen Schutzgüter bei den verschieden Kapiteln eines Umweltberichts (Umweltzustand, Status-Quo-Prognose, Wirkungsuntersuchung, Bewertung) behandelt wurde.

Im Rahmen des weiter oben erwähnten UBA-Forschungsvorhabens zum Schutzgut Fläche wurden in den letzten Jahren unter anderem anhand von über 100 Fallbeispielen aus Deutschland, die mindestens das Schutzgut Fläche explizit erwähnt hatten, die Herangehensweisen in der Praxis in Bezug auf die Bearbeitung dieses Schutzgutes im Rahmen von Umweltprüfungen genauer untersucht.

Obwohl die Fläche als eigenständiges Schutzgut im UVPG definiert ist, wurde in ca. 30 % der untersuchten Fälle (mit Bearbeitung ab 2017) das Schutzgut Fläche komplett in das Schutzgut Boden eingebettet oder zusammen mit diesem Schutzgut (Abschnitt „Boden und Fläche“) geprüft. Diese Zusammenlegung ist zwar rechtlich nicht zu beanstanden, zeigt aber den geringen Stellenwert des Schutzgutes Fläche, speziell in diesen Fällen, in denen unter der Überschrift „Boden und Fläche“ im Wesentlichen nur die Bodenfunktionen nach Bundesbodenschutzgesetz behandelt werden. Auch eine Verlagerung in nachfolgende Planungsverfahren (Abschichtung) konnte vereinzelt festgestellt werden.

Bei den untersuchten Fallbeispielen wurde die quantitative Zieldimension des Schutzgutes Fläche („Flächenverbrauch“ für Siedlungs- und Verkehrszwecke) deutlich am häufigsten bearbeitet und auch teilweise mit methodischen Ansätzen bewertet. Für die qualitative Zieldimension (Auswirkungen auf ökologische Qualität und Leitung von Freiräumen/Freiflächen) wurden bei den Fallstudien nur vereinzelt Ansätze, aber keine tatsächliche Bewertung der Auswirkungen auf das Schutzgut Fläche gefunden. Die Zieldimension einer nachhaltigen Flächenressourcennutzung klang zwar etwas häufiger an, war jedoch ebenfalls nicht Gegenstand einer methodisch fundierten Bewertung.

Neben dem weitbekannten „30-ha-Flächensparziel“ der DNS, welches als Umweltqualitätsziel für die Umweltprüfung relevant, aber bisher über einen einfachen Abwägungsbelang hinaus nur sehr begrenzt zu planungs- oder gar zulassungsrelevanten Umweltstandards konkretisiert werden konnte, und den überwiegend qualitativen Zielen, Grundsätzen und Festlegungen der Raumordnung und Bauleitplanung in Bezug auf kompakte Siedlungsstrukturen und den Schutz wertvoller, unbesiedelter Freiräume gibt es bisher kaum Normen, die auf das Flächensparen bzw. eine Flächennutzungseffizienz abzielen.

Je weniger Normen bzw. Umweltstandards für einzelne Schutzgüter der Umweltprüfung herangezogen werden können, desto wichtiger wird die Alternativenprüfung, die zwar bei der UVP für Projekte kein zwingender, bei der SUP für Programme und Pläne jedoch ein obligatorischer Baustein der Prüfung ist und

eine wesentliche Optimierungsfunktion im Hinblick auf die Berücksichtigung des Schutzgutes Fläche übernehmen kann. Auch hier zeigt die bisherige Praxis der Umweltprüfung, dass das Potenzial der Alternativenprüfung für die Steigerung der Flächeneffizienz als wesentlicher Aspekt einer nachhaltigen Flächennutzung nur selten genutzt wird.

Auffällig bei der Untersuchung der Bewertungspraxis war auch die uneinheitliche, nicht-standardisierte Verwendung flächenbezogener Begriffe. Hier sind als Beispiel vor allem „Flächen(neu)inanspruchnahme", „Versiegelung", „Flächenverbrauch" oder „Flächenverlust" zu nennen. Oft wurden viele unterschiedliche Bezeichnungen benutzt, um das gleiche Thema zu behandeln. Zwischen dem Schutzgut Fläche und der Fläche als Indikator für die Beschreibung und Bewertung von Betroffenheiten der verschiedenen (anderen) Schutzgüter wird bisher kaum begrifflich klar und konsistent unterschieden. Dadurch wird die Nachvollziehbarkeit bei der Betrachtung des Schutzgutes Fläche und so letztlich auch dessen Berücksichtigung im Sinne einer wirksamen Umweltvorsorge bei der planerischen bzw. behördlichen Entscheidung erschwert. Eine einheitliche Nomenklatur wäre für Büros und Behörden sehr hilfreich.

Obwohl die Raumordnungs- und Bauleitplanung seit Langem flächenbezogenen Zielen und Grundsätzen des Umweltschutzes verpflichtet ist (Flächenspargrundsatz, Bodenschutzklausel, Schutz natürlicher Ressourcen etc.), spielt auch in der Umweltprüfung von Raumordnungs- und Bauleitplänen das Schutzgut Fläche im Vergleich zu den anderen Schutzgütern meist nur eine untergeordnete Rolle. Selbst vorhandene flächenbezogene Umweltziele für die Ausweisung neuer Siedlungsflächen wie Flächenkontingente oder Dichtewerte, ob als verbindlich zu beachtende Ziele oder nur abwägungsrelevante Grundsätze der Raumordnung, werden in der Regel nicht adäquat bei der Bewertung der Umweltauswirkungen im Rahmen der Umweltprüfung berücksichtigt.

Nachfolgend soll an einem Beispiel aus der Praxis der Umweltprüfung aufgezeigt werden, dass Ansätze über das rein quantitative Flächensparziel hinaus möglich sind. 2021 wurde erstmals ein Raumordnungsplan des Bundes für den länderübergreifenden Hochwasserschutz aufgestellt. Der hierzu erstellte Umweltbericht (Bosch & Partner GmbH 2020) enthält eine breiter angelegte Zusammenstellung der für die Betrachtung des Schutzguts Fläche maßgeblichen Umweltziele (siehe Abbildung 4).

Fläche	• Sicherung und Schutz der prägenden Vielfalt des Gesamtraumes und geeigneter Flächen vor allem im besiedelten und siedlungsnahen Bereich (§ 1 Absatz 4 Nr. 2 BNatSchG und § 2 Absatz 2 Nr. 2 ROG) • Großflächige, weitgehend unzerschnittene Landschaftsräume sind vor weiterer Zerschneidung zu bewahren (§ 1 Absatz 5 S. 1 BNatSchG) • Vermeidung von weiterer Zerschneidung der freien Landschaft und von Waldflächen sowie Flächeninanspruchnahmen im Freiraum (§ 2 Absatz 2 Nr. 2 S. 6 ROG) • Ausführung zulässiger Vorhaben in einer flächensparenden Weise (§ 1a Absatz 2 S. 1 2. Hs. BauGB, § 35 Absatz 5 BauGB) • Reduzierung der Zunahme der Siedlungs- und Verkehrsflächen in Deutschland von 70 ha/Tag auf 30 ha minus x /Tag bis 2030 (Nachhaltigkeitsstrategie der Bundesregierung Aktualisierung 2018; Die Bundesregierung 2018) • Netto-Null-Flächenverbrauchsziel der Europäischen Kommission (Europäische Kommission 2011) • nachhaltige Sicherung oder Wiederherstellung des Bodens in seiner Nutzungsfunktion als Fläche für Siedlung und Erholung (§ 2 Absatz 1 und 2 BBodSchG)

Abb. 4: Umweltziele zum Schutzgut Fläche im Umweltbericht zum länderübergreifenden Raumordnungsplan des Bundes für den Hochwasserschutz (Bosch & Partner GmbH 2020, S. 12).

Hervorzuheben ist bei dieser Zusammenstellung, dass zunächst die gesetzlichen Ziele bzw. Grundsätze (Abwägungsbelange) des Naturschutzrechts sowie des Raumordnungs- und Bauplanungsrechts genannt werden, die sich primär auf den Freiraum- und Landschaftsschutz beziehen und als qualitative Zielkriterien für die Bewertung von Umweltauswirkungen auf das Schutzgut Fläche herangezogen werden können.

Umweltauswirkungen möglich?	**Ja**	Nein	**Raumbezug?**	**Ja**	Nein
Umweltprüfung Stufe 2: Abschätzung der Auswirkungen auf die Schutzgüter					
Schutzgut	**Betroffenheit**	**Mögliche Auswirkungen**			
Me	↑	Bestehende bau-, anlage- und betriebsbedingte Auswirkungen in Bezug auf das Schutzgut Menschen bzw. menschliche Gesundheit werden durch den Rückbau der Einrichtungen tendenziell reduziert und neu hinzukommende Auswirkungen unwahrscheinlicher. Der hochwassergerechte Umbau senkt das Schadensrisiko und die dadurch hervorgerufenen Auswirkungen auf die Gesundheit.			
Ti, Pf, bV	↑	Bestehende bau-, anlage- und betriebsbedingte Auswirkungen in Bezug auf die Schutzgüter werden durch den Rückbau der Einrichtungen tendenziell reduziert und neu hinzukommende Auswirkungen unwahrscheinlicher.			
Fl	↑	Bestehende bau-, anlage- und betriebsbedingte Auswirkungen in Bezug auf das Schutzgut Fläche werden durch den Rückbau der Einrichtungen tendenziell reduziert und neu hinzukommende Auswirkungen unwahrscheinlicher.			

Abb. 5: Ausschnitt des Prüfbogens zur Abschätzung der Auswirkungen auf die Schutzgüter (Bosch & Partner GmbH 2020, S. 67).

Das quantitative Flächenschutzziel der DNS („30 ha-Ziel“) und das längerfristig angelegte Netto-Null-Flächenverbrauchsziel der Europäischen Kommission kommem hinzu. Ergänzend wird auch das Bodenschutzrecht im Kontext der Altlastenbeseitigung angesprochen. Diese Zusammenstellung weitet den Blick auf die vielfältige Ressource Fläche und unterstützt auf diese Weise eine umfassende, nicht nur quantitativ begründete Schutzgutbetrachtung und -bewertung. Abbildung 5 stellt aus diesem Umweltbericht ein Beispiel für die Abschätzung der Auswirkungen auf das Schutzgut Fläche dar. Für die Ebene der Bundesraumordnung erscheint eine rein verbal-argumentative Betrachtung angemessen.

6 SCHLUSSFOLGERUNGEN

Bei der Verfolgung des Nachhaltigkeitsziels „Reduzierung der Flächenneuinanspruchnahme für Siedlungs- und Verkehrszwecke“ (30 ha minus x bis 2030/Netto-Null bis 2050) geht es seit der Deutschen Nachhaltigkeitsstrategie von 2002 bis zur aktuellen Fassung von 2021 in der Zielperspektive darum, mit der Begrenzung des sog. „Flächenverbrauchs“ die Verluste an Freiräumen zu reduzieren, in dem die Innenentwicklung (mit Nachverdichtung etc.) Vorrang vor der Außenentwicklung erhält und damit Freiräume außerhalb der Siedlungsräume in quantitativer Dimension (ohne Betrachtung ihrer einzelnen Funktionen) stärker geschützt werden. Urbane Freiräume als Grün- und Freiflächen innerhalb der Siedlungsräume bleiben bei diesem quantitativen Flächensparziel außen vor.

Das mit der UVP-Änderungsrichtlinie der EU von 2014 in das Recht der Umweltprüfung hinzugenommene Schutzgut Fläche wird bisher vor allem im Hinblick auf diese quantitative Dimension des Flächenverbrauchs und Freiraumverlusts diskutiert bzw. in der Praxis der Umweltprüfung umgesetzt, obwohl die EU-Richtlinie von 2014 nicht auf die nationale Deutsche Nachhaltigkeitsstrategie abstellt und im deutschen UVP-Gesetz neben anderen Schutzgütern auch die Fläche als qualitatives Kriterium und natürliche Ressource beschrieben wird. Die Betroffenheit von Freiraumfunktionen und -qualitäten bzw. Flächenwertigkeiten ist deshalb beim Schutzgut Fläche hinsichtlich ihrer quantitativen und qualitativen Dimension außerhalb und innerhalb von Siedlungsräumen zu prüfen. Fläche ist dabei nicht zuletzt als Träger von sich räumlich überlagernden Freiraumfunktionen (Multifunktionalität) und als natürliche Ressource im Hinblick auf ihre Entwicklungsmöglichkeiten in Bezug auf die einschlägigen Nachhaltigkeitsprinzipien (Effizienz, Konsistenz, Suffizienz) zu betrachten.

In der Praxis der Umweltprüfung wird das Schutzgut Fläche einerseits als nicht vermehrbare Ressource und wegen seiner multifunktionalen Trägerfunktion für andere Umweltschutzgüter bzw. verschiedene Freiraumfunktionen und -nutzungen zunehmend auch als wichtiges, ja als ein zentrales Schutzgut verstanden. Andererseits ist die rechtliche Einführung des Schutzgutes Fläche in das deutsche Umwelt- und Planungsrecht in Umsetzung der UVP-Änderungsrichtlinie von 2014 sehr „zurückhaltend“ und ohne fachliche Differenzierung erfolgt, weshalb bisher auch in der Praxis nur selten eine differenzierte Ermittlung der Umweltauswirkungen auf das Schutzgut Fläche vorgenommen wird. Insbesondere wird aufgrund der fachlichen Unsicherheiten wie auch fehlender Bewertungsmaßstäbe nur selten eine fundierte Bewertung der Auswirkungen von Planungen und Projekten auf das Schutzgut Fläche durchgeführt, sodass die Bearbeitung des Schutzgutes Fläche in der Praxis der Umweltprüfung in der Regel keine erkennbare Wirkung auf die umweltbezogene Planungsoptimierung bzw. umweltfreundliche Genehmigungsentscheidung zeigt.

Bei genauerer Betrachtung der diesbezüglich einschlägigen Rechtsvorschriften sowie ihren Herleitungen und Begründungen wird deutlich, dass in dem Schutzgut Fläche mit den drei Zieldimensionen

- Quantität (des Flächenverbrauchs reduzieren),
- Qualität (der Flächen- bzw. Freiraumfunktionen und -nutzungen erhalten), und
- Ressource (Fläche nachhaltig im Sinne von Effizienz, Konsistenz und Suffizienz nutzen/entwickeln)

ein großes, bisher noch zu wenig ausgeschöpftes Potenzial für eine wirksame Umweltvorsorge liegt, welches mit Hilfe von Umweltprüfungen gehoben werden könnte. Bisher sind allerdings mit der Einführung des Schutzgutes Fläche kaum Impulse für das Flächensparen in Richtung Netto-Null-Ziel, für einen wirksameren, multifunktional begründeten Freiraumschutz und einen nachhaltigeren, insbesondere effizienteren, konsistenteren oder gar suffizienteren Umgang mit der begrenzten Ressource Fläche in der Planungs- und Zulassungspraxis erkennbar.

Da sich in Verbindung mit einem weiter steigenden „Druck auf die Fläche“ formelle und materiell-rechtliche Anforderungen an die Prüfung und Umsetzung des Flächensparziels verschärfen werden und mit dem Netto-Null-Ziel für 2050 eine Flächenkreislaufwirtschaft erforderlich wird, jedoch die Einführung einer eigenständigen „Flächensparprüfung“ – vergleichbar mit anderen umweltbezogenen Prüfverfahren – mit Blick auf die angestrebte Planungsbeschleunigung und Verfahrensvereinfachung nicht opportun erscheint, besteht die Chance, das vorhandene, EU-weit vorgegebene Instrument der Umweltprüfung für Programme, Pläne und Projekte durch differenzierte Bearbeitung des Schutzguts Fläche für die dringender werdenden Aufgaben des Flächensparens und multifunktionalen Freiraumschutzes gezielt zu nutzen. Auch das Instrument eines „Freiraumchecks“, das vor dem Hintergrund des Ansatzes der doppelten Innenentwicklung bei städtebaulichen Projekten und informellen Planungen der Stadtentwicklung zur Sicherung der urbanen Freiräume mit ihren klimatischen Ausgleichsfunktionen empfohlen wird (BDLA 2022, S. 3), ließe sich ohne Probleme in die Umweltprüfung integrieren.

Zur Wirksamkeit der Umweltprüfung bedarf es neben einer frühzeitigen Integration in die Planungsprozesse möglichst verbindlicher Umweltziele und -standards für die Bewertung der Umweltauswirkungen von Planungen und Projekten. In Bezug auf das Schutzgut Fläche spielen die Festlegungen der Raumordnung und Bauleitplanung zur quantitativen Reduzierung der baulichen Flächenneuinanspruchnahme und zu Schutz und Entwicklung von Freiraumfunktionen entsprechend ihrer datengestützten Wertigkeiten eine entscheidende Rolle. Neben der raumordnerischen Festlegung von Flächenkontingenten und Dichtewerten für die Siedlungsentwicklung sind deshalb auch weiterentwickelte Strategien und verbindliche Instrumente mit Festlegungen zur raumordnerischen Sicherung von Freiraumfunktionen und -nutzungen gerade auch im Hinblick auf die Multifunktionalität/Mehrfachnutzung von Freiräumen erforderlich. Kommunale Strategien einer kompakten Siedlungs- und Freiraumentwicklung, insbesondere dreifachen Innenentwicklung, mit kommunalpolitisch beschlossenen baulichen Dichtewerten und urbanen Freiraumqualitäten, stellen neben den möglichen raumordnerischen Flächenkontingenten zukünftig wichtige Umweltziele für die Umweltprüfung in der Bauleitplanung dar.

Für die künftige Gutachter-Praxis erscheint zudem wichtig, das Schutzgut Fläche einerseits definitorisch und fachlich-methodisch so klar wie möglich von den anderen Schutzgütern abzugrenzen, andererseits die zweifelsfrei existierenden, fachlichen Überschneidungen, insbesondere mit Boden, Landschaft und dem Schutzgut Wechselwirkungen, zu adressieren und mit Hilfe von Schwerpunktsetzungen wie auch Verweisungen auf andere Schutzgüter ohne größere Redundanzen in den Berichten zu bewältigen. Gleichzeitig sind die Potenziale der Alternativenprüfung für eine effizientere Flächennutzung stärker zu nutzen und die Möglichkeiten der Abschichtung bei der Bearbeitung des Schutzgutes Fläche auf den verschiedenen Ebenen der Umweltprüfungen (SUP/UP/UVP) sorgfältig zu prüfen.

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reviewed paper

Did we Build Enough? Pleadings based on Statistics and Technologies for the Building Stock

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1 ABSTRACT

This contribution wants to argue for a fundamental transformative change for future development of the built environment in Austria (and generally Central Europe). Thereby, innovative technologies to update and adapt the existing building stock play a fundamental role, to improve comfort and energy performance of existing buildings and built structures. This contribution is based on a talk the author held two years ago about innovative technologies for building stock improvement in view of we built enough as a statement.

When we address the existing building stock, we find buildings and structures that can be considered of high value for European cities appearance. However, an even larger fraction of existing buildings might not be considered as "beautiful" or "identification landmark" for European cities. While the replacement of the sooner would mean an immense loss of identity, the latter might in part be considered as "the ugly child", but still provides a sink of past Greenhouse Gas (GHG) emissions. If we would demolish and replace these buildings by new ones, huge energy consumption and GHG emissions would be the consequence, connected with the demolition, depositing of old materials, and material movements and utilisation of the new buildings, as circularity concepts in the AEC (Architecture – Engineering – Construction) – Domain are not yet well established. Cities are expanding, which can be explained by rising numbers of population, but on the other side also with a increased space consumption of inhabitants. These expanision tendencies on the one hand require extensive overwork of public infrastructure and accelerate sealing of surfaces and loss of natural resources and green-blue infrastrucutres, and on the other hand seem strange, given that we face empty built infrastructures e.g. on groundfloor level in many residential districts.

Toward this end, the present contribution advocates for holistic view of the update possibilities of the building stock, while at the same time critically warns against romantification of the building stock in view of outdated perspectives of the past. Rather, research, technologies and approaches are presented and discussed that have been worked upon in the past 10–15 years and directly address the existing building stock. These efforts all tried to balance out the difficult relation between heritage protection on the one hand, and comfort and energy performance improvements on the other hand.

As such, this contribution tries to utilise the concept of imperial lifestyle as critically brought up by scientistst from environmental political science and maps it on the AEC-domain.

Keywords: Building Stock, Space consumption, technologies for retrofit, pladoyer, vacuum glazing

2 INTRODUCTION

In recent years the role and responsibility of the built environment regarding climate change shifted from being an issue discussed majorly amongst scientists and domain experts to a convolute of topics perceived and discussed in media and the broad public. This might be due to the fact that the effects of climate change cannot any longer be neglected, especially during Summers in the cities. One example for these topics is urban sprawl, which euphemistically often is named Verhüttelung in German (denoting the sprawl of a large number of detaches houses instead of more condensated forms of dwelling), and the associated issue of surface sealing (WWF 2021). Planning sciences for decades have scientifically worked on the topics and reasons for urban sprawling effects. In Austria, the situation is complex, given the relation between the country administration and its federal states that involves different responsibilities, economic interests and policies, leading to a strange culture that not only not hinders urban sprawl, but provides fruitful grounds for this development (Umweltbundesamt 2001, p147, Bröthaler 2020). Parallely, Austrian Cities, especially Vienna, experience population rises after times of stagnation leading to increased demand for urban dwellings, and at the same time – paradoxically – face large real estate vacancies (Kadi et al. 2020, Plank et al. 2022): Up to one fifth of all residential units in Vienna are considered to be vacant/unused. At the same e time, the AEC (Architecture-Engineering-Construction) sector is subjected to tightening regulations

stipulated by national and supranational administration bodies. This is due to the key role the built environment plays in approaches to fulfill ambitious, but increasingly unlikely to be achieved emission cuts, as defined by the Paris climate targets (UN 2015) and initiatives such as the as the 'European Green Deal' (European Commission 2019). The focus on the built environment seems logical, given the large percentage of climate-damaging emissions that are directly or indirectly related to buildings. This percentage varies in studies due to different geographical or temporal scope. A frequently mentioned statement is that the built environment is responsible for up to 40% of the end energy demand (Weber and Zucker 2022, p18). As a result of the European Building Directives of 2002 and 2010, Austria already has very "harsh" requirements for the thermal-energetic quality of buildings (OIB 2023a, OIB 2023b). While it seems easy to design new buildings to be energy efficient, i.e. with low or almost zero operational energy consumption and climate-damaging (gas) emissions, the existing building stock is often "forgotten" on the one hand, and on the other hand is seen in the literature as the key to energy-saving measures (Weber and Zucker 2022, p3). Buildings should clearly be designed or refurbished in such a way that it is practically possible to minimise the energy required for operation (e.g. to create a high level of thermal comfort for users). comfort for the users) as low as possible in order to minimise as low as possible so that as few or no negative emissions are caused. If the occupants of such buildings behave in a correspondingly "sensible" way, then the low energy consumption might be realizable. However, the everyday experiences illustrate that this is not necessarily the case (see Housez et al. 2014, discussed later in this paper). Moreover, many so-called retrofits conducted in recent years have pursued the goal of preserving (or at least beautifying) existing buildings, but not necessarily improving them thermally/energetically. In 2013, the German Federal Environment Agency assumed that 40 percent of building retrofit did not or barely include any thermal improvements (DENA 2013).

This article aims to highlight innovative technologies and approaches to improving the existing building stock that go into borderline areas where, for various reasons, such as the protection of the ensemble or the preservation of the architectural and aesthetic quality, "conventional" thermal improvements (such as the application of thermal insulation panels) are not possible or not possible without further ado. At the same time, the article aims to show that "all that glitters is not gold". To this end, the article is structured as follows: Firstly, Section 2, under the heading "Everything used to be better", looks at building traditions and their role in today's discourse, as well as the danger of (rather useless) glorification. Section 3 discusses the concept of the existing building stock and the challenges associated with it using a number of examples. Section 4 is dedicated to the concepts of "rebound" and "prebound" as well as the problem of energy performance certificates as a supposedly reliable indicator of building quality. Section 5 looks at which construction measures still appear necessary and sensible despite the 'build enough' paradigm. Section 6 focuses on innovative technologies for the refurbishment/optimisation of existing buildings and illustrates this using current research projects as examples. Section 7 discusses the available and necessary instruments and tools that are required to identify sensible measures for existing buildings and to provide evidence. Section 8 takes stock of the previous chapters and attempts to answer the question: 'Haven't we already built enough?

3 "EVERYTHING USED TO BE BETTER" OR THE DANGER OF ROMANTICISING PAST BUILING STOCK

For centuries, people used to employ locally available materials and constructed residential and other buildings by low energy, majorly manual work. As an example: The arrangement of Mbaru Niang roundhouses from the village of Wae Rebo, Flores, in West Manggarai, Indonesia, shown in Figure 1, demonstrates such a low-energy, high-performance architecture from a long 'trial and error' tradition. In the case of this village, which even today can almost only be reached on foot due to its location in a remote high valley/volcano caldera, these houses were built with the material that could be obtained from the surrounding countryside within walking distance with reasonable, machine-free effort. It was used to withstand the local rigours of nature in the form of strong sunshine, storms, or heavy rainfall. These are renewable raw materials (e.g. the draining, quick-drying roof covering made of lontar palm thatch) or materials that were used as found (stone material underneath the uprights) and combined in such a way that they offered the users (comparatively) pleasant living conditions or a comfortable living centre (e.g. storage tanks in the pitched roof, elevated construction to prevent water ingress in the event of heavy rain). Needless to say, these buildings offer pleasant living conditions all year round without heating or cooling, as many other local building traditions offer passivly. The author of this article is always tempted to show this image when

someone from the architecture scene comes along with a design for a ‘sustainable’ detached house in Vienna's suburbs and praises it with excessive fervour as ‘sustainable architecture’.

Fig. 1: Traditional Mbaru-Niang-Buildings, Wae Rebo, Flores, West-Manggarai, Indonesia (Image by the Author)

But does this mean that we “only” need to look at and copy architectural traditions in order to create “sustainable buildings” for the present day? Not at all. First of all, the traditional houses in this village have been disappearing over time because the inhabitants of the village built houses next to them in the 20th century using materials such as concrete and corrugated iron, where they “preferred” to live (Some of the depicted buildings have been reconstructed for touristic purposes). This also has something to do with the fact that eight families, usually of three to four people, lived together in each of the buildings, which no longer fits in well with today’s requirements in terms of privacy and cohabitation of the residents. The comfort requirements, both in terms of living habits (e.g. eating at a table instead of on a mat on the floor, sleeping in a bed instead of on a mat) and in terms of building physics parameters (temperature, room acoustics, daylight), have also changed over time and can only be met to a limited extent by the buildings shown in the illustration. Instead, the comfort requirements are – energy-intensively, powered on site primarily by diesel generators – fulfilled in newer homes not shown in the illustration. The traditional buildings have been reconstructed from a cultural-historical point of view, some of them rebuilt from scratch and now serve as a main source of income for the village, tourism – as a tourist, you can stay overnight “traditionally” in the village. The fact that the village’s main source of income used to be a different one, mainly from agriculture through coffee cultivation, is only mentioned here in passing, as is the fact that a 1:1 transfer of this building tradition would not even work within Indonesia, as the habitus of the users, other microclimatic conditions, other available materials and other requirements for the buildings would be different. These traditional buildings, just like traditional buildings from Austria, would not fulfil requirements such as “watertightness” (i.e. “sealed” instead of “draining” roofs) or ‘airtightness’ (no convective heat loss through structures). So what can we take away from this example? Taking inspiration from traditional building forms and principles is certainly advisable. This is important for the reactivation of the existing buildings and with regard to the discourse on Haven’t we already built enough?; romanticising the forms and presenting them as the ideal ideal solution is certainly not expedient. At the same time, however, it should also be questioned whether certain requirements that we place on today’s buildings due to “building preservation” and and “comfort requirements” really make sense. For instance, Central European building regulations demand a high degree of air tightness, but such envelopes are usually perforated by pipes of technical systems for ventilation. Another example is the assumption that all rooms of residential units are heated at all times during Winter. We should thus ask ourselves if such requirements make sense or should rather be seen as results of self-made construction problems and false ideas of comfort?

4 CHALLENGES RELATED TO THE BUILDING STOCK

According to Statistics Austria (2023a) (reference year 2021), the building stock in Austria consists of around 2.4 million buildings, of which around 93 per cent are predominantly used for residential purposes.

Figure 2 shows the development of the Austrian building stock over time in terms of the total number of buildings (buildings and buildings with predominantly residential use).

It is striking that the total number of buildings has increased by over 85 per cent within fifty years (1971-2021, Figure 2). In contrast, the population has only increased from 7.5 million to 8.9 million people between 1971 and 2021, which is an increase of 18.7 per cent. In purely mathematical terms, there were 5.85 people per building in 1971; in 2021, there were only 3.75 people per building. This consideration makes comparatively little sense without taking into account the flats or number of residential units per building, but nevertheless shows the trend towards "fewer residential units per residential building". Boom phases of growth were apparently between 1971 and 1981 (+ 23.9 per cent) and between 1981 and 1990 and 1991 and 2001 (14 per cent and 13.1 per cent respectively). So at least the 'growth rate' has fallen somewhat, even though the total number of buildings has risen.

Figure 3 shows the composition of the building stock from different building ages in absolute figures. With regard to the age composition of the buildings, it is striking that between 1971 and 2021 the number of Gründerzeit buildings (built up to 1918) fell by 40 percent, the number of buildings erected between 1919 and 1945 fell by 17 per cent and the number of buildings erected between 1945 and 1960 fell by 15 percent. This contrasts with a large number of buildings erected between 1961 and 1980, which have "only" declined by 5 per cent since 1981. The loss of building fabric, most of which has been replaced by new buildings, has therefore particularly affected the oldest building stock. In a lecture in 2022, civil engineer Andreas Kolbitsch pointed out that, compared to the 13 per cent of buildings from the Gründerzeit period in Austria as a whole, a quarter of Vienna's buildings date from the period up to 1919 (Kolbitsch 2022).

Fig. 2: Absolute number of buildings in Austria 1971 – 2021 (Source: Statistik Austria 2023, illustrated by the author)

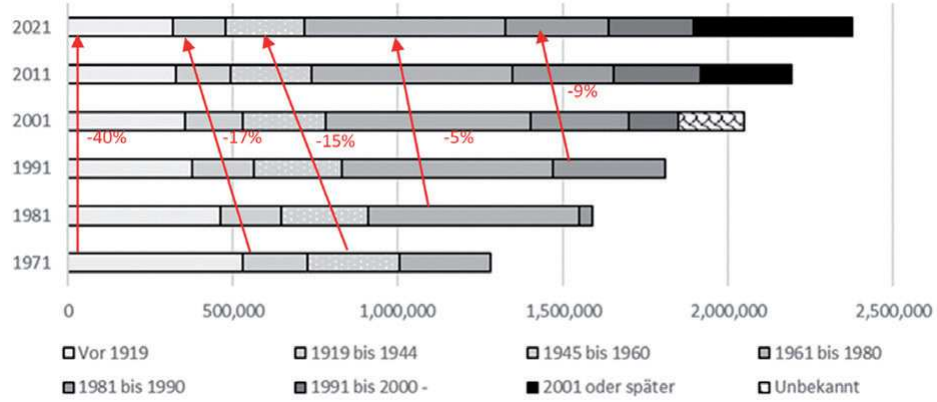

Fig. 3: Age distribution and development of number of buildings in Austria 1971 – 2021 (Statistik Austria 2023, illustrated by the author)

Basically, it should be noted that the "image" of a Central European city is largely constituted by its existing buildings. This applies to cities such as Vienna, Prague, Bratislava, Brno and many others and can be confirmed by looking at cities in Germany that were destroyed and rebuilt during the Second World War: Those cities where efforts were made to "rebuild" the old stock are today perceived as "more attractive" compared to those where reconstruction was carried out purely through new construction. Today, however,

the old stock includes not only the Gründerzeit and the interwar period (as evidenced, for example, by the imposing and architecturally valuable buildings of "red Vienna" to this day), but also the post-war period and the "off-the-peg" buildings of the period between 1945 and 1980. The fact that the question of the value of even relatively "new" architectural icons often depends on the urban planning and utilisation-specific context can be seen when studying the work of some former professors of the TU Wien, Vienna, who held chairs in high-tech architecture, construction and installation (Seidel and Steixner 2020).

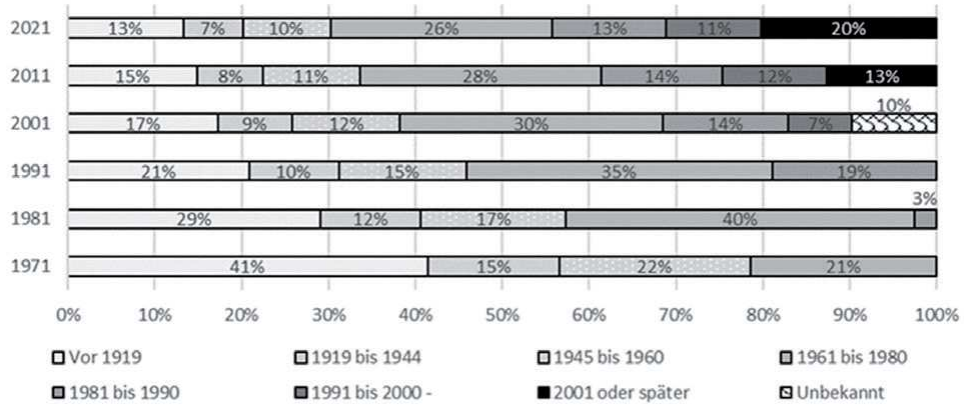

Fig. 4: Relative distribution of different building ages in Austria between 1971 and 2021 (Statistik Austria 2023, illustrated by the author)

The construction of the so-called Juridicum by Ernst Hiesmayr is still considered a milestone among the university buildings that belong to the University of Vienna, even though a Gründerzeit inner-city block was demolished on its site. Hiesmayr's successor at the TU Wien, Helmut Richter, is internationally recognised for the school on Kinkplatz (14th district of Vienna) and for the residential complex on Brunner Straße (23rd district of Vienna). While Brunner Straße is a popular residential building for residents despite a number of adaptations and its difficult location (the building is situated in industrial surroundings along a busy road), the glass and steel icon of the Kinkplatz Computer Science Secondary School, built in the 1990s, is today affected by disuse and slow decay despite its significance for recent Austrian architectural history and was long threatened with potential demolition (the school has since been listed as a historical monument). As far as existing buildings are concerned, one has to accept the idea that a black-and-white approach is not expedient. Looking at social housing from the post-war period up to the 1960s, one will find supposedly low-quality off-the-shelf buildings that are hardly considered adequate in terms of current thermal or acoustic requirements. Nevertheless, a huge proportion of residential units in Vienna is made up of/situated in these buildings. Buildings from the Gründerzeit of 1850–1918 (and even older buildings), which have been set under special protection recently due to certain incidents (deliberate decay to enable demolition), certainly have qualities that should not be underestimated; however, if they are not cared for and fall into disrepair, every building will eventually "come to an end". If this is accepted wilfully by the building owners in order to achieve technical readiness for demolition, the idea that can be found behind is very often that a new building could possibly generate more profit through lower storey heights (which just meet the minimum requirements of the building regulations). From a building ecology perspective, it should be noted that a building that stands for 100 or 150 years represents a certain degree of sustainability, despite possibly poorer thermal-energetic parameters. Bricks that form the construction material of such buildings have a lifecycle that outnumbers the predicted lifespan of today's new buildings by a factor 4 to 5. Replacing the (historic) building stock with new buildings is neither advisable nor expedient; numerous studies and theses have shown that the ecological footprint of existing buildings is significantly lower than that of new buildings over a long service life (Padayhag et al. 2016, Schmidt 2020). Furthermore, the loss of the architectural value cannot be quantified. The endeavour to replace the existing building stock with new buildings would take up to a century at today's new construction rates and would leave an enormous ecological footprint as well as a cultural black hole.

Challenges that the (historical) building stock must cope with today include, in addition to the usual maintenance work that every structure requires, aspects of adaptation to climate change. Urban heat islands in inner-city areas, which often lack sufficient green-blue infrastructure, pose a challenge to users. The fact

that there are often no simple solutions available in densely built-up urban areas will be addressed later in this article.

5 (P)REBOUND, ENERGY CERTIFICATES OR "DO YOU GET WHAT YOU DEMAND?"

This section describes two research efforts that deal with the Key Performance Indicators (KPIs) often used to evaluate buildings. However, before that, two terms will be introduced that occur in the context of such energy metrics in the building sector, as well as generally in the "measurement" of any kind of "performance"'

5.1 Rebound Effect

The term rebound or rebound effect refers to the phenomenon where a specific target (e.g., the potential savings from efficiency improvements in construction) is not or not fully achieved – despite careful attempts. An example of this would be that a building is thermally and energetically upgraded through construction measures, but the energy savings are negated by changed user behavior – such as prolonged showering, the use of additional energy-consuming appliances, or excessive ventilation in winter, etc. It is important to consider the systemic perspective here: a rebound effect could also occur if the saved heating costs are then invested in a vacation trip by airplane, which may cause even higher greenhouse gas emissions.

5.2 Prebound Effect

In contrast to the rebound effect, there is the prebound effect: a 'worse' performance is expected than what actually occurs. An example of this would be heating demand calculations (HWB calculations) for historic buildings that determine much higher heating demands than what is actually evidenced by energy bills. Reasons for this could include differing user behavior, such as heating only one or two living spaces instead of the entire apartment, or overly simplified assumptions regarding the thermal envelope quality of buildings, where default values are used in the HWB calculation instead of real constructions (Sunikka-Blank and Galvin 2020).

5.3 Is it all done with the renovation?

Housez et al. (2014) analyzed the renovations of seven existing residential buildings, mostly apartment buildings for older adults with multiple units. In this study, the actual energy performance before and after the renovation was assessed using data from bills and compared with calculations and simulations of the status quo as well as the planned renovations. The buildings were constructed between 1968 and 1985 and were renovated between 2005 and 2009. The planned target values for the specific heating demand after the renovations, which were designed for high energy efficiency, ranged according to the standards for energy certificate calculations at that time from 6.7 to 17 kilowatt-hours per square meter of gross floor area per year (abbreviated: $kWh.^{m\text{-}2.a\text{-}1}$). These values were and are extraordinarily low energy metrics for residential buildings. The actual specific heating demand (determined from energy bills) was only close to the planned value for one building; for the others, the determined values ranged between 40 and 55 $kWh.m^{-2}.a^{-1}$, meaning in some cases four to five times higher than the anticipated energy performance. Subsequently, parametric estimates were conducted to find out how the deviation occurred: higher indoor temperatures and differing real weather data were quickly ruled out as strong influencing parameters, as the available measurements of indoor temperatures and weather records showed that there were no significant deviations. In terms of adjusting ventilation behavior, it became evident that increased air exchange through more extensive ventilation (e.g., consistently "tilting" windows) served as a very good explanation. Interestingly, in the building where the anticipated and actual performance largely matched, the users directly paid the energy cost bills, while in the other properties, the energy costs were proportionally allocated to the units based on their floor area, meaning that the users could not recognize whether their behavior was causing the "worse" energy performance.

5.4 Building Energy certificates – the solution or the box of Pandora?

In another research effort, the practical creation of energy certificates was examined. Although there are a number of laws (EAVG 2012), guidelines from various institutions (guidelines from the Austrian Institute of Construction Technology, Ö-Normen from Austrian Standards International), and supporting documents for this purpose, there remains a significant interpretive degree of freedon regarding how to handle existing

buildings. Since the issuance of energy certificates is not particularly well compensated and there are no clear training requirements for issuers, the lack of accuracy in energy certificates is likely to be quite high. As part of a research project (see Sommer and Pont 2017, Pont et al. 2016), it was shown that there are significant differences in the results of energy certificates. Two groups of previously identically trained issuer groups each calculated the energy certificates for buildings. The differences in the results were sometimes enormous – at times, the difference in heating demand results was 100 $kWh.^{m-2.a-1}$ (!). Upon closer examination of the calculations from the two groups of issuers, differences in the assumed calculation data were identified: While both groups similarly determined gross floor areas and gross volumes, as well as area calculations and glazing ratios, there were striking differences in the assumed U-values (thermal transmittance coefficients) of the building components. Apparently, components that were not accurately described in the existing building documentation were approximated using default values according to the OIB guideline 6. Unfortunately, there is a significant interpretive degree of freedom for these default values, which means that the described deviations could arise "to the best of the issuers' knowledge and belief." It should also be noted that the energy certificate would certainly be an excellent idea for comparing different buildings if the aforementioned problems did not occur. However, it is fundamentally advisable to refrain from assuming that the energy certificate accurately reflects the actual behavior of occupants (e.g., regarding heating, internal gains from the presence of people, operating devices, artificial lighting, or ventilation behavior). In another project, it was investigated (Pont et al. 2019) how the energy certificate procedure can be used in evaluating large real estate portfolios and making decisions with limited budgetary scope to find the "best" renovation option that can achieve maximum savings effects. What has been described should be kept in mind when conducting the thermo-energetic assessment of the building stock. In short: just because a certain energy key performance indicator (KPI) is assumed for an existing building through a calculation, it does not necessarily reflect reality. Besides the fact that the calculation or simulation is based on sometimes rough assumptions (especially regarding user behavior), the manner in which the calculations or simulations are conducted is also significant, as it is subject to a variety of uncertainties.

6 WHAT WOULD WE BUILD ANYWAY?

Until now, this article has primarily dealt with aspects of proof for buildings, innovative retrofitting technologies, and similar topics. This leads directly to the question: "Should nothing more be built anew?" This can be answered relatively simply, but it unfolds into a series of partial answers. First: It will definitely be necessary to create additional (or altered) residential spaces as the population grows, but this should only be accompanied by measures that make better use of existing structures or sensibly expand them. In a project aimed at reorganizing living space, it was shown that – no matter how absurd a reorganization may sound at first – a win-win situation for residents and energy performance could be achieved with the same or improved living comfort in the existing building stock through organizational and (small-scale) structural modifications in the (historic) building stock (Mahdavi et al. 2012). Of course, legal and ownership-related aspects are significant hurdles here, but the project demonstrates the vast potential of this approach. The idea of sufficiency, meaning a limitation of, for example, living space per person, also comes to mind. Improved utilization of the 'still' available urban area is another aspect that is conceivable in the context of 'new' building. Assuming that many building regulations today have developed prescriptively from a long cascade of evolutionary steps, it is unlikely that the existing "negative space" that still exists will actually be efficiently utilized through core densification. In the course of another project (Pirstinger et al. 2017), it was investigated which core densification potentials could be unlocked with which methods.

A major theme for new buildings will be measures for climate change adaptation. Historical, urban areas with their very limited offerings of green-blue infrastructure and conditionally available root space for trees could benefit from 'artificial' structures for shading and cooling.

As part of a recently completed research project, the essential aspects of artificial tree structures (dubbed Smart & Urban Trees) were examined for urban cooling purposes. It is important to note that such structures do not compete with trees and plantings but are intended to complement areas where natural plantings cannot be implemented or are difficult to implement for technical or organizational reasons. Figure 5 shows result visualizations from this project. The corresponding structures were also examined for their shading effects and cooling potentials through numerical simulations and were confirmed in their effectiveness. The multitude of legal, organizational, technical, and socio-economic questions associated with such structures

indicates that new construction in the future may need to be conceived in a much more holistic and integrative manner than is currently the case.

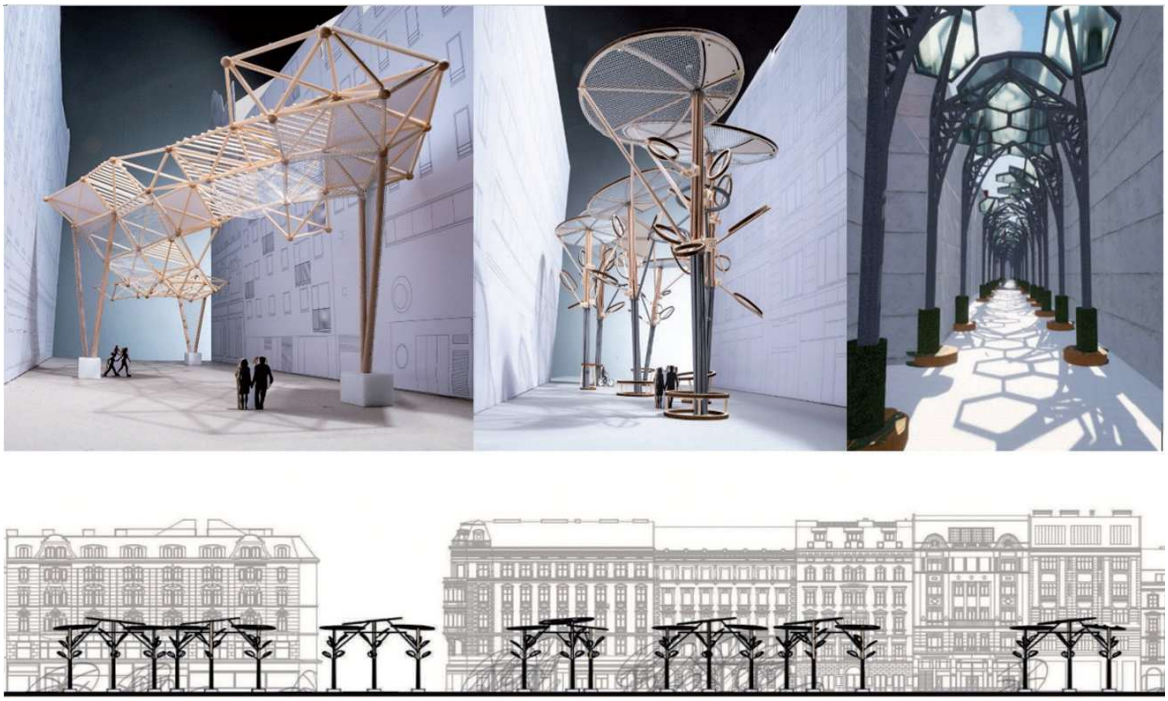

Fig. 5: Visualisations of artificial tree structures for urban cooling (Pont et al. 2025)

7 INNOVATIVE TECHNOLOGIES FOR IMPROVING THE THERMO-ENERGETIC PERFORMANCE OF THE BUILDING STOCK

It has already been suggested that the city, as the largest manifestation of building stock, may also require new organizational approaches for densification and expansion. Therefore, the following will address a whole range of research and development efforts on the topic of 'innovation in optimizing existing structures. When asked how to energetically upgrade existing buildings, the standard response is always “insulation”. What is typically meant by this is the additive (external) application of insulating materials. While this may seem feasible for the unadorned facades of post-war buildings – though even here, a sometimes questionable cultural impact is often hard to deny – this solution often appears not readily applicable to richly decorated cultural heritage buildings. As an alternative, aside from no intervention, internal insulation is mentioned. However, from the perspective of the Central European winter climate, this poses problems: the temperature drop is shifted to the interior side of the load-bearing components, making condensation and mold formation likely, which must be avoided, for example, through diffusion-tight membrane materials or capillary-active insulating materials. The interior ceilings that connect to the load-bearing exterior walls become thermal bridges, and the altered temperature characteristics in this detail area can lead to the rotting of wooden beam ceilings, resulting in a shortened lifespan of the structures and potentially leading to collapse. The significant reduction of interior spaces due to corresponding insulation thicknesses should also be noted as an economic and living space issue.

7.1 Thermal insulation made with Aerogel Plasters and Subtracive Insulating

For the innovative external insulation of culturally significant buildings, plaster systems with insulating characteristics are suitable, provided that the exterior plaster does not represent the preservable cultural asset. In a research project (AGelFa), the insulation potential of the still relatively expensive aerogel plasters was demonstrated (Proskurnina et al. 2015). Aerogels are solid, highly porous gel structures (with up to 97 percent air pore content) that are highly insulating even at low thicknesses. Not only was the benign nature and durability of the material for top plaster systems explored through extensive monitoring, but it was also shown that for average Gründerzeit facades, with an appropriate offset of the facade structure and plaster system thickness, and with accompanying measures on other components (e.g., window upgrades, avoidance of thermal bridges in ceiling connection areas), savings of up to 70 percent in heating energy demand can be achieved. This makes Gründerzeit buildings 'competitive' in terms of heating energy demand (cf.

Proskurnina et al. 2015). Figure 6 shows a test area for aerogel plasters as produced and observed in this project.

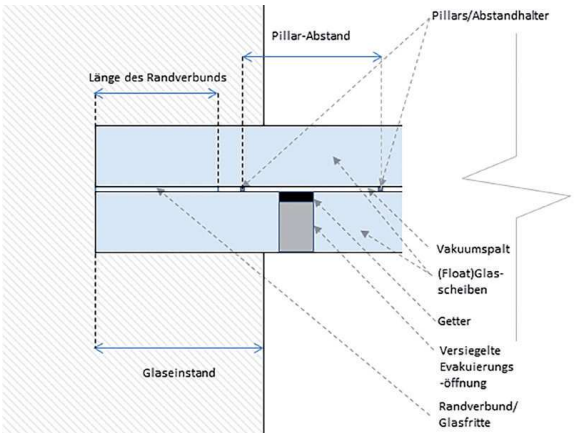

Fig. 6: Aerogel-plaster test surfaces (Image by the Author), fig. 7: Schematic Constituents of vacuum glazing products (Image by the Author)

Another approach regarding the "insulation" of opaque parts of existing facades was recently explored in a preliminary project: The idea here is to insulate "subtractively", meaning to thermally improve the static reserve of Gründerzeit walls by introducing suitable drill holes (and corresponding "caps") with insulating, standing air inclusions. The U-values of Gründerzeit walls could be improved by up to twelve percent concerning the thermal transmittance coefficient (U-Value). In combination with other concepts, such as phase change materials (PCM), the characteristics of heat transfer, especially during cold winter nights, could be positively manipulated. Moreover, an interesting approach to renovation is that it should not be carried out as usual by construction workers on scaffolding, but rather that autonomous robots should gradually upgrade the facade whenever resources (energy, money, time) are available. Future music? It is certainly true that such highly innovative concepts must reach a level of maturity and face challenges (robot technology, appropriate modeling of the facade to clarify where "drilling" is allowed, suitable drill heads/drilling techniques). However, it has become evident, especially in recent years, that such ideas are no longer mere science fiction with the advent of digitalization (Sommer et al. 2021).

7.2 Historic casement windows and their retrofit via innovative glazing products

Buildings are not only made up of opaque components but also of transparent elements like windows. Windows are still considered a weak point in building envelopes, through which a significant amount of heat is lost during the cold season. The existing building stock is often characterized by very elegant window constructions, which, however, do not necessarily meet the current standards for thermal insulation. Unfortunately, the unsustainable practice of "window replacement" has become the primary form of renovation for windows. In this way, and under the false argument of an alleged lack of alternatives regarding improved thermal building performance, thousands of box window constructions are unnecessarily lost each year, and the appearance of the valuable building stock is often negatively altered.

The old casement window constructions represent fundamentally well-thought-out and high-quality window designs that utilize an air cushion between the inner and outer sashes for thermal insulation. However, due to leaks and the high thermal conductivity of float glass compared to multi-pane insulating glass, the thermal insulation effect is often limited. While adjusting the windows and fittings, adding seals, and maintaining the windows can generally counteract leaks and drafts, the heat losses through float glass are difficult to modify. Heavy double or triple glazing with several millimeters of gas inclusions is not feasible as a glass alternative due to the delicacy of box window constructions (often very thin wooden strips as muntins and delicate beams for the window frame). Since box windows also represent an excellent construction from a circular economy perspective (easy separability of materials, durability), a glass alternative would be a great opportunity to make box windows 'fit' for the present time. In fact, there have been durable vacuum glass products for about ten years that meet the requirements regarding glass thickness and weight (vacuum glasses are available from about five millimeters of glass thickness) for box windows. Vacuum glasses are highly insulating due to the thin, less than one millimeter thick vacuum gap, which largely eliminates the heat transport mechanisms of conduction and convection (see Figure 7).

The author has been leading several research and development projects in recent years that focus on the use of vacuum glass in new and existing window constructions. Due to the characteristics of vacuum glass, which have a significant “thermal bridge” at the edge connection of the glass, it was necessary to pull out all the stops regarding the evaluation of the performance of box windows reinforced with vacuum glass: Not only through simulations and laboratory tests, but also through monitoring under real conditions in buildings, it could be demonstrated that box windows reinforced with vacuum glass do not show any tendency for condensation or mold even under harsh winter conditions. In six heritage-related objects, box windows with vacuum glass were implemented for demonstration purposes and subjected to intensive performance monitoring for over a year using high-end measurement equipment. In each of the objects, a control window in its original state was monitored alongside two reinforced windows that were sensorily observed. For the reinforced windows, one window had its outer layer of float glass replaced with vacuum glass, while the same was done for the inner layer.

Ultimately, it was demonstrated that box windows, when carefully planned for structural renovation (in addition to glass replacement, also correct adjustment of fittings and, if necessary, adding seals in the rebate), can achieve a significant performance improvement compared to the original. The use of vacuum glass can be planned so that the windows do not show any signs of condensation or ice formation. If the vacuum glass is used for the inner sash, the energy performance of the renovated window is better; if the vacuum glass is installed in the outer sash, a slightly poorer thermal insulation property results in a warmer space between the panes (thus protecting against condensation formation). With such a minimally invasive renovation option (sash replacement, adjusting the window and fittings, adding a sealing layer), a 10 percent reduction in heating energy demand was found in Gründerzeit houses without large construction sites. The window U-value for box windows reinforced with vacuum glass could be reduced from 2.5 $W \bullet m^{-2}K^{-1}$ to below 1.0 $W \bullet m^{-2}K^{-1}$ (Pont et al. 2016).

8 WHAT INSTRUMENTS DO WE NEED FOR IMPROVING THE BUILDING STOCK?

This article described concepts and showcased exemplary projects that either address the meaningful enhancement of built space for additional effects (e.g., mitigating summer overheating) or focus on the innovative improvement of existing structures with minimally invasive measures. It should be noted that these projects – although often with a built 'demonstration character' – have largely utilized digital tools: For example, numerical thermal bridge simulations were employed for the development of vacuum glass box windows, as well as light and temperature simulations. The use of such technologies plays a key role in the success of evaluations of the potential of ideas, especially given the impossibility of experimentally testing a multitude of variants. Verification and validation of results through monitoring, as in the case of box windows, is also of utmost importance.

In fact, the digital tools available today do not represent the “ceiling” for supporting planners, end users, or decision-makers. A decision support system for renovations was developed ten years ago, aimed at making the overwhelming amount of information for stakeholders involved in renovation processes more “manageable” through “multi-objective optimization” and semantic web technologies (Heurix et al. 2013). The enormous amounts of information needed for building renovations (e.g., building material/product data, subsidies, legislative information, zoning regulations, etc.) often have to be painstakingly compiled manually. This overload often leads to the seemingly 'simplest' but not necessarily “most sensible” path being taken. This problem resulted in the tool SEMERGY (2023), which can still be used today for planning building renovations while considering the parameters of energy performance, ecological footprint, and costs, evaluating several hundred thousand variants regarding optimal performance in typical renovation projects (cf. Pont 2014). In times of artificial intelligence, robotics, and other disruptive technologies, such tools will likely be expanded and utilized even better for the purposes of optimizing existing structures, provided there is the political will to focus on much more efficient and sufficient optimization of existing buildings.

9 CONCLUSIONS

This article presented different approaches to optimizing the existing building stock. They highlighted various points: (a) A holistic approach is required for the optimization of existing buildings, with the involvement of as many relevant stakeholders as possible. It is of no use, for example, if the renovation of

windows through minimally invasive measures is only scientifically proven to be sensible. The industry (small and medium-sized carpentry businesses and guilds) as well as the administration (moving away from funding regimes that only support window replacement as a sole measure) must be involved here – just as civil society must be willing to participate. (b) The existing building stock is somewhat like an 'undiscovered' land: In fact, we still do not know many details about the existing building stock today, particularly concerning thermal building envelope qualities, etc. Further research, development, demonstration, and communication are required. What we do know suggests that the existing stock can do much more than is often acknowledged. (c) The existing building stock must be recognized as a valuable asset that needs to be maintained and improved. The cultural significance of the existing stock already constitutes a large part of the identity, image, and quality of life in many cities. At the same time, we must move away from romanticizing it. Just as in the area of new construction, there are areas where the existing stock has weaknesses: It is necessary to find technologies and approaches that allow for optimization. There is also a building stock that may not be as "presentable" as the historic city centers from the Gründerzeit. Improvements can address the aesthetic and technical problems that may exist there. (d) While a respectful approach to the (historical) existing building stock is a conditio sine qua non, one should remain open to new technologies and methods for its improvement. In times of digitization, 'assemble to order' custom manufacturing, and high-tech materials, addressing the existing stock can not only help rapidly reduce energy consumption and emissions but can also be used to bring the somewhat outdated construction industry into the present and compensate for economic losses due to reduced new construction activity.

No matter how you look at it: Yes, we have already built enough, even in a growing world, and yes, it is necessary, in the spirit of Karl Polanyi (1944), to initiate a 'Great Transformation': The existing building stock can play a key role in this.

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Die Identifikation klimaaktiver Grünflächen mit Hilfe künstlicher Intelligenz

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1 ABSTRACT

Der menschengemachte Klimawandel führt zu einer Erhöhung der durchschnittlichen Lufttemperaturen. Dies hat insbesondere Auswirkungen auf die dicht besiedelten und versiegelten urbanen Räume durch eine Intensivierung des städtischen Wärmeinseleffektes. Ein wichtiges Instrument zur Anpassung an den Klimawandel und die damit einhergehenden Temperaturveränderungen ist die Entwicklung, Erhaltung und Etablierung innerstädtischer Grünflächen. Zur Bestandsaufnahme und Weiterentwicklung der Grünflächen ist die Schaffung einer Grünflächenkartierung essenziell. Die Heterogenität und diffuse Verteilung von Grünflächen im räumlichen Kontext erschweren eine entsprechende Kartierung jedoch maßgeblich. Vorweg ist es notwendig, den Begriff der Grünflächen zu definieren. Anschließend kann bezugnehmend auf die Herausforderung einer vollständigen Kartierung aller Grünflächen vor Ort untersucht werden, inwiefern solche Flächen mithilfe des Einsatzes einer Künstlichen Intelligenz identifiziert, voneinander abgegrenzt und als lokal klimaaktiv bilanziert werden können.

Die initiale Definition der Grünflächen findet aufgrund der heterogenen Ausstattung und Eigenart der Flächen vorerst auf allgemeiner Ebene statt. Hierfür werden verschiedene fachwissenschaftliche/rechtliche Abgrenzungen hinzugezogen. Sie können darauf aufbauend in Gras- bzw. Strauchflächen, Wasserflächen, große Strauchflächen und vegetationslose Bodenflächen sowie vorhandener Baumbestand klassifiziert werden.

Die Analyse der definierten Grünflächen findet mithilfe eines vortrainierten Deep Learning Modells zur Identifikation der allgemeinen Landbedeckungen statt. Hierfür ist im Rahmen der Anwendung der Künstlichen Intelligenz die Nutzung/der Einsatz sehr hochaufgelöster Luftbilder Grundvoraussetzung für eine ausreichend gute Prognose der Lokalisation von Grünflächen und es sollte so eine Identifikation ebendieser Flächen möglich sein.

Die Anwendung dieses vortrainierten Deep-Learning-Algorithmus kann eine Identifikation der grünen Flächen, basierend auf den allgemeinen Landbedeckungen, leisten. Die besten Werte werden hierbei für innerstädtische Lagen erreicht. Die außerhalb der baulichen Strukturen befindlichen Grünflächen werden jedoch aufgrund ihrer Eigenart oftmals falsch abgegrenzt und als Wasserflächen ausgewiesen, sodass durch das vortrainierte Modell eine Gesamtgenauigkeit von lediglich 46 % erreicht wird. Nach Beurteilung der Ergebnisse soll zur potenziellen Verbesserung des Modells ein Nachtrainieren des Deep Learning Algorithmus stattfinden. Das Nachtrainieren des vortrainierten Deep Learning Modells mittels „Transfer Learning“ führt zu einer allgemeinen Verbesserung der Gesamtgenauigkeit auf 78 %. Dabei besitzt das nachtrainierte Modell einen höheren Detailgrad bei der Beurteilung außerstädtischer Grünflächen – innerstädtische Grünflächen hingegen werden im Vergleich zum vortrainierten Modell schlechter identifiziert. Eine sich daran anschließende Kombination aus der Modellierung des vor- und des nachtrainierten Deep Learning Algorithmus führt schließlich zu einer Gesamtgenauigkeit von 86 %.

Darauf aufbauend wird unter Zuhilfenahme der Kombinationsmodellierung die Klimaaktivität der Grünflächen bestimmt. Diese ist charakterisiert durch die potenzielle Kühlleistung der identifizierten Grünflächen mithilfe der Verschattungsanteile, der Bodenoberflächen sowie der absoluten Flächengröße. Hierbei sind die Grünflächen mit niedriger Klimaaktivität in den stark verdichteten und versiegelten innerstädtischen Lagen vorzufinden. Mit einer Zunahme an unversiegelter Fläche nimmt die absolute Flächengröße und damit einhergehend die Klimaaktivität von anfänglichen Kühlleistungen < 1 K in stark versiegelten Gebieten bis zu > 3 K im unversiegelten Bereich außerhalb der Siedlungsräume zu, welche aufgrund der hohen Kühlkraft zudem auch eine Transferwirkung über die eigentliche Grünfläche hinaus besitzen.

Keywords: Urbane Grünflächen, Stadtklima, Klimaanpassung, Künstliche Intelligenz, Blau-Grüne Infrastruktur

2 EINLEITUNG

Prognostizierte Temperaturveränderungen aufgrund des menschengemachten Klimawandels führen zu einer generellen Zunahme der Lufttemperatur. Urbane Räume sind hierbei durch vorhandene bauphysikalische und raumstrukturelle Eigenschaften besonders betroffen. Dies führt dazu, dass die städtische Überwärmung, überdurchschnittlich – ausgelöst durch den Klimawandel – zunimmt. Aufgrund dessen ist es wichtig, neben den Maßnahmen zur Mitigation des Klimawandels auch Maßnahmen zur Adaption an den Klimawandel vorzunehmen.

Eine zentrale Maßnahme zur Anpassung an den Klimawandel stellt die Etablierung, die Erhaltung und die Optimierung innerstädtischer Grünflächen dar. Grünflächen besitzen verschiedene Eigenschaften, welche dabei behilflich sind, das Stadtklima in stark versiegelten und besiedelten urbanen Räumen zu beeinflussen und zu verbessern (IPCC 2023).

Aufgrund der besonderen Stellung von Grünflächen als Bestandteil der Klimaanpassung in urbanen Räumen ist es essenziell, diese bestmöglich zu kartieren. Eine Kartierung fand in der Vergangenheit überwiegend in persona statt und setzte einen hohen zeitlichen und personellen Aufwand voraus. Für die Schaffung einer nachhaltigen Grünflächenkartierung gilt es deswegen zu untersuchen, inwieweit eine (teil-)automatisierte Identifikation von Grünflächen durch den Einsatz der Künstlichen Intelligenz möglich ist. Neben einer bloßen quantitativen Identifikation der Grünflächen (Wo? und Wieviel?) ist es auch Ziel der Forschungsarbeit zu eruieren, welche qualitativen klimaaktiven Effekte (Wie hoch ist die Kühlleistung der Grünflächen?) die jeweiligen (innerstädtischen) Grünflächen aufweisen und inwiefern diese bilanziert werden können.

3 STAND DER FORSCHUNG

Die Identifikation und anschließende Auswertung von Grünstrukturen als Teil der allgemeinen Landbedeckung findet oftmals durch die Auswertung von Fernerkundungs- und Multispektraldaten statt. Die jeweiligen Oberflächen werden bei diesen Verfahren mithilfe ihrer elektromagnetischen Strahlungseigenschaften identifiziert und klassifiziert. Für eine allgemeine Oberflächenklassifikation stehen hierbei verschiedene Klassifikationsmethoden zur Verfügung, welche grundlagentechnisch sowohl auf der Verwendung eines Trainingsgebietes zur Klassifikation der Oberflächen aufbauen (überwachte Klassifikationsverfahren) als auch solche, welche keine zusätzlichen Informationen zur Klassifikation voraussetzen (unüberwachte Klassifikationsverfahren).

Auswertung und Klassifikation finden grundsätzlich bereits mit Methoden des Maschinellen Lernens als Unterbereich der Künstlichen Intelligenz statt. Hier wird mit statistischen Verfahren wie dem Random Forest Algorithmus oder auch die mit der Häufigkeitsverteilung arbeitende Maximum Likelihood Methode in Verbindung mit Maschinellem Lernen gearbeitet (De Lange, 2020) .

Als Unterbereich des Maschinellen Lernens bietet sich zudem die Verwendung des auf die Muster- und Bilderkennung spezialisierten Teilbereichs des „Tiefen Lernens“ (engl. Deep Learning) für die Identifikation und Klassifikation von Grünflächen an. Hierbei wird auf künstliche neuronale Netze zur Identifikation zurückgegriffen. Grundlagendaten für die Bestimmung der Grünflächen sind dabei oftmals Satellitenbilder mit relativ geringer Auflösung (Albert et al., 2017; Nguyen & Chidthaisong, 2022; Zhao, 2022). Neben der Untersuchung der Grünflächen mithilfe der neuronalen Netze findet eine kleinteiligere Untersuchung unter Hinzunahme von Straßenbildern und dem aus dem Nahinfrarot ableitbaren NormalizedDifference Vegetation Index (NDVI) statt (Sun et al., 2021; Wang et al., 2021).

Hinsichtlich vorhandener Literatur bestehen dementsprechend bereits Ansätze zur Identifikation und Klassifikation von Grünflächen sowohl auf übergeordneter Ebene durch Satellitenbilder in Verbindung mit neuronalen Netzen als auch kleinräumigere Untersuchungen unter Zuhilfenahme von Multispektralbildern. Die Forschungsarbeit soll eine Kombination aus beiden Ansätzen untersuchen und eine kleinteiligere Identifikation der Grünflächen mithilfe künstlicher neuronaler Netze eruieren. Hierbei wird auf schon vorhandene Deep Learning Modelle zur allgemeinen Identifikation von Landbedeckungen zurückgegriffen (ESRI, 2024a).

4 UNTERSUCHUNGSGEGENSTAND

Voraussetzung für die Identifikation von Grünflächen mittels neuronaler Netzwerke ist die Auswahl eines passenden Untersuchungsgebietes. Es bietet sich hier an, aufgrund der Voraussetzungen zur Ausführung des Deep-Learning-Modells, ein Gebiet auszuwählen, welches gute Datengrundlagen für eine anschließende Modellierung frei zur Verfügung stellt. Aufgrund der sehr guten Datenverfügbarkeit und der gesamtstädtischen Lokalisation wurde deswegen die Stadt Jena (Thüringen, Deutschland) als Untersuchungsgebiet ausgewählt.

Für eine erfolgreiche Identifikation von Grünflächen ist es zudem wichtig, diese hinreichend zu definieren. Es handelt sich bei den Grünflächen um Flächen, welche sowohl mit natürlicher als auch mit menschengemachter Vegetation ausgestattet sind (L. Li & Pussella, 2017). Sie decken zudem eine breite Anzahl an Ökosystemleistungen ab (Odini & Mhangara, 2012). Arabi et al. (2014) unterteilen Grünflächen in öffentliche, halböffentliche und private Grünflächen sowie in Straßen(begleit)grün (Arabi et al., 2014). Einen anderen Ansatz zur Definition von Grünflächen wählen Yang et al. (2017). Diese differenzieren Grünflächen in sog. angehängte, Straßen- und Parkgrünflächen, produktive Grün- sowie andere Grünflächen (Yang et al., 2017). Wie diese kurze Auswahl aus der Fachliteratur aufzeigt, werden die jeweiligen Arten von Grünflächen bereits differenziert definiert und unterschiedlich abgegrenzt. Allgemein handelt es sich bei diesen Flächen um sehr heterogene Räume ohne scharfe Abgrenzung. Jede fachwissenschaftliche Disziplin grenzt diese unterschiedlich ab (Harasimowicz, 2018).

Auch bei Betrachtung der Definition von Grünflächen im stadtklimatischen Kontext wird deutlich, dass keine allgemeingültige Definition der Grünfläche besteht. Allgemein werden die Ökosystemleistungen aufgegriffen und mit der Speicherung von Kohlenstoff, der Sicherung des Bodens durch das Verhindern der Versiegelung, das Verbessern der Luftqualität sowie der Speicherung von Wasser in Verbindung gebracht. Die stadtklimatische Definition der Grünfläche ist zudem von der Eigenschaft ebendieser geprägt, dass sie angrenzende sowie umliegende Strukturen durch die Prozesse der Evapotranspiration sowie durch eventuell vorhandene Verschattungseffekte abkühlt (klimaaktive Kühlleistung). Diese Eigenschaft haben sowohl großräumige Flächen als auch Einzelbepflanzungen in verschiedenem Maße inne (Bowler et al., 2010).

Weitergehende Attribute, welche die Klimaaktivität einer Grünfläche beeinflussen, sind die Größe und die Lage der Grünfläche, die Form und die Vitalität der Vegetation, die Verbindung mit Wasserflächen sowie exogene Ursachen (z. B. Straßenorientierung, angrenzende Bebauungsdichte) (Bao et al., 2016; Huang et al., 2008; Jaganmohan et al., 2016; Z. Li et al., 2024; Oliveira et al., 2011).

Aufgrund der Heterogenität der Grünflächen sowie deren unterschiedliche Ausstattung ist eine allgemeine Definitionsfindung schwer. Für die weitere Untersuchung werden daher Bestandteile der verschiedenen Definitionen dahingehend kombiniert, dass relativ klar abzugrenzende Grünstrukturen identifizierbar sind. Außerdem handelt es sich bei den Grünflächen zum Zwecke der Identifikation mit Deep Learning Modellen deshalb grundsätzlich um alle Flächen jeglicher Größe, welche den Klassen Gras- /kleine Strauchflächen, große Strauchflächen,unversiegelte Bodenflächen, Baumbestand sowie Wasserflächen zuzuordnen sind.

5 METHODIK

Die Grundlage der Identifikation der Grünflächen stellt ein vortrainiertes Deep Learning Modell mit ursprünglichen Trainingsdaten aus Nordamerika zur allgemeinen Identifikation von Landbedeckungen in Verbindung mit sehr hochauflösenden Luftbildern dar (ESRI, 2024a). Diese werden in ein geographisches Informationssystem (GIS) eingebunden. Mithilfe des Deep Learning Modells sowie der Datengrundlage kann eine Modellierung der Landbedeckungen des Untersuchungsgebietes stattfinden. Nach Entfernen der Landbedeckungen ohne Grünflächenbezug verbleiben die Grünflächenklassen des Modells, welche den entsprechenden Grünflächen zugewiesen werden können. Es kann daran anschließend eine subjektive sowie objektive Analyse und Abschätzung der Genauigkeit stattfinden. Anschließend wird das bereits vortrainierte Modell unter Anwendung von Transfer Learning im GIS mit zentraleuropäischen (deutschen) Landbedeckungen nachtrainiert. Unter dem Hinzuziehen der Modellierungen findet abschließend eine Untersuchung der Klimaaktivität auf Grundlage der durch das Deep Learning Modell identifizierten Grünflächen unter Rückgriff auf eine abgewandelte Methode von Zardo et al. (2017) statt. Hierbei wird die Kühlleistung der verschiedenen Grünflächen mithilfe sogenannter „coolingpoints“ klassifiziert und baut auf den jeweiligen klimaaktiven Eigenschaften der Grünflächen auf. Dabei behandelte Eigenschaften der

Grünflächen, welche die Kühlleistung beeinflussen, sind der Verschattungseffekt, die potentielle Verdunstungsleistung der Fläche, die Art der Bodenbedeckung sowie die absolute Flächengröße (Zardo et al., 2017).

6 MODELLIERUNG MITHILFE DES VORTRAINIERTEN DEEP LEARNING MODELLS

Die Modellierung der Grünflächen in Abbildung 1 mithilfe des vortrainierten Deep Learning Modells zeigt eine sehr heterogene Durchmischung der Grünflächen im Stadtgebiet Jenas auf. Die Analyse der Prognosen der Modellierung lässt sich schwerpunktmäßig sowohl in den stark versiegelten Siedlungsbereich Jenas als auch in den weniger bis gar nicht versiegelten Bereich außerhalb der Siedlungsräume aufteilen.

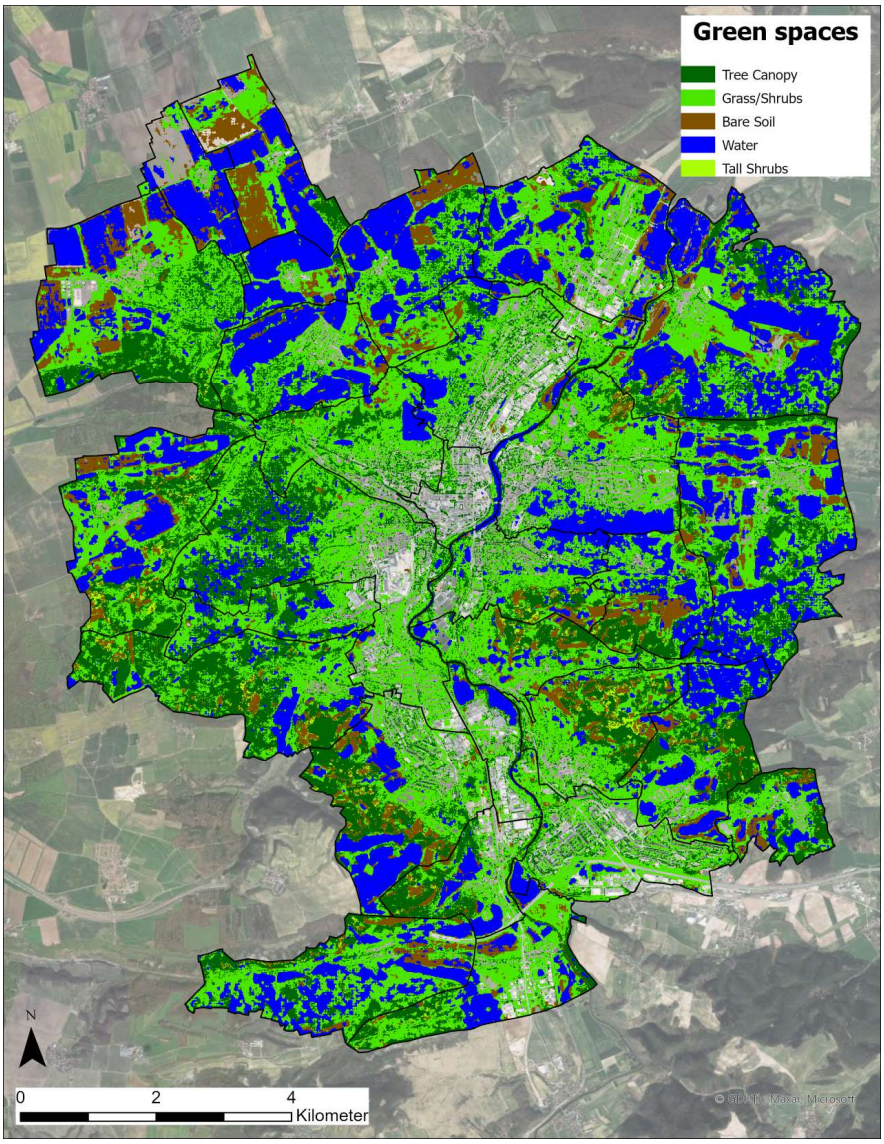

Abb. 1: Modellierung der Grünflächen des Stadtgebietes von Jena mithilfe des vortrainierten Deep Learning Modells (Eigene Darstellung in ArcGIS Pro in Verbindung mit den Deep Learning Libraries (Version 3.3), Datengrundlage: © GDI-Th, Esri, EarthstarGeographics, Maxar, Microsoft und Layer Grünflächen)

Die Untersuchung der peripher gelegenen Bereiche Jenas zeigt eine durchmischte Modellierung von Grünflächen auf. Hervorzuheben ist ein sehr hoher Anteil an (fälschlicherweise) ausgewiesenen Wasserflächen in den Bereichen, bei denen es sich um großflächige heterogene Flächen handelt (z. B. Wälder und Wiesen). Diese werden durch die Modellierung aufgrund ihrer Struktur, ihrer Heterogenität sowie der geringeren Auflösung der verwendeten DOPs als Wasserflächen ausgewiesen.

Bei Betrachtung der Modellierung des innerstädtischen Bereiches wird deutlich, dass es hier im Großen und Ganzen zu einer Ausweisung von Gras- und Strauchflächen sowie von Baumflächen kommt. Wasserflächen werden auch in innerstädtischem Kontext vereinzelt (fälschlicherweise) ausgewiesen, aber es zeigt sich, dass

eine deutlich verbesserte Identifikation der Grünflächen in innerstädtischer Lage im Vergleich zu außerhalb der Siedlungsstrukturen zu verortenden Grünflächen stattfindet.

Insgesamt kommt es bei der Modellierung des vortrainierten Deep Learning Modells zur Identifikation der Grünflächen unter dem Hinzuziehen einer Konfusionsmatrix mithilfe des Vergleiches von Referenzwerten (Ground Truth Werten) zu einer Gesamtgenauigkeit von ca. 46 %.

Zur Verbesserung der Genauigkeit bei der Identifikation und Klassifikation kann das vortrainierte Deep Learning Modell mittels Transfer Learning im GIS mit verhältnismäßig wenig Aufwand nachtrainiert werden (Wallace, 2023). Hierbei wird das vortrainierte Deep Learning Modell mithilfe ausgewählter Trainingsdaten dahingehend nachtrainiert, dass es mit den zur Verfügung stehenden Grundlagendaten (20 x 20 cm Bodenauflösung, zentraleuropäische Vegetation) eine erhöhte Genauigkeit im Vergleich zum ursprünglichen Modell aufweist.

7 MODELLIERUNG MITHILFE DES NACHTRAINIERTEN DEEP LEARNING MODELLS

Die Modellierung des mit Transfer Learning nachtrainierten Deep Learning Modells in Abbildung 2 weist insbesondere bei den außerhalb der Siedlungsräume liegenden Strukturen eine subjektiv deutlich akkuratere Ausweisung von Grünflächen auf.

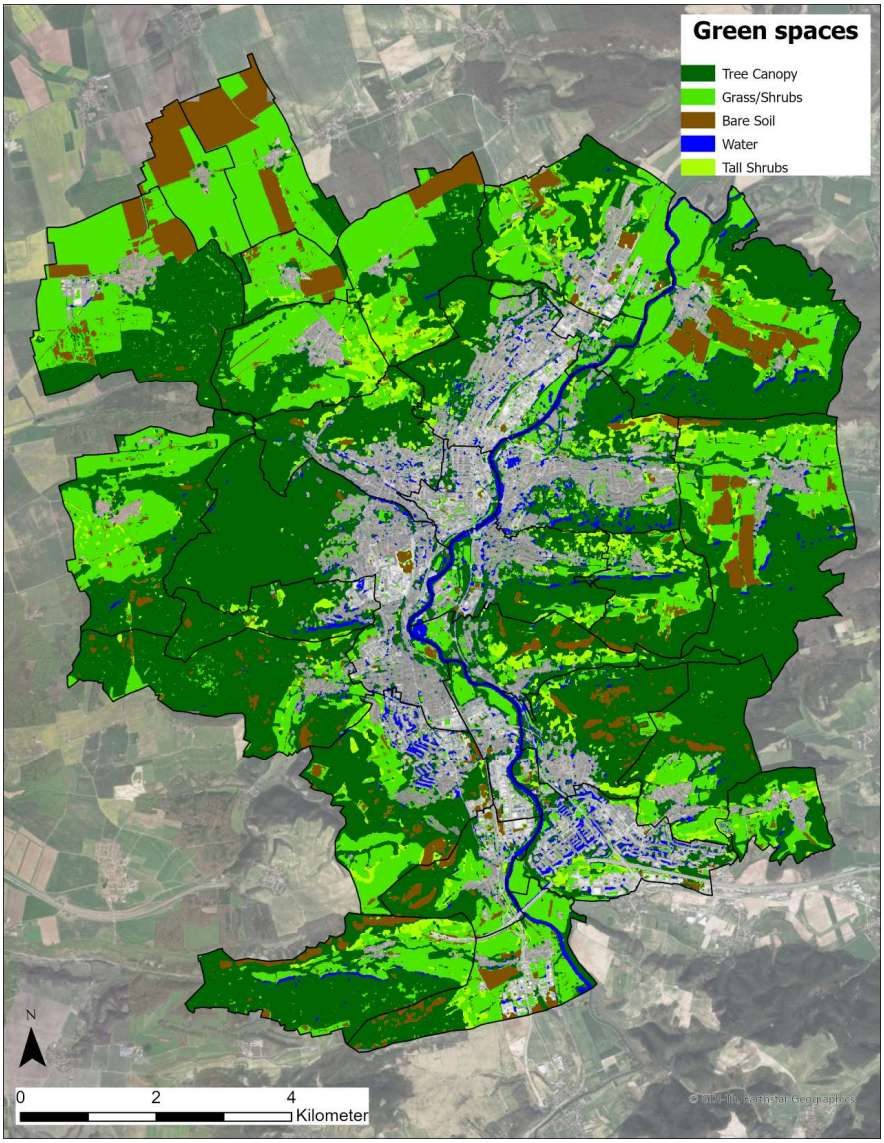

Abb. 2: Modellierung der Grünflächen des Stadtgebietes von Jena mithilfe des nachtrainierten Deep Learning Modells (Eigene Darstellung in ArcGIS Pro in Verbindung mit den Deep Learning Libraries (Version 3.3), Datengrundlage: © GDI-Th, Esri, EarthstarGeographics, Maxar, Microsoft und Layer Grünflächen nachtrainiertes Modell)

Es kommt im Vergleich zu der Modellierung des vortrainierten Modells in den periphereren Gebieten zu einer hauptsächlichen Ausweisung von Gras- und Strauchflächen, Baumflächen sowie Flächen mit großen

Sträuchern. Leider zeigt sich in der nachtrainierten Version aber auch, dass, wenn die Genauigkeit der Identifikation von Grünflächen in den äußeren Gebieten Jenas in subjektiver Betrachtung zugenommen hat, deutlich weniger Grünflächen in innerstädtischer Lage identifiziert werden. Dies ist vermutlich darauf zurückzuführen, dass die Auswahl der Trainingsdaten – insbesondere in innerstädtischer Siedlungsstruktur – aus sehr diversen und heterogenen Strukturen besteht. Dies führt dazu, dass keine eindeutig abzugrenzenden Strukturen entstehen. Infolgedessen wird von dem nachtrainierten Modell ein Großteil der innerstädtischen Grünflächen einer grünflächenfremden Landbedeckung (i. d. R. baulichen Strukturen) zugeordnet.

Allerdings zeigt sich alles in allem, dass die differenzierte Ausweisung von Grünflächen im Vergleich zur vorherigen Untersuchung der vortrainierten Deep Learning Modellierung zu einer Gesamtgenauigkeit des nachtrainierten Modells von ca. 78 % führt. Somit besitzt das nachtrainierte Modell eine deutlich höhere Gesamtgenauigkeit im Vergleich zum vortrainierten Modell – systematische Schwächen bestehen jedoch in der Ausweisung von Grünflächen in innerstädtischer Lage.

8 HYBRIDMODELLIERUNG

Für eine optimierte Ausweisung der Grünflächen sowohl in innerstädtischer als auch in peripherer Lage bietet es sich an, die Grünflächenmodellierung des vortrainierten Modells in innerstädtischer Lage und die Modellierung der Grünflächen des nachtrainierten Modells außerhalb der dicht besiedelten Bereiche zu verschneiden und eine Hybridmodellierung durchzuführen, die die Stärken beider zuvor eingesetzten Modellierungen vereint.

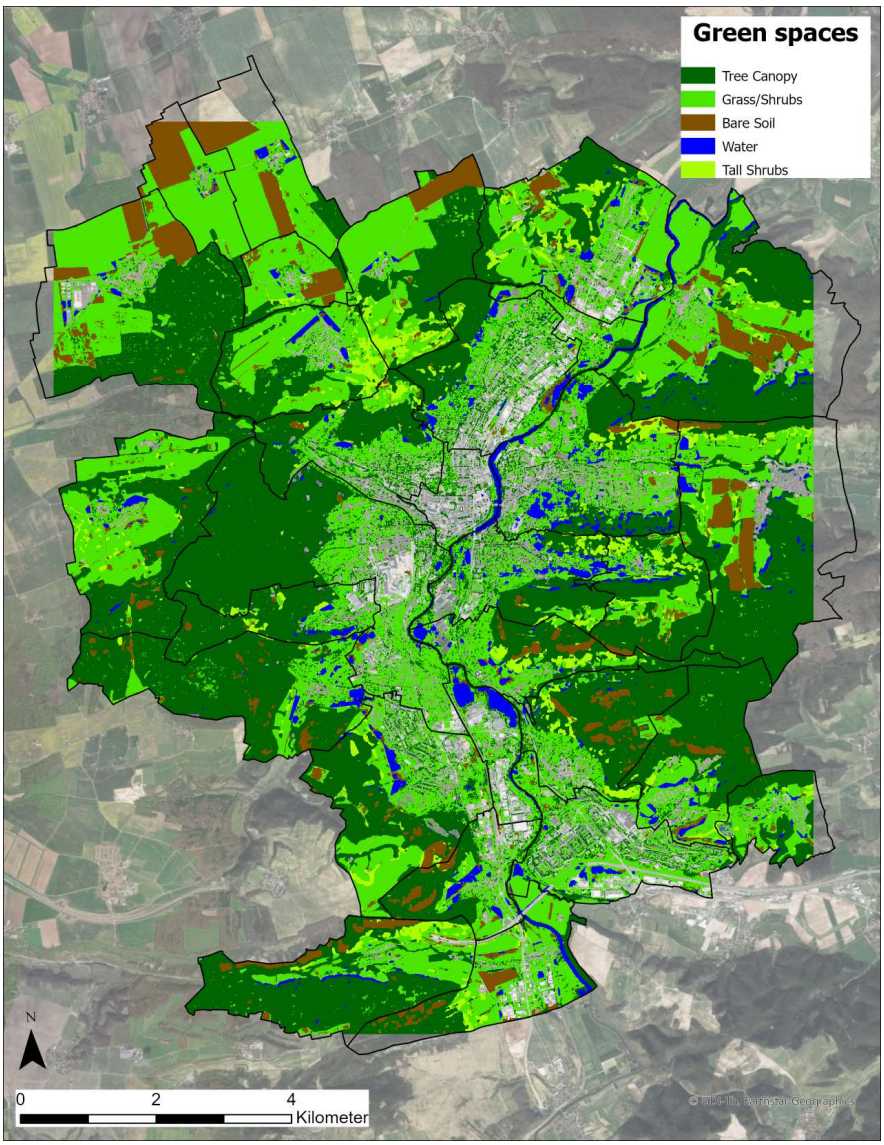

Abb. 3: Hybridmodellierung der Grünflächen des Stadtgebietes von Jena mithilfe der Kombination des vortrainierten sowie des nachtrainierten Deep Learning Modells (Eigene Darstellung in ArcGIS Pro in Verbindung mit den Deep Learning Libraries (Version 3.3), Datengrundlage: © GDI-Th, Esri, EarthstarGeographics, Maxar, Microsoft und Layer Hybridmodellierung Grünflächen)

Die Hybridmodellierung in Abbildung 3 zeigt insgesamt ein deutlich einheitlicheres Bild bei der Identifikation der Grünflächen im gesamten Stadtgebiet auf. Die Grünflächen werden subjektiv sowohl innerhalb als auch außerhalb der Siedlungsräume überwiegend identifiziert und korrekt klassifiziert. Mithilfe der Kombination der beiden ursprünglichen Modellierungen kann mit der Hybridmodellierung eine Gesamtgenauigkeit von ca. 86 Prozent erreicht werden, was als ein mehr als ausreichendes Ergebnis für die initiale Identifikation von Grünflächen bezeichnet werden kann. Auf Grundlage der durch die Hybridmodellierung identifizierten Grünflächen muss anschließend eine grundlegende Bestimmung der Klimaaktivität der zu differenzierenden Flächen erfolgen.

9 KLIMAAKTIVITÄTSBESTIMMUNG

Die Klimaaktivität der Grünflächen kann je nach unmittelbarer Kühlleistung in verschiedene Klassen eingeteilt werden. Es handelt sich hierbei um Grünflächen mit sehr geringer Kühlleistung (< 1 K), Grünflächen mit geringer Kühlleistung (> 1 K < 2 K), Grünflächen mit einer hohen Kühlleistung (> 2 K < 3 K) sowie Grünflächen mit einer sehr hohen Kühlleistung (> 3 K) (Zardo et al., 2017).

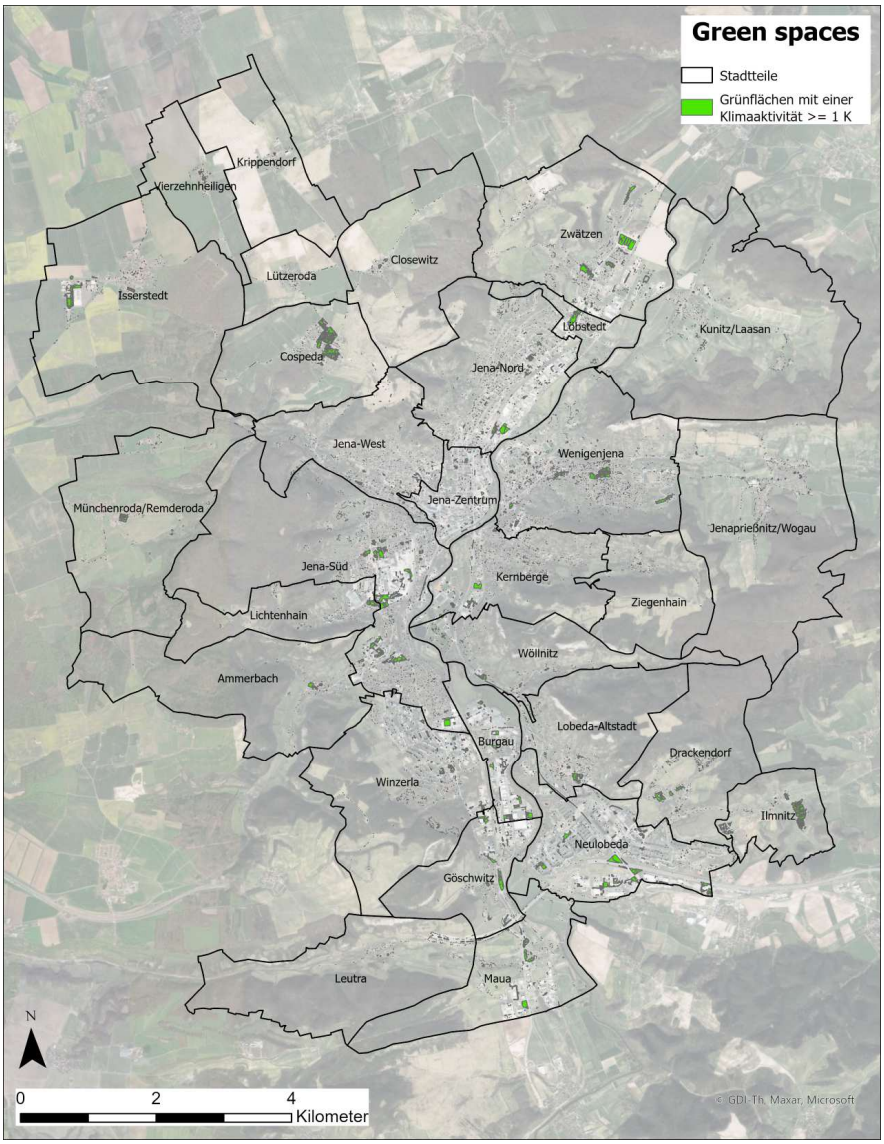

Abb. 4: Klimaaktive Grünflächen mit einer sehr geringen Kühlleistung < 1 K innerhalb des Untersuchungsgebietes von Jena (Eigene Darstellung in ArcGIS Pro in Verbindung mit den Deep Learning Libraries (Version 3.3), Datengrundlage: © GDI-Th, Esri, EarthstarGeographics, Maxar, Microsoft, Stadt Jena, dl-de/by-2-0 (http://www.govdata.de/dl-de/by-2-0), URL: https://opendata.jena.de/dataset/ortsteile und Layer Grünflächen mit einer Klimaaktivität >= 1 K, Stadtteile)

Bei der Betrachtung der klimaaktiven Grünflächen mit einer sehr geringen Kühlleistung in Abbildung 4 wird ersichtlich, dass diese insbesondere in den dicht versiegelten Bereichen im Stadtgebiet von Jena vorzufinden sind. Es handelt sich bei diesen Flächen mit sehr geringer Klimaaktivität um Bereiche mit einer absoluten Flächengröße < 2 ha sowie einem anteilsweise geringen Baumbestand. Flächen, welche dieser

Klimaaktivitätsklasse zugeordnet werden können, sind kleine zusammenhängende Gartenstrukturen, kleinere Abschnitte von Straßenbegleitgrün sowie einzelne Grasflächen.

Die darauffolgende Klasse hinsichtlich der Klimaaktivität aufgrund ihrer abrufbaren Kühlleistung definiert sich durch eine absolute Flächengröße < 2 ha, allerdings mit einem deutlich höheren prozentualen Baumbestand innerhalb der Fläche im Vergleich zur vorherigen mit sehr geringer Klimaaktivität.

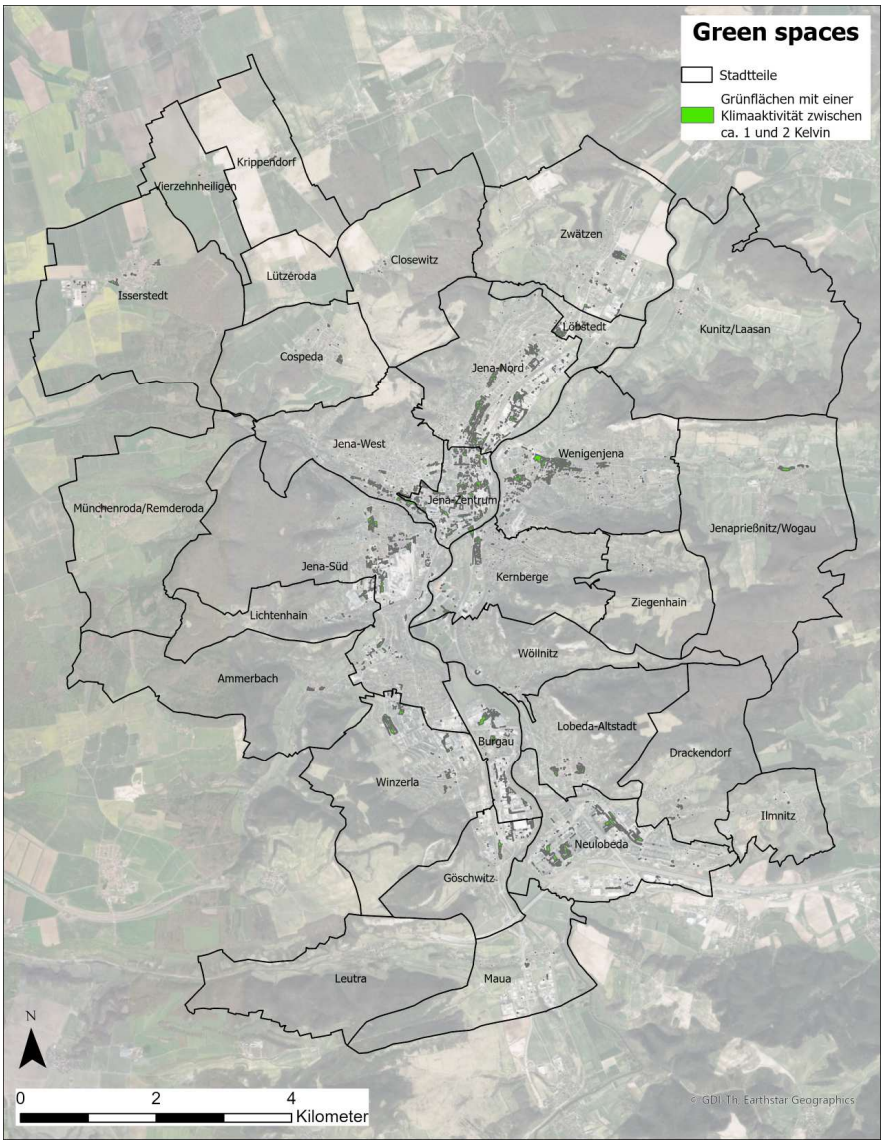

Abb. 5: Klimaaktive Grünflächen mit einer geringen Kühlleistung (> 1 K < 2 K) innerhalb des Untersuchungsgebietes von Jena (Eigene Darstellung in ArcGIS Pro in Verbindung mit den Deep Learning Libraries (Version 3.3), Datengrundlage: © GDI-Th, Esri, EarthstarGeographics, Maxar, Microsoft, Stadt Jena, dl-de/by-2-0 (http://www.govdata.de/dl-de/by-2-0), URL: https://opendata.jena.de/dataset/ortsteile und Layer Grünflächen mit einer Klimaaktivität zwischen ca. 1 und 2 Kelvin, Stadtteile)

In Abbildung 5 wird deutlich, dass Grünflächen mit einer geringen Klimaaktivität subjektiv aufgrund ihres höheren Baumanteils an der absoluten Flächengröße tendenziell größere Bereiche einnehmen, als dies bei den Grünflächen mit einer sehr geringen Klimaaktivität der Fall war. Sie sind noch immer in den dicht besiedelten und versiegelten Räumen vorzufinden, haben sich jedoch hinsichtlich ihrer räumlichen Verteilung in Richtung der Kernstadt (insbesondere Jena-Zentrum sowie Jena-Nord) verschoben. Aufgrund ihrer Standorte und ihren zuordenbaren Eigenschaften handelt es sich bei diesen Flächen beispielhaft um bepflanzte Innenhöfe von Blockbauten, Straßenalleen sowie kleineren Stadtparks. Daher lässt sich insgesamt festhalten, dass die Grünflächen mit sehr geringer und geringer Klimaaktivität überwiegend in den Siedlungsräumen vorzufinden sind. Sie tragen zur Kühlung der unmittelbaren Umgebung nur in geringem Maße bei und stellen einen untergeordneten Teil des Siedlungsraumes dar.

Die Flächen mit einer hohen und sehr hohen Klimaaktivität mit Kühlleistungen von > 3 K werden mithilfe des Deep Learning Algorithmus grundsätzlich den außerhalb der Siedlungsräume liegenden Grünflächen zugewiesen (Gesamtstadt Jena exkl. Jena-Zentrum, Jena-Nord, Jena-Süd sowie Wenigenjena).

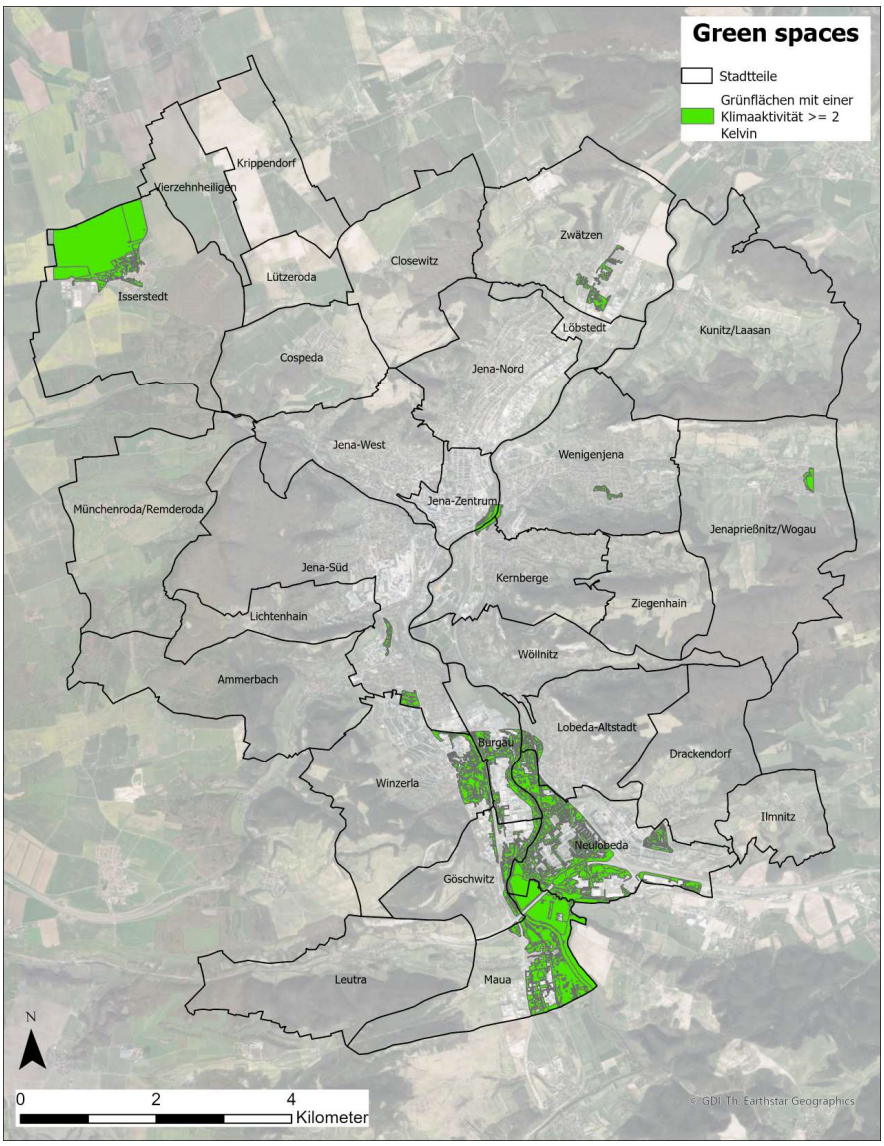

Abb. 6: Klimaaktive Grünflächen mit einer hohen Kühlleistung > 2 K < 3 K innerhalb des Untersuchungsgebietes von Jena (Eigene Darstellung in ArcGIS Pro in Verbindung mit den Deep Learning Libraries (Version 3.3), Datengrundlage: © GDI-Th, Esri, Maxar,EarthstarGeographics, Microsoft, Stadt Jena, dl-de/by-2-0 (http://www.govdata.de/dl-de/by-2-0), URL: https://opendata.jena.de/dataset/ortsteile und Layer Grünflächen mit einer Klimaaktivität >= 2 Kelvin, Stadtteile)

So ist in den Abbildungen 6 und 7 erkennbar, dass die Grünflächen mit einer hohen sowie sehr hohen Klimaaktivität größtenteils außerhalb der Siedlungsbereiche liegen. Diese sind in ihrer absoluten Fläche größer als zwei Hektar und besitzen einen anteiligen Baumbestand zwischen 0 und 40 % (Flächen mit einer hohen Kühlleistung) respektive über 40 % an der Gesamtfläche (Flächen mit einer sehr hohen Kühlleistung).

Die außerhalb der Siedlungsräume liegenden Grünflächen ziehen sich durch Grünverbindungen bis in den Siedlungskern hinein. So ist es möglich, dass Flächen, welche ursprünglich keine bzw. eine deutlich geringere Kühlleistung aufweisen, durch die Verbindung mit anderen Grünflächen, in Summe eine höhere Kühlleistung abrufen können.

Bei den Flächen mit sehr hoher Klimaaktivität, welche in Abbildung 7 zu erkennen sind, handelt es sich um sehr große, außerhalb der Siedlungsräume zu lokalisierende Grünräume in Form von Wiesen, Feldern und Wäldern – aber auch große innerstädtische Grünräume wie Stadtparks.

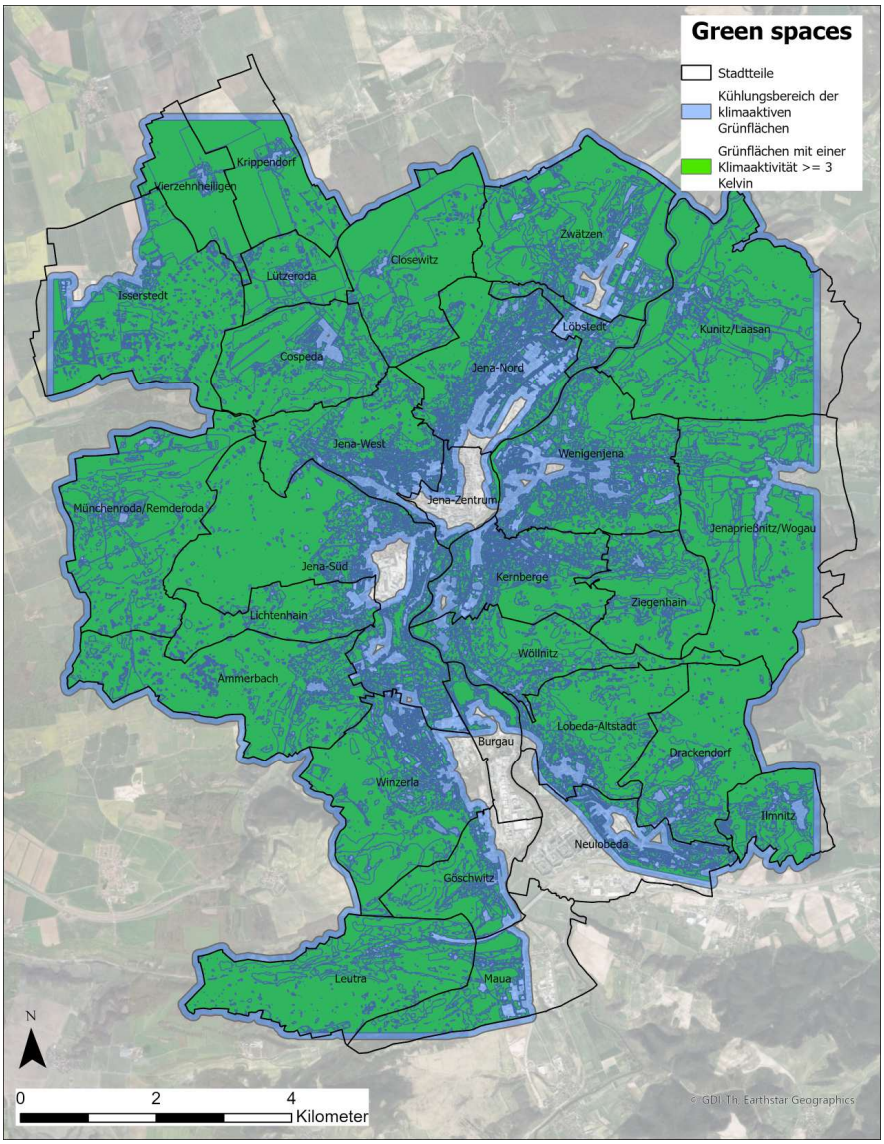

Abb. 7: Klimaaktive Grünflächen mit einer sehr hohen Kühlleistung > 3 K sowie einer Transferkühlleistung von 100 Metern über die eigentliche Grünfläche hinweg, innerhalb des Untersuchungsgebietes von Jena (Eigene Darstellung in ArcGIS Pro in Verbindung mit den Deep Learning Libraries (Version 3.3), Datengrundlage: © GDI-Th, Esri, EarthstarGeographics, Maxar, Microsoft, Stadt Jena, dl-de/by-2-0 (http://www.govdata.de/dl-de/by-2-0), URL: https://opendata.jena.de/dataset/ortsteile und Layer Kühlungsbereich der klimaaktiven Grünflächen, Grünflächen mit einer Klimaaktivität >= 3 Kelvin, Stadtteile)

Es handelt sich bei den Flächen mit sehr hoher Klimaaktivität um Bereiche, die eine unmittelbare Kühlleistung auf ihre nähere Umgebung aufweisen, aber auch Transferkühlleistungen erbringen. So kommt es zu Transferkühlleistungen von ca. 110 Metern um großangelegte Parks. Die unmittelbaren Kühlleistungen von Grünräumen mit einem hohen Anteil an Bäumen, wie beispielsweise Wälder, weisen Transferkühlleistungen von ca. 190 Metern auf. Unter Berücksichtigung der siedlungsstrukturellen Besonderheiten wie beispielsweise der Blockade der unmittelbaren Kaltluft wird hier mit einer Kühltransferleistung von 100 Metern in Form eines Puffers um die klimaaktiven Grünflächen gearbeitet (Jaganmohan et al., 2016; Syrbe et al., 2024).

10 AUSBLICK UND HERAUSFORDERUNGEN

Insgesamt kommt es zu einigen Herausforderungen bei der Modellierung von Grünflächen sowie deren Klimaaktivität. Sie liegen in der Schwierigkeit bei der Definition einer allgemeinen Abgrenzung für eine solche Fläche, in der generellen Arbeit mit Künstlicher Intelligenz im Allgemeinen und Deep Learning Modellen im Speziellen sowie den damit verbundenen Grundlagendaten für die Berechnung der Modellierung bzw. deren Verfügbarkeit.

Wie bereits erwähnt, handelt es sich bei der Begrifflichkeit der Grünfläche keinesfalls um eine allgemeingültige sowie universal anerkannte. Je nach Situation, Ziel sowie anderen Rahmenbedingungen

wird diese subjektiv definiert. Dies macht es schwierig, die „eine“ Grünflächendefinition zu finden. Für die Identifikation dieser Räume mithilfe des Instrumentes der Künstlichen Intelligenz wird mittels einer Kombination aus verschiedenen Abgrenzungen für Grünflächen eine subjektiv definierte Begrifflichkeit für die weiteren Untersuchungen formuliert.

Eine weitergehende Herausforderung besteht in der Abhängigkeit bei der Auswahl des Deep Learning Modells und den damit verbundenen ursprünglichen Trainingsdaten bzw. dem ursprünglichen Trainingsgebiet. Im konkreten Fall handelt es sich um einen Algorithmus, der mithilfe sehr hochauflösender (10 x 10 cm Bodenauflösung) Luftbilder aus dem nordamerikanischen Raum initial trainiert wurde. Er funktioniert dementsprechend mit diesen Inputdaten am besten. Wird nun ein mitteleuropäischer Raum mit den frei zur Verfügung stehenden Luftbildern mit einer sehr hohen Auflösung (20 x 20 cm Bodenauflösung) durch den Algorithmus modelliert, kommt es aufgrund verschiedener geometrischer Auflösung, Landbedeckungsarten bzw. unterschiedlicher Vegetation auch zu differenzierten Prognosen, mit – im Endeffekt – einer Verschlechterung der Ergebnisse.

Für die bestmögliche Modellierung der Grünflächen ist es demnach nötig, so nah wie möglich an die für das ursprüngliche Training verwendete Daten hinsichtlich ihrer Eigenschaften (z. B. Auflösung, Landbedeckungs-/Grünflächenarten, etc.) zu gelangen. Es besteht dementsprechend eine Abhängigkeit in Bezug auf die Grundlagendaten.

Ebenso ist die korrekte Identifikation bodennaher Grünflächen mit Fernerkundungsdaten in Verbindung mit der Identifikation von ebendieser mithilfe Künstlicher Intelligenz eine weitere Herausforderung. Dies wird insbesondere dann zum Problem, wenn Landbedeckungen verschiedener vertikaler Ausdehnung übereinanderliegen und hierdurch durch das Luftbild nicht ausreichend dargestellt werden. Eine korrekte Bilanzierung der Grünflächen wird somit deutlich erschwert. Abhilfe geschaffen werden kann hier mit der Anwendung von Interpolation.

Insgesamt lässt sich feststellen, dass eine grundsätzliche Identifikation von Grünflächen mithilfe Künstlicher Intelligenz möglich ist. Differenziert werden muss dahingehend – aufgrund der unterschiedlichen Eigenschaften – zwischen dem Siedlungsraum und dem unbesiedelten bzw. weniger dicht besiedelten (oftmals peripheren) Raum. Aufbauend auf der Identifikation der Grünflächen ist es zudem initial möglich, eine Bestimmung der Klimaaktivität, definiert durch die abrufbaren Kühlleistungen der Grünflächen, vorzunehmen. Die Identifikation (klimaaktiver) Grünflächen unter der Zuhilfenahme von Künstlicher Intelligenz stellt dahingehend ein Instrument mit sehr hohem Potenzial dar, welches für eine Kartierung sowie Optimierung der Grünflächen innerhalb des Bestandes genutzt werden kann.

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reviewed paper

Digital Approaches to Dealing with Ageing-Related Challenges at Different Levels in Japan

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1 ABSTRACT

The "World Social Report 2023: Leaving no one behind in an ageing world" by the United Nations describes the ageing of the world's population as an irreversible global trend. This trend is particularly significant in Japan. Here, the ageing processes have progressed much further than in other countries, also driven by two age cohorts with particularly high birth rates, known as the baby boom, followed by decades of a baby bust (Nennstiel 2011; Reher 2015). This has fundamental social and spatial implications (Pauly and Pallagst forthcoming).

Digitalization processes are being strongly promoted in Japan. As part of the Japanese government's Society 5.0 program, all areas of life are to be digitalized as an approach to overcome social challenges. Cyberspace and physical space are to be merged (Hitachi-UTokyo Laboratory 2018; Pallagst et al. 2024).

This raises the question of how the Japanese approach to digitalization actually addresses the social and spatial challenges posed by ageing processes. At national level, the PLATEAU project must be mentioned in this context, in which the Japanese government is developing a national digital twin in which around 500 cities are being modeled (Seto et al. 2023, MLIT n.d.) as well as a national big data analysis tool for strategic benchmarking purposes (Matsuura 2020). On the local and regional level, on the other hand, there is a focus on the development of platforms that create a digital space designed to overcome barriers caused by physical limitations and social isolation. Metaverse environments of communities with use cases like avatar cafés, for example, are emerging. (Pauly and Pallagst forthcoming).

The mentioned digital approaches at different levels in Japan are discussed in this contribution and linked to ageing-related challenges that were derived as part of the research project "Ageing Smart – Designing Spaces Intelligently". Interviews with experts and stakeholders on site in Japan in 2024 provided important insights in this regard.

Keywords: Digitalization in Spatial Planning, Social and Spatial Challenges, Ageing Society in Japan, Digital Twin, Metaverse

2 INTRODUCTION

In Japan, there is a strong affinity for new digital technologies. The Japanese national government often plays a key role in technology development, creating strategic plans and funding their implementation with significant financial resources. One example of this is the Society 5.0 vision in the "Science and Technology Basic Plan" y the Japanese government. Through this funding program, digital innovations are being developed to address social and societal challenges (Hitachi-UTokyo Laboratory 2018; Pallagst et al. 2024).

A major example of social and societal challenges is population ageing. It is by no means a phenomenon that is limited to a few regions in the world. Rather, it is a global trend that emerged in the middle of the twentieth century and is considered irreversible (United Nations 2023a, p. 18). In 2022, 9.7% of the world's population were 65years oldor older, and 16.4% are projected for 2050 (United Nations 2023b, p. 8). More developed countries have generally been confronted with the ageing process for many decades, while for many less developed countries it is a new phenomenon and they are still in transition (United Nations 2023a, p. 18). The ageing of the population and resulting population decline are the crucial characteristics of demographic change. It is a trend that has not lost its relevance, but on the contrary, is becoming increasingly important. Demographic change is a topic that has global effects and requires in-depth investigations and an international search for solution strategies.

Ageing populations sometimes lead to drastic problems that pose significant challenges for countries and their municipalities. An ageing society has very specific demands on services and infrastructure, which must

therefore be adapted. While there is an increasing demand for personnel in the healthcare and elderly care sectors, the number of people in the working age population simultaneously decreases (OECD 2019, p. 19; Swiaczny et al. 2008, p. 200; Yu and Lee 2017, pp. 442-444). The phenomenon of social isolation is increasingly spreading in society, and more spaces with homogeneous age structures and 'ghost towns' are emerging (Interview with Dimmer 2024).

However, social and spatial issues arising from ageing are influenced by various factors. They do not solely result from population development but also from path dependencies that differ depending on the country's context. Cultural and governance-structural issues can play a role, among others. Therefore, it is necessary to consider ageing problems and potential approaches for solutions within a specific country context.

As part of the research project "Ageing Smart – Designing Spaces Intelligently", the ageing processes in three countries – the USA, Finland and Japan – were compared with each other. Japan was identified as an extreme example where population ageing is particularly advanced (Pauly and Pallagst forthcoming). This finding is taken up in this article and used as an opportunity to take a more focused look at ageing in Japan and the resulting problems and approaches to solutions at various levels.

The aim is to look beyond the German context in which the research project is situated. Japan represents an extreme example in this regard. Age-related problems have been particularly pronounced here for at least two decades and have a significant impact on civil society. Studying a country where demographic change has been recognized as particularly advanced for a longer period offers distinct advantages for the research and learning opportunities. The investigation makes it possible to identify solution strategies that could also be applicable to other contexts around the world. The findings can provide valuable information for countries and municipalities that are increasingly confronted with demographic challenges and are looking for strategies to address them.

This contribution first examines indicators that describe the ageing processes in Japan. For this purpose, population data is used and analyzed. Then, the social and spatial challenges Japan faces due to its demographic developments are described. Building on this, the digital solution strategies Japan is implementing to address these challenges are explored. For the investigation of the social and spatial implications as well as possible digital solution strategies, guided interviews were conducted on-site in Japan. These interviews involved experts from the academic field in Japan, as well as stakeholders from public administration. On the academic side, interviews were conducted with a researcher from Waseda University in Tokyo and with representatives from the German Institute for Japanese Studies. On the administrative side, interviews took place with officials from the Tokyo Metropolitan Government and the city administration of Takamatsu. Additionally, on-site walks were conducted in Tokyo and Takamatsu.

3 POPULATION AGEING IN JAPAN

As part of an international comparison, Pauly and Pallagst (forthcoming) have carried out an analysis of population data that is suitable for describing ageing processes in a country. This analysis is taken up and summarized here for the specific case of Japan.

The ageing of a population is strongly linked to the number of births in that population. If the number of births declines, the proportion of older people in the population slowly increases over time. The crude birth rate is the ratio of the number of births to the total population and thus provides information about the fertility of a society. However, these factors are closely linked to mortality, for example indicated by the number of deaths in each period.Inward and outward migration also influences the structure of the population and thus ageing processes.Another influencing factor is life expectancy. If life expectancy increases, this means that the people in society tend to get older. Such a trend alone would already lead to ageing. In combination with falling birth rates, this is an aggravating factor. Looking at the composition of the population by age or age group reveals how large the proportions of people of certain ages are. If the development is observed over several decades, trends in the population composition can be identified. Finally, the factor of the proportion of people aged 65 and over indicates how large the proportion of the older population actually is.

In terms of population development, it can be observed that Japan experienced strong population growth in the twentieth century. Since the end of the 1970s, this growth has continued to slow down. In 2009, the

population peaked at just over 128 million inhabitants. Since then, negative population growth has been observed. By 2021, the population had shrunk by almost 3% to less than 125 million inhabitants.

Fig. 1 shows a comparison of the population trend with the trend in live births and deaths. It illustrates that live births have fallen almost every year since the 1970s. At the same time, the number of deaths has been steadily increasing since the 1980s. In 2005, the number of deaths exceeded the number of live births for the first time. This trend has continued up to the latest available data and can explain the population development with initially weaker growth from the 1970s until the peak was reached in 2008 and the subsequent population shrinkage. What is striking about net migration is that it has alternated between a positive and a negative migration balance over the course of history, without appearing to have a significant influence on population development. Since 1988, net migration has always been above zero, meaning that there is more immigration than emigration in Japan. Net migration reached its highest level in 2019. Nevertheless, it should be noted that the positive migration balance is not able to compensate for the population decline caused by the negative natural population balance.

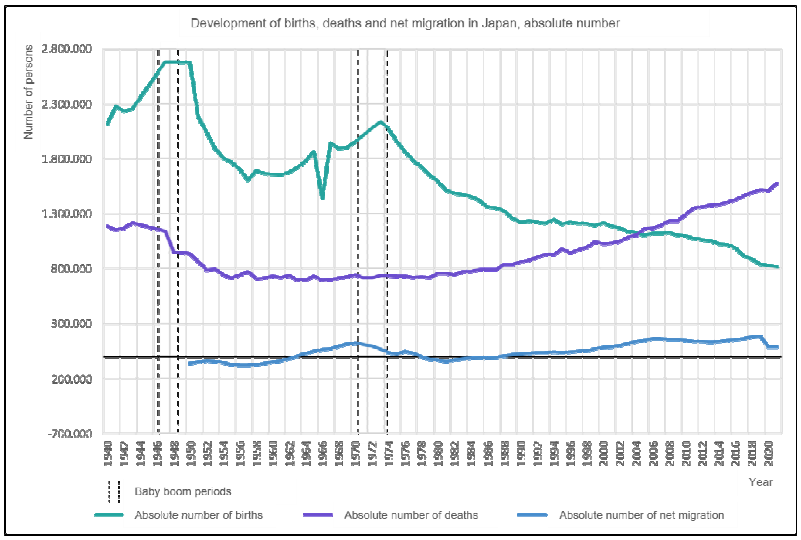

Fig. 1: Development of Births, Deaths and Net Migration in Japan, Own Representation, Data: United Nations, Department of Economic and Social Affairs, Population Division 2024, National Institute of Population and Social Security Research n.d., Statistics Dashboard, Statistics Bureau, Ministry of Internal Affairs and Communications n.d.

Even in the first half of the 20th century, the number of live births was already at a high level. After the Spanish flu, then concerns about the social consequences of overpopulation and the prospect of war caused a decline in births in the previous decades, social policy in the late 1930s and early 1940s led to marriage and childbearing being strategically promoted in the context of military conflicts, resulting in an increase in births (Nennstiel 2011, p. 334). The effects of the Second World War also caused the birth rate to fall in 194 and 1946. Very quickly after the end of the Second World War, however, the number of births rose again, leading to a first baby boom from 1947 to 1949. Remigrants from former overseas territories and war returnees were factors influencing this development (Nennstiel 2011, p. 335). A subsequent renewed decline in births can be explained by eugenics policy and the associated reduction in legal barriers to abortions (Nennstiel 2011, p. 336). In 1966, the graph shows a strikingly sharp decline in live births. This can be explained by the myth about the Year of the Fire Horse, which recurs every 60 years and states that people born in these years are considered to be particularly aggressive (Nennstiel 2011, p. 330). The second baby boom in Japan took place between 1971 and 1974, with a direct connection to the first baby boom generation, as the people who were born during the first baby boom became parents themselves in the early 1970s (Nennstiel 2011, p. 339).

The decline in births in the following decades up to the present cannot be unambiguously explained. Influencing factors discussed include the increased employment of women, but also a decreasing tendency to marry and start a family due to the risk of social demotion against the background that the income of a male single earner is no longer sufficient for the living costs of a family (Schad-Seifert 2006, p. 34-35).

It can be stated that the baby boom in Japan has a statistically detectable effect. There is the peculiarity that two different cohorts are associated with the baby boom:

- 1st baby boom 1947 to 1949
- 2nd baby boom 1971 to 1974

The crude birth rate, which indicates how many live births there were per 1000 inhabitants within a survey year, can be used to make a statement about fertility. If the crude birth rate falls in the sense of a long-term trend, this inevitably means that the population is getting older, as the age group distribution is changing. In theory, this effect could only be compensated by particularly strong and young migration and/or the occurrence of particularly young mortality with falling life expectancy, but this is unlikely to occur in practice.

For Japan it can be observed that the crude birth rate is falling rapidly, which indicates a significant ageing of the population. While the birth rate was particularly high at the beginning of the period under review in 1950 with over 28 births per 1,000 inhabitants, it was extremely low in 2021 with less than 7 births per 1,000 inhabitants. The high birth rates of the 1940s and 1950s are due in particular to the first baby boom. After the subsequent fall in the birth rate, however, the trend is initially positive again, culminating in a second baby boom from 1971 to 1974. This is followed by another negative trend, which continues to the present.

Life expectancy is another factor in connection with the ageing process of a population. If life expectancy were stable in its development, a falling birth rate alone would cause the proportion of older people in a population to rise, ignoring migration effects. This makes it clear that life expectancy, which in reality is not stable but actually increasing, is an additional driver for ageing.

In Japan life expectancy has risen sharply. In 1950, it was just over 59 years, whereas in 2021 it was almost 85 years. This clearly shows that rising life expectancy is continuing to push the ageing population forward.

In order to better illustrate the characteristics of ageing processes in Japan, fig. 2 analyzes the population according to age groups and the statistically surveyed genders male and female. Four points in time were selected with an interval of 20 years. The observation period was chosen so that the population distribution is shown over several generations.

In Japan, the baby boom of the years 1947 to 1949 is very clearly visible in 1960. This is illustrated in the age groups 10-14 and 15-20, which represent the largest groups in the population in 1960. It is noticeable how small the population proportions of the older age groups are. This makes it clear that the population in Japan was very young at this time.

Twenty years later, in 1980, the baby boom cohorts are still visible as particularly large age groups of 30-34- and 35–40-year-olds. It is also clear that there were fewer births in the following years. However, the second Japanese baby boom of 1971-1974 can now be seen in the 5-9 and 10-14 age groups. Both baby booms are now clearly visible and form the two largest population cohorts in Japan.

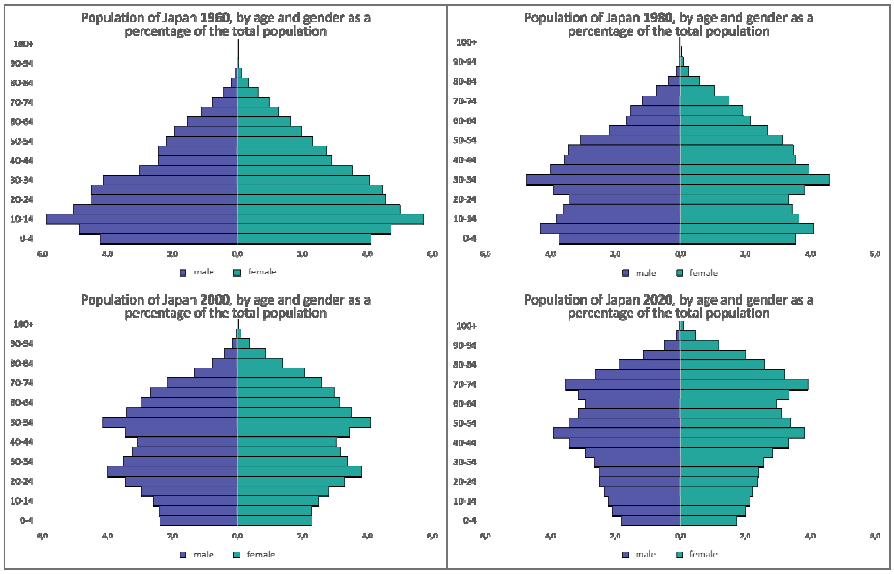

Fig. 2:Population Development in Japan by Age and Gender, Own Representation, Data: United Nations, Department of Economic and Social Affairs, Population Division 2024.

This is still the case in the year 2000. It can be seen that the cohorts of the two baby booms are now each 20 years older. In the cohorts after the second baby boom, there are now significantly fewer births and the percentage of young age groups in the total population is shrinking considerably. Ageing has therefore already visibly set in at this point.

In 2020, it can be observed that thetwo boom generations have become another 20 years older. The cohorts of the first baby boom in the 70-74 and 75-80 age groups are still very much in evidence. The same applies to the cohorts of the second baby boom in the 40-44 and 45-50 age groups. The older population groups dominate the younger generations with their percentage of the population. The population share of the younger age groups has decreased once again.

Overall, the composition of the population in 2020 is completely the opposite of that in 1960. The population has aged considerably and will continue to age in the coming years.

In addition to population development by age and gender, the group of 65-year-olds and older as a proportion of the total population can also be used as an ageing indicator. The same observation years were used for this purpose.

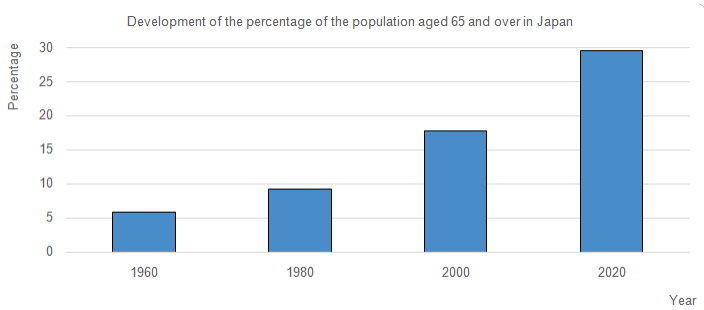

Fig. 3:Development of the proportion of people aged 65 and over, Own Representation, Data: United Nations, Department of Economic and Social Affairs, Population Division 2024

It is evident that the population trends mean that the proportion of people aged 65 and over is continuing to rise and was already almost 30% in 2020. Furthermore, the increase is to be classified as very extreme and proves that the issue of ageing is not new to Japan. An international comparison also shows that Japan is an extreme case. If you compare the indicator of the proportion of people aged 65 and over Japan certainly stands out.

SDGRegion	2022 (percentage)	2050 (percentage)
Worldwide	*9,7*	*16,4*
Sub-Saharan Africa	3,0	4,7
North Africa and West Asia	5,5	12,5
Central and South Asia	6,4	13,4
East and Southeast Asia	12,7	25,7
Latin America and the Caribbean	9,1	18,8
Australia/New Zealand	16,6	23,7
Oceania	3,9	8,2
Europe and North America	18,7	26,9

Table. 1:Proportion of people aged 65 and over in a global comparison in the year 2022, Own Representation based on United Nations (2023b, p. 8)

Japan is assigned to the East and Southeast Asia SDG region. This is one of the regions in which ageing is currently strongest and where, in view of projected future trends, a very sharp increase inthe ageing process is to be expected.Japan, where the proportion of people aged 65 and over was almost 30% in 2020, is an extreme example not only internationally but also within the region, which is also strongly characterized by ageing.

Looking at the population data, it is clear that Japan is affected by ageing to an extreme degree. The country was also affected by the resulting challenges earlier than other countries. At the same time, it is foreseeable that the trend will continue, and the population will become even older. This situation is not expected to change until the people born during the second baby boom have passed away. How birth rates will develop between now and then, however, remains an unknown factor. It is therefore difficult to predict the future population development.

4 SOCIAL AND SPATIAL IMPLICATIONS

Ageing processes in society bring with them various social and spatial challenges. From an economic perspective, the value produced by both the very young and the elderly is lower than their consumption. Between these age groups, however, people produce more added value than they consume (United Nations 2023a, p. 50). If this principle is applied to a society's public system and the related public services, this means that children, young people and older people receive education, health services, social security, pensions, elderlycare, etc. from the proportion of society that is of working age. This working generation, at the time, consumes less of the public services. As a society ages, these age groups shift. On the one hand, this can lead to many more people using the existing services of the public system than before and, on the other hand, to a reduction in the group of people who support the public system (United Nations 2023a, p. 50).

It can be concluded from this that ageing processes demand the adaptation of public services. The associated public infrastructure must be adapted to new conditions too – both quantitatively and in terms of new needs. At the same time, it is becoming difficult to provide public services and infrastructure economically, both financially and in terms of human resources. This means, in practical terms, that it will be more difficult to provide the necessary level of healthcare, and elderly care pensions, for example, which will be even more heavily utilized due to an ageing society (OECD 2019, p. 19; Swiaczny et al. 2008, p. 200).

The changing demands in public services can also give rise to issues of where they should be located. This makes it clear that, in addition to social challenges, specific spatial issues also arise. The topic of 'housing' seems particularly important here. On the one hand, forms of housing must be adapted to the changing conditions associated with an ageing society (Yu and Lee 2017, pp. 442-444) and, on the other hand, cities are often confronted with the fact that older people occupy a disproportionately large living space, which conflicts with the effort to achieve compact urban development (Nelson 2020, p. 480).

However, social and spatial problems arising from ageing are caused by different factors. Various interviews were conducted for the country-specific context of Japan. The interviewees are stakeholder from Japanese-based scientific institutions and public administration. Additionally, on-site walks took place to better understand spatial effects. The findings are now used as the first step to illustrate the implications of an ageing population.

Social Implications

First of all, the social challenges that are perceived in connection with ageing in Japan will be described here. One major issue that is also a major topic of debate in society is the loneliness and isolation that many people face. Older people are particularly affected by this (Interview with Dimmer 2024). In this context, the 'hikikomori' phenomenon must be mentioned, which describes the situation in which an “individual has left the group and is isolated” (Kato et al. 2019, p. 427). The term 'kodokushi' is also often used in this context to describe the solitary dying of people living alone and in isolation (Toyama and Poudyal 2021, p. 2). Both are major media phenomena, which sheds light on the fact that many people are no longer involved in social life and very rarely leave their own homes. This also means that fewer people are visible in public spaces on top of that. Spaces in which people communicate and interact with each other are becoming fewer (Interview with Dimmer 2024). Although older people may be more affected by these phenomena, it is also impacting the society as a whole, if only because of the statistically dominant significance of the older population.

This is also reinforced by the fact that both densely populated urban districts, mostly in outlying areas, and villages in rural regions have a less mixed age structure. This means that older population groups are usually concentrated in one place. This exacerbates the negative social and societal consequences (Interview with Dimmer 2024; Interview with Waldenberger et al. 2024).

Another obvious problem has already been mentioned. The challenges associated with the need for care are a major consequence of ageing in Japan. The individual life situation of a person in need of care can vary greatly. For a person who is socially and familiarly well integrated, care can often be provided by relatives. However, given the trend towards isolation and loneliness, care as a service is becoming increasingly important. Due to the rapid ageing of the population, more and more capacity is needed in this service area, while at the same time care workers are already in short supply (Interview with Dimmer 2024).

Spatial Implications

In addition to the social challenges, there are also significant spatial challenges resulting from ageing. These are presented below. While large metropolitan areas such as Tokyo are confronted with settlement pressure in city centers and areas close to city centers, there is a vacancy problem in rural regions. While many people of working age move to the metropolitan areas to work, it is usually the older generations who stay behind in rural areas. This results in areas that are ageing and affected by strong shrinkage trends. This also has an impact on the public infrastructure in rural areas. Local public transport and the provision of important shopping facilities, such as grocery stores, are no longer viable. As infrastructure is being scaled back, and people are not adequately supplied, these rural areas become even less attractive as residential locations (Interview with Dimmer 2024; Interview with Waldenberger et al. 2024).

At the same time, however, it can also be observed that people who once moved to the city move back to the countryside, for instance after they reach retirement age. They usually return to their own family home, which was inherited after the death of their parents, for example, or move back to their parents to care for them.Those city-dwellers for whom moving is not an option are encouraged by the Japanese government to buy a second home in the countryside.There is also a market specifically for foreign clients, where properties in the countryside with traditional Japanese architecture are specifically promoted (Interview with Waldenberger et al. 2024).

Many (single family) homes in Japan have a very short lifespan of about 30 to 40 years (Komatsu 2008, p. 2202), as they are often demolished and rebuilt generation by generation. When used properties are sold, their value has often fallen sharply and they are in need of renovation, despite their young age (Barlow and Ozaki 2005, p. 11). The renovation of houses with traditional architecture or the construction of a second home is therefore associated with a high financial burden. The undersupply of infrastructure and services further contributes to these properties beingunattractive as potential living spaces. As a result, both approaches to reruralization movements do not have a major effect overall, so that the shrinkage and vacancy trends are not being relativized (Interview with Dimmer 2024).

In contrast, there is high settlement pressure in the city centers and adjacent districts of metropolitan areas. Despite this pressure, there is a measurable ageing of the population and the emergence of vacancies here too. However, the spatial effects are different.If older buildings in inner-city locations in metropolitan areas, often with only one residential unit, become vacant, they are usually demolished plot by plot and replaced by a much denser new-built project with many residential units.Although this creates a higher population density in inner-city locations, buildings that once characterized the neighborhoods also fall victim to this development, while new buildings dominate the cityscape.However, these new buildings, like the single-family homes mentioned above,are often built cheaply for a short life cycle, also with an awareness that new construction is not intended to last for centuries, but that there is a possibility that in a few decades urban transformation could place new demands on the use of the land. This leads to a constant process ofsuccessive, fragmented transformation and revitalization of the city with a lot of construction activity (Interview with Dimmer 2024).

A different development can be observed inurban peripheries. Many suburban regions have been developed as New Towns. These are mostly large-scale housing complexes on the periphery of the city, which were developed in Japan in the 1960s and 1970s and in which there is a strong functional dependence on the city center (Tanabe 1978, p. 39). At that time, mostly young people of the same generation moved into these areas, resulting in a homogeneous age structure. Nowadays, the same generation still lives in the New Towns, making ageing effects particularly visible here. As this generation is ageing, it will also reach the end of their life expectancy together, which means that deaths accumulate over the course of a few years leading to major social changes in the districts. In this way, systemic vacancy arises very quickly (Interview with Waldenberger et al. 2024). Colloquially, one can speak of the emergence of 'ghost towns' in less attractive locations.

It can be summarized that the social and spatial implications of ageing processes in the country-specific context of Japan largely correspond to the general problems outlined at the beginning. Nevertheless, there are some special characteristics in Japan. On the one hand, the issue of loneliness and isolation plays a significant role and, on the other hand, the strongly homogeneous age structures, both in rural and suburban areas, are particularly noticeable. In contrast, the difficulties in providing infrastructure and services, the need for elderly care and the rise in vacancies are more general and typical implications of ageing.

5 APPROACHES AT DIFFERENT LEVELS

In connection with the implications described above, various problems arise for Japan. There are approaches at various administrative levels to deal with the problems. From an administrative perspective, Japan is highly centralized, and the national government generally acts as the main actor in the country's development (Pallagst et al. 2018, p. 7; Martinez-Fernandez et al. 2016, p. 13). Therefore, the approaches from a national perspective are discussed here first. Local and regional approaches will be outlined afterwards.

National Level

At a national level, the Society 5.0 initiative should be mentioned first. Society 5.0 expresses the Japanese governments vision of pushing forward digitalization in all policy areas with the aim of merging cyberspace and physical space (Deguchi et al. 2020, p. 2; Cabinet Office Japan 2017; Pallagst et al. 2024, p. 138). This can be classified as a kind of funding program aimed in particular at researching and testing new technical possibilities. It originated from a Japanese development instrument, the “Science and Technology Basic Plan”, which is updated every five years, has received a lot of media attention and was seen as a response to Germany’s “Industry 4.0” (Interview with Waldenberger 2024).

One specific digitization project that has been developed and implemented at the national level is the “Project PLATEAU” of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The project aims to develop a national digital twin to support urban development tasks and aims to have developed 3D CityGML models in around 500 Japanese cities by 2027 (Seto et al. 2023, p. 202; MLIT n.d.a) Although there is little information about how the project is organized, the MLIT itself offers some insights (MLIT n.d.b, Uchiyama and Ishimaru 2022, p. 15). With the ministry, the highest administrative body at national level is the main actor in the project. This approach to the governance structure corresponds to the top-down, centrally organized administrative system in Japan. Although this is a project that requires large-scale implementation, it is not surprising that development is nevertheless being steered by a higher-level body. However, the technical implementation is not being carried out by the MLIT alone. A consortium has been formed with various participating institutes, organizational units and local authorities. According to MLIT, these come from the fields of science, industry and local administrations. The Association for Promotion of Infrastructure Geospatial Information Distribution is responsible for the provision, creation and maintenance of geographical and other spatial data. Nonetheless, the specific roles of the various stakeholders are not always clear in detail and are difficult to categorize independently. However, it is clear from the MLIT's explanations of the more specific use cases within 'Project PLATEAU' that industry and research institutes play a leading role in their development in particular (MLIT n.d.c).

The overall aim of “Project PLATEAU” is to provide a data platform for geodata, building data, geographical data and other spatial urban data relating to the built environment and to make this available as open-source data. In addition to static data, dynamic camera and sensor data are also used in individual applications (Uchiyama and Ishimaru 2022, p. 13). In this context, Seto et al. (2023, p. 202) found that in spatial planning practice in Japan, data relating to population, settlement areas, land use, traffic and landscapes must be collected and mapped every five years. In many local authorities, however, these maps are still only available in paper form. This makes it clear that the development of digital twins as part of 'Project PLATEAU' is primarily understood as a spatial planning tool. It should make it possible to visualize urban data and thus gain knowledge. MLIT also places the project in the context of the Society 5.0 vision and the associated goal of solving the country’s social and societal problems. It is referred to as the “digital transformation of urban planning” and is intended to connect various actors involved in spatial development, such as administration, private companies, researchers, engineers, etc., via the data platform in the form of digital twins to enable more efficient collaboration. The MLIT aims to model around 500 Japanese cities (MLIT n.d.a). In a first step, 56 Japanese cities have already been modeled, including particularly populous cities (Uchiyama and Ishimaru 2022, p. 7). It is clear that the PLATEAU project is unprecedented in the world due to its intended scale. With regard to other digital twins in an urban planning context, such as that of the city of Helsinki in Finland, the national digital twin in Japan with its formulated goals appears to be very ambitious, but at the same time a logical consequence and comprehensible approach in view of the Japanese government’s policy.

The basic functionalities in the CityGML model, which can be accessed via the “PLATEAU View” application, include, for example, any perspective view within the model, including pedestrian view, the

shadowing by the built environment based on specific date and time input and also the possibility for users to add geometric objects to the built environment and works therefore like a scenario visualization. With regard to building modeling, each building can be selected individually or in combination with other building units in order to obtain specific information associated with the objects. This also includes information relevant to spatial planning, such as building heights, usage typology and information on built-up areas (MLIT n.d.d). In addition, there are special use cases for certain functionalities, some of which have been developed by local administrations for specific problems.

Mayer et al. (forthcoming) took a closer look at two of these use cases and concluded that they hold great potential for spatial planning. Work processes can be made more efficient and the functionalities also offer new opportunities for spatial planning. As the project was developed with the intentionthat various stakeholders can design and implement more specific use cases based on the linked CityGML models and the basic functionalities, it is also possible to thematically address general trends and crises that are shaping spatial planning. This means that there is also potential for age-related problems. So far, however, there is no use case that deals exclusively with this topic, although general planning-related use cases involving locations for infrastructure and the organization of land use naturally have important cross-references for ageing problems. Mayer et al. (forthcoming) consider the project to have great potential for strategic spatial development but also note that there is a need for greater transparency regarding the processing of the data used. Through national implementation, municipalities benefit from the tool that is made available to them without having to incur high development costs themselves.However, due to the aforementioned short lifespan of many buildings and the constant fragmented transformation of the city, high maintenance costs are to be expected. And although there is a risk that local specific needs are not taken into account during development, this can be counteracted by the expandability based on local use cases.

A similar project at national level that should be mentioned in this context is the “RESAS Portal”. The name is an acronym that stands for “Regional Economy Society Analyzing System”. It is a tool for big data visualization, that brings together large amounts of regional data that make it possible to compare regions and municipalities in Japan with each other using selected indicators. “RESAS” is thus used for regional benchmarking in Japan (Interview with Waldenberger et al. 2024). The system was developed by an international company from the private sector, which also has a head office in Tokyo. The commissioning party is the Japanese 'Ministry of Economy, Trade and Industry',which is strongly committed to promoting regional economic policy (Takram Japan Inc. n.d.). This once again illustrates the typical steering system in Japan, where it is the Japanese national government that develops and implements concrete policies and takes action.

The aim of the “RESAS” tool is explicitly related to economic development with special emphasis on the support of regional economic policies. Among other things, it makes specific reference to the challenges associated with demographic change (Takram Japan Inc. n.d). Population declines and ageing, as well as unequal demographic development in rural and urban regions and the resulting economic weakness in certain regions are seen as problems that the instrument is intended to support (Matsuura 2020, p.3-4). It was designed for a broad user group and is not only available to public administrations at all levels, but also to the private sector, citizens and educational institutions. (Takram Japan Inc. n.d.; Matsuura 2020, p. 3).

The tool offers users two main views. Firstly, a geographical image of Japan, which is viewed from a bird's eye perspective, and secondly, a breakdown of specific information on an indicator under consideration, in which regulators can also refer back to the geographical view. Both views can be controlled interactively. In addition to the national borders, the geographical view further shows the borders of other administrative units, such as prefectures and municipalities, but also other vector-based elements at local level, such as the road infrastructure of a city, which enable better orientation. Various methods are used for data visualization. Among other things, areal and octal representations are used, but also different forms of diagrams, some of which are assigned to polygons on the geographical view. In addition, there are network visualizations in which relationships can be established from one polygon to other polygons (Takram Japan Inc. n.d.). Overall, the interactive functionalities are very versatile. And so is the data that the tool can visualize. There is a clear focus on economically relevant data. For example, there are indicators relating to the regional economy suchas the production of certain goods and their distribution, the cultivation of food in agriculture, the economic structure by sector, the labor market and employment figures, energy use, consumption of goods by certain population groups, tourism by overnight stays and accommodation destinations and much

more. However, there are also indicators on other topics, e.g. population development, municipal finances, taxes and healthcare. In addition, there is a separate category for relevant indicators in urban planning, which includes urban structures and some types of public services, such as education (Cabinet Office Regional Revitalization Promotion Office n.d.).

“RESAS Portal” is an outstanding tool that can provide and analyze exceptional amounts of data. For the strategic development and planning of cities and regions, it can thus provide important support for decision-making and help to ensure that decisions are made based on facts and free from intuitive evaluations. The competitive approach can incentivize structurally weak regions to become more competitive. However, as the tool is also explicitly aimed at the private sector and location issues are examined for economic viability, there is also a risk that decisions made based on economic interests may not always preserve the overall view of Japan’s development. The question therefore remains as to how much the tool contributes to solving social and regional problems.

Both projects described show that the national level plays a key role in the development and implementation of digital tools und innovations. It can be observed that the government has an affinity fordrawing up large-scale plans that are then rolled out acrossthe country. In these processes, participatory approaches are often lacking and future users or consumers, where the needs lie, are rarely included in the processes (Interview with Waldenberger et al. 2024). At the same time, however, this ensures fast development times in which coordination requirements are kept to a minimum.

The potential arising from the tools presented for the ageing problem is huge. The basic functionalities alone make it possible to visualize specific spatial distributions of relevant indicators, provided the data is available to the tool. This could serve as decision-making support for spatial planning, which could, for example, help to make age structuresmore heterogeneousin certain areas and strategically determine locations for public services and infrastructures that play a role for an older population, as well as counteract gaps in services.However, this potential applies to all sectoral topics with spatial relevance for which data can be provided. In this respect, it is striking that there are no specific use cases related to ageing so far.

Local and Regional Level

Although national government policies and instruments set the standard and projects at local and regional level are much smaller in scale, digital platforms still play a major role here too.

As part of the smart city Initiative in Japan, many municipalities have developed smart city strategies. The authors talked to responsible people from the administration in Tokyo and the much smaller city of Takamatsu. It emerged that both smart city strategies have great potential to provide a supportive tool for finding solutions to ageing-related problems. Both strategies already include implemented map-based platforms that can be used to visualize certain data on a pointwise or area basis (Interview with Masashige and Asad 2024; Interview with Munenori and Mitsuhiro 2024). This could be used to better coordinate locations for certain services and infrastructures that are needed according to the needs of an aged population, and to analyze the residential distribution of the older population to make it more heterogeneously through spatial planning.

In both Tokyo and Takamatsu, however, the smart city platforms are mainly used for operational issues such as traffic control and many more. So far, there is no approach to planning use or to making strategic decisions about the development of space. There is also no specific link to ageing issues (Interview with Masashige and Asad 2024; Interview with Munenori and Mitsuhiro 2024).Nevertheless, there are indirect links between smart city strategies and ageing issues. The topic of mobility and transportation is central to the Japanese smart city initiative and represents important use cases for the two strategies described above, too (KANTEI n.d., p. 10). This can benefit accessibility to important facilities for an elderly population. In addition, smart city strategies have the potential to make administrative tasks more efficient (Narmeen and Jawwad 2015, p. 9). Since fewer and fewer people are of working age due to ageing processes, this provides an important contribution that can help to maintain important administrative structures.

Metaverse platforms are a development that addresses the problems of loneliness, isolation and unattractive rural areas. These are projects at a local level. Here, certain environments of places are graphically recreated digitally. The target group is citizens. The development usually takes place in the private sector, with citizens taking on the role of consumers. They can use avatars to move around the recreated environments and interact with each other. Virtual reality hardware is also used in some cases. In many cases, metaverse

platforms are used to entertain users or to advertise products or businesses. In some cases, it is also used to impart knowledge, for example in museums (Interview with Waldenberger et al. 2024).

However, it is also seen as an approach to create new meeting and opportunity spaces against the background of many people's loneliness and isolation. People who normally find it difficult to leave their own homes due to physical disabilities, whether caused by illness or ageing, can also participate. In rural areas, metaverse platforms are also used by municipalities affected by population decline to promote them as residential locations with their digital image and increase residents' identity with their town. Users then have the opportunity to explore and get to know the municipality digitally (Interview with Waldenberger et al. 2024).

Another avatar-based approach, which takes place without the use of metaverse but is instead intertwined with physical space, are avatar cafés. In these cafés, robots that resemble humans are able to move within the premises. People who are unable to leave their homes can visit the café remotely via an avatar. The digital avatar takes on the appearance of one of the robots in the café. This allows for interpersonal interactions within the café, where some visitors participate physically and in human form, while others are represented by the robot avatars (Interview with Waldenberger et al. 2024).

The impact of such projects is difficult to assess. In general, however, a great affinity with new technologies can be observed in Japan. People base their actions strongly on pop-cultural imaginaries and also identify themselves as part of them. New technologies and manga graphics are key components of this (Interview with Waldenberger et al. 2024). In this respect, the social and spatial effects that could be triggered by this should not be underestimated. At the same time, this raises the question of whether such approaches could actually be transferred to societies with other cultures.

There are many other digital approaches that are being applied at the local or regional level. These include, for example, ideas for providing peripheral areas with goods using drones. This can be particularly advantageous when municipalities are located on islands, where quick delivery of essential goods may not always be possible, such as in the case of medications. Another example addresses the issue of transportation infrastructures being reduced in rural, shrinking regions. At the same time, it addresses the problem that many people in retirement age remain willing to work. Therefore, Japan places a strong emphasis on volunteer work in sectors that would otherwise not be able to operate due to lack of profitability. This also applies to the transportation sector in rural areas. Such projects are supported by digital technologies, such as platforms where individuals can register for transportation services, and volunteer drivers are then notified and assigned the task of providing the transport service (Interview with Waldenberger et al. 2024).

These types of digital solutions seem to have greater international transferability, as they are less tied to pop culture and imaginary contexts in Japan. The practicality of the solutions appears to be evident, as they directly address existing issues in a very immediate way.

6 CONCLUSIONS

The paper shows that Japan can be a very pertinent example in terms of researching the effects of ageing in the population. Ageing in Japan is particularly advanced compared to other countries. Effects from the decline in births and fertility coupled with a simultaneous increase in life expectancy have a statistically high significance that can explain the ageing process. The baby boom cohorts are a particularly strong driver of ageing.

Generally, insights on demographic trends in Japan and their spatial and social impacts can be transferred well to other countries, especially to developed countries, where ageing processes are evident too. A key difference, however, that needs to be highlighted, is the factor of migration. In many developed countries, there is a clearly positive migration balance. In Japan, the migration balance is also positive, but it is rather small and not statistically significant compared to the total population. For Japan, this means that this mitigating factor for the ageing effect does not apply. Nevertheless, the effects of ageing which are more advanced in Japan than in other countries can serve as an example from which lessons can be learned.

The social and spatial impacts of ageing pose enormous problems for Japan and force the government and administrations to find solutions.

Varioussuch solution approaches have been presented here. It has been noted that the national government plays a special role in Japan. This is due to the centrally organized governance structure. Development and

implementation at the national level, as in the cases of Project PLATEAU and the RESAS Portaloffer several advantages. The development and implementation process can be organized by a single body. The need for coordination among different stakeholders is minimized. In addition, powerful platforms are provided to local governments throughout Japan. Even small, structurally weak municipalities have the opportunity to benefit from digital innovations and are dependent on their own finances and do not depend on the possibility's local efforts.

At the same time, the centralist approach also carries risks. For example, local specificities and interests may not be sufficiently taken into account. The processes are less transparent and leave no room for participation. Another criticism is that national strategies are being rolled out across the country and local authorities may be unprepared. Furthermore, actual local problems cannot always be addressed by these policies.

Applied to other countries' contexts, it can be noted that the centralist approach has both advantages and disadvantages. Coordination in a central body at the national level and funding from that body is an approach that is transferable to other countries, although this could mean that local administrations may have to give up authority fields. However, it would be necessary to implement well-functioning participatory processes, with both actual local needs and specificities forming the basis for the development of digital solutions.

In contrast, the local and regional approaches to the metaverse and avatar platforms are difficult to transfer. Yet, the reliance on Japan-specific pop cultural imaginaries makes adaptation in a different cultural context unlikely. Thus, this approach to solving age-related problems is questionable.

In contrast, the approach of allowing willing retirees to work as volunteers in sectors that provide essential public services and infrastructure, which are increasingly difficult to maintain due to population ageing, seems highly transferable. It is considered worthwhile conducting further research in this area to explore through case studies how digital solutions can provide support in this context.

In the approaches examined at various levels, it is notable that there is rarely a direct connection to real, existing problems related to ageing. Although indirect connections exist, and the potential becomes apparent, further research is needed to determine the extent to which the implemented solution strategies contribute to a transformation process in addressing these challenges.For this purpose, it is assumed that examining path dependencies through empirical case studieswill help describe the synergies related to supporting solutions to aging-related challenges through new technologies.

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Digitaler Zwilling x Denkmalschutz – ein neuer Ansatz zur Vorbereitung eines Solarrahmenplans für eine denkmalgeschützte Altstadt

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1 ABSTRACT

Durch die Änderung des Bayerischen Denkmalschutzgesetzes ist es in der Denkmalpflege nun möglich, Denkmäler zu schützen und erneuerbare Energien zu fördern. Der Art. 6 (2) BayDSchG (Bayerisches Denkmalschutzgesetz BayDSchG 2023) erlaubt es Eigentümern von Baudenkmälern, erneuerbare Energien zu nutzen, sofern keine überwiegenden Gründe des Denkmalschutzes entgegenstehen. Das Bayerische Landesamt für Denkmalpflege betont dabei die Bedeutung einer denkmalverträglichen Energieversorgung, die Denkmalschutz und Klimaschutz vereint.

Ein Solarrahmenplan ist ein Planungsinstrument für Kommunen mit historischer Bausubstanz, das Potenziale und Anforderungen für erneuerbare Energien definiert. Grundlage ist eine Analyse von Einsehbarkeit, historischen Raumqualitäten und Gestaltungskriterien. Ziel ist es, Transparenz zu schaffen und die Entscheidungsfindung zu unterstützen.

Der Beitrag stellt die Erarbeitung eines Solarrahmenplans für die Altstadt Landsberg am Lechs vor. Der Digitale Zwilling des mFUND-Projekts „TwinCity3D“ wird genutzt, um Sichtachsen zu analysieren und sensible Bereiche zu identifizieren. Die Studie liefert methodische Ansätze, zentrale Erkenntnisse und einen Ausblick auf die Umsetzung.

Keywords: Simulation, Denkmalschutz, Solarkataster, Digital Twin, Photovoltaik

2 HINTERGRUND

Am 01.07.2023 ist eine Änderung des Bayerischen Denkmalschutzgesetzes in Kraft getreten. Mit dieser Änderung will das Gesetz Denkmäler schützen, Energiepotenziale nutzen und Kommunen unterstützen. In Art. 6 (2) BayDSchG heißt es „Dient die Maßnahme der Gewinnung erneuerbarer Energien überwiegend für den Energiebedarf im Baudenkmal oder zu einer energetischen Verbesserung, kann die Erlaubnis […] nur versagt werden, soweit überwiegende Gründe des Denkmalschutzes entgegenstehen und diesen nicht durch Nebenbestimmungen zur Art der Umsetzung Rechnung getragen werden kann.“ Der Gesetzgeber möchte also Eigentümern von Baudenkmälern grundsätzlich die Möglichkeit geben, erneuerbare Energien zu nutzen. Auf der Homepage des Bayerischen Landesamtes für Denkmalpflege ist hierzu Folgendes aufgeführt: „Solarenergie im Ensemble und im Baudenkmal: Eine in denkmalfachlicher Sicht verträgliche Versorgung von Baudenkmälern mit bezahlbarer regenerativer Energie dient auch dem Denkmalerhalt und ist gerade heute von ganz besonderer Bedeutung. Denkmalschutz und Klimaschutz sollen Hand in Hand gehen und ihre Belange verantwortungsvoll verbunden werden. Denkmäler sollen dabei aber natürlich ihre besondere Eigenheit als einzigartige, identitätsstiftende und höchst wertvolle Zeugnisse der bayerischen Geschichte behalten. Für die Vereinbarkeit von Denkmalpflege und Solarenergienutzung bietet das Bayerische Landesamt für Denkmalpflege Lösungen für städtebauliche Konzepte zur Energieversorgung im Ensemble und Möglichkeiten am oder in der Nähe eines Baudenkmals an.“

Ein Solarrahmenplan ist ein informelles Planungswerkzeug, dass sich speziell an Kommunen mit einem umfangreichen historischen Baubestand richtet. Solch ein Rahmenplan soll die Möglichkeiten der Nutzung erneuerbarer Energien im Ensemble differenziert betrachten. Dafür wird der öffentliche Raum auf der Grundlage einer städtebaulich-denkmalpflegerischen Analyse kategorisiert, um für die einzelnen Bereiche abgestimmte Gestaltungsanforderungen formulieren zu können. Der Plan kann so als Werkzeug für die

Verwaltung dienen, um entsprechende Anträge auf Solaranlagen im Denkmalbereich zu bearbeiten und eine Transparenz für die Eigentümer herzustellen. Ziele der Stadt bei der Erstellung eines solchen Plans sind:

- Klarheit und Transparenz für den Umgang mit Solaranlagen für alle Beteiligten
- Defintion von Gestaltungsqualitäten für die Dachflächen als 5. Fassade im historischen Kontext
- Informelle Planung als Werkzeug für die Untere Denkmalschutzbehörde (UDB)

Für die Erstellung eines Rahmenplans sind drei Fragestellungen denkmalfachlich zu untersuchen und zu bewerten:

- Einsehbarkeit und Sichtachsen
- Analyse der historischen Bedeutung von städtischen Räumen
- Gestaltungsanforderungen für die Anlagen

Als Ergebnis soll eine digitale Karte entstehen, die Auskunft über die denkmalpflegerischen Werte und Qualitäten von Räumen, Einzelgebäuden, Straßen- und Platz-, sowie Stadtansichten gibt, die Einsehbarkeit vom öffentlichen Raum beschreibt sowie die Potenziale und Anforderungen zur Integration von EE-Anlagen darstellt.

Mithilfe des virtuellen 3D-Stadtmodells von Landsberg am Lech sollen diese Arbeitsschritte durchgeführt werden. Mithilfe der Sichtachsenanalyse werden die betroffenen (Teil-)Dachflächen abgeleitet und kategorisiert. Durch die Auseinandersetzung mit der historischen Bedeutung des Stadtraums findet eine weitere Einstufung sensibler Bereiche innerhalb des Altstadtgefüges statt. Aus der Überlagerung der angefertigten Analysen werden anschließend Gestaltungsanforderungen abgeleitet, die dachflächengenau Aussagen zur möglichen Verwendung von PV-Modulen liefert.

Im Rahmen eines Forschungsseminars an der Professur für Stadtquartiersplanung des KIT wurden diese Arbeitsschritte 2024/2025 in Zusammenarbeit mit dem BLfD und der Stadt Landsberg am Lech mit den zuständigen Referaten der Technischen Bauaufsicht als Untere Denkmalschutzbehörde und dem Referat Digitaler Zwilling, Klimaschutz und Mobilität (DZKM) durchgeführt, die nachfolgend näher beschrieben werden.

3 STAND DER FORSCHUNG

3.1 PV-Anlagen und Denkmalschutz bisher

Vor der Gesetzesänderung 2023 konnten gewichtige Gründe für den Erhalt des bestehenden Zustands die Genehmigung erneuerbarer Energien verhindern. Nun müssen überwiegende Denkmalschutzgründe vorliegen, sofern diese nicht durch Auflagen zur Umsetzung berücksichtigt werden können (Bayerisches Denkmalschutzgesetz BayDSchG 2023). Dies bedeutet, die Frage lautet nun nicht mehr „ob“ erneuerbare Energien am Denkmal erlaubnisfähig sind, sondern „wie“. Dabei soll die Substanz des Baudenkmals soweit wie möglich erhalten bleiben während eine möglichst denkmalverträgliche Integration in das Erscheinungsbild angestrebt wird. Maßgebend ist, dass vorrangig der Energiebedarf im Baudenkmal abgedeckt werden soll.

Das Staatsministerium für Wissenschaft und Kunst (STMWK) hat hierzu das Stufenmodell als Handlungsanweisung herausgegeben, wonach zunächst Nebengebäude und nicht einsehbare Flächen zu Belegen belegen sind. So sind auf Flächen, welche nicht vom öffentlichen Raum einsehbar sind, regelmäßig auch herkömmliche Anlagen erlaubnisfähig (Bayerisches Staatsministerium für Wissenschaft und Kunst 2023).

Bei vom öffentlichen Raum aus einsehbaren Dachflächen wird unterschieden in Ensemble und Einzeldenkmäler. Bei Ensembles gilt: Mit dem Erscheinungsbild denkmalfachlich vereinbare Anlagen, z. B. in die Dachfläche integrierte Anlagen, sind regelmäßig erlaubnisfähig. Bei Einzeldenkmälern gilt analog zu den Ensembles zusätzlich der Substanzschutz. So sind aufwendige Ertüchtigungen eines Dachtragwerks zur Installation einer Anlage nicht im Sinne des Denkmalschutzes.

Die immer effizienter werdende Zelltechnologie sowie die steigenden Produktionsraten der Zellen begünstigen den kostengünstigen Erwerb von Solarprodukten. So hat sich der Wirkungsgrad seit 2002 von durchschnittlich 13% auf 23% fast verdoppelt und der Preis pro kWp ist nunmehr ein Fünftel im Vergleich

zum Jahr 2006 (Bundesministerium für Wirtschaft und Klimaschutz BMWK 2021; Lackner et al. 2024). Produktinnovationen in Art, Form und Farbe ermöglichen heutzutage wirtschaftliche und gestalterisch anspruchsvolle Lösungen.

Photovoltaik-Indachanlagen sind im Falle einer Dachsanierung preislich konkurrenzfähig zu einer herkömmlichen Aufdachanlage und bringen weitere Vorteile mit sich. Die geringere Auflast und geringere Wind-Soglasten vermeiden Ertüchtigungen im Dachstuhl und die witterungsgeschützte Verlegung der Installationen trägt zu einer längeren Lebensdauer der elektrischen Bauteile bei. Mindererträge durch eine geringere Hinterlüftung können bei kleinteiligen Anlagen durch eine höhere Flächenausnutzung kompensiert werden.

Farbliche Anpassungen können durch die Verwendung von farbigen Rückgläsern, die Bedruckung mit wetterbeständigem keramischem Siebdruck oder die Verwendung von Farbfolien erfolgen und ermöglichen damit eine farbliche Annäherung an beispielsweise naturrote Ziegel oder patinierte Kupferdächer.Die Produktpalette bietet neben farblich angepassten Aufdachmodulen auch kleinteilige Indachlösungen, wie Solarziegel in verschiedenen Formen und Farben, spezielle Lösungen für Schiefer und Blechdächer, sowie PV-Folien, welche sich flexibel an bestehende Dachformen anpassen können. So können für die meisten Denkmäler individuell verträgliche Lösungen zur Integration von Photovoltaikanlagen gefunden werden.

Innovationen hinsichtlich Materialität und Oberflächen wie beispielsweise die Verwendung von satinierten Gläsern, welche die Reflexion der Deckgläser reduziert, versprechen weitere Verbesserungen hinsichtlich einer denkmalverträglichen Integration in das Erscheinungsbild der Denkmäler.

3.2 Erscheinungsbilder und Ensembles – Orte öffentlicher Aushandlung

Neben der baulichen Substanz zählt das Erscheinungsbild von Denkmälern zu den zentralen Schutzgütern der Denkmalpflege und ist als solches auch in allen deutschen Denkmalschutzgesetzen verankert (Eidloth et al. 2019).Besonders facettenreich ist dieses Erscheinungsbild in den Ensembles historischer Stadt- und Ortskerne überliefert, die nicht allein durch die Erhaltungsbestrebungen der Denkmalpflege, sondern vor allem den Gestaltungsansprüchen einer seit mehr als 100 Jahre andauernden kommunalen Planungskultur geprägt werden. Städte, Märkte und Dörfer, die ihre Kernbereiche im Sinne der Daseinsvorsorge attraktiv und lebendig halten wollen, haben dafür schon seit dem Ende des 19. Jahrhundert Regularien und Leitbilder in Form von Bebauungsplänen über Gestaltungssatzungen bis hin zu Werbeanlagensatzungen erlassen (Sandmeier 2023). Dem Erscheinungsbild eines Ortes scheint daher nicht nur im denkmalpflegerischen, sondern auch in gesellschaftlichen Wertbildungsprozessen eine besondere Rolle zuzukommen. Idealerweise soll es den Bewohnerinnen oder Besuchern durch Beständigkeit und Wiederholung von Strukturen Orientierung geben und zugleich offen sein für Innovation, Erneuerung und individuelle Zuschreibungen (Meier 2010, 2013). Aufgrund ihrer Komplexität und Geschichte bilden insbesondere denkmalschützte Orts- und Stadtkerne intuitive Bedeutungs- und Erfahrungsräume, die den Betrachtern leicht zugänglich erscheinen. Um diese Vielschichtigkeit und Aneignungsfähigkeit zu erhalten, setzen viele Kommunen darauf in der Entwicklung ihrer Ortskerne eine Brücke zwischen Zukunft und Vergangenheit zu schlagen und beispielsweise die Anpassung der Gesellschaft an gegenwärtige Bedürfnisse im baulichen oder strukturellem Bestand umzusetzen. Dabei investieren sie in der Regel viel Zeit und Geld in partizipative Aushandlungs- und Planungsprozesse, profitieren aber langfristig von diesen Bemühungen und den darin gesammelten Erfahrungen.

3.3 Solarrahmenpläne (in Bayern)

Der Solarrahmenplan will als sektorale, informelle Planung der Denkmalpflege Kommunen und ihren Bürgerinnen und Bürgern Hilfestellung in Mitten eines solchen Transformationsprozess geben. Ziel ist es, die spezifischen Werte und Potenziale des historischen Ortes zu erkennen und auf dieser Grundlage Handlungsräume für die energetische Erneuerung zu eröffnen. Die Grundzüge dafür wurden in einem ersten umgesetzten Solarrahmenplan für die kleine Stadt Lichtenberg in Oberfranken festgesetzt: Die Zonierung des Ensembles in eine Kernzone als die „Gute Stube“ des historischen Ortes– dazu zählen beispielsweise der Stadtplatz oder die Marktstraße, der Schlossplatz oder der Promenadenpark – und eine Nebenzone mit untergeordneten Straßen oder (halb-)privaten Bereichen, die als dienende Räume gesehen werden (Sandmeier und Fischer 2023). Neben dem Erscheinungsbild der Kernzone prägen vor allem die Fernsichten von besonders prominenten Aussichtspunkten ein historisches Ortsbild, das bedingt die Festlegung einer

entsprechenden weiteren Zone. Zusätzlich gibt es eine Verständigung auf sogenannte Stadtbausteine, das heißt Gebäude, die für den Ort aus kulturellen, gesellschaftlichen und geschichtlichen Gründen von maßgeblicher Bedeutung sind, das können beispielsweise das Schloss, die Pfarrkirche oder das Rathaus sein. Meist handelt es sich um Einzeldenkmäler oder ikonischen Bauwerke, so dass Solaranlagen hier gänzlich vermieden werden sollen beziehungsweise einer intensiven, auf den Einzelfall zugeschnittenen Planung bedürfen.

Inzwischen konnten für mehr als 20 Kleinstädte und Märkte, zunehmend auch für größere und komplexere Altstadtensembles nach dem Vorbild von Lichtenberg Solarrahmenpläne erarbeitet werden. Dabei wird die genaue Ausformulierung immer wieder neu dem Baubestand, der besonderen städtebaulichen Struktur und den verwaltungstechnischen Vorstellungen der Kommune angepasst. In Haßfurt, einer Kleinstadt in Unterfranken wurde die Nebenzone beispielsweise weiter ausdifferenziert, um der unterschiedlichen Wertigkeit und Bedeutung für das Stadtbild gerecht zu werden (Stadt Haßfurt 2023).In Bad Windsheim in Mittelfranken führten die Bearbeiter für die Gebäude im Bereich des ehemaligen Stadtgrabens als „Vorzone“ des Ensembles eine eigene Kategorie ein (Stadt Bad Windsheim et al. 2025).

In die Betrachtungen werden dabei in der Regel nur jene Dachflächen einbezogen, die aus dem öffentlichen Raum einsehbar sind, um damit den neuen gesetzlichen Regelungen Rechnung zu tragen. Die stadträumliche Analyse für den Solarrahmenplan in Weißenburg stellte in dieser Hinsicht eine besondere Herausforderung dar, da nahezu jede Dachfläche von einer der umliegenden Straßen und Plätze zu sehen ist. So wurden innerhalb der einzelnen ausdifferenzierten Zonen besondere Sichtachsen und Blickbeziehungen definiert, die sich aus der Morphologie der Stadt ableiten ließen (Stadt Weißenburg in Bayern et al. 2024).

Der Solarrahmenplan Bayreuth basiert ebenfalls auf der Zonierung des Ensembles in der beschriebenen Form, wird aber zusätzlich verschnitten mit einer Entscheidungsmatrix, in der Kriterien wie eine exponierte Lage oder die Angrenzung an eine Platzsituation abgefragt werden (Stadt Bayreuth und RHA Reicher Haase Assoziierte 2024).

Die Erstellung eines Solarrahmenplanes für das ausgedehnte Ensemble der Altstadt Würzburg wiederum startete zunächst mit einer topographischen Analyse. Anhand des 3D-Gebäudemodells wurden automatisiert Dachflächen ermittelt, die aus dem jeweiligen Straßenraum nicht, bzw. nur geringfügig einsehbar sind. Überlagert wurde diese Erhebung mit einer Fernsichtstudie vom Würzburger Burgberg, dem prägnantesten Aussichtspunkt auf das Stadtensemble. Erst in einem nächsten Schritt wurde die räumliche Sichtanalyse mit denkmalpflegerischen Werten verschnitten (Büro G.A.S. planen bauen forschen 2024).

Die dicht bebauten Mittel- und Großstädte stehen vor der Herausforderung, über eine Solaranlagensatzung hinaus vielfältige weitere Interessen und teilweise widerstreitende Belange der städtebaulichen Planung ausgewogen in die Betrachtung einzubeziehen. In Bayern bietet sich dafür die Bearbeitung in einem Kommunalen Denkmalkonzept (Bayerisches Landesamt für Denkmalpflege 2017) an, dass Kommunen, Fachplaner und Behörden in einen gemeinsamen Aushandlungsprozess bringt und in dem die Bedürfnisse der Bürgerinnen und Bürger besondere Beachtung finden. Ein erstes Modellprojekt dieser Art konnte für die Stadt Wasserburg zur Vereinbarkeit von Denkmalschutz und regenerativer Energie im Altstadtensemble bereits seit 2021 umgesetzt werden. Hier wurde die stadträumliche Analyse parzellenscharf vertieft, um für einzelne Gebäude- und Dachtypolgien angepasste Energieplanungen der Strom- und Wärmeversorgung anzubieten. In Modellprojekten wurde die Machbarkeit der Fallstudien demonstriert, innovative Produkte ausprobiert und Erfahrungen für die praktische Umsetzung gesammelt, um dieses Wissen auf weitere Solarplanungen in der Altstadt übertragen zu können (Solfrank 2024).

Unverzichtbarer Bestandteil eines jeden Solarrahmenplanes ist die Formulierung von abgestuften Gestaltungsleitlinien für die einzelnen Zonen. Ausgehend von der Bewertung der Ortsräume und –bauten, mitunter auch unter Einbeziehung der jeweiligen Dach- und Haustypologien, wird eine Aussage zu Lage, Maß, Materialität und Farbigkeit von Solarenergieanlagen getroffen. Im Zusammenspiel mit der kartografischen Fassung steht den Kommunen damit ein Planungswerkzeug zur Verfügung, das Transparenz gegenüber den Bürgern schafft.

3.4 DigitaleZwillinge

3D-Stadtmodelle stellen seit Jahrzehnten ein zentrales Werkzeug für die visuell ansprechende Vermittlung von Planungsinhalten dar – sei es analog oder seit den 1990er Jahren zunehmend digital. Bereits frühe

Projekte wie das Stadtmodell Graz (Luser & Lorber, 1997) oder das 3D-Stadtmodell von Bamberg (Zeile et al. 2005)verdeutlichten das Potenzial der Wissensvermittlung als auch der Planung im dreidimensionalen, digitalen Kontext. Die Entwicklung von CityGML und der darin enthaltenen Level-of-Detail (LOD) Spezifikation als universelles Austauschformat für 3D-Stadtmodelle (Kolbe und Gröger 2004; Brüggemann und von Both 2015; Benner et al. 2016) beschleunigten und standardisierten diese Entwicklung: Durch CityGML wurde es möglich, eine standardisierte Modellierung urbaner Strukturen und ihre Anwendbarkeit für verschiedenste Szenarien, etwa Energiebedarfsanalysen (Benner et al., 2016) durchzuführen. Offene Werkzeuge wie der KIT-ModelViewer für IFC als auch CityGML (KIT – IAI 2024) erleichtern mittlerweile die Arbeit und den Austausch der Dateien.

Parallel dazu etablierte sich das Konzept des digitalen Zwillings, das aus der Produktentwicklung stammt (Grieves 2014).Es beschreibt die virtuelle Replikation physischer Objekte und ermöglicht eine ganzheitliche Modellierung. Diese Idee wurde später in die Stadtplanung übertragen (Batty 2018). Digitale Zwillinge finden insbesondere Anwendung in großmaßstäblichen Modellen und Simulationen, wie etwa beim Projekt Herrenberg in Deutschland. Dieses nutzte immersive virtuelle Umgebungen zur Analyse urbaner Herausforderungen und zur Einbindung von Verkehrssimulationsmodellen (Dembski et al. 2019, 2020).

4 PROJEKT LANDSBERG AM LECH

Nachfolgend werden die durchgeführten Arbeitsschritte von der Datensichtung, die Ideen für eine Methodenentwicklung, Vorschläge für einen Solar-Rahmenplan sowie die Anwendung der gewonnenen Erkenntnisse auf Beispielgebäude näher beschrieben.

4.1 Datenverfügbarkeit

Im Rahmen des mFUND-Forschungsprojekts „TwinCity3D“ entwickelt die Stadt Landsberg am Lech zusammen mit 3D RealityMaps GmbH aus München aktuell eine Grundlage für einen digitalen Zwilling.Auf der Basis von Befliegungen des Stadtgebietes mit einem Multisensorkamerasystem (bestehend aus insgesamt fünf RGB-, einer Multispektral-, sowie einer Thermalkamera) werden verschiedene Luftbildprodukte zur späteren Analyse erzeugt. Das Multisensorsystem befindet sich dabei an dem elektrisch betriebenen Ultraleichtflugzeug „Elektra One Solar“ der Landsberger Firma Elektra Solar GmbH. Die realisierbare Flughöhe von 300m über Grund ermöglicht eine hohe Auflösung und sichert in der Folge einen hohen Informationsgehalt für die Anwendungsbereiche aus Klimaschutz, Mobilität und Stadtentwicklung. Das nach fotogrammetrischem Prinzip erstellte 3D-Meshmodell des Stadtgebietes bildet das Kernelement der prototypischen „TwinCity3D“-Plattform (Abb.1 rechts), welche zukünftig weiter ausgebaut werden soll. Aufgrund des niedrigen Abstraktionsgrades und der intuitiv angelegten Bedienoberfläche kann das Stadtgebiet – auch ohne Vorkenntnisse – nach kurzer Einarbeitungszeit virtuell erkundet werden (Broschart et al. 2024).

Zudem verfügt die Stadt Landsberg am Lech bereits über einen digitalen Zwilling des Straßenraum. Im Jahr 2023 wurde zuletzt eine Straßenbefahrung durch die in Baden (CH) ansässige Firma iNovitas AG durchgeführt. Dabei wurden die Straßen und Wege ebenfalls mit einem Multisensorsystem befahren. Dieses setzt sich aus drei stereoskopisch gerichteten RGB-Kameraeinheiten, einer hemispherischen „Ladybug“-RGB-Kamera, sowie einem ergänzenden LIDAR zusammen.

Diese „veredelten“ Geodaten werden ergänzt um die, von Seiten des Bayerischen Landesamtes für Digitalisierung, Breitband und Vermessung (LDBV) bereitgestellten Geobasis- und Geofachdaten im Rahmen der OpenData-Strategie.

Für die Anfertigung des Solar-Rahmenplanes konnte auf folgende Datensätze zurückgegriffen werden:

- 3D-Gebäudemodelle (LoD2) im CityGML-Format mit ALKIS®-konformen Standarddachformen und beschreibenden Attributen (Abb. 1 links)
- Digitales Geländemodell 1m (DGM1) als Punktwolke im ASCII-Format
- OSM-Datensatz der Stadt Landsberg am Lech
- Fotogrammetrisch identifizierte Dachformen als geschlossene Polygonzüge inklusive Neigungswinkel und Orientierung im SHP-Format. Die Daten wurden im Rahmen des TwinCity-Projektes erstellt.

- Zugriff auf den WebClient von TwinCity3D zur visuellen Sichtbarkeitsanalyse
- Zugriff auf den infra3D-Client zur Anfertigung von Straßenquerschnitten und Arbeiten mit Vorort-Bildmaterial sowie Zugriff auf die LIDAR-Punktwolke im LAS-Format.
- Ensemble-Daten / Baudenkmal-Daten des Bayerischen Denkmal-Atlasses im SHP-Format
- Aus Denkmalschutz-Gründen wichtige Stadtbausteine in SHP-Format

Abb. 1: Ausschnitt aus dem TwinCity3D-Client mit dem CityGML-LOD2-Modell auf der linken und des kongruenten texturierten Mesh-Modell aus den Befliegungsdaten auf der rechten Seite (RealityMaps)

4.2 Methodik

Im Rahmen eines Solarrahmenplans werden Untersuchungen durchgeführt, anhand derer beurteilt werden kann, wie eine PV-Anlage auf einem Gebäudedach zulässig ist und welche technischen und gestalterischen Kriterien aus denkmalpflegerischer Sicht einzuhalten sind.Die Sichtbarkeit aus öffentlichen Bereichen werden digital analysiert und validiert (Abb 2).

Für die Erstellung des Solarrahmenplans zur Klassifikation von Gebäudedächern für Photovoltaikanlagen werden folgende Arbeitsschritte definiert:

1) Grundlagenprüfung, bei der relevante Rahmenbedingungen aufgenommen werden. Dies sind im Einzelnen die Analyse von allgemeinen,rechtlichen Festsetzungen und Schutzstatus des Denkmals, die Bewertung der Dachneigung und -ausrichtung sowie die Prüfung der Sichtbarkeit – einer Identifizierbarkeit von Dachfarbe und -form im Radius von 800 m und 400 m – für eine potenziell stärker zu integrierende Form der PV-Module.

Dauraufhin werden in 2) die Gebäude für den Solarrahmenplan kategorisiert. Ausschlaggebende Attribute sind aus dem Bereich des Denkmalsschutzes ob ein Ensemble- oder Einzeldenkmalschutz vorliegt. Zusätzlich zu einer Solarpotenzialprüfung und der o.g. Sichtbarkeitsprüfung werden die Dachflächen, teilweise sogar Teildachflächen in vier Kategorien eingeordnet (von „höchste Anforderungen“ – Kategorie 0 bis „geringe Anforderungen“ Kategorie 3.3)Die PV-Modulkonfiguration schlägt dann Modulgrößen, Farben und Oberfläche für eine optimale Flächennutzung und visuelle Integration vor. 4) Der abschließende Gestaltungsvorschlagintegriert als eine Art „Fliesenspiegel Solar“ den Vorschlag als Textur auf die Dachflächen im digitalen Zwilling.

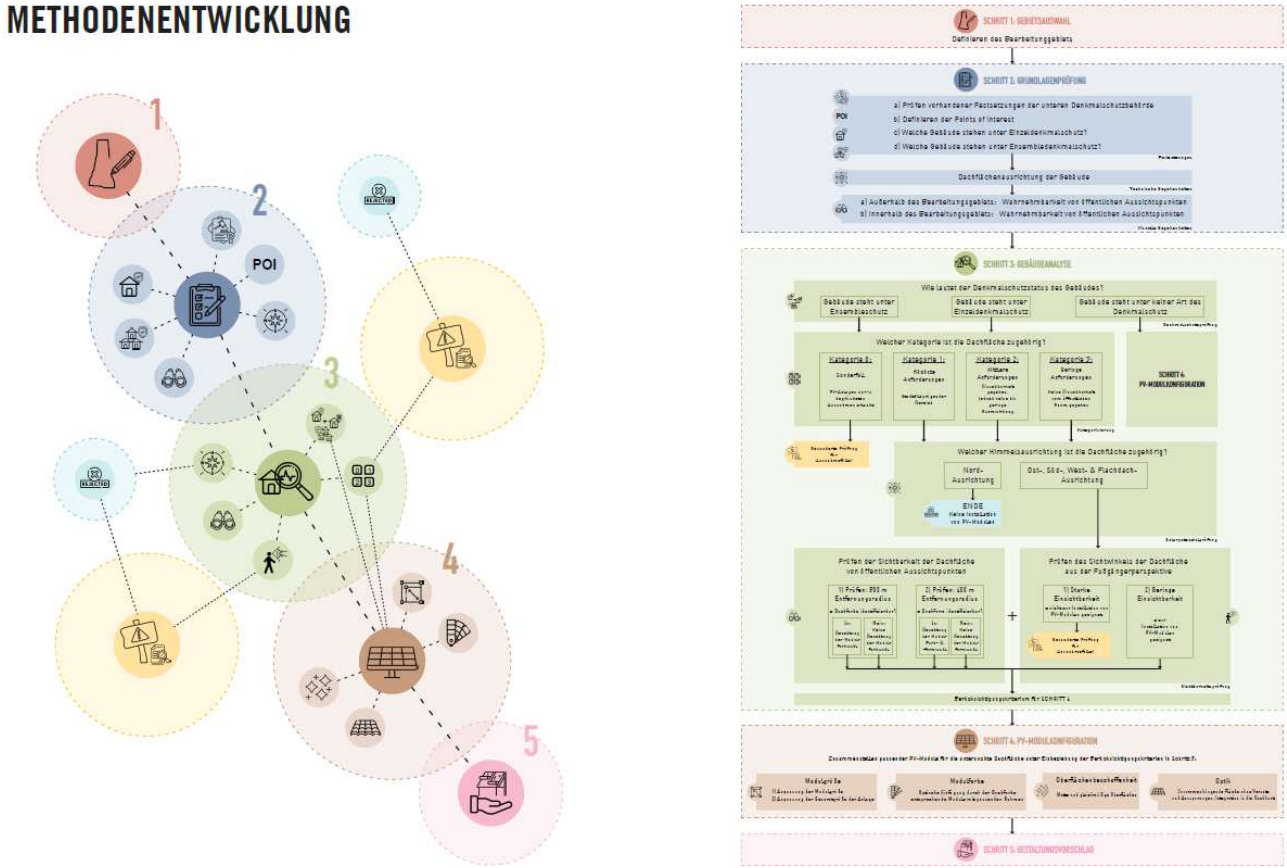

Abb.2: Methodisches Ablaufschema der einzelnen Untersuchungsschritte (Bürkle & Bauder 2025)

4.2.1 Grundlagenprüfung mit Sichtbarkeitsanalyse und Dachformen – Alles was Licht berührt

Ein besonderer Punkt von Gestaltungsplanung ist nicht nur im Denkmalschutz die Überprüfung von Sichtbarkeiten. Methoden wie „Line of Sight“ in 3D-Stadtmodellen (Kolbe und Donaubauer 2021) oder Isovist-Technologien (Lonergan und Hedley 2016)stehen hier als neue Arten der Berechnung von Sichtbarkeiten im dreidimensionalen Kontext. Ein einfacher Weg der ersten Klassifikation von Sichtbarkeiten ist eine Radius-Berechnung um einen bestimmten, historisch wichtigen Beobachtungspunkt in Form eines Puffers. Diese Berechnung funktioniert allerdings nur bei wenigen wichtigen Punkten, ist das Ensemble / das Denkmal stark einsehbar, stößt diese generelle Berechung an seine Grenzen bzw. muss auf Gebäudeebene nochmals über die o.g. Viewer überprüft werden.

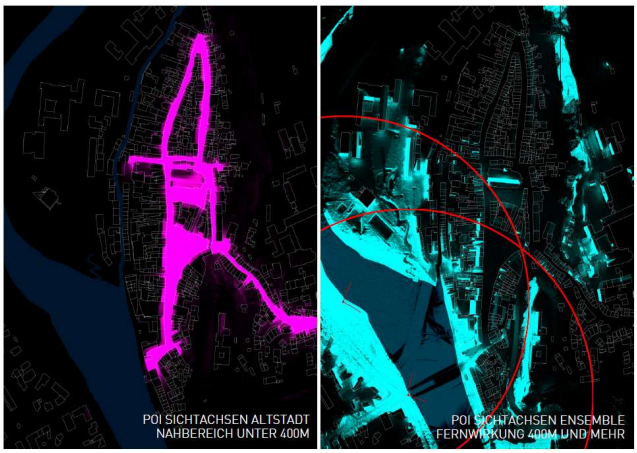

Abb. 3: Berechnung der sichtbaren Bereiche mithilfe von 2D-Radien um einen bestimmten Beobachtungspunkt (links) und mithilfe von Lichtberechnungen in den rechten drei Bildern inklusive der Sichtbarkeitslassifikation in Nah-, Fern- und Nah-und-Fernbereich (Bürkle & Bauder 2025, Herm&Benkeser 2025)

Ein in der Studie vielversprechender Ansatz ist die Sichtbarkeitsberechnung mithilfe von Flächenlichtern. Durch das Anheben des Flächenpolygons des öffentlichen Straßenraums auf 180cm über Bodenlevel und

Setzen einer über die Gesamtfläche ausstrahlenden Lichtquelle werden an jeder Stelle des Polygons die Einsehmöglichkeiten eines Beobachter simuliert. Alle Dachflächen, die direktes Licht von dieser Lichtquelle aus aufnehmen, sind einsehbar. Im Umkehrschluss sind die Schattenbereiche Potenzialbereiche für PV-Anlagen, in denen aufgrund der fehlenden Einsehbarkeit KEINE besonderen Gestaltungsmaßnahmen formuliert werden müssen.

4.2.2 Kategorisierung der Gebäude als Grundlage des Solarrahmenplans

Aus den Aspekten der stadthistorischen Bedeutung, dem Schutzanspruch des Denkmals und der Einsehbarkeit findet im nächsten Schritt eine Kategorisierung statt. Dabei wurden vier Kategorien gebildet, die sich nach der strenge der Anforderungen von „Kategorie 0 – Höchste Anforderungen“, über „Kategorie 1 – Hohe Anforderungen“ und „Kategorie 2 – Mittlere Anforderungen“ bis zur „Kategorie 4 – Geringe Anforderungen“ erstrecken. Die höchsten gestalterischen Anforderungen zur Nutzung von Solarenergie werden bei den Dachflächen derjenigen Gebäude formuliert, die aufgrund ihrer stadthistorischen Bedeutung und als Einzeldenkmal besonders sensibel zu behandeln sind. Für diejenigen Gebäude, die aufgrund ihrer Präsenz eine wichtige Bausteinwirkung innerhalb des denkmalgeschützten Ensembles haben, werden hohe Anforderungen formuliert werden müssen. Für Gebäude, die selbst keine oder nur eine geringe Raumwirkung aufweisen, im Hinblick auf die Dachlandschaft des Ensembles jedoch leicht einsehbar sind, werden später mittlere Anforderungen formuliert. Dachflächen von Gebäuden, die keine Einsehbarkeit aus dem öffentlichen Raum aufweisen, können mit geringen gestalterischen Anforderungen um eine solarenergetische Nutzung erweitert werden.Abb. 4zeigt die exemplarische Kategorisierung eines zu beurteilenden Gebietes in der Altstadt Landsberg am Lech, das anhand des o.g. Ablaufschemas / Datenworkflows beurteilt und kategorisiert wurde.

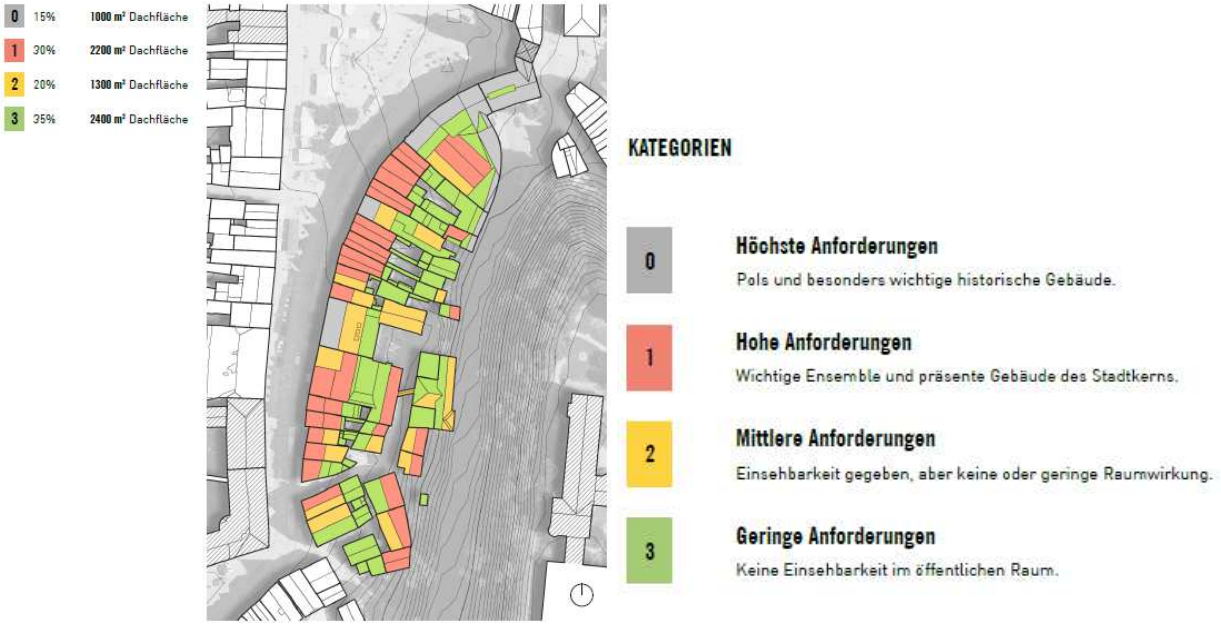

Abb.4: Solarrahmenplan des Gebietes östlich des Hauptplatzes in Landsberg am Lech inklusive der Kategorieeinteilung sowie Dachflächenbilanzierung (Heim & Mink 2025)

4.2.3 Geopositionierte Bearbeitung am Objekt – auf dem Dach

Mithilfe der in den vorigen Arbeitsschritten erstellten Datensätze kann nun relativ einfach ein hausbasierter Steckbrief erstellt werden, der wie in einer Art Steckbrief sämtliche für die Installation von PV-Modulen benötigten Informationen enthält. Neben der formalen Einteilung in den Kategorietypus sind dies Informationen zur potenziell installierbaren PV-Fläche nach Modultypus inklusive eines Muster-Vorschlages, eine Sichtbarkeitsüberprüfung des installierten Moduls sowie eine grobe Ertragsrechnung aus den, in der GIS-Analyse ermittelten, räumlichen Werten.

Im Rahmen der Studie wurden für verschiedene Kategorien auch Belegungspläne für die jeweiligen Module in der zugeordneten Kategorie erstellt, die ähnlich eines Fliesenspiegels den räumlichen Eindruck vermitteln. Dieser Belegungsplan wird wiederum als Textur ausgegeben und kann später, im Idealfall georeferenziert als optionale Dachinformation in das komunale GI-System zurück gespiegelt werden – CityGML liefert in der

LOD3-Beschreibung hierfür eine Möglichkeit des Speicherns. Diese Textur kann auch für eine Fotomontage in der Ansicht des infra3D-Clients oder TwinCity3D zur schnellen visuellen Prüfung überlagert werden. Ein Beispiel für diese Möglichkeiten ist in Abbildung zu sehen.

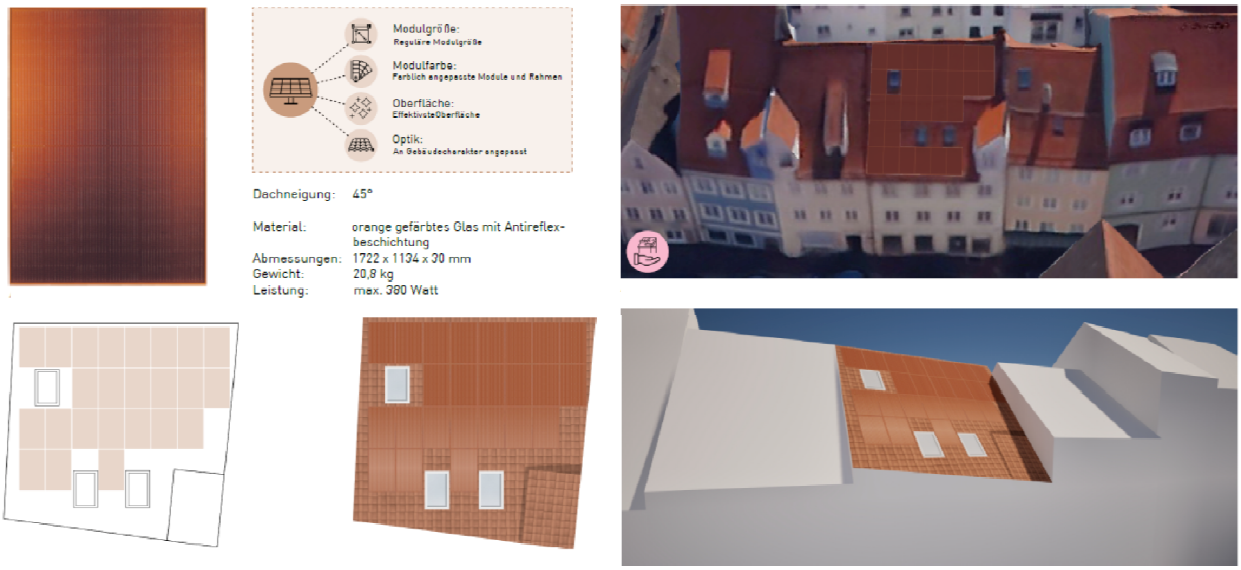

Abb.5: Informationen zum PV-Modul, der Belegungsplan als Rohzeichnung und mit Textur, sowie die Fotomontage in TwinCity3D und der gerenderten Ausgabe im LOD2-Stadtmodell der Stadt Landsberg (Bauder & Bürkle 2025)

5 FAZIT

Innerhalb der Forschungsstudie konnten die für die Aufstelllung eines Solarrahmenplans geforderten Aspekte in Kombination mit den vorhandenen Geodatenbeständen und unter Zuhilfenahme von Werkezeugen des digitalen Zwillings nicht nur erfolgreich bearbeitet werden, sondern die methodischen Ansätze für die Erstellung eine Solarrahmenplanes gehen über die bisher erfolgreich umgesetzten Projekte wie in Wasserburg, Würzburg oder Bayreuth einen Schritt weiter. Die konsequente Einbeziehung der dreidimensionalen Morphologie und der Gestalt der Dachflächen im Einzelfall bei einer gleichzeitigen Möglichkeit der Automatisierung einzelner Klassifikationsschritte könnte in Zukunft die Aufstellung von Solarrahmenplänen erleichtern, beschleunigen, teilweise automatisierten und bauteilorientierter (dachflächenorientierter) verständlicher gestalten. Die getesteten Methoden helfen, örtliche Begebenheiten ohne zeitaufwändige Ortsbegehungen im Vorfeld zu analysieren, ersetzen jedoch im Einzelfall nicht die zielgerichtete Expertise von Experten am Objekt – denn, wie bei allen digitalen Methoden: Das Online geht nicht ohne das Offline.

6 AUSBLICK

In den nächsten Schritten sind Verschneidungen von (theoretischem) Solarpotenzial und den Möglichkeiten nach denkmalpflegerischer Beurteilung vorstellbar. Desweiteren ist vorgesehen, die exemplarisch angefertigten Steckbriefbewertungen einzelner Gebäude auf die verbleibenden Altstadtgebäude auszuweiten. Der resultierende Solarrahmenplan als Ganzes soll schließlich in den TwinCity3D-Viewer integriert werden, so dass Bauinteressenten sich vorab darüber informieren können, was auf den eigenen (Teil-)Dachflächen unter Berücksichtigung denkmalschutzfachlicher Aspekte zur Nutzung von Solarenergie möglich ist.

Durch die weitere, konsequente Einbeziehung von CityGML bzw. sogenannte „City Information Modelling (CIM)“-Ansätze, die Eigenschaften von GIS und BIM/IFC komprimiert verbinden, sollten auch fehlende Dimensionen wie Energiebedarfe, Aussagen über Fassaden und weitere Parameter (eine DSGVO-Konformität vorausgesetzt) über ein Schnittstelle wie z.B. OpenFOAM in den digitalen Zwilling überführt werden können.

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🏆 reviewed paper

Dynamics of Conscious, Individual and Collective Unconscious

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1 ABSTRACT

The paper presents the discussion regarding up-to-date development in such subject domains as “digital twins”, artificial assistant and etc. The two main topic will be presented in this paper: philosophical background and representation of a person as a digital automate. Philosophical background presents some conclusions from the our previous papers, published in REAL CORP proceedings.

Representation of a person as a digital automate aims to investigate how to present main philosophical existences form the modern computer science point of view. We have used our experience in computer science in such fields as systems of ontology, inference machine, scenario approach, object oriented approach. As an example, we should say that some abstractions in OOA are very similar to key abstractions in classical philosophy.

Keywords: Individual Track, Individual Profile, Digital Human, Digital World, Individual and Collective Unconscious

2 INTRODUCTION

In our previous works, published in the CORP proceedings, we have tried to consider the views of classical philosophers on such eternal problems as the relationship between consciousness and existence, the essence of human thinking, space and time, nature (the external world) and human, the ability to perceive the surrounding world and oneself.

And now we have set ourselves the task of transforming philosophical concepts and categories into the language of computer science. The goal of this transformation is to try to represent certain aspects of a person in the computer world. In this regard, existing ideas of “digital twins” concern only superficial, external factors, such as passport data, biography, medical characteristics, physical data. Such data do not characterize a person as a phenomenon. This is a social and physical portrait, which very approximately relates to the very essence of “human”.

Of course, it would be foolish to ignore these characteristics of a person, but focusing only on them is even more utopian in the direction of a digital twin. The theoretical developments that we present here serve as a theoretical and technological basis for building a real intelligent assistant for each person. An intelligent human assistant (Human Artificial Assistant (HA²)) should really help a person navigate our complex world, including with the advent of powerful computers and networks, some of which are even called artificial intelligence (AI), although before that there is a qualitative leap to overcome. So far, this is an imitation of AI, and not AI itself. BUT, in our opinion, the main task of HA² for a person is a tool for self-knowledge. We hope that HA² itself will be discussed in our next article.

3 PHILOSOPHICAL BACKGROUND

Based on the works of such philosophers as Spinoza, Descartes, Kant, Hegel, Fromm, Jung and others, which we have reviewed in our previous publications at CORP, we will consider the dynamics of the interaction of such entities as the conscious, individual and collective unconscious. Fig. 1 presents the hypothesis of individual’s development.

Point “O” is the beginning of the creation of human as a representative of a new civilization on planet Earth. Before this, “was” something else. The concept of “was” is not entirely appropriate, since perhaps there is something in parallel, but we have nothing else as an understanding, except for “was”. Point “X” is the point of “original sin” – let us call it that. At this point, presumably, the synthesis of spirit and matter is realized, and the spirit begins to know itself and matter.

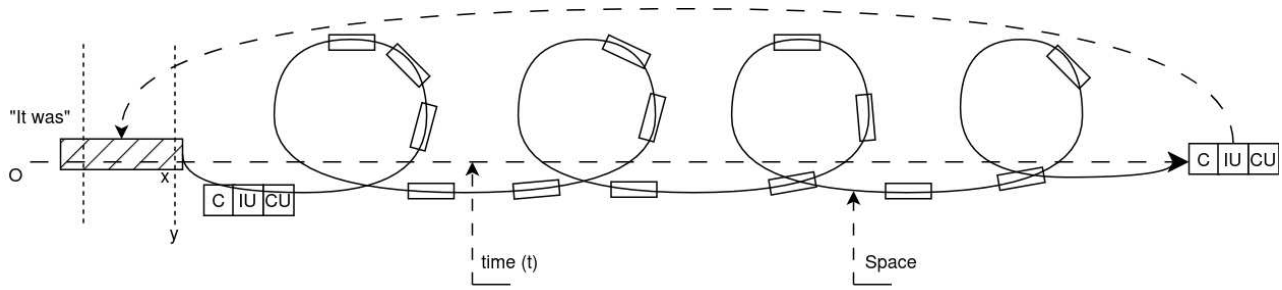

Fig. 1: Hypothesis of Individual Evolution – conscious (C), /// – individual unconscious (IU), xxx – collective unconscious (CU).

In this case, consciousness begins to divide into at least three parts: conscious, individual unconscious and collective unconscious, this is what was “installed” in the interval 0 – t. At point X, time t and space S appear. Apparently, the evolution of the individual, presented in Fig. 1, is common to all living beings. The interval X-Y is “childhood”.

It has two meanings – it is the beginning of modern civilization, and the period of childhood at birth. The birth of a person is also an imitation of the "original sin", a rupture of primary bonds. During this time, a person begins to adapt to the world he has entered. During this period, all three elements: conscious, IU and CU are closely connected. Therefore, a child after birth is of a significantly higher order than an adult, who is already very limited and has strong gaps between C, IU and CU. Apparently, the task of an individual is to make three entities united: C, IU and CU.

It is quite possible that it is impossible to do this in one period of life. The idea of reincarnation, for example, in the culture of Buddhism, has a similar meaning. The existing and diverging gap of the second kind (mathematical analysis) sharply limits the cognitive activity of the individual. But it is objectively conditioned. The fact is that the appearance of these “gaps”, the concepts of “space”, “time” is conditioned by our physical capabilities. Man is greatly limited, apparently due to energy capabilities. Even in the current state, the human brain spends more than 25% of all human energy. Any increase in brain function leads to an increase in energy costs. Man will need a completely different physical body and energy supply system, which, in the current conditions of planet Earth, is quite possibly already impossible. Here, according to the expression of Marxists, being clearly defines the limits of consciousness, our capabilities. To increase intellectual (cognitive) capabilities and progress in general, duality is encountered almost everywhere in our world. Man is also “divided” into two halves: man (M) and woman (W). In this sense, if we look again at Fig. 1, it shows a spiral of one half. Two spirals will have the form shown in Fig. 2.

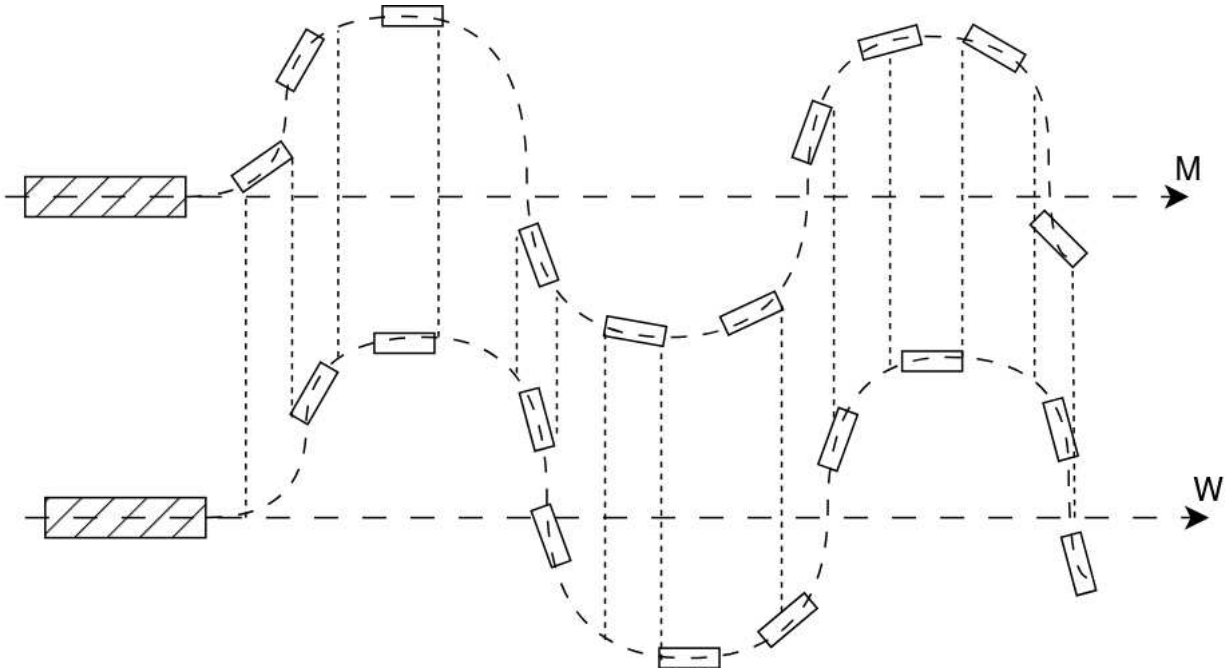

Fig. 2: Two spirals of evolution, probably for man (M) and woman (W).

The axes M and F shown in Fig. 2 look like curved lines, although this may not be the case at all, but the essence of the explanations does not change. In addition to the reproductive instinct and libido described by Z. Freud, the attraction between M and F may also be based on an unconscious desire to eliminate the second-order breaks between C, IU and CU. If we imagine that the spirals M and F coincide in phase, but the second-order breaks do not coincide, then we obtain an integral projection that is practically continuous, or with minimal breaks, when the second-order break turns into a first-order break, and ideally they tend to solid spiral rings, see Fig. 3. Note. Fig. 2 shows the idea itself, but not the appearance and essence of this hypothesis.

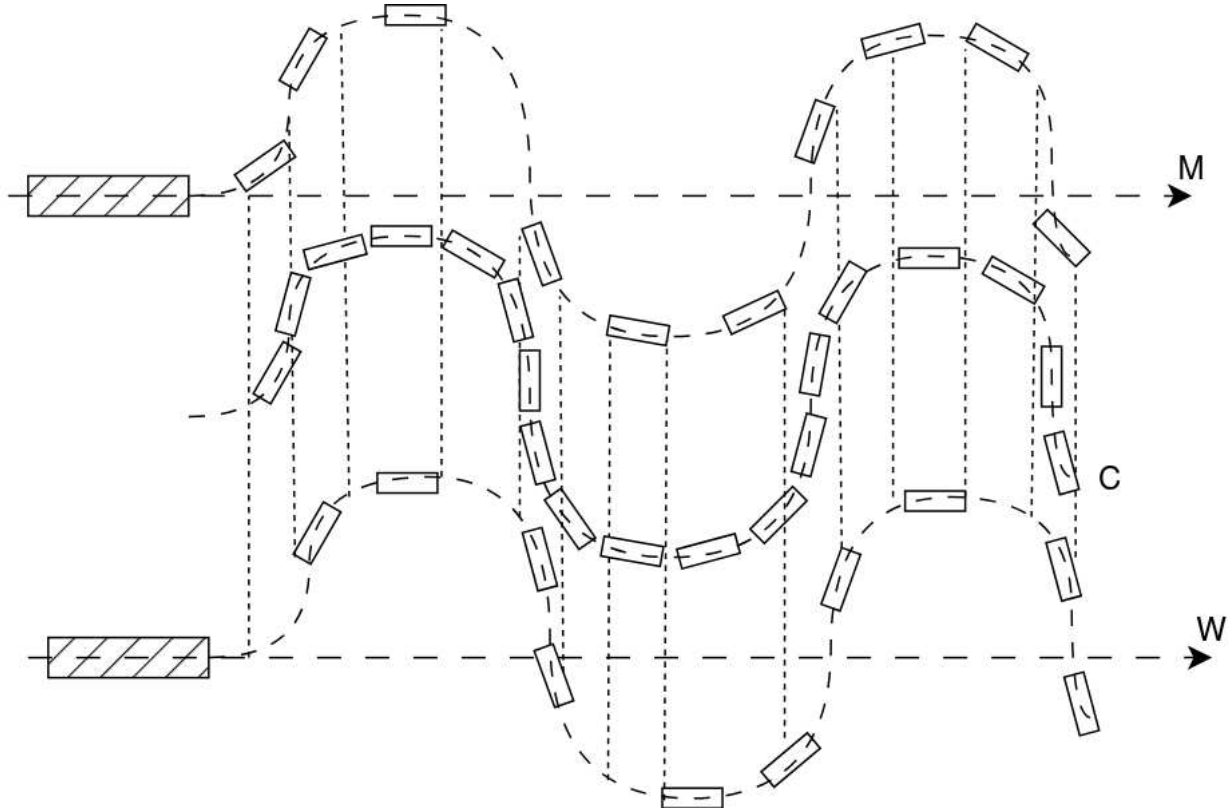

Fig. 3: Projection of two spirals for man (M) and woman (W).

The integral projection shown in Fig. 3 has unreal power and energy. When synchronizing spirals, such a concept as Anima in Hume's terminology arises. Let's make a few comments on the idea shown in Fig. 3.

(1) For synchronization, it is necessary to apply efforts, preferably from both sides.

(2) The feeling of synchronization is frightening with its power and energy and its beginning can be repulsive, especially for a modern person.

(3) The period of existence of synchronization depends on many factors. It can last for months, or even a lifetime.

(4) The fact of synchronization remains for life, regardless of the duration and result.

(5) The state of synchronization gives birth to brilliant scientific ideas, works of art, and motivates a person to a feat.

Another option is possible, an option for human development compared to the one shown in Fig. 1.

Fig. 4 shows a variant of a “diverging” spiral. In this case, not only does the second-order rupture increase, but there is also no tendency toward convergence. In this case, we can say that a person has lived his life in vain for himself. It is quite possible that he has become a negative example for others and has also fulfilled his assigned mission. It is quite possible that such a spiral can also be synchronized with another, which will entail sad consequences for the other spiral.

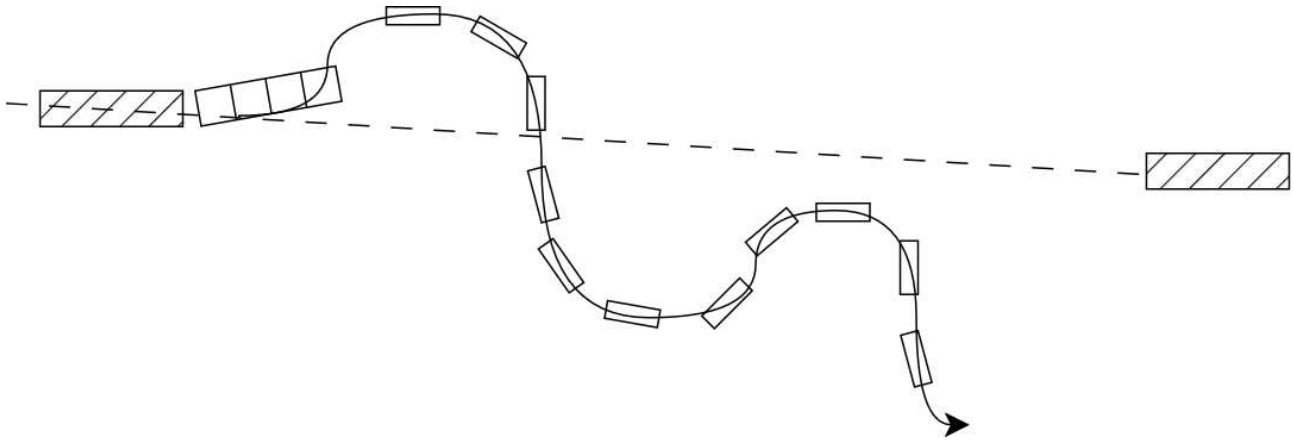

Fig. 4: Divergent spiral.

Notes. 1). It is necessary to separately study the question of when an ideology or religion takes hold of the consciousness of large masses of people? What happens in this case, what mechanisms are involved? What does it affect, what part of the soul? 2). Why does the fetus go through many forms of life on Earth during fetal development? Probably, this is due to the adjustment of a new life to the conditions of planet Earth, "training" and the formation of data, information, knowledge and understanding for existence in specific conditions occurs. This is evidence of the fact that planet Earth is not the only possible place for the existence of intelligent beings (the fusion of the spiritual and the material in one entity). A rational being must have multiple cycles of rebirth.

4 HUMAN REPRESENTATION AS A DIGITAL AUTOMATE

Human representation as a digital automate is the first step to connect computers directly to the essence of this topic, i.e. Human research. For such a representation, we will use the object-oriented approach – a direction in the field of development of large and complex computer systems that arose in the mid-60s of the last century. This is more than a programming paradigm, it is a programming philosophy based on real software development tools. Mechanical use of OOA languages leads to failures and disappointment, OOA itself is criticized. In our opinion, this is due to shortcomings in computer education and a lack of understanding of the basic foundations of this methodology (OOA).

Vulgar use of OOA leads to anarchy in classes, overloading computers, code redundancy and the impossibility of maintaining anarchic and tangled code. This was a lyrical digression, and now, in accordance with OOA, we will define the domain architecture of a human. In accordance with philosophical views, three level architecture of human: body (physical existence), soul and spirit can be selected. Let's try to make several analogies of a “philosopher's man” and a “computer man” at a primary, very simplified level. Let's assume that a person's physical body is the computer's “hardware”. We can connect power to the hardware, it will indicate that it is working, but will not be able to perform any functions (provided that the software is not pre-installed in memory, or is not implemented in hardware). In order for the hardware to come to life, an operating system is required, which organizes the work of all elements of the hardware and can load application software, i.e. what can be loaded. Thus, in our primitive analogy, the operating system is a kind of analogue of the human soul, which animates the physical body, makes it capable of existence and ready for learning, for a certain mission or actions. Application software is actually the implementation of the mission, or purpose of the computer. In our greatly simplified interpretation, it is the spirit of man. Thus, we have defined the main components for representing a person as a digital machine in a computer. A computer representation is the implementation of a virtual model of a person with various goals. We are primarily interested in the possibility of self-knowledge and the search for like-minded people. Possibility of self investigation.

Possibility of self investigation.

1. Individual conscious. That which we are relatively clearly aware of and can imagine in various forms.

2. Individual unconscious. That which we are not clearly aware of and can only imagine indirectly, through various mechanisms, possibly with the help of psychologists and psychotherapists.

3. Collective unconscious. That which we are not aware of and cannot individually imagine. A collective approach, a system of research and scientific knowledge are required.

Let us consider a set of modern computer technologies, the use of which can help in the implementation of a digital twin and a tool for helping a person.

5 SOFTWARE TOOLS

To present a set of tools from the software field, let us consider a person as a certain entity interacting with the outside world at the level of physical sensors and abstract thinking (consciousness).

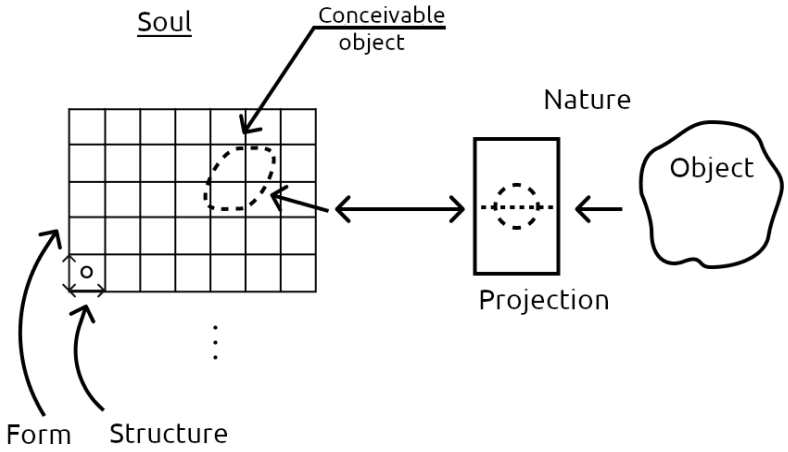

Fig. 5: "Mechanics" of nature and human interaction by K.G. Jung.

Let us also keep in mind that some elements of consciousness are pre-installed in us (I. Kant, K.G. Jung), so we perceive the reality around us through a system of filters. The first filter is the physical ability to react to external fields (limitations on wave ranges for vision and hearing, for example). Therefore, we will imagine the ability to have data about the outside world as capabilities (limitations) when working with a certain framework. At the same time, the choice of frameworks is very limited and determined by the power of our computer, perhaps this is the brain, unless it is an interface, and everything else is part of the virtual space. Thus, the main channels of communication with the outside world that are familiar to us are vision (the main flow of information), hearing, tactile capabilities, vibrations, etc. Information that comes through our senses is data that requires preliminary processing, which our brain does unnoticed by a person. Then the data acquires the meaning of information that is already obtained as a result of training and individual experience of the individual.

Tools such as data analysis packages, including big data, work with data. At this level, a computer today works better than a person. Information is indirect data or meta-data. For example, some information on a GIS map (streets, buildings, institutions, etc.). Modern computer technologies cope well with this level, but data models must first be developed, or clustering packages or pattern detection packages must be applied in data arrays. The use of neural networks and the SVD method allows us to detect information that is not obvious and not directly accessible to humans. The concept of "knowledge" arises only in the process of huge experience and/or training. This concept is no longer trivial for modern computer technologies. It can be implemented through some patterns or scenarios that have received approval, or have positive multiple experience of scenario behavior. It can be derived from logical inference. At the current time, first-order predicate algebra is a good approach in this regard. Logical inference can also be. automated using machines, such as the Rete logical inference machine (LIM). This LIM is widely used in various logical languages and programming environments. We use this technology to develop a scripting system, and have developed a visual script editor that greatly simplifies the use of logical languages. The situation with such a phenomenon as "understanding" is quite complicated.

As E. Fromm noted, modern humanity strives to know, but does not want to understand. This is the fundamental difference between these two concepts (knowledge and understanding). If the concept of "knowledge" can be implemented through a certain repository of scenarios implementing a certain business analytics, i.e. directly using existing tools, then with "understanding" everything is more complicated. After all, understanding is the establishment of cause-and-effect relationships of events. The answer to the question

of why exactly this happens and not something else. This property allows a person to make a decision in situations for which there are no patterns. In fact, only through understanding can new knowledge be generated. Experience is a weak assistant here. Thus, you can endlessly watch the sun rise and set. But without the appropriate theoretical knowledge, an ordinary person on Earth cannot imagine that the Earth revolves around the Sun, and not vice versa. In order to somehow get closer to the implementation of "understanding", we proposed an approach based on the theory of situational management – the analysis of tactical situations. Although the concept of "analysis of tactical situations" is widely used in military affairs, it was apparently first introduced by Gabriel Jacobson, a student of A. Pospelov.

Let's list the existing technologies that can be used to form a digital twin of oneself.

1. Implementation of interfaces: – Interfaces: human←-→environment, human←-→devices. Can be done using web devices (camera, microphone, etc.) and saved on a computer. We implement it using the appropriate protocols that are connected to the ontology system so that the input data stream is meaningful and ordered, and also open for analysis by humans and other applications. Tool – Java code or script.

2. Ontology system – ontology (individual, individual unconscious, collective unconscious, environment, scenarios). Individual conscious can be presented in the form of ontologies using visual ontology editors according to previously formed recommendations. Ontology can be formed by surveying and/or analyzing human actions on a computer. Tool – Java code and Drools logical programming language.

3. Business analytics. It is implemented on the basis of an ontology in the form of a scenario system. Tool – Protege ontology editor, or our own editor.

4. Body properties. It is implemented on the basis of an ontology in the form of a system of properties obtained as a result of instrumental measurements.

5. Soul properties. It is difficult to obtain such an ontology explicitly. It is necessary to develop special methods and analyzers with the ability to manually or automatically edit the editorial version.

6. Spirit properties. This is the most complex substance and determines a person's purpose in this life, his global goals. We do not have any ideas for implementing this phenomenon at the current time.

6 CONCLUSION

In this article we tried to form a certain system of correspondences between classical philosophy and computer science. This is the first step to form the idea of creating an artificial human assistant and a tool for studying oneself. The article showed that many categories of philosophy coincide with concepts in computer science, especially in the OOA methodology. However, the issue of creating an artificial human assistant – HA² has a number of difficulties, namely:

- to help a person, HA² must know who it is helping, i.e. know a lot about the person. Thus, the computer must store a real digital twin of a specific individual, and not formal characteristics;
- HA² must have access to all incoming and outgoing information from a person. This is very difficult and quite dangerous, given attempts to hack personal information, or erase it, or distort it;
- the entire ontology about a person will occupy quite a large physical space, so it must be stored in the cloud, well protected and reliable;
- for the full implementation of HA², interaction with other similar entities is necessary, sometimes in real time. Hence, a mechanism of mutual trust must be implemented, excluding unwanted or even malicious individuals, and sometimes banal scammers, from getting into a certain social group. This task can be implemented using technologies similar to Blockchain.

Despite the obvious difficulties, the creation of applications like HA2 is already on the way. In the near future, we expect the first such applications to appear, possibly based on social networks, or standalone applications.

In our next article, we plan to describe the technology of creating HA2 and its application to real people.

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reviewed paper

Empowering Urban Transformation: The Role of Citizen Observatories in Inclusive and Data-Driven Governance

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1 ABSTRACT

This paper explores how Citizen Observatories can foster participatory, data-driven governance by actively engaging local communities in co-creating urban knowledge and contributing to evidence-based decision-making processes. Within the EU-funded Innovation Action GREENGAGE (HORIZON 2020), five innovative Citizen Observatories have been established as dynamic ecosystems where technology, citizen science, and policy intersect. These ecosystems empower local communities through interactive socio-technical methodologies and tools, enabling them to monitor environmental conditions, share insights, and collaboratively develop solutions to pressing urban issues. Hence, the creation of Citizen Observatories requires a strong focus on two dimensions: social (socio-economic and political context) and technical (digital tools and platforms). By bringing together citizens, scientists, policymakers, and other stakeholders, GREENGAGE harnesses collective knowledge and expertise to co-create sustainable solutions. In GREENGAGE, Citizen Observatories are located in diverse geographical and social contexts: Bristol (UK), North Brabant (NL), Copenhagen (DK), Turano Valley (IT) and Gerace (IT). This paper highlights initial implementations carried out in these Observatories where local communities, further supported by the consortium members, were provided with skills for collecting valuable, community-sourced data from their neighborhoods using the provided tools. Citizens are involved as Citizen Observers throughout the onboarding, training, and implementation phases, contributing to environmental monitoring and urban planning. The data that is currently being gathered will help directly address local urban challenges that are identified as the most critical by these communities, helping to resolve issues that resonate with local needs and concerns. Furthermore, the paper also illustrates how such initiatives have the potential to not only contribute to healthier, more sustainable urban environments but also foster a culture of participatory governance, where citizens are co-creators of the cities they inhabit.

Keywords: Citizen Observatories; Urban Governance; Sustainable Urban Development; Data-Driven approaches; Community Engagement

2 INTRODUCTION

2.1 Background

As cities increasingly confront challenges posed by climate change and urbanisation – ranging from extreme heat events to increasing demands on infrastructure and resources – there is a growing need for governance models that are both inclusive and data-driven (Asadzadeh et al. 2023). This demand is becoming a key priority in the international arena, highlighting a global recognition of the necessity for more collaborative and inclusive strategies of policy-making (Rocha Menocal et al. 2019; Hölscher et al. 2019; Avoyan 2023). Central to this need are socio-ecological challenges such as extreme weather events, social inequality, climate injustice, biodiversity loss, ecosystem degradation, and the growing mistrust among communities in

their local authorities' ability to address these issues effectively. Given the gravity of these challenges, the European Commission has made an ambitious effort to tackle climate change and drive a transition toward more sustainable development. This commitment is reflected in the EU Green Deal (Broto 2021), a comprehensive policy framework aimed at embedding sustainability and climate action across all EU policies and programs. The Green Deal presents cities with a unique opportunity to drive systemic economic and social transformation.

However, a significant obstacle to reshaping urban governance effectively is the persistent disconnect with local communities, including their concerns, needs, and perspectives. This gap is exacerbated by the absence of robust participatory approaches. As a result, the marginalisation of such grassroots perspectives is expected to exacerbate inequalities and existing disparities in access to opportunities and knowledge. At the same time, it is becoming increasingly clear that traditional top-down urban governance models are often ill-equipped to address the complexity and interconnected nature of these challenges (Baud et al. 2021). These models rely heavily on centralised decision-making by higher authorities, which can overlook the nuanced realities and diverse needs of local communities. Hence, the conventional urban governance approaches are being challenged by an imperative for innovative solutions that transcend institutional silos. Furthermore, there is a significant gap in comprehensive in-situ data (i.e., site-specific, real-time data gathered directly at the location where the phenomena occur) that can effectively capture the intricate and interconnected dynamics of urban environments. This absence of high-quality in-situ data severely limits the ability of decision-makers to identify and address emerging context-specific challenges (Tonne et al. 2020). As a result, responses often lack the timeliness, precision, and relevance needed to tackle complex urban issues in an informed and proactive manner. To address this, cities are increasingly turning to innovative solutions that prioritise public engagement through equitable participation and open dialogue. Prominent among these practices is citizen science, which empowers non-professional volunteers from the general public to contribute and co-produce new and complementary knowledge that benefits both science and society (Haklay et al. 2021). Despite its potential, citizen science has faced criticism for its fragmented landscape, often consisting of isolated activities focused on specific issues (O'Grady et al. 2021). Examples include initiatives centered on air quality monitoring (Mahajan et al. 2022), bird monitoring (Ding et al. 2022), butterfly counts (Butler et al. 2024), biodiversity conservation (Peter et al. 2021), and water quality assessment (Yevenes et al. 2022). This fragmentation highlights the need for more integrated and cohesive approaches that maximise the collective impact of citizen science efforts.

In response, a complementary concept, known as the Citizen Observatory (CO), has emerged. This concept builds upon the foundations of conventional citizen science while addressing its fundamental limitations and expanding its scope (Lie et al. 2017, O'Grady et al. 2021). Citizen Observatories (COs) function as comprehensive ecosystems of collaborative observation and action, tackling urban planning challenges linked to climate change and community disengagement through diverse and holistic perspectives. Unlike traditional citizen science initiatives, which often focus on singular issues, Citizen Observatories adopt an integrated approach that fosters a multifaceted understanding of complex problems (Rathnayake et al. 2020, O'Grady et al. 2021). This approach brings together the collective knowledge and expertise of citizens, scientists, policymakers, and other stakeholders to co-create solutions. Additionally, while citizen science primarily focuses on collecting objective, scientific data, COs go beyond that by integrating subjective information such as personal perceptions and experiences, which are crucial for understanding how people's attitudes and behaviours evolve. By incorporating diverse perspectives and methodologies, COs enable a more nuanced, participatory, and citizen-centric approach to problem-solving. This, in turn, facilitates deeper reflection and more agile, context-sensitive responses to emerging societal and environmental challenges.

2.2 Overview

The transformative potential of COs is currently being leveraged within the pan-European Innovation Action GREENGAGE, funded by the Horizon Europe program (GREENGAGE 2025). As part of this initiative, five innovative COs in diverse geographical and social contexts have been established as dynamic ecosystems where technology, citizen science, and policy intersect: Bristol (UK), North Brabant (the Netherlands), Copenhagen (Denmark), Turano Valley (Italy), and Gerace (Italy). The five pilots serve as living laboratories of innovation, showing how citizen engagement, technological advancement, and governance transformation can intersect to reshape civic participation and policymaking. To achieve this, a range of initiatives is being

implemented within these COs, supported by the GREENGAGE consortium. By providing expertise, resources, and guidance, the consortium ensures that local communities are equipped with tailored socio-technical methodologies and tools to observe, monitor, and actively engage with their neighborhoods. In this collaborative process, community members take on the role of Citizen Observers, actively participating in environmental monitoring, mobility pattern analysis, and the evaluation of public space usage in tourism. These thematic areas are selected based on the priorities identified by the communities themselves, ensuring that the initiatives address issues most relevant to their specific needs and concerns.

3 METHODOLOGY

3.1 Innovation pilots in GREENGAGE

GREENGAGE innovation pilots span diverse geographical and social contexts, with activities specifically designed to address local environmental and sustainability challenges, further aligned with the broader Green Deal priorities (see Figure 1). In Bristol, a densely populated city in southwest England, the CO operates at a neighbourhood level, engaging local communities in reimagining their neighbourhoods as people-centred, liveable spaces of clean air, quality green spaces, and a strong sense of community. In North Brabant, a predominantly rural and peri-urban province in the south of the Netherlands, the CO functions at the regional level, fostering community participation in the transition to a sustainable and smart mobility while enhancing climate resilience. Copenhagen, the capital of Denmark known for its waterfront developments and green urban planning, hosts its CO at the district level, mobilising citizens to contribute to the city's climate targets through air quality monitoring and climate adaptation initiatives. In the Turano Valley, a sparsely populated rural region in central Italy close to Rome, the CO operates at the municipal level, empowering communities to support climate resilience, regenerative practices, and the preservation of its rich cultural heritage. Similarly, Gerace, a historic hilltop town in southern Italy, hosts its CO at the municipal level, involving local communities in climate adaptation efforts and sustainable heritage conservation.

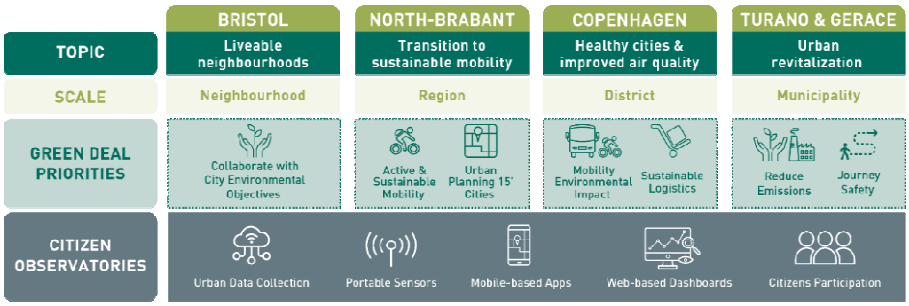

Fig. 1: Overview of the GREENGAGE pilots, highlighting their specific topic areas, scales of impact, Green Deal priorities, and core components of Citizen Observatories.

3.2 Foundational aspects of Citizen Observatories

The process of establishing Citizen Observatories in five pilot areas involves both social and technical dimensions. From a social perspective, it requires a deep understanding of the local socio-economic and political context, such as identifying key decision-makers, assessing community dynamics, and evaluating the unique challenges and opportunities within the area. From a technical perspective, it entails designing and implementing a robust technological framework, including digital tools and platforms, to facilitate data collection, analysis (including data validation), and collaboration effectively. The social dimension and its corresponding socio-political context are thoroughly mapped through a combination of surveys and interviews with key project partners leading each pilot area (i.e., pilot owners), offering a comprehensive overview of the local context with valuable insights into the social fabric, political structures, and community perspectives. The technical dimension was conceptualised through a series of collaborative discussions within the consortium to determine the appropriate tools and their intended applications, as well as the necessary levels of training and support.

However, both aspects are inherently dynamic and continuously evolving, shaped by the ever-changing real-world conditions, shifts in local power structures, and the evolving expectations and needs of communities. Therefore, to navigate the fluid nature of these challenges, our approach emphasizes flexibility through

adaptable strategies and continuous reassessment to ensure the COs remain relevant, responsive, and effective in tackling the priorities of the communities they serve. Hence, we have established a series of structured bi-weekly intra-consortia meetings, known as Pilot Support Teams (PST), to regularly reassess the local conditions, actively incorporate stakeholder feedback, and adjust our collective strategies accordingly. The PSTs consist of dedicated consortium members representing both technical domains (i.e., technology providers) and non-technical domains (i.e., participatory and social sciences). Together, they provide ongoing support to the pilot owners, who act as community representatives, ensuring a collaborative and holistic approach to addressing the needs of the communities involved. These meetings serve as a channel for ongoing collaboration and monitoring, enabling assessment of shifts in local power dynamics, as well as evolving community concerns and goals. This approach ensures agility, and through the iterative process, a continuous adaptation of the pilots to meet the changing needs and challenges.

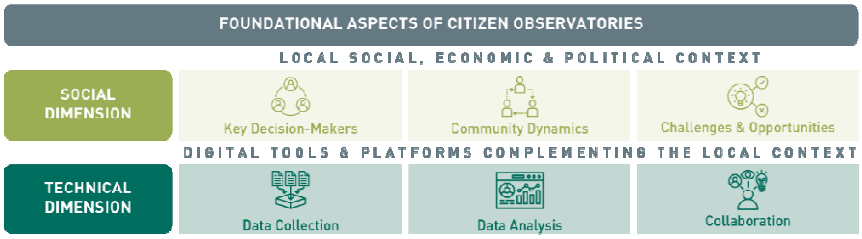

Fig. 2: Foundational aspects of Citizen Observatories: social and technical dimensions.

The PST sessions also provided the foundation for in-depth discussions on technical aspects. They facilitated the identification of the most suitable digital platforms, data collection methods, and socio-technical tools that would be most effective in meeting the goals of each CO. Specifically, participants in the COs have access to a diverse suite of technological assets designed to support the entire data-to-policy lifecycle. Curated for interoperability and scalability, these assets form the GREEN Engine – a comprehensive toolbox comprising three categories: (1) GREENGAGE tools, developed by the project consortium enabling data collection, visualisation, and analysis, also effective collaboration and engagement; (2) pilot-specific tools, tailored to the unique needs of individual pilots; and (3) open-source tools adopted by GREENGAGE, which enhance functionality and adaptability. Within proprietary GREENGAGE suite of tools, the starting point is the Collaborative Environment (Collaborative Environment 2025), a foundational tool for COs that facilitates the setup and management of co-production processes within a CO. Following, a range of mobile-based applications enables real-time mapping and image analysis (MindEarth app 2025), mobility patterns capture and modes of travel detection (MODE Software Library 2025), and qualitative spatial data collection on, e.g., local air quality or safety levels (GREENGAGE app 2025). Additionally, wearable environmental data capture devices (AtmoTube 2025), combined with visualisation dashboards and data analytics platforms, equip participants with powerful capabilities to visualise, analyse, and interpret environmental information effectively (Superset 2025). Altogether, these three categories of tools serve to facilitate community and process management as well as data crowdsourcing, empowering participants to contribute effectively to environmental monitoring and policy development.

3.3 Preparing for participatory data collection & analysis

In a participatory setting, individuals are not passive recipients of information; rather, they are recognized as active contributors, with their perspectives, knowledge, and skills integral to the process (Vaughn and Jacquez 2020). This collaborative principle is central to the GREENGAGE framework, which leverages co-creation and crowdsourcing to develop innovative data-driven solutions to urgent environmental challenges. At its core, the GREENGAGE project ensures that local communities are actively engaged from the very beginning, fostering a sense of shared responsibility and ownership in addressing these critical issues.

This process is realized through several steps that aim to co-deliver a thematic co-exploration (GREENGAGE Documentation 2025). Essentially, a thematic co-exploration is a collaborative process in which diverse stakeholders – including citizens, scientists, policymakers, and other relevant actors – jointly investigate, analyse, and develop insights on a specific theme or issue. This process unfolds in four key stages: (1) preparing, which involves identifying the theme, onboarding the core team, and providing necessary training; (2) designing, where experiments are specified, tools are selected, refined, and tested; (3) experimenting, which includes onboarding and training observers, followed by data collection and analysis;

and (4) sharing, where findings are communicated through storytelling and advocacy to drive awareness and action. All these aspects are addressed in the PST meetings, ensuring a structured and collaborative approach to planning, execution, and knowledge sharing throughout the process.

Once the theme of co-exploration is identified based on community concerns, the process moves forward with onboarding and training. Onboarding focused on identifying who should be involved, when and how they can best contribute to the co-creation process within COs. It defined the roles of key actors in collaborative efforts and assesses their technological and scientific capabilities. Essentially, it ensured a clear understanding of the communities to engage, the best timing and methods for their involvement, and their specific needs. Building on these insights, particularly technological and scientific needs, the next step focused on training. To support this, a range of training resources is developed as a part of the GREENGAGE Academy, including video tutorials on project-specific digital tools from the GREEN Engine toolbox, as well as guidance on the scientific methods, data standards, collection, processing, handling, and analysis. These were delivered through interactive online workshops, referred to as "Train the Trainers" training series. Initially, the training targeted the core team of Citizen Observers (i.e., selected members of the consortium), equipping them with the knowledge needed to oversee and support external participants (i.e., key actors from the onboarding phase), ensuring effective knowledge dissemination and capacity building beyond the consortium. The external training was conducted through community-oriented workshops held on-site in pilots, designed to foster hands-on learning and active engagement with key actors. These workshops were tailored to the specific needs of participants, ensuring accessibility and relevance while also incorporating their feedback on the proposed materials. This iterative approach allowed for continuous refinement, ensuring that emerging needs and perspectives were effectively addressed.

3.4 Advancing participatory governance models

To advance participatory governance models, the GREENGAGE project employs a robust approach grounded in transparency and inclusivity while fostering meaningful collaboration between local communities, policymakers, and experts. A crucial element of this approach is maintaining an open and continuous dialogue with these stakeholder groups, ensuring their voices are not only heard but actively integrated into decision-making processes. Efforts have been made to govern the co-creation process through the Collaborative Environment, supported by the thematic co-exploration process model. This model provides a structured framework that guides communities through the various phases, steps, and assets from the GREENGAGE Knowledge Base, ensuring they can effectively navigate and utilise the resources available at each stage of the process. However, not all aspects of this model have been fully embraced or implemented across GREENGAGE pilot contexts. This is primarily due to the varying local conditions, needs, and capacities of different communities, which can influence how certain tools or steps are adopted and integrated. To further facilitate a meaningful engagement, the GREENGAGE project is actively engaging in several structured activities, including public talks at international conferences, community forums, academic symposiums, and environmental summits. These events serve as a platform to connect with diverse audiences, share insights on participatory governance, and discuss innovative solutions to environmental challenges on both local and global scales. By bridging all these perspectives, we aim to create more effective and resilient governance structures.

In addition, we are organising a series of participatory workshops and are actively preparing for an upcoming datathon in Turano pilot in Italy. The aim of these activities is to create interactive spaces for co-creation, knowledge exchange, and data-driven decision-making. Specifically, participatory workshops empower both communities directly involved in the project and those beyond its scope to share firsthand experiences and insights. For instance, a series of workshops held with local communities from each pilot site are providing a valuable context on community dynamics, helping identify local priorities and better understand typical decision-making processes. Additionally, participatory workshops aimed at external audiences are engaging with students, academics, and other stakeholders to gather fresh perspectives on GREENGAGE activities. By incorporating external viewpoints, these workshops are continuously enriching the project's impact and ensuring its relevance across diverse contexts. Our upcoming datathons aim to engage citizens, researchers, technologists, and local stakeholders in collaboratively analysing real-world data and generating innovative, evidence-based approaches to environmental and urban challenges. The citizens who previously participated

in data collection will be invited to participate in the datahon, which should further deepen engagement and enrich the analysis.

4 RESULTS

4.1 Situational context and dynamics of pilot areas

We begin our discussion by reporting on the distinct situational context and dynamics of innovative pilots involved in the GREENGAGE project, as highlighted by our survey results, which collectively shaped the specific needs and priorities of each pilot area and influenced the design and implementation of COs.

Bristol, UK: The Bristol Pilot focuses on the East Bristol Liveable Neighbourhood (EBLN) initiative, which aims to enhance the quality of life in East Bristol through a smart urban governance approach. This approach involves co-discovery and co-development phases to understand the needs of the community, identify desired changes, and uncover barriers to creating a more liveable neighbourhood. During these phases, Bristol City Council (the GREENGAGE pilot owner) used a design toolkit to gather community aspirations through events and an online platform (Commonplace 2025). These phases served as precursors to a trial scheme design and delivery, where some of the community's aspirations will be tested. The EBLN project went through the Traffic Regulation Order (TRO) process. Bristol City Council held official consultations on proposed measures like bus gates and modal filters, which need TROs to make legal changes to the roads. Based on these consultations, the city council approved the trial scheme. At the time of writing this article, the trial scheme is being delivered. In addition to traditional methods, the GREENGAGE project plays a crucial role in monitoring the trial scheme. Continuous monitoring during the trial scheme will help assess the impact of changes on mobility, air quality, and equality. This monitoring will provide a basis for consultation with the community and implementing permanent changes in the EBLN.

North Brabant, NL: The North Brabant pilot focuses on exploring COs as a sustainable means of citizen participation. Following the Omgevingswet (Environmental Law) (Ministerie van Koninksrijkrelaties, 2024), public authorities (amongst others) have a duty to include citizen participation in projects. However, how this change in procedure should be sustainably integrated into the governance process is still debated. The pilot experiments with using a CO to structure citizen participation for the benefit of public authorities, civic organisations, and citizens alike. Following Pappers et al. (2022), the focus is on exploring COs as a valid method of policy participation by initiating a discussion rather than large-scale data collection. To test the validity of COs, a strong foundation was necessary. Therefore, the CO was built to complement existing governance processes with citizen data or input, rather than replacing or merely supplementing already existing practices. By consulting the citizen cyclist collective of the Fietsersbond (Fietsersbond 2025), cycle path maintenance was identified as a key topic for citizen engagement (in this case cyclists), ensuring intrinsic motivation. Currently, cycle path maintenance governance is a two-way but disconnected process. Public authorities assess and maintain paths through periodic expert judgment, while citizens can report maintenance needs through online mapping portals, often unsure of the correct authority to report to. Alternatively, citizens can collaborate with civic advisory organisations like the Fietsersbond, which collect subjective experiences to public authorities. The pilot aims to see how this two-directional process could complement each other to make the cycle path maintenance more inclusive and effective, enhancing the attractiveness of cycling overall.

Copenhagen, DK: Copenhagen pilot focuses on discovering new solutions and alternatives to fossil-based behaviours, particularly within the current transport systems, towards creating a climate-positive neighbourhood. At the core of the initiative is the definition of a new local traffic plan, introduced by the City Hall with a strong emphasis on citizen participation and a vision for a new approach to urban mobility. The plan has sparked political controversy, as the residents resist the City Hall’s plan of creating a new island in the Copenhagen area without fully considering the impact of heavy traffic in the district – given the added pressure from ongoing urbanisation. To address this, the pilot aims to develop a truly citizen-driven traffic plan for its Amager Vest district. Given the contentious nature of the project, the CO seeks to build a reliable and widely accepted dataset that can serve as a shared foundation for decision-making among all stakeholders. A key principle of the pilot is that data collection, when integrated with community engagement, can drive sustainable change. To achieve this, the project has focused on developing a citizen-led data collection methodology, ensuring the final dataset is credible and trusted by all involved parties.

Beyond data quality, the initiative also prioritises inclusivity, ensuring diverse representation in the data and identifying the key parameters that matter to both citizens and stakeholders.

Turano Valley & Gerace, IT: Turano Valley and Gerace, though located in different regions of Italy, share historical significance and face similar issues. Both regions struggle with hydrogeological instability, inadequate road infrastructure, and insufficient public transport. Additionally, poor broadband connectivity hampers economic development and exacerbates depopulation and aging population challenges, straining social services. The villages in these areas are part of the National Programme for Resilience and Recovery (NPRR 2024) and the 'Borghi più Belli d'Italia' consortium, which aims to preserve their significance by regenerating and revitalising heritage villages. The goal is to balance historic preservation with modern needs to attract investments, stimulate economic growth, and support local communities through cultural initiatives, despite demographic challenges. The CO in these areas aims to analyse socio-economic dynamics, focusing on mobility, environment and tourism. Improving infrastructure, connectivity, and urban revitalisation are essential to attract investment, enhance liveability, and support economic growth. The CO aims to achieve this through direct data collection from citizens, engaging with both political and social realities, and community datathons. A big focus of the Observatory is to educate residents on understanding and analysing the risks of degradation to natural and built heritage, assessing the current conditions, such as pollution and mobility, and raising awareness about interventions needed to protect the villages. Timely action can set a precedent for the wider region and serve as a model for other municipalities with similar characteristics. Therefore, the Observatory emphasises citizen science and a participatory approach in environmental monitoring. The goal is to involve citizens in monitoring their environment, advocating for inclusive and participatory decision-making processes that improve community sustainability and resilience.

4.2 Individual readiness of pilot areas

The maturity levels of each pilot significantly influence the activities and approaches employed throughout the project. More mature pilots, like those located in Bristol and North Brabant, build upon already established frameworks that provide a solid foundation for citizen engagement and the implementation of more tangible activities. In Bristol, this foundation is rooted in the Liveable Neighbourhood concept, which embraces a co-design approach that actively seeks community feedback to reimagine local streetscapes. The North Brabant pilot integrates COs into a larger public participation scheme that explores the contribution of cycle path users in ensuring a maintenance pattern more attuned to daily and recreational use, to remove deterrents for taking the bicycle. These strong foundations allow for a more seamless integration of planned GREENGAGE initiatives and a smoother real-world implementation process. In contrast, pilots in Copenhagen and Italy, still in earlier stages of execution, focus more on experimentation and future-oriented transformations. Without established frameworks to build upon, these pilots rely on testing new concepts, fostering cross-sector collaboration, and actively involving citizens in shaping the direction of the initiatives. This exploratory nature allows for innovative solutions but may also present challenges in securing long-term stability and integration.

4.3 First steps towards functioning Citizen Observatories

Building on the structured approach of continuous reflection established in the GREENGAGE methodology, our pilot implementations demonstrate varying degrees of progress in engaging local communities and integrating COs. As previously noted, some pilots remain in the experimental phase and have yet to implement concrete actions.

Bristol, UK: Through its methodology and tools, GREENGAGE reached out to seldom-heard voices, such as school children and youth groups, to identify their aspirations. It aligned these aspirations with the previously collected needs during the co-discovery and co-development phases, particularly through participatory workshops, and identified key gaps. The process began with awareness workshops focusing on sustainable travel and the environment, gathering around 35 participants, followed by a second round of workshops (15 participants per workshop and a wrap-up session with 24 attendees) to discuss possible solutions and highlight key issues. As a result, issues such as anti-social behaviour, poor lighting, narrow kerbs for pedestrians, safety concerns, lack of CCTV (Closed-Circuit Television, a video surveillance system), and public transport accessibility were highlighted. Although most of the issues are not directly relevant to the transport focus of the EBLN project, they can indirectly influence the implementation of the scheme. For

instance, anti-social behaviour, inadequate CCTV, and safety concerns while walking in poorly lit areas or on narrow kerbs were key barriers identified by the target (children and youth) groups. These issues were directed to relevant departments of Bristol City Council for action. Travel diaries were collected over a specific period, and a soft approach (without technology) was used to identify key points of interest and roads needing urgent attention. This data will be used to design experiments within the GREEN Engine, particularly using the GREENGAGE app and MindEarth app, in the upcoming phase. Both apps require setting up experimental tasks, such as Points of Interests (PoIs), research questions, and tasks for recording images between predefined geographical points (routes), to collect qualitative and quantitative observation data. The specifics on how these tools will be applied in the Bristol context are outlined as follows:

(1) Monitoring the environment and automatically identifying safety/threat levels: This use case helps the Bristol pilot owner gain insights into safety concerns and mobility conditions, enabling informed policy decisions on transportation and public safety in liveable neighbourhoods. MindEarth app will be used to gather images on specific roads at different times of a day to perform image analysis and predefined features such as road crossings, cars parked over kerbs, poor lighting, littering, accessibility such as level surfaces for people with disabilities etc will be detected from the collected images using AI. This will be complemented with the qualitative data collected through GREENGAGE app that will provide PoIs on a 2D map and residents will be able to identify spots of concerns and provide textual response to specific questions.

(2) Analysing and visualising the impact on the quality of journeys due to road closures: This use case provides valuable data on how road closures affect travel experiences, helping to optimize traffic management and improve journey quality. The GREENGAGE app with MODE integration is able to detect which routes people take to reach to specific PoIs (e.g., shops, schools, and other local amenities) and what mode of journey (walking, cycling, vehicle) is used. This data will be complemented with qualitative data of rating the overall journey experience by the participants.

Overall, the GREENGAGE methodology ensured that seldom-heard voices are included in the decision-making process, leading to more inclusive and representative outcomes. This bottom-up information collection contributes to top-down decision-making. The data collected and analysed through GREENGAGE tools will provide a robust basis for making informed policy decisions, thereby improving the effectiveness of interventions.

North Brabant, NL: A five-step process was set up, to streamline the expectation management of all parties, and explore the needs and contribution of each partner. Following the suggestions from Keseru et al. (2019), the CO would make use of the existing pilot-specific technology and collaboration infrastructures provided by the Fietsersbond. These technologies have the benefit of familiarity in interface and language to the volunteers of the Fietsersbond, while being comparable to the GREEN Engine technology. The process is carried out in the following steps:

(1) Voice of the Volunteers: Members from the Fietsersbond were onboarded (9 participants) and asked what they understand by ‘Maintenance’ and what they specifically look for in cycle path maintenance.

(2) Voice of the Road Authority: Public authorities explained their approach to bike path maintenance and considered where the volunteer additions from step 1 could potentially be of use. Volunteer representatives (30 participants) were present in this step to immediately attune the data complementation. The complement was found in a subjective assessment of bike paths qualified good, medium, and bad, according to the road authority. The contrast on seven scored characteristics provides added information for the maintenance departments and elaborates on the observations through subjective descriptions.

(3) Voice of the Bike Path: Volunteers go out and gather the data.

(4) Voice of the Data: A scientific partner analyses the data on maintenance, environmental, and traffic safety level, and visualises the results in a data platform.

(5) Voice of All: The visualisations are presented, and the road authority and volunteers discuss contrasts and similarities. A systematic continuation is discussed as well.

Copenhagen, DK: The pilot aims to establish a reliable and consistent data foundation as grounds for informed decision-making and democratic participation in the new Local Traffic Plan. To achieve this, the pilot builds on past and ongoing neighbourhood initiatives, prioritising areas where local contributions can have the most impact, but also integrating diverse data sources to provide a comprehensive picture of how

the neighbourhood's current layout affects its use. Ultimately, the goal is to use data as a tool for engagement, encouraging broader participation and cross-sector collaboration to develop innovative solutions. This approach considers three strategic steps:

(1) Baseline Assessment: Engaging citizens to document existing living and environmental conditions, ensuring data is both trustworthy and verifiable. The first implementation engaged around 40 participants in air quality measurement activities.

(2) Shared Dialogue: Creating a feedback loop where stakeholders recognize findings, leading to actionable steps for monitoring and improvement.

(3) Implementation Planning: Securing funding and political support to achieve long-term outcomes.

Two main use cases have been developed:

- Analysis of Public Space Usage: Examining how people interact with urban areas, how factors like traffic, trees, and urban design influence usage patterns, and identifying areas that should be protected from traffic.
- Participatory Traffic and Environmental Monitoring: Tracking traffic volumes, composition, and their impact on air and noise pollution to inform the Local Traffic Plan.

Turano & Gerace, IT: The Italian pilots adopted a similar approach to Copenhagen, focusing on collecting air quality data using portable sensors. This demonstrates that despite differing local contexts, the CO model can be effectively implemented in a comparable manner. It highlights the framework's adaptability, enabling diverse communities to engage in participatory data collection, analysis, and decision-making while addressing their unique environmental and social challenges. By following a structured yet flexible methodology, the Italian pilots demonstrate that COs can be scaled and replicated across various settings, fostering inclusive and data-driven policy development. The participatory workshops engaged between 19 and 39 participants varying across these sessions based on availability and relevance of the topics discussed.

4.4 Insights from first Citizen Observatory implementations

Bristol, UK: In the context of the Bristol pilot use cases, the GREENGAGE project has demonstrated its potential to contribute to creating safer and more livable neighborhoods by addressing safety concerns and environmental issues. Despite these benefits, the project faces several challenges. Key difficulties include collecting and integrating accurate data from a wide variety of sources and ensuring it is representative for informing policy decisions. Onboarding and maintaining sustained engagement, particularly from seldom-heard voices, requires ongoing effort and innovative strategies. Targeting existing communities of interest and collaborating with local schools has been crucial for expanding the participant base and increasing readiness to collaborate. The resulting benefits extended beyond the project itself, supporting Bristol schools in rewarding young people for engaging in sustainable practices. The scale of issues in the EBLN is widespread, requiring significant resources and coordination across multiple departments and stakeholders, which extends beyond the GREENGAGE project's scope and may affect its perceived effectiveness. Clear communication is essential to help stakeholders understand that GREENGAGE serves as a method for collecting observations on specific topics. While the evidence-based information gathered can influence policy, decision-making power ultimately lies with the pilot owner.

North Brabant, NL: The North Brabant Citizen Observatory demonstrated that, within a government mandated participation strategy and an existing data-rich environment, citizen observers can provide a valuable addition to maintenance of data, planning, and processes. The addition of more contextualised data provides a detailed layer to the objective maintenance inventory, offering insights into when safety and environmental departments (and their respective budgets) need to be involved in maintenance activities. This enriches decision-making and ensures that the relevant departments are informed and can allocate resources more effectively. Despite the promising complementary insights from closer collaboration with citizens, engaging new members presented several challenges. Firstly, intrinsic motivation for bike maintenance was predominantly found among avid cyclists, resulting in a less representative sample of respondents. Secondly, a more relaxed participatory setting proved more effective in fostering engagement, whereas overly complex and technical content hindered participation. This also limited the reach and data quality of the citizens observers. For future engagement, a specified approach for more specific target audiences is required.

Copenhagen, DK: Unlike municipal or authority-led pilots, the Copenhagen pilot is managed by a community organization that mediates in a politically sensitive environment. This highlights the importance of high-quality, citizen-led data in fostering democratic debates among diverse stakeholders. A key challenge identified is developing methodologies for citizen engagement that integrate new technologies while operating within resource constraints to ensure effectiveness and long-term sustainability. Additionally, the Copenhagen use case has shown the difficulty of aligning data collection timelines with municipal processes, often delayed by the procurement of external advisors and differing approaches – particularly due to municipal departments' limited interest in adopting a "new paradigm". Despite these challenges, the pilot has revealed greater-than-expected public interest in political participation. Many residents are eager to engage in discussions about the city's future but prefer accessible and time-efficient ways to contribute without becoming deeply involved in formal politics.

Turano & Gerace, IT: Italian pilots faced more challenges than other cases, due to the target community's demographics, which are predominantly older with limited digital and data literacy. Thus, a key challenge was building capacity within the community to effectively use the provided tools and to interpret the data collected through the CO activities. This pilot demonstrated that reliance on expert support throughout all stages of the process is absolutely essential to ensure meaningful participation and data utilisation. Also, constant interaction and communication with local communities to identify and align activities with the most pressing concerns and motivations proved to be essential for engagement consistency and deeper commitment. This sustained interaction equally affected the readiness to participate and fostered a stronger responsibility among participants, as the issues addressed are directly relevant to their everyday lives.

4.5 Reflections on participant profiles and participatory readiness

While each pilot area implemented tailored engagement strategies, a cross-cutting analysis reveals important differences in profiles, motivations, and readiness of participants across contexts. In more mature pilots such as North Brabant and Bristol, citizens were already involved in community or civic initiatives (e.g., Fietsersbond, school programs), which facilitated recruitment and sustained participation. These groups had higher digital and organizational readiness and required minimal support to use GREENGAGE tools. In contrast, Italian pilots faced challenges due to older and less digitally literate participants, requiring hands-on facilitation and social incentives. This highlights the need for inclusive governance models that consider participants diversity in demographics, digital skills, and prior civic involvement. Motivations also varied widely: from climate and mobility concerns (Copenhagen), to improving daily commuting experiences (North Brabant), to heritage preservation (Italy). These intrinsic motivations played a key role in participants' motivation and interest retention. However, ensuring that participants understood how their input would influence decisions remained a shared challenge across pilots. Ultimately, participatory governance in COs depends not only on tools and methodologies, but on the alignment between participant capabilities, expectations, and the governance structures in place. Future GREENGAGE phases will explore more systematic ways to match engagement strategies with local conditions and to create clearer pathways from participation to impact.

5 LESSONS LEARNED & FUTURE DIRECTIONS

As noted at the outset, GREENGAGE project adopts a reflexive approach that is used to derive recommendations for public authorities as well as the general public, highlighting crucial aspects of designing and managing COs, including methodological frameworks, digital tools, data use and validation, piloting, governance, evaluation, and impact assessment. These recommendations can be summarised across several critical dimensions, derived from the insights gathered across individual pilots:

- Methodological Framework: The situational scoping framework requires a context-sensitive, inclusive, and iterative approach that empowers local authorities to collaboratively develop customised solutions that address specific community needs. Central to this process is effective communication, which ensures that all stakeholders are engaged and informed, fostering a clear and collaborative development of customised solutions.
- Governance & Policy: Innovation in governance must be grounded in the unique challenges of each neighbourhood, district, city, or region where COs are situated. While existing models provide some

guidance, it is essential for local partners to actively engage in experimentation and collective learning, tailoring solutions to the unique context and dynamics of their specific environment.

- Public/Stakeholder Engagement: Understanding stakeholder motivations is crucial for the success of COs. COs must offer adaptable engagement pathways that go beyond mere data collection, fostering deeper involvement. Continuous dialogue is key to ensuring that stakeholder expectations are aligned, especially when navigating the complexities and limitations of policy frameworks.
- Pilot Readiness & Data Governance: Iterative co-design strengthens usability and builds trust, while scalable technologies enhance adaptability across diverse contexts. Transparent data workflows and interoperability are essential for ensuring accessibility and encouraging broad engagement. A well-structured data management plan ensures clarity in managing the entire data lifecycle, ensuring consistency and transparency throughout the process. Given the challenge of diverse levels of digital and data literacy at the pilot areas, the approach needs to be adapted to the local capabilities and needs.
- Training & Capacity Building: Engaging training methods, such as storytelling and visual aids, empower non-technical audiences by making complex concepts more accessible. Online platforms like the GREENGAGE Academy support continuous learning, while feedback mechanisms help refine and improve training effectiveness. Given the challenge of building capacity to interpret data collected by Citizen Observatories, collaboration with the scientific community can play a crucial role in enhancing understanding and providing expert support for data analysis and interpretation.
- Piloting & Experimentation: Iterative piloting helps refining tools and methodologies while effectively managing participant expectations, having solutions evolve based on real-world feedback. The use cases should be closely aligned with socio-political needs, integrating diverse dimensions such as cultural, economic, and environmental, to achieve impactful results.
- Evaluation & Impact Assessment: Defining measurable KPIs, such as evaluating the usability of provided solutions (digital tools) and assessing their impact, particularly in terms of innovation in governance, remains a challenge. This process requires a combination of quantitative and qualitative approaches. Simplifying assessment methods enhances evaluation clarity, focusing on practical applicability and ensuring that outcomes are both actionable and meaningful.

6 CONCLUSION

This paper introduces the GREENGAGE framework as a concrete example of how participatory approaches within Citizen Observatories can foster evidence-based decision-making. By utilising collaborative tools and methodologies, the GREENGAGE framework enables communities to actively engage with and address local urban/rural challenges, ensuring that solutions are not only relevant but also tailored to the specific needs and priorities of each context. While there are similarities across pilots, it is important to acknowledge that each observatory has a unique governance structure and diverse needs. Citizens' engagement can be workshop-based, targeting specific groups such as school children, minority communities, and employees, or sensor-based data collection, such as mobile air quality sensors. These co-creation and co-design processes help refine the technology, improve its accessibility, and enhance participant adoption. Our approach not only highlights the potential of citizen-driven initiatives to create more sustainable and responsive urban environments, but also draws attention to the challenges and limitations that can arise in their implementation, offering valuable insights for future initiatives. Ultimately, the GREENGAGE project is laying the groundwork for full-scale deployment of the Citizen Observatories.

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🏆 reviewed paper

Enhancement of Minibus Taxis through Technological Innovations: A Case of Soweto, Johannesburg, South Africa

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1 ABSTRACT

Minibus taxis are a prominent mode in the transport sector and serve as a backbone of public transport in South Africa. They are a transport of choice and more convenient, and they are the most easily accessible even if not preferred. They provide affordable and flexible mobility for South African commuters. However, the sector faces challenges such as safety concerns, inefficiencies, and a lack of formalized systems. The study aim to explore how technological innovations can enhance the efficiency, safety, and sustainability of minibus taxis and the spatial route network serviced by minibus taxi system in Soweto. It examines the impact of digital payment systems, GPS tracking, ride-hailing apps, and smart fleet management on improving service delivery and commuter experience.Through a qualitative case study approach, the research evaluates existing technological interventions and their effectiveness in modernizing the minibus taxi industry. Findings indicate that while digital innovations have the potential to streamline operations, barriers such as resistance to change, infrastructure limitations, and regulatory challenges hinder widespread adoption, and the minibus taxi system service many neighbourhood in Soweto.The study concludes by noting that there is a limitation of technological innovations deployed in the current operations of the minibus taxis in Soweto and there is a possibility of implementing technological innovations in transforming informal transport networks. Further, the study recommends to integrate smart solutions into Soweto's minibus taxi sector to improve urban mobility in vaious aspects for this mode and the system as a whole.

Keywords: Minibus taxis, technological innovation, urban mobility, digital transformation, Soweto, public transport.

2 INTRODUCTION

Travelling takes places everyday, everywhere globally. In developing countries, public transport is the most used transportation for travelling, and in South Africa minibus taxis is the most used mode of public transport. Many South Africans depends on this mode of transport due to its (i) flexibility and availability; it is available in many locations and its network can connect commuters from origin to destination, (ii) pricing; the pricing for a trip is mostly affordable for many South African as it caters for low income communities (iii) operation schedule; it is available from as earliest as 4am in morning to 11pm or 00:00am, however, this varies by location (iv) luggage accommodation; this mode is not very large to accommodate a large quantity of luggage, but taxi drivers try to fit all commuters luggage inside a taxi and if there are many commuters with too much luggage, commuters are strategically included in different taxis with other commuters with small quantity of luggage. This mode of transport is used by 80% of public transport users for daily commuting in South Africa (Kriel and Burger, 2023). Traditionally, minibus taxis operations use a manual method for scheduling, pricing and other methods that are found in transportation services to ensure easy services to passengers for commuting. The taxi industry has been falling behing with regards to deployment of technological innovations in their operations. However, recently there are new technological developments that are found in minibus taxi operations which include smart card payment through speed points inside a taxi and availability of wifi to commuters to connect to the internet, and in some areas there has been development of smart applications that allow commuters to request a ride. Therefore, the study aim to explore how technological innovations can enhance the efficiency, safety, and sustainability of minibus taxis and the spatial route network serviced by minibus taxi system in Soweto.

3 LITERATURE REVIEW

The use of biblometric mapping of literature has been adopted for this study. This is to identify suitable literature for this study and identify most of the common themes researched by various scholars on related to minibus taxis, technology and South Africa.

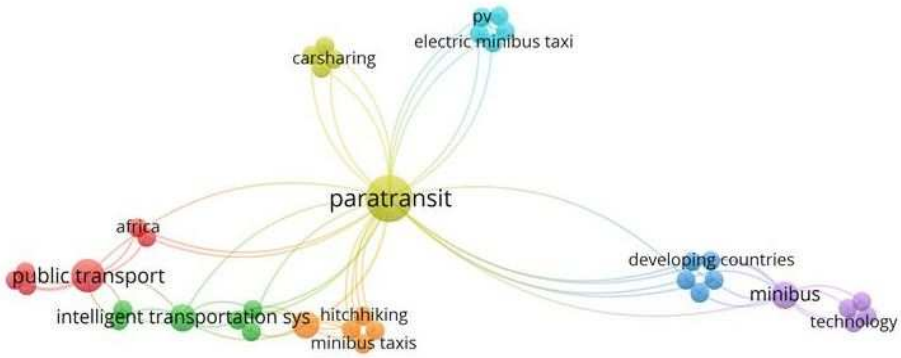

Figure 1: Keyword co-occurrence network visualisation 1

The above figure 1 indicates a biblometric mapping of literature about authors keywords. These keywords indicate the most used keywords related to the study. There are 37 items (keywords), 7 clusters (grouped keywords), 103 network links, and the 104 total link strength. Accordingly, the authors keywords formed 7 clusters that are indicated by different colours. Each cluster has subfields that most authors work focuses on. In cluster 1, there are six keywords indicated by red node which include Africa, infrastructure, mini-bus taxis, motor-bikes taxis, public transport and work. The cluster indicates that in African countries there are discussions of having improved public transport infrastructure specifically to minibus taxis and motorised taxis as mostly this is a daily used public transport to various areas of interest including work. Cluster 2 there are also six keywords represented by a green node which include intelligent transport systems, safe systems, service perfomance, service quality, transport safety and trotro. The cluster indicates the need of deploying intelligent transport systems to enhance service quality, service perfomance, and transport safety for trotro (term used for minibus taxi or shared public transport in Ghana).

In cluster 3 there are five keywords represented by a navy blue node which includes bussiness model, developing countries, maaslite, mobility as a service, and sub-saharan africa . In cluster 4 represented by a yellow node, there are also five keywords such as carsharing, jitneys, micromobility, paratransit, and station cars. These keywords are all related to improvement of shared public transportation and the importance of having micromobility supporting easy connectivity to paratransit. In cluster 5 represented by a purple node, there are five keywords such as digitalization, informal transport, minibus, South Africa, and technology. This cluster is related to the study indicating the importance of leveraging innovative technologies in informal transport and minibus taxis in South Africa. In cluster 6 represented by a light blue node, there are five keywords such as electric minibus taxi, pv, solar, storage, and wind. The cluster indicates that there are various studies taking place regarding green public transport through the introduction of electric minibus taxis. In cluster 7 represented by a orange node, there are five keywords such as contentious mobility, hitchhiking, maas, minibus taxis, and rural tranportation. Further, below figures 2 is the second keyword co-occurrence network visualisation.

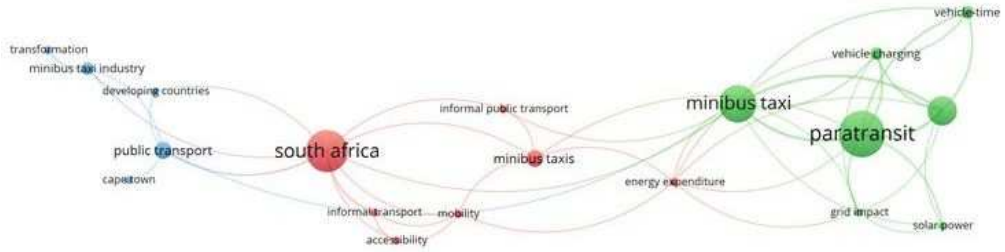

Figure 2: Keyword co-occurrence network visualisation 2

Figure 2 indicates a co-occurrence network visualisation 2 about authors keywords. The first biblometric mapping was based on the following keywords: Miibus taxis and technology and the second biblometric mapping keywords selected are minibus taxis and South Africa. These keywords indicate the most used keywords related to the study. There are 19 items (keywords), 3 clusters, 47 network links, and the 79 total link strength. The authors keywords formed 3 clusters that are indicated by 3 colour nodes. As in figure 1, each cluster has subfields that most authors work focuses on.

The first cluster represented by a red node, include accessibility, energy expendixure, informal public transport, minibus taxis, mobility, and South Africa. This cluster indicates that there are various works that are done on accessibility of informal public transport, specifically, minibus taxis in South Africa. The second cluster represented by a green node, include electric vehicle, grid impact, minibus taxi, paratransit, solar power, vehicle charging, vehicle time. The second cluster highlights that various works looks at the possibility of introducing electric minibus taxis that could be charged using various power sources such as solar power. The third cluster represented by a blue node, include Cape Town, developing countries, minibus taxi industry, public transport, and transformation. Cluster 3 highlights that in developing countries looking at various cities such as Cape Town there is a need to transform taxi industry to provide quality operation services to commuters. Accordingy, below is a table representing top 10 keywords of the biblometric map.

No	Keywords	Links	Occurences	Total link strengths
1.	Paratransit	8	17	54
2.	Minibus taxis	10	11	32
3.	Electric vehicle	7	7	22
4.	Maas	9	3	16
5.	Vehicle charging	6	3	12
6.	South Africa	9	10	11
7.	Public transport	8	3	11
8.	Vehicle-time	4	3	10
9.	Intelligent transport systems	8	2	8
10.	Developing countries	6	1	6

Table 1: Top 10 keywords

The above table 1 indicates the top 10 authors keywords that are mostly used by authors.This highlights most of the work that has been conducted related to the study. Accordingly, the table provides a further explanation of figure 1 and figure 2. Links indicate the connection between various keywords in the biblometric mapping of literatures, and the occurences shows how much a keyword has appeared in the networks. Furthermore, the total link strengths indicates which keywords are most connected to other keywords indicating that most author's works focuses on such keywords. According to the above table 1, paratransit is the most used keyword used in publications linking with more many keywords, followed by minibus taxis, and all the other keywords provided. The table indicates that there are various studies done in paratransit and minibus taxis, however, there are even fewer works on technological innovation in public transport as the table indicates most publications are on electric vehicle and fewer on intelligent transport system. This indicate that there are more studies that need to be conducted on minibus taxis and technological innovations in South Africa.

3.1 Minibus taxis in South Africa

Minibus taxis are one of the dominant modes of urban public transport in the republic. They do not operate according to timetables, a taxi departs from the starting point (taxi rank) when it is full and not according to a schedule, and most vehicles used are 16-seater minibuses. Further, in all cases that taxis start from the starting point (taxi rank), it picks up passengers on the main routes in any streets unlike bus or train as there are demarcated stops. Routing is structured (by the taxi associations to which all operators belong), and operators are assigned to a particular route or group of routes.

According to South African National Taxi Council (SANTACO) statistics (Competition Commission 2018) it has a collective national fleet of more than 250,000 minibuses with 123,000 owners. The government's official statistics put the number of minibus taxis at 130,996 (Grice and Oldjohn 2018). These are almost certainly an underestimate of the total numbers, with many taxis still unregistered. The deregulation of the industry in the 1980s had unleashed uncontrolled growth of the industry and provided fertile ground for conflicts ("turf wars") over route and ranking facilities. During the same period the industry boomed into a giant sector and became unmanageable in the absence of any form of regulatory framework. After a long and intensive government consultative process with taxi operators, the South African National Taxi Council

(SANTACO) was established in 2001 as an umbrella body governing the industry and act as the principal representative body for taxi owners. It was formed from 34 taxi federal organisations and three national bodies. It brought a significant amount of unity to the industry, but didn't completely end the conflicts (Labour Impact Assessment, 2018). Further, the government also attempted to modernise and regulate the industry through a programme of "taxi recapitalisation", whereby smaller vehicles would be phased out, and new larger and safer minibuses would be introduced with an electronic fare system. If properly registered and members of a recognised taxi association, owners were given the option of getting cash compensation for scrapping their old vehicle, or a deposit for a new vehicle.

In many cities, especially developing countries regular public transportation systems do not meet all the demands of the marketplace. The reasons for this shortfall often vary. It can result from an insufficient response to constantly changing travel and settlement patterns, poor attendance to service places (speeds, levels of service, job changes etc.), or purely from a lack of total capacity (Golub 2003). Cervero (1991) states that regular public transportation services normally employ full size vehicles, many times are poorly connected and coordinated and these vehicles cannot always serve residential areas with narrow entryways, poor roads and at times difficult terrain. In many of these cases informal modes of transportation they, illegally enter the market to fill the gaps that are left open by the regular public transit system.

According to (Statistics South Africa report on measuring household expenditure on public transport, 2015) 51,1% of public transport users use taxis and followed by busses at 18,1% and then trains 7,6%. It can be argued that in bus and train services were the first to be formally introduced to the public as a means of public transport. Amid the criticisms of the taxi industry, it remains the most popular mode of transport. The two possible reasons of which (1) being that it is a transport of choice and more convenient or (2) it is the most easily accessible even if not preferred. Noting that both bus and train services are the formal modes of transport and cheaper. The two cheaper transport modes are not the most popular and to add that the taxi customer service has been under criticism for many years (SA 2015). Further, to improve minibus services, few studies have indicated the importance of technology deoployment which could provide (i) Reliability of the service, (ii) variability in cost and (iii) responsiveness. Further, it has been noted that technologies could assist to (a) book, (b) report driver misbehavior, (c) make safe e-payments and (d) track the location of minibus taxis, as most likely to improve their minibus taxi service quality (Dzisi el al., 2021).

4 APPROACH AND METHODOLOGY

The use of biblometric mapping of literature was used in the study. The use of biblometric mapping of literature is to assist in identifying common research areas related to minibus taxis, and this assist to find the literature gab. The study used two methods to download publications which (i) included the keywords: minibus taxis and technology, and (ii) keywords were: minibus taxis and South Africa. Below is table 2 indicating types of publications used.

No.	Types of publications	Number of Documents	Citations
	Keywords: Minibus taxis and Technology		
1.	Journal articles and reviews	13	162
2.	Book chapters	4	4
3.	Conference papers	6	13
	Keywords: Minibus taxis and South Africa		
1.	Journal articles and reviews	38	371
2.	Book chapters	4	3
3.	Conference papers	9	16

Table 2: publication types adopted.

To perform biblometric analysis on VOSviewer, scopus was used to identify journal articles, and 25 articles were identified. During the refining process of selecting journal articles, 1 article was in french and 24 articles remaining were in the selected language which is English. Accordingly 24 abstracts were analysed and only one was retracted due to being not relevant to the study. Therefore 23 publications that were used for the biblometric analysis that featured keywords that include minibus taxis and technology. Accordingly, the second biblometric analysis publications were also downloaded from scopus. Keywords that were used were minibus taxi and South Africa only, this was done to see most of the works done in minibus taxis and south africa and to relations of themes. 87 documents were identified, and publications used are from 1995-2025. All 87 publication are published in English. 36 Publications were retracted due to being not related to

the study, unknwown authors identified and some are international studies. Only 51 publications were used for the final analysis.

Accordingly, semi structured interviews were conducted with 40 commuters, 10 minibus taxi drivers, and 5 queue marshalls. The questions conducted with minibus taxi drivers and queue marshalls were based on daily operations, technology integration, training and support, and community impacts. Consequently, the questions conducted with commuters were based on usage and preference, technology experience, safety concerns, and quality of service. Further, spatial approach was used to create a map that indicate spatial route network of minibus taxis and minibus taxi ranks. The data to create the map was received from the City of Johannesburg department of transport.

5 RESULTS AND ANALYSIS

Soweto is a township that is found in the City of Johannesburg in South Africa. It is a township that is dominated by black community followed by a coloured comunity. It is a home to a population of around 1271627 residents, with 37 different neighbourhoods. The below map indicates where Soweto is located in the Republic of South Africa, which is demarcated with blue in the locality showing the City of Johannesburg below in figure 3.

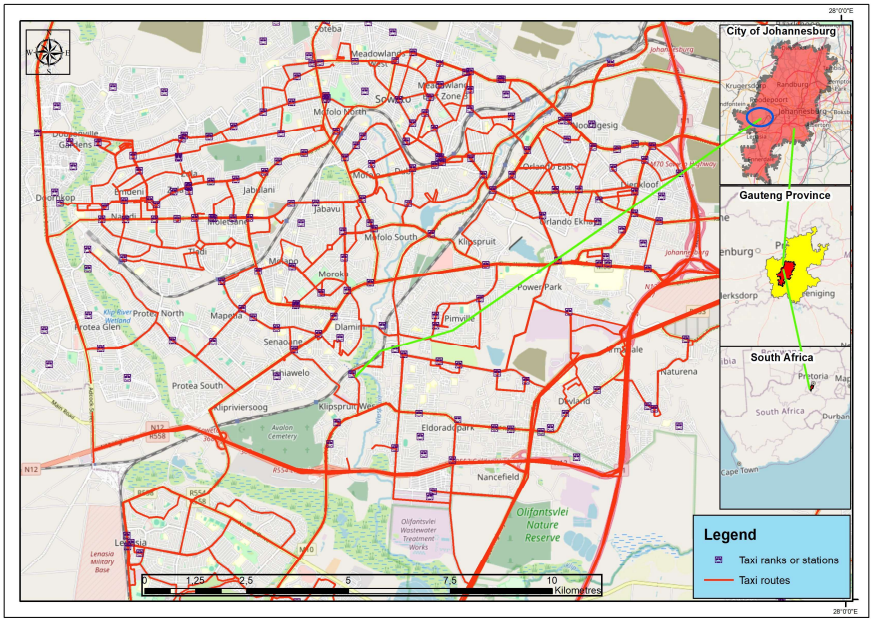

Figure 3: Soweto Taxi routes and ranks map

Soweto is serviced by various modes of public transport systems which include metrorail train system, bus rapid transit system (BRT, known as Rea Vaya system), metrobus, eyakho putco bus and more other public transport services. The above figure 4 indicates the minibus taxi spatial route network and taxi ranks in Soweto. This mode of transport is one of the modes offering a service that covers a large extent of geographical area in Soweto. As can be seen on the above map, the minibus taxi system services many routes which are indicated in red, and these routes are main routes. The minibus taxis penetrate inside the neighbourhood to collect commuters from various locations to provide a convenience service. Each neighbourhood has provision of minibus taxi ranks/ stations which some are informal, and some are formal but all of them are recognised by the commuters. Minibus taxis are one of the modes that provide reliability in servicing all Soweto locations and routes. These areas are serviced from early hours of the morning from approximately 4am till late which is around 11pm. Taxi ranks, or station are strategically located in all neighbourhoods to ensure easy access to commuters, in big neighbourhoods there is more than one taxi rank found to ensure that different sections of the neighbourhood are serviced by minibus taxis. Furthermore, there is a form of integration between minibus taxis, as commuters from certain locations can make switch inbetween from one taxi to another taxi to complete a journey which this however requires a different taxi fare, and commuters are dropped in suitable locations and stations for intended minibus taxi. Consequently, on various instance minibus taxi while in a journey communicate with each other to switch various commuters to suit the locations of where commuters are going without any extra payment.

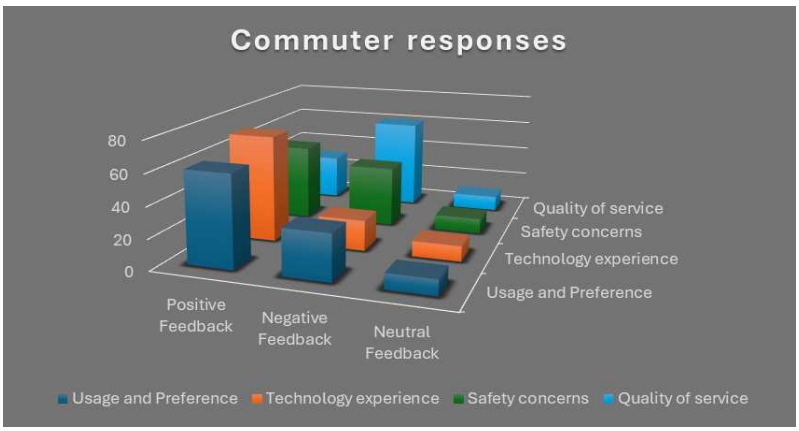

Figure 4: Commuter responses

The above figure 4 indicates the semi interviews conducted with minibus taxi users. 60% of the responses were positive about the usage and preferences. The commuters have indicated that the minibus services provides convinient services for them to reach intended destination around Soweto and beyond, the movement of minibus taxis are flexible as commuters can reach locations of interest easily as the minibus taxi system offers flexibility, hence, they prefer to use this mode of transport. 30% of commuters indicated that, due to limitation of other modes of public transport in their locations they use minibus taxis. On various occassions, minibus taxis travel slow due to trying to collect more commuters along the journey, and sometimes for a commuter to reach a desired destination they need to connect to other minibus taxis which is costly, especially when travelling from Soweto to other location. 10% of commuters indicated that minibus taxi usage is used based on that it the available mode in their are locations and it is cheap as well. On some instances, the journey is smooth but on some occasions it is not which this provides mixed feelings when using minibus taxis.

Most of the commuters have indicated that minibus taxis are not technological savvy. It is difficult to retrieve information about the mode of transport and for a commuter to be able to know travel times through online platforms. Accordingly, the commuters indicated that if a commuter does not have hardcash for a taxi fare, there is no electronic payment alternative that could be used which makes it hard on some occasion to use a minibus taxi when a commuter does not have hardcash. 70% of commuters indicated that it is important for minibus operations to introduce technological operations in the system for payment purposes as on some occassions they do not have hardcash. Accordingly, there is a need for online plartforms that can provide informartion of minibus taxis to know the availability of minibus taxis in certain specific times to know the intended taxi that they can use, also in the evening there is a need to know the times of the availibitity of the minibus taxis so that commuters can take an alternative mode of public transport than being found vulnerable at the minibus taxi routes that collect commuters and minibus taxi ranks. Consequently, commuters have indicated a need to have a online platform were they can share comments or remarks about the operations of the system and improvements that they need as most of the commuters shared frustrations that they are not sure were to share any grievances and when shared they do not reach the right people. 20% of the commuters shared that they are not used to technological operations which might make the use of minibus taxis complicated for them, and the traditional method of using minibus taxis compliment they are way of making trips. It was further indicated that if they need information they can receive it straight from the minibus taxi ranks as usual. Accordingly, some commuters feel like they can be inconvinienced if commuters will have to pay using smartcards as some commuters do not own any bankcards and if specific smartcards can be introduced to be used for minibus taxis only, to such an extent this can cause delays as they will have to load money in they cards first before they can use a taxi and what would happen if the systems to load money in the smartcards are offline as this they have experienced with the current modes of public transport that are operated electronically. Furthermore, 10 % of the commuters are neutral to the introduction of technological innovations within the minibus systems as mostly indicated that it could bring positive change in various aspects of the system operations but at the sametime there could be negative impacts due to technoligical errors that might occur during the process of using some of the services and then ending up inconviniencing commuters leading to missing of rides and ending up not being able to use the mode of transport intended.

Many commuters have shared they views on safety issues when using minibus taxis. 50% of the commuters indicated that using minibus taxi is safe as minibus taxi drivers are respected by people who commit crime, as criminal activities are not committed inside minibus taxis, and in taxi ranks. Accordingly, when they use minibus taxi's from origin to destination they arrive safe. However, 40% of commuters shared opposite views as it has been indicated that reaching some of the taxi ranks could be complicated as they have to pass through dangerous locations to get a taxi, and in some areas where they wait for taxi's on various routes is dangerous and minibus taxis take long to reach such areas making them vulnerable especially early mornings and later in the evening. Further, 10% of commuters indicated that taxi's are a safe mode of public transport but are unsafe on some instances as on some occassions dangerous commuters board in taxis and then rob commuters belongings when a taxi has left the rank. Accordingly, when commuters are dropped off in various locations of interested they become target of crime wereby they get robbed, and also there are some taxi drivers who are wreckless when they are driving leading to car accidents. Consequently, taxi drivers become involved in taxi wars wereby shoutout takes place in a random day leading to commuter injuries and death.

In addition, commuters have indicated different views in the quality operations of minibus taxis. 30% of the commuters have indicated that taxis provide a good service as they ensure that commuters are transported efficiently from origin to destination and they try to deliver fast service to commuters and there is provision of assistance by queue marshalls and taxi drivers when commuters need certain information related to the transport services and directions to a certain area. 60% of the commuters indicated that on various occassions the treatment that they receive from taxi drivers is unpleasant as taxi drivers do not communicate in a well mannered way and on other instances are threatened by the drivers. Accordingly, it has been indicated that the journey sometimes could be unsettling due to wreckless driving and a very slow movement of minibus taxis, and also the fights that emerge from know were due to fighting over commuters is unsettling and commuters on some instances are threatened. 10 % of the commuters have indicated that the quality of service provided differ, on some occasions its better and on some occassions is bad. The movement of minibus taxis is faster and on some instances the movement of the minibus taxis is slow. Accordingly, sometimes the taxi drivers understand a certain situation and sometimes they do not want to understand which this bring mixed feelings about the entire service quality of minibus taxis. Below are the responses received from minibus taxi drivers.

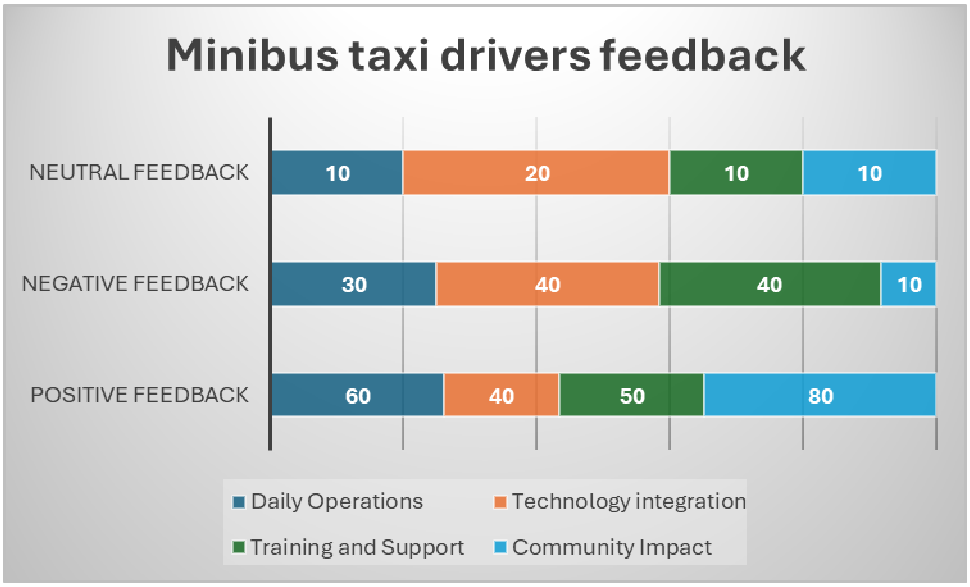

Figure 5: Minibus taxi drivers responses

The above figure 5 indicates the responses received from the semi interviews conducted with the minibus taxi drivers and some queue marshalls. 60% of minibus taxi drivers and queue marshalls have indicated that the daily operations run smooth as they ensure that they deliver fast services for commuters without any delays. 30% of minibus taxi drivers and queue marshalls have indicated that on some instances there are various challenges from the operations due to some taxi drivers not wanting to follow rules of operations making it hard for easy operations. Accordingly, some commuters make the customer service difficult due to

wanting to control locations of where commuters should be delivered and some infromation is always provided to commuters such as when paying taxi fare they should not bring a higher amount of hardcash as on some occassions they do not have loose counts of hardcash to provide change for commuters. 10% of minibus taxi drivers and queue marshalls indicated that the daily operations are better, however, on some instances its tough to provide efficient services as they have minibus taxi breakdowns during the operations but this does not happen all the time and on some instances they are challenged by traffic congestions.

Accordingly, minibus taxi drivers have indicated various views regarding technology integration in the minibus taxi system. 40% of minibus taxi drivers and queue marshalls have indicated that technological innovations can improve the minibus system operations in various aspect such as the payment method as this can make the transaction easy and so that the taxi owners can be able to review all the payments. Accordingly, there is an indication that commuters can be able to view locations that are serviced by certain minibus taxi lines online, as sometimes commuters want to make a fuss by making minibus drivers to drop them in areas that they do not service. There could be fair taxi collection of commuters in the taxi ranks and minibus taxi whereabouts could be identified, and arrival times to the taxi ranks for collection. 40% of drivers have indicated that the usage of technology will bring close monitoring to the services and these could lead to unneccessary penalties, and could make them not perform in a comfortable manner to deliver efficient services. Accordingly, it has been indicated that technological services have never been used in the area, and introducing such will require serious infrastructure meaning that they will have to spend more money and this will affect various parties in the mibus taxi system. 20% of minibus taxi drivers have indicated that technological innovation can assist improve the services, however, most of them are not good with technological operations which this will also lead them to attend training, as they are there to work (drive taxis), and also if they don't understand trainng what would happen.

Consequently, 50% of minibus taxi drivers are keen to training and support to improve quality of services by the minibus taxi system. 40% of minibus taxis drivers are hesitant about receiving training as it has been indicated that they are already producing a good service. 10% of minibus taxis support the notion of training but indicated that the challenge will be time to attend such trainings and these training will not pay them. Further, most of the taxi drivers have indicated that minibus taxis have a high impact to the community as they provide efficient services and they are cost effective, and they ensure that they deliver the commuters wherever they want. In addition, it is indicated that wherever minibus taxis are found there is less criminal activities as they ensure that they protect the community as this is humanity (ubuntu) and also the people are their customers.

6 DISCUSSIONS

There are different kinds of associations from different locations that regulate the taxi industries. Each location is serviced by the taxi association from that area to a specific destination. Taxi's registered from a certain location are not allowed to service another area they are not registered to and also with routes serviced, a taxi should remain servicing that particular route is registered for. Passengers on certain specific routes are not allowed to be transported by taxi drivers not registered to service that specific route (Mbatha and Gumbo 2022). Minibus taxis in Soweto are functional and efficient to a certain extent under traditional operations without the usage of technological innovations. There is no available platform for timetable schedule for commuters to plan trips. Commuters walk to the nearest taxi rank to take available minibus taxi, and to board in a taxi is based on the first come first serve basis where commuters have to queue. There are queue marshalls found in all taxi ranks to keep order on the commuters perspective that no passenger cut in a queue or moves forward, and as well as each minibus taxi comes in at a suitable time scheduled. There is a system used to ensure that there is fairness in the operations of minibus taxis. A queue marshall control which taxi can pickup commuters at which time and the information is recorded in a book manually.

Travelling from Soweto using minibus taxis to the CBD were there are larger taxi ranks and commuters connect to reach desired destination or to areas affording various activities of interest to commuters during the morning, usually, during the peak hours the movement of minibus taxis is efficient and fast whereby one taxi comes after the next to ensure that commuters are transported in a fast manner and during this period in some instances there arent much delays due to a quick movement of taxis. However, minor delay could be caused by long queues.

In this system developed in the taxi industry, commuters are aware that in the morning, the peak hour ends at 8:30am from 7:00am depending by location especially in small taxi ranks that are found in Soweto neighbourhoods. From after 8:30am, a taxi is not completely filled with passengers and it need an average of 7 passengers to live the rank so that other minibus taxis can also collect commuters. After 8:30am upto 11:30am commuters are required to take taxi's from the taxi ranks, and a taxi needs to have certain number of passengers to leave the taxi rank, and this leads to delays. Consequently, from this period to 12:00pm the mini (small) taxi ranks do not operate and commuters catch aminibus taxi along the routes that taxi's routes service. In the evenings, there is also a quick movement of minibus taxis transporting commuters from taxi ranks. However, the system time after time gets overwhelmed as much as there are many fleets but commuters are even more. Minibus taxis run out in the rank and then commuters have to wait longer in the queues.

Accordingly, in Soweto, Baragwanath taxi rank is a large taxi rank where commuters from different neighbourhoods across Soweto commuters use to connect to various locations away from Soweto. Which these areas could be to the CBD, other surburban locations and other provinces or states. There is smooth transition from local minibus taxis to minibus taxis making long distance trips.

Technological innovations provide enhancement in various disciplines. In the minibus taxi industry, if deployed, there could be aspects in the operations that can improve the system as a whole and provide quality services. With regards to payment services, this can allow easy transaction for commuters and minibus taxi operators. Commuters do not have to worry with carrying hardcash and as on some occasion there are issues of taxi drivers not having loose counts change for commuters, also commuters do not have to count the entire money and ensure that everyone has paid were certain conflicts emerge, and also this provide an alternative if a commuter does not have hardcash and having to worry about finding a nearest atm to withdraw hardcash for a taxifare. Consequently, minibus taxi operators could be assisted to keep track of earning, and which this makes it easier to ensure that all commuters have paid the appropriate taxi fare. Accordingly, commuters can be able to find relevant information about network of minibus taxis and could assist them to know which intended taxi maybe taken. Technological innovations such as global positiong system, can make a positive impacts in the operations as it could allow minibus taxi drivers to be aware of various challenges such as traffic congestion to take alternative routes. Further, this could also provide safety and security as real-time tracking can provide emegerncy response if a minibus taxi is under attack, and wreckless driving could be monitored which this could prevent unneccessary vehicle accidents. In addition, there could be reduction of taxi breakdown as minibus taxi operators could be notified by such technologies that the minibus needs a certain service.

7 CONCLUSION

In Soweto, there is a huge service of minibus taxi system which plays a vital role in providing functional and efficient public transport services which are used by a majority of the households, and minibus taxi services are found in all the neighbourhoods in Soweto. However, from the study it has been noted that the minibus taxi system still uses the traditional way of providing services without the usage of technology. The study has indicated that deployment of technological innovations in minibus taxis could improve the quality of services, and safety and security of the commuters. Therefore, the study reccomends minibus taxi application or online platforms that can provide various technolohical services making the entire usage of minibus taxi systems pleasant. With the introduction of such platforms, commuters can be able to share grievance, comments and remarks to reach in the right people, there could be an alternative method of payment that can create fast transactions, commuters could be able to know which suitable minibus taxi to use as there is provision of real-time tracking which this can provide safety for commuters. According minibus taxi drivers could be able to share communication to switch commuters effeciently to ensure that all commuters are transported to desired destinations. With efficient, functional, safe, reliable, competent, quality operation of services by minibus taxi services, minibus taxis could attract motorist and this could reduce various road negative impacts on the roads.

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reviewed paper

Enhancing Urban Resilience through Integrated Energy, Climate, and Spatial Planning: Introducing the IN-PLAN Practise

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1 ABSTRACT

Fragmented sectoral policies hinder spatial planning from driving sustainable development and diminish the impact of EU-funded investments, posing a significant challenge for urban development in Europe (ESPON, 2018). The IN-PLAN project addresses this problem by empowering local and regional authorities to integrate climate adaptation, energy and mobility policies and spatial planning. The developed IN-PLAN Practice provides a structured framework, milestones and strategies for action and stakeholder engagement to support integrated planning. Pilot projects in Croatia, Ireland, Italy, Sweden and Romania demonstrate the adaptability and feasibility of implementation of the practice. This paper presents the findings throughout the project and highlights the lessons learnt from these pilot projects to stimulate a wider uptake of integrated planning approaches across Europe. It also reflects the provision of support structures and documents for integrated planning.

Keywords: Governance, Sustainability, Integrated Planning, IN-PLAN, Integrated Energy, Climate, and Spatial Planning

2 INTRODUCTION

Since 2021, the European Climate Law has established a legally binding target of net zero greenhouse gas emissions by 2050 (EU Regulation 2020/0036/COD from 30/06/2021) in alignment with the UN Paris Agreement of 2015. For the period from 2021 to 2030, EU Member States developed integrated National Energy and Climate Plans (NECPs) outlining their strategies for achieving the necessary greenhouse gas emissions reduction to meet the EU's climate neutrality objective.

In recent years, many local and regional authorities have set ambitious climate neutrality targets and are actively transforming energy and mobility systems to achieve them (Net Zero Cities, 2025). Despite operating under different overarching frameworks, these authorities play a crucial role in translating national and European climate targets into practical actions. They have control over spatial development within their jurisdictions and often hold the legal mandate to develop and enforce spatial development plans. These plans outline future settlement and economic development while imposing restrictions on land use. Given the close link between spatial structures, energy demand and supply, large and small-scale climate adaptation measures and mobility patterns, spatial planning is an enabler for municipalities to take meaningful action on climate change and advance toward net-zero targets.

2.1 Integrated planning as a holistic approach

Accelerating the transition to climate-neutral and climate-friendly cities requires not only the implementation of diverse sector-specific measures but also the adoption of a holistic approach. Given the constraints on time and financial resources, this approach should seek to harness synergies and proactively identify potential conflicts to develop effective solutions. Integrated energy, climate, mobility and spatial planning is pivotal to achieving climate neutrality while simultaneously preserving or enhancing the quality of life in municipalities. The concept of integrated planning can be illustrated through three key dimensions:

- Vertical integration involves cooperation across different levels of governance, from local to national and international bodies. This coordination ensures that policies and plans are harmonised to minimise redundancies and to create coherent development strategies.

- Horizontal integration focuses on cross-departmental collaboration within municipalities. Therefore, challenges are tackled holistically rather than in silos, integrating climate adaptation, sustainable mobility and renewable energy issues into spatial planning.
- Territorial integration entails regional partnerships among municipalities. Joint efforts enable them to tackle common issues, optimise resources, and implement strategies that extend beyond individual borders, resulting in a more coordinated and effective regional development.

2.2 Theory of integrated planning and its state of implementation

Considerations concerning energy production and consumption in urban environments first emerged during the 1920s energy crisis. De Pascali and Bargaini (2018) trace the evolution of spatial and energy planning integration, noting that the link between urban characteristics and energy systems has been studied since the 1970s. In 1974, "The Cost of Sprawl" examined the relationship between settlement density and energy consumption (Real Estate Research Corporation, 1974), whereas Knowles et al. (1974) highlighted the connection between urban environmental conditions and quality of life. The two-way relationship between energy and urban planning, stressing the need for a systemic approach that considers urban structure, mobility, and distribution of urban activities was defined by Owens et al. (1986).

Despite the concept of integrated spatial planning existing in various forms since the 1960s, a clear gap remains between theory and practical implementation at the municipal and regional levels in the EU. While some EU countries have been able to develop integrated planning processes, aligning sectoral policies under shared goals and creating joint policies spanning different sectors, others have a rather coordinated practice, which reflects clear efforts to align policies and enable mutual adjustment across sectors. Only a few Member States entirely neglect the integration of sectoral policies in spatial planning and therefore miss tangible relationships between sectors or acknowledgment of other sectoral policies (Nadin et al., 2020). Independent of their level of integrated planning, most of the European regions and municipalities continue to face the challenges of integrating different policy disciplines.

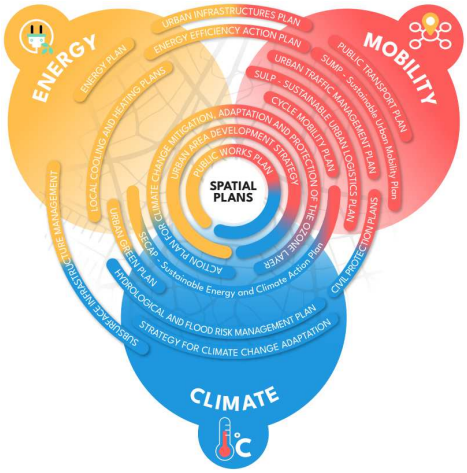

Fig. 1: Diagram mapping the intersections and overlaps between sectoral plans. https://fedarene.org/wp-content/uploads/2024/10/IN-PLAN_SPATIAL-PLANS.pdf

Several reasons can be identified to explain the discrepancy between the theory and the level of integration as well as the difficulties arising from a stable integration. With the Covenant of Mayors initiative in 2015, more than 8,000 municipalities signed up for the development of SECAPs – Sustainable Energy and Climate Action Plans (United Nations, 2024). Despite the enormous success of the initiative, it seems that SECAPs still miss the opportunity to translate energy, climate and environmental policies into ordinary spatial planning instruments because of sectoral-based responsibilities of urban strategies, as e.g., SECAPs and SUMPs (Sustainable Urban Mobility Plans) lie within different municipal and regional departments. Furthermore, local and regional governments often lack the authority to establish and enforce binding energy and climate strategies, plans and policies, as their competencies in developing and implementing such measures are typically limited, frequently restricted to voluntary schemes such as the SECAP. This lack of institutionalization also hampers the monitoring of measure implementation and the integration of plans into municipal and regional budgets. As a result, local and regional governments rarely have the necessary

financial resources to plan and implement energy and climate measures and therefore end up acting reactively.

2.3 A methodological approach to roll out integrated planning

The LIFE project IN-PLAN running from 2022 until 2026, addresses various planning systems across Europe with a diverse set of project partners entailing the Institute for European Energy and Climate Policy, UIV Urban Innovation Vienna GmbH, Technological University of the Shannon, Area di Ricerca Scientifica e Tecnologica di Trieste Area Science Park (IT), and FEDARENE as well as regional climate and energy agencies from Tipperary (IR), Alba (RO), North-West Croatia and West-Sweden. To help local and regional governments integrate climate and energy considerations into spatial planning, it offers general guidelines adaptable to different legal and planning contexts instead of a one-size-fits-all approach. Therefore, the project developed a long-lasting support structure with the IN-PLAN Practice and a two-step Capacity-Building Programme to empower regional agencies and local authorities to implement and monitor integrated strategies aligned with budget commitments to foster sustainable development.

3 THE IN-PLAN PRACTICE

A central product of the project is the IN-PLAN Practice (Höftberger et al., 2024), a comprehensive guidebook for integrating climate adaptation, mobility, and energy planning into spatial planning processes. The Practice is designed to support local and regional governments in developing, implementing, and monitoring ambitious integrated spatial plans with climate neutrality targets. It provides municipalities, regions, and other public authorities with a structured framework for identifying high-impact areas for climate action, a clear outline for an integrated planning process, and practical tools to use alongside exemplary case studies from across Europe. By fostering institutionalised collaboration among departments and various stakeholders, the IN-PLAN Practice promotes civic engagement and participatory governance.

To identify specific barriers faced by municipalities in integrating climate, energy, and mobility planning, a Europe-wide survey and a series of consultations with municipalities were conducted. The insights gained informed the design of a series of workshops aimed at identifying key characteristics of spatial planning systems and the challenges of integrated planning in different national and regional contexts. A comprehensive capacity gap assessment summarizes the findings (Forstinger et al., 2023). Based on this, the IN-PLAN Practice was designed as an advisory tool, also synthesising best practices identified in a stocktake of effective planning approaches (Holodkov et al. 2023). The document was further refined through an iterative feedback process with local project partners, incorporating lessons learned from their engagement with municipalities. This participatory approach ensures that the IN-PLAN Practice is not just a theoretical framework, but a practical, hands-on guide tailored to the real needs of local and regional planners.

3.1 Leveraging Synergies: Focus Topics for Climate Action

According to the Torremolinos Charter (CEMAT, 1983), spatial planning gives geographical expression to the economic, social, cultural, and ecological policies of society. While this definition dates back several decades, it already acknowledges the multifaceted factors of spatial development. Today, however, we emphasise that spatial planning is also a powerful instrument for actively shaping how land is used, energy is distributed, and mobility systems are implemented. It offers essential tools to drive progress in key policy areas that must be integrated to maximise its impact: energy, mobility and climate adaptation. Addressing these interlinked areas holistically enables municipalities to create sustainable, adaptable environments.

Spatial planning is key to aligning energy demand with renewable energy supply. Cities and industrial areas have high energy needs, while renewable sources – such as solar, wind, geothermal, and waste heat – vary in availability and space requirements. Effective planning helps municipalities identify optimal sites for energy production while minimising land-use conflicts. Built-up areas, such as rooftops and infrastructure zones, should be prioritised for solar PV to maximise output without encroaching on natural spaces. Additionally, strategic heating and cooling planning ensures that district heating, geothermal systems, and energy infrastructure match settlement patterns of municipalities and regions. By embedding energy considerations into spatial planning, municipalities can enhance energy efficiency and drive decarbonisation while ensuring a secure and cost-effective energy supply.

Spatial planning is vital for climate adaptation, helping cities and regions manage extreme weather and biodiversity loss. Integrating nature-based solutions – like green corridors, permeable surfaces, and urban forests – can reduce heat islands and boost resilience. Flood-prone areas benefit from sustainable drainage and retention zones, while coastal and mountainous regions need protective zoning, shoreline management, and slope stabilisation to prevent erosion and landslides. Climate-resilient public spaces with vegetation, shade, and water features enhance liveability during heatwaves. Biodiversity conservation through habitat protection and ecological corridors supports ecosystems adapting to change. Regulatory frameworks should require climate-responsive building design, such as passive cooling, green roofs, and rainwater management. Embedding these strategies into spatial planning enables municipalities to build resilience, protecting public health, infrastructure, and ecosystems from the long-term impacts of climate change.

Finally, spatial planning sets the basis for sustainable mobility by designing compact, multimodal urban environments that prioritise walking, cycling, and public transport. By applying the Avoid–Shift–Improve approach, municipalities can reduce travel demand through mixed-use neighbourhoods, shift mobility towards low-carbon modes, and enhance vehicle efficiency. Streets should be restructured to support active transport, with shaded pedestrian paths, dedicated bike lanes, and well-integrated public transit. Parking reform, including reduced on-street parking and repurposing spaces for urban greenery and mobility hubs, discourages car dependency. Additionally, traffic calming measures such as pedestrian zones and shared spaces improve safety and liveability. Mobility hubs offering public transport, bike-sharing, and carpooling enhance accessibility while zero-emission zones and EV charging infrastructure support the transition to CO_2-neutral propulsion technologies. Integrating sustainable mobility into spatial planning helps municipalities reduce congestion, lower emissions, and foster vibrant, friendly urban spaces.

With spatial planning as a major lever for advancement in these three climate-relevant fields, many synergies can be exploited when these fields are approached together.

3.2 Breaking Silos: How to Design and Implement an Integrated Spatial Plan

Integrated planning maximises synergies by addressing spatial interventions holistically:

(1) The process starts by establishing a planning framework, securing political support, and defining clear roles. A cross-sector team and steering committee enable collaboration across departments and governance levels, while a stakeholder engagement plan ensures broad, inclusive participation.

(2) The baseline assessment reviews existing policies, legal frameworks, and best practices to align sectoral strategies with spatial planning. Comprehensive data collection and analysis on energy, mobility, and climate risks informs decision-making, identifying conflicts and synergies.

(3) A common vision and goals provide strategic direction. Stakeholders align on priorities such as climate neutrality, sustainable land use, and resilient infrastructure, with measurable objectives ensuring a structured implementation.

(4) The planning phase translates this vision into actionable measures. Scenario planning assesses long-term impacts, and stakeholder feedback refines interventions. Ensuring regulatory coherence strengthens the spatial plan as a tool for implementation.

Fig. 2: Five phases of an integrated planning process according to the IN-PLAN Practice.

(5) Monitoring and evaluation of key performance indicators like emissions reduction, energy efficiency, and mobility improvements ensures adaptability. GIS mapping and digital tools support ongoing assessment,

while stakeholder feedback loops drive continuous improvement, keeping the plan responsive to evolving climate and sustainability targets.

3.3 Practical Tools and Good Practices for Implementation

The IN-PLAN Practice supports spatial, energy, and mobility planners with hands-on tools and international best practices. Each chapter includes structured approaches, decision-making frameworks, technical guidelines and practical tools as well as good practices to address complex planning challenges. Below are some key tools, while a comprehensive overview is available in the IN-PLAN Practice. The U4SSC Guideline (Rodriguez et al., 2021) highlights digital tools that support sustainable urban planning like the Digital Transformation Toolkit (International Telecommunication Union, 2022) which facilitates data-driven governance.

The IN-PLAN Checklist provides a structured overview of key considerations in energy, climate adaptation, and mobility planning. It ensures that planners systematically address all relevant aspects within their projects.

The guide for developing a Heating and Cooling (H/C) plan (Gnehm et al., 2022) offers a detailed methodology for creating an H/C plan. It covers infrastructure assessment, heat demand and potential mapping, feasibility analysis of heat supply, economic considerations, data quality, and the integration of H/C with the power grid amid increasing electrification.

Climate-ADAPT is a platform designed to support Europe's adaptation to climate change. It provides accessible data and insights on expected climate impacts, vulnerability assessments, adaptation strategies, case studies, and planning tools. Information is categorized by EU policy sectors, countries, and cities (European Environment Agency, 2024).

Two cities serve as examples of innovative tools supporting integrated planning:

- Zurich's climate information maps (Kanton Zürich, 2024) offer detailed data on air temperatures, cold air currents, and bioclimatic conditions during summer days and nights. These maps identify heat islands, compensation areas, and ventilation routes, helping planners mitigate urban heat.
- Paris' Climate Resilience Strategies integrate climate adaptation into public spaces through initiatives such as the Paris Resilience Strategy and the Bioclimatic PLU. These strategies enhance urban mobility and summer recreation while strengthening climate resilience (City of Paris, 2017).

4 GOOD PRACTICE: APPLICATION OF INTEGRATED PLANNING IN MUNICIPALITIES

Many municipalities already have different energy and climate action plans, strategies, and policy frameworks, yet struggle to translate them into enforceable measures within spatial planning often slowing down the energy transition, preventing key measures from being effectively implemented. The IN-PLAN project helps bridge this gap by providing municipalities with a structured methodology to embed sustainability into legally binding spatial plans. By leveraging existing energy and climate documents, cities can align their planning processes with long-term decarbonisation and resilience goals.

The following section presents two case studies in Karlovac (HR) and Narni (IT) where local partners have supported municipalities in strengthening spatial plans as tools for driving the energy transition. Their experiences demonstrate how technical expertise, stakeholder collaboration, and regulatory adaptation can turn climate commitments into actionable urban development policies.

4.1 Case study I: City of Karlovac

Through the IN-PLAN project, Karlovac became the first city of the IN-PLAN project to embed its SECAP measures into its General Urban Plan (GUP), ensuring enforceable, long-term sustainability commitments. This case outlines the initial urban and energy challenges faced by Karlovac, the opportunities leveraged for transformation, and the concrete planning and regulatory modifications made to align spatial development with energy transition goals. A detailed examination of the integrated planning process highlights how the City of Karlovac is effectively bridging the gap between strategic ambition and practical implementation.

4.1.1 Initial Situation of the Municipality

Karlovac, a mid-sized city in central Croatia, with approximately 50,000 residents, is uniquely positioned at the intersection of lowland and mountainous regions. Its strategic location in the narrowest part of Croatia, approximately 50 km from Slovenia and Bosnia and Herzegovina gives it significant transport and economic importance. The city is well connected to key regional hubs, lying less than 50 km from Zagreb, 90 km from the major port of Rijeka, and within 400 km of Ljubljana, Sarajevo, Budapest, and Vienna. Karlovac is also known as the "City on Four Rivers", referring to the Kupa, Korana, Mrežnica, and Dobra rivers, which shape both its landscape and environmental challenges, including frequent flooding risks.

Despite its historical and economic strengths, Karlovac, like many European cities, faced challenges in integrating sustainability measures into its urban development framework. The city's energy infrastructure was historically centred around gas, creating obstacles for decarbonisation. District heating systems existed but were underutilized, while renewable energy adoption remained limited. Urban planning was guided by multiple strategic documents, yet they often operated in isolation, leading to inefficiencies in energy distribution, mobility planning, and sustainability initiatives.

While Karlovac had adopted a SECAP to outline its long-term climate and energy goals, the lack of an implementation mechanism meant that these strategies were not effectively translated into action. At the same time, spatial planning policies governed zoning and construction permits but did not systematically incorporate climate resilience and energy efficiency measures. This disconnection between strategy and execution highlighted the need for a more integrated, enforceable planning framework – one that would align Karlovac's urban development with its energy transition and climate adaptation commitments.

4.1.2 Challenges as an Opportunity for Change

The decision to integrate energy planning into the spatial framework stemmed from a recognition that urban development and sustainability efforts must be interlinked. The North-West Croatia Regional Energy and Climate Agency (REGEA) and the City of Karlovac identified several structural challenges that, if properly addressed, could be transformed into opportunities for innovation and long-term resilience.

The primary challenge was the lack of enforcement mechanisms for the city's SECAP. While the document detailed decarbonisation pathways, its recommendations held no legal power, meaning proposed measures were dependent on political will and voluntary implementation. In contrast, the city's spatial plan had binding authority, making it a logical vehicle for embedding sustainability into urban governance.

Another issue was the inefficiency of Karlovac's energy infrastructure. The city had both a gas network and a district heating system, but they operated in competition. Gas infrastructure expansion conflicted with district heating development, preventing the efficient use of existing energy resources. Without regulatory intervention, the city's energy transition would remain stalled by entrenched infrastructure dynamics.

From a governance perspective, Karlovac faced the fragmentation of strategic documents, where urban mobility, energy planning, zoning, and climate adaptation were treated as separate spheres rather than components of a unified vision. This led to inefficiencies such as disjoint transport policies, weak incentives for energy-efficient construction, and no guidance on the integration of renewables for new construction. The city leadership recognised that integrating SECAP measures into the GUP could create a legally binding framework for sustainability, ensuring that energy transition and climate resilience became structural components of urban development rather than optional initiatives.

4.1.3 Influence of the IN-PLAN Project in the Change Process

Karlovac's participation in the IN-PLAN project played a critical role in supporting its energy transition and defining context-specific sustainability measures. Through collaboration with IN-PLAN experts, Karlovac received technical guidance and a structured methodology for integrating energy and climate policies into spatial planning.

A key outcome was the development of a systematic approach for future spatial planning iterations, ensuring that new energy and climate measures could be continuously integrated into the GUP. The IN-PLAN Practice methodology provided Karlovac with a clear framework for assessing sustainability policies, refining them over time, and aligning them with European energy transition goals.

The IN-PLAN team also advised Karlovac on which energy and climate measures could be expanded beyond individual pilot projects and incorporated into city-wide spatial planning regulations. Through further consultations with REGEA and key stakeholders, recommendations were developed for ensuring coordination between municipal departments, infrastructure providers, and urban developers. This collaborative process strengthened Karlovac's ability to institutionalise integrated planning, aligning urban development with long-term decarbonisation and resilience strategies.

4.1.4 Description of the Integrated Planning Process

Driven by the City of Karlovac's ambition for a greener spatial plan, the integration of SECAP measures into the General Urban Plan was carried out through a structured, step-by-step approach, combining technical analysis, stakeholder engagement, and policy development. In partnership with the City of Karlovac, REGEA conducted a comprehensive assessment of existing urban planning and energy strategies to identify gaps and opportunities for embedding SECAP provisions into spatial planning regulations.

To enable data-driven decision-making, Karlovac conducted a detailed energy and climate analysis, mapping heating demand, hot water consumption, and renewable energy potential across the city. The results guided the identification of priority zones for district heating expansion, areas for phasing out gas, and optimal locations for renewable energy integration. By embedding these insights into spatial plans, the city developed zoning regulations that aligned land-use policies with its energy transition goals.

The Lušćić district was chosen as a pilot project to test the integration of energy and climate measures into spatial planning. The resulting plan introduced progressive sustainability measures, including the exclusion of gas infrastructure, mandatory use of district heating or renewable energy, and the implementation of higher energy efficiency standards for new buildings. Additionally, green infrastructure and sustainable mobility solutions were incorporated. After a public consultation process, the Lušćić spatial plan was officially adopted, confirming the feasibility of integrating decarbonisation measures into urban planning.

Building on this success, Karlovac expanded its efforts, receiving expert guidance and technical support to further incorporate energy and climate policies into the GUP. With the assistance of the IN-PLAN team, Karlovac adopted legally binding measures for all new urban developments, including:

- Prohibition of gas infrastructure in new residential and commercial buildings.
- Mandatory use of 100% renewable energy or district heating for heating and domestic hot water.
- Implementation of strict energy efficiency standards to reduce overall energy demand.

By embedding these sustainability measures into the GUP, Karlovac became the first city within the IN-PLAN project to successfully integrate energy and climate planning into its spatial development framework, setting a scalable example for other municipalities.

4.2 Case study II: Municipality of Narni

The municipality of Narni, is located in the province of Terni in central Italy. It spans an area of 198 km2 and has a population of approximately 18,000 inhabitants. The most populous area is Narni Scalo, followed by the old city centre situated on a hill above the Nera River. Narni, with its pre-Roman origins, has preserved its medieval old town, rich in historical, artistic, and cultural sites.

4.2.1 Initial Situation of the Municipality

The General Urban Plan (GUP) of Narni, developed over 20 years ago, remains valuable for its focus on high-quality outdoor spaces. However, it is now outdated and lacks the capacity to support climate-resilient urban development in the face of increasingly frequent extreme weather events.

Despite its small size, Narni has faced administrative fragmentation, leading to a lack of cooperation between departments. This fragmentation had historically hindered the municipality's ability to implement cohesive and comprehensive urban planning strategies.

Municipal staff also struggle with limited access to the knowledge and data needed for effective climate adaptation and spatial planning. The absence of up-to-date, reliable data further challenges the development of informed, data-driven plans. To address this, IN-PLAN is supporting the municipality in institutionalising integrated planning and embedding a data-driven approach from the earliest stages of drafting the new GUP.

4.2.2 Occasion or Challenge of the Municipality

The involvement as a lighthouse municipality in IN-PLAN coupled with the National Resilience and Recovery Plan (NRRP) funded projects – whose implementation requires an effective, multidisciplinary management team in order to meet the tight deadlines – and the initiation of a new GUP presented Narni with an opportunity for change. The municipality began the process of updating its GUP in 2024, starting the revision of the cartography through photogrammetric and topographic surveys, an essential step for enhancing the knowledge framework as a basis for the integrated planning process.

It quickly became evident that enhancing the quality of geospatial data – both in geometry and content – is essential to optimizing land management and urban planning processes. This initiative aims to create a Land Cover vector database that meets the latest EU and AgID (Agency for Digital Italy) standards, promoting the interoperability of urban plans and facilitating territorial exchanges (SNPA, 2024). The funding and support from National Recovery and Resilience Plan (NRRP) projects have provided the necessary resources to address long-standing issues and modernise the municipality's planning processes, aligning them with current standards and sustainability goals.

4.2.3 Modifications and Developments in Favour of Integrated Planning

To foster integrated planning, Narni implemented internal governance reforms, establishing interdepartmental working groups with clear goals, deadlines, and responsibilities. These groups were tasked with ensuring that various departments collaborated effectively, breaking down the silos that had previously impeded progress (Alessandrelli et al., 2024).

The process of integrating energy and climate considerations into spatial planning took shape with the roll out of the IN-PLAN project at the end of 2022 and could benefit from capacity-building activities, peer learning, and jointly developed guidelines for a data management plan.

4.2.4 Description of the Integrated Planning Process

The integrated planning process in Narni involved several key steps:

(1) Committing to the UN-Agenda 2030 standards as a reference framework for the update of the GUP.

(2) Creation of an interdepartmental working group: as the team encountered cross-sectoral complex issues, such as adhering to the Do No Significant Harm (DNSH) principle to implement also NRRP funded projects, the IN-PLAN Practice provided a practical common framework for facilitating knowledge transfer and collaboration among colleagues belonging to different departments.

(3) Developing distinct sets of strategic objectives in three key areas: land consumption, sustainable mobility, and air quality improvement. For each area, the municipality established metrics to ensure effective monitoring and integration of measures. For each strategic objective, Narni identified additional action plans already in place (e.g., for air quality improvement, the Air Quality Agreement for air pollution mitigation in the Terni Valley). This approach enhanced awareness for the regulatory context and ensured strong vertical, horizontal and territorial synergies between strategies and stakeholders.

(4) Adopting a data-driven approach for the definition of the knowledge framework and the spatial planning process to acquire more detailed and comprehensive data layers, enhancing the municipality's ability to analyse and plan for various environmental, climatic and urban factors and ensuring consistency and accuracy in the data used for planning.

(5) Signing an agreement with national, regional and local stakeholders for data-driven spatial and urban planning (AgID, Umbria Region, and Bastia Umbra municipality).

(6) Working on land cover data according to a 4-step methodology:

(a) Analysis of the EAGLE[1] matrices used for creating the Land Cover national Chart

(b) Definition of a "Land Cover" data model

[1] EAGLE is a concept aiming at providing a tool to address the ambiguity between different nomenclatures or their comparability. It is based on description and characterization of land units through Land Cover (LC), Land Use (LU) and Characteristics and Parameters (CH) rather than their classification (ARNOLD et al., 2018)

(c) A detailed mapping plan was created to relate the objects contained in the Geographic Database to the instances expected in the new "Land Cover" data model.

(d) Application of the mapping procedure: this procedure was verified first on an urban test area of the municipality of Narni and later on the whole territory of the municipality.

The process is aiming to create an integrated map database with land cover and national information sheets, ensuring interoperability. The first results show the advantage of a data quality increase without significant additional costs, but, on the other hand, the weakness consists in the input data update frequency, which is not yearly or regular but depends on the specific needs and resources of the single local public administrations. The updated knowledge framework, based on aerial images and detailed layers (built environment, infrastructures, hydrography, orography), supports more informed and effective spatial planning.

4.2.5 Influence of the Change Process through the IN-PLAN Project

The IN-PLAN project played a key role in Narni's transition to integrated planning by advocating for the formation of interdepartmental working groups. The development of a shared vision in the beginning of the process and the participation of all relevant stakeholders supported streamlining the process.

Due to the initiative of developing a data-driven approach and a data management plan with consulting expertise from the IN-PLAN team, the municipality also focused on adopting new methods and technologies, such as advanced GIS systems and data analytics, to enhance the accuracy and efficiency of their planning processes. An intersectional knowledge framework based on geospatial data is now being developed by means of an innovative methodology for Land Cover content derivation through a multi-level-governance collaboration. This framework is facilitating the integration of various cartographic themes. The approach emphasises the importance of high-quality geospatial data for optimising territorial governance and planning processes.

A focus was put on urban resilience and ensuring that planning processes remain adaptable to future challenges, particularly those related to climate change. Therefore, the updated knowledge framework also incorporates information on climate-related risks.

The focus on digitization and technological innovation positions the municipality as a front runner in utilizing new data sources and methods for integrated and resilient urban planning. Narni's experience serves as an example for other small and medium-sized municipalities, demonstrating the benefits of an integrated and holistic approach to sustainable urban planning, capable of providing comprehensive solutions to complex challenges. Narni will continue the development of its new GUP with a strong focus on urban resilience baes on the updated and more detailed cartography as a solid foundation.

5 INNOVATIVE LEARNING APPROACHES FOR INTEGRATED PLANNING

Besides the direct support of cities and municipalities through the regional partners of the IN-PLAN project, another important pillar to enhance an integrated planning practice was capacity building amongst professionals from the planning and energy sector. The two activities of course benefited from each other with local practitioners from lighthouse and pilot cities participating in the trainings and successful pilot projects serving as best practices being presented within the capacity building programme.

Capacity building describes a range of activities aimed at strengthening the abilities, knowledge, and resources of individuals, organisations, and communities. It involves equipping key actors with necessary skills, knowledge, and resources to achieve goals and improve effectiveness. In the long-term, building capacity among policy makers – crucial decision makers in advancing integrated spatial planning – can support the sustainable development of appropriate policy measures. Effective capacity building requires an approach that involves identifying needs, setting clear goals and objectives, providing appropriate training and resources, and monitoring progress and impact. To be truly comprehensive, capacity building also requires the involvement of engaged stakeholders, including community members, civil society organisations, government bodies and statutory agencies, to ensure that efforts are tailored to the specific needs and contexts of the communities they serve.

Capacity building in the IN-PLAN context, of course, focused on integrated spatial planning. As this type of planning lends a holistic approach to land use planning and seeks to organise and integrate the various

aspects of spatial development, including social, economic, and environmental considerations, the capacity building was delivered as a multi-disciplinary approach that aims to address complex spatial problems and challenges, such as urban sprawl, environmental degradation, and social inequality.

As training is subject to time constraints, it is important that each session was utilised as effectively as possible. Based on these considerations, the Activity, Discussion, Input, Deepening and Synthesis (ADIDS) method was identified as being most adequate as adults learn most effectively when they are presented with information in a series of stages and using a variety of different formats and methods, such as relevant and thought-provoking case study presentation, group activities and breakout sessions, slide and audio-visual presentations, as well as hands-on practice, discussion and reflection. In particular, peer-to-peer exchanges created an integral part of the training experience, as it recognises the variety of experiences and range of expertise, whilst allowing participants to share their own perspectives and real life, lived experiences on the associated topics. ADIDS refers to the five main activities of a session including:

- Activity and Discussion – focusing on interaction, such as a poll or case study reading, followed by discussion. In the IN-PLAN training, participants first engaged in interactive introductions, which enabled them to share basic information like geographic background and areas of interest
- Input – Interactive expert lecture or presentation thus building capacity to act as multipliers of the IN-PLAN practice.
- Deepening and Synthesis – Hands-on activity to apply the input by completing a template analysis, policy framework, or guideline in small groups. Group work reinforced trust and mutual recognition building networks for sustainable local and regional application of the IN-PLAN practice.

Participants had to frame, understand and develop the skills and knowledge they were gaining within the IN-PLAN capacity building programme and apply them in real time. As the trainings were held online, it was vital that they were formatted around activities and interactive sessions while building on assignments and thus constructing strong knowledge bases and adding value to the work already carried out by participants. The methodology employed ensured that pertinent questions could be posed to carefully curated break out groups of likeminded peers. Over the course of three weeks, participants worked towards a final assignment using structured templates. Each group was asked to provide a real-world local example or case study regarding the integration of climate targets in urban planning within a local municipality. Using online break out rooms, online tools (e.g., mural workspace, expert capacity building facilitators, guest speaker involvement, peer-to-peer-learning and practical applications of new knowledge) participants built a solid, considered response to the posed query in collaboration with peers. These discussions allowed participants to hear outside perspectives and take away new ideas and concepts.

The two step capacity building measures as part of the IN-PLAN project, have to date (March 2025), resulted in more than 45 multidisciplinary participants from diverse European regions, having successfully completed the programme.

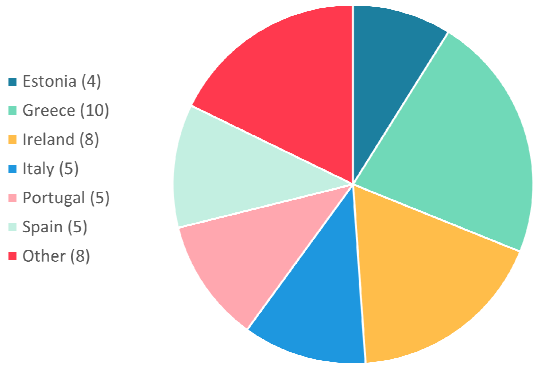

Fig. 3: Participation in the capacity building programme by country of origin.

5.1 Layout of the educational format

The four training modules included valuable and specific learning outcomes and are devised as follows:

5.1.1 Module 1 Spatial Planning an Introduction

The First Module aims to introduce participants to Spatial Planning and Integrated Planning. While participants may have a perception of what spatial planning is, this module addresses the topic from a novel perspective. Even seasoned spatial planners benefited from the conceptual overview.

5.1.2 Module 2 IN-PLAN Practice

The finalised IN-PLAN practice has been developed within the IN-PLAN project. This methodology was used to develop a presentation specifically tailored to the participants of each capacity building programme. This module consists of how to use the IN-PLAN practice and specifically highlight the most relevant areas and case studies to the participants of the capacity building.

5.1.3 Module 3 Case Study examples

Understanding what Integrated Planning looks like in practice is key to developing the capacity of participants and over the 4 sessions run to date, diverse European cities such as Karlovac, Galway, Vienna and Tipperary have been profiled by guest speakers.

5.1.4 Module 4 Module 4: Leadership and Communication

The final module aims to take the understanding of what needs to be done to examine different strategies and how this will be communicated through leadership. This module is a lively mix of activities and interactions primarily led by the main training facilitator.

5.2 Reflections on the IN-PLAN Training Experience

Evaluations have been conducted with all participants in the capacity building process resulting in generally positive feedback. The only criticism was related to the online delivery of the training programme as an in-person exchange would be more engaging. Participants appreciate the extra time to learn, reflect and consider spatial planning and energy and climate issues in a context of integration. The idea of fostering an "integrated planning mindset" amongst all stakeholders is gaining traction but some member states expressed this more than others. For example, participants from Croatia expressed greater optimism regarding the integration of different planning spheres within their regions, whereas in Ireland, further progress is needed before this approach becomes a well-established practice.

IN-PLAN regularly welcomes two types of stakeholders in its two-step capacity-building programme: local and regional authorities, and energy, climate, or development agencies. Step 1 aims at empowering energy, climate and/or development agencies from across Europe to become IN-PLAN Multipliers. Step 2 aims at passing on knowledge to local and regional authorities, which will be tutored either by the project partners or by the trained multipliers. Local and regional authorities as well as energy, climate, and development agencies will become increasingly important to spread the connected methodologies and tools of integrated planning as they are working together with spatial planners and technical energy and climate planners.

6 CONCLUSION

The IN-PLAN project demonstrates the value of a participatory approach to integrated spatial, energy, and climate planning. By fostering collaboration across different levels of governance and disciplines, the project has contributed to embedding integrated planning processes in municipalities such as Narni and Karlovac. However, further efforts are needed to achieve broader implementation. Improving the accessibility and applicability of the IN-PLAN Practice is a key step in this direction. Translating the IN-PLAN Practice into local languages and developing an interactive online version would significantly enhance its usability, facilitating its wider adoption.

Institutionalizing integrated planning remains a central challenge, as seen in Narni, where consolidating a transdisciplinary team proved to be essential. Addressing data gaps is also crucial – municipalities need reliable knowledge frameworks to make informed decisions, particularly in the context of climate change, where large amounts of data are being generated, yet many datasets and their applications are to present relatively unknown or untested but are gradually being explored and integrated into planning processes. A key challenge in this regard is that while data availability is increasing, institutional capacities for processing and utilizing this data remain limited.

Furthermore, municipalities often struggle to implement integrated planning due to limited resources and reliance on external consultants. This highlights the importance of equipping municipal staff with the necessary expertise in integrated planning to ensure they can provide the right guidance and oversight. Additionally, integrating learning formats such as the capacity building programme into professional education could further strengthen the efforts to build long-term institutional capacity. For example, incorporating integrated planning into academic curricula in the fields of energy, planning, and climate change could help prepare future consultants and civil servants more effectively.

Experiences from Karlovac underscore the need to equip spatial planners with knowledge about the energy sector and reinforce the value of localized training modules that reflect regional planning contexts and governance structures. This can be achieved by adapting the IN-PLAN Practice to align with regional planning systems and administrative structures in different European regional contexts, as well as by making insights from municipalities that have implemented the IN-PLAN Practice widely accessible.

To ensure the long-term sustainability of the IN-PLAN project and to enhance the integration of climate adaptation, energy and mobility policies and spatial planning, national and European coalitions will be established to support policy development and provide additional resources for capacity building. Strengthening these collaborative efforts will help secure the future of integrated planning and promote its widespread adoption across municipalities.

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reviewed paper

Entwicklung eines Bewertungssystems für Radverkehrsnetze auf der Grundlage eines digitalen Modells und einer 4-D-Bewertungsmethode

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1 ABSTRACT

Im Rahmen des Transferprojektes „move.mORe“ wird ein nachhaltiges Asset-Management-System entwickelt, das zur Förderung der Mobilitätswende und zur Steigerung der Entwicklungspotenziale von Radverkehrsnetzen, insbesondere im ländlichen Raum, beitragen soll. Die konzeptionellen Aufgaben der Modellierung und Bewertung werden dargestellt. Durch eine multidimensionale Qualitätsbewertung auf Grundlage eines einheitlichen Datenmodells kann die Qualität von Radverkehrsnetzen strukturiert evaluiert und Handlungsbedarfe gezielt ermittelt werden.

Keywords: Datenmodell, Radwegenetzmodellierung, 4-D-Qualitätsbewertung, Asset Management, Radverkehrsinfrastruktur

2 EINLEITUNG

2.1 Hintergrund und Motivation

Das Fahrrad ist in Deutschland essenzieller Bestandteil der alltäglichen Mobilität. Es benötigt im Vergleich mit anderen Verkehrsmitteln eine geringe Flächeninanspruchnahme und besitzt unabhängige Betriebszeiten. Trotz der flexiblen Einsatzmöglichkeiten des Fahrrades ist die wesentliche Grundlage für die sichere und komfortable Nutzung eine befahrbare und funktionsgerechte Infrastruktur. Für eine Erhöhung des Radverkehrsaufkommens ist diese von wesentlicher Bedeutung (Popp et al., 2024). Verwaltungen, die Verantwortlichkeiten für Unterhaltung, Erhaltung, Instandhaltung, Bau und Betrieb auf Radverkehrsnetzen besitzen, müssen kompetent und organisiert sicherstellen, dass alle Anforderungen für eine qualitätsgerechte Infrastruktur erfüllt werden, sind jedoch gleichzeitig dazu verpflichtet mit ihrem zu betreuenden Anlagenbestand möglichst ressourcenschonend und sparsam zu wirtschaften. Hierfür müssen gezielt und strukturiert Maßnahmen über den gesamten Lebenszyklus priorisiert werden – eine Definition des Asset Managements. Vorhandene Problemstellen mit qualitativen Mängeln müssen in Abhängigkeit ihrer Ausprägung priorisiert und durch Maßnahmen optimiert werden. Ausreichende Fachkenntnisse zur effektiven und sachgerechten Entscheidungsfindung bilden die Grundlage der Umsetzung. Strategische, taktische und operative Aufgaben müssen hierfür definiert und in Prozessabläufen berücksichtigt sein. Ein einheitliches System, welches digital und objektbezogen den Bestand und Zustand der Infrastruktur übersichtlich und dynamisch widerspiegelt und infolge der notwendigen Anforderungen die Qualität bewertet, kann bei einer strukturierten Entscheidungsfindung helfen. Der nationale Radverkehrsplan beschreibt das Ziel vom Fahrradland Deutschland im Jahr 2030 und betont die Infrastruktur mit dem Leitziel von lückenlosen, sicheren, komfortablen und intuitiv nutzbaren Radverkehrsnetzen (BMDV, 2022). Um diese Ziele in der Praxis umzusetzen, müssen unzureichende Netzbereiche erkannt, identifiziert und verbessert werden. Für eine möglichst wirtschaftliche Nutzung von Ressourcen, sollten identifizierte Problemstellen in Hinblick auf deren Gesamtbedeutung priorisiert werden. Ein digitales Asset-Management-System auf Radverkehrsnetzen ist daher erstrebenswert, wofür bereits Ansätze zur Implementierung vorgestellt wurden (Stöckner, 2023). Die wesentlichen Teilbereiche der Modellierungsaufgabe und konzeptionellen Bewertung werden im Folgenden dargestellt.

2.2 Ziele

Ziele dieses Asset-Management-Systems sind die digitale Abbildung der Radverkehrsinfrastruktur sowie die Visualisierung einer Qualitätsbewertung. Dies bildet die Grundlage für Priorisierungen und Finanzprognosen späterer Maßnahmen. Der Qualitätserhalt der Infrastruktur soll dadurch effizient sichergestellt werden. Der

Bewertungsprozess soll anhand der ausgewählten Kriterien so aussagekräftig sein, dass ein repräsentatives Abbild geschaffen wird, ohne dabei zu viele Details zu berücksichtigen. Der Fokus liegt auf der Betrachtung von Radverkehrsnetzen für den Alltag.

3 THEORETISCHER HINTERGRUND

3.1 Asset Management

Im Infrastrukturwesen umfasst Asset Management die strukturierte Optimierung im Rahmen von Instandhaltung, Erneuerung und Verwaltung infrastruktureller Vermögenswerte über den gesamten Lebenszyklus eines Assets, welcher den Bau, Betrieb, Instandhaltung und Rückbau beinhaltet. Die Infrastruktur soll unter Berücksichtigung von anfallenden Kosten innerhalb der Lebensdauer, möglichst effizient betrieben werden, sodass der Lebenszyklus möglichst lange und der finanzielle Aufwand möglichst gering ist. Hierfür müssen zunächst die Assets, also der zu erfassende Anlagenbestand, definiert werden. Für den Radverkehr werden die Radverkehrsinfrastrukturelemente berücksichtigt. Um präventiv durch Wartung und Instandhaltung die Lebensdauer der Anlagenbestände zu maximieren, müssen deren gegenwärtige materiellen und technischen Zustände hinsichtlich Leistungs- und Betriebsfähigkeit klassifiziert werden. Die Zustandsermittlung erfolgt auf Basis von Indikatoren, um Kennwerte zur Leistungsfähigkeit bilden zu können. Der Zustand unterschiedlicher Infrastrukturelemente wird in Hinblick auf Ressourcenaufwand zur Wiederherstellung abgeglichen, sodass eine Priorisierungsreihung für die jeweiligen Elemente entsteht. Dies ermöglicht ein effizientes Risikomanagement, zur Reduktion von Kosten und Erhöhung der Langlebigkeit der Assets. Auf Grundlage dessen können spätere Finanzbedarfsberechnungen, welche im Rahmen von Maßnahmen zur Wiederherstellung und Verbesserung aufgewendet werden müssen, erstellt werden.

3.2 Radverkehrsnetze

In Deutschland wird unterschieden in Radverkehrsnetze für Tourismus, Freizeit und Alltag (FGSV, 2018). Diese können sich überschneiden, haben jedoch grundsätzlich variierende Anforderungen. Innerhalb eines Radverkehrsnetzes kann der Radverkehr unterschiedlich geführt werden. Welche Netzabschnitte dafür berücksichtigt werden, hängt in erster Linie vom Verkehrsaufkommen und der Netzbedeutung ab. Obwohl es standardisierte Vorgehensweisen für eine integrierte Netzgestaltung in Deutschland gibt (FGSV, 2009), finden sich auf Radverkehrsnetzen vielerorts noch Netzlücken. Zukünftig müssen diese Lücken im Radverkehr ermittelt und geschlossen werden. Zusätzlich muss der verfügbare Bestand des Radverkehrsnetzes bestimmte Qualitätskriterien erfüllen, um möglichst attraktiv für dessen Nutzung zu sein. Ein Radverkehrsnetz kann als hochwertig klassifiziert werden, wenn es eine hohe subjektive und objektive Verkehrssicherheit aufweist und komfortabel mit möglichst geringem Energiebedarf zu befahren ist. Außerdem sollten Verbindungen direkt sein und mit geringen räumlichen oder zeitlichen Umwegen einhergehen, wofür ein konnektives und zusammenhängendes Netz benötigt wird, welches relevante Orte miteinander verknüpft und gleichzeitig attraktiv in die Umgebung eingegliedert ist. (Ahmed et al., 2024; Arellana et al., 2020; FGSV, 2002, 2010; McCarthy et al., 2016; Weikl& Mayer, 2023). Konkrete Qualitätsbeschreibungen eines Radverkehrsnetzes ermöglichen einen gezielten Einsatz von Maßnahmen zur Erhaltung, Umbau, Ausbau sowie Neubau.

3.3 Qualität und Bewertung von Radverkehrsinfrastruktur

Zur Bewertung der Qualität auf Radverkehrsnetzen zeigt sich aus der Literatur eine Zieldefinition hinsichtlich der Kriterien Sicherheit, Komfort, Direktheit, Konnektivität und Attraktivität, wobei Sicherheit als wichtigstes Kriterium definiert wird. (Ahmed et al., 2024; Arellana et al., 2020; McCarthy et al., 2016; Weikl& Mayer, 2023). Eine Bewertung auf Basis dieser Kriterien ermöglicht die angepasste Kriterienkombination in Abhängigkeit des betrachteten Radverkehrsnetzes. Für die Analyse von Alltagsradverkehrsnetzen sollte dem Kriterium Direktheit eine größere Gewichtung zugeteilt werden als dem Kriterium Attraktivität, wohingegen für ein Freizeitradverkehrsnetz die Attraktivität höher gewichtet werden sollte (McCarthy et al., 2016). Laut (FGSV, 2018) ist der Einfluss der infrastrukturellen Umgebung für die Routenwahl des Radverkehrs deutlich höher als bei anderen Verkehrsmitteln. Eine Vielzahl von Indikatoren wirkt sich auf die Hochwertigkeit und Nutzbarkeit eines Radverkehrsnetzes aus. Hierzu zählen dieFührung des motorisierten Individualverkehrs (FGSV, 2021a; Liu et al., 2019; Rossetti et al., 2019; Watkins et al., 2020), parkende Kraftfahrzeuge (FGSV, 2021b, 2021a; Liu et al., 2019; Rossetti et al., 2019; Watkins et al.,

2020), Führungen des Fußverkehrs (Arellana et al., 2020; Barrero& Rodriguez-Valencia, 2022; FGSV, 2021b), Längsneigungen (Barrero& Rodriguez-Valencia, 2022; FGSV, 2021b), dieBreite der Radverkehrsführung (FGSV, 2021a; Pais et al., 2022; Song et al., 2021; Watkins et al., 2020), Hindernisse und Barrieren (FGSV, 2021b: Ros-McDonnell et al., 2020), das Verkehrsaufkommen des motorisierten Individualverkehrs (Arellana et al., 2020; FGSV, 2021a, 2021b; Song et al., 2021), die zulässige Höchstgeschwindigkeit für Kraftfahrzeuge (Arellana et al., 2020; Song et al., 2021), Beleuchtungen (Barrero& Rodriguez-Valencia, 2022; FGSV, 2018, 2021b; Grigore et al., 2018), Markierungen (Ahmed et al., 2024; Lowry et al., 2016; McCarthy et al., 2016), dieOberflächenqualität (Ahmed et al., 2024; Merkens et al., 2024; Pais et al., 2022; Silvestri et al., 2024), Vorfahrtsregelungen an Knotenpunkten (Arellana et al., 2020; Jensen, 2012), Wartezeiten und Zeitverluste (Ahmed et al., 2024; FGSV, 2018; Reggiani et al., 2022; Silvestri et al., 2024), die Überquerungsdistanz an Knotenpunkten (Jensen, 2012; Lowry et al., 2016), der Umwegefaktor (Arellana et al., 2020; Reggiani et al., 2022; Schmid-Querg et al., 2021; Weikl & Mayer, 2023), Abstellanlagen (Ahmed et al., 2024; Ros-McDonnell et al., 2020; Schmid-Querg et al., 2021), die ÖPNV-Anbindung (Pucher & Buehler, 2008; Silvestri et al., 2024) oder die Netzdichte (Ahmed et al., 2024; Gu et al., 2018; Vierø et al., 2024).

Analysen zu infrastrukturellen Einflüssen auf den Radverkehr sind international weit verbreitet (Ahmed et al., 2024). Mit dem BSIR (Bicycle Safety Index Rating) wurde bereits in den 80er Jahren die erste Bewertungsmethode für die Sicherheit von Radfahrenden entwickelt (Davis, 1987). Seither hat sich eine Vielzahl weiterer Bewertungsmethoden gebildet, wie beispielsweise dem BLOS (TRB, 2010), dem BCI (Liu et al., 2019), dem LTS (Mekuria et al., 2012) oder dem BI (Arellana et al., 2020).

Nach (Ahmed et al., 2024) ist der systematische Prozess zur Konzeption von Bewertungsmethoden in mehrere Bereiche aufgeteilt. Er beginnt mit einer Zieldefinition von Kriterien, für welche eine Zusammensetzung aus Indikatoren ermittelt wird. Für jeden Indikator muss eine klassifizierende Einstufung gebildet und in Abhängigkeit dessen Ausprägung bewertet werden. Anschließend müssen die Indikatoren untereinander in Abhängigkeit ihres Einflusses gewichtet werden (Ahmed et al., 2024). Der Gewichtungsprozess gestaltet sich hierbei komplexer als die Identifikation der Indikatoren, eine Gewichtung ist jedoch essenziell, da eine gleichgroße Berücksichtigung der Indikatoren nicht repräsentativ ist.

3.4 Analytischer Hierarchieprozess

Der Analytische Hierarchieprozess (AHP), entwickelt durch (Saaty&Kearns, 1985), ermöglicht die Gewichtung mehrerer Parameter, um auf Basis komplexer, multikriterieller Einflüsse, strukturiert und konsistent, Entscheidungen treffen zu können. Wesentlicher Bestandteil des AHP ist der paarweise Vergleich im Rahmen einer Präferenzenmatrix entsprechend der relativen Bedeutung der Kriterien untereinander. Im Rahmen der Bewertung von Radverkehrsnetzen wurde der AHP von (Karolemeas et al., 2022; Zuo& Wei, 2019) verwendet. Im Kontext der durchgeführten Methodik wird der AHP zur Gewichtungsermittlung eingesetzt, um die Relevanz der Parameter relativ zueinander zu bewerten.

3.5 DigitaleModelle

Die Zukunft des Planens, Bauens und Betreibens wird wesentlich durch den digitalen Wandel bestimmt (BMDV, 2015). Um von der Digitalisierung zu profitieren und damit die Anforderungen bei der netzweiten Qualitätsbewertung und bei einem effizienten Asset Management der Radverkehrsnetze erfüllen zu können, ist ein geeignetes digitales Modell erforderlich. Hierzu ist eine klare Standardisierung für die Datendefinition und -struktur von zentraler Bedeutung. Vor diesem Hintergrund stellt die Building Information Modelling (BIM) Methode ein gutes Beispiel dar. Die Quintessenz von BIM besteht unter anderem darin, eine konsistente und kompatible Datengrundlage zu schaffen, sodass gemeinsame, reibungslose Kommunikation und Arbeit möglich sind. Der Standard für die Datengrundlage ist als „Industry Foundation Classes" (IFC) bekannt und setzt sich aus der semantischen Beschreibung eines Bauteils und seiner geometrischen Repräsentation zusammen. Dabei ist die semantische Beschreibung als eine Entität dominierend und kann mit einer oder mehreren geometrischen Verkörperungen verbunden werden (Borrmann et al., 2021). Die BIM-Methode schafft große Vorteile durch realitätsnahe 3D-Modellierung für die Planung und den Neubau eines Bauwerks. Wird der Schwerpunkt von Neubau auf die Betriebs- und Erhaltungsphase verlagert, dann werden zusätzlichen externen dynamischen Echtzeitdaten aus dem Bestand in Ergänzung zu statischen Daten aus der Planungsphase benötigt, um ein immer mit der Realität synchronisiertes digitales Modell zu erhalten.

Somit wird die Arbeitsmethode „Digitaler Zwilling“ als Erweiterung von BIM genutzt, um eine optimierte Entscheidungsgrundlage für ein nachhaltiges Management im Lebenszyklus der Infrastruktur zu schaffen (Fazekas, 2024). Im Vergleich zu BIM und dem digitalen Zwilling konzentriert sich die GIS-Methode auf geodatenbezogene Analysen und Darstellungen eines Betrachtungsraums. Die detaillierten Geometrie- und Funktionsbeschreibungen besitzt teilweise nur eine sekundäre Bedeutung, sodass diese oft vereinfacht oder weggelassen werden können. Die Grundstruktur bei der Modellierung, also die Kombination von Geometriemodell und dem damit verbundenen standardisierten Datenmodell bleibt jedoch gleich. Ein typischer Standard für GIS ist beispielsweise das GML (Geography Markup Language) entwickelt vom OGC (Open GeospatialConsortium) (Jarosch, 2023).

Im Sinne von Asset Management eines Straßennetzes liegt der Schwerpunkt eines digitalen Modells auf einer großräumigen, netzweiten Zustandsanalyse zur optimalen Erhaltung der vorhandenen Infrastruktur. Zu diesem Zweck wurde die Anweisung Straßeninformationsbank (ASB) erarbeitet, sodass alle überörtlichen Straßen im Netz mit umfassend genauen Daten analysiert und bewertet werden können. Die Straßeninformationsbank (SIB) nach ASB setzt sich aus einem Ordnungssystem basiert aus Netzknoten und Stationierungssystem sowie einer damit verbundenen Datenbank zusammen. Das Ordnungssystem bildet die Grundlage für die Visualisierung der Daten und Auswerteergebnisse in GIS. Die damit verbundene Datenbank ist ein Datenmodell mit einer standardisierten Struktur, auf dem eine beliebige Anzahl von Daten angehängt werden können. Die Standardisierung für den Datenaustausch wird in dem OKSTRA festgehalten und fortgeschrieben. OKSTRA ist ein Katalog von Objekten des Straßen- und Verkehrswesens sowie den zugehörigen Sachdaten und Beziehungen (BMDV, 2024). Die SIB nach ASB ist somit eine Art „Semi-“ Digitaler Zwilling, sie übernimmt die Vorteile von BIM, GIS und digitalem Zwilling und passt die Konzipierungsstruktur nach konkreten Anwendungsfällen und Zielsetzungen für ein geeignetes Datenbanksystem an.

Für Radverkehrsnetze bestehen derzeit weder standardisierte Verfahren zur Zustandserfassung und -bewertung (ZEB), noch ein offizielles Netzmodell. Bestehende Modelle zur Radverkehrsinfrastruktur konzentrieren sich vor allem auf die Routingfähigkeit und grundlegenden Datendokumentationen. OSM (Open Street Map) ist eine communitybetriebene Datenplattform für Karten und beinhaltet auch Daten zur Infrastruktur. Es folgt einem einfachen Modell basierend aus Punkten (Nodes), Linien (Ways) und Relationen (Relations), wobei Punkte sowohl Knotenpunkte als auch zahlreiche andere Objekte wie Bäume, Gebäude und Lampen darstellen können. Die Geometrie von Linien kann durch Referenz von Punkten definiert werden. Zusätzliche Eigenschaften können durch sogenannte „Tags“ beliebig hinzugefügt werden. Da die Daten nicht aus offiziellen Quellen stammen, sind die Qualität und Vollständigkeit oft unzureichend. Es bietet jedoch eine Datengrundlage mit guter Aktualität und globaler Zugänglichkeit, die auf Überprüfung und Korrektur bei Datenmängeln nützlich sein können. In Baden-Württemberg wurden 2011 die Online-Anwendung des Radroutenplaner und 2020 die Datenplattform RadVIS (Radverkehrs-Infrastruktur-System) entwickelt. Der Radroutenplaner berücksichtigt unter anderem das Radnetz von Baden-Württemberg und ist in erster Linie für Nutzende gedacht, um Empfehlungen zu einfachen und bequemen Routen zu geben. RadVIS ist eine Datenbank zur Unterstützung der Städte und Kommunen bei der Konzeption und Dokumentation ihrer Radnetze. Im Rahmen der Digitalisierung der Radverkehrsinfrastruktur können beide Plattformen als großer Fortschritt verzeichnet werden. Angesichts der steigenden Anforderungen eines Managementsystems für die Fahrradinfrastruktur zeigen sich dennoch Schwächen. So wird beispielsweise in RadVIS nur ein vereinfachtes Modell für Knotenpunkte gepflegt, sodass nur die reine Information der Knotenpunktart berücksichtigt werden kann, was für eine repräsentative Bewertung der Knotenpunkte und folglich des gesamten Netzes ungünstig wirken kann. In (BALM, 2023) wurden die Rahmenangaben des nationalen Datenschemas der Radverkehrsdaten analog zum OKSTRA im Straßensystem vorgelegt. Damit ist eine Grundstruktur für ein einheitliches Datenmodell vom Radverkehrssystem errichtet. Das Datenschema ist jedoch derzeit auf kein Bewertungsverfahren ausgelegt, sodass die Vollständigkeit und Umsetzfähigkeit noch zu prüfen sind. Im Rahmen des vier-dimensionale Qualitätsbewertungsverfahren für Radverkehrssysteme nach (Stöckner, 2023) sind deutlich höhere Anforderungen zum digitalen Radnetzmodell zu erwarten, insbesondere bezüglich Netzstruktur und Datenmodell. Die bestehende Datenbank muss auf eine standardisierte Weise erweitert werden. Es ist davon auszugehen, dass ein geeignetes Informationssystem je nach gesonderten Anwendungsfällen und Ansprüchen für Radwegenetze analog zur SIB in naher Zukunft eine immer wichtigere Rolle spielen wird, wodurch eine Standardisierung

zweckmäßig ist. Im Kontext der Zielsetzung einer Qualitätsbewertung und Asset Management des vollständigen Radverkehrsnetzes liegt der Fokus nicht auf nuancenreichen 3D-Geometrie-Planungen und Visualisierungen von einzelnen Straßenelementen. Vielmehr spielen ihre geographischen Positionen und Qualitätsmerkmalen eine wichtige Rolle. Aus diesem Grund ist eine Kombination zwischen einem Geometriemodell auf Basis von GIS und einem Datenmodell im Sinne von BIM oder digitalem Zwilling zielführend. Dabei ist zu beachten, dass eine Standardisierung mit Berücksichtigung bestehender Datenmodelle bei der Modellierung anzustreben ist, um den künftigen Datenaustausch reibungslos zu gestalten.

4 METHODIK

4.1 Entwicklung des konzeptionellenBewertungsmodells

Das Bewertungsmodell soll bisherige Methoden durch die Kombination der Zielkriterien mit einer differenzierten Elementbetrachtung von Strecke und Knotenpunkt erweitern und so eine georeferenzierte Defizitanalyse bei gleichzeitig ganzheitlicher Qualitätsbetrachtung ermöglichen. Zunächst wird das Radverkehrsnetz in Elemente von Streckenabschnitten und Knotenpunkten eingeteilt, da aufgrund der individuellen Qualitätsmerkmale eine Bewertung getrennt für beide Elemente durchgeführt werden muss. Diese sind in beliebiger Form und Anzahl miteinander verknüpfbar, sodass durchgehende Verbindungen entstehen können, welche als Routen bezeichnet werden. In Abhängigkeit der zu bewertenden Eigenschaften, werden individuelle Streckenabschnitte, Knotenpunkte, Routen oder das gesamte Netz betrachtet. Nach (Taubitz et al., 2025) können unterschiedliche Zielgrößen für die Bewertungsbereiche gebildet werden. Hierbei bleibt die Attraktivität im Rahmen der Betrachtung von Alltagsradverkehrsnetzen unberücksichtigt, da diese stark von subjektiven Faktoren beeinflusst wird und eine vernachlässigbare Bedeutung im Alltagsradverkehr aufweist. Ein einzelner Streckenabschnitt ist gekennzeichnet durch Sicherheit und Komfort. Knotenpunkte können ebenfalls hinsichtlich Sicherheit und Komfort bewertet werden. Für Routen ergibt sich eine zusätzliche Bewertung der Direktheit und im gesamten Netz kann die Konnektivität analysiert werden. Das aufeinander aufbauende System ermöglicht je nach Anwendungsbereich, Einzelbewertungen und Gesamtbewertungen. Dies ist erforderlich, um Mängel innerhalb des Radverkehrsnetzes georeferenziert zu identifizieren, da eine gesamtheitliche Betrachtung auf Netzebene keine Georeferenzierung erlaubt. Im Rahmen der durchgeführten Methodik wird je ein Gesamtwert für die individuellen Bewertungsbereiche Strecke, Knotenpunkt, Route und Netz benötigt. Dies erfordert die Gewichtung und Erstellung von je einem analytischen Hierarchieprozess für alle Parameter je Bewertungsbereich.

4.2 Parameter und Daten

Die zu berücksichtigende Parameter sollten keine zeitlich zu hohen Änderungen aufweisen, da kurzweilige Qualitätseinschränkungen keine langfristigen Auswirkungen auf die Gesamtqualität das Radverkehrsnetz haben. Ziel des Bewertungssystem ist es, die grundlegenden und langfristigen Qualitätseinschränkungen zu identifizieren und quantifizieren und nicht geringfügige Aspekte in Form von Details in die Betrachtung einfließen zu lassen. Die Befahrbarkeit sollte auf hochwertigen Radverkehrsnetzen durch eine betriebliche Unterhaltung sichergestellt sein, ist jedoch aufgrund der nicht kompensatorischen Eigenschaften nicht in den folgenden Parametern berücksichtigt. Die betriebliche Unterhaltung umfasst die Abwicklung der betrieblichen Aufgaben hinsichtlich Winterdienst, Reinigung, Grünpflege, Wartung und Instandhaltung der Ausstattung sowie baulicher Unterhaltung. Diese Aufgaben unterliegen im Verlauf eines Jahres starken Schwankungen und müssen über die Zuständigkeiten der Baulastträger hinweg koordiniert werden. Dafür ist eine ausreichende Personal- und Maschinenkapazität notwendig. Diese Anforderungen resultieren in einer komplexen Umsetzungssituation, die jedoch an dieser Stelle nicht weiter ausgeführt wird. Nach (Taubitz et al., 2025) werden den Kriterien Sicherheit und Komfort an Streckenabschnitten und Knotenpunkten folgende Parameter zugeteilt:

Sicherheit Strecke: Baulicher Zustand, Breiten, Verkehrsaufkommen Kfz, zulässige Höchstgeschwindigkeit Kfz, Trennungen zum Kfz-Verkehr, Parken Kfz, Beleuchtungen, Markierungen

Komfort Strecke: Baulicher Zustand, Breiten, Längsneigung, Trennungen zum Fußverkehr, Hindernisse

Sicherheit Knotenpunkt: Baulicher Zustand, Breiten, Verkehrsaufkommen Kfz, zulässige Höchstgeschwindigkeit Kfz, Vorfahrtsregelung, Trennungen zum Kfz-Verkehr, Markierungen

Komfort Knotenpunkt: Baulicher Zustand, Breiten, Überquerungslängen, Wartezeiten, Trennungen zum Fußverkehr

Die Einzelbewertungen der Parameter werden in eine Skala von eins (sehr schlecht) bis fünf (sehr gut) übertragen. Der bauliche Zustand (BZ) bewertet die Oberflächenqualität auf Basis von Ebenheit, Substanzmerkmalen und Griffigkeit (Merkens et al., 2024). In Abhängigkeit der vorhandenen Ausprägungen von beispielsweise Rissen, Abplatzungen oder Wurzelhebungen wird ein Gesamtwert zur Oberflächenqualität auf Basis des vorhandenen Oberflächenmaterials im Rahmen einer Zustandserfassung und -bewertung gebildet. Für die Bewertung der Breiten (BR) wird die vorhandene Breite mit der vorgegebenen Mindestbreite (Bmin)und Regelbreite (Breg) aus dem Regelwerk abgeglichen (FGSV, 2010; Weikl & Mayer, 2023). Das Verkehrsaufkommen (VA) entspricht der durchschnittlich täglichen Verkehrsstärke (DTV) für den Kfz-Verkehr. Die zulässige Höchstgeschwindigkeit des Kfz-Verkehrs wird stufenhaft eingeteilt und geringere Geschwindigkeiten besser bewertet. Die Führungsform des Radverkehrs im Vergleich zum Kfz-Verkehr dient der Bewertung von Trennungen zum Kfz-Verkehr (TK). Zur Bewertung von Parken Kfz (PA) wird der Abstand zu parkenden Fahrzeugen von der Radverkehrsführung ermittelt (Weikl & Mayer, 2023). Die Bewertung der Beleuchtung (BE) umfasst das Vorhandensein und die Abwesenheit von Beleuchtungsanlagen. Die Bewertung der Markierungen (MA) erfolgt in Abhängigkeit von vorhandenen Bodenmarkierungen. Zur Bewertung der Längsneigung (LN) werden vorhandene Steigungen als auch die Länge der Steigungsstrecke benötigt. Die Bewertung erfolgt nach (Weikl & Mayer, 2023) in Form eines Steigungsindex, mit der Formel $S = H^2*L$ (S = Steigungsindex, H = Steigung, L = Streckenlänge). Die Bewertung von Trennungen zum Fußverkehr (TF) basiert auf der Führungsform des Radverkehrs und des Fußverkehrs. Hindernisse (HI) wie beispielsweise Poller, Pfosten, Umlaufgitter oder sonstige Einbauten werden zur Bewertung entsprechend der Anzahl pro 1.000 Meter bewertet. Die Bewertung erfolgt mit der Formel HI = 1000m/L*AH (L = Streckenlänge, AH = Anzahl der Hindernisse). Zur Bewertung der Vorfahrtsregelung (VR) wir die Art der Vorfahrtsregelung für den Radverkehr ermittelt und die Bewertung der Überquerungslängen (ÜL) berücksichtigt die Länge des zu überquerenden Knotenpunktes. Die Bewertung der Wartezeiten (WZ) erfolgt stufenhaft in Abhängigkeit der vorhandenen Wartezeiten am Knotenpunkt. In Tabelle 3 sind die möglichen Einteilungen zusammengefasst, welche in Abhängigkeit des erstrebten Qualitätsniveaus angepasst werden können.

Parameter	1	2	3	4	5
BZ [-]	5	4	3	2	1
BR [m]	$<0,7*B_{min}$	$0,7*B_{min}– B_{min}$	$>B_{min} – <B_{reg}$	B_{reg}	$>B_{reg}$
VA [Kfz/Tag]	≥5.000	≥2.500	≥2.000	≥1.000	<1.000
HG [km/h]	>70	70	50	30	<30
TK [-]	Mischverkehr	Radfahrstreifen; Schutzstreifen	Fahrradstraße	Straßen-begleitende Führung	Separate Führung
PA [m]	<0,75	<1,50	<2,00	<5,00	≥5,00
BE [-]	Nicht vorhanden				Vorhanden
MA [-]	Keine Markierung		Randstreifen		Flächenhafte Einfärbung
LN [m]	≥0,400	≥0,200	≥0,075	≥0,033	<0,033
TF [-]	Gehweg mit Radverkehr frei	Geh- und Radweg gemeinsam	Landwirtschaft-licher Weg; Waldweg	Geh- und Radweg getrennt	Separate Führung
HI [1/km]	≥4	3	2	1	0
VR [-]	Keine Regelung	Rechts-vor-links	Verkehrszeichen ohne Vorfahrt	Verkehrszeichen mit Vorfahrt	Lichtsignal-anlage
ÜL [m]	>20	≤20	≤15	≤10	≤5
WZ [s]	>20	≤20	≤15	≤10	≤5

Tabelle 1: Mögliche Bewertungen für Parameter von Strecke und Knotenpunkt, teils basierend auf (Weikl & Mayer, 2023)

Die Parameter, welche zur Bewertung der Kriterien Direktheit und Konnektivität verwendet werden, sind:

Direktheit Route: Umwegefaktor, Zeitverluste an Knotenpunkten

Konnektivität Netz: Abstellanlagen, ÖPNV-Anbindung, Netzdichte, Hauptradwegenetzanteil

Zur Bewertung des Umwegefaktors (UF) muss das Verhältnis aus Luftliniendistanz und Routenlänge zwischen Start- und Zielort mittels folgender Formel gebildet werden UF = LR/LD (LR = Routenlänge, LD = Luftliniendistanz). Die Zeitverluste an Knotenpunkten (ZK) werden pro Routenkilometer angegeben und mit der Formel ZK = ∑(WZ)/LR (WZ = Wartezeit je Knotenpunkt, LR = Routenlänge) berechnet. Die

Bewertung von Abstellanlagen erfordert die Ermittlung des Typs der Abstellanlage sowie deren Auslastung (Weikl & Mayer, 2023). Die Kombination der Bewertungen wird durchgeführt durch AA = (BS+AL)*0,5 (BS = Stellplatzbewertung, AL = Auslastung). Die ÖPNV-Anbindung (ÖA) wird durch Ermittlung der Luftliniendistanz zwischen Haltestelle und Radverkehrsnetz ermittelt. Die Netzdichte (ND) setzt sich zusammen aus der Länge des Radverkehrsnetzes und der Fläche des Radverkehrsnetzes mit der Formel ND = FN/LN (FN = Netzfläche, LN = Netzlänge). Zur Bewertung des Hauptradwegenetzanteils (HN) wird die Länge des Hauptradwegenetzes im Verhältnis zur Netzlänge berechnet mit HN = LH/LN (LH = Hauptradwegenetzlänge, LN = Netzlänge). Mögliche Einstufungen der Bewertungen basieren größtenteils auf (Weikl & Mayer, 2023) und sind in Tabelle 2 dargestellt.

Parameter	1	2	3	4	5
UF [-]	>1,5	>1,4	>1,3	>1,2	≤1,2
ZK [s/km]	>46	>36	>26	>16	≤16
BS [-]	Vorderradanschluss	Anlehnbügel	Sammelanlage	Fahrradbox	Fahrradparkhaus
AL [%]	≥90	<90	<80	<70	<60
ÖA [m]	>500	>400	>300	>200	≤200
ND [m]	>1000	>500	>400	>250	≤250
HN [%]	<40	≥40	≥50	≥60	≥70

Tabelle 2: Mögliche Bewertungen für Parameter von Route und Netz, größtenteils nach (Weikl & Mayer, 2023)

4.3 Gewichtungs- und Bewertungsverfahren

Damit eine georeferenzierte Gesamtwertanalyse ermöglicht wird, müssen für jeden Bewertungsbereich neue Kombinationen der Gesamtwertbildung erfolgen. Auf Basis der Analyse verschiedener wissenschaftlicher Quellen (Arellana et al., 2020; McCarthy et al., 2016; Weikl & Mayer, 2023) wurde eine mögliche Struktur für die Gewichtungsverteilung für Alltagsradverkehrsnetze abgeleitet.

Gesamtwert Strecke = 0,60 * Sicherheit Strecke+ 0,40 * Komfort Strecke

Gesamtwert Knotenpunkt = 0,60 * Sicherheit Knotenpunkt + 0,40 * Komfort Knotenpunkt

Gesamtwert Route = 0,48 * Sicherheit + 0,31 * Komfort + 0,21 * Direktheit

Gesamtwert Netz = 0,40 * Sicherheit + 0,29 * Komfort + 0,16 * Direktheit + 0,15 * Konnektivität

Da im Gesamtbewertungssystem jeder Parameter individuell angezeigt werden kann, kann spezifisch nach Schwachstellen gefiltert werden. Die Gesamtwertbildung dient der Priorisierung auf Netzebene. Die Gewichtungsermittlung der jeweiligen Parameter wurde durch analytische Hierarchieprozesse in Abhängigkeit der definierten Parameter durchgeführt. Die Gewichtungen innerhalb der analytischen Hierarchieprozesse basieren auf generischen Einschätzungen, welche durch Ergebnisse der Literaturanalyse gestützt werden, da keine numerischen Daten verfügbar waren.

Die Bewertung der Streckenabschnitte erfordert Gesamtwerte zu Sicherheit und Komfort. Für jeden dieser Kriterien wurde ein analytischer Hierarchieprozess durchgeführt, um Einzelgewichte der Parameter zu ermitteln. Die Ergebnisse sind in den folgenden Gleichungen dargestellt.

Sicherheit Strecke = 0,10*BZ + 0,09*BR + 0,19*VA + 0,13*HG + 0,39*TK + 0,02*PA + 0,03*BE + 0,05*MA

Komfort Strecke = 0,17*BZ + 0,38*BR +0,36*LN + 0,06*TF + 0,03*HI

Zur Ermittlung der Gewichte der Parameter für Knotenpunkte wurden ebenfalls zwei analytische Hierarchieprozesse entsprechend den definierten Parametern durchgeführt mit folgenden Ergebnissen.

Sicherheit Knotenpunkt = 0,04*BZ + 0,03*BR + 0,22*VA + 0,20*HG + 0,37*VR + 0,11*TK + 0,03*MA

Komfort Knotenpunkt = 0,10*BZ + 0,20*BR + 0,04*ÜL + 0,54*WZ + 0,08*TF*0,04*MA

Die Gewichtungsverteilungen zu den Kriterien Direktheit und Konnektivität sind nachstehend dargestellt. Für beide Kriterien wurde ein AHP durchgeführt.

Direktheit Route = 0,83*UF + 0,17*ZK

Konnektivität Netz = 0,57*AA + 0,05*ÖA + 0,25*ND + 0,13*HN

Um die vollständige Bewertung einer Route durchzuführen, werden zusätzlich zur Direktheit die Kriterien Sicherheit und Komfort benötigt. Diese setzen sich zusammen aus der relativen Sicherheit für Strecken unter

Berücksichtigung der jeweiligen Streckenlänge sowie der durchschnittlichen Sicherheit an Knotenpunkten entsprechend deren Anzahl. Die folgenden Gleichungen veranschaulichen dies.

Sicherheit Route = (∑ (Sicherheit Streckenabschnitt * Streckenlänge) / Routenlänge +

∑ (Sicherheit Knotenpunkt) / Anzahl Knotenpunkte) / 2

Komfort Route = (∑ (Komfort Streckenabschnitt * Streckenlänge) / Routenlänge +

∑ (Komfort Knotenpunkt) / Anzahl Knotenpunkte) / 2

Für die Gesamtbewertung des Netzes muss zusätzlich zum Kriterium Konnektivität eine Betrachtung von Sicherheit, Komfort und Direktheit unter Berücksichtigung aller Strecken, Knotenpunkte und Routen erfolgen. Sicherheitswert und Komfortwert werden aus Streckenabschnitten und Knotenpunkten gleich der Vorgehensweise der Routenkombination gebildet, mit der Erweiterung, dass alle Streckenabschnitte und alle Knotenpunkte berücksichtigt werden. Um eine Aussagekräftige Bewertung zur Direktheit eines Radverkehrsnetzes geben zu können, müssen alle relevanten Routen berücksichtigt werden, bevor der Durchschnittswert als Kriterium der Netzbewertung einfließt. Dies betrifft die Verbindung relevanter Start- und Zielpunkte in Form individueller POI (Points of Interest) innerhalb des Radverkehrsnetzes. Die Kombinationen der Kriterien sind in den folgenden Formeln veranschaulicht.

Sicherheit Netz = (∑ (Sicherheit Streckenabschnitt * Streckenlänge) / Netzlänge +

∑ (Sicherheit Knotenpunkt) / Anzahl Knotenpunkte) / 2

Komfort Netz = (∑ (Komfort Streckenabschnitt * Streckenlänge) / Netzlänge +

∑ (Komfort Knotenpunkt) / Anzahl Knotenpunkte) / 2

Direktheit Netz = ∑ (Direktheit Route * Routenlänge) / ∑ Routenlängen

Auf Basis der bisherigen Bewertungen können Einstufungen entsprechend der infrastrukturellen Qualität unabhängig vom Radverkehrsaufkommen getroffen werden. Sofern vorhandene Daten zum Radverkehrsaufkommen vorliegen, können diese mit den vorhandenen Qualitätswerten überlagert werden. Dies ermöglicht eine verkehrsabhängige Priorisierung, sodass die Qualität auf Netzbereichen mit viel Radverkehrsaufkommen eine höhere Bedeutung hat als die Qualität auf Netzbereichen mit wenig Radverkehrsaufkommen. Sofern keine Daten zum Radverkehrsaufkommen auf dem Radverkehrsnetz vorliegen, kann die Netzbedeutung in Abhängigkeit der räumlichen Relevanz des Netzabschnitts berücksichtigt werden.

4.4 Modellierungsrichtlinie

Um das Bewertungsmodell umzusetzen, wird ein digitales Netzmodell als Grundlage benötigt. Grundelemente dafür sollten die bestehenden Modellsysteme und Zustandserfassungsmethoden berücksichtigen. Infolge von unterschiedlichen Nutzungsansprüchen der Anwendungsfälle muss ein Kompromiss zwischen Übersichtlichkeit, Leistungsfähigkeit, Begreifbarkeit, Genauigkeit, Effizienz und Wirtschaftlichkeit gefunden werden. Dies bedeutet, dass das Modell möglichst einfach aber gleichzeitig ausreichend robust für folgende Anwendungsfälle sein muss:

- Darstellung der Topologie und Geometrie des Radverkehrsnetzes
- Georeferenzierung
- Dokumentation und Fortschreibung der umfangreichen Bestands- und Zustandsdaten der Infrastruktur
- Streckenbezogene, Knotenpunktbezogene, Routenbezogene sowie Netzbezogene Qualitätsbewertung und Defizitanalyse anhand der Bewertungsalgorithmen und Zustandsdaten
- Visualisierung der Bewertungsergebnisse
- Effiziente Datenübertragung und -zuweisung aus Quellen wie SIB und RadVIS

Demzufolge wird ein Objektmodell mit den Grundelementen in Tabelle 3 erarbeitet.

Die Trennung der Richtung für eine Strecke hängt ausschließlich davon ab, ob Radfahrende aus zwei Richtungen dieselbe Fahrspur teilen müssen oder ob eine zusätzliche Zustandserfassung für die Gegenrichtung durchgeführt werden muss. Die Unterscheidung von NK und LK besteht darin, die

Verkehrssituation ausreichen bewerten zu können. Typische LK finden sich dort, wo Radfahrende als häufigstes Verkehrsmittel vertreten sind. In solchen Fällen sind die zu verbindenden Strecken oft auch durch eine einzige Primärstrecke für beide Richtungen repräsentativ. An großen Knotenpunkten mit LSA ist es sowohl für die Bewertung des Knotenpunktes als auch für Routenbewertung relevant, die Fahrbeziehungen getrennt zu betrachten. Die Verbindungsstrecken sind entsprechend der vorhandenen Verkehrsführung anzulegen, indem zum Beispiel für indirektes Linksabbiegen eine zweistufige Verbindung modelliert wird und für direktes Linksabbiegen eine diagonale Verbindung anzulegen ist. Die Verbindungsstrecken sind neben ihrer topologischen Verbindungsfunktion wichtig für die Betrachtung der Sicherheit und Leistungsfähigkeit. Unabhängig von Start- und Endnetzknoten wird die Geometrie einer Strecke analog zur SIB bzw. OSM durch eine Punktliste definiert. Abb. 1 zeigt eine Beispielmodellierung.

Objektkategorie	Objekttyp	Kennzeichen	Bedeutung und Merkmale
Knotenpunkt	Netzknoten	NK	Große Knotenpunkte, Netzbedeutung; Achsenschnittpunkt
	Teilknoten	TK	Teil von einem großen Knotenpunkt; Streckenanschlusspunkt
	Lokalknoten	LK	Kleine Knotenpunkte, lokale Verbindung; Streckenanschlusspunkt
Streckenabschnitt	Primärstrecken	PS	Beschreibt eine ganze Strecke zwischen NK; Zur Datenübertragung, ZEB-Datenimport
	Sekundärstrecken	SS	Segmente von zugehöriger PS; Zur differenzierten Datenhaltung und Datenvisualisierung
	Verbindungsstrecken	VS	Verbindet TK; Zur separaten Betrachtung unterschiedlicher Fahrbeziehungen

Tabelle 3: Grundelemente als Kernkonzept für das Netzmodell

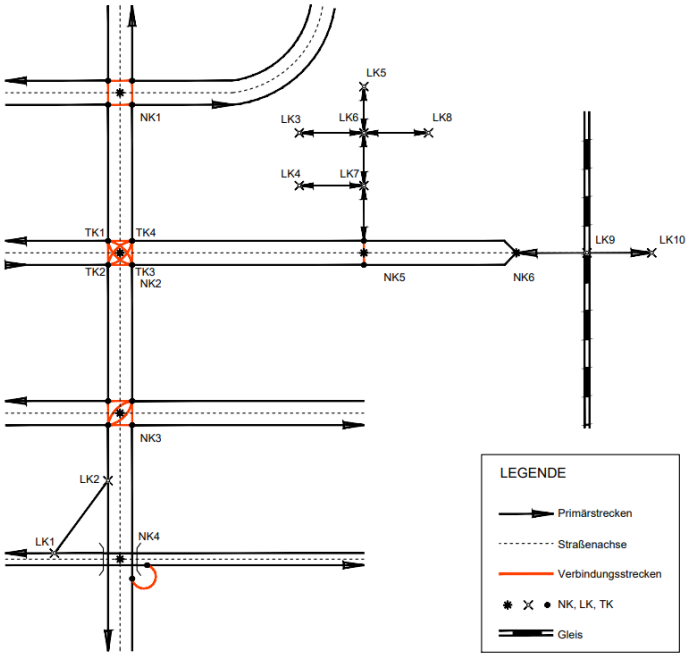
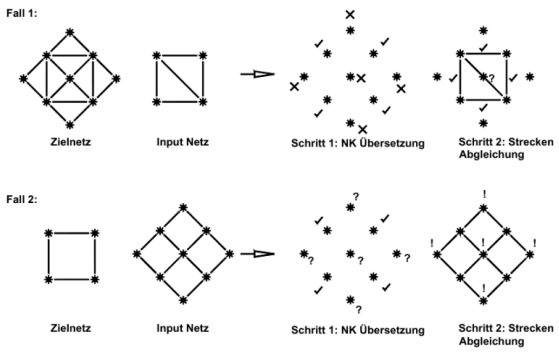


Abb. 1: Schematische Darstellung für das Modellierungsgrundprinzip

Aufbauend auf dem Modell können Routen sowie Netze zusätzlich definiert werden. In Abhängigkeit der Verkehrssituation kann die Netzstruktur vereinfacht dargestellt werden oder komplexe Fahrbeziehungen repräsentieren. Dabei wird besonders die Datenübertragung aus dem Netzknotensystem der SIB berücksichtigt. Zwischen Netzknoten und Teilknoten sowie Primärstrecken und Sekundärstrecken soll eine Referenzstelle hergestellt werden, sodass die Beziehung verdeutlicht und unterschiedliche Darstellungen ermöglicht werden können. Die Netzübertragung und Datenzuweisung kann über zwei Lösungsansätze erfolgen. Die erste Lösung umfasst die Datenzuweisung durch den Abgleich von klar definierten Routen aus zwei Systemen. Hierbei müssen Von- und Nach-Netzknoten sowie der gesamte Routenverlauf aus zwei Systemen klar definieren werden. Um beispielsweise die Ergebnisdaten der ZEB von NK1 nach NK6 aus der SIB auf das Zielmodell zu übertragen, wird zunächst die gleiche Route in zwei Systemen festgelegt, beispielsweise von NK1 über NK2 und NK5 nach NK6. Anschließend wird der Datenstrom aus dem Quellsystem exportiert, sortiert und auf das Zielmodell übertragen. Die Primärstrecken werden dabei entsprechend der Auflösung vom Quelldatenstrom in Sekundärstrecken segmentiert, welche den einzelnen

Datensatz pro Einheitstrecke mit einer räumlichen Auflösung von beispielsweise einem Meter auffangen. Ein Nachteil dieser Vorgehensweise ist, dass für die manuelle Definition ein Abgleich der Routen erforderlich ist.

Die zweite Lösung umfasst die Datenübertragung auf Basis automatischer Abgleichung der Koordinaten der Netzknoten aus zwei Systemen. Hierbei werden die Lokalknoten des Zielmodells wie Netzknoten behandelt, Teilknoten jedoch vernachlässigt. Sobald die Koordinaten der Netzknoten aus zwei Systemen innerhalb von bestimmten Abweichungstoleranzen übereinstimmen, werden sie als identische Netzknoten betrachtet, obwohl sich die Nummerierungen unterscheiden können. Dieser Schritt kann als NK-Übersetzung verstanden werden. Anschließend sollen im Zielnetz alle vorhandene Streckenobjekte basierend auf ausgefilterten NK aufgelistet werden und mit denen im Zielnetz verglichen werden. Wenn die Strecke in zwei Systemen besteht, wird diese Strecke als eine Route betrachtet und die Datenübertragung analog zur Vorgehensweise der ersten Lösung durchgeführt. Sofern eine Strecke der gleichen NK-Matrix im Inputnetz vorhanden, jedoch im Zielnetz nicht vorhanden ist, werden die Von- und Nach-NK von der Strecke verwendet, um die kürzeste Route im Zielnetz zu erzeugen. Sobald die Länge der erzeugten Route im Rahmen bestimmter Abweichungstoleranzen der Länge der Strecke im Inputnetz entspricht, werden die Route und die Strecke gleichgesetzt. Andernfalls kann diese Strecke entweder als neue Strecke ins Zielmodell aufgenommen oder abgelehnt werden. Falls der NK im Inputnetz nicht vorhanden ist, wird er für die Datenübertragung nicht berücksichtigt. Falls der NK im Inputnetz vorhanden, jedoch im Zielnetz nicht vorhanden ist, dann kann dieser entweder ins Zielnetz aufgenommen oder abgelehnt werden. Eine Aufnahme sorgt automatisch für die Vervollständigung des Netzes und Einbezug von Daten. Abb. 2 zeigt die schematische Darstellung des Übertragungskonzeptes.



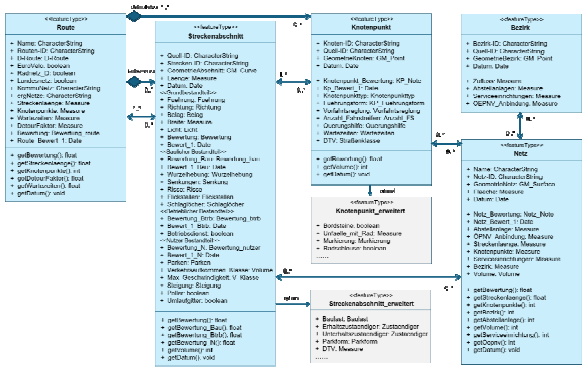


Abb. 2 (links): Schematische Darstellung für das Datenübertragungskonzept. Abb. 3 (rechts): UML für die Objektplanung des Modells.

Je nach Anforderung des Bewertungsmodells lassen sich Attribute zum jeweiligen Objekt ableiten und somit ein Objektkatalog verfassen. Dies stellt die Grundlage für die Implementierung des Datenmodells dar (Abb. 3).

Zur Unterstützung des Datenimport aus unterschiedlichen Quellen ist es zweckmäßig, ein Parameter-Wörterbuch zu erstellen, sodass die Barriere zwischen unterschiedlichen Semantiksystemen abgebaut werden können. Mit der Integration von Bewertungsalgorithmen des Bewertungsmodells lassen sich so auf netzweiter Analyse, Ergebnisse visualisieren.

5 DISKUSSION

Es wurde eine Methodik vorgestellt, um die Qualität auf Radverkehrsnetzen ganzheitlich zu bewerten und digital abzubilden. Um die Nutzung des Fahrrads als Verkehrsmittel besser zu ermöglichen, muss die Radverkehrsinfrastruktur nicht nur die baulichen und regulatorischen Anforderungen einhalten, sondern auch den Bedarfen und Bedürfnissen der Nutzenden entsprechen. Eine effektive Förderung des Radverkehrs setzt voraus, dass Qualitätsmängel nicht nur identifiziert, sondern auch behoben werden. Hierbei sind für bauliche Maßnahmen oder betriebliche Unterhaltungen die Baulastträger auf den verschiedenen Abschnitten verantwortlich. Das digitale Modell und die Bewertungsmethodik können zwar Defizite identifizieren, für die spätere Instandsetzungen, Umbauten, Ausbauten sowie Neubauten müssen jedoch konkrete Maßnahmen und Vereinbarungen erbracht werden. Um aussagekräftige Qualitätswerte zu erhalten, welche die Basis für eine langfristige, ganzheitliche Förderung des Radverkehrs sicherstellen, ist eine Vielzahl von Daten

notwendig. Diese müssen für die Bewertung auf dem gesamten Radverkehrsnetz vorliegen. Landesweite Radverkehrsnetze, wie beispielsweise das Radnetz Baden-Württemberg verfügen bereits über eine hohe Anzahl von Bestandsdaten. Kleinere Gebietskörperschaften verfügen jedoch häufig nur über geringere Datenbestände, was eine vollumfängliche Bewertung erschwert. Um dennoch Qualitätsbewertungen durchführen zu können, müssen zukünftig alternative Parameter und Minimalanforderungen zur Bewertung definiert werden. Die Ermittlung der Gewichtungen ist bisher nur qualitativ durchgeführt worden. Um genauere Ergebnisse liefern zu können, muss eine Sensitivitätsanalyse in realen Netzen durchgeführt werden. Hierbei können auch Parameter mit Einflüssen auf die Attraktivität berücksichtigt werden, um zukünftige Bewertungen für Radverkehrsnetze für den Tourismus und Freizeit durchführen zu können. Das beschriebene Modell ist auf Basis von der Modellierungsrichtlinie zu implementieren und mithilfe von Pilotprojekten auf Handhabung und Leistungsfähigkeit zu prüfen.

6 FAZIT

Das bisherige System ermöglicht die Abbildung und Bewertung von Radverkehrsnetzen zur Unterstützung der datengetriebenen Entscheidungsfindung zu Maßnahmen auf Radverkehrsnetzen. Die Erweiterung der Parameter ist durch die Berücksichtigung von beispielsweise Unfalldaten, Serviceeinrichtungen, wegweisender Beschilderung, Sichtfeldern oder Fahrtgeschwindigkeiten möglich, sofern der Gewichtungsprozess angepasst wird. Eine Ergänzung des Bewertungssystems kann durch die Implementation von Erreichbarkeiten erfolgen. Auch die Verteilung von Bevölkerungsdichten kann in einer Erreichbarkeitsanalyse berücksichtigt werden. So könnte beispielsweise eine Pufferzone um das bestehende Radverkehrsnetz gelegt werden und diese mit den Bevölkerungszahlen überlappt werden. Inwiefern sich die Qualität eines Radverkehrsnetzes auf das Verkehrsmittelwahlverhalten auswirkt, kann wichtige Erkenntnisse zur Förderung zukünftiger nachhaltiger Mobilität geben. Hierzu müsste untersucht werden, wie sich eine Veränderung der Qualität auf die Verkehrsmittelwahl auswirkt. Das bisherige System berücksichtigt ausschließlich Anlagen des Radverkehrs. Eine Erweiterung des Systems unter der Berücksichtigung des Fußverkehrs ermöglicht eine vollumfängliche Aussagekraft zu komplexen Verkehrssystemen.

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Erfolgsfaktoren und Herausforderungen der Öffentlichkeitsbeteiligung: Ein Modell zur Verbesserung der Partizipation in kommunalen Transformationsprojekten

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1 ABSTRACT

Das Forschungsprojekt PART-COM zielt darauf ab, Bürgerinnen und Bürger aktiv in kommunale Transformations- und Innovationsvorhaben einzubinden, wofür durch nationale und internationale Expertinnen- und Experteninterviews neun Konfliktfelder und zehn Erfolgsfaktoren identifiziert wurden. Die Konfliktfelder wurden in einer Abwärtsspirale visualisiert, wobei sechs Hauptkonflikte (mangelhafte Repräsentativität, fehlender politischer Wille, mangelhafte Kommunikation, fehlende Transparenz, Wissensmangel und hohe Hürden) zu tieferliegenden Problemen wie Entfremdung, Scheinpartizipation und Gleichgültigkeit führen können. Die Erfolgsfaktoren, die teilweise durch eine Bürgerinnen- und Bürgerumfrage validiert wurden, betonen die Bedeutung vielfältiger Kommunikationsformate, einer starken Feedbackkultur, niederschwelliger Beteiligungsangebote sowie der Integration digitaler und analoger Kanäle für eine erfolgreiche Öffentlichkeitsbeteiligung.

Keywords: Partizipation, Erfolgsfaktoren, Konfliktfelder, Öffentlichkeitsbeteiligung, Beteiligungsprozesse

2 EINLEITUNG: BÜRGERINNEN UND BÜRGER ALS AKTIVE GESTALTENDE

Partizipation wird durch das Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung als die aktive Mitgestaltung von Leben beeinflussenden Entscheidungen durch Bevölkerungsgruppen, Organisationen und Parteien definiert (BMZ 2023, o. S.).

Um diese Mitgestaltung zu sichern und damit Bürgerinnen und Bürger als aktive Gestalter in kommunale Transformations- und Innovationsvorhaben einzubinden spielt Öffentlichkeitsbeteiligung eine entscheidende Rolle. Im Infrastrukturbereich reicht diese von im BauGB gesetzlich festgeschriebener formeller Beteiligung (BauGB 2024) bis hin zu informellen Verfahren, die über gesetzliche Anforderungen hinausgehen (Quilling & Köckler 2018, S. 102). Die Intensität der ausgeführten Partizipation hat dabei Wright et al. (2010, S. 3) sehr anschaulich durch sein Stufenmodell dargestellt. Bei diesem Modell kann die Partizipation von der reinen Instrumentalisierung bis zur Selbstorganisation der Bürgerinnen und Bürger gehen.

Eine stärkere Partizipation führt in der Wirtschaft nachweislich zu höherer Produktakzeptanz, indem Konsumentinnen und Konsumenten in den Wertschöpfungsprozess eingebunden werden (Hofbauer 2013, S. 1; Merlo et al. 2014, S. 88). Diese Erkenntnisse lassen sich auch auf Infrastrukturprojekte übertragen: Die frühzeitige Einbindung der Bürgerinnen und Bürger ermöglicht es, deren Wissen und Erfahrungen zu nutzen und gleichzeitig die Akzeptanz gegenüber einem Vorhaben zu steigern (Quilling & Köckler 2018, S. 101).

Dass Partizipation aber nicht immer gelingt, zeigt sich besonders, wenn sich die Fronten zwischen Politik, Verwaltung und Bürgerinnen und Bürgern verhärten – wie zum Beispiel im Fall Stuttgart 21. Das Gefühl der Ausgrenzung führte dort zu massiven Protesten, die 2010 im „Schwarzen Donnerstag“ ihren Höhepunkt fanden (DLF 21). Stuttgart 21 wurde zu einem Wendepunkt, der ein Umdenken in der Öffentlichkeitsbeteiligung nach sich zog, mit der Folge, dass Verwaltungen und Politik Bürgerinnen und Bürger heute früher in Planungsprozesse einbinden wollen (DLF 21). Doch die Herausforderung bleibt, Beteiligung nicht nur anzubieten, sondern auch Bürgerinnen und Bürger zu erreichen und zu motivieren, an dieser teilzunehmen.

Welche Konfliktfelder dabei eine Rolle spielen und welche Impact- und Erfolgskriterien die Partizipation im Infrastrukturbereich von Städten und Gemeinden verbessern können, wurde durch die Befragung von Expertinnen und Experten aus verschiedenen Bereichen ermittelt.

3 FORSCHUNGSFRAGE UND METHODIK

Wie lassen sich Bürgerinnen und Bürger effektiver in Planungs- und Entscheidungsprozesse einbinden und welche Kriterien werden von Expertinnen und Experten dabei als wesentlich für den Erfolg und den Impact von Öffentlichkeitsbeteiligung angesehen?

Zur Bearbeitung dieser Fragestellung kommt eine zweistufige Methodik zum Einsatz. Im ersten Schritt werden Interviews mit Expertinnen und Experten aus den Bereichen Verwaltung, Planung, Wissenschaft, Wirtschaft und Nichtregierungsorganisationen (NGOs) durchgeführt (Brow et al 2023). Ziel dieser Gespräche ist es, ein fundiertes und umfassendes Verständnis der aus Expertinnen- und Expertensicht entscheidenden Kriterien für den Erfolg und die Wirkung von Beteiligungsverfahren zu gewinnen. Die Auswahl der Expertinnen und Experten erfolgt dabei anhand ihrer Fachkompetenz und Erfahrung in der praktischen Umsetzung oder wissenschaftlichen Untersuchung von Öffentlichkeitsbeteiligung.

Im zweiten Schritt werden die in den Expertinnen- und Experteninterviews ermittelten Kriterien durch eine Umfrage unter Bürgerinnen und Bürgern überprüft und validiert (Penka et al 2024). Ziel dieser Umfrage ist es, die Bedeutung der von den Expertinnen und Experten genannten Kriterien aus der Perspektive der Bevölkerung zu bewerten und gegebenenfalls weitere, aus Sicht der Bürgerinnen und Bürger relevante Kriterien zu identifizieren. Durch die Kombination von qualitativen Interviews und quantitativen Befragungen entsteht ein differenziertes Bild der Impact- und Erfolgskriterien. Dies ermöglicht die Ableitung fundierter Empfehlungen für die Praxis der Öffentlichkeitsbeteiligung. Die Methodik stellt sicher, dass die entwickelten Kriterien nicht nur theoretisch durch Expertinnen und Experten fundiert, sondern auch praxisnah und breit akzeptiert sind aus Bürgerinnen- und Bürgerperspektive.

3.1 Expertinnen- und Experteninterviews

3.1.1 Durchführung der Expertinnen- und Experteninterviews

Die Experteninterviews wurden mit 18 Fachpersonen und drei zusätzlichen Workshops mit Stadtverwaltungen durchgeführt (Brow et al. 2023). Die Auswahl der Expertinnen und Experten erfolgte gezielt auf Basis ihrer Fachkenntnisse und Erfahrungen in der praktischen Umsetzung oder wissenschaftlichen Analyse von Öffentlichkeitsbeteiligung. Dabei wurde ein flexibler Interviewleitfaden verwendet, der es ermöglichte, die Gespräche strukturiert zu führen, gleichzeitig aber auch individuell auf die spezifischen Perspektiven und Fachkenntnisse der Gesprächspartnerinnen und Gesprächspartner einzugehen. Diese auf Döringer 2020 und von Soest 2023 basierende Vorgehensweise ermöglichte das Erfassen von explizitem Wissen wie auch impliziten Perspektiven. Die Länge der Interviews variierte zwischen etwa 30 und 90 Minuten, abhängig von der terminlichen Verfügbarkeit sowie der Gesprächsfreude der Interviewten.

Um dabei ein möglichst breites Spektrum an Perspektiven abzudecken wurden Expertinnen und Experten aus unterschiedlichen Bereichen befragt:

- Wissenschaft: Fünf Interviews, darunter drei mit internationalen Expertinnenund Experten, lieferten Einblicke in aktuelle wissenschaftliche Diskurse und länderspezifische Unterschiede.
- Stadtverwaltungen: Zwei Interviews, eines davon international, beleuchteten praktische Herausforderungen und Erfolgsfaktoren aus Verwaltungssicht.
- Planungsbüros: Zwei Gespräche brachten praxisnahe Perspektiven zur Gestaltung von Beteiligungsverfahren ein.
- Agenturen und Mediationsbüros: Sechs Interviews fokussierten auf die Moderation und Vermittlung zwischen Stakeholdern.
- Nichtregierungsorganisationen (NGOs): Drei Gespräche boten Einblicke in die zivilgesellschaftliche Perspektive und deren Rolle als Sprachrohr für Bürgerinnen- und Bürgeranliegen.

Zusätzlich fanden drei halbtägige Workshops mit zwei Verwaltungen und einem Arbeitskreis statt, die durch ihre interaktive Natur eine kollektive Bearbeitung der Themen ermöglichten. Diese Kombination aus Interviews und Workshops erlaubt es, sowohl individuelle als auch gruppendynamische Erkenntnisse zu gewinnen.

3.1.2 Analyse der Expertinnen- und Experteninterviews

Die Analyse der Interviews wurde mithilfe des Tools Miro durchgeführt, das durch Mind Maps eine visuelle Strukturierung der Daten ermöglichte. Die zentralen Themenfelder für die Analyse wurden aus den Projektzielen sowie gängiger Literatur aus der Öffentlichkeitsbeteiligung abgeleitet. Diese sind: Folgen von Öffentlichkeitsbeteiligung, Nutzung von Sprache und Technischer Kommunikation, Input-Verwertung und Feedback, Digitale Beteiligungslösungen und -plattformen, Erreichen von Bürgerinnen und Bürgern, Beteiligungsscore, Unterschiede National und International sowie Häufigkeit und Zeitpunkt des Dialogs. Diese Kategorien dienten als Rahmen für die systematische Auswertung jedes Interviews. Dabei wurden relevante Aussagen extrahiert, thematisch gebündelt und quantitativ ausgewertet.

Die Ergebnisse wurden tabellarisch aufbereitet, wobei alle relevanten Aussagen kategorisiert wurden. Punkte, die mindestens zweimal genannt wurden, wurden in die weitere Analyse einbezogen. Insgesamt ergaben sich so über 60 Aspekte, die schließlich in neun Konfliktfelder sowie zehn thematisch gegliederte Impact- und Erfolgskriterien zusammengefasst wurden. Der Einsatz von Mind Maps erwies sich dabei als besonders hilfreich, um Beziehungen zwischen Themen visuell darzustellen und eine ganzheitliche Perspektive auf die umfangreichen Daten zu ermöglichen.

4 KONFLIKTFELDER DER ÖFFENTLICHKEITSBETEILIGUNG

Abbildung 1: Abwärtsspirale der Öffentlichkeitsbeteiligung (Sagnol et al 2024, Icons generiert mit OpenAI)

Basierend auf diesen Interviews konnten eine Reihe sich wechselseitig beeinflussende Konfliktfelder identifiziert werden, die, wenn unbeachtet, in einer gefährlichen Demokratieverdrossenheit gipfeln können. Diese Konfliktfelder wurden in einer Abwärtsspirale (Abbildung 1) zusammengefasst (Sagnol et al 2024).

Die oberste Ebene der Abwärtsspirale zeigt insgesamt sechs Konfliktfelder. Mangelhafte Repräsentativität der Bürgerinnen und Bürger, Fehlender Wille seitens Verwaltung/Politik, Mangelhafte Kommunikation, Fehlende Transparenz, Mangel an Wissen seitens Bürgerinnen und Bürger sowie Hohe Hürden. Je intensiver und je stärker diese sechs Konfliktfelder ausgeprägt sind, desto stärker sind auch die weiterführenden und tiefer sitzenden Konfliktfelder Gleichgültigkeit, Scheinpartizipation und Entfremdung. Diese tiefer sitzenden Konfliktfelder sind in der Auswirkung deutlich gravierender sowie in der Problembehandlung wesentlich schwieriger zu lösen und führen im schlimmsten Fall zu einem Systemversagen.

Im Folgenden werden die einzelnen Konfliktfelder erläutert sowie Lösungsansätze dafür beschrieben.

4.1 Mangelhafte Repräsentativität der Bürgerinnen und Bürger

Die Recherchen im Rahmen des Projektes haben ergeben, dass es in der aktuellen Öffentlichkeitsbeteiligung bei Infrastrukturprojekten, ohne entsprechend größeren Aufwands seitens der Verwaltung bzw. der Stadt oder Kommune, nicht möglich ist eine gemischte und repräsentative Gruppe an Menschen anzuhören.

Betrachtet man zuerst die Bevölkerungsgruppen, die an Öffentlichkeitsbeteiligungen im Rahmen der Infrastrukturplanung teilnehmen, trifft man auf zwei unterschiedliche, überrepräsentierte Gruppen:

(1) Es beteiligen sich hauptsächlich die „üblichen Verdächtigen“:

Der Tenor der Interviewten charakterisierten diese Teilnehmergruppe als männlich sowie meist im fortgeschrittenen Berufslebensalter oder darüber hinaus. Damit bestätigen die Interviews die Ergebnisse der Studie der Universität Hohenheim (Brettschneider, 2022).

(2) Es beteiligen sich hauptsächlich diejenigen, die dagegen sind:

„Wir gehen selten für etwas auf die Straße. Wir gehen eigentlich immer gegen etwas auf die Straße. [...] Dadurch entstehen in der Beteiligung immer Verzerrungseffekte“ – Matthias Burgbacher, PLAN:KOOPERATIV, 2023

Eine Beobachtung, die sowohl in Deutschland, als auch im internationalen Kontext gültig ist. Je unzureichender die Repräsentativität in Formaten der öffentlichen Beteiligung ist, desto größer die Gefahr, dass Entscheidungen auf der Basis individueller Interessen einer kleinen Gruppe getroffen werden, anstatt im Sinne des Gemeinwohls. Insbesondere die ältere Generation, deren direkte Betroffenheit an den Entwicklungen in 15 Jahren und darüber hinaus begrenzt ist, tragen maßgeblich an der Entscheidungsfindung bei. Gleichzeitig bleiben die Meinungen der jüngeren Generationen, die von solchen Zukunftsentscheidungen maßgeblich betroffen sind, oft gänzlich unausgesprochen. Es wäre aber verfehlt, die Ursache hierfür bei der älteren Generation zu suchen. Vielmehr sollte die Frage aufgeworfen werden: Warum bleiben viele Menschen stumm, und wie lässt sich dieser Umstand ändern? Besondere Aufmerksamkeit muss dabei auch den stillen Gruppen gewidmet werden, wie etwa Migrantinnen und Migranten, die sich von Sprachbarrieren betroffen fühlen, oder jenen, die der Überzeugung sind, dass ihre Teilnahme keinen Einfluss hat.

„Ich glaube Bürgerbeteiligung ist für viele Menschen einfach so ein total abstraktes Konzept“ – Jakob Krieger, Fridays for Future, 2023

Niedrigschwellige und dezentralisierte Formate	Beteiligungsprozesse an Orte anpassen, wo sich Menschen aufhalten (z. B. Märkte, öffentliche Plätze).
	Nutzung von Tools wie interaktiver Poster oder QR-Codes zur einfachen Beteiligung.
Barrieren gezielt abbauen	Sprachliche Hürden durch Sprach- und Gebärdendolmetscherinnen und Gebärdendolmetscher oder einfache Sprache überwinden.
	Zeitlich flexible Formate und spezifische Zugänge schaffen.
Aufklärung und Bildung fördern	Informieren, wie Bürgerinnen und Bürger Einfluss nehmen können.
	Frühzeitige Einbindung von Kindern und Jugendlichen in kurze aber auch langfristige Projekte, etwa durch interaktive Methoden.

Lösungsansätze für das Konfliktfeld „Mangelhafte Repräsentativität der Bürgerinnen und Bürger“

4.2 Fehlender Wille seitens Verwaltung/Politik

Ein Mangel an frühzeitiger Rückkopplung mit der Bevölkerung kann dazu führen, dass wertvolles lokales Wissen ungenutzt bleibt und geplante Lösungen an den Bedürfnissen der Bürgerinnen und Bürger vorbeigehen. Widerstand wird oft erst erkannt, wenn Entscheidungen bereits getroffen sind. Die Gründe, warum eine Stadt oder Kommune dennoch nur begrenzt in die Öffentlichkeitsbeteiligung investiert, sind vielfältig – sie können sich gegenseitig beeinflussen, aber auch unabhängig voneinander wirken.

Der erste Aspekt Machtabgabe basiert dabei auf den hierarchischen Strukturen, die in Deutschland weit vorherrschend sind. Merkmale einer solchen Struktur sind zum einen eine klare Rollenverteilung, zum anderen eine vertikale Kommunikation. Interpretiert wird dieses Verständnis gerne damit, dass gewählte Vertreter sich bereits durch das Gewählt-sein legitimiert sehen, zu entscheiden, ohne die Öffentlichkeit abermals zu fragen.

„Da gibt es [in Deutschland] unheimlich viel Angst und Bedenken, zu viel Macht abzugeben.“ – Jelena Gregorius, Go Vocal, 2023

Eine mangelnde Repräsentativität bei von der Verwaltung organisierten Öffentlichkeitsbeteiligungen führt auch unweigerlich zu dem Gefühl, dass Bürgerinnen und Bürger ein mangelndes Interesse an der Mitgestaltung ihrer Stadt oder Gemeinde an den Tag legen. Die Bruchsaler Verwaltung erklärte diesbezüglich, dass die geringen Rücklaufquoten von Beteiligungsangeboten dazu führten, dass eine effiziente Zusammenarbeit auf Augenhöhe nicht möglich ist (Stadt Bruchsal 2023).

(1) Mangelnde Ressourcenfreigabe für Öffentlichkeitsbeteiligung

Häufig wird der Prozess als weitaus unkomplizierter angesehen, als er in Wirklichkeit ist, was dazu führt, dass unzureichende Ressourcen bereitgestellt werden. Im Ergebnis fehlt es an den notwendigen Mitteln, um eine hochwertige Beteiligung zu ermöglichen.

„Und häufig ist alles was in die Richtung Marketing, Kommunikation, Öffentlichkeitsarbeit und Beteiligung geht so nach dem Motto: Das ist das Sahnehäubchen auf der Torte. Aber das ist es halt eben nicht. Eigentlich ist es Grundvoraussetzung für den Erfolg von Projekten und Maßnahmen, hier eine gute Arbeit zu machen“ – Kristina Oldenburg, KOKONSULT, 2023

(2) Fehlendes Bewusstsein über die Vorteile von Öffentlichkeitsbeteiligung

Die positiven Aspekte einer frühzeitigen und umfassenden Einbindung der Öffentlichkeit, wie die Verringerung von Konflikten, die Einsparung von Zeit und die Gewinnung wertvoller Erkenntnisse, werden nicht ausreichend erkannt.

Ziele und Grenzen definieren	Klare Kommunikation der Entscheidungsmöglichkeiten der Bürgerinnen und Bürger.
	Transparenz, um Vertrauen aufzubauen und Enttäuschungen zu vermeiden.
Ressourcen bereitstellen	Schulung von Verwaltung und Politik, um den Nutzen von Beteiligung zu verstehen.
	Sicherstellen, dass personelle und finanzielle Ressourcen für kontinuierliche Beteiligung vorhanden sind.
Hierarchie als Chance nutzen	Zentrale Vorgaben können standardisierte, effiziente und qualitativ hochwertige Beteiligungsprozesse sicherstellen.

Lösungsansätze für das Konfliktfeld „Fehlender Wille seitens Verwaltung/Politik“

4.3 Mangelhafte Kommunikation

Bevor eine Beteiligung beginnen kann, muss die Stadt oder Kommune zunächst ihre Bürgerinnen und Bürger umfassend informieren und erreichen. Dies stellt ein größeres Problem dar, als es auf den ersten Blick erscheinen mag. Viele Städte und Kommunen kämpfen mit veralteten Technologien und Prozessen, die den Anforderungen einer zunehmend digitalen Gesellschaft nicht gerecht werden. Neben der Auswahl geeigneter Medienkanäle ist es daher ebenso entscheidend, dass der Inhalt und die Zielsetzung der Kommunikation klar und zielgerichtet formuliert werden.

Je länger Menschengruppen nicht erreicht werden oder worden sind, desto höher wird der Aufwand, diese wieder in die Beteiligung einzubringen. Kommunen und Städte befinden sich insofern in einer Holschuld, die sich auch unter dem Aspekt der aufsuchenden Beteiligung zusammenfassen lässt. Hier geht es also darum, dezentral auf die Bürgerinnen und Bürger zuzugehen um ihnen die Möglichkeiten der Beteiligung vorzustellen.

„Ich finde die Zielgruppen nicht schwierig. Nur ich muss erst entscheiden, dass ich ganz gezielt den Aufwand betreiben möchte, diese Menschen zu erreichen.“ – Kristina Oldenburg, KOKONSULT, 2023

Multi-Channel und hybride Kommunikation	Kombination aus Online- und Offlineangeboten, in diverser Art, um unterschiedliche Zielgruppen anzusprechen.
	Nutzung von sozialen Medien, Plakaten, interaktiven Plattformen und spielerischen Ansätzen (z. B. Wettbewerbe oder Gamification).
Aufsuchende Beteiligung	Bürgerinnen und Bürger proaktiv aufsuchen, z.B. bei Stadtfesten, in Kitas oder auf Marktplätzen.
	Dezentrale Formate und die Nutzung neutraler Orte wie Hochschulen oder Bibliotheken fördern eine niederschwellige Teilnahme.
Emotionale und kreative Ansprache	Triggernde negative Aufrufe (z. B. provokative Plakate) regen Diskussionen an.
	Positive oder humorvolle Aufrufe (z. B. witzige Projekt-Namen, z.B. buxtewho.de) schaffen einen freundlichen Zugang.
Transparenz und Bildung	Klar kommunizieren, warum die Beteiligung wichtig ist, welche Einflussnahme es gibt und welche Auswirkungen sie hat.
	Bürgerinnen und Bürger durch verständliche Inhalte und humorvolle oder spielerische Formate aktivieren.

Lösungsansätze für das Konfliktfeld „Mangelhafte Kommunikation“

4.4 Fehlende Transparenz

Ein Mangel an Transparenz in Bezug auf Abläufe, Ergebnisse und Ziele von Beteiligungsprozessen kann schnell zu Missverständnissen und Frustration zwischen Verwaltung, Politik und Bürgerinnen und Bürger

führen. Die effiziente Meinungsbildung wird durch unzureichende Informationsvermittlung stark behindert oder sogar gänzlich verhindert. Besonders kritisch wird es, wenn fehlende Transparenz das Vertrauen der Bürgerinnen und Bürger in die städtische Verwaltung erschüttert. Dies geschieht, wenn der Eindruck entsteht, dass Informationen absichtlich zurückgehalten oder verschleiert werden.

Letztlich ist es ein Abwägungsprozess: Hat die Verwaltung mehr zu verlieren, wenn Informationen zurückgehalten werden oder dadurch, dass das Vertrauen der Bürgerinnen und Bürger verspielt wird? Die Antwort dürfte in aller Regel sein: Verprelle die Bürgerinnen und Bürger nicht.

„Vertrauen in den Prozess heißt, dass es ein glaubwürdiger, transparenter, ehrlicher Prozess ist, finde ich. Ein Beteiligungsprozess.“ – Jochen Plückelmann, CP/COMPARTNER, 2023

Regelmäßige und transparente Kommunikation	Kontinuierliche Updates zu Projekten, auch bei fehlenden Neuigkeiten, um Vertrauen zu wahren.
	Klar kommunizieren, warum bestimmte Maßnahmen Zeit brauchen oder Ideen nicht umgesetzt werden können.
Feedback und Verständlichkeit sicherstellen	Rückmeldungen zu Beiträgen von Bürgerinnen und Bürgern verständlich kommunizieren.
	Fachsprache vermeiden und komplexe Abläufe in einfacher Sprache, bzw. ziel- gruppenorientiert Sprache erklären.
Koordination und Struktur stärken	Einrichtung zentraler Koordinations- stellen für große Projekte, um Abstimmungen zwischen Ämtern zu verbessern.
	Moderationspersonen innerhalb der Verwaltung einsetzen und mit Entscheidungs- und Weisungsbefugnis ausstatten.
Erweiterung der Kommunikationskanäle	Nutzung etablierter zusammen mit neuen Kanälen wie Newsletter, digitale Plattformen oder Plakate.
	Reichweite und Sichtbarkeit von Informationen erhöhen, wie in „Mangelhafte Kommunikation“ empfohlen.

Lösungsansätze für das Konfliktfeld „Fehlende Transparenz“

4.5 Mangel an Wissen seitens Bürgerinnen und Bürgern

Zur Erläuterung dieses Konfliktfeldes muss zwischen drei grundsätzlichen Punkten unterschieden werden:

(1) Allgemeines ingenieurtechnisches Wissen

Bürgerinnen und Bürgersind zum Großteil weder ausgebildete Planerinnen und Planer, Ingenieurinnen und Ingenieure oder ähnliches. Einen technischen Text zu verstehen oder einen Plan zu erfassen mag den jeweiligen Mitarbeitenden aus der Verwaltung einfach fallen, weil sie jeden Tag damit konfrontiert sind. Für Bürgerinnen und Bürger kann das aber durchaus eine zu komplexe Aufgabe bedeuten.

(2) Spezifisches Wissen zu Projekten

Werden Informationen zu Projekten nicht oder unzureichend weitergeleitet, können sich Bürgerinnen und Bürger kein Bild von dem Thema machen. Das Zurückhalten von Informationen ist dementsprechend nicht nur als ein Problem für das Verhältnis zwischen Bürgerinnen und Bürger und Stadt bzw. Kommunen zu sehen. Können sich Bürgerinnen und Bürger nicht informieren, wird zum einen das Interesse, an einer Veranstaltung teilzunehmen, sinken.

Nutzung einfacher Sprache und Visualisierungen	Vermeidung von Fachsprache und „Beamtendeutsch“ zugunsten verständlicher und zielgruppengerechter Sprache.
	Visuelle Hilfsmittel wie realistische Visualisierungen, Vorher-Nachher-Vergleiche oder Virtual Reality erhöhen das Verständnis und wecken damit Betroffenheit.
Sprachbarrieren abbauen	Bereitstellung von Informationen in mehreren Sprachen, dazu zählt auch einfache Sprache oder Gebärdensprache.
	Einsatz von unterstützenden Tools, wie z. B. interaktiven Erklärungen oder Videos.
Bildung und Unterstützung anbieten	Aufbau von Wissenskapazitäten durch die Aufklärung über Beteiligungsprozesse und -rechte der Bürgerinnen und Bürger.
	Durchführung von sogenannten Ideenwerkstätten, in denen Bürgerinnen und Bürger bei der Formulierung ihrer Vorschläge aktiv unterstützt werden.
Realistische Erwartungshaltung schaffen	Projekte und deren Konsequenzen objektiv aber nachvollziehbar darstellen, um Missverständnisse und unrealistische Erwartungen zu vermeiden.
	Klare Abgrenzung und Kommunikation darüber, welche Aspekte Bürgerinnen und Bürger mitentscheiden können und welche in der Verantwortung der Fachleute liegen.

Lösungsansätze für das Konfliktfeld „Mangel an Wissen seitens Bürgerinnen und Bürgern“

(3) Wissen zu den Möglichkeiten der Partizipation und der Teilhabe

Schon die alleinige Tatsache, dass es bei Infrastrukturprojekten mindestens ein Recht auf Anhörung geben muss, ist keine allgemeingesellschaftlich bekannte Tatsache. Damit fehlt die Kenntnis innerhalb der Bevölkerung über das Recht sich einzubringen und aktiv Einfluss zu nehmen. Doch auch wenn das Recht bekannt ist, wird durch intransparente Kommunikation nicht immer klar, wo und wie das geschehen kann.

Solange aber Kommunikationsdefizite nicht behoben und Bürgerinnen und Bürger nicht umfassend über ihre Rechte und Mitwirkungsmöglichkeiten informiert werden, bleibt ihre Teilhabe stark eingeschränkt.

„Wenn man eine gute Öffentlichkeitsbeteiligung will, muss man auch ein bisschen politische Bildung betreiben, immer wieder Kapazitäten aufbauen und den Menschen das geben, was sie brauchen, um sich effektiv zu beteiligen." – Winnie Mitullah, University of Nairobi, 2023 (übersetzt aus dem Englischen)

4.6 Hohe Hürden

Unter den hier aufgeführten Hürden im Bereich der Partizipation sind Barrieren gemeint, die Menschen daran hindern, sich aktiv an Entscheidungs- oder Planungsprozessen zu beteiligen. Dabei handelt es sich nicht nur um physische oder sprachliche Barrieren und Hürden, sondern um alle Arten von Hürden, die einen Menschen im Allgemeinen aufgrund seiner Lebensweise oder seiner Alltagszwänge daran hindern könnten, an Partizpationsveranstaltungen teilzunehmen.

(1) Mangel an Information und Bildung

Aufbauend auf den vorherigen Abschnitten lässt sich der Mangel an (verständlicher) Information in der Öffentlichkeitsbeteiligung als Hürde betrachten.

„Information ist der erste Schritt hin zu einer co-kreativen Prozessgestaltung. Und wenn ich gut informiere, dann kann ich auch motivieren und aktivieren." Kristina Oldenburg, KOKONSULT, 2023

(2) Mangel an Zeit

„[...] dass wir ja die Beteiligungen in der Regel zu Zeiten durchführen sollten, die man auch den Beschäftigten der Stadt noch irgendwie zumuten kann, aber gleichzeitig auch, wo man das Potenzial sieht, dass die Bewohner, dass die Betroffenen eben auch können. Das sind dann meistens so spätnachmittag bis früher Abend. In der Theorie ist das so die Schnittmenge. In der Praxis ist es so, dass die Leute – die Beteiligten – vor Ort sind, die halt Zeit haben. Das sind nicht die jungen Berufstätigen, erst recht nicht die Familienväter und -mütter, sondern das sind die Rentner." – Jan Riel, Hochschule Karlsruhe, 2022

(3) Ungeeigneter Veranstaltungsort

Stellt der Ort der Veranstaltung für die Interessierten einen erhöhten Reiseaufwand dar, wird sich das negativ auf die Teilnehmerquoten auswirken. Das Stichwort Dezentralisation sollte auch hier nochmal zum Tragen kommen. Ebenfalls bedacht werden muss die multimodale Erreichbarkeit des Ortes.

(4) Mangel an digitaler Affinität

Als vierten Punkt ist die Hürde der Digitalität zu nennen. Nicht jede Person hat das passende Endgerät, das nötige Wissen oder auch die passende technische Ausstattung um an einer digitalen Beteiligungsveranstaltung teilzunehmen.

Überwindet man sowohl die Verständnishürde, wie auch die zeitlichen und örtlichen Beschränkungen, eröffnen sich also für deutlich mehr Bürgerinnen und Bürger die Möglichkeit, sich in der Beteiligung einzubringen.

Niedrigschwellige und verständliche Kommunikation	Bereitstellung klarer, einfacher Informationen über geeignete Kanäle.
	Kombination von Texten, Visualisierungen und digitalen Hilfsmitteln, um Verständnis zu fördern.
Zeitliche Flexibilität bieten	Veranstaltungen zu verschiedenen Tageszeiten und an unterschiedlichen Tagen wiederholen.
	Asynchrone Beteiligungsmöglichkeiten bereitstellen, wie Kommentierung, Online-Umfrage oder abrufbare Inhalte.
Dezentrale und barrierefreie Veranstaltungsorte	Veranstaltungen an leicht erreichbaren und barrierefreien Orten mit multimodaler Zugänglichkeit organisieren.
Digitale und hybride Formate fördern	Kombination aus analogen und digitalen Angeboten für unterschiedliche Zielgruppen.
	Nutzung von interaktiven Tools wie Poster, Umfragen oder VR-Simulationen zur niederschwelligen Teilnahme.
	Sicherstellen, dass digitale Formate benutzerfreundlich sind.
Partizipation durch Gamification	Spielerische Ansätze, wie einfache Planungs-Tools oder Wettbewerbe, motivieren zur Beteiligung.

Lösungsansätze für das Konfliktfeld „Hohe Hürden"

4.7 Scheinpartizipation, Gleichgültigkeit und Entfremdung

„Meiner Meinung nach ist schlechte Beteiligung schlimmer als gar keine Beteiligung, weil die Leute dann beim nächsten Mal einfach nicht mehr kommen." – Jelena Gregorius, Go Vocal, 2023

Werden Bürgerinnen und Bürger zwar formal beteiligt, aber nicht ernst genommen wird das schnell dazu führen, dass jene, die sich noch die Mühe machen, Stellungnahmen zu Projekten abzugeben, enttäuscht und frustriert werden. Besonders kritisch wird es, wenn die Stadt mehr als nur formale Beteiligung anbietet, die daraus gewonnenen Erkenntnisse jedoch dann einfach ignoriert.

„Das schreckt die Leute wirklich ab, denn sie denken: ‚Was hat es für einen Sinn, sich zu beteiligen und mitzumachen, wenn man mir nicht zuhört?'" – Winnie Mitullah, University of Nairobi, 2023 (übersetzt aus dem Englischen)

Gleichgültigkeit entsteht dort, wo nicht nur das Engagement der Bürgerinnen und Bürger, sondern auch ihr Interesse an den Geschehnissen ihrer lokalen Umgebung schwindet. Eine Stadtverwaltung wird das insbesondere daran spüren, dass sie den Eindruck bekommt, dass die Menschen kein Interesse mehr daran haben, ihre Lebenswelt aktiv mitzugestalten. Es geht dann längst nicht mehr nur um ein Erreichbarkeitsproblem – die Menschen sehen schlicht keinen Sinn mehr darin, über Projekte zu diskutieren.

Eine effiziente Zusammenarbeit, geschweige denn eine Partnerschaft auf Augenhöhe, wird hier unmöglich. Die Rücklaufquoten bei Beteiligungsangeboten sinken drastisch, und die Bürgerinnen und Bürger distanzieren sich zunehmend von der Arbeit und den Ideen der Stadtverwaltung.

Die Entfremdung beschreibt dann die Situation, in der sich Bürgerinnen und Bürger emotional von ihrer Stadt oder Kommune distanziert haben. Es ist ein Ergebnis mehrerer bereits stark ausgeprägter Konfliktfelder der Abwärtsspirale. Bürgerinnen und Bürger haben an dieser Stelle zunehmend das Gefühl, dass ihre Bedürfnisse in der Mitgestaltung des Lebensumfeldes keine Rolle mehr spielen.

„[...] wir arbeiten daran, dass ein Platz im Viertel San Lorenzo als Fußgängerzone umgestaltet werden soll. [...] Also werden wir dort etwas vorschlagen, und es ist nicht die Schwierigkeit das Vorschlagen dieser Sache selbst, aber es geht um die Bürger, die sich über etwas anderes beschweren. [...] So wie ‚Schau, wir können über alles reden, auch das was du möchtest, aber zuerst musst du diese vier, fünf wichtigen Probleme lösen, und dann werden wir darüber reden.' – Fabrizio Benvenuti, Roma Servizi per la Mobilità, 2023 (übersetzt aus dem Italienischen)

Informationsverbreitung und Sichtbarkeit erhöhen	Präsenz auf Social Media ausbauen, um Bürgerinnen und Bürger gezielt und zeitgemäß zu erreichen.
	Verbindung von Beteiligungsformaten mit Stadtfesten oder anderen lokalen Events in entspannter und neutraler At- mosphäre.
	Unterstützung durch Agenturen oder Forschungseinrichtungen einholen, um Expertise und Struktur aufzubauen.
	Emotionale und affektive Beteiligung durch kreative, spielerische (Gamification) oder visuelle Ansätze.
	Direkte Programme zur Einbindung isolierter oder unterrepräsentierter Gruppen entwickeln.
Echtes Mitspracherecht schaffen und Transparente Feedbackkultur etablieren	Beteiligung zu einem möglichst frühen Zeitpunkt, wenn Ziele und Rahmenbedingungen noch mitgestaltet werden können.
	Offene Kommunikation über die Verwertung von Vorschlägen und die Gründe für deren Annahme oder Ablehnung.
	Regelmäßige Berichte in einfacher Sprache auf mehreren Kanälen.
	Moderierte, professionelle Formate für respektvollen Austausch und Konsens- bildung auf Augenhöhe.
Lokale und kleine Projekte zur Wiederannäherung	Schaffung neuer Identifikationspunkte durch bspw. Nachbarschaftsgärten, kulturelle Veranstaltungen, lokale Märkte oder kleine Quartiersprojekte.
	Gestaltung von Grünflächen, Spielplätzen oder anderen öffentlichen Räumen mit Bürgerinnen- und Bürgerbeteiligung.
Echtes Mitspracherecht schaffen und Transparente Feedbackkultur etablieren	Identifikation von Problemen und Erstellung eines Maßnahmenkatalogs mit Priorisierung.
	Kombination kurz-, mittel- und lang- fristiger Maßnahmen, deren Wirksamkeit aufeinander abgestimmt ist.
	Kinder und Jugendliche gezielt ansprechen, um eine neue Generation aktiver Bürgerinnen und Bürger zu fördern.
	Systematisierte Beteiligungsprozesse einführen, die klare und vorhersehbare Abläufe für Beteiligungsprozesse darstellen, die sowohl für Verwaltung und Bürgerinnen und Bürger nachvollziehbar sind.

Lösungsansätze die Konfliktfelder „Scheinpartizipation, Gleichgültigkeit, Entfremdung"

Um eine Wiederannäherung zu ermöglichen muss umfassend gedacht werden. Einzelne technische Anpassungen reichen nicht mehr aus, Lösungsansätze sind deshalb in erster Linie aus den Lösungsansätzen der vorigen sechs unterschiedlichen Konfliktfeldern herauszusuchen.

Insgesamt ist eine Abkehr von rein hierarchischen Strukturen erforderlich, hin zu einer Konsens- und Diskussionskultur, in der alle Beteiligten gleichberechtigt miteinander agieren und eine echte Mitgestaltung

zu ermöglicht. Dafür gilt es, den Bürgerinnen und Bürgern mehr Möglichkeiten der Einbindung an die Hand zu geben, als das gesetzlich vorgeschriebene Minimum. Statt eines reinen Anhörungsrechts braucht es ein echtes Diskussionsrecht, das ihnen die Möglichkeit gibt, aktiv Einfluss zu nehmen.

„Mit diesen ‚Bausteinen-Maßnahmen' in einer neuen Leitlinie geht es ja darum, Sachen in die Routine zu bringen und auch nach einem bestimmten Schema durchlaufen zu lassen, die jetzt quasi immer individuell gelöst werden. Deswegen Systematisierung. Und das reduziert natürlich ganz stark auch Abläufe oder den Aufwand, den man in sie investieren muss" – Jan Lange, Büro für Mitwirkung und Engagement, Stadt Karlsruhe, 2022

5 IMPACT- UND ERFOLGSKRITERIEN

Aus den Experteninterviews wurden nicht nur zentrale Konfliktfelder sichtbar, sondern auch entscheidende Kriterien für eine nachhaltige und wirkungsvolle Öffentlichkeitsbeteiligung herausgearbeitet. Diese Kriterien spiegeln die wesentlichen Faktoren wider, die nach Einschätzung der Expertinnen und Experten maßgeblich zum Erfolg und Impact von Beteiligungsprozessen beitragen (Brow et al 2024).

(1) Aufsuchende Formate
Die zielgruppenorientierte und proaktive Ansprache ist ein elementares Kriterium für erfolgreiche Öffentlichkeitsbeteiligung und wirkt sich positiv auf die Teilnahmebereitschaft aus, während ausschließlich zielgruppenunspezifische oder allgemeine Ansprachen die Öffentlichkeitsbeteiligung hemmen.
(2) Feedback und Kommunikationskultur
Klare Kommunikation über die Möglichkeiten und Grenzen der Beteiligung werden als relevanter Teil erachtet, um Scheinpartizipation zu vermeiden. Mangelhafte Kommunikation über den aktuellen Projektfortschritt stellt ein großes Problem dar. Kontinuierliches Feedback wird als elementares Kriterium angesehen.
(3) Visualisierung
Pläne und technische Informationen sind für Laien häufig unverständlich und zu kompliziert. Gute und verständliche Visualisierungen erhöhen die Bereitschaft und den Grad der Teilnahmemöglichkeit.
(4) Niederschwellige Informations- und Beteiligungsangebote
Niederschwellige Informations- und Beteiligungsangebote sind notwendig um Aufmerksamkeit zu erregen und eine erste Form der Beteiligung zu generieren. Dabei impliziert Niederschwelligkeit, dass ein Angebot unmittelbar bei der Person ankommt und dieses schnell aufgefasst werden kann, wodurch eine sofortige Informationsaufnahme und/oder Beteiligung ermöglicht wird.
(5) Zeitpunkt der Beteiligung
Eine frühzeitige und umfassende Beteiligung aller relevanten Akteure ist essenziell, da eine verspätete Einbindung oft schwerwiegende negative Auswirkungen in verschiedenen Bereichen (z. B. Verzögerungen in Projekten, erhöhte Kosten, mangelnde Akzeptanz von Entscheidungen und ineffiziente Prozesse) nach sich zieht.
(6) Multi-Channel
Gute Öffentlichkeitsbeteiligung ist asynchron und vereint digitale und analoge Beteiligungsformate. Dabei ist eine gut aufgesetzte Plattform ebenso wichtig wie eine enge Social-Media-Begleitung und Vernetzung allgemein.
(7) Digitale Beteiligungslösungen und -plattformen
Digitale Beteiligungsplattformen sind ein elementarer Bestandteil des Multi-Channel-Ansatzes und eignen sich besonders gut dazu, die Kommunikations- und Feedbackkultur im Rahmen von Beteiligungsprozessen zu verbessern. Digitale Beteiligungsplattformen werden analoge Beteiligung nicht verdrängen, sondern ergänzen.
(8) Diskussionskultur
Die vorliegenden Erkenntnisse verdeutlichen, dass Deutschland von einer stark hierarchischen Struktur geprägt ist, die von einer Kultur des Dissenses anstelle des Konsenses geprägt ist. Dies äußert sich insbesondere in Frontalveranstaltungen als Ausdruck dieser Kultur. Als Lösungsansatz wird die Schaffung von Räumen betont, in denen Ideenaustausch auf Augenhöhe und in respektvollem Rahmen ermöglicht wird.
(9) Beteiligung der Jugend
In deutschen Schulen mangelt es an Informations- und Beteiligungsformaten zur demokratisch partizipativen Bildung junger Menschen. Darüber hinaus, haben junge Menschen aufgrund des mangelnden Wahlrechts keine Möglichkeiten, ihre Meinungen über Bürgerbegehren oder Petitionen einzubringen. Dies sind, unter anderem, Gründe dafür, dass sich die Jugend nicht ernst genommen fühlt.
(10) Übergreifende Dialoge
Das Fehlen von Transformationsdialogen führt dazu, dass gesellschaftliche Muster und Entwicklungen nicht erkannt werden. Dies wiederum resultiert darin, dass es keine bis wenige Möglichkeiten gibt, die Zukunft der Gemeinde oder Stadt gemeinsam strategisch weiterzuentwickeln.

Tabelle 1: Die zehn relevanten identifizierten Impact- und Erfolgskriterien gelungener Öffentlichkeitsbeteiligung auf Basis der Interviews ohne Reihenfolge.

5.1 Bürgerinnen- und Bürgerumfrage

5.1.1 Durchführung der Bürgerinnen- und Bürgerumfrage

Bei der Gestaltung der Umfrage wurde das Ziel verfolgt, eine möglichst hohe Teilnahmebereitschaft zu erreichen. Daher wurde die Befragung bewusst kompakt und fokussiert gestaltet. Die soziodemografische Abfrage wurde dafür auf ein Minimum beschränkt und lediglich nach Geschlecht und Altersgruppe gefragt. Auf weitere demografische Fragen, wie etwa zum Haushaltseinkommen, wurde verzichtet, obwohl diese für die Auswertung potenziell relevant gewesen wären. Dieses Befragungsdesignsollte die Teilnahmehürden senken und sicherstellen, dass sich die Befragten auf die inhaltlichen Fragen zur Öffentlichkeitsbeteiligung konzentrieren können.

Allerdings führte diese Herangehensweise dazu, dass nicht alle Kriterien der Öffentlichkeitsbeteiligung gleichermaßen detailliert überprüft werden konnten. Die Umfrage deckt jedoch alle Erfolgskriterien zumindest indirekt ab (siehe Tabelle 2). Zu den Kriterien Aufsuchende Formate, Feedback- und Kommunikationskultur, Niederschwellige Informations- und Beteiligungsangebote, Multi-Channel sowie Digitale Beteiligungslösungen und -plattformen konnten fundierte Aussagen getroffen werden.

Andere Kriterien, wie beispielsweise Visualisierung, erfordern eine tiefere Herangehensweise, die über den Rahmen einer Online-Befragung hinausgeht. Um die Verständlichkeit und Wirksamkeit von Visualisierungen zu bewerten, wären praktische Beispiele und detaillierte Feedbackprozesse notwendig gewesen. Ähnlich verhält es sich mit den Kriterien Beteiligung der Jugend, Diskussionskultur oder Übergreifende Dialoge. Diese Bereiche hängen stark von spezifischen Zielgruppen oder kulturellen Kontexten ab und lassen sich durch allgemeine Umfragen nur schwer erfassen. Für eine umfassendere Analyse dieser Aspekte wären qualitative Methoden wie Fokusgruppen oder vertiefende Interviews besser geeignet. Ein weiteres Beispiel ist der Zeitpunkt der Beteiligung. Dieser wurde zwar teilweise durch Fragen zur Informationsfrequenz und Projektkommunikation adressiert, hätte jedoch eine spezifischere Fragestellung erfordert, um detaillierter untersucht zu werden.

Die für diese Umfrage konzipierten Fragestellungen wurden mit vorgegebenen Antwortmöglichkeiten versehen. Diese basierten auf den Interviews bzw. den definierten Impact- und Erfolgskriterien (Penka et al 2024):

(a) In welcher Altersgruppe bist du?

(b) Welches Geschlecht hast du?

(1) Deine Stadt oder Kommune möchte deine Meinung einholen. Wie möchtest du darauf aufmerksam gemacht werden?

(2) Deine Stadt hat dich erreicht. Welche Möglichkeit würde dich jetzt ansprechen, um deine Meinung zu einem Projekt abzugeben?

(3) Feedback zu meinen Beiträgen oder Meinungsäußerungen im Rahmen einer Beteiligung zu bekommen ist mir wichtig.

(4) Ich wünsche mir eine gemeinsame Reflektionsveranstaltung mit Verwaltung und Projektträgern zum Abschluss eines Projekts.

(5) Das Projekt geht voran. Wie soll dich die Stadt weiter informiert halten?

(6) Und wie oft möchtest du über Projektfortschritte informiert werden?

(7) Öffentlichkeitsbeteiligung stärkt das Demokratieverständnis.

(8) Öffentlichkeitsbeteiligung ermöglicht die Entwicklung gemeinsamer Leitbilder.

(9) Ich habe das Gefühl, dass Öffentlichkeitsbeteiligung zu weniger Konflikten im spätereren Projektverlauf führt.

(10) Ich habe das Gefühl, Öffentlichkeitsbeteiligung bereichert die Qualität der Planung.

(11) Ich fühle mich aktuell durch Formate der Öffentlichkeitsbeteiligung erreicht.

(12) Ich finde, meine Meinung wird momentan durch Öffentlichkeitsbeteiligung vertreten.

(c) Möchtest du uns noch etwas anderes mitteilen?

Der Schwerpunkt lag darauf, die wichtigsten und die am besten messbaren Kriterien innerhalb der gegebenen Rahmenbedingungen zu validieren. Eine tiefergehende Untersuchung anderer Kriterien könnte im Rahmen ergänzender Studien oder spezifischer Erhebungsmethoden erfolgen. Tabelle 2 zeigt auf, welche der Fragestellungen welche Erfolgskriterien direkt (D) oder indirekt (ID) validieren.

Die Zielgruppe wurde nicht eingegrenzt, da grundsätzlich alle Bürgerinnen und Bürger angesprochen waren. Allerdings könnten bestimmte Zielgruppen durch das gewählte Umfragedesign schwerer erreichbar sein. Die Umfrage war online verfügbar und konnte in den Sprachen Deutsch, Deutsch – Leichte Sprache sowie Englisch ausgefüllt werden. Zur Verbreitung wurden verschiedene Online-Kanäle wie LinkedIn, WhatsApp und Instagram genutzt. Zusätzlich wurden 2.500 Flyer mit einem Hinweis auf die Online-Umfrage in Briefkästen unterschiedlicher Stadtteile im Stadtkreis Karlsruhe verteilt.

		Kriterium									
		1	2	3	4	5	6	7	8	9	10
Fragestellung	1	D			D		D				
	2	D			D			D			
	3		D								
	4		D								
	5		D				D	D			
	6		ID			ID					
	7								ID		ID
	8										ID
	9		ID			ID					
	10		ID			ID					
	11	ID			ID						
	12		ID								

Tabelle 2: Validierungsmatrix zwischen Fragestellung und zu validierendem Erfolgskriterium.

5.1.2 Ergebnis der Bürgerinnen- und Bürgerumfrage

Im Befragungszeitraum vom 14.08.2024 bis 26.09.2024 wurden insgesamt 213 vollständig abgeschlossene Fragebögen erfasst. Obwohl diese Zahl im Vergleich zur Gesamtbevölkerung Deutschlands gering erscheint, liefern die Ergebnisse dennoch wertvolle Einblicke. Die errechnete Fehlermarge beträgt etwa ±7,2 %, was auf eine gewisse Unsicherheit hindeutet. Aufgrund der begrenzten Stichprobe können die Resultate möglicherweise nicht vollständig repräsentativ für alle Bevölkerungsgruppen sein, sodass Verzerrungen in Bezug auf Altersstruktur, regionale Verteilung und soziale Schichten auftreten können. Für präzisere und umfassendere Analysen sollten zukünftige Untersuchungen mit größeren Stichproben durchgeführt werden.

5.1.3 Validierung der Kriterien

Das methodische Vorgehen zur Validierung der Impact- und Erfolgskriterien erfolgte durch die Kombination und den Abgleich von Expertinnen- und Expertenmeinungen und den Ergebnissen der Bürgerumfrage. Die Validierung beschränkt sich auf die Kriterien die mit den Ergebnissen der Umfrage fundiert durchgeführt werden können.

Die Ergebnisse der Bürgerinnen- und Bürgerumfrage sowie die Validierung der Expertinnen- und Expertenmeinungen verdeutlichen, dass eine erfolgreiche Öffentlichkeitsbeteiligung auf mehreren zentralen Säulen basiert: zielgerichtete und vielfältige Kommunikationsformate, eine ausgeprägte Feedbackkultur, niedrigschwellige und leicht zugängliche Beteiligungsangebote sowie die Verknüpfung digitaler und analoger Kanäle. Gleichzeitig wird deutlich, dass weitere wichtige Aspekte wie die Visualisierung von Informationen, die Einbindung junger Menschen, übergreifende Dialoge und die Qualität der Diskussionskultur stärker in zukünftige Beteiligungsprozesse integriert werden müssen, um eine umfassende und nachhaltige Öffentlichkeitsbeteiligung zu gewährleisten. Für diese Kriterien steht eine Validierung durch die Bürgerinnen und Bürger noch aus. Die gewonnenen Erkenntnisse sollten in künftige Planungen und Umsetzungen von Beteiligungsprozessen einfließen, um die Akzeptanz und Wirksamkeit von Projekten zu steigern und eine breite sowie engagierte Teilhabe der Bevölkerung zu fördern.

6 FAZIT UND AUSBLICK

Die Analyse der Erfolgsfaktoren und Herausforderungen der Öffentlichkeitsbeteiligung in kommunalen Transformationsprojekten zeigt deutlich, dass eine effektive Bürgerinnen- und Bürgerbeteiligung mehrdimensional zu betrachten ist. Trotz bestehender Defizite, wie etwa mangelnder Repräsentativität, fehlender Transparenz oder unzureichender Kommunikation rückt das Thema in der Praxis immer weiter in den Fokus. Ein zentrales Problem bleibt jedoch die geringe Beteiligung und Rückmeldequote, mit der viele Kommunen konfrontiert sind. Daher ist es entscheidend, neben der Schaffung zielorientierter Beteiligungsformate auch konsequent und strategisch daran zu arbeiten, die Bürgerinnen und Bürger zur Teilnahme zu motivieren. Besonders hervorzuheben ist in diesem Zusammenhang die Bedeutung aufsuchender Formate und die partizipative Bildung der jungen Generation. Eine frühzeitige Verankerung des Themas in der Gesellschaft ist für die Etablierung einer stärkeren Mitgestaltungskultur von entscheidender Bedeutung. Eine gemeinsame und multiperspektivische Erschließung des Themas ist von wesentlicher Bedeutung für dessen Erfolg. In diesem Zusammenhang kann Bildungs- und Forschungseinrichtungen eine Schlüsselrolle zukommen, indem sie zur Sichtbarkeit und Weiterentwicklung von Beteiligungsprozessen beitragen. Die Hochschule Karlsruhe geht diesbezüglich mit gutem Beispiel voran, indem sie das Thema Partizipation und Öffentlichkeitsbeteiligung durch Forschungsprojekte wie

PART-COM, die Entwicklung eines Öffentlichkeitsbeteiligungsscores und gemeinsamer Beteiligungsformate mit Studierenden und der Stadt Karlsruhe sowie Vorlesungsinhalten in den Hochschulalltag integriert.

Insgesamt zeigt sich, dass eine nachhaltige und wirkungsvolle Beteiligung der Öffentlichkeit eine strategische, ressourcengestützte und inklusionsorientierte Herangehensweise erfordert. Die gewonnenen Erkenntnisse liefern wertvolle Impulse für Kommunen und politische Akteure, um partizipative Prozesse langfristig zu verbessern und das demokratische Engagement der Bevölkerung zu fördern.

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Erfordernis eines Flächenkompensationsmodells zur Erreichung des Flächensparziels "Netto-Null-Flächenverbrauch"

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1 ABSTRACT

Fläche ist eine Ressource, welche aufgrund ihrer Trägerfunktion für Funktionen des Naturhaushalts, der Erholung, der Klimaregulation, etc. schützenswert ist. Aufbauend auf der grundlegenden Bedeutung von Flächenveränderungen und deren Wirkungen auf den Naturhaushalt wird die Fläche als Ressource und Gegenstand vieler Nachhaltigkeitsstrategien beleuchtet. Dabei steht die anhaltend hohe, nicht nachhaltige Flächeninanspruchnahme für Siedlungs- und Verkehrsflächen im Vordergrund, welche mithilfe verschiedener Umweltziele begrenzt, bzw. in der Bilanz gestoppt werden soll. Bis zum Jahr 2030 ist in Deutschland das 30-X-Hektar-Ziel zu nennen und in Österreich wird ein Zielwert von netto 2,5 Hektar pro Tag anvisiert. Auf europäischer Ebene ist bis zum Jahr 2050 ein Netto-Null Flächenverbrauchsziel gesetzt, welches eine Flächenkreislaufwirtschaft bedeutet.

Da bisher einige Unsicherheiten die Umsetzung der Flächensparziele behindern, werden die nicht rechtlich bindenden Umweltziele näher betrachtet, um mögliche Ursachen für die schleppende Umsetzung auszumachen. Desweiteren werden inhaltliche Lücken aufgezeigt und Forderungen formuliert, welche eine bessere Handhabung der Umweltziele bewirken sollen. Es existieren bereits einige vielversprechende Modelle zur Reduzierung der Flächeninanspruchnahme, wovon zwei Beispiele kurz vorgestellt und deren Erfolgsaussichten zur Erreichung der Flächensparziele ausgelotet werden. Dabei wird deutlich, dass die genannten Umweltziele bis 2030 – bei entsprechender Implementierung – durchaus erreicht werden könnten. Das Netto-Null Flächenverbrauchsziel benötigt für seine Zielerreichung bis 2050 jedoch weitergehende Instrumente, um wirksam etabliert werden zu können.

Für eine stabile Flächenkreislaufwirtschaft bedarf es eines Flächenkompensationsmodells, welches Flächen vergleichbar, und dadurch substituierbar macht. Dabei wird Flächen eine individuelle, numerische Wertigkeit (Flächenwertigkeit) zugewiesen, welche sich aus Indikatoren und Parametern berechnet. Zudem wird die Struktur und Funktionsweise des Flächenkompensationsmodells dargestellt, welche an die naturschutzfachliche Eingriffsregelung im deutschen Recht angelehnt sind. Dieser Beitrag zeigt mit der Vorstellung des Flächenkompensationsmodells einen möglichen Weg zu einem Netto-Null-Flächenverbrauch auf, und weist im Fazit auf weitere erforderliche politische, rechtliche und planungspraktische Rahmenbedingungen für eine Flächenkreislaufwirtschaft hin.

Keywords: Flächenkreislaufwirtschaft, Netto-Null-Flächenverbrauch, Flächensparziele, Flächenverbrauch, Flächenkompensationsmodell

2 ÖKOLOGISCH-NACHHALTIGE FLÄCHENNUTZUNGSDYNAMIK

Flächenveränderungen sind grundsätzlich natürliche Vorgänge, denn es bedeutet in erster Linie, dass Flächen neugestaltet werden. Dabei ist ein Eingreifen des Menschen nicht zwingend erfolrderlich. Flüsse ändern bei starken Hochwässern ihren Lauf, Hangrutsche schaffen Ruderalstandorte, Biber (Castor fiber L. 1758) gestalten durch Aufstauen von Gewässern und der Fällung von Gehölzen Auen neu, etc. Diese natürlichen Prozesse gestalten Flächen neu, schaffen ökologische Nischen und bieten Lebensraum für spezialisierte Artengemeinschaften, indem sie die Strukturvielfalt in der Landschaft erhöhen. Auch seitdem der Mensch sesshaft wurde und Flächen gezielter für seine Bedürfnisse umnutzte, schuf er Orte mit verschiedenen Sukzessionsstufen und ökologischen Nischen, welche ohne menschlichen Einfluss gar nicht oder nur selten in Erscheinung treten. Strukturreiche Kulturlandschaften mit Elementen wie Hecken, Feldrainen und Wiesen sind dabei nur eines von vielen Beispielen.

Problematisch ist jedoch die steigende Effizienz und Dominanz der menschengemachten Flächenumnutzungen, welche vom Begriff des Flächenverbrauchs widergespiegelt werden. Flächen werden effizienter genutzt, das bedeutet eine Fläche wird für eine Nutzung optimiert und der Verlust anderer

Funktionen wird dabei in Kauf genommen. Die steigende Monofunktionalität der Flächen ist ökonomisch teilweise sinnvoll, da Flächen maximalen Ertrag bringen. Jedoch ist es die Multifunktionalität, welche Flächen aus ökologischer Sicht wertvoll macht. Als Beispiel können hier intensiv landwirtschaftliche genutzte Flächen wie Äcker angeführt werden. Solche Flächen werden auf die anzubauende Pflanzensorte optimiert und weitere Funktionen wie Lebensraum für wilde Tiere, Pilze und Pflanzen gehen weitgehend verloren. Versiegelte Flächen für Siedlungen und allgemeine Infrastrukturen stellen das Maximum an Monofunktionalität dar. Solche Flächen haben eine dominante Nutzung und weitere Funktionen im Sinne des Naturhaushalts fallen meist so gering aus, dass diese vernachlässigt werden können. Dem Naturhaushalt sind solche versiegelten Flächen faktisch vollständig entzogen worden, da ökologische Funktionen, wenn überhaupt, nur stark begrenzt ihre Wirkung entfalten können.

Insgesamt ist zu sagen, dass aus ökologischer Sichtweise Flächenumnutzungen nicht grundsätzlich einen negativen Einfluss auf unsere Umwelt haben. Die Art und die Intensität der Umnutzungen sind entscheidend. Wenn Flächen so gestaltet werden, dass sie multifunktional und/oder strukturell vielfältig sind, können Umnutzungen von Flächen sogar einen positiven ökologischen Effekt haben. Werden Flächen jedoch zu monofunktional gestaltet, wirkt sich dies negativ auf die Umwelt aus. Diese negativen Effekte auf die Umwelt und den Naturhaushalt gilt es kurzfristig zu minimieren, mittelfristig eine weitere Zunahme zu vermeiden, und langfristig wieder abzubauen. Dafür bedarf es einer Form von Kompensation, welche speziell auf die Fläche ausgerichtet ist. Mit dem Fokus auf der ökologischen Dimension der Nachhaltigkeit wird die Fläche aus der Perspektive ihrer drei Zieldimensionen (Quantität, Qualität und nachhaltige Entwicklung) jeweils separat beleuchtet und zielgerichtet der Handlungsbedarf herausgestellt.

3 SCHUTZ DER RESSOURCE FLÄCHE ALS NACHHALTIGKEITSZIEL

Der Begriff Flächenverbrauch steht für die Inanspruchnahme von Flächen für Siedlungs- und Verkehrszwecke (SuV). Dieser Indikator wird im Rahmen der Deutschen Nachhaltigkeitsstrategie (vgl. u.a. Die Bundesregierung 2021) erhoben und betrachtet dabei den täglichen Anstieg der bebauten Siedlungsfläche (Nutzungsarten: Wohnbaufläche, Industrie- und Gewerbefläche, öffentliche Einrichtungen, sowie Erholungsflächen und Friedhöfe) und die Verkehrsfläche (Nutzungsarten: Straßen- und Wegeverkehr, Bahn-, Flug- und Schiffsverkehr) in Hektar pro Tag [ha/d] (Destatis 2023). Die Flächenerhebung und deren Abgrenzung wird nach ALKIS (Amtliches Liegenschaftskataster) vorgenommen. Flächenumnutzungen, welche als Flächenverbrauch gewertet werden, sind allerdings nicht mit kompletten Versiegelungen von Flächen gleichzusetzen, da diese zwar gänzlich umgenutzt, aber meist nur teilweise versiegelt werden.

Flächenverbrauch als Begriff ist jedoch nicht korrekt, da Flächen nicht verbraucht, sondern nur umgenutzt werden können (vgl. z. B. LfU 2015, S. 84). Flächeninanspruchnahme, bzw. Flächenneuinanspruchnahme sind bessere Alternativen für den Begriff Flächenverbrauch. Da der Begriff Flächeninanspuchnahme besser etabliert ist als “Flächenneuinanspruchnahme” wird folgend dieser Begriff verwendet. Ebenfalls als fachlich eher unpassend wird der Begriff des Flächensparens gewertet. Obwohl damit der sparsame Umgang mit der Ressource Fläche gemeint ist, können Flächen nicht, im Gegensatz zu z.B. Geld, angespart werden. Treffender wäre die Verwendung des Begriffs Flächeninanspruchnahmen-Reduktion, da dieser unmissverständlich den Sachverhalt wiedergibt. Dennoch kann der Begriff des Flächensparens als Synonym weiterhin verwendet werden, da dieser relativ prägnant und bereits etabliert ist.

Fläche fungiert im ökologisch-nachhaltigen Sinn als Träger der Funktionen des Naturhauhalts. Oft erfüllt eine Fläche mehrere Funktionen und wird dadurch zunehmend schützenswerter. Der Schutz der Flächen dient also keinem Selbstzweck, sondern u.a. dem Schutz des Freiraums sowohl im Innen-, als auch im Außenbereich.

Für den Indikator Siedlungs- und Verkehrsfläche (siehe Deutsche Nachhaltigkeitsstrategie) wird eine Begrenzung der Flächeninanspruchnahme für SuV-Flächen bis zum Jahr 2030 auf unter 30 Hektar pro Tag angestrebt. Das deutsche Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB) präzisiert den Zielwert 20-X Hektar pro Tag auf maximal 20 Hektar pro Tag (BMUB 2016, S. 82). Nach der aktuellen Statistik liegt der Anstieg der Siedlungs- und Verkehrsfläche in Deutschland bei 52 Hektar pro Tag (Stand 2022) und deutet somit auf eine Zielverfehlung hin (vgl. Figure 1). Eine erneute Zielverfehlung ist dringend zu vermeiden, da das vorherige Ziel, bis zum Jahr 2020 weniger als 30 Hektar pro Tag in Anspruch zu nehmen, bereits deutlich verfehlt wurde. Der Bedarf an einer baldigen und wirksamen Umsetzung des Flächensparens ist klar erkennbar.

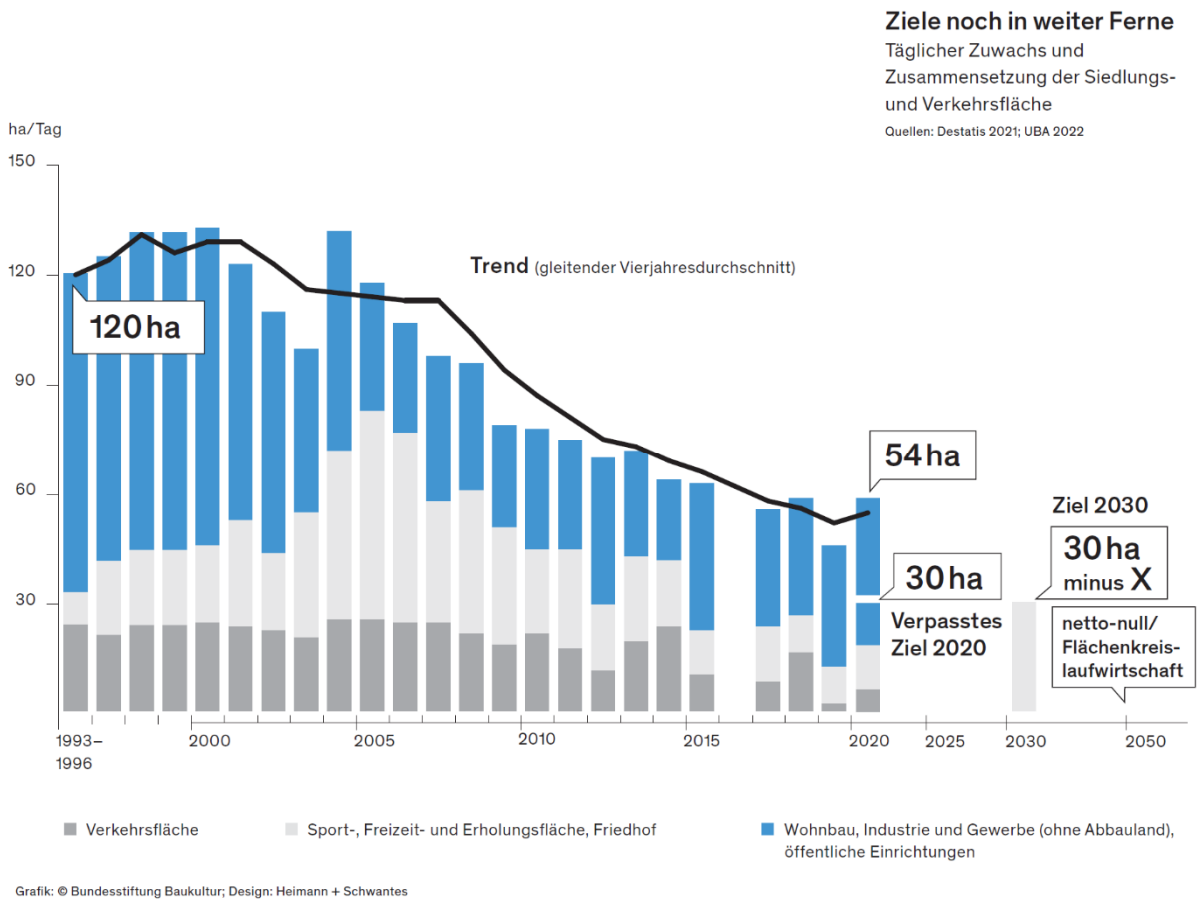

Fig. 1: Entwicklung der Flächeninanspruchnahme in Deutschland der letzten Jahrzehnte mit Abbildung der deutschen Flächensparziele (Bundesstiftung Baukultur, S. 39)

3.1 2,5-Hektar-Ziel in Österreich

In seinem Umweltkontrollbericht des Österreichischen Umweltbundesamtes (2022, S. 117 ff.) wird trotz der leicht sinkenden Flächenneuinanspruchnahme eine Verfehlung des im Regierungsprogramm festgehaltenen Ziels von 2,5 Hektar pro Tag bis 2030 erwartet. So lag der Wert der Flächeninanspruchnahmen im Jahr 2020 bei 11,5 ha/d, wobei im Umweltkontrollbericht vor allem die zuletzt gestiegenen Baulandumwidmungen und der Ausbau erneuerbarer Energien als wichtige Treiber erachtet werden. Obwohl die negativen Auswirkungen der anhaltend hohen Flächeninanspruchnahme, wie zunehmend gefährdete Versorgungssicherheit, der Biodiversität oder dem Klimaschutz, in Österreich bekannt sind, wird voraussichtlich nicht nur das nationale 2,5 Hektar-Ziel, sondern auch übergeordnete Flächensparziele europäischer Programme verfehlt. Zu nennen sind hier vor allem der Green Deal (Europäische Kommission 2019) und die EU-Bodenstrategie (Europäische Kommission 2021).

3.2 30-X-Hektar-Ziel in Deutschland

Die Absicht bis zum Jahr 2030 weniger als 30 Hektar, möglichst maximal 20 Hektar (BMUB 2016, S. 82) pro Tag für SuV-Flächen in Anspruch zu nehmen, stellt ein Umweltziel mit dem Namen 30-X-Hektar-Ziel dar. Dabei wird die Flächeninanspruchnahme für SuV-Flächen im Außenbereich auf rein quantitativer Ebene betrachtet und bewertet und ist in der Nachhaltigkeitsstrategie der deutschen Bundesregierung verankert (vgl. Die Bundesregierung 2021 und 2024). Obwohl dieses Umweltziel keine rechtliche Bindungswirkung hat, wird dem 30-X ha-Ziel eine hohe Bedeutung zugesprochen, da es neben nationalen auch internationale politische Interessen widerspiegelt. Die Nachhaltigkeitsstrategie orientiert sich an der Agenda 2030 der Vereinten Nationen (UN 2015), welche 17 SDGs (Sustainable Development Goals, deutsch: Ziele für nachhaltige Entwicklung) formuliert, und ist im Grundsatzbeschluss der Bundesregierung zur Deutschen Nachhaltigkeitsstrategie festgehalten (vgl. Die Bundesregierung 2022).

Bis zum Jahr 2030 sollen alle 17 Ziele erreicht werden. Dafür erscheint als Monitoring-Maßnahme im zweijährlichen Rhythmus der Indikatorenbericht, um die Fortschritte der einzelnen SDGs zu messen (vgl.

Destatis 2023). Im 11. Ziel „Nachhaltige Städte und Gemeinden“ wird der Bereich Flächeninanspruchnahme anhand der Indikatoren Anstieg der SuV-Fläche, Freiraumverlust und Siedlungsdichte betrachtet.

Das 30-X-Hektar-Ziel thematisiert die Flächeninanspruchnahme dabei rein auf der quantitativen Ebene, da es nur den täglichen Anstieg der Flächen berücksichtigt, welche dem SuV-Bereich zuzuordnen sind und im Außenbereich liegen. Grundlage für die Einschränkung auf SuV-Flächen im Außenbereich ist der Bezug auf den Indikator Anstieg der Siedlungs- und Verkehrsfläche. Im Rahmen dieses Indikators werden SuV-Flächen folgendermaßen definiert: „Siedlungs- und Verkehrsfläche ist nicht gleichzusetzen mit versiegelter Fläche. Zur Siedlungsfläche zählen die Nutzungsarten Wohnbaufläche, Industrie- und Gewerbefläche, öffentliche Einrichtungen sowie Erholungsfläche und Friedhöfe“ (Destatis 2023, S. 90). Dadurch wird der Innenbereich, inklusive noch vorhandener Freiflächen und dem Außenbereich im Innenbereich komplett zu den SuV-Flächen gezählt. Fände eine Nachverdichtung im Innenbereich statt, würde diese nicht als Flächeninanspruchnahme für SuV-Flächen zählen, da bereits vorhandene SuV-Fläche lediglich umgenutzt würde. Deswegen kann der Indikator nur Flächeninanspruchnahmen im Außenbereich betrachten.

Eine weitere Einschränkung bei der Betrachtung von Flächeninanspruchnahmen aus Sicht des 30-X-Hektar-Ziels ist die Ausnahmeregelung für Nutzungen des Rohstoffabbaus und der Energieerzeugung. Diese werden nicht für den Indikator Anstieg der SuV-Fläche gerechnet. Dies wird ebenfalls im Indikatorenbericht deutlich, in welchem es heißt: „Fläche ist eine begrenzte Ressource. Um ihre Nutzung konkurrieren beispielsweise Land- und Forstwirtschaft, Siedlung und Verkehr, Naturschutz, Rohstoffabbau und Energieerzeugung“ (Destatis 2023, S. 90).

Zusammengefasst ist das 30-X-Hektar-Ziel ein Umweltziel, welches nur einen Teil der tatsächlichen Flächeninanspruchnahmen betrachtet und damit kein realitätsgetreues Bild zeichnet. Flächeninanspruchnahmen werden zudem rein quantitativ und ausschließlich im Außenbereich erfasst. Um die tatsächliche Flächeninanspruchnahme besser widerspiegeln zu können, werden hier einige Erfordernisse formuliert, um das 30-X-Hektar-Ziel inhaltlich aufzuwerten:

(1) Der Fokus des Umweltziels sollte nicht ausschließlich auf dem Außenbereich liegen, sondern auch die Flächen des Innenbereichs miteinbeziehen. Die aktuelle Annahme, alle Flächen des Innenbereichs seien bereits durch SuV-Flächen in Anspruch genommen, ist zu grob und lässt wertvolle freie, unbebaute Flächen im Innenbereich außer Acht. Findet eine Nachverdichtung im Innenbereich statt, schont dies zweifelsohne den Außenbereich, nimmt aber trotzdem hochwertige, unbebaute Flächen in Anspruch. Diese Form der Flächeninanspruchnahme sollte mitberücksichtigt werden. Eine Unterscheidung des Innen- und Außenbereichs ist und bleibt sinnvoll und sollte nicht aufgehoben werden. Im Rahmen einer Variantenanalyse kann es in Bezug auf die Ressource Fläche wichtig sein, wo eine Fläche räumlich verortet ist.

(2) Statt Siedlungs- und Verkehrsflächen sollte der Indikator besser Siedlungs- und Infrastruktur-Flächen (SuI) betrachten und entsprechend umbenannt werden. Damit würden alle Flächeninanspruchnahmen, welche vom Menschen verursacht werden, untersucht und angemessen beleuchtet. Aus Sicht des aktuellen Indikators Anstieg der Siedlungs- und Verkehrsfläche würden dann auch die Nutzungen, welche in die Kategorie Rohstoffabbau (vgl. UBA 2024b) und Energieerzeugung fallen, mitdazugerechnet werden. Während Flächen für Energieerzeugung eindeutig zur Infrastruktur gezählt werden, ist das bei Flächen für Rohstoffabbau weniger offensichtlich. Sie gelten dennoch aus Sicht der Raumordnung als eine Freiraumnutzung und nehmen erheblich Flächen in Anspruch (vgl. UBA 2024b). Unbebaute Flächen der Land- und Forstwirtschaft sowie des Naturschutzes sollten weiterhin nicht zur Flächeninanspruchnahme von SuV-, bzw. SuI-Flächen zählen. Zu klären wäre auch der Umgang mit Wasserflächen, da auch solche Flächen erheblich von ihrem natürlichen Zustand und funktionalem Beitrag für den Naturhaushalt durch menschliches Eingreifen abweichen können.

(3) Neben der quantitativen Zieldimension, welche beim Indikator Siedlungs- und Verkehrsfläche ausschließlich betrachtet wird, sollte auch die Qualität der Flächen mitbetrachtet werden. Bei der Flächeninanspruchnahme wird bereits der Indikator Freiraumverlust miteinbezogen, welcher als ein erster Ansatz für die Betrachtung der Flächenqualität betrachtet werden kann. Inhaltlich geht es dabei um das Verhältnis von Freiraumflächen und der Einwohnerzahl. Unter Freiraumflächen werden Vegetationsflächen, Abbauflächen und Wasserflächen bezeichnet (vgl. Destatis 2023, S. 93). Freiflächen im Innenbereich werden trotz ihrer hochwertigen Qualitäten nicht in diesem Indikator betrachtet. Für die Qualität von Flächen sollte

unter anderem die (Multi-)Funktionalität der Flächen für den Naturhaushalt betrachtet und ein Bezug zur räumlichen Verortung hergestellt werden.

(4) Das letzte Erordernis für das 30-X-Hektar-Ziel besteht in dem Bedarf nach einem Flächenkompensationsmodell. Mit fortschreitender Zeit, der Verschärfung des Ziels von weniger als 30 Hektar auf besser maximal 20 Hektar pro Tag und dem ebenfalls zunehmenden Anteil der Siedlungs- und Verkehrsfläche, bzw. der Siedlungs- und Infrastrukturfläche an der Gesamtfläche, wird die Einhaltung der Flächenschutzziele zunehmend dringlicher. Mit der Einführung eines solchen Kompensationsmodells würde jeder Fläche eine substituierbare Wertigkeit zugewiesen, welche planerische Spielräume offenhält und eine Flexibilität bei der Einhaltung der Flächenschutzziele bewirkt.

3.3 Netto-Null Flächenverbrauchs-Ziel

Das Netto-Null-Flächenverbrauchs-Ziel beschreibt, wie der Name bildlich erklärt, eine Netto-Reduzierung des Flächenverbrauchs bis zum Jahr 2050. Dabei ist jedoch kein absoluter Stopp aller Flächeninanspruchnahmen für SuV-Zwecke gemeint, sondern vielmehr eine ausgeglichene Bilanz der Flächeninanspruchnahmen. Bedeutet, wenn eine bisher unbebaute Fläche in eine SuV-Fläche umgenutzt wird, muss eine andere Fläche aufgewertet werden, um den Flächenverbrauch zu kompensieren. Eine konkrete Definition, bzw. ein inhaltlich-scharfes und allgemein akzeptiertes Verständnis, was unter diesem Flächenschutzziel zu verstehen ist, fehlt bisher jedoch. Ebenso wie das 30-X-Hektar-Ziel ist dieses Ziel ein Umweltziel ohne rechtliche Bindung, aber mit Erwähnung in den Nachhaltigkeitsstrategien der deutschen Bundesregierung (vgl. 2021 und 2024), in welchen eine Flächenkreislaufwirtschaft angestrebt wird. Seinen Ursprung hat dieses Ziel auf europäischer Ebene, welches ein Teil einer Strategie ist, die Europäische Union nachhaltiger zu gestalten (vgl. z. B. Europäische Kommission 2011 und EEA 2021).

In ihrem Positionspapier 149 nähert sich die Akademie für Raumentwicklung in der Leibniz-Gemeinschaft (ARL) dem Thema Netto-Null Flächenverbrauch und lotet die Bedeutung einer Flächenkreislaufwirtschaft aus(vgl. ARL 2024). Die eben angesprochene nötige Kompensation wird durch folgendes Zitat gestützt: „Eine Flächenkreislaufwirtschaft mit netto-null Flächenverbrauch ist nur zu erreichen, wenn bei der Neuausweisung von Siedlungs- und Verkehrsflächen an einer Stelle an anderer Stelle im selben Umfang Siedlungs- und Verkehrsflächen an Natur und Landschaft zurückgegeben werden“ (ARL 2024, S. 10). Weiter wird gefordert, dass eine solche Rückgabe von Flächen an Natur und Landschaft mit einer Aufwertung der freiwerdenden Flächen einhergehen muss (ARL 2024, S. 10). Zu dieser Folgerung gelangen auch Eichhorn et al. (2024, S. 90) und weisen darauf hin, dass eine Renaturalisierung (bzw. Flächenaufwertung) ein Novum sowohl im akademischen Diskurs als auch in der planerischen Praxis darstellt.

Auch für das Netto-Null-Flächenverbrauchsziel werden einige Erfordernisse dargestellt, mit der Intention das Umweltziel zu schärfen und praktikabel zu gestalten:

(1) Wie bereits beim 30-X-Hektar-Ziel gefordert, soll bei einer Flächeninanspruchnahme für SuV-, bzw. SuI-Flächen sowohl die Flächen des Außenbereichs als auch die Flächen des Innenbereichs gleichermaßen betrachtet werden. Eine Aufhebung der Unterscheidung der beiden Bereiche allgemein wird auch hier als unnötig erachtet. Der Miteinbezug des Innenbereichs hat neben der realitätsnäheren Betrachtung auch den großen Vorteil, dass viele Flächen mit hohem Aufwertungspotenzial im Innenbereich liegen. Ein Beispiel sind hierfür Industriebrachen oder sonstige stillgelegte und damit untergenutzte Flächen im Innenbereich. Würde weiterhin nur der Außenbereich auch bei Einhaltung des Netto-Null-Ziels betrachtet, erschöpfen die Flächen zur Aufwertung rapide, welche dringend für weitere Flächenumnutzungsdynamiken erforderlich sind. Auch würden Aufwertungen, welche im Innenbereich stattfinden, folglich nicht positiv in der Flächenbilanz erscheinen und die Spielräume bei der Planung einschränken. Die planerische Flexibilität, welche der Miteinbezug des Innenbereichs bietet, wird maßgeblich zur erfolgreichen Implementierung des Umweltziels beitragen.

(2) Obwohl das 30-X-Hektar-Ziel und das Netto-Null-Flächenverbrauchsziel im weiten Sinn denselben Zweck haben, nämlich effektiven Flächenschutz zu gewährleisten, darf das Netto-Null-Ziel nicht als eine bloße Verschärfung des 30-X-Hektar-Ziels betrachtet werden. Während das 30- Hektar-Ziel lediglich einen reduzierten Anstieg der SuV-Flächen fordert, verlangt das Netto-Null-Ziel einen Netto-Stopp der Flächeninanspruchnahmen für SuV, bzw. SuI, welcher in der Flächenbilanz sichtbar werden soll. Zudem betrachtet das 30-X-Hektar-Ziel aktuell nur die quantitative Zieldimension der Flächeninanspruchnahme für

SuV-Flächen. Spätestens bei Etablierung einer Flächenkreislaufwirtschaft wird es zwingend notwendig, auch die Qualitäten der Flächen miteinzubeziehen, da Flächen gleicher Ausdehnung unterschiedliche Qualitäten aufweisen können.

(3) Fläche ist eine Ressource: nicht vermehrbar, in ihrer Ausdehnung begrenzt und steht unter hohem Nutzungsdruck, vor allem in Bezug auf Nutzungsansprüche (vgl. Hüppauf 2023, S. 389). Dieser Ressourcencharakter der Fläche sollte stärker hervorgehoben werden. Die aktuelle Planungspraxis und Rechtslage erweckten den Anschein, dass weiterhin SuV-Flächen unbegrenzt ansteigen könnten. Die negativen Folgen für Natur und Mensch sind zwar bereits bekannt, werden jedoch aktuell nicht relevant in den Entscheidungsprozess miteinbezogen. Ohne den Einbezug der belegten Folgen ist die Einführung einer vollumfänglichen Flächenkreislaufwirtschaft nicht nur schwer umsetzbar, es ist auch schwierig solch einem System Akzeptanz zu verschaffen. Das Netto-Null-Ziel und die damit zusammenhängende Flächenkreislaufwirtschaft sind spätestens zum Jahr 2050 anzustreben, um einen nötigen ökologisch-nachhaltigen Umgang mit der Ressource Fläche zu etablieren. Des Weiteren wäre die Einführung eines Verschlechterungsverbots und eines Verbesserungsgebots anzustreben, welches bereits aus der deutschen Wasserrahmenrichtlinie (WRRL) bekannt ist (vgl. z.B. §27 WHG), da diese Regelungen den Ressourcencharakter der Fläche stärker hervorheben.

4 BISHERIGE MODELLE ZUR REDUZIERUNG DER FLÄCHENINANSPRUCHNAHME

Es gibt bereits einige Ansätze, wie die Flächeninanspruchnahme für SuV-Flächen gesenkt werden können. Vielversprechend sind dabei planerische Ansätze, wie die Regionalplanung, über eine gesteuerte Innenentwicklung und der Abbau von Fehlanreizen. Es existiert bereits eine Vielzahl an vielversprechenden Ansätzen, welche aktuell aber noch keine, bzw. eine unzureichende Anwendung finden und somit auch nicht wirksam sein können (vgl. u.a. Blecken et al. 2024 und Adrian et al. 2018). An dieser Stelle sollen zwei ausgewählte Modelle vorgestellt werden, welche bereits intensiv wissenschaftlich untersucht worden sind: Die Flächenkontingentierung und dem darauf aufbauenden Flächenzertifikatehandel (vgl. Bizer et al. 2021) (Henger et al. 2019).

Bei der Flächenkontingentierung wird einer Planungsebene, bzw. einer Planungseinheit wie beispielsweise eine Kommune, eine fixe Anzahl an Flächenzertifikaten ausgestellt. Die Anzahl der Flächenzertifikate hängt dabei von der Fläche der Kommune und deren Einwohnerzahl ab. Solch ein Zertifikat, meist in der Einheit [m²] wiedergegeben, befähigt die verwaltende Behörde dazu Flächen, welche vorher noch nicht den SuV-Flächen zugerechnet wurden, in eine solche zu überführen. Damit wird die Flächeninanspruchnahme für SuV-Flächen also rein quantitativ gesteuert. Die Qualität der Flächen kann dadurch nicht differenziert werden. Das 30-X-Hektar-Ziel könnte mit diesem Instrument theoretisch einfach erreicht werden, indem von Seiten der Politik jeder Kommune nur eine begrenzte Anzahl von Flächenzertifikaten pro Jahr ausgestellt wird. In Bezug auf das Umweltziel Netto-Null-Flächenverbrauch müsste die Flächenkontingentierung aber ausgebaut und umstrukturiert werden. Würden bis zum Jahr 2050 den Kommunen in Summe keine Flächenkontingente ausgegeben, würde sich dieses Modell selbst abschaffen. Lediglich über die Rückführung von SuV-Flächen in naturnähere Flächennutzungen könnte noch ab 2050 weiter die SuV-Flächen-Struktur ausgebaut werden.

Auf der Flächenkontingentierung aufbauend stellt der Flächenzertifikatehandel ein Handelssystem mit Flächenzertifikaten dar. Dieser umweltökonomische Ansatz, welcher ebenfalls den Flächenschutz als Ziel hat, stellt ein überregionales Handelssystem dar, welches auf eine Kombination aus Mengenbegrenzung und Preisimpuls setzt. Flächenzertifikate können also unter den Kommunen gehandelt werden. Strukturschwache Regionen könnten Zertifikate, welche sie durch ihre Bevölkerungsentwicklung nicht benötigen, an Interessenten verkaufen. Dadurch können dann Kommunen mehr SuV-Flächen schaffen, als ihnen ursprünglich zugesprochen wurden. Strukturschwächere Regionen würden durch diesen Handel finanziell profitieren.

Durch die künstliche (politische) Verknappung der Flächenzertifikate soll eine Verhaltensanpassung der Marktakteure bezüglich des Umgangs mit der Ressource Fläche bewirkt werden. Sowohl mit der Flächenkontingentierung als auch mit dem Flächenzertifikatehandel würde die kommunale Planungshoheit erhalten bleiben, wenngleich auch Einschränkungen einen festen Rahmen vorgeben.

Bezüglich der Flächenschutzziele ließe sich auch mit dem Flächenzertifikatehandel das 30-X-Hektar-Ziel leicht erreichen. Von politischer Seite müssten lediglich die verfügbaren Zertifikate mengenmäßig angepasst werden. Das Netto-Null-Flächenverbrauchsziel wäre jedoch auch nur in Kombination mit einer Form eines Flächenkompensationsmodells nachhaltig zu erreichen. Dabei muss zwingend neben der Quantität der Flächen auch deren Qualität eine wichtige Rolle einnehmen. Das ist wichtig, um dem natürlichen Haushalt nicht weiter unreflektiert wertvolle Flächen zu entziehen. Hochwertige Flächen wiederherzustellen kann sehr lange dauern, je nachdem wie stark diese überprägt wurden. Sobald eine Flächenkreislaufwirtschaft mit in der Bilanz gleichbleibender Flächenwertigkeit etabliert wurde, ist es auch ökonomisch sinnvoller geringerwertige Flächen, welche beispielsweise schon baulich überprägt wurden, für Flächeninanspruchnahmen heranzuziehen. Würden hochwertige Flächen in Anspruch genommen, ist der Kompensationsbedarf erheblich höher und deswegen unattraktiver. Bei der Eingriffsregelung ist es auch gängige Praxis größere Flächen ökologisch aufzuwerten, da diese ihre volle Funktionalität erst in einigen Jahren, meist Jahrzehnten, entwickeln. Der Kompensationsbedarf muss auch hier bereits frühestmöglich gedeckt werden, was zu einem erhöhten Kompensationsaufwand führt.

5 VERGLEICHBARKEIT VON FLÄCHEN

Die Kompensation von Flächen beruht auf der Annahme, dass Flächen eine Wertigkeit besitzen, welche substituierbar ist. Jede Fläche hat demnach eine individuelle Flächenwertigkeit, die in Form eines numerischen Werts wiedergegeben wird und sich aus mehreren Indikatoren berechnet. Die Indikatoren werden dabei in die Zieldimension Quantität und Qualität unterteilt. Aufgrund ihrer Struktur, der Zusammensetzung aus mehreren Indikatoren, welche unterschiedliche Teilbewertungen über eine Fläche abgeben, kann die Flächenwertigkeit verändert werden. Je höher der Wert der Flächenwertigkeit ist, desto höherwertiger ist die Fläche.

Für die Berechnung der Flächenwertigkeit soll ein 5-stufiges Bewertungsmodell herangezogen werden. Die Flächenwertigkeit wird als numerischer Wert wiedergegeben. Je höher die der Wert ist, desto wertvoller ist die Fläche. Die Flächenwertigkeit kann dabei einen Maximalwert erreichen, welcher durch die Ausgestaltung und Gewichtung der Indikatoren definiert ist. Es ist sicherzustellen, dass die Flächenwertigkeit keine negativen Werte annimmt. Das bedeutet, dass eine Fläche im schlechtesten Fall eine Wertigkeit von Null Punkten innehaben kann. Die beiden beschriebenen Extremfälle werden höchst unwahrscheinlich eintreten, vor allem der Null-Fall, dennoch müssen beide beschrieben werden.

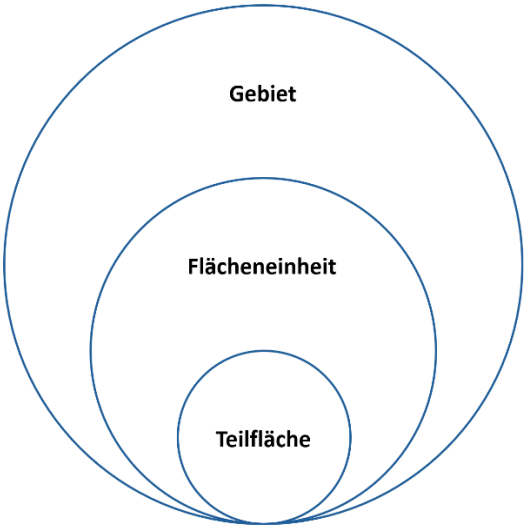

Fig. 2: Schema zur Veranschaulichung der Systematik bei Flächen, eigene Darstellung

Oftmals wird aber nicht nur eine Fläche in SuV-Flächen umgenutzt, sondern gleich mehrere. Sobald mehrere Flächen betroffen sind, bezeichnet man diese Anzahl an Flächen als Gebiet. Ein Gebiet besteht aus mindestens zwei bis beliebig vielen Flächen. Da jede Fläche eine eigene Flächenwertigkeit besitzt, können auch die verschiedenen Flächenwertigkeiten der Flächen eines Gebiets zu einem Wert addiert werden: Das Flächenkapital. Abgegrenzt werden die Flächen dabei nach ALKIS. Es kann jedoch vorkommen, dass eine Fläche sehr heterogen ausgestaltet ist. Dann kann es sinnvoll sein, diese Fläche, bzw. eine Flächeneinheit, in mehrere Teilflächen aufzuspalten. Für jede Teilfläche wird dann die entsprechende Teilflächenwertigkeit

ermittelt und im Anschluss mit den anderen Teilflächenwertigkeiten zur eigentlichen Flächenwertigkeit summiert. In Figure 2 ist das entsprechende Schema vereinfacht dargestellt.

Im Beispiel in Figure 3 ist ein Beispielhaftes Gebiet als Polygon dargestellt, welches aus mehreren Flächen(-einheiten), hier dargestellt als Dreiecke, besteht. Jede Flächeneinheit hat dabei eine individuelle Flächenwertigkeit, welche summiert das Flächenkapital des Gebiets darstellt. Im Fall von Figure 3 beträgt das Flächenkapital 437.

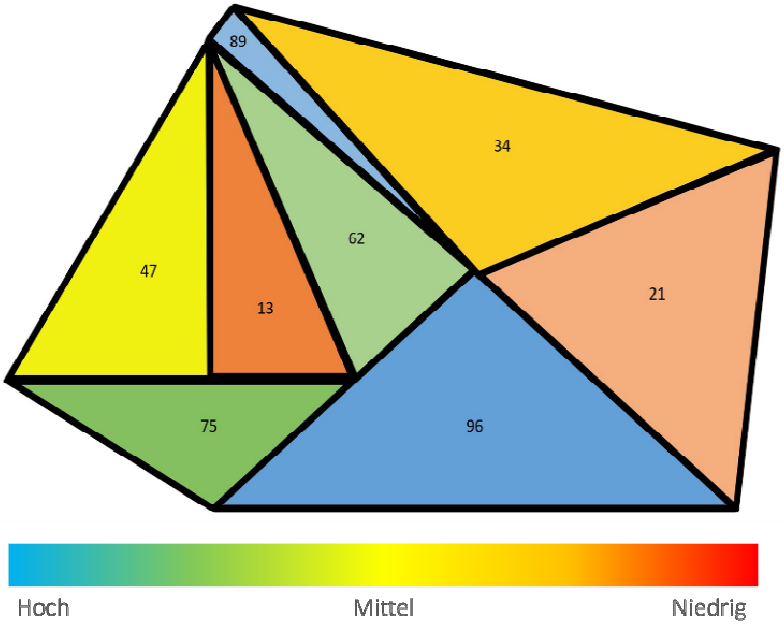

Fig. 3: Beispielhaftes Gebiet mit mehreren Flächeneinheiten, eigene Darstellung

Wenn nun für das in Figure 3 abgebildete Gebiet eine Änderung der Flächennutzung geplant ist, verändern sich die individuellen Flächenwertigkeiten der Flächeneinheiten, und dadurch auch das Flächenkapital des Gebiets. Ergibt sich eine Verringerung der Flächenkapitals, stellt dieser Wert X den Flächenkompensationsbedarf dar, wenn das Netto-Null Flächenverbrauchsziel eingehalten werden soll.

6 FLÄCHENKOMPENSATIONSMODELL ALS LÖSUNGSANSATZ ZUM ERREICHEN DER FLÄCHENSPARZIELE

Ziel des Flächenkompensationsmodells ist eine Flächenkreislaufwirtschaft. Das bedeutet, dass sich das Flächenkapital nicht mehr verringern darf. In Bezug auf Deutschland darf ab dem Jahr 2050 das gesamte Flächenkapital in der Bilanz nicht unter den Wert zum Stichtag 31.12.2049 fallen, bzw. muss eine Flächenkreislaufwirtschaft schon vorher etabliert worden sein. Der genaue Wert des Flächenkapitals am 31.12.2049 kann nur unter unverhältnismäßig hohem Aufwand ermittelt werden. Die Ermittlung des Flächenkapitals ist aber nicht notwendig, da jede Kommune, bzw. sonstige Planungsverwaltung, dazu verpflichtet ist, das eigene Flächenkapital in der Bilanz nicht zu verringern. Dadurch bleibt der voraussichtlich unbekannte Wert des gesamten Flächenkapitals gleich, bzw. verringert sich nicht, und es ist ein vollumfänglich funktionierender Flächenkreislauf gewährleistet.

Wie in den vorherigen Kapiteln angedeutet, gibt es bereits vielversprechende Ansätze, um das 30-X-Hektar-Ziel zu erreichen. Um jedoch eine Flächenkreislaufwirtschaft, das Resultat einer erfolgreichen Umsetzung des Netto-Null-Flächenverbrauch-Ziels, zu erreichen, genügen die bestehenden Ansätze nicht. Ein Flächenkompensationsmodell stellt einen möglichen Weg zur Zielerreichung dar. Folgend werden die wichtigsten Merkmale eines solchen Modells vorgestellt:

6.1 Struktur

Die Struktur des Flächenkompensationsmodells basiert auf dem der deutschen naturschutzrechtlichen Eingriffsregelung und bedarf einer noch final zu definierenden Datengrundlage: dem Flächenkonto. Auch das Flächenkonto lehnt sich in seiner Struktur am Ökokonto an, wobei das Flächenkonto die Flächenwertigkeiten enthält und inhaltlich klar vom Ökokonto abgegrenzt ist. Mit der Übernahme bereits in

der Planung angewandter Strukturen soll eine leichtere und schnellere Etablierung des Flächenkompensationsmodells erreicht werden.

Theoretisch kann ein solches Flächenkompensationsmodell auf allen planerischen Ebenen eingesetzt werden. Da der Fokus und auch die Datenlage aber von Ebene zu Ebene variiert, muss das Kompensationsmodell pro Ebene angepasst werden. Auf hohen Ebenen, wie beispielsweise des Bundesraumordnungsplans, kann mit dem Modell ein grober Flächenkompensationsaufwand ermittelt werden. Dies ist vor allem bei Variantenvergleichen wichtig, um hochwertige Flächen zu schützen. Auf niedrigeren Planungsebenen, wie zum Beispiel der Bauleitplanung, liegen oft detaillierte Daten vor und lassen eine flächenscharfe Ermittlung der Flächenwertigkeiten und des Flächenkapitals des Gebiets zu.

6.2 Funktionsweise

Ähnlich wie die Funktionsweise der naturschutzfachlichen Eingriffsregelung verlangt das Flächenkompensationsmodell die restlose Kompensation von Flächenwertigkeit im Sinne des Netto-Null Flächenverbrauchsziels, welche in den meisten Fällen durch den Ausbau der Siedlungs- und Infrastruktur verursacht wird. Wertet man ein Gebiet, oder auch nur eine Fläche, ab, so muss die Menge an Flächenwertigkeitspunkten möglichst räumlich nah durch Aufwertungen von Flächen komplett kompensiert werden. Dabei ist die räumliche Nähe wichtig, um die Funktionsfähigkeit des lokalen Naturhaushalts bestmöglich zu erhalten.

Außerdem soll die Bündelung von kleineren Kompensationsbedarfen möglich sein, um große Flächen, wie Industriebrachen etc., aufwerten zu können. Eine komplette oder nur teilweise Kompensation durch Ersatzzahlungen, wie sie in der Eingriffsregelung erlaubt sind, entsprechen nicht dem Gedanken der Kreislaufwirtschaft und sind deshalb strikt abzulehnen. Des Weiteren soll ein Mindestaufwertungsmaß bzw. eine Bagatellschwelle eingerichtet werden, welche sich an der gesamten Flächenwertigkeit orientiert und nicht nur an einzelnen Indikatoren. Damit soll der planerische Aufwand verhältnismäßig gestaltet und trotzdem die Einhaltung der Flächenschutzziele garantiert werden.

6.3 Indikatoren

In den vorherigen Kapiteln bereits erwähnt, wird die Wertigkeit einer Fläche aus verschiedenen Indikatoren ermittelt, welche in die Zieldimensionen Quantität und Qualität unterteilt werden. Zur Bewertung ist eine fünfstufige Skala der Flächenwertigkeit vorgesehen. Des Weiteren soll eine gesonderte Prüfung für die dritte Zieldimension der nachhaltigen Entwicklung erstellt werden, welche zwar nicht mit die Flächenwertigkeit beschreibt, aber eine Aussage trifft, wie sehr ein geplantes Vorhaben, Programm, etc. zur ökologisch-nachhaltigen Entwicklung der betroffenen Flächen beiträgt. Statt rechnerisch mit messbaren Indikatoren wird diese Prüfung verbal-argumentativ durchgeführt. Aufgrund der unterschiedlichen Gegebenheiten im Untersuchungsgebiet und der Vielfalt an möglichen Flächeninanspruchnahmen ist eine Bewertung über Indikatoren nur schwer darstellbar.

6.3.1 Quantitative Zieldimension

Im Rahmen der Quantitativen Zieldimension sollen Indikatoren wertgebend sein, welche zum Beispiel die räumliche Ausdehnung, die Beschaffenheit und die Häufigkeit der betroffenen Flächen im Untersuchungsgebiet ermitteln.

Ein möglicher Indikator, welcher anteilig die quantitative Zieldimension in der Flächenwertigkeit angemessen repräsentieren könnte, ist die Freiraumversorgung. Hierbei ist die verfügbare Freifläche pro Einwohner wertgebend. Je mehr Einwohner auf einen Quadratmeter Freiraum angewiesen sind, desto höher wird die Fläche aus Sicht dieses Indikators gewertet. Ebenfalls den Freiraum betreffend ist der Indikator Freiraum-Zerschneidung. Alternativ könnte hierfür auch die Zersiedlung herangezogen werden. Dabei wird die Ausdehnung unzerschnittener Freiräume untersucht. Eine Fläche ist dabei höherwertiger wenn der unzerschnittene Freiraum, in dem sie sich befindet, groß ist. Je größer der Freiraum, desto höherwertiger die Fläche für diesen Indikator.

6.3.2 Qualitative Zieldimension

Im Fall der qualitativen Zieldimension werden die Flächennutzungsfunktionen in Form von Indikatoren wiedergegeben und damit bewertet. Ein möglicher Sammelindikator, welcher viele Aspekte beinhaltet, ist

der Biotopwert nach BKompV (D). Dabei werden hochwertige Lebensräume bewertet, welche hohe Ansprüche an ihren Standort stellen. So sind solche Standorte meist nur wenig mit Schadstoffen belastet, die Bodenerosion ist nur in natürlichem Ausmaß ausgeprägt und der Erhalt der heimischen biologischen Vielfalt ist auch berücksichtigt. Es ist auch anzunehmen, dass solche Standorte aufgrund ihres geringen menschlichen Einflusses auch standorttypische, naturnahe Filter- und Reinigungsfunktionen erhalten haben und ein standortgemäßes Leitungs-/ Puffer-/ Speicher- und Rückhaltemedium sind.

Zudem wird auch die Multifunktionalität der Flächen als wertgebend angesehen, da aufgrund des steigenden Nutzungsdrucks Flächen umso wertvoller werden, je mehr Funktionen diese erfüllen. Mit dem Indikator Klimawirkung der Fläche wird die Aufnahme, Speicherung oder Emission von klimawirksamen Gasen (in CO_2-Äquivalenten gemessen) beleuchtet.

6.3.3 Gesonderte Bewertung der Zieldimension nachhaltige Entwicklung

Nicht wertgebend für die Flächenwertigkeit, aber dennoch wichtig, um den Beitrag zu einer ökologisch-nachhaltigen Entwicklung von Plänen, Programmen, Vorhaben, etc. zu erfassen, werden folgende Aspekte fokussiert: Effizienz, Konsistenz und Suffizienz. Mit diesen drei Schwerpunkten können zum Beispiel festgestellt werden wie sehr eine geplante Nutzung das Potenzial der Fläche ausschöpft und wie sehr die Fläche überprägt wird, was die Regenerationsdauer der Fläche beeinflusst. Die Erfassung des Beitrags einer ökologisch-nachhaltigen Entwicklung ergänzt die Flächenwertigkeit inhaltlich und trägt zu einer vollumfänglichen Flächenkreislaufwirtschaft bei.

7 FAZIT

Der Schutz der Ressource Fläche ist essenziell für einen funktionsfähigen Naturhaushalt und seiner nachhaltigen Nutzung. Dabei wird der Flächenschutz zunehmend dringlich, da die Flächen für SuV, bzw. SuI, stetig zunehmen. Dies liegt an einem mangelnden Bekenntnis zum Flächenschutz sowohl in Gesellschaft, Wirtschaft und damit auch der Politik. In allen drei Bereichen ist ein Umdenken erforderlich, um die Flächenschutzziele wie das 30-X-Hektar-Ziel als auch das Netto-Null-Flächenverbrauchsziel einhalten zu können. Zudem müssen bereits existierende Flächenschutzziele verbindlich im Gesetz verankert werden. Der bisherige Ansatz über die Freiwilligkeit ist fehlgeschlagen und es bedarf nun verbindlicher und stringenter Vorgaben für den Umgang mit der Ressource Fläche.

Das Flächenkompensationsmodell, welches in seinen Grundzügen vorgestellt wurde, ist ein möglicher Weg, um die Flächenschutzziele zu erreichen und trotzdem weiterhin genug planerische Flexibilität für weitere Flächenumnutzungsdynamiken zuzulassen. Ein weiterer Vorteil ist die Kombinationsmöglichkeit mit anderen Instrumenten, wie dem Flächenzertifikatehandel, was weitere Spielräume ermöglicht. Bei flächendeckender Anwendung des Flächenkompensationsmodells ist der Erhalt der Flächenwertigkeit garantiert und damit auch eine Flächenkreislaufwirtschaft etabliert.

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🏆 reviewed paper

Erhebung und Analyse des Flächenverbrauchs in Deutschland sowie Abschätzung der zukünftigen Flächenverbrauchsentwicklung

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1 ABSTRACT

Der weltweite Verlust von natürlichen Böden durch Überbauung zu Siedlungs- und Verkehrszwecken ist nach wie vor hoch. Damit gehen auch immer mehr Flächen für die Landwirtschaft verloren. Derartige Böden werden aufgrund der wachsenden Weltbevölkerung und dem erforderlichen Wandel zu einer ökologischen Landwirtschaft dringend gebraucht. Darauf verweist auch der Wissenschaftliche Beirat der Bundesregierung Globale Umweltveränderungen in seinem Hauptgutachten“ Landwende im Anthropozän“ (WBGU, 2021)

Die Verhinderung eines weiteren Verlustes an Biodiversität, die Gewährleistung der Ernährungssicherheit und die Produktion gesunder Lebensmittel, die Verhinderung weiterer Zersiedelung und Landschaftszerschneidung sowie die Regionalisierung von Kreisläufen, dies alles sind Ziele der ökologischen Transformation. Lösen lässt sich das Problem des Flächenverbrauchs nur durch eine konsequente Kreislaufwirtschaft von Siedlungs- und Verkehrsflächen, d. h. keine neue Inanspruchnahme von Freiraumflächen ohne adäquaten Flächenausgleich. Eine vollständige Kreislaufwirtschaft bis 2050 zu erreichen, hat sich die EU und auch Deutschland zum Ziel gesetzt (Fina et al., 2023; BUMB 2016).

In Indikator der Sustainable Development Goals (SDGs) und in der Deutschen Nachhaltigkeitsstrategie (DNS), erstmals formuliert im Jahre 2002, ist der Flächenindikator „Anstieg der Siedlungs- und Verkehrsfläche“ (11.1.a) kurz auch Flächen(neu)inanspruchnahme oder Flächenverbrauch genannt (Bundesregierung 2002). Dieser Indikator erfordert eine verlässliche, genügend genaue und aktuelle Bestimmung. Nur so können Erfolge und Misserfolge einer Flächensparpolitik raumscharf bewertet werden. Den dahinterliegenden Herausforderungen und Lösungsansätzen widmet sich dieser Beitrag. Er enthält u. a. Ergebnisse eines erst kürzlich abgeschlossenen Forschungsprojekts „Konsistenz und Aussagefähigkeit von Flächendaten – Untersuchungen zur Zeitreihenfähigkeit der amtlichen Flächenstatistik“ des Umweltbundesamtes (UBA, 3719 751020).

Einleitend wird die Methodik der Flächennutzungserhebung in Deutschland beschrieben. Dabei wird auf die Datengrundlagen der Flächenstatistik – das Amtliche Liegenschaftskatasterinformationssystem (ALKIS, AdV 2023) – eingegangen. Dieses hat Schwächen bzgl. der deutschlandweiten Homogenität und Aktualität der Daten. Zudem sind die darauf basierenden Indikatorzeitreihen durch methodische Veränderungen der Erhebung des Attributs „Tatsächlichen Nutzung“ (TN) im Liegenschaftskataster beeinträchtigt. Besonders sensibel darauf reagiert der Flächenverbrauchswert, da er der einzige Differenzindikator der Flächenstatistik ist.

Die Erhebung des Flächenverbrauchs wird darum auch auf geotopographischer Datengrundlage vorgestellt und die Werte verglichen. Denn das Basis Landschaftsmodell des Amtlichen Topographisch-Kartographischen Informationssystem (ATKIS Basis-DLM, AdV 2021) ist deutschlandweit homogener und aktueller und liefert verlässlichere TN-Attribute und Indikatorwerte.

Eine gegenwärtig besondere Herausforderung bei der Erstellung von Flächennutzungsstatistiken sind die Erfassung und Bilanzierung von Flächen für erneuerbare Energiegewinnung (EE-Flächen). Denn Freiflächen-Photovoltaikanlagen (FF-PVA)benötigen riesige Flächen. Da diese derzeit in der TN-Erhebung als Siedlungsflächen bewertet werden, beeinflussen sie den Indikatorwert Flächenverbrauch. Wie sich die Gesamtfläche von FF-PVA in den letzten Jahren entwickelt hat und wie sich die Entwicklung fortsetzen wird, ist Teil dieses Beitrags.

Zudem wird ein Vorschlag unterbreitet, wie die Erhebung des Flächenverbrauchsindikators durch den Rückgriff auf originäre Informationen zur geplanten Überbauung und der Bodenversiegelung aus den Bauerhebungsbögen verbessert werden könnte und die Ergebnisse einer Abschätzung des zukünftigen Flächenverbrauchs durch automatisierte GIS-basierte Auswertung von Bebauungsplänen vorgestellt.

Keywords: Flächennutzungsstatistik, Flächenverbrauch, Erneuerbare-Energie-Flächen, ATKIS, IÖR-Monitor

2 HINTERGRUND

Die Überbauung von natürlichen Böden und die Inanspruchnahme von Freiraum für Siedlungs- und Verkehrszwecke ist weltweit fortschreitend und ein erhebliches Problem einer nachhaltigen Entwicklung. Darum hat die UN in den Sustainable Development Goals (SDGs) u. a. das Ziel formuliert, Städte und Siedlungen nachhaltiger zu entwickeln. Der Flächenverbrauch wird in Europa gemessen auf Grundlage des CORINE Land Cover (CLC).[1] CLC-Daten sind europaweit verfügbar seit 1990. Aller sechs Jahre wird die Landnutzung differenziert nach 44 Landnutzungsklassen im Maßstab 1:100.000 auf Basis von Satellitenbilddaten erhoben. Abb. 1 zeigt den Flächenverbrauch zwischen 2000-2018 für die europäischen Länder in Vergleich. Weitere Analysen findet man hier. Allerdings wird durch die begrenzte Auflösung der CLC-Daten (25 ha Mindestgröße einer Erfassungseinheit), die eine Erfassung kleiner neuer Siedlungsflächen oder Verkehrstrassen unmöglich macht, der Flächenverbrauch stark unterschätzt. Während die fernerkundliche CLC-Erhebung die Flächenbedeckung erhebt, erfassen nationale Systeme wie die deutsche Flächenstatistik die Flächennutzung. Dadurch ist die Zuordnung überbauter Flächen nicht gut vergleichbar. In Deutschland wird der Flächenverbrauch durch die CLC-Daten um fast 80 % unterschätzt.

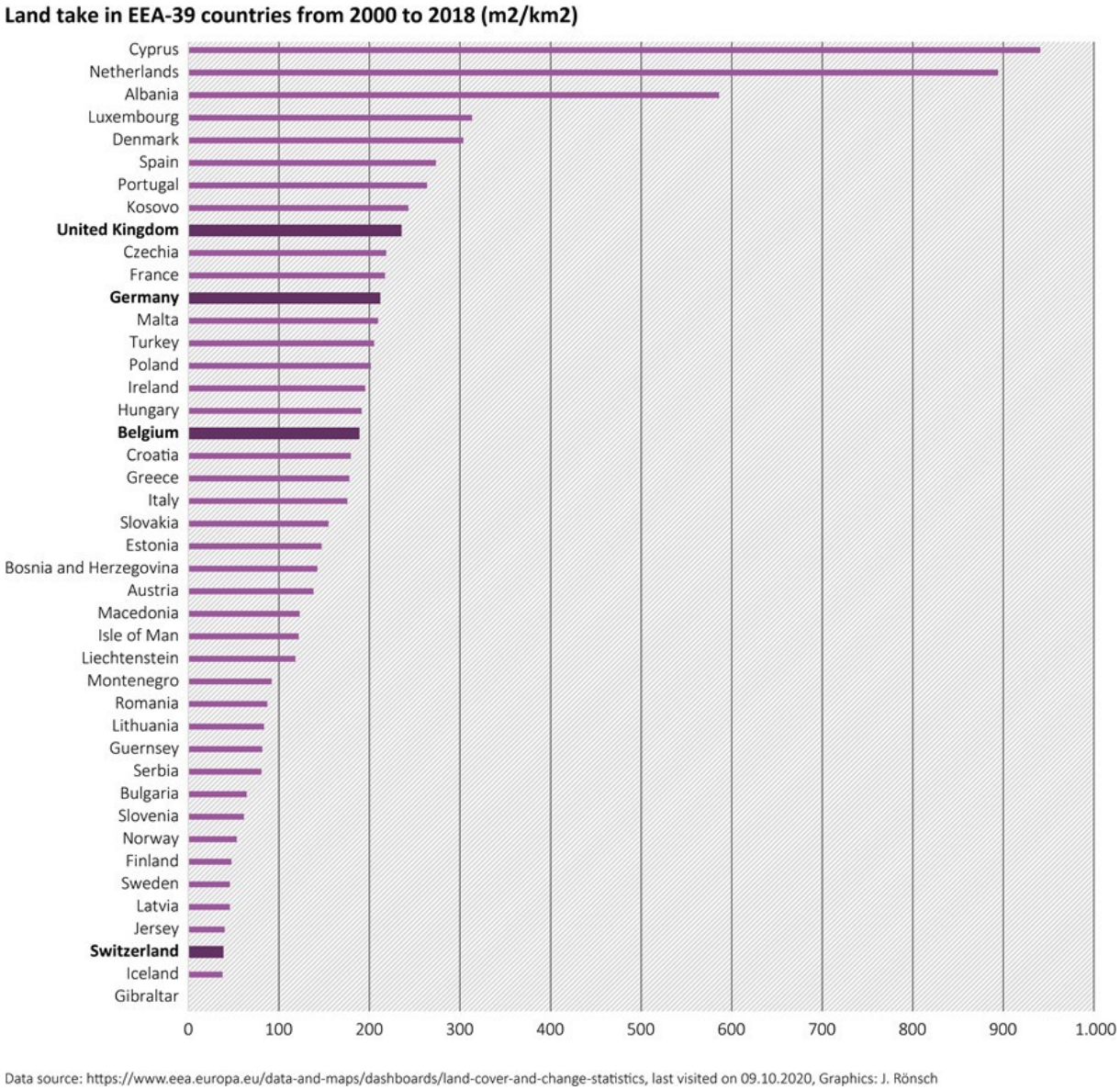

Abb. 1: Flächeninanspruchnahme europäischer Länder zwischen 2000 und 2018, https://www.eea.europa.eu/en/analysis/indicators/net-land-take-in-cities

[1] https://land.copernicus.eu/en/products/corine-land-cover

In Österreich wird die Flächeninanspruchnahme und die Bodenversiegelung landesweit von der Österreichischen Raumordnungskonferenz (ÖROK) publiziert.[2] Das Datenmodell wurde mit dem Bund, den Ländern, Städten und Gemeinden abgestimmt. Als Ergebnisse liegen robuste Daten zur Flächeninanspruchnahme für Siedlungs- und Verkehrszwecke, Freizeit- und Erholungs-, Ver- und Entsorgungszwecke sowie der Versiegelung für das Referenzjahr 2022 („Baseline“) vor. Gesamterhebungen werden in einem dreijährigen Zyklus durchgeführt. Belastbare Zahlen zu Entwicklungstendenzen werden erstmals Ende 2025 vorliegen.

3 FLÄCHENSPARPOLITIK IN DEUTSCHLAND

Die Reduzierung des täglichen Anstiegs der Siedlungs- und Verkehrsfläche kurz Flächenneuinanspruchnahme oder auch Flächenverbrauch auf max. 30 ha pro Tag (30-Hektar-Ziel) bis 2020 fand im Jahr 2002 als Flächenindikator Eingang in die Nationale Nachhaltigkeitsstrategie der Bundesregierung. In der seit 2016 aktualisierten Fassung der Deutschen Nachhaltigkeitsstrategie (DNS) lautet das Ziel nunmehr unter 30 ha pro Tag bis zum Jahr 2030 (Bundesregierung 2017). Bis 2050 soll nach dem Klimaschutzprogramm der Bundesregierung (BUMB 2016) der Übergang zu einer Flächenkreislaufwirtschaft realisiert werden, so dass netto keine neuen Flächen mehr für Siedlungs- und Verkehrszwecke mehr in Anspruch genommen werden müssen (Netto-Null-Ziel).

Auch wenn der Flächenverbrauch in Deutschland sukzessiv in den letzten 20 Jahren abgenommen hat, wird derzeit mit ca. 55 ha/Tag das Ziel weit verfehlt. Das hast viele Gründe. So soll die Baukonjunktur nicht eingeschränkt werden und es besteht eine erhebliche Nachfrage nach mehr Wohnraum und neuen Gewerbeflächen. Bauen im Bestand, Innen- vor Außenentwicklung können diese Nachfrage nur zum Teil decken. Auch wurde das bundesweite Flächensparziel nie regionalisiert, d. h. untersetzt auf Ebene der Bundesländer, Regionen und Kreise. Inzwischen haben sich aber 12 von 16 Bundesländern Flächensparziele gesetzt. Auch ein vom Umweltbundesamt in drei Forschungsprojekten ausgetesteter handelbarer Flächenzertifikatehandel wurde nie installiert. Dieser hätte durch die Festlegung von Kontingenten, die über die Jahre immer weniger werden, die Flächensparziele genau erreicht.

Ambitionierte Flächensparpolitiken findet man in Deutschland auf unterschiedlichen Ebenen: Beispielhaft hingewiesen sei z. B. auf die NRW-Flächenampel (Siedentop et al. 2024),im Landesentwicklung plan von Baden-Württemberg wird eine Flächenkreislaufwirtschaft bis 2035 angestrebt[3] und auf kommunaler Ebene sei das Bodenschutzkonzept Stuttgart (BOKS[4]) hervorgehoben.

4 MESSUNG DES FLÄCHENVERBRAUCHS

4.1 Amtliche Flächenerhebung

Die Landnutzung beschreibt die sozioökonomische Nutzung des Bodens z. B. für Wohn- oder Erholungszwecke oder Land- bzw. Forstwirtschaft, während die Landbedeckung das physische Material an der Erdoberfläche wie Gras, Bäume, Gestein, Wasser oder versiegelte Siedlungs- und Verkehrsflächen beschreibt. Dabei sind die Begriffe Land-, Boden- und Flächennutzung bedeutungsgleich. Das gilt auch für die Begriffe Land-, Boden- und Flächenbedeckung.

Die Flächenstatistik ist Teil der Agrarstatistik. Nur eine kurze Zeit war sie auf Bundesebene Teil der Umweltökonomischen Gesamtrechnungen der Länder (UGRdL). Grundlage der Berechnung des Indikators „Anstieg der Siedlungs- und Verkehrsfläche“ und der Erstellung der entsprechenden Indikatorzeitreihen sind die jährlich erscheinenden statistischen Berichte zur Flächenerhebung nach Art der tatsächlichen Nutzung von Bund und Ländern. Die Fachserie 3 Reihe 5.1[5] mit den Angaben der Bodenfläche nach Art der tatsächlichen Nutzung erschien 2021 zum letzten Mal. Die Angaben werden seitdem nur noch in der Datenbank GENESIS-Online[6] veröffentlicht.

[2] https://www.oerok.gv.at/monitoring-flaecheninanspruchnahme

[3] https://www.landesentwicklung-bw.de/de/mitmachen/beteiligungen/eckpunktepapier-zum-lep/thema/reduzierung-des-flaechenverbrauchs

[4] https://www.stuttgart.de/leben/umwelt/boden/bodenschutz.php

[5] https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Flaechennutzung/Publikationen/Downloads-Flaechennutzung/bodenflaechennutzung-2030510217005.html

[6] https://www-genesis.destatis.de/genesis/online?sequenz=statistikTabellen&selectionname=33111#abreadcrumb

Die Statistischen Berichte zur Flächenerhebung weisen in den Bundesländern eine unterschiedliche räumliche und sachliche Informationstiefe auf. Mehrheitlich erfolgt eine räumliche Ausweisung der Flächennutzung bis auf Gemeindeebene. In einigen Bundesländern werden die Werte jedoch nur bis auf Kreisebene kostenfrei veröffentlicht.

Die inhaltliche Auswertung variiert zwischen der alleinigen Angabe der SuV-Fläche oder der zusätzlichen Angabe der Veränderung der SuV-Fläche gegenüber Vorjahr. Eine direkte Ausweisung des Anstiegs der Siedlungs- und Verkehrsfläche in Hektar pro Tag erfolgt in der Regel nicht (Ausnahmen Bayern und Hessen). Auch weist das Statistische Bundesamt diesen Indikatorwert in seinen Berichten zur amtlichen Flächenerhebung nicht aus. Dieses erfolgt nach Plausibilisierungen mit halbjähriger Verzögerung im Internet. Auch einige Bundesländer weisen die Flächenneuinanspruchnahme nur separat im Internet aus und nicht in ihren statistischen Berichten.

Die Ausgabe des Indikatorwertes „Anstieg der Siedlungs- und Verkehrsfläche“ auf Ebene der Bundesländer in Hektar pro Tag erfolgt zudem auf dem gemeinsamen Statistikportal der Statistischen Ämter des Bundes und der Länder.[7] Eine weitere Informationsquelle stellt die Regionaldatenbank Deutschland[8] dar, welche die Daten bis zur kommunalen Ebene bereitstellt.

Weiterhin werden vom Statistischen Bundesamt die Jahreswerte[9] sowie der gleitende vierjährige Mittelwert seit 2000 jährlich im Rahmen der Umweltökonomischen Gesamtrechnung veröffentlicht. Durch die Ausweisung des gleitenden Mittelwertes werden die Indikatorvarianzen einzelner Jahre geglättet, was allerdings die Aktualität des Indikatorwertes beeinträchtigt.

4.2 Indikator Flächenneuinanspruchnahme

Dieser sogenannte Flächenindikator der Deutschen Nachhaltigkeitsstrategie beschreibt die Umwandlung von Freiraumfläche (meist Vegetationsfläche) in Siedlungs- und Verkehrsfläche (SuV). Dabei werden Flächennutzungsänderungen aus der Freiraumfläche hin zur SuV-Fläche als Differenz der kumulierten Werte der TN zweier aufeinanderfolgender Jahre ermittelt. Um migrationsbedingte Schwankungen zu minimieren, wird ein gleitender vierjähriger Mittelwert berechnet, der den amtlichen Wert des Flächenindikators (Anstieg der Siedlungs- und Verkehrsfläche (Flächenneuinanspruchnahme bzw. Flächenverbrauch) darstellt. Dieser wird zur Bewertung der Flächenentwicklung im Vergleich mit den Flächensparzielen der Bundesregierung herangezogen. So soll der Anstieg der SuV-Fläche bis 2030 auf unter 30 Hektar pro Tag und bis 2050 durch den Übergang zu einer Flächenkreislaufwirtschaft soweit gesenkt werden, dass netto keine neuen Flächen mehr in Anspruch genommen werden (Netto-Null-Ziel, Die Bundesregierung 2017, BMUB 2016). 2022 beträgt der vierjährige Mittelwert (2019-2022) der Flächenneuinanspruchnahme 52 ha/Tag[10], nachdem er 2021 (2018-2021) noch 55 ha/Tag betrug. Die Entwicklung des Indikators zeigt Abbildung 2. Die migrationsbedingten Einflüsse auf den Indikatorwert werden differenziert für die Bundesländer im Methodenbericht zur Flächenerhebung dargestellt (Statistisches Bundesamt, 2019a). Unter migrationsbedingten Einflüssen sind alle Effekte zu verstehen, die durch geänderte Modellierungsvorschriften der TN-Erhebung im Kataster die Flächenstatistik unabhängig von realen Änderungen der Flächennutzung beeinflussen.

Einige Bundesländer haben eigene Flächensparziele festgelegt.[11] Einen Vorschlag für eine Berechnung legte das UBA 2009 vor und schlägt auch für den maximalen Flächenverbrauch Zwischenziele für 2010 und 2015 vor.[12] Das Ziel und die Zwischenziele wurden jeweils deutlich verfehlt.

[7] https://www.statistikportal.de/de/ugrdl/ergebnisse/flaeche-und-raum/ffsv#6689

[8] https://www.regionalstatistik.de/genesis/online?operation=statistic&levelindex=0&levelid=1692710345425&code=33111#abreadcrumb

[9] https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Flaechennutzung/Tabellen/anstieg-suv.html

[10] https://www.destatis.de/DE/Presse/Pressemitteilungen/Zahl-der-Woche/2024/PD24_11_p002.html

[11] https://slub.qucosa.de/api/qucosa%3A72287/attachment/ATT-0/

[12] https://www.umweltbundesamt.de/daten/flaeche-boden-land-oekosysteme/flaeche/siedlungs-verkehrsflaeche#politische-ziele

Für das Monitoring der Flächenentwicklung und der Flächensparziele ist eine verlässliche Datengrundlage mit kontinuierlich fortgeführten Zeitreihen erforderlich. Die SuV-Fläche als Basisgröße zur Berechnung der Flächenneuinanspruchnahme wird dabei durch das Statistische Bundesamt folgendermaßen definiert:

„Die Siedlungs- und Verkehrsfläche setzt sich zusammen aus den Nutzungsarten Gebäude- und Freifläche, Betriebsfläche (ohne Abbauland), Verkehrsfläche, Erholungsfläche und Friedhof. Diese Zuordnung macht deutlich, dass die SuV-Fläche nicht mit versiegelter Fläche gleichgesetzt werden darf, da die SuV-Fläche auch unbebaute und nicht versiegelte Flächen enthält. Schätzungen ergeben einen Versiegelungsgrad der Siedlungs- und Verkehrsfläche zwischen 43 % und 50 %." (Statistisches Bundesamt ohne Jahreszahl).

Abbauland wird nicht zur Siedlungs- und Verkehrsfläche gezählt, da es sich durch die spätere Rekultivierung um eine temporäre Nutzung handelt. Diese riesigen und sich dynamisch entwickelnden Flächen würden die Zeitreihe des Flächenverbrauchs stark beeinflussen.

Auch Flächen für erneuerbare Energien (Photovoltaik-Freiflächenanlagen) sowie Kranstellflächen und Zuwegungen zu Windkraftanlagen werden der SuV-Fläche zugeordnet.

Das Statistische Bundesamt (StaBA) wurde beauftragt, die Daten für den Indikator zu liefern, um eine nachvollziehbare Erfolgskontrolle dieser politischen Zielsetzungen auf der Zeitachse zu ermöglichen. Dieser – auch als Flächenstatistik bezeichnete Datensatz – ist ein vom StaBA eigens zusammengestellter Datensatzauszug aus der Agrarstatistik, der die „Bodenfläche nach Art der tatsächlichen Nutzung" – auch Statistische Berichte genannt – beschreibt. Die Flächenstatistik ist eine Sekundärstatistik. Das heißt, das StaBA aggregiert die Datenlieferungen der 16 Statistischen Landesbehörden. Diese erhalten ihrerseits die Daten von den Behörden der Landesvermessung (Katasterämter). Statistische „Unplausibilitäten" werden vom StaBA bearbeitet. Etwaige Unplausibilitäten ergeben sich als Folge von Umstellungen im Katasterwesen sowie immer wieder vorgenommenen Umschlüsselungen einzelner Flächennutzungen durch die Länder. Zur Interpretation der Daten – insbesondere im Hinblick auf Vergleiche mit den Daten aus den Vorjahren – musste das Statistische Bundesamt deshalb die Datensätze in den jährlichen Flächenstatistiken zunehmend durch Fußnoten erläutern und erklären.

Die Zeitreihenfähigkeit der Flächenstatistik wurde zum Diskussionsgegenstand. Verstärkt wurde die o. a. Entwicklung durch die sukzessive Einführung des Amtlichen Liegenschaftskataster-Informationssystem ALKIS. Dreh- und Angelpunkt dieser Umstellung ist ein von der Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland (AdV) für ALKIS leicht verändertes Nutzungsartenverzeichnis. Daraus ergaben sich weitere „Umschlüsselungserfordernisse", so dass eine konsistente Darstellung der Flächenstatistik auf der Zeitachse kaum noch möglich war.

Zuverlässige, zeitstabile und valide Daten der Flächennutzung sind jedoch nötig, um die Entwicklung der Siedlungs- und Verkehrsflächenzunahme (Flächenverbrauch) auf der Zeitachse zuverlässig abzubilden und eine Erfolgskontrolle des Flächenindikators im Rahmen der Umsetzung der Deutschen Nachhaltigkeitsstrategie zu ermöglichen.

4.3 Messung der Flächenneuinanspruchnahme im IÖR-Monitor

Der IÖR-Monitor stellt Daten und Informationen zur Flächennutzungsstruktur und deren Entwicklung sowie zur Landschaftsqualität für die Bundesrepublik Deutschland zurück bis zum Jahr 2000 bereit. Er ist Teil des IÖR-Forschungsdatenzentrums (IÖR-FDZ) des Leibniz-Instituts für ökologische Raumentwicklung (IÖR).

Der IÖR-Monitor bietet quantitative indikatorbasierte Beschreibungen durch Analyse amtlicher Geobasis- und Geofachdaten (ATKIS, LoD2, GA, Schutzgebiete, Bodenversiegelung) in Kombination mit amtlicher Statistik und Fernerkundung (Copernicus). Jährlich erfolgt eine Auswertung aller TN-Objekte des ATKIS Basis-DLM nach einem Flächenschema. Stand und Veränderung der Flächennutzung wird durch eine GIS-basierte Berechnung von derzeit 90 Indikatorwerten für alle administrativen Gebietseinheiten (Länder, Kreise, Gemeindeverbände, Gemeinden), Raumordnungsregionen, Stadtteile und Rasterzellen bis 100 m Rasterweite für das terrestrische Staatsgebiet der Bundesrepublik bereitgestellt. Darüber hinaus erfolgt eine Berechnung statistischer Merkmale und eine Visualisierung der Indikatoren werte durch Karten, Tabellen, Entwicklungsdiagramme und Statistiken für administrative Gebietseinheiten und als hochaufgelöste Raster. Ein Kartenviewer[13] ermöglicht die interaktive Darstellung von Entwicklungsdiagrammen, den Export von

[13] https://www.ioer-monitor.de/

Karten, Tabellen und Diagrammen sowie die Bereitstellung der Daten in Form von Geodiensten (WMS, WCS, WFS) zur Einbindung in eigene GIS-Umgebungen. Grundlage, Methodik und Anwendungsbeispiele des IÖR-Monitors wurden u.a. hier beschrieben (Meinel et al. 2023). Die Berechnung der Flächenneuinanspruchnahme berücksichtigt auch Verschiebungen von TN-Objekten im Zuge von geometrischen Genauigkeitsverbesserungen sowie thematische Neuzuordnung von TN-Objekten im Zuge von Migrationsprozessen (Schorcht et a. 2016).

Der Flächenverbrauchsindikator wird berechnet in der amtlichen Flächenerhebung, die auf dem Liegenschaftskataster beruht. Eine alternative Berechnung des Indikators erfolgt im IÖR-Monitor auf Grundlage geotopographischer Daten des ATKIS Basis-DLM. Die tägliche Flächenneuinanspruchnahme im Vergleich zeigt Abb. 2. Zur SuV-Fläche zählen dabei Flächen für Wohnbau, Industrie und Gewerbe (ohne Abbauland), Flächen für öffentliche Einrichtungen, für Sport, Freizeit und Erholung (inkl. Friedhofsflächen) sowie Verkehrsflächen.

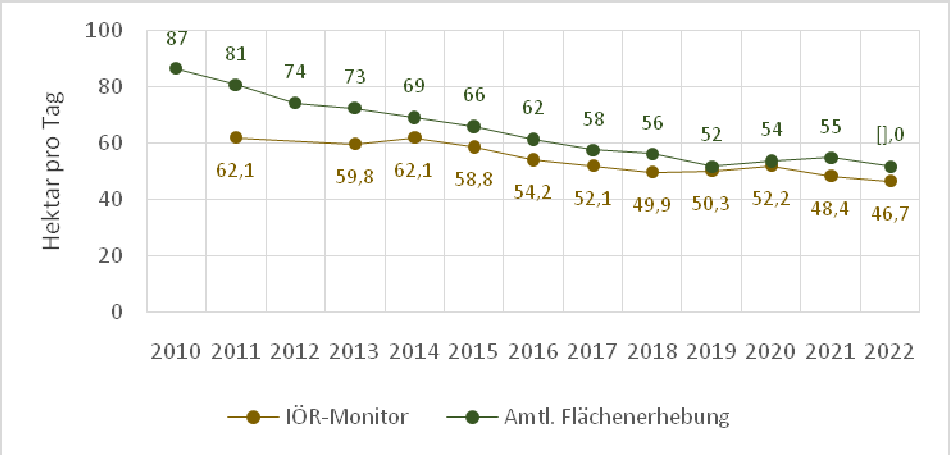

Abb. 2: Flächenneuinanspruchnahme in ha/Tag nach amtlicher Flächenerhebung im Vergleich zum IÖR-Monitor (vierjähriger bzw. fünfjähriger Mittelwert)

4.4 Flächenverbrauchsmessung auf Grundlage der Bauerfassungsbögen

Die amtliche Flächenstatistik gibt die Flächenneuinanspruchnahme nur mit großem Zeitverzug wieder. Das macht eine zeitnahe Nachjustierung der Flächenhaushaltspolitik unmöglich. Grund dafür sind die verzögerte Erfassung einer Flächenneuinanspruchnahme im Liegenschaftskataster nach der Einmessung eines Gebäudeneubaus, einer Gebäudeerweiterung oder eines Gebäudeabrisses.

Andererseits liegen mit den Erhebungsbögen der Bautätigkeitsstatistik[14] hochaktuelle Informationen zum gegenwärtigen Gebäudeneubaugeschehen vor, die wertvolle Aussagen zur aktuellen bzw. geplanten Flächeninanspruchnahme ermöglichen würden.

Die Bautätigkeitsstatistik erfasst die genehmigten, fertiggestellten und abgegangenen Gebäude. Die zugrundeliegenden Erhebungsdaten bieten viele interessante Auswertemöglichkeiten. Die Datenqualität der Bautätigkeitsstatistik ist vergleichsweise hoch durch die Vollerhebung, die gesetzlich geregelte Auskunftspflicht, die tiefe regionale Gliederung, die Verfügbarkeit längerer Zeitreihen und den umfangreichen Merkmalskatalog. Obwohl die Erhebungsdaten der Bautätigkeitsstatistik die aussagekräftigste Primärinformation für die bauliche Entwicklung in Bezug auf die geplante oder neu bebaute Fläche ist, werden diese derzeit nicht für die Bestimmung des Flächenverbrauchs genutzt. Sie dient ausschließlich zur Fortschreibung des Bestandes an Wohngebäuden und Wohnungen und zur Feststellung des Umfangs und der Struktur der Hochbautätigkeit. In den Erhebungsbögen der Bautätigkeitsstatistik sind die Lage, Nutzungsart, der Gebäudeart, der Haustyp, der Rauminhalt, die Geschosszahl, Fläche, Wohnungs- und Raumanzahl erfasst.

Grundlage der Bautätigkeitsstatistik ist das „Gesetz über die Statistik der Bautätigkeit im Hochbau und die Fortschreibung des Wohnungsbestandes (Hochbaustatistikgesetz)“(HBauStatG 1998), Informationsgrundlage der Erhebungsbogen, der vom Träger eines genehmigungs- oder anzeigepflichtigen Bauvorhabens – das sind weitestgehend alle Gebäude – zwingend auszufüllen ist. Die Angaben dieser

[14] https://www.statistik-bw.de/baut/servlet/LaenderServlet

Erhebungsbögen werden in den Statistischen Landesämtern aggregiert und die Baugenehmigungen nach § 5 monatlich, die Baufertigstellungen jährlich veröffentlicht.

Zur Beantragung einer Baugenehmigung muss ein Statistikbogen ausgefüllt werden, sodass alle Baugenehmigungen erfasst werden. Für all diese Baugenehmigungen muss bei Fertigstellung der Baumaßnahme auch eine Meldung zur Statistik der Baufertigstellungen erfolgen. Bei der Statistik der Baufertigstellungen handelt es sich also um eine Totalerhebung und keine Stichprobe. Darum wird die Genauigkeit der Bautätigkeitsstatistik im Qualitätsbericht zur Statistik als hoch eingeschätzt (Destatis 2016a).

Wie könnten nun die Informationen der Erhebungsbögen der Bautätigkeitsstatistik für die Ermittlung der Flächenneuinanspruchnahme einen Beitrag leisten und welche Vorteile hätte dieses Vorgehen? Die Erhebungsbögen beinhalten – bezogen auf die Bestimmung der Flächenneuinanspruchnahme – fast alle wichtigen Informationen zum aktuellen Baugeschehen, sowohl im Neubau als auch Umbau und Gebäudeabriss. Das sind insbesondere die adressgenaue Lage der aktuellen Flächenneuinanspruchnahme, die Nutzungsart (Wohnen oder Gewerbe) und die Nettogrundfläche des Baukörpers. Derzeit ist die Adresse des Baugrundstücks aber leider ein Hilfsmerkmal nach § 4 HBauStatG und darf darum nach § 9 Abs. 2 nur auf Nachfrage der kommunalen Verwaltung an deren abgeschottete Statistikstellen weitergegeben werden. Diese Umstände verhindern derzeit eine Nutzung der Basisinformationen der Bautätigkeitsstatistik für eine deutschlandweite Auswertung der aktuellen Flächenneuinanspruchnahme.

Durch Auswertungen der Lage neuer Baugrundstücke aus den Erhebungsbögen der Bautätigkeitsstatistik könnten aktuelle, lagegenaue, vollständige und verlässliche Angaben zur laufenden Flächeninanspruchnahme in Deutschland gewonnen werden. Der Auswerteaufwand dazu wäre relativ gering und der Nutzen hoch. Die Datennutzung erfordert eine Novelle des Hochbaustatistikgesetzes, die die Auswertung der Lage des Baugrundstücks erlauben würde. Durch Verschneidung der Adresspunkte der neuen Gebäude mit dem Liegenschaftskataster könnte die Grundstücksgröße der Neubebauung erfasst werden. Dann könnten aktuelle und qualitativ hochwertige, flächenbezogene Informationen zur Bautätigkeit in Deutschland gewonnen werden, beispielsweise gemeindescharfe Indikatorwerte zur Flächenneuinanspruchnahme, differenziert nach Nutzungsarten einschließlich des Verhältnisses von Innen- zu Außenentwicklung.

5 FLÄCHENINANSPRUCHNAHME VON FREIFLÄCHEN-PHOTOVOLTAIKANLAGEN

5.1 Derzeitige Erfassung von FF-PVA

Flächen für erneuerbare Energien wie Windkraft- (WKA) und Photovoltaik-Freiflächenanlagen (PV-FFA) prägen zunehmend das Landschaftsbild. Sie haben aufgrund ihrer großen Zahl und ihrem Flächenanspruch einen erheblichen Einfluss auf die Flächennutzung. Dabei werden PV-FFA sowohl in ALKIS als auch in ATKIS als Bauwerk separat von der Tatsächlichen Nutzung mit der Funktion Solarzelle erfasst (Lipfert 2023). Nach einer Statistik von Kurstedt 2023 liegen die 4.713 PV-FFA mit einer Fläche von 18.438 ha (Stand: I/2023, Quelle: ATKIS Basis-DLM) zu über 98 % auf Industrie- und Gewerbeflächen. (Wenige Anlagen liegen auf Unland- oder Verkehrsflächen, Flächen gemischter Nutzung oder Flächen besonderer funktionaler Prägung, Landwirtschafts- oder Wasserflächen oder auf Tagebauflächen). Durch die Kennzeichnung der Tatsächlichen Nutzung unterhalb der Bauwerke als Industrie- und Gewerbeflächen gehören sie zum Nutzungsartenbereich Siedlung und gehen in die Flächenneuinanspruchnahme ein.

Nicht relevant für die Berechnung der Flächenneuinanspruchnahme sind PV-FFA oder WKA, die im bestehenden Siedlungsraum errichtet wurden wie auf Halden, Straßen- oder Flugverkehrsflächen. Auch wenn diese Anlagen keine Freiraumfläche beanspruchen, wäre deren Erfassung für statistische Auswertungen von Bedeutung.

Schon im Jahre 2018 wurde durch PV-Freiflächenanlagen eine Fläche von 25.500 ha eingenommen. Die Flächenentwicklung der Anlagen bis 2022 wird bei Walz. et al. 2022 beschrieben. Die Flächenneuinanspruchnahme durch FF-PVA in den letzten 10 Jahren beträgt rechnerisch ca. 10 ha/Tag (Kurstedt 2023, Walz et al. 2022). Mit den gesetzten Ausbauzielen der Bundesregierung wird bei Böhm 2023 abgeschätzt, dass sich die Gesamtfläche auf 150.000 ha bis 2030 erhöhen wird. Um den landwirtschaftlichen Flächenverlust zu begrenzen, sollte man zunehmend zu einer multifunktionalen Flächennutzung durch aufgeständerte Freiflächen-PV-Anlagen (Agri-PV) oder schwimmender Photovoltaik

(FPV) auf Wasserflächen übergehen. Auch darum sollte eine Erfassung derartiger multifunktionaler Flächennutzung im Flächenmonitoring zum Standard werden.

5.2 Berücksichtigung von FF-PVA-Flächen in der Flächenstatistik

Genau genommen stellen diese Anlagen nur eine temporäre Nutzung dar, denn deren Betriebszeit beträgt ca. 20 Jahre. Zudem handelt es sich oft um eine multifunktionale Flächennutzung, denn unter diesen Anlagen erfolgt häufig z. B. eine Beweidung, also eine landwirtschaftliche Nutzung. Der Verlust an Landwirtschaftsfläche kann in Zukunft durch aufgeständerte Anlagen (Agri-PV) gemindert werden. In Umsetzung der Ausbauziele für Solarenergie rechnet Böhm 2023 mit ca. 150.000 ha neuer PV-FFA allein auf Agrarflächen. Das zeigt, wie wichtig eine separate Erfassung dieser überlagerten Nutzung wäre. Darum sollten diese Anlagen auch nicht wie derzeit in die Berechnung des SuV-Anstiegs einfließen. Es empfiehlt sich eine separate Ausweisung der Flächenneuinanspruchnahme durch erneuerbare Energien in einem eigenen Indikator. Denn die Vermischung von erwünschten Entwicklungen (Ausbau Freiflächen-Photovoltaik) und unerwünschten (Flächenverbrauch) im Indikator Flächenneuinanspruchnahme wird als problematisch angesehen und konterkariert das Netto-Null-Ziel des Flächenverbrauchs.

6 ABSCHÄTZUNG DES ZU ERWARTENDEN FLÄCHENVERBRAUCHS

Will man vorausschauender in der Flächensparpolitik agieren und wirkliche Steuerungsoptionen gewinnen, sollte man die geplanten Flächenneuinanspruchnahmen in den Blick nehmen. Das erfolgte früher schon einmal durch die „Statistik der Bodenfläche nach Art der geplanten Nutzung“ zwischen 1996 und 2004. Diese Statistik basierte auf der Auswertung der Flächennutzungspläne der Kommunen durch Summierung der geplanten Nutzungen der Kommunen. Für den Vergleich der Planungen mit dem aktuellen Stand der Bodennutzung musste die Planzeichenverordnung mit dem AdV-Nutzungsartenverzeichnis in Einklang gebracht werden. Zudem war die Erhebung hochaufwendig und wurde im Zuge der Verwaltungsliberalisierung ab 2004 eingestellt.

Eine Erhebung der geplanten Flächenneuinanspruchnahme wäre heute sehr viel einfacher und genauer zu realisieren als vor 20 Jahren. Denn der Zugriff auf Bebauungspläne (B-Plan) ist heute in der Regel digital möglich geworden. B-Pläne werden bereits in 11 Bundesländern (Stand 2024) in Form von landesweiten Datenpaketen der rechtskräftigen B-Pläne digital und Open Data angeboten. Durch Verschneidung der geplanten Siedlungs- und Verkehrsflächen mit den Freiraumflächen einer aktuellen Flächennutzungskarte könnte die geplante Flächenneuinanspruchnahme berechnet werden, um die tägliche Flächenneuinanspruchnahme abzuschätzen. Für die Umsetzung der Pläne würde man nach Expertenmeinung einen Zeitraum von 8-10 Jahren ansetzen. Damit kann man den zukünftigen Flächenverbrauch abschätzen und kommt auf eine tägliche Flächenneuinanspruchnahme von 80 ha/Tag (Bronold 2024), was das Ziel von unter 30 ha/Tag weit überschreitet.

Die Ergänzung bisher noch fehlender digital und frei verfügbarer B-Pläne wird durch INSPIRE[15] befördert. Dort wird die Bereitstellung von Daten zur geplanten Flächennutzung zwingend vorgeschrieben. Zudem würde die Bereitstellung aller neuen Pläne im XPlan-Datenaustauschformat, wie diese in Deutschland seit 2023 vorgeschrieben ist, die GIS-technische Auswertung noch wesentlich erleichtern. Auch die mit der geplanten Flächenneuinanspruchnahme einhergehende Bodenversiegelung wäre analysierbar, denn diese ist Bestandteil in XPlan.

Die Ergebnisse, sind diese anfänglich auch noch nicht flächendeckend für Deutschland verfügbar, würden über den Stand neuer geplanter Siedlungs- und Verkehrsflächen und damit die zu erwartende Flächenneuinanspruchnahme informieren. Es liegt in der Natur der Sache, dass die Ergebnisse unsicher bleiben, denn nicht jeder Plan wird auch umgesetzt. Durch eine jährliche Wiederholung könnte ein Monitoring der geplanten Nutzung aufgebaut und eine entsprechende Statistik abgeleitet werden. Auch wenn es nach Expertenmeinung noch ca. drei Jahre dauern wird, bis alle Bundesländer die Pläne downloadbar und GIS-analytisch bereitstellen, könnten die Vorbereitungsarbeiten dazu schon beginnen. Damit würden erstmals empirische Datengrundlagen für Entscheidungs- und Genehmigungsprozesse bereitstehen, die eine evidenzbasierte Steuerung der Flächenneuinanspruchnahme ermöglichen.

[15] https://www.geoportal.de/INSPIRE/3

7 EMPFEHLUNGEN UND AUSBLICK

Zusammenfassend werden an die Akteure der Erhebung der Flächennutzung folgende Empfehlungen ausgesprochen.

Empfehlungen an die AdV, Vermessungsverwaltungen und Katasterbehörden:

- Einheitlichere Erfassung der Tatsächlichen Nutzung in allen Katasterämtern Deutschlands. Dafür müssen diese unmissverständlicher beschrieben werden durch Sammlungen mit TN-Erfassungsbeispielen mit unterlegtem Luftbild, erläuternden Handbüchern und Schulungen der TN-Erfasser.
- Schnellere Aktualisierung der Tatsächlichen Nutzung in ALKIS auf Grundlage potenzieller Änderungsflächen abgeleitet aus dem neuen Produkt Landbedeckung (LB).
- Bundesländer mit derzeit noch anlassbezogener Aktualisierung sollten so bald wie möglich eine zyklische Aktualisierung einführen.
- Photovoltaik-Freiflächenanlagen (in ALKIS und ATKIS als Solaranlagen bezeichnet) sollten im Kataster vollständig und einheitlich erfasst werden.
- Erstellung und jährliche Aktualisierung eines ALKIS-Produktblattes mit Informationen zur Datenaktualität. Diese fehlt derzeit noch im Kataster, ist aber zur Bewertung der Zeitreihen der Flächenstatistik erforderlich.
- Die Kennzeichnung der Ursache für jedes geänderte TN-Objekt, ob technisch bedingt oder real im Attribut „ErgebnisDerUeberpruefung“ (EDU) ist im Referenzmodell GeoInfoDok 7.1 angelegt. Nur wenn man diese auch konsequent ausfüllt, kann man perspektivisch zu genaueren Indikatorwerten für den Anstieg der Siedlungs- und Verkehrsfläche kommen.
- Einheitlichere und schnellere Umsetzung der AdV-Beschlüsse durch die Vermessungsverwaltungen und Katasterämter der Länder.
- Leichtere Auffindbarkeit von Dokumenten im AdV-Online-Auftritt (Übersichtlichkeit, Struktur, Vermeidung kryptischer Links).
- Katasterdaten sollten generell archiviert werden. Nur so sind spätere Rekonstruktionen und Behebungen von Unstimmigkeiten in den Zeitreihen von Bund und Ländern möglich.

Empfehlungen an die Statistischen Ämter des Bundes und der Länder:

- Systematische Auswertung des Attributs EDU, um unreale TN-Änderungen aus dem Flächenverbrauchsindikator zu eliminieren.
- Schnellere und nutzerfreundlichere Ergebnisveröffentlichungen z. B. in einem Dashboard vergleichbar mit dem „Kommunalen Flächenrechner“ des UBA[16] (Gutsche und Grimski 2021).
- Ergänzende statistische Auswertungen u. a. zur Flächeninanspruchnahme durch Freiflächen-Photovoltaikanlagen, neue Abbau- und Tagebauflächen und deren Nachnutzung, Flurneuordnungen usw.
- Auswertungen der primären Erhebungsbögen der Baugenehmigungen, welche Grundlage für die Erstellung der Bautätigkeitsstatistik sind. Diese enthalten die verorteten und fachlich präzisen aber bisher fehlenden Primärinformation des Flächenverbrauchs.
- Nutzung der geotopographischen ATKIS-Daten statt des Katasters für die Erstellung der Flächenstatistik.
- Wiedereinführung einer Statistik zur geplanten Flächennutzung.

Bezüglich der Homogenität gibt es in ALKIS noch zahlreiche Länderspezifika, welche die Vergleichbarkeit zwischen den Bundesländern einschränken. Einen besonders starken Einfluss auf die Flächenneuinanspruchnahme haben schon heute die Flächen für erneuerbare Energien (PV-FFA und WKA). Diese Anlagen, in der Regel im Freiraum errichtet, bewirken schon jetzt einen SuV-Zuwachs von ca. 10 ha/Tag (Walz et al. 2022). Deshalb ist eine einheitliche, flächendeckende und aktuelle Erfassung dieser

[16] https://gis.uba.de/maps/resources/apps/flaechenrechner/index.html?lang=de

Anlagen sicherzustellen und die derzeit bestehenden bundeslandspezifischen Erfassungsunterschiede zu beseitigen.

Die Einbeziehung der Primärdaten der Erhebungsbögen der Bautätigkeitsstatistik als Referenzdaten neuer Gebäude würde die Qualität der Flächenerhebung und deren Zeitreihen wesentlich verbessern (Meinel, 2017). Sie würde eine direkte objektscharfe Auswertung aller Flächenneuinanspruchnahmen ermöglichen. Leider aber wird dieses derzeit noch durch das Hochbaustatistikgesetz (HBauStatG) verhindert. Eine Einzelauswertung der primären Bauerfassungsbögen könnte neben einer verlässlicheren Bestimmung des Flächenverbrauchs auch ein wichtiger Baustein eines Gebäudemonitorings werden, das dringend gebraucht wird.

Anzustreben wäre zudem die Erstellung eines Referenzdatensatzes der Flächennutzung einschließlich dessen zyklischer Aktualisierung für eine kleine Teilfläche in Deutschland. So könnte die Güte von Flächennutzungserhebungsverfahren bestimmt werden. Mit Hilfe derartiger Referenzflächen könnte zudem ein Training neuer KI-basierter Bildklassifikatoren erfolgen.

Ein genügend genaues und belastbares Flächennutzungsmonitoring ist und bleibt eine große Herausforderung (Meinel 2023). Aber eine sichere Bewertung der Entwicklung der Flächenneuinanspruchnahme ist erst auf Grundlage langer robuster Zeitreihen möglich. Sowohl das Liegenschaftskataster ALKIS als auch das geotopographische Landschaftsmodell ATKIS sind nicht ursächlich für ein Flächennutzungsmonitoring und daraus abgeleitete Flächenstatistik konzipiert. So zeigen beide Datenmodelle Schwächen, wenn auch einige Gründe für die Nutzung geotopographischer Daten im Flächenmonitoring sprechen.

Sowohl ALKIS auch als ATKIS werden sich mit der Umsetzung der GeoInfoDok 7.1 (AdV 2023) verändern. Auch in Zukunft sind immer wieder Modelländerungen zu erwarten, da beide Modelle auch andere Aufgaben haben als die Flächenerhebung. Bei zukünftigen Modelländerungen ist stärker als bisher darauf zu achten, welche Auswirkungen diese auf die Zeitreihen des Anstiegs der SuV-Fläche haben. Denn die schleichende und vergleichsweise geringe Dynamik der Flächennutzungsänderungen erfordert ein sehr behutsames Vorgehen bei jeglichen Erhebungsveränderungen.

Die Hinzunahme der geotopographischen ATKIS-Daten für die amtliche Flächenerhebung hat im Jahr 2024 mit der Erstellung des Produkts Landnutzung begonnen. Nach der Zusammenführung der Nutzungsartenkataloge sollte darüber nachgedacht werden, ATKIS-Daten noch stärker als Grundlage der Flächenstatistik zu nutzen, denn diese sind homogener (nur 14 ATKIS im Vergleich zu 300 ALKIS-Erfassungsstellen mit bestehenden Erfassungsunterschieden), in dynamischen Veränderungsgebieten aktueller (keine verzögerte Erfassung von großflächigen Flächenveränderungen bedingt durch die Vermessung, die erst nach Abschluss der Baumaßnahme oder der Renaturierung von Bergbaugebieten erfolgt), differenzieren die Landnutzung stärker und ermöglichen die Erfassung multifunktionaler Flächennutzungen (z. B. Freiflächen-Photovoltaik), die immer mehr an Bedeutung gewinnen. Das Problem der nur linienhaften Erfassung von Straßen in ATKIS könnte durch Pufferung mit dem Attribut Straßenbreite zu Flächen behoben werden bzw. die bestehenden Straßenflächen aus ALKIS entnommen und verschnitten werden.

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🏆 reviewed paper

EVA – Evaluierung und neuer Zielekatalog für „aspern Die Seestadt Wiens“

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1 ABSTRACT

aspern Die Seestadt Wiens ist eines der größten Stadtentwicklungsprojekte Europas. Die Überlegungen zur Entwicklung des multifunktionalen Stadtteils auf dem Rollfeld des ehemaligen Flughafens Aspern im 22. Wiener Gemeindebezirk starteten bereits vor Jahrzehnten. Heute ist mehr als ein Drittel der rund 240 Hektar großen Seestadt realisiert, in den 2030er-Jahren soll sie komplett fertig gebaut werden. Am Ende werden über 11.500 Wohneinheiten und mehr als 20.000 Arbeits- und Ausbildungsplätze geschaffen sein. Für die nächsten Etappen stellt sich aspern Seestadt selbst auf den Prüfstand: die Entwicklung eines umfassenden Zielsystems ermöglicht, das bis dato Erreichte einer Zwischenbilanz zu unterziehen und die Performance der Seestadt von nun an laufend zu monitoren.

Die Evaluierung wurde entlang von zwei Säulen – Empirie und Benchmarking – durchgeführt. Der empirische Teil umfasst den Blick auf die Seestadt von außen, also wie sie wahrgenommen wird. Das Benchmarking zeigt auf, wo die Seestadt gemessen an ihren Ansprüchen und Zielen steht. Kern der Empirie war ein „Deep Dive“, bei dem über 100 Expertinnen und Experten zu ihren Einschätzungen sowie zu den Herausforderungen und Potentialen der Seestadt befragt wurden. Ergänzt wurde dies durch eine Fortführung des in den 2000er Jahren gestarteten „Markencontrollings“, einer standardisierten Befragung zum Image der Seestadt. Das Benchmarking ermöglichte eine Objektivierbarkeit der Qualitäten der Seestadt. Das zu diesem Zweck entwickelte Zielsystem umfasst neun strategische Leitziele, die über eine Reihe an Subzielen konkretisiert werden. Diesen werden Key Performance Indikatoren (KPIs) zugeordnet, welche den Stand der Zielerreichung messbar machen.

Mit EVA wurde eine fundierte Basis geschaffen, um die Performance der Seestadt im Hinblick auf eigene Projektziele wie auch übergeordnete Ziele der Stadt Wien objektiv messbar zu machen. Das Reporting soll den Fachdiskurs bezüglich nachhaltiger und zukunftsorientierter Stadtentwicklung mit einer breiten Zielgruppe, wie Developern, Investorinnen, Investoren, der Wirtschaftswelt, der österreichische und internationale Fachcommunity und nicht zuletzt auch interessierten Laien, unterstützen.

Keywords: Stadtentwicklung, Zielekatalog, Evaluierung, aspern Seestadt, Key-Performance-Indikatoren KPI

2 EIN BLICK ZURÜCK – STRATEGIE UND PLANUNGSPRINZIPIEN VON ASPERN SEESTADT

In den 1920er-Jahren war das Flugfeld Aspern einer der modernsten Flughäfen Europas. Heute, rund 100 Jahre später, ist an derselben Stelle aspern Seestadt entstanden, eines der modernsten Stadtentwicklungsprojekte Europas. Der Baustart erfolgte 2010, doch die Planungen begannen bereits in den 1990er-Jahren. Nach dem Fall des Eisernen Vorhangs wuchs der Bedarf an Wohnraum und wirtschaftlicher Infrastruktur in Wien. Zunächst scheiterte die Entwicklung jedoch an der fehlenden Verkehrsanbindung. Erst durch den „Masterplan Verkehr 2003“, der den Ausbau von U-Bahn, Bahn und Straßeninfrastruktur vorsah, wurden die Voraussetzungen für die heutige Seestadt geschaffen. 2007 wurde der Masterplan für die Entwicklung des neuen Stadtteils vom Wiener Gemeinderat einstimmig beschlossen.

Die Seestadt liegt strategisch günstig im Nordosten Wiens zwischen den „Twin Cities“ Wien und Bratislava, mitten in der wirtschaftlich und demografisch dynamischen Region Centrope. Dank der Nähe zu Bahnhöfen, Flughäfen und Stadtzentren beider Hauptstädte bietet die Seestadt enormes Potenzial. Konzipiert wurde sie als multifunktionaler Stadtteil vom schwedischen Architekturbüro Tovatt Architects & Planners. Die Kernidee: ein Mix aus Wohnbau, Gewerbe, sozialen Einrichtungen, Arbeitsstätten, Industrie und Forschungseinrichtungen. Im Zentrum des Stadtteils liegt mit dem asperner See ein künstlicher

Grundwassersee, der als Herzstück und Namensgeber dient. Dieser Erholungsraum symbolisiert ein neues Planungsprinzip: öffentlicher Raum zuerst, Gebäude danach. Rund die Hälfte der Fläche sollen später als öffentlicher Raum zugänglich sein. Die Leitlinien für sämtliche Freiraumplanungen basieren auf der „Partitur des öffentlichen Raums“ des dänischen Büros Gehl Architects.

Der Masterplan der Seestadt wurde mehrfach überarbeitet und setzt klare Leitlinien: Der öffentliche Raum soll eine hohe Aufenthaltsqualität bieten, flexibel nutzbar und ansprechend gestaltet sein. Ein vielfältiges Angebot soll unterschiedliche Lebens- und Arbeitsformen ermöglichen, während lebendige Erdgeschoßzonen und nutzungsoffene Gebäude für nachhaltige Quartiere sorgen. Zudem wird auf Klimaschutz, Ressourcenschonung und energieeffizientes Bauen Wert gelegt. Ziel ist es, mehr Energie vor Ort zu produzieren, als verbraucht wird. Auch die Mobilität ist ausbalanciert: umweltfreundliche Verkehrsmittel werden gefördert, während der Autoverkehr reduziert wird.

Die Seestadt sollte seit jeher als regionales Zentrum der Donaustadt fungieren. Heute liegt sie als Zentrum an der Entwicklungsachse U2. Diese befindet sich in stetem Wachstum, nicht nur was die Bevölkerung betrifft. Auch die Wirtschaft hat den Standort entdeckt und schafft laufend neue Arbeits- und Ausbildungsplätze, die nördlich der Donau dringend gebraucht werden. Federführend bei der Entwicklung der Seestadt ist die eigens zu diesem Zweck gegründete Entwicklungsgesellschaft Wien 3420 aspern Development AG, ein Public-Private Partnership, das Städtebau, Infrastruktur, Investorinnen und Investoren koordiniert.

3 STADTENTWICKLUNG MESSBAR MACHEN

Für die Entwicklung von aspern Seestadt wurde von Beginn an ein umfangreiches Zielsystem mit begleitenden Instrumenten für das Qualitätsmanagement entwickelt. Dazu gehören unter anderem der Masterplan, die Ziele und Prinzipien einer qualitätsvollen Stadtteilentwicklung, die Smart City Leitlinien für die Seestadt sowie baufeldbezogene Qualitätsvorgaben. Darüber hinaus orientiert sich das Projekt an den Strategien der Stadt Wien, insbesondere an der Smart City Strategie, dem Stadtentwicklungsplan STEP 2025 und den zugehörigen Fachkonzepten, die als Rahmen für die städtebauliche Entwicklung dienen. In den letzten Jahren wurde diese Grundlage durch die IBA_Wien (Internationale Bauausstellung) ergänzt, die für ausgewählte Quartiere und Projekte spezifische Qualitäten sicherstellt.

Das so entstandene Zielsystem zeichnet sich durch eine große inhaltliche Breite aus, was dem Anspruch der Seestadt gerecht wird, auf nahezu allen Ebenen der innovativen, nachhaltigen und zukunftsorientierten Stadtentwicklung als Vorzeigeprojekt zu gelten. Die Mehrdimensionalität und Detailtiefe der Zielsetzungen bringt jedoch auch Herausforderungen mit sich. Einerseits besteht die Gefahr, im Laufe des langjährigen Entwicklungsprozesses die „großen Linien“ und übergeordneten Leitideen aus den Augen zu verlieren. Andererseits wird es zunehmend schwieriger, nach außen klar zu kommunizieren, was die Seestadt im Kern ausmacht und worin ihre Hauptmerkmale liegen.

Vor diesem Hintergrund initiierte die Wien 3420 eine umfassende Strategie-Evaluierung zur Seestadt. Ziel war es, eine kritische Zwischenbilanz zu ziehen und daraus strategische Leitlinien für die kommenden Entwicklungsphasen abzuleiten. Im Rahmen der Evaluierung (EVA) im Jahr 2022 wurde der aktuelle Stand analysiert. Aufbauend darauf entstand 2023/2024 ein neues Zielsystem, das mit dem klaren Commitment verbunden ist, die erreichten Fortschritte zukünftig kontinuierlich zu überwachen und zu dokumentieren. Dieses Monitoring soll sicherstellen, dass die Seestadt weiterhin als Modellprojekt für innovative und nachhaltige Stadtentwicklung gilt und ihre langfristigen Visionen bewahrt.

3.1 Strategie-Evaluierung: Prozess und Methodik

Die Strategie-Evaluierung für aspern Seestadt wurde auf zwei zentrale Säulen gestützt: Empirie und Benchmarking.

Die Säule Empirie umfasste einen „Deep Dive“, bei dem die Entwicklungsansätze und Qualitäten der Seestadt durch Expertinnen-, Experten- und Stakeholder-Gruppen analysiert wurden. Über 100 Expertinnen und Experten wurden in Fokusgruppengespräche und 30 Einzelinterviews eingebunden. Das Ergebnis ist ein umfassender Überblick über aktuelle Stärken, Potenziale und Herausforderungen der Seestadt aus Expertensicht.

Das Benchmarking hingegen diente dazu, die Performance von aspern Seestadt objektiver zu bewerten. Ein zentraler Output war die Entwicklung von Key Performance Indicators (KPI). Diese ermöglichen die

Ausrichtung und Bewertung der Projektentwicklung und sollen künftig unter dem Motto „Daran sollt ihr uns messen“ transparent gemacht werden. Die KPIs erfüllen mehrere wichtige Funktionen:

- Strategische Prioritätensetzung: Durch die Auswahl weniger, aber zentraler Indikatoren wird der Fokus auf die wichtigsten Erfolgsfaktoren gelegt.
- Grundlage für Steuerung: Die regelmäßige Erhebung der KPIs macht Entwicklungen sichtbar und schafft eine evidenzbasierte Entscheidungsgrundlage.
- Werkzeug für Kooperation: KPIs fördern Transparenz und Verbindlichkeit für eine abgestimmte Umsetzung zwischen den verschiedenen Akteurinnen und Akteuren, die an der Seestadt-Entwicklung beteiligt sind.
- Kommunikationsinstrument: Sie ermöglichen eine klare Kommunikation priorisierter Ziele und Fortschritte im öffentlichen Diskurs.

KPIs allein ersetzen jedoch keine Strategie, sondern müssen in ein übergeordnetes Zielsystem eingebettet sein. Dieses Zielsystem wurde im Rahmen der Evaluierung auf Basis der Erkenntnisse aus dem „Deep Dive“ angepasst, um neue Herausforderungen und Ambitionen zu berücksichtigen. Auch internationale Vergleichsprojekte wurden analysiert, um das KPI-Set zu bereichern und eine globale Vergleichbarkeit zu ermöglichen.

Als Ausgangspunkt der Zwischenbilanz wurden über 25 Strategiepapiere und Dokumente analysiert. Dabei wurden acht zentrale Handlungsfelder definiert, die in den „Deep Dive“-Prozess eingeflossen sind. Zur Vorbereitung wurden auch Daten aus dem sogenannten Markencontrolling genutzt, darunter ein Besiedelungsmonitoring, das die Wohnzufriedenheit in der Seestadt wissenschaftlich untersucht. Diese Untersuchung wurde bereits 2015, 2019 und zuletzt 2022 durchgeführt. Ergänzt wurde dies durch Umfragen zur Wahrnehmung der Seestadt bei Bewohnerinnen, Bewohnern und Betrieben innerhalb und außerhalb des Stadtteils sowie durch eine Medienresonanzanalyse und Erhebungen zur wirtschaftlichen Entwicklung.

Insgesamt waren 116 Personen in den „Deep Dive“ involviert. Neben 30 Einzelinterviews fanden elf Fokusgruppengespräche statt. Zu jedem der acht Handlungsfelder wurden Qualitäten, Potenziale und Herausforderungen der Seestadt herausgearbeitet.

Abschließend wurde das neue Zielsystem in einem intensiven Diskussionsprozess mit dem Team der Wien 3420, dem aspern Beirat und externen Expertinnen und Experten abgestimmt. Dieses Zielsystem bildet die Grundlage, um aspern Seestadt auch künftig als innovativen und zukunftsorientierten Stadtteil zu entwickeln.

3.2 Internationale Vorbilder

Bei der Entwicklung des KPI-Systems von aspern Seestadt dienten auch ausgewählte internationale Stadtentwicklungsgebiete, die sich einem ähnlich ambitionierten Weg der Erfolgsmessung von urbaner Quartiersentwicklung verschrieben haben, als Inspiration, darunter London (Olympic Legacy), Paris (Clichy-Batignolles), Kopenhagen (Nordhavn), Stockholm (Royal Seaport) und Freiburg (Dietenbach). Diese Referenzgebiete befinden sich in unterschiedlichen Entwicklungsphasen, von der Planung bis hin zur fast vollständigen Fertigstellung. Erkenntnisse aus der Analyse:

- Einbettung in Zielsysteme: In allen untersuchten Projekten sind die KPIs Teil eines umfassenden Zielsystems. Übergeordnete Ziele werden oft durch Subziele und konkrete Indikatoren präzisiert.
- Unterschiedliche Komplexität: Die Zahl der KPIs variiert stark: Kopenhagen arbeitet mit 12 KPIs, während London knapp 50 und Stockholm über 50 Indikatoren einsetzt.
- Referenz auf gesamtstädtische KPIs: London verknüpft das KPI-System mit dem übergeordneten „London Plan“, der für Stadtteile ein individuelles Monitoring vorsieht.
- Steuerung und Kommunikation: KPIs dienen sowohl der internen Steuerung als auch der Außenkommunikation. Kopenhagen und Stockholm konzentrieren sich in ihrer Kommunikation auf positive Ergebnisse, um Fortschritte hervorzuheben.
- Monitoring-Rhythmus: In den untersuchten Projekten werden jährlich umfassende Monitoring-Berichte erstellt. Dies ermöglicht ein rasches Reagieren auf Fehlentwicklungen und die Verstärkung positiver Trends.

Die internationale Analyse belegte, dass ein gut durchdachtes KPI-System nicht nur der Steuerung dient, sondern auch ein wirkungsvolles Werkzeug für die Kommunikation der Erfolge und Ambitionen eines Stadtentwicklungsprojekts ist.

4 EVA-ZIELEKATALOG NEU – STRATEGISCHE ZIELE, SUBZIELE UND KPIS

Innerhalb der Handlungsfelder wurden neun strategische Leitziele erarbeitet und jeweils in einer Reihe von „Subzielen“ konkretisiert. Den Subzielen sind wiederum Key Performance Indicators (KPIs) zugeordnet, die den Stand der Zielerreichung mess- beziehungsweise beurteilbar machen.

Für die kommenden Umsetzungsetappen ist ein periodisches Monitoring des Entwicklungsfortschritts der Seestadt entlang der definierten Ziele und KPI vorgesehen. Um eine größtmögliche Vergleichbarkeit der Monitoring-Ergebnisse im Zeitverlauf sicherzustellen und Unschärfen durch subjektive Interpretationen gering zu halten, definiert ein Monitoring-Handbuch für jeden KPI die exakte Erhebungsmethodik, einen angestrebten Zielwert und Entwicklungspfad dorthin.

Strategisches Ziel 1	**Der öffentliche Raum ist hochwertig, klimaresilient und interagiert mit privaten Räumen.**
Subziel	Der öffentliche Raum in aspern Seestadt ist inklusiv und qualitätsvoll gestaltet; die Menschen halten sich gerne im öffentlichen Raum auf. KPI Subjektive Wahrnehmung der Qualität des öffentlichen Raums
Subziel	Die Gestaltung des öffentlichen Raums reduziert Hitzeinseln. KPI Versiegelungsgrad im öffentlichen Gut KPI Beschattung auf allen relevanten Wegerelationen im öffentlichen Raum KPI Überschirmungsgrad durch ausgewachsene Bäume im öffentlichen Gut
Strategisches Ziel 2	**aspern Seestadt bietet allen Personen, die hier leben und arbeiten, eine hohe Lebensqualität und die Möglichkeit, das Alltagsleben gut und komfortabel zu gestalten.**
Subziel	Die Bewohnerinnen und Bewohner leben gerne in der Seestadt. KPI Wohnzufriedenheit KPI Qualität des Zusammenlebens KPI Wahrgenommene Sicherheit
Subziel	aspern Seestadt bietet ein angenehmes Arbeitsumfeld für alle Formen der Arbeit. KPI Gesamteindruck der hier Beschäftigten von der Seestadt
Subziel	Die Seestadt bietet ein gesundheitsförderndes Umfeld. KPI Spiel-, Bewegungs- und Sportplätze, die allen Bewohnerinnen, Bewohnern, Besucherinnen und Besuchern zur Verfügung stehen KPI Niedergelassene Ärztinnen, Ärzte und gesundheitsnahe Dienstleister KPI Möglichkeiten für Urban Gardening
Subziel	Der Wohnraum in aspern Seestadt ist vielfältig und leistbar. KPI Anteil leistbarer Wohnbau an der gesamten Wohnnutzfläche KPI Realisierte Sonderwohnformen KPI Vielfalt von Wohntypen
Strategisches Ziel 3	**aspern Seestadt zeigt als Klimamusterstadtteil vor, wie die Wiener Klimaziele erreicht werden können, schafft die Voraussetzungen für einen nachhaltigen Lebensstil und geht sorgsam mit den Ressourcen um.**
Subziel	Ein schonender Umgang mit der Ressource Boden zeichnet aspern Seestadt aus. KPI Flächeninanspruchnahme pro Einwohnerin oder Einwohner
Subziel	Alle Quartiere und Gebäude in der Seestadt sind in der Lage, die Wiener Smart City Klimaziele und die Vorgaben der EU-Taxonomie hinsichtlich Klimaschutz zu erfüllen. Der aspern klimafit-Standard schafft die Voraussetzungen im Neubau, der Bestand wird laufend nachgerüstet und ertüchtigt. KPI Tatsächlicher Endenergieverbrauch der Gebäude KPI Jährliche Stromproduktion aus Photovoltaik am Gebäude KPI Energieaufbringung für Gebäudeheizung und -kühlung aus erneuerbaren Quellen KPI Graues CO2 bzw. graue Energie in Gebäuden (für zukünftige Bauvorhaben/in progress:

	Zielwerte und Erhebungsmethodiken in Abstimmung mit öffentlicher Verwaltung, Forschung und Bauträgern)
Subziel	aspern Seestadt steht für Rückbau- und Recyclingfreundlichkeit von Gebäuden und von Materialien im öffentlichen Raum. KPI Umnutzbarkeit bzw. Rückbau- und Recyclingfreundlichkeit von Gebäuden und Materialien KPI Anteil von Recycling- (bzw. Re-use-) Material im Neubau (für zukünftige Bauvorhaben/in progress: Zielwerte und Erhebungsmethodiken in Abstimmung mit öffentlicher Verwaltung, Forschung und Bauträgern)
Strategisches Ziel 4	**aspern Seestadt ist Vorbild für die Klimawandelanpassung und den Erhalt der Biodiversität.**
Subziel	In aspern Seestadt gelingt die Verbindung zwischen Urbanität und Natur. KPI Grünflächenanteil von aspern Seestadt (Straßen, Plätze, Parks, bebaute Baufelder und Grüngürtel) KPI Grün- und Freiflächenfaktor von Baufeldern
Subziel	Die Seestadt weist eine hohe ökologische Resilienz gegenüber den Auswirkungen des Klimawandels auf. KPI Anteil der Flächen, die ermöglichen, dass Regenwasser vor Ort versickert oder zur Bewässerung gesammelt werden kann KPI Artenvielfalt im öffentlich zugänglichen Raum
Subziel	Durch vorausschauende Planung sind in der Seestadt alle Menschen vor übermäßigen Hitzebelastungen geschützt. KPI Gebäude mit außenliegendem Sonnenschutz KPI Überschirmungsgrad durch ausgewachsene Bäume im öffentlichen Gut KPI Beschattung auf allen relevanten Wegerelationen im öffentlichen Raum KPI Erreichbarkeit von hochqualitativen Grünflächen im öffentlichen Raum KPI Versiegelungsgrad im öffentlichen Gut
Strategisches Ziel 5	**aspern Seestadt ist lebendig, urban und zeichnet sich durch hohe architektonische Qualität und Vielfalt im Stadtbild aus.**
Subziel	Eine professionelle Wettbewerbs- und Baukultur sichert ein qualitätsvolles Stadtbild. KPI Anteil von Bauplätzen, die bei Verkauf über städtebauliche Leitbilder, ein standortbezogenes Quartiersprofil und/oder einen vertraglich überbundenen Qualitätenkatalog verfügen KPI Anteil an Bauplätzen, deren Qualität durch Wettbewerbe (o.Ä.) gesichert ist auf Basis von Leitbildern, Quartiersprofilen, Qualitätenkatalogen KPI Anteil der Projekte, die bis in die Umsetzung vom aspern Beirat auf Zielerreichung überprüft werden
Subziel	Nutzungsmischung und Nutzungsoffenheit sind Grundprinzipien der Seestadtstruktur. KPI Anteil der Nicht-Wohnnutzungen auf Baufeldern mit Wohnen KPI Realisierte Sonderwohnformen
Strategisches Ziel 6	**aspern Seestadt ist ein Businessstandort, der inspiriert und für Fortschritt, Innovation und Pioniergeist steht.**
Subziel	aspern Seestadt bietet Unternehmen in deren unterschiedlichen Entwicklungsphasen ein dynamisches Umfeld. KPI Bis zum Ende der Bauzeit werden ca. 20 000 Arbeits- und Ausbildungsplätze geschaffen KPI Anzahl Betriebsansiedlungen national und international
Subziel	Die Seestadt ist attraktiver Standort für Life Science und Industrie 4.0. KPI Anzahl branchenspezifischer Betriebsansiedlungen
Strategisches Ziel 7	**aspern Seestadt garantiert eine CO2-arme, stadtverträgliche, komfortable und sichere Mobilität.**
Subziel	aspern Seestadt und das Umfeld sind gut im Umweltbund vernetzt. KPI Modal Split der Bewohnerinnen und Bewohner KPI Motorisierungsgrad der Bewohnerinnen und Bewohner KPI Differenzierte Sharing-Angebote pro Bewohnerin oder Bewohner

	KPI Anzahl Fahrrad-Abstellplätze KPI Erreichbarkeit der Seestadt aus dem Umfeld und vice versa mit dem Rad bzw. dem ÖV
Subziel	Der Arbeits- und Wirtschaftsverkehr in der Seestadt ist bis 2030 weitgehend CO2-frei. KPI Anteil der neuen „Seestadt-Betriebe“ mit über 20 Mitarbeiterinnen^und Mitarbeitern, die ein betriebliches Mobilitätsmanagement umsetzen KPI Anteil der neuen Unternehmen in der Seestadt, die Maßnahmen für CO2-freie Logistik-Verkehre umsetzen KPI Abdeckung mit White Label Paketboxen
Subziel	Wege können in der Seestadt sicher zurückgelegt werden. KPI Verunglückte im Straßenverkehr KPI Barrierefreiheit im öffentlichen Raum
Subziel	Die Organisation des ruhenden Kfz-Verkehrs wird im Sinne der Mobilität im Umweltverbund optimiert. KPI Anzahl der dauerhaften Stellplätze im öffentlichen Raum KPI Anzahl von innovativen Pilotprojekten für autoreduziertes Wohnen
Strategisches Ziel 8	**aspern Seestadt ist ein nutzungsgemischter Stadtteil, der mit dem städtischen und regionalen Umfeld vernetzt ist und weit über seine Grenzen hinaus wirkt.**
Subziel	aspern Seestadt ist ein Hauptzentrum der Donaustadt und weist einen vielfältigen Angebotsmix auf. KPI Branchenmix und Nahversorgung in aspern Seestadt KPI Passantinnen- und Passantenfrequenz an ausgewählten Punkten KPI Hohe Kaufkraftbindung innerhalb des Standorts KPI Leerstandsquote
Subziel	Die Seestadt ist attraktiv für die Marchfelder Bevölkerung und Wirtschaft. KPI Beschäftigte, die aus der Region kommen (Transdanubien und angrenzende Bezirke in NÖ) KPI Kundinnen und Kunden, die aus der Region kommen (Transdanubien und angrenzende Bezirke in NÖ)
Strategisches Ziel 9	**aspern Seestadt ist lokal und international als Vorzeigestadt mit Mut zum Experiment anerkannt.**
Subziel	aspern Seestadt hat eine unverwechselbare Marke als Urban Lab für die Smart City Wien mit ausgeprägten Stärkefeldern und hoher Sichtbarkeit. KPI Positive Konnotationen zur Seestadt KPI Positive Medienrezension
Subziel	aspern Seestadt ist ein attraktiver Ort für Events und ein Ort, der Besucherinnen und Besucherinspiriert. KPI Besucherinnen- und Besuchergruppen in der Seestadt KPI Events in der Seestadt
Subziel	Ko-Kreation trägt zur Identitätsbildung bei. KPI Identifikation mit der Seestadt als Ort, wo man seine Ideen einbringen kann KPI Bereitstellung von Räumen für Ko-Kreation

Tabelle 1: Übersicht EVA Zielsystem inkl. Key Performance Indikatoren

5 FAZIT UND AUSBLICK

Der Rahmen ist gesetzt, der erste Schritt getan. Ein initialies Pilotreporting ausgewählter KPIs liegt vor und bildet die Grundlage für das künftige langristig laufende Monitoring.

Das Monitoring ist als „Work in Progress“ zu sehen – nicht alle KPIs konnten von Beginn an erhoben werden, da einige erst in späteren Entwicklungsphasen relevant werden. Wie das Stadtentwicklungsprojekt selbst ist auch die Strategie-Evaluierung ambitioniert. Mit EVA stellt sich die Seestadt bewusst auf den Prüfstand und ermöglicht einen „Blick in die Werkstatt“.

Das Pilotmonitoring zeigt: Die Seestadt entwickelt sich in vielen Bereichen gut, teils sogar sehr gut. Aber es ist klar: es gibt Verbesserungspotenzial., insbesondere in der Außenwahrnehmung. Während Seestädterinnen

und Seestädter ihre Lebensqualität schätzen, ist das Image bei Außenstehenden weniger positiv. Auch Wirtschaftstreibende vor Ort sehen die Entwicklung grundsätzlich positiv, wenn auch mit kritischem Blick.

Die Erfahrungen zeigen, dass rein quantitative Analysen nicht ausreichen. Ergebnisse müssen kontextualisiert und qualitativ interpretiert werden. Denn es ist wichtig zu reflektieren, warum Ziele erreicht bzw. nicht erreicht wurden oder Ergebnisse im Hinblick auf das Erreichen des Anspruches, der in den Sub-Zielen formuliert wurde, abzuwägen.

Transparenz ist essenziell für Glaubwürdigkeit und Akzeptanz. Eine offene Kommunikation der Ergebnisse stärkt die Seestadt als Vorbild und Innovationsmotor. Neben dem laufenden Monitoring sollte in größeren Zeitabständen auch eine strategische Reflexion, Etwa in Form eines komprimierten „Deep Dives“ zur Anpassung und Weiterentwicklung der Ziele erfolgen.

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reviewed paper

Evaluating the Effectiveness of Spatial Development Policies in Promoting Spatial Justice and Integration in Johannesburg

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1 ABSTRACT

This paper investigates the effectiveness of spatial development policies in addressing spatial inequalities in the City of Johannesburg (CoJ), a city marked by historical exclusion and segregation. Despite efforts through Integrated Development Plans (IDPs) and Spatial Development Frameworks (SDFs) to promote spatial justice and integration, significant disparities still persist, particularly for marginalised communities who continue to face barriers to essential resources such as housing, transport, and public services. By analysing the evolution and implementation of these policies, the research revealed that while they aimed to rectify historical injustices, their impact remains uneven. The study contextualised spatial justice within broader social and economic transformations, examining how urban policies interact with power dynamics and resource distribution to affect the residents' daily lives. The findings underscored ongoing challenges related to urban inclusion and exclusion, highlighting the disconnect between policy objectives and real-world outcomes. The paper advocates for transformative approaches that prioritise participatory governance and equitable resource distribution as critical components of sustainable urban planning. Ultimately, this research enhances the understanding of spatial justice complexities and contributes to discussions on fostering more integrated and just urban environments in cities facing similar spatial challenges.

Keywords: spatial development, spatial justice, integrated development planning, urban governance, Johannesburg

2 INTRODUCTION

The CoJ remains a manifestation of old apartheid geographical planning, where race, class, and spatial locations were isolated one from the opportunity to have access to housing, transport, and economic opportunities. Johannesburg, or Joburg as it is commonly known, was established in 1886, following the discovery of gold. Not only did it develop rapidly from a small mining town to a thriving city, but also made significant contributions to the national markets (Beavon, 2004; O'Meara, 1996; Roodt, 2012).While the CoJ is characterised as one of the most economically affluent neighborhoods in Africa, there also exist areas of abject poverty in informal settlements and townships, as well asinformal settlements such as Diepsloot which are located close to the wealthy neighborhood of Steyn City (Huchzermeyer, 2004). These areas face persistent struggles due to decades of intentional socio-spatial division that has its roots in colonial/apartheid spatial planning, as well as the post-1994 inefficiencies in urban governance (Mabin, 1990; Parnell and Pieterse, 2010; Turok, 2016).

This colonial/apartheid racial planning legacy has resulted in the creation of Johannesburg and other South African cities as arguably the world's most spatially divided cities, where social, economic, and environmental inequalities continue to define the urban landscape (Bremner, 2000; Nleya, 2017; Turok and Visser, 2018).While policies that are aimed to remedy these inequalities such as the IDPs, theSDFs, and the Integrated Urban Development Framework aim to address these gross disparities, many residents of Johannesburg still experience exclusion and economic marginalisation (CoJ, 2021).It ultimately justified the promotion of spatial justice through higher levels of infrastructure, affordable housing, urban regeneration, and the reintegration of informal settlements (Harrison and Todes, 2017; Parnell, 2019; Sutherland, 2020). Beyond access to services, spatial justice advocates for equitable access to resources and a voice in the economy and community (Soja, 2010).However, the apartheid-era segregation is still apparent in many of our communities that are still without reliable public transport, opportunities work work, and access to education. This exacerbates rather than ameliorating socio-economic inequalities (Mabin, 2020).

This study undertook a qualitative research approach, which is appropriate for understanding complex social problems such as spatial justice and urban planning (Creswell, 2013). This approach enables an exploration of policy formation, policy implementation, and policy perceptions, particularly about the complexities of an urban environment such as that of the CoJ.This research specifically used content analysis as the method of analysis to be applied to key spatial policy documents. In this capacity, it will help reveal how spatial justice, alongside urban integration, is conceived and accounted for within the CoJ's strategic intent and projects outlined in these documents.This method will contribute to understanding the trajectory and prominence of commitments towards spatial inequalities and consolidating cities through the analysis of the rhetoric, priorities, and strategic direction enshrined in these documents.

3 STUDY AREA

The CoJis a metropolitan municipality, and one of the three metros located in the Gauteng province. It is also the largest metropolitan municipality in South Africa (Johannesburg City Profile, 2020). With the fastest-growing urban area on the continent with over 5.6 million people (Statistics South Africa, 2022), it is South Africa's most populated city.The city boasts exceptional infrastructure such as world-class telecommunications, transport, water, and electricity, in addition to world-class healthcare and education.The city has a diverse range of ethnic groups, which are broadly reflective of the national demographic, including those identified as African, White, Coloured, and Indian/Asian. The majority of the people, about 80% of the city's residents, have African roots. The rest of the population blends well with the existing cultural fabric of the city(CoJ, 2021).

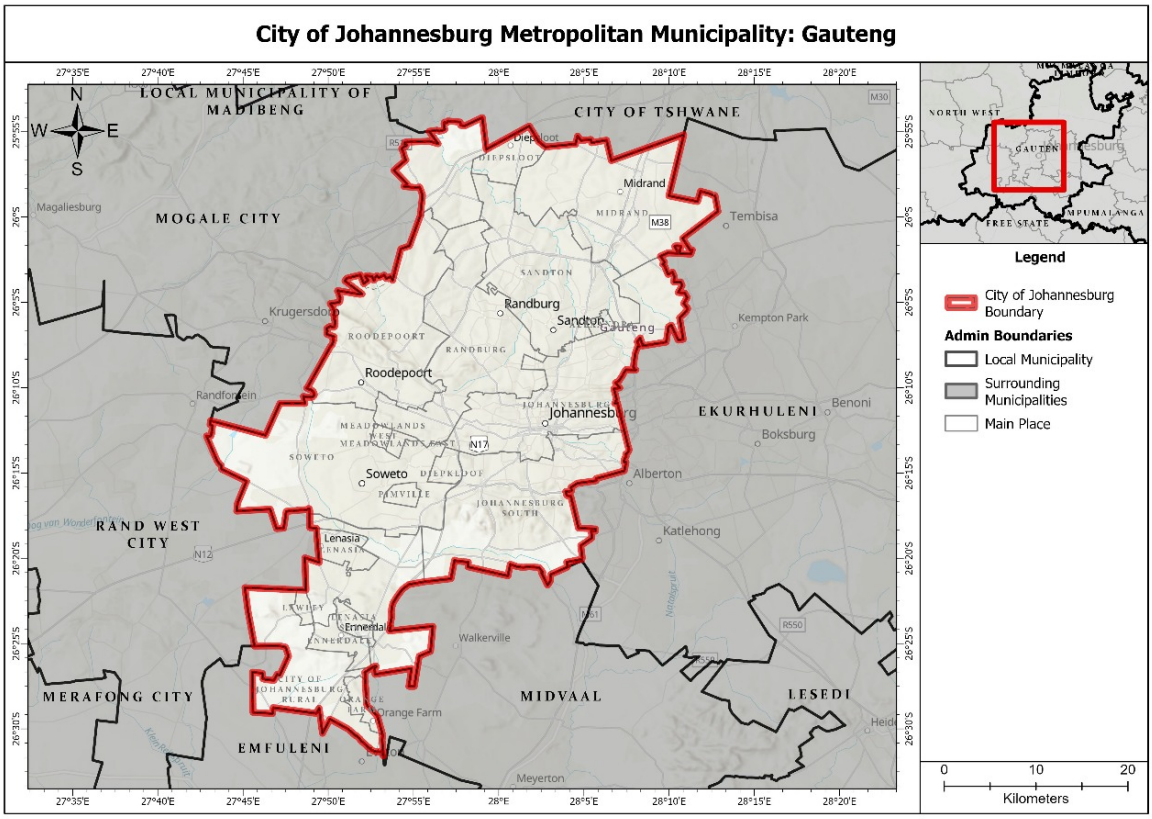

Fig. 1: Locality map showing the study area

Johannesburg has to reconcile its practices around urban development and spatial planning with a history of inequalities and the need to sustain urban growth. For example, the apartheid legacy in South Africa has heavily influenced the spatial configuration of cities characterised by segregation, uneven development, and poor access to resources for impoverished groups (Turok, 2016).To overcome the above-mentioned challenges, a plethora of policies which are referred tospatial development policies have emerged with the purpose of fostering spatial justice and integration. This study examined how these policies have fared in terms of inclusivity, equity, and balanced growth in the CoJ.

The spatial disposition of Johannesburg is informed by the sociopolitical landscape of South Africa, more specifically the apartheid era (1948–1994). This resulted in stark racial segregation, an apartheid tool for control and marginalisation of the non-white majority that informed the urban planning vision. Policies such as the Group Areas Act dictated people's residency in a segregated urban landscape, with separate public services available for each group, effectively creating a well-resourced, predominantly white city, next to townships that housed non-white communities (Creswell, 2013).This history has proven spatial injustices embodied in walls that segregate communities along racial and class lines, unequal allocation of resources, and large discrepancies in infrastructure, public amenities, and economic opportunities in disparate neighborhoods (Harrison and Todes, 2017). Moreover, the lack of an efficient model of public transport hinders disadvantaged communities from accessing their jobs and social services.

4 SPATIAL JUSTICE IN JOHANNESBURG'S SPATIAL TRANSFORMATION POLICIES

Scholars such as Harrison et al. (2019) and Robins (2018)stated that in Johannesburg, spatial transformation has been a key policy objective since the end of apartheid, as the city sought to address the spatial inequalities rooted by decades of racially discriminatory urban planning. Furthermore, in Johannesburg, spatial transformation has been one of the primary objectives of post-apartheid policy as the city strives to overcome and address the spatial inequalities that were compounded by years of racially discriminatory urban planning. The spatial planning of the apartheid state was manifestly evident through legislation such as the Group Areas Act of 1950 that forcibly segregated urban space, relocating non-white people into township peripheries, leaving the city centre and white northern suburbs for the whites(Makhura, 2020; Nleya, 2017; Turok, 2016). The end result is a deeply segregated city, marked by a geographic distribution of socio-economic opportunities and unequal access to essential services such as housing, jobs, and transport.However, post-apartheid space policy (for example, the IDP and the SDF) has sought to address the legacy of spatial inequality, mainly through the promotion of spatial justice via urban integration, mobility, and equitable access to services (Harrison et al., 2019). One such policy approach introduced was the Corridors of Freedom initiative, which aimed to dissolve the spatial restrictions of apartheid by establishing transit-orientated development corridors linking peripheral areas to economic centres, thus improving marginalised populations' access to jobs and services (Tomlinson, 2018). This was an effort to try to connect the direct economic regeneration of space back to the notion of social justice in space, to make sure the communities that had historically been excluded were brought into the socio-economic mainstream of the city.

Besides the IDP and SDF, the spatial development of Johannesburg was informed by various policies such as the Growing Gauteng Together 2030, the Gauteng Environmental Management Framework, the 25-year Gauteng Integrated Transport Master Plan, the Gauteng SDF 2030, and the Johannesburg Growth and Development Strategy 2040. The Growing Gauteng Together 2030 focused on the regeneration of townships and transit-orientated development, but does not radically change spatial inequalities. Also, the Gauteng Environmental Management Framework does guide land usage, referring to the structure of land used for the production of disclosure services, such as agriculture, tourism, and industry;however, it is not actually a tool for spatial restructuring but is more like a regulatory system. Moreover, there are the 25-year Gauteng Integrated Transport Master Planthat focusseson effective and efficient transport connectivity between residential and economic zones, and thestratigraphies of ecologies of scale: the SDF – Good Soil Development Facilitator. The Growth and Development Strategy 2040, however, is an aspirational document, and its plans for moving beyond deep inequalities are modest (SDF 2040, 2024).

Overall, these spatial plans are well linked to the national and provincial frameworks, but there are limits to their efficacy in enabling transformative spatial outcomes. According to Berrisford (2021), the CoJ'spolicies have had some positive impact, but fragmented governance, financial limitations, and market-mediated gentrification continue to limit their effectiveness. Gentrification, as an unintentional consequence, has been a significant driver of a central polemic in the spatial transformation–spatial justice nexus: the material enhancement of infrastructure can make neighborhoods more connected and accessible for some but can also increase property values, leading to the displacement of poorer neighborhood residents from areas activated for development (Tomlinson, 2018). Such displacement undermines the broader pursuit of spatial justice, whereby marginalised populations are pushed further outside of important spaces, reinforcing cycles of spatial exclusion.

Informality remains one of the most urgent concerns regarding the relationship between Johannesburg's spatial transformation and spatial justice. These include settlements such as Alexandra, Diepsloot, and Ivory Park, which accommodate a large percentage of the low-income population of Johannesburg and are typified by poor access to basic services, insecure land tenure, and limited access to economic opportunities (SACN, 2020). Johannesburg's spatial policies have sought to formalise and integrate these settlements into the wider urban fabric, but progress has been slow, and precarious living remains the default for many residents. The battle of informal settlements remains a key obstacle to spatial justice in Johannesburg. As asserted by Turok (2016), spatial justice will not be achieved without addressing the housing needs of those living in informal settlements, who are among the most spatially marginalised groups in the city. Meanwhile, efforts to regularise these settlements often meet resistance from both residents and the state: upgrading infrastructure and service provision involves a high cost, and many informal settlers would prefer to keep their homes if their settlements are regularised. This mimics broader tensions in spatial justice discussions, such as how to balance the short-term needs of marginalised communities (CoJ, 2020); and what spatial transformation should look like in the long run.

The plans are central tools through which the city confronts the structural challenges it faces and are updated over time to embody the city's changing strategic priorities. This means the city will address issues like spatial segregation, economic inequality, and equal access to essential public services, through these plans. Grounded in their location and their impatience to build a just society, the desire for integration and transformation from the heritage of apartheid, they were meant to unmake and remake Johannesburg as a more connected, spatially just, and integrated city. But the impact of these policies and strategies is contested; it is important to interrogate their effects on spatial justice and urban integration.

5 CONTENT ANALYSIS OF JOHANNESBURG'S SPATIAL PLANNING TOOLS

5.1 City of Johannesburg Integrated Development Plan 2016–2021

The IDP 2016–2021 was meant to tackle these spatial inequalities through interventions such as the Corridors of Freedom and transit-orientated development.These are strategies that aimed to change the apartheid-era settlement of the city by consolidating high-density housing and mixed-use developments around public transport corridors.Intended to enable accessibility and promote spatial justice by connecting historically disadvantaged communities to economic opportunity, the initiative sought to create equitable access to transport systems.These existing policies, overall, enhanced the urban fabric in terms of connectivity due to the investment in the Rea Vaya BRT (Bus Rapid Transit) systemand the Gautrain stations, although the spatial and socio-economic inclusiveness of such developments were not universally experienced across the entire landscape.

Housing development mentioned preceded focus, especially in places like Diepsloot, Zandspruit, and Soweto, over informal settlements and overcrowding. The IDP also aimed to expedite affordable housing delivery by using public–private partnerships as a funding supplement to the government. However, the strategy was incomplete as adequate infrastructure was not provided, while delivery rates were slow, which further restricted living standards.Many low-income communities ended up far from economic centres, aggravating spatial inequalities, not alleviating them. This was further compounded by the introduction of a small number of mixed-income housing projects that never attracted the level of private sector investment necessary to create fully integrated communities, resulting in continued segregation by status and race.The IDP also emphasised infrastructure investment in marginalised areas, especially Soweto, Orange Farm, and Diepsloot. These neighborhoods, which have in the past been excluded from essential services, had been marked for upgrades in transport, water, sanitation, and energy supply.While there was extensive investment and some gains were made, infrastructure development always played catch-up to population growth, decreasing the overall effectiveness of these investments. In Diepsloot, for instance, "rapid urban expansion outstripped service delivery", resulting in a "pervasive struggle for resources" and deteriorating living conditions.This disconnect of infrastructure in these regions resulted in the unreliability of electricity supply and road conditions, which hampered economic opportunities as they would not encourage business developments, infrastructure establishments, and investment.

The IDP also specifically concentrated on service delivery in Soweto, Alexandra, and Orange Farm, with the aim of boosting local economic development. Although these initiatives sought to incorporate townships into

the formal urban structure, inequalities persisted. Specifically, there was more development of the private sector in richer areas, such as Sandton, but less development of the private sector in townships.Such spatial inequalities were exacerbated as job opportunities and investments continued to cluster in areas that have always benefited from the machinery of planning, and the IDP, rather than ameliorating this inequity, perpetuated it. The absence of concrete land planning worsened these issues, as some of the people living in informal settlements still lacked any kind of formal development, increasing the vicious cycle of informality and marginalisation.

One of the main components of the IDP was to expand the public transport system as a way to improve the linkages between the peripheral townships and the economic centres. The Rea Vaya BRT system was expandedin an effort to be more accessible and help residents of low-income areas cut costs. However few routes were covered, which resulted in many areas being disconnected, such as Midrand, Lenasia, and Fourways.Even worse, without a fully integrated and expansive transit network, true spatial transformation for Johannesburg is unlikely to ever be achieved. Moreover, due to the inefficiencies and financial sustainability issues of public transport systems, they were also unable to induce substantial spatial restructuring, with many residents continuing to rely on informal and unreliable transport modes.

Figure 2 shows the number of land development applications within 1 km of each 400 m hexagon used in the Nodal Review policy. The figure also shows that formal development is limited in some areas, especially in previously Black-only townships like Soweto. It compares the location of land use applications over two periods: the six years before the 2016 SDF and the six years thereafter. This provides a visual representation of major trends, such as increased development around key urban nodes located in the already affluent northern parts of the city.

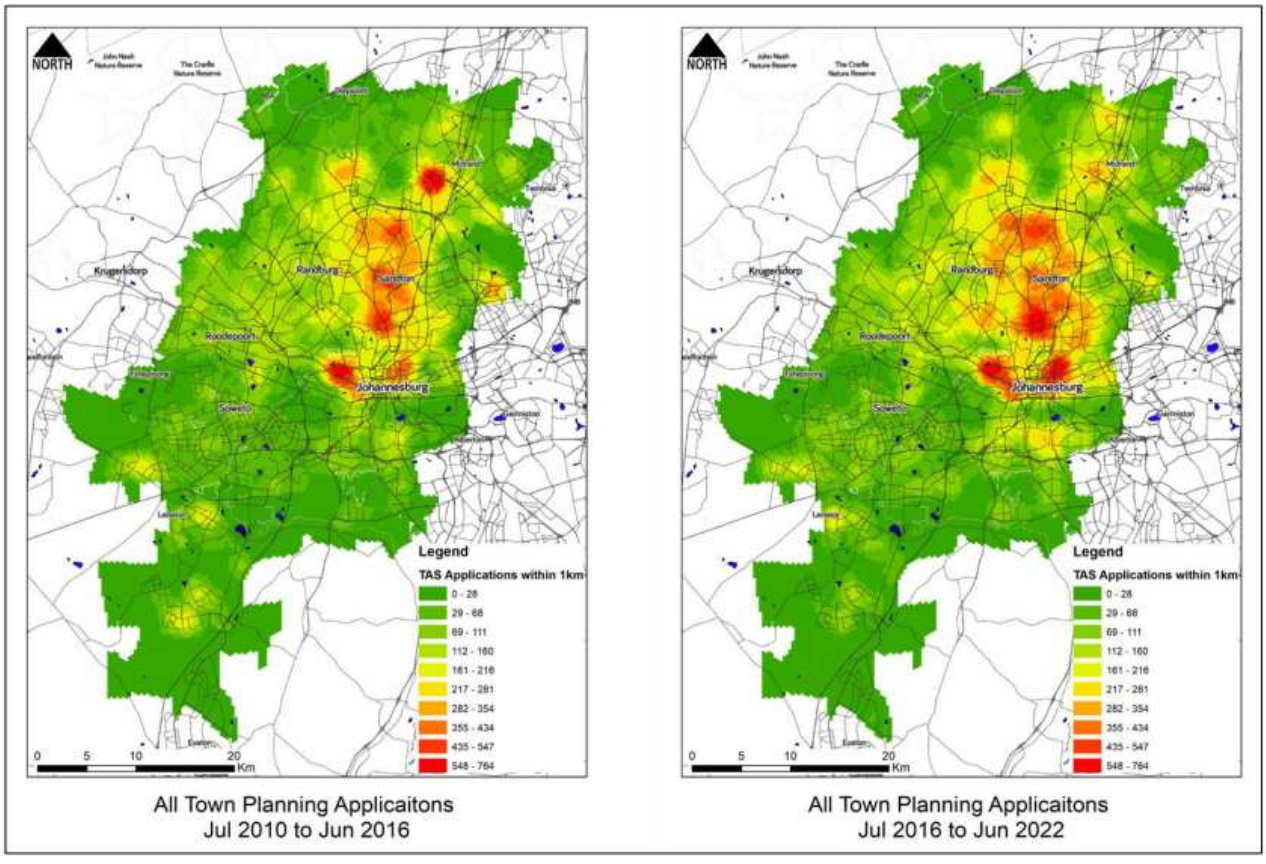

Fig. 2: All town planning applications within 1 km before and after the SDF 2016 (Source: CoJ 2040)

Long-term investments in the area, significant infrastructure developments, and the existence of major economic hubs have meant that Johannesburg's northern suburbs are still favored in terms of the spatial distribution of town planning applications.Northern areas continue to attract the bulk of development proposals, establishing an already prosperous part of the city while stifling growth in other parts.This trend persists despite demographic data indicating that population growth is quickening in the southern and other

historically marginalised areas of Johannesburg, including Ledwaba's cross between Soweto, Orange Farm, and parts of the inner city.Given this disconnect between growth and planning applications, there are difficulties in achieving spatial transformation for spatial justice.

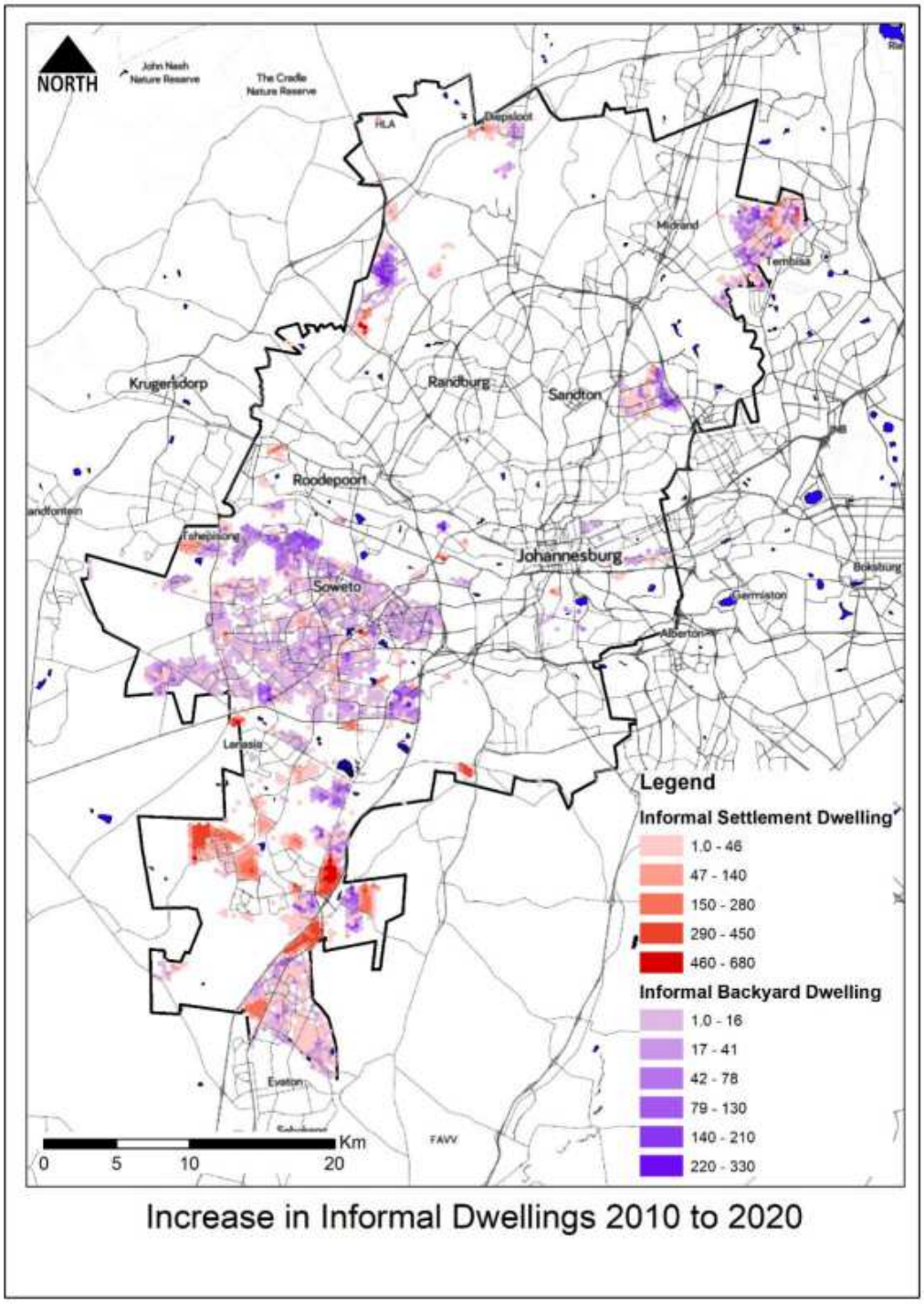

Fig. 3: Increase in informal dwellings 2010 to 2020 per 400 m hexagon (Source: CoJ, 2021).

The primarily northern nature of town planning applications is largely driven by economic and infrastructure benefits.The northern suburbs have historically served as the commercial and financial centres of Johannesburg and have attracted businesses, investors, and high-income residents. These areas tend to have better roads, efficient public transport systems such as the Gautrain, and far superior service delivery to that seen in the suburbs, making them a great option for real estate developers.The legacy of apartheid-era spatial planning also meant much greater investment in infrastructure and zoning in the north and underdevelopment in the south and west. This historical bias still informs investment decision-making, as developers view

projects north of Johannesburg as more financially viable due to stable property values and perceived security.

However, this trend has to be reversed since population data suggest that the strongest population growth has recently occurred in the southern and peripheral areas of the city. Soweto, for example, is still the largest township in Johannesburg and keeps growing, partly as a result of natural population growth and rural–urban migration.If the planning applications continue to be concentrated in the north, there is a danger that the city will become blind to where demand for housing, commercial diversity, and essential services is greatest. Also, pushing development north only exacerbates spatial inequity, entrenching economic and social divides within the city. A more balanced view of typed planning applications would call for town planning applications in historically deprived areas to be balanced with applications in historically wealthy areas.To that end, increasing infrastructural usage in underutilised zones of underdeveloped regions will also be critical to Johannesburg's long-term urban sustainability. Many areas in the south, like Lenasia and Orange Farm, for instance, have underutilised infrastructure that is needed as a population explosion is experienced (CoJ, 2021).A better way: Rather than swelling the already sprawling northern suburbs, invest more in enhancing and expanding services in these robustly growing regions to meet consumer needs (Harrison et al., 2019). Yet if the city does not change course, facilitating urban inefficiency, congestion, and informal settlements will continue. Economic decentralisation should be incentivised through investment in the south and west, forming new concentration areas of business out of over-reliance in Sandton and the central business district. Such part-time work would create jobs, facilitate access to services, and ensure an economically strong urban way of life.

CoJ should also work towards making town planning applications across the southern and western regions more conducive.Tax breaks for developers, fast-tracked rezoning, and prioritised upgrades to infrastructure in these areas are incentives that can help channel investment.Particularly, public–private partnerships must be encouraged to establish mixed-use development that combines housing with commercial and economic centres in emerging growth centres.Johannesburg can address those discrepancies in its urban strategies and ensure that they are tailored to their citizens in an inclusive way.

5.2 City of Johannesburg Integrated Development Plan 2022–2027

While the previous IDP covered a wide range of issues, the 2022–2027 IDP gives greater emphasis to urban regeneration and emphasises it as a solution for urban decay, a means for promoting economic growth as well as attracting investment.The plan focuses on the inner city with the same spirit in mind, with significant concentration on areas such as Hillbrow, Braamfontein, Newtown, and Jeppestown, which have been neglected, over-occupied, and have poor infrastructure.Although this regeneration is intended to make the area safer and with better infrastructure, and also to attract businesses, the gentrification of the area and the displacement of lower-income residents is still a major problem. This has been clearly articulated through the vision of the CoJ to transform Johannesburg into a world-class African city; however, this must extend to ensure that activities can be spatially just.Gentrification is a major issue surrounding urban regeneration, with price increases in housing and cost of living forcing long-term, low-income residents out of the area. Maboneng provides a case in which regeneration efforts have resulted in such steep rent increases that lower-income groups can no longer afford the area. Areas such as Hillbrow, which have significant low-income and immigrant populations, are especially vulnerable.While the IDP recognises these risks and suggests social housing and affordable rental units as potential solutions, the proposed actions remain policy-orientated rather than tangible steps toward addressing the issues at hand. This demonstrates that faster on-track usage needs more vigorous intervention to force urban renewal spreading to all residents, instead of just investors and upper-income groups.The IDP also includes projects that will deliver affordable housing to help address socio-economic segregation through the integration of different income groups within the same neighborhoods. The goal is a socially cohesive city with access to essential services, and better mixed-income communities.Land and construction costs in urban areas can be prohibitive, which remains one of the principal challenges to delivering affordable housing, often leading to new developments in the suburbs. Unfortunately, this means that the areas these people move to have even fewer access to the essentials of life, such as affordable and quality housing, quality education, health care, and jobs, which only amplifies the economic status of the area against achieving true equity in accessing housing.

As with the 2016–2021 IDP, infrastructure development is another important dimension of the IDP, with the focus on historically marginalised areas like Soweto, Alexandra, and Orange Farm. These regions have historically experienced poor access to basic services such as water, sanitation, electricity, and public transport along with the aforementioned challenges. Through investments in infrastructure upgrades, the city hopes to enhance the quality of life of its residents in ways that address long-term spatial inequality. It will facilitate more equitable living conditions and sustainable urban development to improve public services in these two areas.The focus on targeting those areas mentioned above is because these areas were historically marginalised under apartheid and were severely socio-economically disadvantaged, leading to the current socio-economic challenges we find ourselves in today. Soweto, for all the vibrancy of its community, still suffers from high unemployment and crumbling infrastructure. One of Johannesburg's most overcrowded areas, Alexandra, suffers from serious sanitation and housing problems. Orange Farm is not immune to the scourge of inadequate basic services and much of the population live in informal settlements. Concerned with past disparities in geographical development, the IDP aims to improve the social well-being of the people in these locales if properly operationalised.

5.3 Evolution and progress between the two 'generations' of integrated development plans

The IDPs of the CoJ for the years 2016–2021 and 2022–2027 mark two unique yet interrelated phases in the ongoing journey to tackle urban challenges and foster economic prosperity for the city. The previous IDP is characterised by ambitious, large-scale initiatives, while the latter reflects a shift to more pragmatic, incremental approaches, incorporating lessons learned from its precursor's successes and failures.

The 2016–2021 IDP set ambitious targets that promised exciting responses such as the Corridors of Freedom as well as growing the Rea Vaya BRT services. The Corridors of Freedom was a project around high-density mixed-use developments along major transport routes, tying previously disconnected areas like Orange Grove and Westbury into economic nodes like Sandton and Rosebank. As towns in the developing world grow, urban transport systems must keep pace; this was the broader rationale behind expanding the BRT system to link residents in peripheral townships such as Soweto and Diepsloot with the spatial and economic opportunities of the urban core.However, the conceptual nature of these initiatives posed major challenges. Those objectives, while consistent with advancing spatial justice and urban regeneration, faced a multitude of challenges due to a lack of capital investment, bureaucratic inefficiencies, and, above all, a lack of support from the local population. In Alexandra and Ivory Park, for example, residents resisted urban regeneration projects for fear of expulsion, while others complained about housing delivery in new developments in Kliptown and Jabulani being too slow. These challenges demonstrated the ambitious scope of the 2016–2021 IDP, with many of its goals proving difficult to meet in the given timeframe.

The 2022–2027 IDP provides a more pragmatic stance, drawing from the lessons of the preceding IDP, and containing more attached to what is realistic.Rather than focusing on big transformative projects as it did in the past, the updated plan signals a shift to creating incremental improvements, strengthening collaborations between the public and private sectors, as Curbelo (2023) added. Public–private partnerships are now viewed as crucial to solving the funding shortfalls that constrained the last IDP goals (Smith, 2022). One can clearly see this in how mixed-income housing projects in places such as Fourways and Randburg are developed, offering a mix of affordable and market-rate housing with the city receiving deliveries through private developers.

6 CONCLUSION

In a worst-case scenario, the IDPs from 2016–2021 to 2022–2027 reveal startling evolutions in focus and intention but also reveal repeating failures and unfulfilled promises. The lingering of certain risks, in particular those related to spatial justice, urban integration, and public transport, illustrate that many of the city's most pressing problems are still to be solved.Integration of informal settlements is probably the most visible sense of being repeated. These include informal settlements in areas of Zandspruit, Thembelihle, and Diepsloot, which have been identified in both the 2016–2021 and the 2022–2027 IDPs and the need to address them. These settlements, often remote from basic services and economic opportunities, were identified as major contributors to spatial inequality. The unfulfilled promises from the earlier IDP repeat themselves in the latter, the provisions in both plans promising the city better housing and infrastructure.

This marked a significant evolution in theIDPs, as they worked to learn from previous years, culminating in the 2022–2027 IDP being grounded in a strategic approach to address challenges and issues within the built environment. The 2022–2027 IDP acknowledges deficiencies in previous plans, placing greater emphasis on public–private partnerships which serve as an avenue for overcoming some of the challenges that led the 2016–2021 plan to fall short.The issues of spatial justice, integration of informal settlements, affordable housing, and public transport are still in the centre of attention for IDPs, but real progress on the ground remains limited. As such, the relevance and effectiveness of the 2022–2027 IDP hinges on the revelation of what went wrong, the reorientation towards attainable goals, and the resource mobilisation and utilisation towards enabling actions that achieve the spatial transformation objectives.Until these and other persistent challenges are addressed, the city runs the risk of slipping back into a cycle of unfulfilled promises, repeated goals, and continued obstacles to the realisation of spatial transformation.

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reviewed paper

Examining the Influence of 4IR Technologies in Urban Planning: A Case of the City of Johannesburg

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1 ABSTRACT

There is rapid increase of new technologies that are being implemented in many fields benefiing their operations positively, and urban and regional planning is also slowly growing in deploying various tecbnologies. The Fourth Industrial Revolution (4IR) has introduced transformative technologies such as Artificial Intelligence (AI), Big Data, the Internet of Things (IoT), and Geographic Information Systems (GIS), which are reshaping urban planning and governance. The city of Johannesburg is located in South Africa which is in the developing world. The city is working towards becoming a world class city. To achieve this, there is a need of deploying advance technological tools in urban planning learning from developed countries. The aim of the study is to explore the influence of 4IR technologies that might have in the City of Johannesburg (CoJ), focusing on how these innovations enhance decision-making, optimize resource allocation, and improve urban efficiency. By analyzing real-time data, predictive analytics, and smart infrastructure solutions, the research analysis the potential of 4IR technologies in addressing urban challenges. With the adoption of a qualitative case study approach, through the use of literature, this research evaluates existing applications and applications that could be implemented of AI and Big Data in Johannesburg's urban planning strategies, as well as the challenges related to data privacy, and infrastructure readiness, The findings highlight the benefits of technology-driven urban management while also identifying barriers to widespread adoption. Therefore, the study recommends the integration of 4IR technologies into Johannesburg's urban planning framework to foster sustainable and inclusive city development.

Keywords: Smart Cities, Big Data, Artificial Intelligence, urban planning, 4IR

2 INTRODUCTION

Fourth Industrial Revolution provides techonological advancements that could bring solutions to urban planning challenges and drive the City of Johannesburg towards becoming a smart city. These technologies require to be deployed correctly to be functional, and effectively. Accordingly, there is a need for them to be well-utilized by both the governmnent and the city residents. The aim of the study is to explore the influence and impact of 4IR technologies that might have in the City of Johannesburg, focusing on how these innovations enhance decision-making, optimize resource allocation, and improve urban efficiency. By analyzing real-time data, predictive analytics, and smart infrastructure solutions, the research analysis the potential of 4IR technologies in addressing urban challenges. The city has been adopting various technologies in various aspects such as the CoJ municipality integrating e-services in their operations to ensure tha the city residents can easily obtain information, communicate and other related services, there has been smart mobility developments such as the Bus Rapid Transit system (Known as Rea Vaya system), High speed rail system (known as Gautrain system which includes Bus, train and midi-buses), rising number of ride e-hailing services, Free WiFi services in various neighbourhoods and parks for city residents to connect to the internet, usage of green energy such as the adoption of solar powers, Geographic Information System services used to assist in planning and also providing the city residents with real-time navigation information, CCTV networks to prevent crime, sensored waste management, and environment sensors monitoring conditions to prevent natural disasters, and other technologies. The use of more technological innovations can enhance the urban living leading to quality of life and promote sustainable development.

3 BIBLOMETRIC LITERATURE REVIEW

The use of biblometric mapping of literature has been adopted for this study. This is to identify suitable literature for this study and identify most of the common themes researched on related to fourth industrial revolution, Artificial intelligence, Big data, smart cities, urban planning and South Africa. Further, the results of the mapping network indicates a summary of themes that are most studied and or that need attention.

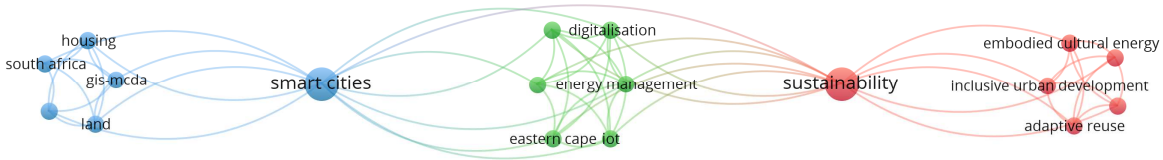

Figure 1: Keyword co-occurrence network visualisation

The above figure1 indicates a biblometric mapping of literature about authors keywords. These keywords indicate the most used keywords related to the study. There are 18 items (keywords), 3 clusters, 58 network links, 198 total link strength, and there is a total of 43 occurences. Only 18 keywords formed the network as 22 keyworkds could not connect to other keywords. Accordingly, links indicate the connection between various keywords in the biblometric mapping of literature, and the occurences shows how much a keyword has appeared in the networks. Furthermore, the total link strengths highlights that which keywords are most connected to other keywords indicating that most author's studies focuses on such themes. The authors keywords formed 3 clusters that are indicated by different colours. Each cluster has subfields that most authors work focuses on. In cluster 1, there are six keywords indicated by red node which include adaptive-reuse, cultural resilience, embodied cultural energy,inclusive urban development, sustainability, Tshwane/ Pretoria. The cluster indicate that some of the studies conducted are based on inclusive urban development with cultural resilience and embodied cultural energy. Accordingly, adaptive-reuse is a significant concept that needs to be implemnted for creating sustainabilty smart cities.

In cluster 2, there are six keywords represented by a green node which include Eastern Cape, digitization, enegry management, internet of things, urbanization, and smart municipalities. This cluster highlights that various studies conducted indicate that municipalities in the Eastern Cape are transitioning towards smart municipalities were there is deployment of internet of things and digitization for energy management and urbanization. In cluster 3 there are two keywords represented by a blue node which include gis-mcda, housing, land, smart cities, South Africa, and well-located. The cluster indicates that there are various studies conducted of identify suitable land location for housing development and smart cities development across South Africa using gis multi-criteria decision analysis. Further, there is a strong connection in the network for the keyword smart cities as it is strongly linked with cluster 2, cluster 3 and also with one keyword in cluster 1 which is sustainability. The keyword connects with Eastern Cape, digitization, enegry management, internet of things, urbanization, and smart municipalities in cluster 2 highligting that for successful smart cities development in the Eastern Cape there is a need for all the keywords in cluster 2 to be implemented or included in planning. Consequently, there is a need for gis multi-criteria decision analysis to identify suitable land location for succesful development of smart cities, which this will produce sustainable smart cities.

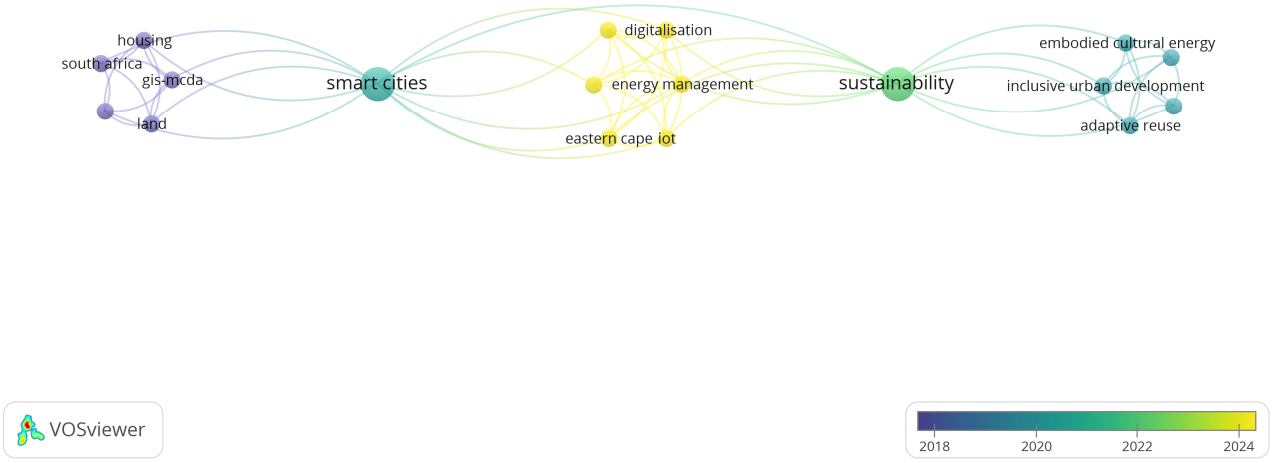

Figure 2: Keyword co-occurrence overlay visualisation

The above figure 2 highlights the publication themes that were most trending from the year 2018 to the year 2024. Consequently, this indicates that studies on smart cities, sustainability and technological innovations in urban and regional planning experience boost from late 2019 to 2024 in South Africa. However, there are very few studies conducted related to this study which highlights that there is more research that could be

done in this area. As seen on the above keyword co-occurrence overlay visualisation, there are few keywords that are creating a network of authors keywords, indicating that this research area in South Africa has not been explored sufficiently to assist provide positive impact using this approach in urban planning. During 2018, studies conducted related to the study focused on deployment of technology such as gis multi-criteria decision analysis to identify suitable locations for development of smart cities, suitable land for housing in South Africa. In 2020 to 2022, more studies were conducted on smart cities and sustainability. Accordingly, in 2023 to 2024, more studies were conducted on digitalization, internet of things, energy management, and sustainability.

4 APPROACH AND METHODOLOGY

The study deployed a case study research design were the City of Johannesburg was selected to explore how the 4ir technologies can influence urban planning. Accordingly, a qualitative approach is followed were variouss publications are examined related to the study through the use of biblometric mapping of literature. The use of biblometric mapping of literature assist to identify common research areas related to smart cities, urban planning, artificial intelligence, big data, digital mapping, Johannesburg and South Africa, and this allow the study to identify a literature gab. 12 publications were downloaded on scopus which included 4 conference papers, 6 journal articles and 2 book chapters. The keywords selected were urban planning, smart cities, and South Africa. Only three keywords were used to ensure that the study obtain most suitable publications and also if more keywords are added no publication is obtained. Which this indicates that there is a gab on studies conducted that include urban planning, 4IR, artificial intelligence, big data, smart cities, digital transformation, Johannesburg, and South Africa. Therefore, there is a need of more studies conducted to assist developing South African cities using advancement of technology which could assist producing smart cities where South African cities can go where they have never been.

During the data cleaning process, the abstracts of all publications generated were examined and all the publications were relevant to the study. Selected publications were exported to a excel sheet csv document to provide a suitable file that VOSviewer allow for biblometric mapping of literature. Accordingly, the excel sheet was inserted in the VOSviewer to start the process of biblometric mapping of literature. Accordingly, the type of analysis chosen is co-occurrence and the unit of analysis selected are authors keywords. Consequently, the threshold chosen is based on the number of occurrences of a keyword should appear which was once. 40 keywords were generated, and when the threshold was selected, 40 keywords meet the threshold. when the number of co-occerences were reduced to two, only three keywords meet the threshold which this will lead to poor network analysis produced. Therefore, the results produced figure 1 representing keyword of co-occurrence network visualisation and figure 2 representing keyword co-occurrence overlay visualisation.

5 RESULTS AND DISCUSSIONS

This section provides the results and analysis on the influences of 4ir technologies in urban planning, and how these technology could enhance the City of Johannesburg. There are various technologies that are developed in the City of Johannesburg to address urban challenges, development, governance, city operations and service delivery. Building information modelling are deployed for risk management. The technologies referred here include BIM, automatic rule checking, knowledge based systems, reactive and proactive safety systems based on information technology. There is a distinct difference between reactive and proactive safety systems for risk management. Forsythe (2014) and Teizer et al. (2010) pointed out reactive systems using information technologies such as VR, 4D CAD, and GIS seldom use real-time data and need a post data collection processing effort for analysis, while in contrast proactive technologies can collect and analyse real-time data, and provide real-time warning and immediate feedback to construction site about dangers in time. It has been found that BIM, on one hand, can be used as a systematic risk management tool in the development process and, on the other hand, can perform as a core data generator and platform to allow other BIM-related tools for further risk analysis, where most of these technologies can be used interactively in related investigations (Zou et al., 2017). The municipality of johanesburg use technology such as GIS for mapping to identifying suitable sites for development and identifying areas that need the provision of service delivery.

Accordingly, Big Data is the term being used to describe a wide spectrum of observational or "naturally-occurring" data generated through transactional, operational, planning and social activities.The major potential of big data applications is in four areas: (1) improved strategies for dynamic urban resource management, (2) theoretical insights and knowledge discovery of urban patterns and processes, (3) strategies for urban engagement and civic participation, and (4) innovations in urban management, and planning and policy analysis (Thakuriah et al., 2017). The city deploys such technology to collect real-time information to provide quality of services to the citizens. Prior to this era which we can loosely call the age of the smart city (Batty, 2020), describes that computers were mainly used to support plan-making functions, although data and information had become central to the operation of the routine planning system as well. This is best seen in planning skills which in the year 2000 were still organised around spatial representation through GIS and CAD, forecasting models from transportation to housing, the development of web pages to communicate ideas that might be organised digitally such as database access and the development of a national infrastructure for the archiving and transmission of data (Batty, 2021).

The IoT is considered the next large prospect for the world of the Internet, as it has come out of its early stages and is entering into the era of revolutionizing the traditional network infrastructure into a fully integrated future with the internet. Thus, this leads us to the concept of smart homes where different electronic appliances are interconnected with each other and achieve high-quality two-way interactive multimedia services. In such a system where a large number of devices are communicating with each other, a massive volume of data (called Big Data) is generated. To enrich smart home technology, the better analytics of Big Data could play a vital role in the advancement of Information and Communications Technologies (ICTs). This type of Big Data analysis provides a better understanding and useful information about the future as well as about planning and development, thus providing us insight into Big Data. This type of technology is used to enable a large variety of security as well as monitoring applications, and for urbanization, it is of utmost importance to comprehend the demand for service profiling to enhance efficiency and may advance city management (Rathore et al., 2016).

Smart city is a concept that encapsulates various technological innovation concepts into a single architecture (Alvi et al., 2016; Silva et al., 2018). The key concept of the smart city is to obtain the right information at the right place and on the right device to make a city-related decision with ease and to aid citizens more quickly (Rathore et al., 2016). According to Manville et al.(2014;7) 'it is in this context that smart cities emerge not just as an innovative modus operandi for future urban living, but as a key strategy to tackle poverty and inequality, unemployment and energy management'. Many cities around the world adopted smart urban technologies with an aim to become a smart city, maintain a scientific-technologic position of excellence via ensuring and expanding economic competitiveness to transforming and modernising their societies and cities, and sustain their growth and development. Examples of some the smart city initiated concepts; the Amsterdam Smart City initiative formed a collaboration between the citizens, government and businesses to develop smart projects to make a change by energy saving, which a concept more or less like this is initiated in CoJ as more solar power energy devopemnts are created such as solar power street light and more houses and companies generate electricity from solar power; the Southampton City Council utilised smart cards to stress the importance of integrated e-services, which this is similar to some of the CoJ city services of having one e-smart card for different purposes; the City of Edinburgh Council formed a smart city vision around an action plan for government transformation; the Malta Smart City formed a strategy to promote a smart business park as a way to leverage economic growth (Yigitcanlar, 2015), a similar strategy is implemented in Johannesburg were various city parks are provided with free WiFi for residents to use for various purposes such as work and entertainment.

Figure 3 indicates a concept of a technology driven City of Johannesburg supported by the 4ir technological innovations which can lead to a functional smart city. This demonstrate that 4IR technologies such as artificial intelligence, internet of things, big data, digital transformation can allow the provision of massive amount of data to provide efficient suitable response to urbanisation challenges and services delivery. Accordingly, optimization of land use zoning for areas across the city to function efficiently and sustainable. Consequently, more advance technologies could be integrated with the use of GIS to identify suitable locations that can provide affordable housing for the city residents and combat the challenge of the increasing informal settlements and optimize infrastructure planning ensuring that the city is resilient to natural disasters.

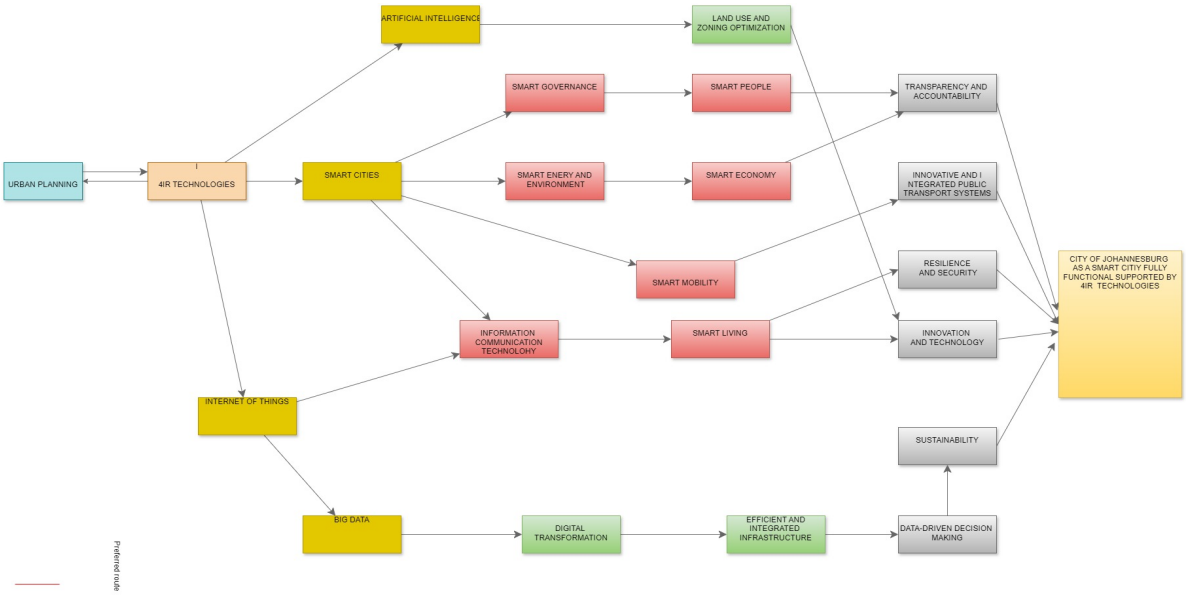

Figure 3: Concept of technology driven City of Johannesburg

Further, these technologies could assist with the vision of the city to become a world class city and becoming a smart city. This would include smart governance which will change governance and coordination processes as well as planning processes with public participation leading to transparency and accountability, smart people and smart economy were people are compatible with technology and assist in the development of the economy eradicating the levels of poverty. Accordingly, smart mobility were various innovative public transport systems such as Gautrain and bus rapid transit system (Rea Vaya system) and other modes could be integrated to ensure effective and reliable public transport systems, smart living ensuring that there is safe and security in all the neighbourhoods and 24hrs policing response services across the city. Consequently, smart energy and the environment were there could be provision of effcient solar-energy as the country is struggle with power provision and more technologies that could monitor the environment to provide in-time alert to communities and areas that are prone to disasters before hand.

In addition, innovative technologies afford opportunities for data-driven cities which is generated from various technologies that could assist with spatial transformation as informed decisions are taken and this is very important in Johannesburg neighbourhoods to transpire as there is spatial injustice and would create sustainability. All this can help transform the city and be resilience creating City of Johannesburg to be a functional smart city. However, the challenge of reaching this point lies in the tools and resources in the city and the policies and legislative frameworks to support this approach.

6 CONCLUSION

The City of Johannesburg is a transitional city working towards being a developed world class city. There are various types of infrastructure developed making the city functional, and with 4ir technological innovations being integrated towards enhancing the city. Enhancing the city towards being a smart city, there is a need of ensuring that the technological innovations that are deployed are functional and utilized by both the service providers and city residents. These various technologies such as internet of things, artificial intelligence, big data analytics, geographic information systems, smart infrastructure and digital twins, autonomous vehicles and smart transportation, renewable energy and smart grids, digital platforms for citizens engagement, automation, and virtual reality and augemented reality are suitable in urban planning which could enhance the city's functionality making the City of Johannesburg to go where no cities have gone before. Technological integration is critical in urban innovation to provide solutions that traditional urban planning systems struggle to provide. Lastly, technology could transform the city to be more data driven making it effective, efficient, functional , sustainable and provide a quality of life for the residents.

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reviewed paper

Experiences of Socio-Spatial Injustice and Inequality: a Case of Galeshewe Township, Kimberley

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1 ABSTRACT

The enduring legacy of spatial apartheid continues to shape the lived experiences of many South Africans, particularly in urban areas. Historical injustices have resulted in fragmented spatial configurations that exacerbate socio-economic inequalities. Galeshewe Township in Kimberley, Northern Cape province, South Africa, serves as a case study of a community grappling with these challenges. This study aims to investigate the socio-spatial injustices and inequalities experienced by Galeshewe residents. The research is motivated by the significant and ongoing impact of these issues on the community, as well as the dearth of scholarly research addressing this topic within the South African context. Ten key socio-economic factors were identified for analysis: income disparity, rural-urban divide, educational attainment, health outcomes, public service access, land tenure security, poverty, employment patterns, and spatial freedom. A qualitative research methodology, employing semi-structured interviews and a qualitative survey, was utilized to collect data. The sample comprised fifteen residents of Galeshewe and five professional planners. Purposive sampling and snowball sampling techniques were employed to select participants from the township. Thematic analysis was used to analyze the collected data. The findings revealed that the unequal distribution of societal benefits significantly contributes to economic deprivation and limited access to essential services. Based on these results, the study concludes by advocating for social cohesion, inclusivity, and equitable planning practices. This research contributes to the field of urban planning by highlighting the enduring impacts of historical injustices and the need for more equitable and socially just urban development.

Keywords: Socio-spatial justice, Socio-spatial inequality, Galeshewe Township, Kimberley, Challenges

2 INTRODUCTION AND BACKGROUND

Globally, stark disparities between different places and social groups characterize socio-spatial injustice and inequality (Brenner & Theodore, 2020). Wealthy areas boast well-maintained infrastructure, access to quality services, and green spaces, while marginalized communities often face overcrowded housing, limited sanitation, environmental hazards, and a lack of basic amenities (UN-Habitat, 2020). The African continent presents a particularly acute example of how these global trends intersect with specific regional challenges. Furthermore, the legacy of colonial land dispossession and racial segregation continues to shape spatial inequalities, with certain groups having limited access to prime land and opportunities (Watson, 2022). In South Africa, these inequalities are deeply intertwined with the nation's colonial and apartheid history. Discriminatory policies and practices systematically disadvantaged Black South Africans, resulting in a significant racial wealth gap that persists to this day (Wolff et al., 2018).

Townships, established under apartheid to segregate the Black population, often lack basic infrastructure, quality education facilities, and access to reliable transportation (Ballard & Desai, 2009). Conversely, wealthier suburbs, historically reserved for white residents, benefit from proximity to jobs, green spaces, and well-maintained public services (McDonald, 2021). This uneven distribution of resources perpetuates a cycle of disadvantage in marginalized communities, reinforcing social segregation and limiting opportunities for social mobility. Discontent and social unrest often arise in response to these inequalities, as residents struggle with inadequate healthcare, limited access to resources, and a lack of political representation (Satterthwaite, 2017). The ongoing challenge of spatial inequality is further amplified by the rise of gated communities within South African cities (Wu et al., 2020). These enclaves of privilege, often located in previously white suburbs, offer residents access to high-quality amenities and security. However, their exclusivity reinforces social segregation and limits opportunities for interaction and integration between different socio-economic groups. The latest data from Statistics South Africa (Stats SA) in 2024 indicated that the gini coefficient in South Africa remained high at 0.63 points in 2024, highlighting the persistent challenge of income inequality that spatial planning efforts must address.

The Spatial Planning and Land Use Management Act (SPLUMA) of 2013 marked a significant step towards redressing spatial inequalities in South Africa. Recognizing the enduring legacy of apartheid's discriminatory spatial planning, SPLUMA aimed to create a more inclusive and equitable urban landscape. As a means of restoring the unjust spatial configuration of the apartheid era, SPLUMA's distinguished principle of spatial justice, seeks to address the past spatial imbalances such as, improving access to land and the use thereof. However, SPLUMA's implementation faces significant challenges rooted in the enduring spatial form of apartheid South Africa. The fragmented ownership patterns within townships, with a mix of formal and informal settlements (Govender, 2016), pose a complex obstacle to integrated planning and development. While there are policies, plans and frameworks developed to address such imbalances, the greatest challege remains to be the implementation of the respective tools. The main objective of the study is to identify the causes and forms of socio-spatial injustice and inequality within the Galeshewe township, while exploring the perceptions of the residents on the socio-spatial injustice and inequality embedded in their daily lives, as well as identifying any gaps and limitations within the exisiting policies and frameworks in addressing the specific needs of the Galeshewe residents.

3 LITERATURE REVIEW

3.1 Conceptualizing socio-spatial injustice and inequality

This section lays the groundwork for understanding socio-spatial justice and inequality by establishing clear definitions of the key concepts that underpin the research. A precise grasp of these terminologies is crucial for effectively analyzing the lived experiences of residents in Galeshewe and the challenges they face. In order to get a meaningful insight on what the study focuses on, the key concepts pertaining this study are explained here below.

3.1.1 Socio-Economic Inequality

The concept of socio-economic inequality touches upon many factors which essentially covers the social disparities and inequalities to a greater extent. Socio-economic inequality denotes a state where there is unequal distribution of resources, services, opportunities, and social classes within a specific geographical space. This means that certain areas are provided with better access to social and economic opportunities than others. Furthermore, the concept of socio-economic inequality considers a number of factors ranging from education, health, income, and services disparities; therefore, presenting an economic and political challenge of many developed and developing countries.

3.1.2 Spatial Disparities

The concept of spatial justice has been discussed extensively by scholars since the coining of the two theories being, Lefebvre's Right to the City as well as Harvey's Social Justice and the City (Garnica-Monroy & Alvanides, 2019). It does not only refer to the unfair and unjust access of physical space, but also considers the change in which the quality of life of individuals in different geographical locations of the city should be pursued. Furthermore, spatial disparities concept does not anchor its focus on spatial patterns only, which shape the horizons of urban lives, but mobility, housing, and infrastructure quality (Bhan & Jana, 2015). The concept is further associated with the spatial distribution of resources and economic opportunities in urban centres or cities. Greenberg (2016) emphasized that spatial disparities are rooted on the notion of "who gets what and where". This refers to the limited resources availed to the community in accessing their essential services.

3.1.3 Socio-spatial Justice

Socio-spatial justice is understood as the equitable distribution of social resources in a given geographical space. This concept considers the involvement of equity, participation, and accessibility of societal resources over space. However, Cassiers & Kesteloot (2012), argue that there is a possibility of creating a socially unequal city without spatial inequality. Spatial justice lays ground for social justice. When thinking about space, we should remember that the society shapes the space in which they live. It is imperative to emphasize that when deliberating on the concept of socio-spatial justice, we need to understand how space is structured socio-economically, and that socio-spatial justice is derived from the spatial arrangement of economic activities (Han, 2022).

3.2 South Africa: The legacy of apartheid and spatial justice

The apartheid government of the Republic of South Africa passed pieces of legislation which were used as legislative tools to enforce the segregation of various races to specific areas within the urban spaces. It was during this era that South Africa was racially segregated; leading to the enactment and enforcement of a series of laws, which institutionalized white supremacy. The apartheid era in South Africa, which was controlled by the white ruled government, continued as an institutionalized policy in effect from 1948 to 1994. It was in 1948 after the National Party won elections and occupied the office. The racial segregation of people was legally governed by the Popular Registration Act 30 of 1950, and the Group Areas Act 40 of 1950 (Davies, 1981). The Population Registration Act of 1950 classified South African racial groups into 4, being the Whites, Blacks, Coloureds and Asians. The allocation of space and land was racially dependent which resulted in what was known as the apartheid city (See Fig.1).

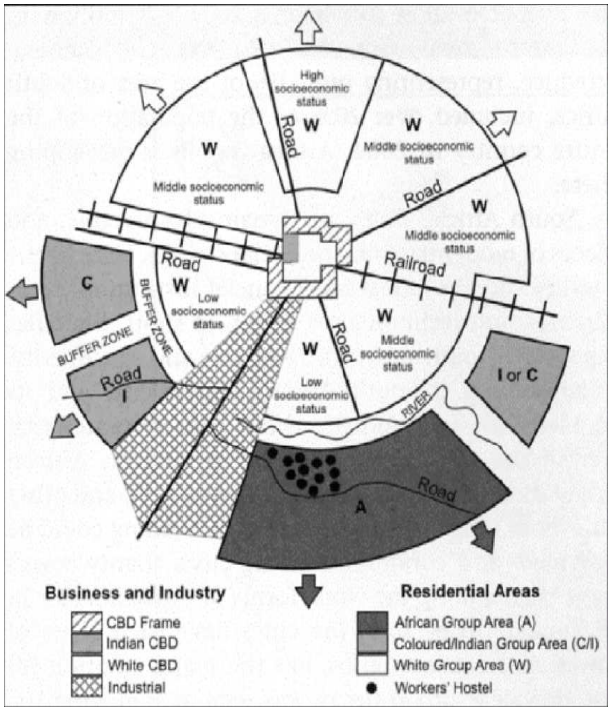

Fig. 1: Apartheid City Model. Source Davies (1981:69)

Through the regulations of this Act, (Population Registration Act, 1950), separation of residence, public facilities and transportation systems, labour market, education and health systems, were strictly enforced. The model (Fig 1) illustrates how the White dominated areas were located in a very close proximity to the central business district frame, whilst the African Blacks, Indians and Coloureds were placed on the outskirts of urban areas. The apartheid city model was contrary to the social justice theory coined by Henri Lefebvre in 1968. Lefebvre emphasized the effects that capitalism had on social collaborations contributing to the rise of spatial inequalities throughout cities across the world. Such effects led to a point where urban life became a commodity. Lefebvre called for man (citizens) to save the city which he had built and make a city an accessible meeting point for all; not an exclusive good.

Lefebvre's slogan was realized by social movements as the cities around the world saw a rise in the struggle for social justice and distinguished access to urban life. In support of Lefebvre's slogan about inhabitants having the right to the city, a British Geographer, David Harvey; emphasized that the right to the city is a collective right to have an all-inclusive participative democratic society, whereby the inhabitants have the power to be decisive in terms of the conditions that benefit and affect their livelihoods.

The right to a clean, healthy, safe and sustainable environment without excluding quality health is also a right to the city. The city inhabitants are also entitled to a safe and sound neighbourhood without any fear. Additionally, the right to the city should allow equitable access to housing, health facilities, education, and economic opportunities to citizens.

3.3 The context of Galeshewe Township

In 1871 a township called Galeshewe was established, which was named after the baTlhaping Chief, Kgosi Galeshewe. The township was inhabited by the black people who were mine workers. The areas surrounding the city were segregated based on skin colour where, the black people were meant to reside in Galeshewe; whilst the coloured people resided in Greenpoint, an area located outside of the city centre. Areas beyond the city centre were not serviced, only the white dominated areas received adequate municipal services. Following the opening of the mine, a large compound known as "The Greater No. 2" was established, located closer to the mine open pits which accommodated the black people employed as mine workers as they needed to reside closer to their workplace. After a while, the Greater No. 2 area expanded due to the high influx of people from various places seeking job opportunities (Sol Plaatje Integrated Development Plan, 2022). Furthermore, there was a law practice firm along the main street of Greater No. 2 known as Royal Street that was owned and managed by the first president of the Pan African Congress (PAC), Mr. Robert Sobukwe. It was during the apartheid period that the Greater No. 2 area became popularly known for many protests against the then system. The area therefore became known as the most violent part of Galeshewe.

On 8th November 1952, there were campaigns led by political and social activists raising their voices for poor housing, lighting, and public transport as well as "unfulfilled promises". These campaigns and uprisings led to the riots that transpired then. The city has considerable history due to its diamond mining activities in the past and the siege during the Second Boer War.

Post-apartheid, the Kimberley City Council was then renamed to Sol Plaatje Local Municipality, named after a prominent writer and activist who spent much of his life in Kimberley. Additionally, the District City Council which was then known as Diamantveld District Council was also renamed to Frances Baard District Municipality. The district municipality was accordingly renamed after a trade unionist, Frances Baard who was a resident of a 'coloured area' Greenpoint. The segregation of land based on race took effect pre-apartheid and led to the current spatial configuration present. Evidently, the community of Galeshewe are to date still experiencing the aftermath of apartheid regime socio-spatial imbalances. These imbalances are characterized by poor service delivery challenges, social and economic exclusion as well as spatial marginalization.

4 METHODOLOGY

This research forms part of the Masters study concerning the experiences of socio-spatial injustice and inequality within the residents of Galeshewe Township in Kimberley. This study adopts a qualitative research approach to understand the experiences of socio-spatial injustice and inequality within the community of Galeshewe township. A qualitative research approach is described as a holistic approach and an unfolding model applied to understand an experience of a phenomenon in a more natural way (Williams, 2007). Moreover, qualitative research approach can be understood as a model occurring in a more natural set-up, enabling the researcher to establish a detailed level of involvement in the actual experience (Khan, 2014). This study is designed as a case study. A case study research design considers an in-depth examination of a case, people or a group of people. When using this design, the researcher searches for themes and patterns. A case study research design assists the researcher to concentrate on keeping the focus of their research within the confines of space and time. Creswell et.al (2007) asserted that case studies focus predominantly on a specific case selected to understand the issues thereof.

Case study design is best suited for this study because it explores an understanding to a greater length of complexities of issues in the real-life context. The study employed semi-structured interviews and qualitative survey methods which allowed the researcher to gain deeper understanding of the experiences of the Galeshewe community. Fifteen community members, four professional town planners and one ward councillour formed part of this study during the data collection process. The study was sampled through purposive and snowball sampling techniques. Lastly, the results of this study were analyzed through the thematic analysis process.

5 FINDINGS AND DISCUSSION

This section of the study outlines findings and discussins to shape the data collection and analysis through the development of themes and subthemes. The presented findings emerged from the data collection process and was analyzed in order to guide the researcher in finding answers to the research questions of the study.

5.1 Identifying the causes and forms of socio-spatial injustice and inequality in Galeshewe

The apartheid era reflected the racial imbalances through spatial configuration. According to Tutu (2005), apartheid was a policy of exclusion. Racializing land significantly drew a line between the blacks and the whites in South Africa, and legalizing it through the Natives Land Act of 1913, took land tenure even a step further (Ramutsindela, 2012). The historical legacy of discriminatory land policies, such as the Natives Land Act of 1913 and the Group Areas Act of 1950, continues to shape the spatial and social realities of Galeshewe. These policies resulted in forced removals, spatial segregation, and restricted access to land and resources for Black South Africans. The spatial legacy of these policies is evident in the fragmented and marginalized location of Galeshewe. Participants in this study highlighted the ongoing impact of these historical injustices, emphasizing the unfair distribution of land and resources. One participant noted that "there is no fairness for as long as the township is known as an area for the previously disadvantaged." Another participant expressed their frustration with the discriminatory policies of the past, stating "the apartheid era was so discriminatory, and laws were suppressing us. We were forced to stay in townships yet work for the whites who were staying in urban suburbs. I really felt oppressed for the longest time, and here I am, still in the township." These firsthand accounts underscore the enduring impact of historical land policies on the spatial and social fabric of Galeshewe. This aligns with what Kloppers & Pienaar (2014) said when they outlined their perspective on the historical context of land reform in South Africa that: “the effect of this racially based segregation legislation was to force black people to be ‘perpetual tenants’ with very limited rights.” What Kloppers & Pienaar (2014) alluded links with the study through the identification of forms and causes of injustice and inequality where the legalized apartheid laws discussed in this study enforced strict racial segregation. Such pieces of legislation institutionalized racial discrimination, causing severe economic, social, and psychological harm to Black Africans. Considering land as a critical matter in the broader South African context, upon attainment of democracy in 1994, the government of South established policies and programmes which aimed at addressing the land issue. For the community of Galeshewe, attempting to purchase land is almost impossible because either “there is no land available” or it’s exorbitantly priced.

Evidently, the demand for land is currently high as citizens, particularly the under privileged and previously disadvantaged blacks want ownership of land in urban and sub-urban areas, closer to economic opportunities, hence the rapid urbanization leading to the mushrooming of informal settlements and illegal land invasion in and around urban areas. Mather (2002) argued that despite the passing of numerous legislations and policies aimed to redress the inequalities brought by the apartheid legacy, the success of overcoming such legacy is very limited. Although the government employed the ‘land reform programme’ after attainment of democracy in 1994, with the aim of addressing the past racial inequalities and social injustices, land will remain a greater challenge in South Africa. Zantsi & Greyling (2021) asserts that land reform is quite complex as it has social justice and equity features with which it encompasses. Land reform is made up of 3 pillars known as the land restitution, land redistribution and land tenure, and is considered a step in the right direction towards responding to land issues and claims. This aligns with a statement made by Hall (2004) that:

“Land reform was conceived as a means by which the South African state would provide redress for past injustice and promote development. It would pursue these twin goals by restoring land rights to those dispossessed by segregation and apartheid through a land restitution programme, securing and upgrading the rights of those with insecure rights to land through a land tenure reform programme, and changing the racially skewed land ownership patterns through a land redistribution programme.”

In support of the statement made by Hall (2004), the land reform programme has made strides toward addressing the legacy of apartheid but has also faced significant challenges that have perpetuated or even exacerbated socio-spatial inequality. Despite the land reform programme being designed to address these historic spatial inequalities, its slow pace, insufficient support for new landowners, and continued concentration of wealth and land in urban and commercial sectors have meant that spatial inequalities remain entrenched. For land reform to effectively reduce socio-spatial inequality, it will need to address not only

land redistribution but also broader issues of infrastructure, economic opportunities, and support for small-scale farmers, while ensuring that the benefits of land reform reach all South Africans, particularly those in rural and historically marginalized areas.

During the data collection process, one participant expressed their view on access to and security of land post 1994 when they said "we are in the democratic country right now, but the issue of land is still a topic for continuous discussion in government. It seems like the process of land will not happen in the near future because, the people leading the process also want a piece of land to themselves, and there's also political instability and corruption which generally affect the whole process." On the other hand, another participant indicated that "I believe that our government had good initiatives, policies and programmes in place which were meant to redress our challenges from the apartheid times. However, the problem became the implementation part, where the goals and objectives of such programmes were not achieved over the prescribed period, therefore delaying the whole process."

In addition to the land issue, municpal service delivery was identified as a key challenge for the community. They further emphasized that local government sector is the closest sphere of government to them; and should make services accessible to them easily; however, the respective sector still fails to render its services to the local community as mandated by the Constitution of the Republic of South Africa. In terms of Section 152 of the Constitution, the object of local government sphere is to render a provision of services to the communities in a sustainable manner and promote a social and economic development. The frustrations of the community was recorded where they highlighted that "we are just paying for services, but we struggle to get our value for money. If it's not water cut due to a burst pipe somewhere around the township almost every day, then it's electrical cable that are stolen or damaged." Another participant indicated that "poor service delivery has become a norm to us. If it's not water, then it's electricity or sewerage flowing down the streets." The dissatisfactions raised by the participants align with what was highlighted by Zondi & Nzimakwe (2017) when they indicated that:

"Municipalities are legally obliged to deliver services such as water and sanitation, and to involve communities in the formulation of developmental priorities. However, low levels of public satisfaction with government performance indicate that citizens are increasingly discontented with the state of local government."

In support of the statement made by Zondi & Nzimakwe (2017), the dissatisfaction with municipal service delivery in Galeshewe reflects deep-rooted issues such as inequality, corruption, poor governance, and resource mismanagement. Addressing these concerns requires a multifaceted approach that includes better planning, transparent governance, improved accountability, effective use of public funds, and stronger community engagement.

5.2 The perceptions of Galeshewe residents on socio-spatial injustice and inequality embedded in their daily lives

The economic growth of Kimberley as a financial hub has been gradually declining over the years. The town that is situated along the N12 treasure route has its economy largely concentrated on the tertiary sectors. The rise of economic difficulties put many businesses under pressure, therefore forcing the closure of some businesses, resulting in poorer economic growth and higher unemployment rate. The continued decline of business in private sector, exerts more pressure on the public sector to establish some employment opportunities. In terms of employment and income, it is mostly the dwellers of urban areas that are employed and can afford to properly sustain their livelihoods. Nonetheless, there are township residents who are employed, but the percentage is quite minimal; therefore, pressuring the dependency ratio. The inhabitants of the township are mostly unemployed, or discouraged job seekers, or even economically inactive. In essence, a society cannot not develop if they are not economically active.

While Kimberley remains the capital and economic hub of the Northern Cape, economic activities are drawn central to the city centre respectively and further disseminated to the eastern part (white dominated areas) of the town. The participants outlined their economic challenges when they said: "I have been unemployed for than 6 years now. I am a single mother of 2, residing in this shanty with my kids. I used to work on a contract job, and it ended in 2019, I have since been struggling to make ends meets. I had to resort to a being street vendor so that I can put food on the table." Another participant indicated that "unemployment is a serious problem that we especially the youth are faced with. We are advised to go to school, study and obtain

qualification to fit with the corporate market. However, once you're qualified, then the reality of unemployment kicks in. It is an overwhelming reality, but I remain positive and hopeful for a better outcome." According to the Sol Plaatje Integrated Development Plan (2022), the implications for the municipality as brought forth by the income gaps adversely affects the disposable income of households, exacerbating social unrest and crime. Furthermore, the purchasing power gets eroded, and the dependency of government grants increases. The participants of this study within the Galeshewe community are of the view that they are economically and socially excluded. Factors such as limited access to improved education quality other social services and facilities contribute to the socio-economic exclusion of such community.

5.3 Gaps and limitations within the existing policies and frameworks in addressing the needs of Galeshewe

Several policies and programmes established years ago post 1994, aimed at remedying the past spatial planning system that burdens the current planning system. It started in 1994 post attainment of democracy and the greatest predicament still presented to this day is lack of implementation of established policies. The most recent piece of legislation being Spatial Planning and Land Use Management Act, 2013 (SPLUMA) is tasked with guiding land use and land development across SA. The underlying problems from the past spatial planning leave a big challenge for SPLUMA and it will take a longer period to attain spatial justice as advocated for by the said Act respectively. The professional planners across sectors departments attest to the fact that yes, policies are in developed, but the non-implementation leads to the said policies not being effective. Despite all the policies, plans, acts and programmes; Galeshewe is still faced with socio-spatial inequality and injustice.

The one participant shared their opinion when they said: "yes, SPLUMA can redress past spatial imbalances if Urban Planners are given the space to lead the spatial transformation agenda in organizations without any hinderance (e.g. political interference). However, common in local government level, the challenge remains whereby there is no political-will and lack of departmental budget to support initiatives from the Urban Planning Section which seeks to fast-track spatial transformation in line with the SPLUMA Principles." Another participant highlighted that "socio-spatial injustice and inequality are practical in Kimberley. There are only two malls (North Cape Mall & Diamond Pavilion Mall) which are situated in areas previously classified for the minority population. Therefore, one proposal is for the local authority to stimulate investment by creating an enabling environment where private sector can develop malls with similar magnitude to the existing two malls in areas such as Galeshewe, Roodepan, Colville. This could stimulate social and economic spin-offs such as job creation, decrease unemployment, reduce travel time and spending on transportation for the poor and redress the current spatial inequalities experienced in areas classified as previously disadvantaged (i.e. coloured and black communities)".

The government must, especially at the municipal sphere ensure that there is suitable and sufficient capacity to implement the programmes and plans. Considering that land as source is central to development; the redistribution process by government should not only focus on peripheral areas; but should also in the urban areas so as to promote inclusivity and spatial reconciliation. One of the participants touched on the issue of prime land still being under the control of the elite when they said "land redistribution needs to be prioritized firstly to the previously marginalized. The reality on the ground is that the minority or elite still control the prime development land. Additionally, the rapid release of land is often in unserviced and inaccessible location. What then is the role of the private sector in ensuring spatial justice?"

6 CONCLUSION

The study has outlined how the spatial configuration of Galeshewe was formed as a result of racial segregation which transpired during the apartheid era. The concepts of spatial injustice and socio-economic inequalities have been in existence for decades, and in the context of South Africa, such injustices were legislated during the apartheid era. The study revealed that Galeshewe in still confronted with socio-spatial injustice and inequality despite the formulation of programmes and plans aimed at addressing socio-spatial imbalances. It is important to emphasize that although spatial justice may be understood as the form of equity in spatial distribution and allocation, it also encapsulates factors such as transportation, health, education and employment issues, which form a larger part of the socio-economic and spatial imbalances.

The study outlined the lived experiences and perceptions of the Galeshewe community in respect of socio-spatial inequalities and injustices and has discovered some common ground factors which are evidently affecting their lives. Legislative and policy framework non-implementation have been noted to be the catalyst in delayed development and poor service delivery. Therefore, it can be concluded that socio-spatial inequality and injustice in disadvantaged, impoverished communities will continue to occur because the strategic tools established to address such challenges are not effectively implemented.

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reviewed paper

Exploring Spatial Patterns of Urban Heat Islands in Zagreb

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1 ABSTRACT

Urban heat islands are a spatial phenomenon characterized by increased temperatures in urban areas compared to their suburban and rural surroundings, driven by spatial patterns of built-up areas, land use, and land cover, as well as the absence of vegetation and variations in land surface temperature (LST). This study examines the relationship between built-up intensity, planned land use, and LST in the City of Zagreb, focusing on its core urban area. Utilizing Landsat-9 satellite data for LST extraction and urban spatial planning documents for vegetation classification, the study explores key spatial factors influencing the intensity and spatial distribution of urban heat islands. The methodological approach integrates Exploratory Spatial Data Analysis (ESDA), regression models, and spatial autocorrelation to determine the spatial dependencies between land use and temperature variation, conducted using the R programming language. The analysis identifies specific areas where built-up land use categories contribute most to temperature increases, while planned green zones have a significant cooling effect. Spatial regression highlights the varying impact of different planned land-use categories on local thermal conditions, particularly the role of designated green areas in mitigating urban heat accumulation. Spatial autocorrelation techniques confirm the presence of clustering effects in heat island distribution, emphasizing the spatial dependency of UHI formation. These results emphasize the need for an integrated urban planning approach to mitigate the negative effects of urban heat islands and improve the quality of life.

Keywords: Urban Heat Islands, Zagreb, R, Spatial Analysis, Land Use

2 INTRODUCTION

The Urban Heat Island (UHI) phenomenon, characterized by increased temperatures in urban areas compared to their rural counterparts, is a major issue in urban climate research. This temperature disparity arises due to a combination of factors, including land-use changes, impervious surface expansion, anthropogenic heat emissions, and reduced vegetation cover. As urbanization intensifies, cities across the world are experiencing heightened UHI effects, which pose significant environmental challenge thus making UHI mitigation an essential component of sustainable urban planning.

Recent advancements in remote sensing and geographic information systems (GIS) have provided valuable insights into the spatial and temporal distribution of UHI. Researchers have employed multi-temporal satellite analyses, thermal imaging, and statistical modeling to assess the impact of different land-use types on urban thermal environments. Studies on cities worldwide have consistently emphasized the role of vegetation in mitigating UHI effects, highlighting the importance of integrating green infrastructure into urban landscapes.

For Zagreb, the capital of Croatia, several studies have investigated the impact of urban expansion and land-use transitions on the city's thermal environment. This review synthesizes findings from recent research on UHI in Zagreb and other comparable cities, with a focus on land-use patterns, vegetation cover, remote sensing methodologies, and mitigation strategies.

3 LITERATURE REVIEW

Land use and urban morphology play a crucial role in influencing land surface temperature (LST) and the intensity of UHIs. The spatial distribution of built-up areas, green spaces, and water bodies significantly affects temperature variations. Research in Wuhan, China, revealed that industrial and commercial zones contribute extensively to elevated surface temperatures due to anthropogenic heat emissions (Lu et al., 2021). Similarly, a study in Izmir found that areas with high street network centrality exhibited intensified UHI effects, whereas increased street connectivity mitigated heat buildup (Erdem et al., 2021). Functional zones

such as commercial and industrial areas have been identified as UHI hotspots due to heat absorption by impervious surfaces and limited vegetation (Chen et al., 2022). Studies in European cities reinforce these findings. In Berlin, Germany, research demonstrated that densely built-up areas exhibit the highest temperatures, while green spaces provide cooling effects (Dugord et al., 2014). An assessment of urban temperature distributions across Europe found that industrial and commercial areas consistently exhibit higher LSTs than vegetated areas (Hellings & Rienow, 2021). In Seville, Spain, urban expansion and a reduction in agricultural land over 30 years have significantly increased LST (Halder et al., 2022). Nighttime UHI intensity has risen in Istanbul due to continuous urban expansion and reduced green cover (Ünal et al., 2020), while a study in Prishtina demonstrated a strong correlation between built-up intensity and increased surface temperatures (Isufi et al., 2021). Additionally, the growing urbanization of rapidly developing regions has exacerbated heat island effects, making mitigation efforts more urgent.

These findings underscore the strong relationship between urban development patterns and temperature variations, highlighting the need for effective mitigation strategies. One of the most effective approaches to counteracting the UHI effect is the integration of vegetation, which plays a crucial role in cooling urban environments.

Vegetation plays a crucial role in mitigating the UHI effect by providing shade, enhancing evapotranspiration, and reducing heat absorption. The correlation between the Normalized Difference Vegetation Index (NDVI) and LST has been widely studied, with consistent findings that higher vegetation cover results in lower temperatures (Guha & Govil, 2018). A study in Bochum, Germany, confirmed a strong negative correlation between LST and green volume, indicating that increasing urban greenery can effectively mitigate heat stress (Schmidt & Lawrence, 2022). Research in Andalusia, Spain, further supports these findings, emphasizing that urban planning strategies incorporating green spaces are essential for maintaining a balanced thermal environment (Hidalgo García & Díaz, 2023). Case studies in Naples and Florence found that UHIs predominantly formed in built-up and bare land areas, while regions with dense vegetation exhibited significantly lower temperatures (Guha et al., 2018). Similarly, research in Dubrovnik, Croatia, revealed a rising trend in maximum summer temperatures from 1961 to 2019, with urbanized surfaces heating up more than vegetated areas (Boras et al., 2022). The cooling effect of tree cover is further highlighted in studies conducted in Italy, where increased impervious surface density led to higher UHI intensity, while inland cities suffered more than coastal cities due to a lack of cooling from nearby water bodies (Morabito et al., 2020). The findings highlight the necessity for large-scale tree planting initiatives, green corridor development, and the protection of existing green infrastructure.

These studies collectively emphasize the critical role of vegetation in regulating urban temperatures, reinforcing the need for strategic urban planning focused on expanding green infrastructure. To accurately assess and monitor these thermal dynamics, remote sensing and GIS methodologies have emerged as essential tools, enabling researchers to analyze UHI patterns with greater precision and develop targeted mitigation strategies.

Remote sensing and GIS methodologies have become indispensable tools for analyzing UHI spatial patterns. The use of Landsat satellite imagery and geospatial indices like NDVI and the Normalized Difference Built-up Index (NDBI) enables researchers to quantify UHI intensity and identify mitigation strategies. A study in Hefei, China, used Landsat 8 OLI_TIRS data to explore how spatial scale impacts UHI intensity, finding that smaller spatial scales provide more precise insights into the urban thermal environment (Lin et al., 2024). The integration of spatial regression models, clustering techniques, and spatial autocorrelation has been effective in identifying heat island clusters and their driving factors (Erdem et al., 2021). European studies confirm the efficacy of remote sensing in UHI analysis. In Skopje, North Macedonia, Landsat 8 data revealed a strong negative correlation between NDVI and LST, reinforcing the cooling effect of vegetation, while built-up areas significantly intensified UHI (Kaplan et al., 2018). In Andalusia, Sentinel-3 satellite data demonstrated that daytime urban heat hotspots are primarily located in rural areas with minimal vegetation, whereas nighttime hotspots cluster in highly impervious urban zones (Hidalgo García & Arco Díaz, 2023). In Ahvaz, Iran, bare lands and built-up areas were directly correlated with UHI intensity (Amindin et al., 2021). The continued advancement of satellite-based analysis provides increasingly accurate assessments.

Addressing the UHI effect requires a multi-faceted approach, including increasing green spaces, implementing high-albedo surfaces, and enhancing urban ventilation. Studies show that increasing albedo

through reflective surfaces significantly reduces surface temperatures (Hidalgo García, 2023). The strategic placement of water bodies and green corridors enhances local microclimates and reduces urban heat stress. Urban planning policies should prioritize sustainable design principles, such as tree canopies, green roofs, and urban parks, to counteract UHI effects.

Research in Granada, Spain, emphasizes that increasing impervious surfaces has led to a significant rise in LST, highlighting the need for proactive land-use planning (Hidalgo-García & Arco-Díaz, 2022). Studies in various European cities indicate that UHI mitigation strategies must be tailored to local climatic and urban conditions, considering factors such as wind flow, surface permeability, and spatial planning frameworks (Hellings & Rienow, 2021). In Sivas, Turkey, urban expansion and the reduction of barren land contributed to rising LST over a 26-year period, with urbanized areas exhibiting the highest temperatures (Karakuş, 2019).

Urban green infrastructure (UGI) has been widely recognized as a key strategy for reducing urban temperatures. A study on European functional urban areas found that UGI can lower city temperatures by an average of 1.07°C, with tree cover playing a crucial role in microclimate regulation (Marando et al., 2022). The study recommended that at least 16% of urban land should be covered by trees to achieve effective temperature reduction. Green infrastructure investments not only mitigate temperature extremes but also contribute to improved air quality and public health outcomes (Chen et al., 2022). Additionally, the implementation of green roofs and vertical gardens has proven effective in high-density urban areas where open green space is limited.

Building upon these broader insights, the Urban Heat Island (UHI) effect in Zagreb, Croatia, reflects similar patterns observed in other urban environments, with land use changes, urban morphology, and anthropogenic activities playing a decisive role in temperature variations. As urbanization intensifies, the spatial and temporal characteristics of UHI in Zagreb have become increasingly evident, necessitating a deeper examination of its driving factors and mitigation strategies.

Long-term satellite-based monitoring has provided valuable insights into the distribution and intensity of UHI in Zagreb. Analysis of Landsat 8 imagery from 2013 to 2022 revealed that built-up areas consistently exhibited higher land surface temperatures (LST), whereas vegetated zones, particularly forested areas, maintained significantly lower thermal anomalies. These findings underscore the importance of green infrastructure in reducing urban heat stress and maintaining thermal balance within the city (Seletković et al., 2023). Further research using multi-temporal Landsat datasets has demonstrated a strong negative correlation between LST and vegetation indices such as the Normalized Difference Vegetation Index (NDVI), reinforcing the critical role of urban greenery in mitigating heat accumulation (Krtalić et al., 2020).

Urban morphology has also proven to be a key determinant of UHI intensity in Zagreb. A temporal analysis spanning from 1984 to 2014 highlighted that densely built-up areas – including the city center and industrial districts – experience the most pronounced temperature increases. In contrast, areas with higher vegetation cover, such as parks and tree-lined streets, demonstrate a measurable cooling effect, aligning with global findings on the role of green spaces in urban heat mitigation (Krsnik, 2024). Additionally, research assessing spatial heterogeneity in UHI patterns has identified commercial hubs and transportation corridors as persistent heat hotspots, primarily due to their high concentration of impervious surfaces and anthropogenic heat emissions (Krtalić et al., 2020).

Beyond the influence of land use, remote sensing methodologies have been instrumental in evaluating Zagreb's thermal environment and identifying vulnerable areas. The Environmental Criticality Index (ECI), derived from satellite thermal data, has pinpointed districts with extreme temperature anomalies, highlighting the disproportionate impact of UHI on commercial and industrial zones. These areas, characterized by low vegetation density and high impervious surface coverage, exhibit the most significant heat retention, emphasizing the urgent need for mitigation interventions (Krsnik, 2024). Comparative analyses of different types of green infrastructure in Zagreb further confirm that urban forests, public parks, and interconnected green corridors offer the most effective cooling benefits, with temperature reductions of up to 2°C recorded in densely vegetated areas (Seletković et al., 2023).

Seasonal and diurnal variations further shape Zagreb's UHI intensity. Studies have shown that summer months exhibit the most pronounced heat buildup due to higher solar radiation and reduced

evapotranspiration in built-up environments, whereas winter periods present less thermal contrast due to lower solar input and seasonal vegetation loss (Krtalić et al., 2020).

Mitigation strategies for UHI in Zagreb emphasize the need for integrating urban greenery into city planning. A study on urban green space effectiveness in climate regulation found that tree cover, green roofs, and permeable surfaces significantly contribute to reducing surface temperatures, particularly in high-density neighborhoods (Krsnik, 2024). Furthermore, the role of large-scale green infrastructure was explored through scenario modeling, demonstrating that a 16% increase in tree cover could lead to a temperature reduction of approximately 1.5°C across the city (Seletković et al., 2023). These findings are aligned with European urban sustainability studies, which advocate for policy-driven initiatives to expand urban vegetation and enhance climate resilience.

4 MATERIALS AND METHODOLOGY

4.1 Research scope

This research builds upon and extends the existing body of knowledge on Urban Heat Islands (UHIs) by providing spatially explicit analysis of UHI intensity in the city of Zagreb, focusing on the relationships between land surface temperature (LST), planned land-use categories, built-up intensity, and vegetation cover. While previous studies have examined the impact of urban form on UHI, few have integrated spatial regression modeling with high-resolution Landsat-9 imagery and urban planning data. This study bridges that gap by quantifying the statistical influence of zoning regulations on temperature variations. While they also have examined general trends in UHI formation, vegetation's cooling effects, and urban expansion's role in heat accumulation, this study takes methodological approach by integrating multiple spatial analysis techniques to identify and quantify factors driving temperature variations. Research emphasizes the importance of urban planning decisions in shaping local microclimates and investigates how different land-use types, contribute to spatial patterns of heat intensity. The spatial scope of this research is limited to the area covered by the General Urban Plan (GUP) of the city of Zagreb, rather than the entire administrative territory of the city. This delineation ensures a more precise analysis of temperature variations within the core urban area, where land-use planning and built-up intensity have the most significant impact on UHI formation. By focusing on the GUP-defined urban zones, the study effectively captures localized temperature fluctuations.

The primary objective is to establish statistically correlations between LST and planned urban land-use categories as well as built-up intensity parameters to assess the extent to which specific urban planning and development strategies influence temperature distribution. A crucial extension of previous research is the incorporation of a composite UHI index, constructed by integrating both LST and the Normalized Difference Vegetation Index (NDVI) to refine the identification of heat-prone areas. Unlike conventional studies that solely rely on thermal remote sensing, this research defines UHI zones based on two critical criteria: (1) LST values exceeding the daily mean temperature, which highlights localized heat anomalies, and (2) NDVI values below 0.2, which indicate areas with minimal vegetation cover and, therefore, limited natural cooling capacity. This combined approach ensures a more precise delineation of heat islands by incorporating both thermal and vegetation-based factors, offering a nuanced representation of urban heat stress zones in Zagreb.

The research further builds on previous findings by examining the spatial clustering of UHIs through spatial autocorrelation analysis, enabling a better understanding of how heat islands are distributed across the urban landscape and whether specific spatial patterns emerge due to land-use planning and built-up intensity.

4.2 Materials

Core datasets used in this research consist of high-resolution remote sensing data, urban planning documentation, and spatial statistical modeling techniques. The study relies primarily on Landsat-9 satellite imagery from July 10, 2024, which provides thermal infrared data to assess land surface temperature (LST) and multispectral data for NDVI calculations, allowing for the evaluation of vegetation cover. The integration of LST and NDVI data enables the identification of heat-prone areas where a lack of vegetation correlates with elevated surface temperatures. Additionally, the study utilizes the General Urban Plan of the City of Zagreb (GUP) and its 2024 amendments, which define planned land-use categories and provide spatial constraints for urban development. The GUP outlines different types of planned green spaces,

including; protective green areas (Z), public parks (Z1), urban park-forests (Z2), thematic parks (Z3), and public green zones (Z4), which are analyzed in relation to their effectiveness in mitigating high temperature effects. Furthermore, the study incorporates urban planning regulations that specify built-up intensity parameters, allowable plot coverage, which is some of key determinants of urban density and surface heat retention. By analyzing the spatial distribution of these regulatory parameters, the study assesses how different levels of urbanization impact LST. The use of spatial datasets from official planning documents allows for an in-depth evaluation of how zoning regulations influence temperature dynamics.

4.3 Methodology

Methodological framework employed in this research represents an advancement over prior studies that relied solely on thermal remote sensing or statistical temperature analysis. Previous Zagreb-based UHI assessments, such as those by Krtalić et al. (2020) and Seletković et al. (2023), primarily focused on broad-scale thermal imagery analysis and identified general UHI patterns. By integrating Exploratory Spatial Data Analysis (ESDA), this research moves beyond descriptive analysis to establish causal relationships between land-use categories and temperature anomalies.

This research is structured around three core analytical stages:

- Correlation and regression analysis between LST, planned land-use, and built-up intensity;
- Integration of NDVI and LST to define UHI areas;
- Spatial autocorrelation analysis to assess the clustering of heat islands.

First stage involves correlation analysis which is used in this step to examine the strength and direction of relationships between temperature and urban features, helping to identify whether built-up intensity is positively associated with higher LST, while planned green areas contribute to temperature reduction. Then regression analysis is used to quantify the impact of planned land-use categories and built-up density on LST, where land surface temperature (LST) serves as the dependent variable, while independent variables include land-use type, built-up intensity, and vegetation cover.

Second stage focuses on constructing the UHI index, which is defined by combining LST values higher than the daily mean temperature with NDVI values below 0.2, ensuring that heat islands are classified based on both thermal excess and lack of vegetation. The NDVI threshold of 0.2 was selected based on prior studies that define low vegetation cover in urban settings as NDVI < 0.2 (Guha et al., 2018). This threshold ensures that areas classified as UHI zones are those with minimal vegetation cover. This approach refines conventional UHI identification by distinguishing between areas where temperature anomalies result from built-up density rather than other environmental factors.

Third stage applies spatial autocorrelation analysis to evaluate the spatial clustering of heat islands, using Moran's I to measure global clustering patterns of UHIs across Zagreb and Local Indicators of Spatial Association (LISA) to identify localized hot spots and cold spots, highlighting districts where temperature accumulation is most pronounced. Spatial autocorrelation methods help determine whether high-temperature zones are randomly distributed or whether they form significant clusters due to specific urban planning characteristics.

This analytical approach enables a systematic assessment of how planned green spaces and built-up areas influence temperature distribution and whether heat islands are spatially clustered in areas of high-density urbanization. The combination of these methods provides a robust, evidence-based framework for urban planners and policymakers to develop targeted climate adaptation strategies, such as optimizing the distribution of green infrastructure, adjusting zoning regulations to mitigate heat retention, and improving urban design strategies to enhance thermal comfort. By integrating geospatial analysis, spatial statistics, and urban planning data, this study advances the scientific understanding of UHIs in Zagreb.

5 RESULTS

Building upon the outlined methodological framework, the results of this research provide a detailed examination of the relationships between land surface temperature (LST), built-up intensity, and planned green spaces, offering insights into the drivers of Urban Heat Island (UHI) intensity in Zagreb. The first stage of the analysis focuses on statistical correlations and regression modeling to quantify how built-up

areas and green spaces impact LST. By evaluating the strength and direction of these relationships, the analysis highlights the degree to which urban planning decisions influence local microclimates. This is followed by the construction of a UHI index in the second stage, integrating LST and NDVI to refine the identification of heat-prone areas and differentiate zones where elevated temperatures are primarily attributed to built-up density or lack of vegetation. Finally, the third stage applies spatial autocorrelation techniques, including Moran's I and LISA, to identify spatial clustering of high-temperature zones and assess whether these clusters align with specific urban planning characteristics. Together, these results provide a comprehensive understanding of how urban planning variables such as built-up intensity and planned green spaces affect UHI patterns, forming a basis for evidence-based urban climate adaptation strategies.

The correlation and regression analysis provide insights into relationships between land surface temperature (LST), built-up intensity, and the total area of planned green spaces. The findings reveal a moderately strong positive correlation (0.68) between built-up intensity, and mean temperature. This confirms that higher built-up intensity significantly contributes to elevated LST, emphasizing the role of impervious surfaces, such as asphalt and concrete, in retaining and amplifying heat.

On the other hand, the total area of planned green spaces demonstrates a moderate negative correlation (-0.32) with mean temperature, highlighting the critical cooling effect of vegetation in mitigating LST. Areas with greater coverage of planned green spaces exhibit lower temperatures, reinforcing the importance of greenery in reducing UHI effects.

These findings align with the hypothesis that built-up surfaces exacerbate urban heating, while green spaces serve as an effective countermeasure. From a planning perspective, the analysis underscores the urgent need for urban regulations to balance high-density development with the integration and preservation of green infrastructure. Planned green zones (Z, Z1, Z2, Z3, Z4) are essential in reducing urban heat, while high-density areas require targeted interventions, such as green infrastructure, to mitigate localized heating effects (Figure 1).

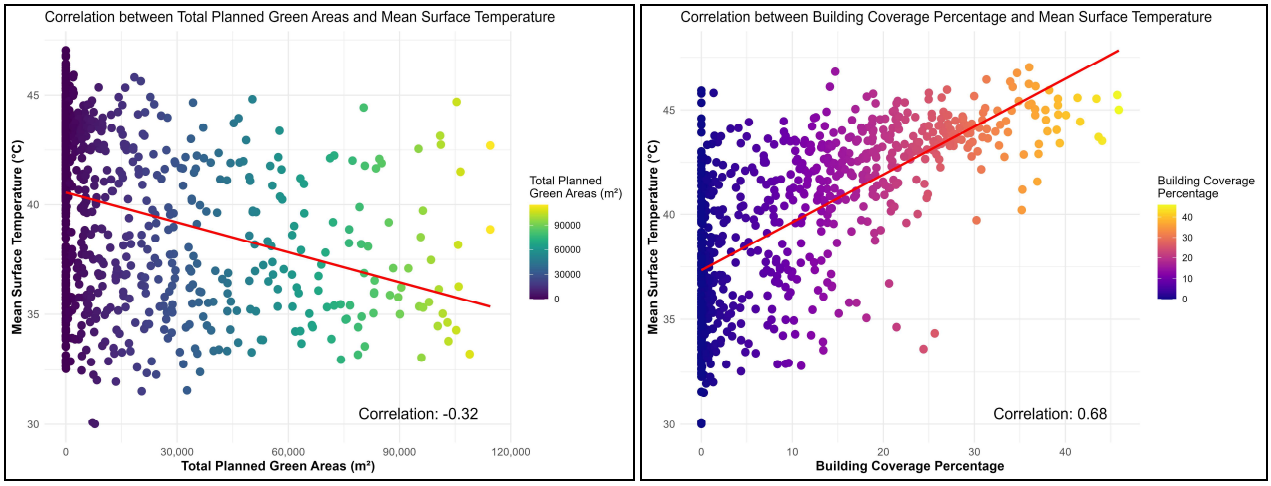

Fig. 1: Correlation analysis between planned green areas and built-up intensity and LST

Analysis provides critical insights into the relationship between land surface temperature (LST) and various land-use categories defined in the General Urban Plan (GUP) of Zagreb. The results reveal that park-forests (Z2) and protective green areas (Z) have a statistically significant cooling effect on LST, with coefficients of -3.11×10^{-6} and -3.29×10^{-6}, respectively, highlighting their effectiveness in mitigating the heat effects. The overall model is statistically significant (F-statistic = 7.25, $p < 0.001$), though it explains a modest proportion of variance in LST (adjusted R-squared = 0.064), reflecting the complexity of factors influencing urban heat dynamics.

Building upon the statistical correlation and regression analysis, the construction of the composite Urban Heat Island (UHI) index represents the second stage of the methodological framework. This composite index integrates land surface temperature (LST) and Normalized Difference Vegetation Index (NDVI) to refine the identification of areas most affected by hight temperature effects. The threshold for LST > 39°C, chosen based on the average land surface temperature on the day the satellite images are dated, which ensures that regions experiencing significant heat accumulation are highlighted. Simultaneously, the threshold of NDVI <

0.2 identifies zones with minimal vegetation cover. This dual-filtering approach enables the differentiation of heat-prone areas primarily driven by built-up intensity from those influenced by the absence of vegetation (Figure 2).

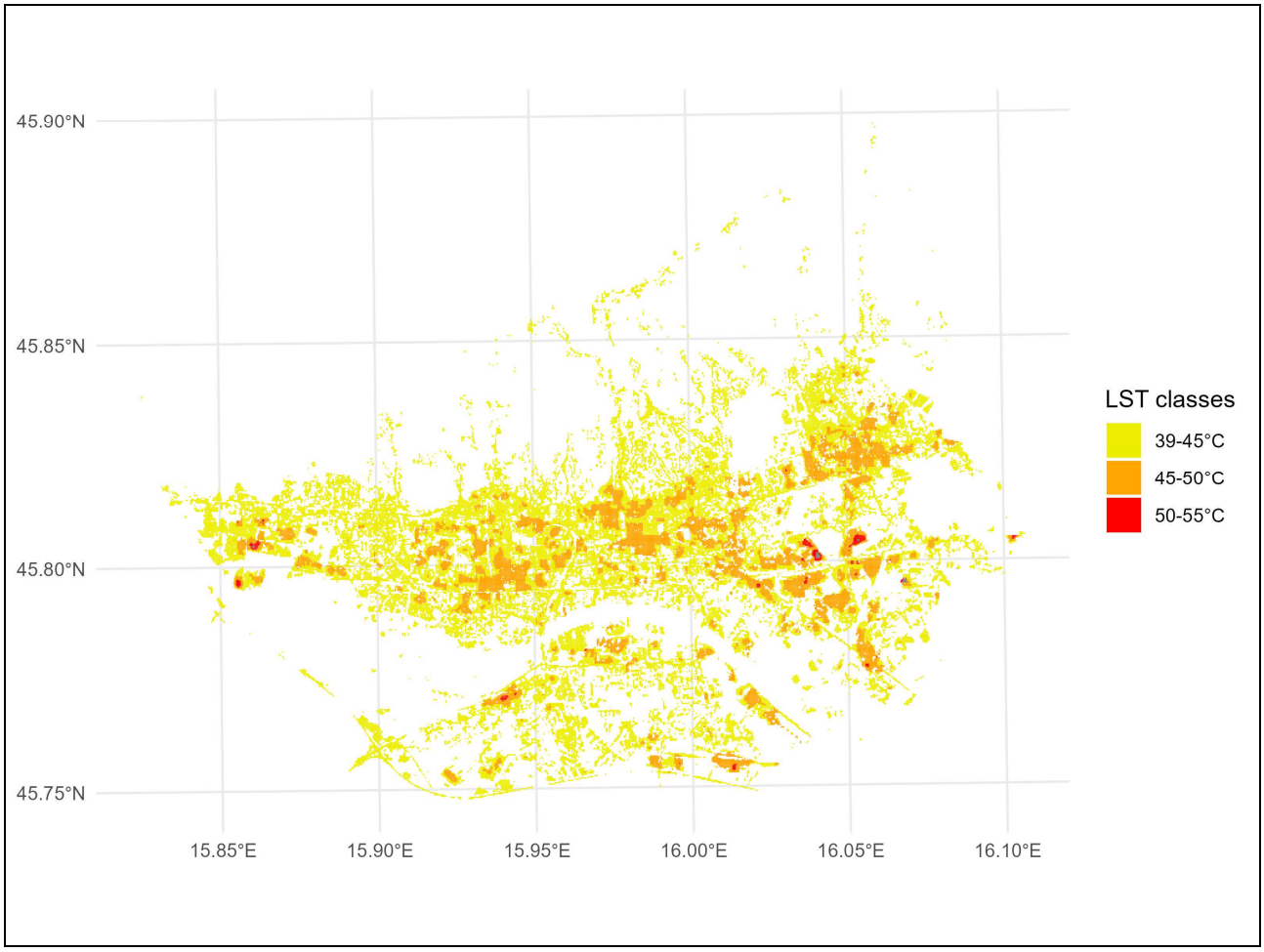

Fig. 2: Distribution of Land Surface Temperature

Building upon the statistical correlation and regression analysis, the spatial autocorrelation analysis represents a critical step in identifying and understanding the spatial clustering of Urban Heat Island (UHI) hotspots. Utilizing Moran's I and Local Moran's I (LISA), this stage examines the spatial patterns of high land surface temperature (LST) values to determine whether they are randomly distributed or form statistically significant clusters. The key focus of this analysis is to identify hotspots, or areas where elevated temperatures are spatially concentrated.

The Moran's I test under randomization indicates a highly significant positive spatial autocorrelation (Moran I = 0.920, p-value < 2.2×10^{-16}), confirming that high LST values are strongly clustered rather than randomly dispersed. This result validates that UHI effects in Zagreb are driven by systematic spatial processes rather than random temperature variations, underscoring the role of urban planning and land-use patterns in shaping heat accumulation. The Moran I statistic's standard deviation deviate (394.04) further supports the strength of this clustering, highlighting the robustness of the identified patterns.

Local Moran's I (LISA) refines this global insight by pinpointing the exact locations of statistically significant hotspots. These hotspots are areas where high LST values are not only concentrated but are also surrounded by other high-temperature zones, creating pockets of intense heat accumulation (Figure 3).

The ability of the spatial autocorrelation tools to statistically identify these clusters makes them indispensable for understanding UHI dynamics. Hotspot detection enables urban planners to spatially delineate the areas most vulnerable to heat accumulation, providing a clear foundation for targeted mitigation strategies..

By focusing exclusively on hotspots, this analysis emphasizes the power of spatial modeling in addressing urban heat challenges. The integration of Moran's I and LISA with high-resolution LST data provides a

comprehensive tool for modeling heat distribution and highlighting areas of concern. This approach moves beyond descriptive analyses to deliver statistically validated insights, reinforcing the need for evidence-based interventions in urban planning. In doing so, it not only enhances the scientific understanding of UHI effects but also equips stakeholders with precise spatial intelligence to prioritize climate adaptation measures effectively.

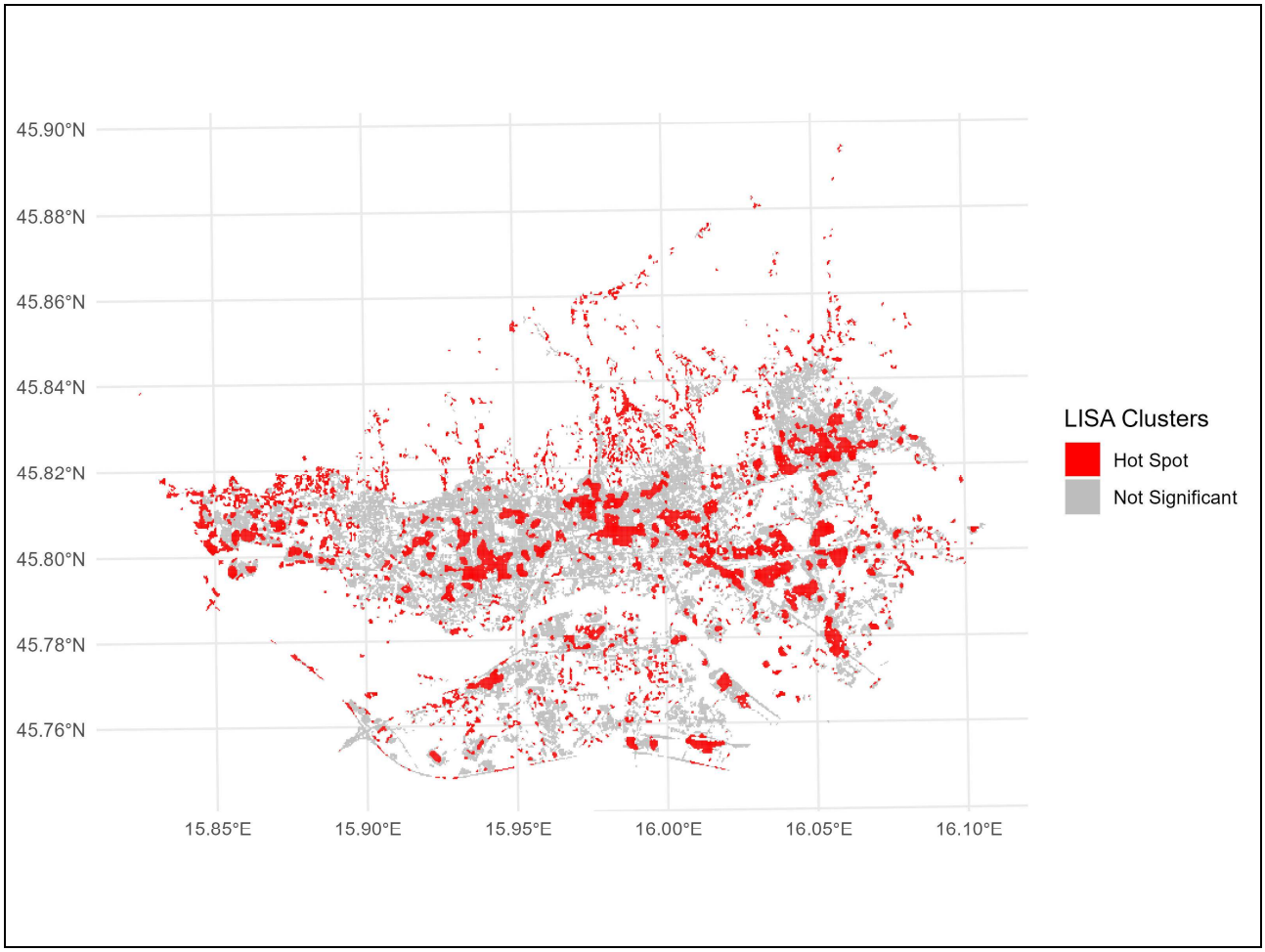

Fig. 3: Spatial Autocorrelation of UHI

6 CONCLUSION

This study provides significant insights into the spatial dynamics of Urban Heat Islands (UHIs) in Zagreb by employing a methodological framework that integrates correlation, regression, and spatial autocorrelation analyses. The findings reveal that built-up intensity is a key driver of elevated land surface temperature (LST), while planned green spaces, such as park-forests (Z2) and protective green areas (Z), play a critical role in mitigating UHI effects.

The spatial autocorrelation analysis, using Moran's I (Moran I = 0.920, p-value $< 2.2 \times 10^{-16}$) and Local Moran's I (LISA), identifies statistically significant UHI hotspots that are spatially clustered in high-density urban zones characterized by impervious surfaces and minimal vegetation. This precision in hotspot detection underscores the spatial dependency of UHI formation and validates the influence of urban planning and land-use patterns on the thermal environment.

The study advances UHI research by moving beyond traditional descriptive methods, employing spatial autocorrelation techniques to validate clustering patterns and incorporating regulatory zoning frameworks (GUP) to contextualize thermal patterns. By integrating high-resolution Landsat-9 satellite imagery from July 10, 2024, the research provides a snapshot of UHI intensity on an extreme temperature day, ensuring accurate identification of heat-prone areas. However, this single-day analysis does not capture seasonal or annual variations, and future research could incorporate multi-temporal analysis to assess UHI evolution over time and the effectiveness of mitigation strategies. Additionally, expanding the methodological framework to include broader climatic influences, such as wind circulation, humidity levels, and

anthropogenic heat emissions, could further refine the understanding of UHI drivers in an urban environment.

The identification of UHI hotspots in high-density zones provides a foundation for targeted urban interventions, such as expanding green infrastructure, increasing vegetation density, and implementing reflective surfaces, particularly in areas most affected by heat accumulation. Furthermore, the preservation and enhancement of planned green spaces (Z1, Z2, Z3, Z4) emerge as vital components for sustainable urban design, reinforcing the importance of climate-adaptive policies in city planning.

However, the primary objective of this study was not necessarily to propose direct solutions for mitigating UHI effects but rather to conduct a systematic spatial analysis to identify the zones most vulnerable to negative temperature impacts and to assess the extent to which planned land-use categories influence temperature variations. By establishing a spatially explicit understanding of UHI formation, the findings serve as a foundation for integrating urban heat mitigation strategies into spatial planning frameworks. Based on these analyses, conclusions can be incorporated into urban planning policies and regulatory documents, ensuring the protection of green areas, strategic tree planting, and improved zoning regulations to enhance climate resilience.

Future research should incorporate multi-temporal analysis to assess long-term trends in UHI intensity and evaluate seasonal variations in land surface temperature. Expanding the study to include meteorological factors such as wind patterns, humidity, and anthropogenic heat emissions would provide a more comprehensive understanding of UHI drivers. Additionally, refining statistical models by integrating urban geometry indices (e.g., building height, albedo, sky view factor) could enhance the explanatory power of UHI predictions. Further investigation into the effectiveness of different types of green infrastructure – such as tree canopy density, water bodies, and rooftop gardens – would offer targeted strategies for mitigating urban heat. These advancements would strengthen the link between geospatial analysis and urban planning, ensuring more effective climate adaptation strategies.

This research contributes to UHI analysis by:

- Advancing the methodological framework for UHI studies by integrating remote sensing, regression modeling, and spatial autocorrelation techniques.
- Providing statistically validated evidence for the role of built-up intensity and green spaces in temperature regulation.
- Utilizing spatial clustering methods to precisely identify UHI hotspots, strengthening the case for targeted mitigation efforts.
- Aligning findings with urban planning regulations (GUP), bridging the gap between geospatial analysis and policy implementation.

Overall, this research highlights the critical role of spatial modeling in addressing urban heat challenges and offers a replicable framework for integrating geospatial data with urban planning to support climate-resilient cities. By leveraging advanced spatial statistical tools, this study provides a robust evidence base for designing effective UHI mitigation strategies, ensuring that urban policies align with climate adaptation objectives to enhance the long-term sustainability of urban environments.

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reviewed paper

Exploring the Intersection of Gender Equality, Urban Planning, and Sustainability: A Systematic Review

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1 ABSTRACT

Gender equality is a critical yet often overlooked aspect of urban planning and sustainability. Urban environments significantly shape social, economic, and environmental dynamics but frequently fail to account for the distinct needs, experiences, and challenges faced by women. This systematic review examines the intersection of gender equality, urban planning, and sustainability, highlighting how traditional urban planning practices, when developed without a gendered perspective, perpetuate existing inequalities, particularly in areas such as access to public spaces, safety, and essential services. The study aims to fill a gap in the literature by exploring the integration of gender-sensitive approaches into urban sustainability practices. Bibliometric analysis will be conducted using VOSviewer to map and analyse research trends in gender equality, urbanism, and sustainability. The PRISMA protocol for systematic reviews will be followed to ensure a rigorous and transparent methodology in selecting and analysing relevant publications. This review provides an overview of the current state of research and offers insights for future studies and policy development aimed at integrating gender-sensitive approaches into urban planning to promote sustainability and social equity.

Keywords: Gender Equality, Urban Planning, Sustainability, Gender-Transformative Urbanism, Bibliometric Analysis

2 INTRODUCTION AND BACKGROUND

Cities are not neutral spaces – they reflect and reproduce social hierarchies, including gender inequalities. Despite growing global commitments to gender equality, urban environments often remain designed for an assumed universal user who is typically male, able-bodied, and economically mobile (Jabeen, 2020). This oversight in urban planning has far-reaching implications, particularly for women, who face challenges related to safety, mobility, and access to public spaces. Sustainable cities cannot be achieved without addressing these disparities and ensuring that urban environments are inclusive and equitable for all. This study is significant because it highlights the critical intersection of gender equality, urban planning, and sustainability, offering a systematic review of how gender-sensitive approaches can transform urban environments. While research on gender and urbanism has expanded in recent years, much of it remains fragmented, and the implementation of gender-inclusive planning remains inconsistent (Rampaul & Magidimisha-Chipungu, 2022). This study conducts a bibliometric analysis to identify key research trends, gaps, and thematic developments in the field. The literature provides a background for the study, highlights perspectives on gender equality, and points out the significance of this research. It emphasises the underrepresentation of gender considerations in urban planning practices and examines global and regional frameworks related to gender equality. The study also reflects on key theoretical frameworks, particularly feminist urbanism, gender mainstreaming, and sustainable urban development informing the research. Furthermore, it discusses the challenges and opportunities associated with gender-inclusive urban planning, aiming to contribute to a clearer and more structured understanding of gender-responsive urban planning.

3 LITERATURE REVIEW

Gender equality is a critical yet often overlooked aspect of urban planning and sustainability. Urban environments significantly shape social, economic, and environmental dynamics but frequently fail to account for the different needs, experiences, and challenges faced by women (UN-Habitat, 2022). Traditional urban planning practices, when developed without a gendered perspective, perpetuate existing inequalities, particularly in areas such as access to public spaces, safety, and essential services (Westendorp, 2021). In many African cities, deeply entrenched patriarchal systems and the lasting socio-economic and spatial impacts of colonialism further marginalise women in urban spaces (Parnell & Pieterse, 2019). Addressing

these challenges requires alignment with international frameworks such as Agenda 2063 and the Sustainable Development Goals (SDGs), specifically Goals 5 and 17, which advocate for gender equality and collaborative implementation strategies (United Nations, 2023). This study reviews existing literature at the intersection of gender equality, urban planning, and sustainability, specifically focusing on women's experiences and needs. The review synthesises key insights and identifies research gaps that hinder the development of truly inclusive urban environments.

3.1 Underrepresentation in Urban Planning

While gender-based marginalisation in urban planning is a key focus, the paper argues the broader issue of underrepresentation extends to other marginalised groups, including low-income communities, ethnic minorities, people with disabilities, and LGBTQ+ individuals (Fainstein & Servon, 2005; Sandercock, 1998). Urban planning literature increasingly highlights how exclusionary policies and planning frameworks have reinforced social hierarchies and spatial inequalities (Soja, 2010). Historically, city development has prioritised economic growth over inclusivity, often neglecting the voices of those who are most affected by inadequate infrastructure, housing insecurity, and unsafe public spaces (Miraftab, 2009). Examining gender alongside these intersecting forms of marginalisation, this review contributes to a more comprehensive understanding of urban inequities and the necessity of inclusive planning approaches.

3.2 Global and Regional Frameworks on Gender Equality in Urban Planning

Moreover, the global significance of gender equality, urban planning, and sustainability is firmly embedded within international development frameworks such as the SDGs and the New Urban Agenda (United Nations, 2016). SDG 5 emphasises achieving gender equality and empowering all women and girls, recognising that sustainable development cannot be achieved without addressing women's needs and rights (United Nations, 2015). Research has demonstrated a positive correlation between gender equality and improvements across various sectors, including economic growth, public health, and social cohesion (Duflo, 2012). Simultaneously, SDGs 11 and 17, as outlined in Agenda 2063, emphasise the need for urban planning to create inclusive, safe, resilient, and sustainable cities through collaborative implementation strategies (United Nations, 2015). The African Union's Agenda 2063 calls for gender-sensitive urban policies that rectify historical injustices and ensure equal access to urban resources, services, and decision-making structures (African Union, 2015).

3.3 Theoretical Frameworks and Key Debates in Gender and Urban Planning

The interdisciplinary nature of this research is rooted in three core theoretical frameworks: feminist urbanism, gender mainstreaming, and sustainable urban development. Feminist urbanism critically examines why gender-sensitive planning is necessary, challenging traditional male-centric urban design (Kern, 2020). Gender mainstreaming provides a structured approach to institutionalising these changes by ensuring gender perspectives are integrated into urban policy and decision-making (UN-Habitat, 2022). Additionally, sustainable urban development places gender equity within the broader goal of long-term urban resilience and sustainability, ensuring that cities address the needs of all citizens, particularly women and other marginalised groups (Campbell, 2016).

3.4 Challenges and Opportunities in Gender-Inclusive Urban Planning

Historically, urban planning has overlooked women's unique experiences, often reinforcing societal biases (Spain, 2016). This has resulted in urban spaces designed primarily for men, neglecting the realities faced by women in terms of mobility, safety, and access to essential services (Kern, 2019). Feminist urbanism serves as a key theoretical lens in this study, critiquing traditional urban planning and advocating for gender-sensitive design approaches that enhance inclusivity. Research increasingly highlights the benefits of incorporating gender considerations into urban planning, leading to safer, more accessible, and equitable cities (UN-Habitat, 2016). Inclusive urban design that considers women's needs – such as well-lit streets, safe public transport, and accessible childcare facilities – can enhance social cohesion and create vibrant, livable communities (Sandilands, 2020).

Beyond gender, urban planning scholarship highlights the need for an intersectional approach that considers race, class, disability, and other factors in city design (Crenshaw, 1989; Parnell, 2020). Cities that fail to consider these factors risk perpetuating inequality through exclusionary infrastructure and policy decisions

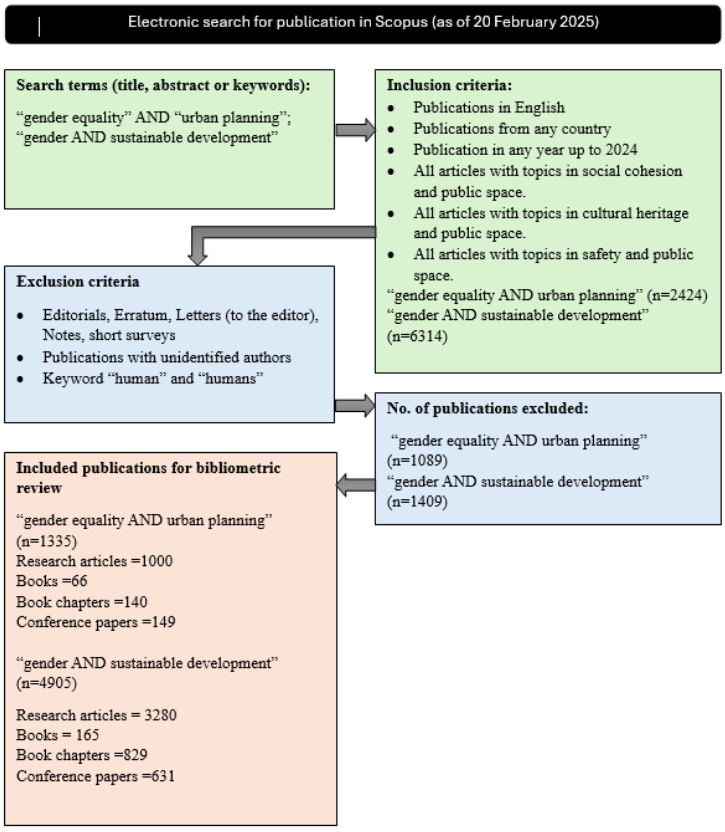
(Robinson, 2016). Gender mainstreaming ensures that women's perspectives are embedded in all levels of urban planning and decision-making (UN-Habitat, 2022). However, research also highlights the challenges of implementing gender-inclusive strategies, emphasizing the necessity of institutional support and policy integration. Furthermore, gender-inclusive policies can enhance sustainability outcomes by addressing the specific needs and challenges faced by women, leading to more effective and equitable urban solutions (UN Women, 2016). As African cities plan for future development, sustainability becomes a key priority, necessitating gender equality within broader urban sustainability goals, such as those outlined in Agenda 2063 and the SDGs. This perspective aligns with social, economic, and environmental sustainability, advocating for cities that are inclusive, resilient, and equitable (Campbell, 2016).

4 METHODOLOGY

This study employs a bibliometric review methodology to explore the intersection of gender equality, urban planning, and sustainability, with a particular focus on integrating gender-sensitive approaches into urban development practices. Intersectionality recognises that women's experiences are shaped by multiple social categories such as race, class, and geographic location, creating unique challenges of marginalisation and privilege (Crenshaw, 1989). The Scopus database was selected as the primary source for this study due to its extensive coverage of peer-reviewed literature across various disciplines, including urban planning, architecture, sociology, and cultural studies (Bass et al.,2020). The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol was used to ensure a rigorous and transparent process for selecting and analysing relevant publications. These findings provide valuable insights for researchers, policymakers, and urban planners, ensuring that gender-sensitive urban planning is a core component of sustainable development. This is particularly crucial in African contexts, where historical and socio-cultural dynamics have shaped spatial inequalities that disproportionately affect women and other marginalised groups.

4.1 Selection criteria

On 20 February 2025, a Scopus database search was conducted to access and evaluate the body of research on gender equality, urban planning, and sustainability.



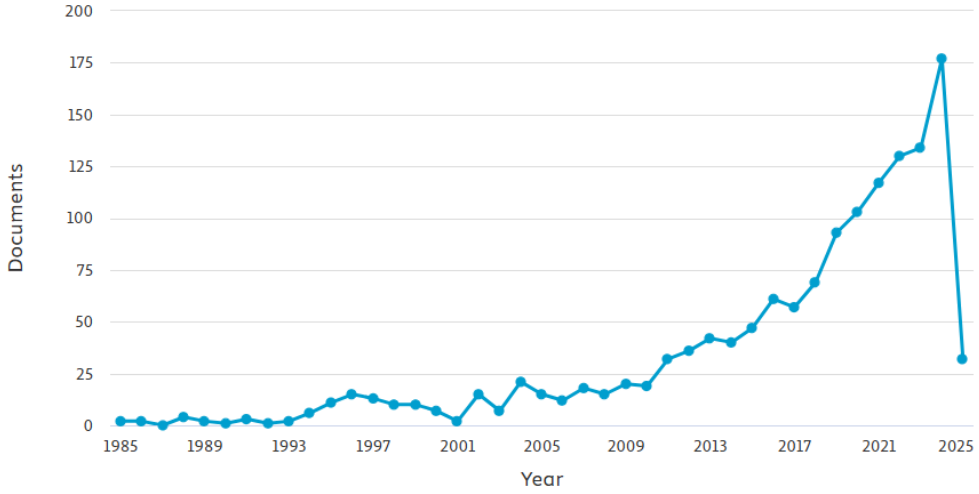
To ensure a comprehensive review, no specific time frame was imposed. The search terms included "gender equality AND urban planning" and "gender AND sustainable development". The inclusion criteria focused

on English-language publications from any country and any year up to 2025. Exclusion criteria eliminated editorials, errata, letters, notes, short surveys, publications with unidentified authors and books, book chapters, reviews, and conference papers not published in English. To ensure rigorous selection, titles and abstracts were screened to confirm eligibility, guided by the PRISMA protocols, which provide a robust and systematic framework for literature reviews, minimising bias, increasing the reliability of results, and ensuring clear and organized presentation (Selcuk, 2019; Page et al.., 2021). The analysis includes network maps, graphs, and tables to demonstrate key trends, influential authors, and emerging themes in gender equality and urban sustainability. This approach will allow for the identification of research gaps and key scholarly trajectories in the intersection of these fields (Jia and Mustafa, 2022). Furthermore, the review will synthesise the findings, highlighting the contributions of leading scholars and tracking the evolution of research topics. By addressing these disparities, this study contributes to the discourse on fostering truly inclusive and sustainable urban futures that prioritise women's needs and create equitable urban environments for all.

5 RESULTS AND DISCUSSIONS OF THE BIBLIOMETRIC ANALYSIS

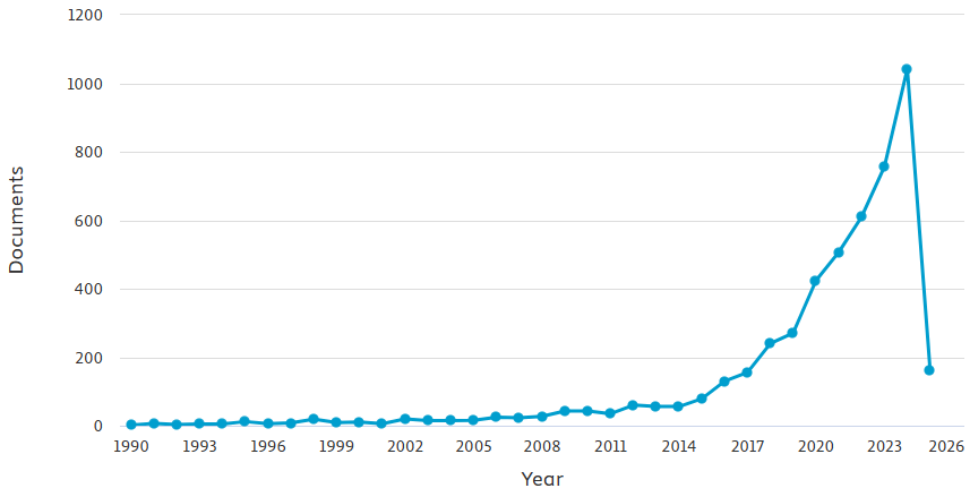
5.1 Publication trends

The analysis of the publication trends at the intersection of "gender equality" and "urban planning" reveal a significant increase in scholarly interest, particularly from 2010 onwards. This surge aligns with global initiatives emphasizing gender equality and sustainable urban development, such as the Sustainable Development Goals (SDGs) adopted in 2015. Specifically, SDG 5 aims to achieve gender equality, while SDG 11 focuses on making cities inclusive, safe, resilient, and sustainable. The heightened research activity post-2015 suggests that these international frameworks have catalyzed academic exploration into how urban planning can address gender-specific needs (Rampaul and Magidimisha-Chipungu, 2022; Yu-an Chung and Grichting Solder, 2024).



Graph 1: Publication trends for research on gender and urban planning (Authors, 2025)

The peak in publications observed in 2024, exceeding 175 documents, indicates that gender-sensitive urban planning has become a well-established research area. This trend may be attributed to increased policy shifts, funding opportunities, and a heightened academic focus on integrating gender perspectives into urban studies (Melin and Levonen, 2024). However, the sharp decline in 2025 could be due to incomplete data for that year, as academic databases often experience delays in indexing newly published articles. Alternatively, it might reflect a saturation point in the literature or a shift towards emerging themes within the field. These findings underscore the evolving recognition of the importance of incorporating gender-sensitive approaches in urban planning to promote sustainable and equitable cities. The growing body of research highlights the necessity for urban policies that consider the unique experiences and challenges faced by different genders, aiming to create inclusive public spaces and infrastructure that cater to all community members (Barker, et al. 2024).



Graph 2: Publication trends for research on gender and sustainable development (Authors, 2025)

The graph depicts a significant upward trend in publications related to gender and sustainable development over the past three decades, indicative of a growing scholarly interest in the intersection of these two critical areas. The steady increase from 1990 to the mid-2010s suggests a gradual recognition of the importance of gender considerations in sustainability discourses. However, the dramatic surge in publications from 2017 onwards points to a more recent and pronounced emphasis on this nexus. This escalation likely reflects the increasing awareness of gender's pivotal role in achieving the Sustainable Development Goals (SDGs), particularly Goal 5 on Gender Equality, and its interconnectedness with other goals. The spike could also be attributed to increased funding opportunities, progressive policy frameworks, and a broader societal push for inclusivity and equity in sustainable development initiatives. While the graph illustrates a positive trajectory in research output, it also underscores the need for continued scholarly engagement to translate research into tangible impacts on policy and practice, ensuring that gender perspectives are effectively integrated into sustainable development agendas globally (UN Women, 2018). Furthermore, future research should focus on addressing existing knowledge gaps, exploring the nuances of gender dynamics across diverse cultural contexts, and promoting intersectional approaches that consider the interplay of gender with other social categories in shaping sustainable development outcomes (Broome and Ranford, 2021).

5.2 Keyword Analysis

The keyword analysis of “gender” AND “urban planning” using VOSviewer reveals three major thematic clusters shaping scholarly discourse in this field. The first cluster (red) focuses on the direct relationship between gender and urban planning, emphasizing key topics such as urban areas, perception, surveys, women’s status, and greenspace, highlighting how women experience and interact with urban spaces in terms of access, safety, and mental well-being. The second cluster (green) centers on transportation planning, urban transport, roads, streets, and micromobility, indicating that gender-sensitive urban planning research heavily intersects with mobility and accessibility concerns, particularly in regions like the United Kingdom and Catalonia, where progressive transport policies may influence research. The third cluster (blue) addresses socioeconomic and policy dimensions, linking public policy, economic factors, employment, and urbanization in developing countries, with strong geographic connections to Africa, Bangladesh, and Southern Asia.

The presence of terms related to health, psychology, and marital status suggests an intersectional approach, linking gender disparities in urban planning to broader sociopolitical and behavioral factors. These findings underscore that traditional urban planning has largely overlooked gender-specific needs, leading to inequities in mobility, accessibility, and economic opportunities (Harrison et al., 2022). The transport and mobility cluster reinforces existing research indicating that women face greater transport insecurity, limited mobility options, and gendered constraints in urban transport systems, necessitating more inclusive policies (Ng et al., 2020). The prominence of policy and economy-related keywords suggests that gender disparities in urban planning are not just about infrastructure but are deeply tied to broader governance and development structures, particularly in the Global South (Kabeer, 2021). As global urbanization accelerates, integrating

gender-sensitive policies into urban planning becomes crucial for achieving sustainable and equitable cities (UN-Habitat, 2022). This bibliometric analysis highlights key research gaps in gender-sensitive urban planning, particularly in mobility, accessibility, and policy-driven inclusivity, reinforcing the urgent need for more intersectional and gender-responsive urban governance frameworks.

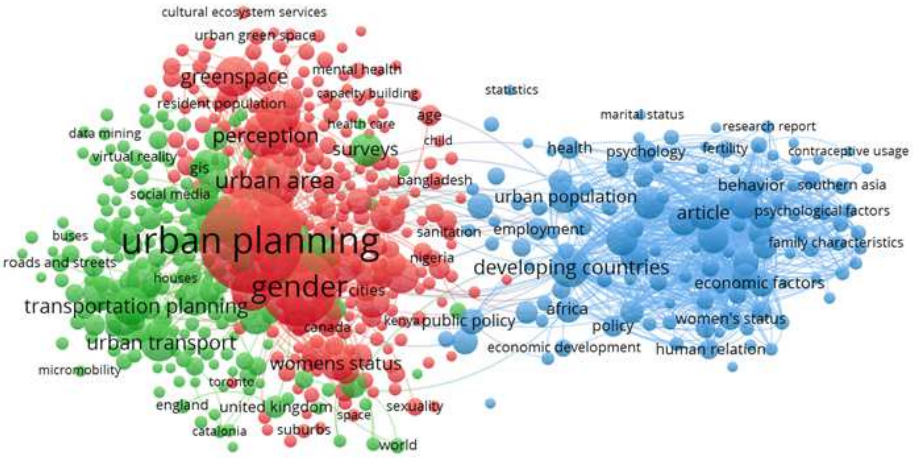


Figure 1: A co-occurrence network analysis of keywords on gender and urban planning research (Authors, 2025).

5.3 Top countries publishing in gender equality, urban planning, and sustainability

The global research landscape on gender, urban planning, and sustainability in the table below shows that the United States and the United Kingdom are the leading contributors, with substantial publications, citations, and total link strength, indicating both academic dominance and global influence. Total link strength reflects the level of international collaboration and the impact of research beyond national borders (Van der Heijden, 2016). Countries like China and India, though producing a significant number of documents, have lower citation counts and link strengths, suggesting more localized research. Meanwhile, countries like Canada, Spain, and Germany show moderate output with a strong regional focus. Emerging nations, such as India, and smaller contributors like Italy and the Netherlands, reflect a growing interest in gender-sensitive urban planning but may not yet have the same global recognition. Overall, the research highlights a dynamic global conversation, with the U.S. and U.K. at the forefront, but increasing contributions from other countries that address diverse urban challenges, such as gender equity, sustainability, and public space design (Parnell and Robinson, 2012; UN-Habitat, 2019).

No	Country	Documents	Citations	Total Link Strength
1	United States	262	7087	87
2	United Kingdom	159	3769	76
3	China	130	1999	44
4	Canada	85	1862	36
5	Spain	63	1067	36
6	Germany	63	967	29
7	India	94	784	28
8	Italy	42	1080	23
9	Netherlands	35	587	20
10	Australia	66	1509	18

Table 1: Top ten countries publishing on urban planning, gender, and sustainability

5.4 Top authors publishing in gender equality, urban planning, and sustainability

The field of gender, urban planning, and sustainability has seen significant contributions from a diverse range of scholars, each focusing on unique aspects of gendered urban spaces.

Leading this academic discourse is Tiziana Campisi, an Italian author with extensive publications on gender-sensitive urban design and accessibility, whose recent work explores gendered perspectives in sustainable urban development. Campisi's research emphasizes the importance of creating inclusive urban environments that prioritize safety and accessibility for women (Campisi, 2023). Donna Asteria, an academic from Brazil, examines urban governance and social inclusion, with her most recent work focusing on gender-responsive

governance and urban resource distribution (Asteria, 2022). While Asteria's citation count is lower, her contributions are still valuable in promoting gender equity through urban policy reform. Socrates Basbas, from Greece, has published research on gendered mobility in transportation systems, and his latest article, "Does Gender Matter in Daily Urban Mobility? Exploring Travel Perceptions, Attitudes, and Behaviours," advocates for transportation policies that address the needs of women and marginalized groups. Giovanni Tesoriere, an Italian researcher, focuses on public space design and social inclusion with his recent research on designing gender-inclusive public spaces. Tesoriere's work stresses the role of public spaces in promoting gender equality. Dyah Utari, from Indonesia, has written extensively on gender issues in informal settlements, with her latest work exploring urban informality and gender in Southeast Asia. Jo Beal and Alison Todes are both South African scholars whose work primarily addresses the intersection of gender, race, and transformation in urban planning. Collectively, these authors highlight the crucial need for gender-responsive urban planning practices that empower women, address gender inequalities in urban spaces, and ensure equitable access to resources and opportunities.

Author	Documents	Citations	Total Link Strength
Tiziana Campisi	9	317	8
Donna Asteria	6	19	5
Socrates Basbas	4	222	5
Giovanni Tesoriere	4	279	5
Dyah Utari	5	18	5
Jo Beal	6	137	2
Alison Todes	4	93	2
Doris Damyanovic	5	24	1
Ines Sanchez De Madariaga	4	55	1
Liisa Horelli	4	54	1

Table 2: Top ten authors publishing on urban planning, gender and sustainability

One interesting takeaway from this analysis is the geographic diversity of scholars contributing to gender and urban planning research. While European researchers like Tiziana Campisi (Italy), Giovanni Tesoriere (Italy), and Socrates Basbas (Greece) dominate in terms of citations and international influence, scholars from the Global South, such as Donna Asteria (Brazil), Dyah Utari (Indonesia), and Jo Beal (South Africa), bring critical perspectives on gender and urban equity in developing contexts. This suggests a growing recognition of gender disparities in urban planning across different socioeconomic and cultural landscapes. Another key takeaway is the focus of their research. While European scholars tend to emphasize gender-sensitive urban design, public space accessibility, and transportation equity, those from the Global South highlight informal settlements, urban governance, and the intersectionality of race, class, and gender in urban development. This highlights how gender-related urban issues are not universal but rather shaped by local contexts, governance structures, and socioeconomic conditions.

Moreover, the varying total link strength among these researchers suggests differing levels of international collaboration. Highly cited authors like Campisi and Basbas likely engage in global research networks, while others with lower citations and link strength may have regional or localized impacts. This underscores the need for more cross-regional collaboration to bridge knowledge gaps and create inclusive urban policies that are globally informed but locally relevant. Finally, a common thread among these scholars is the call for participatory urban planning that includes women and marginalized groups in decision-making. Whether addressing transportation, public space, or informal settlements, their work reinforces the argument that gender-responsive planning is not just about inclusion but about fundamentally reshaping cities to be more equitable, safe, and accessible for all.

6 CONCLUSION AND RECOMMENDATION: TOWARDS A CONCEPTUAL FRAMEWORK ON GENDER-RESPONSIVE URBAN PLANNING

In conclusion, the analysis of research trends in gender equality and urban planning highlights the growing scholarly focus on integrating gender-sensitive perspectives into urban development. The increase in publications post-2010 aligns with global initiatives such as the Sustainable Development Goals (SDGs), particularly SDG 5 (Gender Equality) and SDG 11 (Sustainable Cities and Communities). The peak in publications in 2024 indicates that gender-sensitive urban planning has become a well-established research

area, largely influenced by international policy shifts and funding opportunities. However, variations in research output across countries and the diverse thematic focus among scholars suggest that gender disparities in urban planning are shaped by local governance structures, socioeconomic conditions, and cultural contexts (Yu-an Chung and Grichting Solder, 2024). The dominance of the United States and the United Kingdom in publication output and citations reflects their well-established research networks, while emerging contributions from China, India, and South Africa highlight increasing scholarly engagement from the Global South. Despite the significant progress in gender-focused urban planning research, critical gaps remain. The keyword analysis reveals strong research clusters around urban accessibility, transportation equity, and policy frameworks, yet more attention is needed on the intersectionality of gender with race, class, and disability in urban environments (Ng et al., 2020; Kabeer, 2021). Additionally, the lower total link strength of many Global South researchers suggests limited international collaboration, which may hinder knowledge exchange and policy translation.

There lies an opportunity, therefore, to develop a conceptual framework that incorporates the works of the top scholars and key gaps identified and discussed in the findings section of this paper. This framework serves as a key recommendation and unique contribution to policy in ensuring that cities adopt gender-responsive urban governance and urbanism. The Gender-Responsive Urban Planning Framework (GRUPF) is structured around four key dimensions: policy and governance, participatory and inclusive planning, gender-sensitive urban design, and data-driven decision-making.

Figure 2: Gender-Responsive Urban Planning Conceptual Framework (GRUPF) (Authors, 2025).

The policy and governance dimension emphasizes institutionalizing gender-sensitive policies, multi-stakeholder collaboration, and legal reforms to ensure gender equity in urban planning. By embedding gender considerations into planning regulations, decision-making processes become more inclusive and accountable. The participatory and inclusive planning dimension highlights the need for co-creation with communities, grassroots empowerment, and gender-responsive governance structures. Women and marginalized groups must actively shape urban policies and infrastructure through participatory budgeting, design workshops, and policy dialogues. The gender-sensitive urban design dimension focuses on integrating gender-responsive mobility planning, safe and inclusive public spaces, and mixed-use zoning. This involves designing cities that accommodate the unique mobility patterns of women, ensuring adequate lighting, safe sidewalks, and accessible transportation systems that enhance safety and convenience. Lastly, the data-driven decision-making dimension underscores the importance of gender-disaggregated data collection, urban equity audits, and the use of digital tools such as GIS and smart city technologies. This ensures that planning interventions are based on evidence, enabling continuous assessment and improvement of gender equity in urban development. Collectively, these dimensions offer a comprehensive and systematic approach to embedding gender equity in urban planning, fostering more inclusive, accessible, and sustainable cities.

The Gender-Responsive Urban Planning Framework (GRUPF) offers a comprehensive approach to promoting gender equality and inclusivity in urban development. By embedding gender-sensitive policies,

fostering participatory planning, and integrating gender-responsive urban design, it ensures that cities are safer, more accessible, and equitable for all residents, especially women and marginalized groups. The framework's focus on data-driven decision-making and institutional accountability enhances the effectiveness of urban policies while encouraging global collaboration, particularly from the Global South. Ultimately, GRUPF supports sustainable, resilient, and inclusive urban environments, contributing to the broader goals of gender equality and sustainable development.

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Exploring the Property Values of Logistics Facilities in the Vicinity of Cape Town International Airport

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1 ABSTRACT

Amid the growing logistics processes, numerous studies analyse the placement of economic activities near airports á la the models of airport-led development. However, to deepen the knowledge on the catchment of airports, further research is required to analyse logistics spaces near airports compared to other logistics clusters in a territory. The paper, therefore, aims to analyse property values of logistics facilities in the vicinity of Cape Town International Airport relative to six other main logistics clusters within the City of Cape Town municipality, South Africa. These clusters are Philippi, Paarden Eiland, Epping, Parow Industrial, Montague Gardens/Milnerton, and Blackheath, wherein 15 randomly identified properties were analysed in each area. The identification of logistics firms in the seven focus areas involved examining company details on Google Maps, and verifying their locations on the company websites. The property details were then searched on the City of Cape Town's cadastral GIS shapefile, which was overlaid on the Google Satellite in QGIS 3.32.0. Three key attributes were captured from the cadastral shapefile and recorded on an Excel spreadsheet: property/land parcel extent, street address, and property number. The latter two attributes were used to extract the 2022 property market values from the City of Cape Town's valuation roll, available on the municipal website. Statistical analysis was then conducted in the IBM's statistical package for social sciences (SPSS), version 29. The results showed that the mean property values in the vicinity of the airport ranked sixth among the seven focus areas, with Montague Gardens/Milnerton having the highest value and Blackheath the lowest. In terms of the range, the airport environs ranked fourth, with Montague Gardens having the widest and Epping the narrowest. Regarding the property value relative to extent, the mean in the vicinity of the airport ranked second, following Paarden Eiland. The findings show that from the perspective of property values, the area near the airport does not significantly stand out compared to other logistics nodes in the municipality. Holding other locational factors constant, it can be argued that logistics firms near the airport could potentially be located in various zones within the broader airport catchment area.

Keywords: Cape Town International Airport, property values, logistics facilities, airport catchment, Planning

2 INTRODUCTION

The relationship between airports and the geographical distribution of economic activities has become a key focus in academic and policy discourse (Mokhele, 2022). This interest is epitomised by the popularity of the normative models of airport-led development, notably the airport city and aerotropolis. Although the airport city encompasses various categories (Conway, 1993), it is largely used to promote urban development in the immediate vicinity of airports (Kasarda, 2009). As the airport city evolves, development is expected to radiate outward, eventually shaping the spatial form of aerotropolis, which could extend for miles beyond the airport (Kasarda & Lindsay, 2011). Policymakers, spatial planners and airport authorities, inter alios, employ these models to market and guide the economic activity mix and spatial form of development that is understood to have a reciprocal relationship with airports.

The significance of airports in the contemporary economy is best understood against the backdrop of logistics processes. The logistics industry, which is a wide-ranging sector encompassing, inter alia, transportation, warehousing, storage, handling, processing, and delivery (Lan, Yang & Huang, 2017), facilitates the flow of goods between points of origin and consumption globally (Verhetsel, 2015). Among the various transport modes used in logistics, air cargo/airfreight is one of the backbones of global trade (Schwarz, 2006). According to the International Air Transport Association (n.d.), air transport accounts for about 35% of the value of global trade, highlighting the crucial role of airports in global supply chains and logistics processes. The airfreight market continues to expand, driven by the rapid growth of e-commerce, and the associated advantages of a timely delivery of goods (Kim & Lee, 2019). The rise of global supply

chains and e-commerce has, therefore, contributed to the development of a dynamic logistics estate market worldwide (de Oliveira, Dablanc & Schorung, 2022).

While airport-related literature has traditionally focused on the spatial economic characteristics of the immediate surrounds of airports, covering topics such as logistics sprawl, logistics parks, and the concentration or clustering of logistics facilities (Mokhele, 2022), a growing body of research examines airfreight catchment at different geographical scales (for instance, see Rodrigue, 2003; Hesse, 2010; Mokhele & Mokhele, 2023). To enhance our understanding of the catchment of airports, further research is needed to compare logistics spaces near airports with other logistics zones. The paper, therefore, aims to explore the property values of land used for logistics facilities near Cape Town International Airport compared to other logistics clusters within the City of Cape Town municipality, South Africa. The findings are expected to offer insights for strategically guiding the location of logistics firms within the airport's catchment area.

3 LITERATURE REVIEW

To contextualise the discussion on the property market values of land used for logistics facilities near the airport compared to other logistics nodes in the City of Cape Town municipality, this section reviews the literature on the real estate valuation methods, and the factors that influence the location of logistics firms.

3.1 Factors influencing the location choice of logistics firms

Identifying and analysing factors that influence the location of logistics facilities is essential for developing appropriate logistics-related land-use planning policies, strategies and guidelines (Sakai, Beziat & Heitz, 2020). As noted by Verhetsel et al. (2015), the location choices of logistics firms are influenced by a wide array of factors, including land availability and affordability, availability and quality of transport infrastructure, the level of economic development, the availability of labour, and land-use planning.

As the relationship between transport and the placement of logistics firms has been extensively examined in the literature (e.g. Heitz & Dablanc, 2015; Kang, 2018), the paper focuses specifically on the aspect of land affordability. The literature suggests that, due to the limited supply of land for development in the urban core, logistics facility development shifts toward peripheral areas where land is more readily available (Yang et al., 2022). At a micro level, land price plays a crucial role in location decisions, driving logistics development away from dense urban centres (Heitz et al., 2018). Unlike office and retail developments, it is argued that logistics firms can only afford smaller land rents (Verhetsel et al., 2015). As a result, Heitz et al. (2018) observe that logistics operators or their real estate investors search for areas with cheaper land/rent, typically at the periphery of urban areas. Fernández, Caralt & Valcarce (2023) emphasise that peripheral nodes near airports, for instance, consequently attract space-intensive activities such as warehousing.

Several studies have empirically analysed the connection between the location of warehouses and land value or rent. In the study exploring, among others, the hypothesis that the placement of warehouses is closely related to the land value of logistics facilities, de Oliveira, Dablanc and Schorung (2022) found a statistically significant evidence that the location of warehouses and average rent prices were dependent. In the Sao Paulo Metropolitan Region, Brazil, zones with the highest number of warehouses were those with the lowest real estate values (Guerin et al., 2021). In another Brazilian study, de Oliveira et al. (2022) found land cost to be one of the critical factors influencing warehouse location decisions in Belo Horizonte.

The paper intends to empirically test the foregoing literature's assertion that land values are relatively lower in the vicinity of airports, a factor attracting the development of space-intensive logistics facilities like warehouses.

3.2 Real estate valuation methods

The value of land is influenced by various factors, including physical, economic, social, environmental, and legal considerations (Bencure et al., 2019). Dale et al. (2002) as cited in Thontteh (2013) expounded that the factors affecting a property's financial worth include location, size, condition, the type of construction, the type and security of tenure, permitted land use, and the state of the economy. Additionally, the dynamics of demand and supply play a crucial role, showing that the equilibrium between demand and supply, along with the purchasing power, influences property values (Demetriou, 2016).

Land valuation is the process of estimating the value of land, which can be expressed in relative or absolute terms (Bencure et al., 2019). The process is intended to provide an unbiased assessment of a property to establish its value (Kartikasari et al., 2023, cited in Wentzel & van der Merwe, 2024). Valuation exercises can be performed manually or through automated techniques. The latter involve collecting market values that serve as a sample, which are then calibrated to develop a valuation model for a given area (Bencure et al., 2016).

Mass valuation techniques have been widely adopted in various countries, either as components of land administration systems or as part of fiscal systems that utilise land cadastre data for taxation and other purposes (UNECE, 2001; Wang & Li, 2019). Consequently, mass valuation models form part of a property attribute system, such as a cadastre or land registry, which is used for various land management purposes (Grover, 2016).

Mass valuation is a systematic assessment of a large number of properties performed on a certain date utilising uniform procedures and statistical analyses, which is in contrast to individual valuations, which focus on determining the value of individual properties (UNECE, 2001). Therefore, mass valuations are utilised when a large number of properties have to be valued simultaneously on a single date. As alluded to above, this approach relies on standardised procedures, common sets of data, usually derived from a property attribute system, and statistical models of the relationship between value and property attributes. These involve estimating the relationship between the market price (the dependent variable) and the varied characteristics of properties that influence the price (Grover, 2016).

As discussed further in the research methods section, the study that the paper reports on was based on the City of Cape Town's market property values, compiled by the municipality through mass valuation processes.

4 STUDY AREA

The study explored the market property value patterns of land used for logistics facilities near Cape Town International Airport (CTIA) compared to selected other industrial/logistics clusters in the City of Cape Town municipality, South Africa. CTIA is the second busiest airport in South Africa, which handled about 10 million passengers during the 2023/2024 financial year (https://www.airports.co.za/airports/cape-town-international-airport/statistics/passenger). The City of Cape Town municipality is also home to the country's second-largest seaport, the Port of Cape Town, positioned approximately 17 km to the north-west of CTIA, an expansive passenger rail infrastructure and roads of regional and national significance.

The analysis focused on the following seven logistics clusters in the City of Cape Town: the airport and its environs (encompassing Airport Industria and Airport City), Philippi, Paarden Eiland, Epping, Parow Industria, Montague Gardens/Milnerton, and Blackheath (Fig. 1). In light of the propensity of logistics firms to locate in industrial areas, these zones represent some of the densest clusters of logistics facilities in the City of Cape Town (Mokhele & Mokhele, 2023; Mokhele & Fisher-Holloway, 2023). From a geographical perspective, the selected nodes are diverse in terms of, among others, proximity to the central business district, the seaport and the airport (Fig. 1).

Regarding the study's reference point of the airport and its environs, it is important to note that during the 1970s and 1980s, the government strategically and actively promoted industrial development in the area (Mokhele, 2017); and by 1993, a growing trend in warehousing and storage facilities had begun to emerge in the vicinity of the airport (Mokhele & Fisher-Holloway, 2024).

5 RESEARCH DESIGN AND METHODS

This section outlines the research design, the units of analysis, as well as the data collection and analysis methods used in the study.

5.1 Research design

The study was based on an exploratory quantitative design to analyse the market values of land used for logistics facilities in the environs of Cape Town International Airport compared to other logistics clusters in the City of Cape Town municipality.

5.2 Units of analysis

The study's units of analysis were the land parcels used for logistics facilities within the selected industrial areas in the City of Cape Town municipality. It should, therefore, be noted that the units of analysis were not individual logistics buildings, as a single land parcel could accommodate several buildings. The study considered land parcels housing at least one of the following categories of logistics facilities: warehousing, storage, distribution (including shipping container yards), self-storage, courier services, freight forwarding, and recycling depots (a component of reverse logistics).

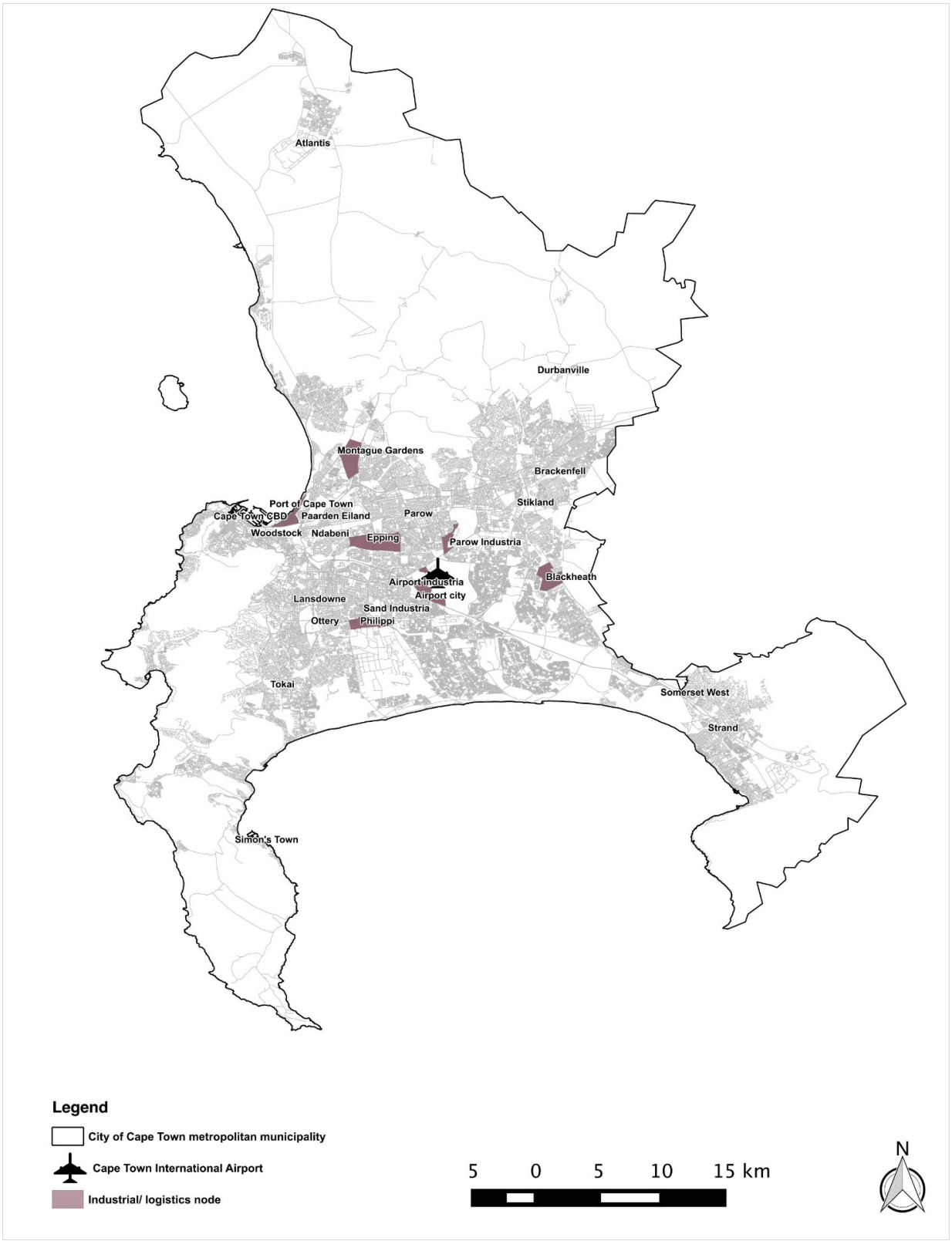

Fig. 1: The location of Cape Town International Airport relative to other selected industrial/logistics clusters.

5.3 Data collection methods

According to Heitz, Launay and Beziat (2017), a growing body of research highlights the acute lack of geo-spatial data on urban freight, resulting in a lack of a dedicated and accurate database on the geography of logistics firms (Heitz et al., 2018). Due to this lack of secondary information accurate at a land parcel level, alternative approaches were, à la Heitz, Launay and Beziat (2017), Heitz et al. (2018), and Mokhele (2018), employed to identify the applicable land parcels in preparation for the analysis of the property market value patterns. The identification of logistics firms involved examining the applicable company details on Google Maps, viewing the company names on the signage in Street View, and verifying their locations on the respective business websites where available. Per Heitz, Launay and Beziat (2017), several visual indicators were also important in identifying and validating logistics infrastructure and buildings like warehouses, terminals, and shipping container yards. These indicators included the shape and size of the building, large parking and manoeuvring areas for trucks (Heitz, Launay & Beziat, 2017), row buildings typical of the traditional self-storage facilities, and a rectangular shape and distinctly small size of shipping containers.

A total of 15 land parcels used for logistics facilities were randomly identified in each node per the process above. For comparability purposes, it was decided to analyse the same number of properties across the seven industrial/logistics zones. All in all, 105 land parcels housing logistics facilities were identified. It is intended that this exploratory study provides a foundation for the development of a geo-spatial dataset of logistics facilities in the City of Cape Town municipality, which can be continuously updated.

The unique property details of each identified land parcel were searched on the City of Cape Town's cadastral GIS shapefile, which was overlaid on Google Satellite in QGIS 3.32.0. Three key attributes were obtained from the cadastral shapefile and recorded on an Excel spreadsheet: land parcel extent (in m2), street address, and property number. The data for each logistics node was recorded on a separate tab in the spreadsheet.

The street addresses and property numbers were then used to extract the 2022 property market values from the City of Cape Town's valuation roll, available on the municipal website. The website makes provision for the values to be searched using either the unique property reference, sectional title, street address, and erf (property/parcel) number. The latter was primarily used in the study, and triangulated with the street address information. The property value information was extracted in December 2024. At the time of the study, the 2022 property market value data (as at 01 July 2022) were the latest available information for the City of Cape Town municipality. The City of Cape Town utilises a computer-assisted mass appraisal (CAMA) system to generate property values across the municipality (City of Cape Town, 2024) (also refer to the literature review section).

5.4 Data analysis methods

The information for the airport environs and other six industrial/logistics clusters (including the name of the applicable industrial area, property/land parcel extent, and market value) were collated into a single spreadsheet and loaded to IBM's statistical package for social sciences (SPSS), version 29, for analysis. Basic statistical analysis was then conducted to identify property market value similarities and differences between the area in the vicinity of the airport and other key logistics nodes in the City of Cape Town municipality.

6 RESULTS

This section presents the results of the statistical analysis conducted to compare the environs of Cape Town International Airport with selected other logistics clusters.

6.1 Descriptive statistics

The results showed that the mean property values of land used for logistics facilities in the vicinity of the airport (at R37 965 333) ranked sixth among the seven logistics clusters analysed. The mean property values were highest in Montague Gardens/Milnerton at R128 286 666, followed by Parow Industria, Philippi, Paarden Eiland, Epping, and the airport environs. Blackheath had the lowest mean of R33 464 133. In terms of the range, the land used for logistics facilities near the airport ranked fourth, with Montague Gardens having the widest range of approximately R706 million, followed by Philippi, Parow Industria, Blackheath,

and Paarden Eiland. Like the relatively low mean property values, Epping had the narrowest range of R101 300 000 (Table 1).

A land parcel with the highest market value in 2022, at R712 million, was situated in the Montague Gardens/Milnerton area, followed by properties in Philippi, airport environs, Parow Industria, Blackheath, and Paarden Eiland. Epping had the lowest maximum value of R1.08 million. The 2022 standard deviation for the zone near the airport and other six logistics clusters show that the figures ranged significantly above and below the mean values, implying the moderate to high variability of the market property values of land housing logistics facilities across the municipality.

		Airport environs	Blackheath	Epping	Montague Gardens/Milnerton	Paarden Eiland	Parow Industria	Philippi
N	Valid	15	15	15	15	15	15	15
	Missing	0	0	0	0	0	0	0
Mean		37 965 333.33	33 464 133.33	51 620 000.00	128 286 666.67	54 111 000.00	63 033 333.33	59 013 333.33
Median		16 700 000.00	16 800 000.00	38 700 000.00	41 200 000.00	19 350 000.00	62 500 000.00	23 000 000.00
Std. Deviation		70 407 442.978	41 784 874.013	34 767 908.027	182 056 972.506	55 914 306.890	53 345 326.033	84 977 685.026
Range		280 700 000	161 000 000	101 300 000	706 100 000	150 730 000	200 500 000	305 000 000
Minimum		3 300 000	2 800 000	7 100 000	5 900 000	4 670 000	5 500 000	5 000 000
Maximum		284 000 000	163 800 000	108 400 000	712 000 000	155 400 000	206 000 000	310 000 000

Table 1: Statistical patterns of the values of land used for logistics activities. Values are in South African Rand (ZAR).

6.2 Average market property values

To gain a more meaningful and disaggregated understanding of the property values, it was essential to analyse them in relation to the extent of each land parcel. Regarding the property value relative to extent, the mean values in the vicinity of the airport ranked second, following Paarden Eiland. Notably, Paarden Eiland had three land parcels with top average values relative to extend i.e. R9 507/m², R9 206/m² and R7 656/m², with a land parcel near the airport following at R5 960/m2. A land parcel with the lowest average value, at R509/m², was in Blackheath.

Table 2 presents the values of the 15 land parcels analysed in the vicinity of the airport, including the average market value per property extent. Although the highest value was R284 million (Land Parcel 10), the average was R3 509/m2 due to the large extent of the land parcel (Table 2). This expansive business park houses various logistics establishments, including courier companies and storage facilities. The land parcel with the lowest market value near the airport was R598/m2. In terms of the physical extent, this was the second- largest land parcel in the vicinity of the airport.

	Extent (m^2)	Market value (2022)	Average value/m^2 (2022)
Land Parcel 1	30 208	65 400 000	2 165
Land Parcel 2	2 097	6 800 000	3 243
Land Parcel 3	2 836	6 480 000	2 285
Land Parcel 4	2 075	6 300 000	3 036
Land Parcel 5	1 287	5 100 000	3 963
Land Parcel 6	4 454	12 600 000	2 829
Land Parcel 7	1 503	5 100 000	3 393
Land Parcel 8	4 970	16 700 000	3 360
Land Parcel 9	1 054	3 300 000	3 131
Land Parcel 10	80 941	284 000 000	3 509
Land Parcel 11	76 859	46 000 000	598
Land Parcel 12	8 510	38 100 000	4 477
Land Parcel 13	5 668	19 600 000	3 458
Land Parcel 14	10 812	32 000 000	2 960
Land Parcel 15	3 691	22 000 000	5 960

Table 2: Values of land used for logistics near Cape Town International Airport. Values are in South African Rand (ZAR).

7 DISCUSSION

The findings presented in the preceding section show that, in terms of the 2022 market property values, the land used for logistics facilities near Cape Town International Airport did not significantly differ from those in other logistics nodes within the City of Cape Town municipality. This challenges the literature suggesting that land values around airports are significantly lower, a factor attracting space-intensive activities such as warehouses (for instance, refer to Fernández, Caralt & Valcarce, 2023). The placement of logistics firms near

the airport are, therefore, potentially influenced by a combination of other factors beyond merely property values.

These findings show that, holding other locational factors constant, logistics firms near the airport could potentially locate in various zones across the broader airport catchment area. As noted by Mokhele and Mokhele (2023), the possible airfreight catchment of Cape Town International Airport can extend to approximately a 20 km radius of the airport. In light of the findings, the authorities are urged to, in the spatial planning efforts, take cognisance of the potential extent of the catchment, in which airfreight-related firms do not necessarily locate geographically near the airport (Mokhele & Mokhele, 2023).

Two logistics nodes in the City of Cape Town municipality (out of the seven analysed) stood out in terms of the highest land parcel values and average values. A land parcel with the highest market value in 2022 was in Montague Gardens/Milnerton at a staggering R712 million while the highest value near the airport was a relatively lower R284 million. Notably, in the 2000s, Montague Gardens was regarded as the fastest-growing industrial area in the City of Cape Town since 1985 (Mokhele & Fisher-Holloway, 2024). In terms of the average market values, Paarden Eiland, situated near the Port of Cape Town, had the highest average of R9507/m2 compared to the airport environs' highest average of 5960/m2. This provides evidence that Paarden Eiland has maintained a historical trend of relatively high property values. For instance, back in 1996, the area had a prime industrial rental rate that was three percent higher than the municipal average (City of Cape Town municipality, 2002).

8 CONCLUSION

To supplement the literature on the possible logistics catchment of airports, the paper explored the market values of the land used for logistics facilities in the vicinity of Cape Town International Airport compared to other six selected main industrial/logistics clusters in the City of Cape Town municipality, South Africa.

It was found that the patterns of land values near the airport did not significantly stand out, either at the highest or lowest end of the spectrum, compared to the other logistics clusters analysed. Therefore, it can be deduced that the values in the area are not a potential primary centrifugal or centripetal factor, showing that other factors might influence the placement of logistics facilities near the airport. From the perspective of land values, it can therefore be argued that, ceteris paribus, the logistics firms near the airport could locate in various areas within the municipality and vice versa.

A main shortcoming of the study is that it focused solely on market property values in comparing the land used for logistics facilities near the airport with other logistics nodes, and analysed the values for one year, 2022. It is, therefore, recommended that further research be conducted to analyse the market value patterns over time, and to examine additional factors influencing the location of logistics facilities within the catchment area. A more comprehensive analysis could also extend to a sub-regional scale, transcending administrative municipal boundaries.

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reviewed paper

Exploring the Relationship Between Gentrification and Vulnerability in Taipei City

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1 ABSTRACT

Gentrification is a process of urban development in which an area undergoes redevelopment, which raises the cost of housing, rent, and standard of living, attracting middle-class and other higher-income earners to move in, which in turn leads to the displacement of lower-income residents, changing the composition of neighborhoods and generating population replacements. This study takes Taipei City as the study area, utilizing Multiple Criteria Decision Making (MCDM) to synthesize the data on socioeconomic indicators and overlapping them into a Geographic Information System (GIS). The overlapping results identify the areas that meet the screening criteria of each indicator to recognize the gentrification areas in Taipei City and analyze the characteristics of the areas. The results were used to indentify gentrification area in Taipei City and explore relationship between gentrification and social vulnerability.

Keywords: Planning, social vulnerability, Geographic Information System (GIS), Multiple Criteria Decision Making (MCDM), gentrification

2 INTRODUCTION

Gentrification is a process of urban development in which an area undergoes redevelopment, which raises the cost of housing, rent, and standard of living, attracting middle-class and other higher-income earners to move in, which in turn leads to the displacement of lower-income residents, changing the composition of neighborhoods and generating population replacements[1], [2], [3], [4], [5], [6], [7]. In addition to changing the physical environment, gentrification also affects the existing social structure, culture, economy, and industries. Many scholars have put forward different research explanations on gentrification, such as “New-Build Gentrification”, “ Rural Gentrification”, “Greentrification”, “Studentification”, “Commercial Gentrification”.

According to the research on gentrification, the change in the physical environment will generate suction and thrust, which will make the existing residents move out and the new residents move in. This will lead to the replacement of social classes in gentrification areas and change the composition of residents in these areas. In order to cope with the population replacement caused by gentrification, the current strategy is to minimize the displacement of disadvantaged groups such as low-income households. To this end, relevant measures include rent control to avoid excessive rents and eviction restrictions to protect tenants from forced evictions. Regulating land ownership and development through taxation provides public or affordable housing and promotes the regeneration of local communities. [10], [11].

An effective gentrification strategy should be based on a certain understanding of the development of gentrification. Therefore, the results of gentrification analysis should be used as an important reference for the formulation of various mitigation strategies. The government should be able to assess the impact of gentrification on different regions and provide the relevant departments with the necessary information to formulate a response to the specific situation. The development of tailor-made mitigation strategies [12] can effectively mitigate the potential negative impacts of gentrification, especially in the protection of disadvantaged groups.

The application of quantitative analyses to explore neighborhood changes derived from gentrification is still much debated. For example, Rent Gap is often applied to compare actual and potential rent differences [13], [14], or the application of census data to study socioeconomic changes [15], [16]. Huynh & Maroko (2014) used 1990 Census data and 2005 to 2009 American Community Survey (ACS) estimates to assess changes in economic status across communities. Three variables were chosen to construct indicators of community economic status: the number of people over the age of 25 with a college degree, the number of residents living below the federal poverty line, and Median Household Income (MHI). The study examines the

association between gentrification and preterm birth (PTB) and analyzes the effects of maternal race and educational attainment. Millard-Ball (2002) used income and residential mobility to study gentrification using Stockholm as the study area. Many communities have experienced significant changes in their economic and social structures that may have impacted the health of their residents, with particular differences in the impact on different ethnic groups (e.g., low-income groups, and minority groups).

Vulnerability refers to the propensity and predisposition to negative impacts. The United Nations Office for Disaster Risk Reduction (UNISDR) points out that vulnerability is a disaster-sensitive characteristic formed under the interaction of natural, social, economic and environmental factors; the United Nations University – Institute for Environment and Human Security (UNU-EHS) points out that vulnerability is a disaster-sensitive characteristic formed under the interaction of natural, social, economic and environmental factors; UNU-EHS points out that vulnerability is a disaster-sensitive characteristic formed under the interaction of natural, social, economic and environmental factors. UNU-EHS, on the other hand, recognizes that vulnerability is determined by the interaction of natural, social, and environmental factors that determine the expected loss from a disaster.

The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) states that the level of risk will depend on the latest trends in vulnerability, exposure, socio-economic status, and adaptive capacity, with vulnerability being an important factor affecting human and socio-ecological systems, and age, Vulnerability is an important factor affecting human and social ecosystems, while age, medical resources, and social deprivation, as well as working and living conditions combine to determine human vulnerability [19].

The existence of vulnerability is widely recognized by various international organizations, and many studies have pointed out that vulnerability is often expressed in a negative and passive form, that is, the degree of sensitivity to disasters. Past research on vulnerability can be divided into three main orientations: (1) vulnerability is a condition that exists before a disaster occurs; (2) vulnerability is a key factor affecting the ability to adapt and respond to a disaster; and (3) vulnerability can have a certain degree of impact on a specific site. Turner et al. (2003) defined “vulnerability” as a condition consisting of natural hazards, including exposure, resistance, and vulnerability to natural hazards. Turner et al. (2003) defined “vulnerability” as being caused by natural hazards, including Exposure, Resistance and Resilience. With the development of disaster-related research, more and more studies have shown that different traits and capabilities reflect the degree of impact after an environmental shock [21], [22].

Over the past 30 years, vulnerability has become a fundamental concept in local, national, and international disaster research and the development of mitigation strategies [23], [24]. In this context, social vulnerability refers to the analysis of factors that are known or unknown to produce certain outcomes of an event. Yiing-Jenq et al. (2004) analyzed the social vulnerability of different segments of society based on the characteristics of age, gender, health, social welfare, and economy, as well as the coping strategies of social groups in response to emergencies. The study showed that children, the elderly, the sick, and the disabled may react to risk quite differently from the young and healthy. Evans & Kantrowitz (2002) also pointed out that characteristics such as income level, occupation, and household size determine socioeconomic status, which in turn determines the place of residence, its quality of life, and infrastructure, and ultimately the impact of risk.

Social vulnerability is recognized as a consequence of existing social inequalities, and many studies have shown that poor health, physical and mental impairments, and poverty are strongly associated with vulnerability [27], [28], [29]. In addition, social inequality determines an individual's living space and the nature of that living space. The vulnerability of the living space (including the means and empowerment of the dwelling, the neighborhood, and the infrastructure of neighborhood) can also effectively determine socio-economic vulnerability, which is closely related to the characteristics of the individual. Factors such as the degree of urbanization, population growth and density can further increase the vulnerability of living space.

The northern part of Taiwan has been developing rapidly in the past few decades, however, there is a relative lack of research on gentrification in Taiwan. As urban development accelerates, real estate prices continue to rise. Many areas with low socio-economic status have gradually attracted middle-class and high-income groups, leading to the replacement of social classes and changes in local characteristics. It is worthwhile to discuss how to reduce or even avoid the impact of gentrification on communities and disadvantaged groups.

Therefore, this study is expected to take Taipei City as the research field and use socioeconomic indicators to identify gentrification areas and explore the relationship between gentrification and social vulnerability.

2.1 Conceptual Model

This study is divided into two parts. First, the socio-economic indicators were integrated using a multi-criteria decision-making approach based on the key factors related to gentrification. This was then overlaid onto the GIS to identify areas that met the screening criteria for each indicator. The social vulnerability indicators were organized to create a vulnerability map. Next, this study attempts to analyze the spatial correlation between gentrification and social vulnerability variables and explore the relationship between gentrification and vulnerability (fig. 1).

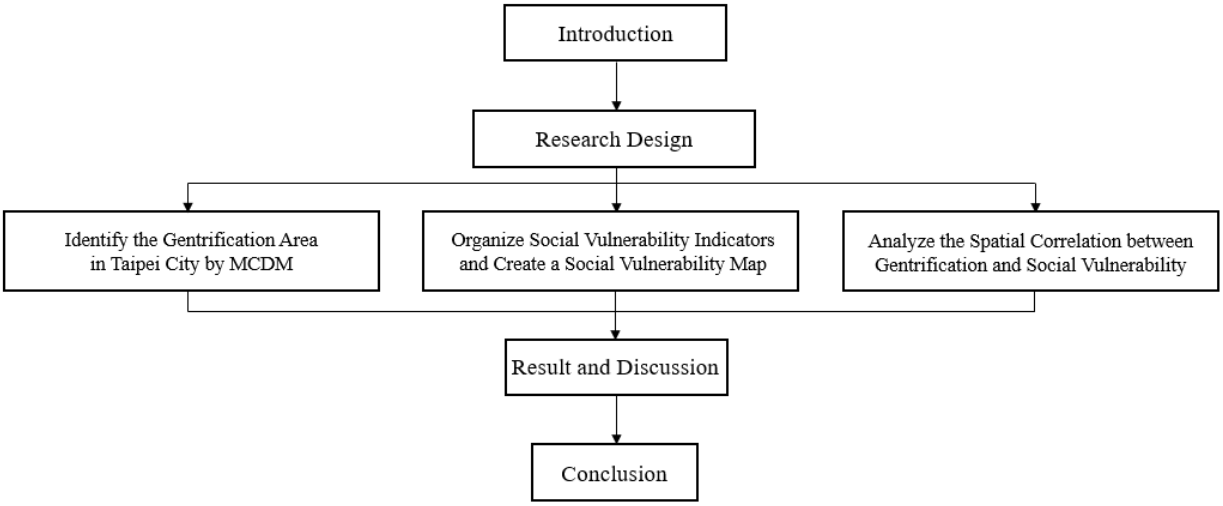

Fig. 1: Conceptual framework.

Fig. 2: Study Area (Source: generated by the authors).

2.2 Intro of Study Area

The northern part of Taiwan has developed rapidly over the past few decades and is the economic capital of Taiwan. It has many job opportunities, well-developed transportation facilities, abundant education and medical resources, and the most significant commercial development. As urban development accelerates, real estate prices continue to rise. Many areas with low socioeconomic status are gradually attracting middle-class and high-income groups, leading to a shift in social class and a change in the character of the area. Therefore, the scope of this study was chosen to be Taipei City (fig. 2), and the village was used as the unit of statistics and analysis. Multiple criteria decision aking (MCDM) was used to synthesize the socio-economic indicators and apply them to the GIS. To identify the areas that meet the screening criteria of each indicator, we identified the areas of gentrification in Taipei City and explored the relationship between gentrification and social vulnerability.

2.3 Methods

2.3.1 Multiple Criteria Decision Making (MCDM)

In this study, Multiple Criteria Decision Making (MCDM) was adopted for the first time for the gentrification indicators and the subsequent field screening. MCDM is an analytical tool used to measure multiple criteria or to make decision choices for multiple scenarios. MCDM is widely used by the planning community to solve problems in various fields because of its ability to consider multiple functions, attributes, criteria, objectives, and problems simultaneously [30], [31], [32]. Seo & Sakawa (2012) categorized the process into six stages: identifying decision objectives, determining decision preferences, evaluating alternatives, selecting weighting methods, aggregating, and making decisions. In this process, the broad and abstract objectives are transformed into more specific goals, and the weights of each factor are evaluated to compare the advantages and disadvantages of the alternatives so that the most suitable and practical alternatives can be selected to effectively help solve the decision-makers problem. In this way, the most suitable and practical solution can be selected to help the decision-maker solve the problem effectively. Different objectives and weights may affect the solution.

2.3.2 Spatial Autocorrelation Statistics

The purpose of spatial autocorrelation statistics is to examine the similarity between spatial units based on spatial distance. This approach is summarized in the “First Law of Geography”: everything is related, but proximity is more related [33]. If there is significant positive spatial autocorrelation, spatial units with similar spatial properties tend to be close to each other. In addition, spatial autocorrelation can also be used to measure geographic proximity between units or binary events [34]. Spatial autocorrelation statistics apply to the whole region (global) or neighboring regions (local). While global spatial autocorrelation explores whether there is spatial clustering among spatial units, local spatial autocorrelation explores the spatial variability of spatial autocorrelation at the local scale [35]. In this study, we will explore the degree of similarity between objects in the space, examine the aggregation or dispersion of spatial phenomena in the space due to different attributes, and analyze the correlation between the two variables (gentrification & social vulnerability) to explore the spatial correlation between the two variables.

2.4 Measurement Indicators of the Survey

This study focuses on the relationship between gentrification and vulnerability. Based on the literature review, five socioeconomic indicators of gentrification were selected: income, working-aged population, high degree population (university education or above), real estate sales, and house rent. The rate of change from 2012 to 2021 was used to identify gentrification areas. Based on the literature review, three indicators of social vulnerability were selected from 2021: the proportion of the elderly population, the proportion of the low-income population, and the proportion of disability (table 1). The indicators of gentrification and vulnerability were then standardized to obtain a map of gentrification and a map of social vulnerability.

Type	Indicators	Period
Socioeconomic	Income	2012 to 2021
	Working-aged population	2012 to 2021
	High degree population	2012 to 2021

	Real estate sales	2012 to 2021
	House rent	2012 to 2021
Social vulnerability	Proportion of aged population	2021
	Proportion of low-income population	2021
	Proportion of disability	2021

Table 1: Indicators of this study.

3 RESULT AND DISCUSSION

3.1 Socioeconomic Features of Gentrification in Taipei City

The rate of change in high degree has the highest value (1.08%) in Sanchong Vil., Nangang Dist., and the lowest value (-0.15%) in Xuefu Vil., Daan Dist. (fig. 3). The Rate of change in working-age has the highest value (0.35%) in Sanchong Vil., Nangang Dist., and the lowest value (-0.38%) in Longfu Vil., Zhongzheng Dist. (fig. 3). The rate of change in income has the highest value (16.68%) is located in Chongyang Vil., Nangang Dist., and the lowest value (-0.99%) in Laoquan Vil., Wenshan Dist. (fig. 3). The highest value of rate of change in real estate sales (2.18%) was found in Daan Dist., while the lowest value (0.25%) was found in Nangang Dist. (fig. 4). The highest value of rate of change in house rent (0.22%) was found in Wenshan Dist., while the lowest value (-0.11%) was found in Datong Dist. (fig. 4). The Gentrification map is obtained by standardizing and adding up the values of the above indicators. The highest value (15.15) is distributed in Sanchong Vil., Nangang Dist., while the lowest value (-8.48) is distributed in Longfu Vil., Zhongzheng Dist. (fig. 4).

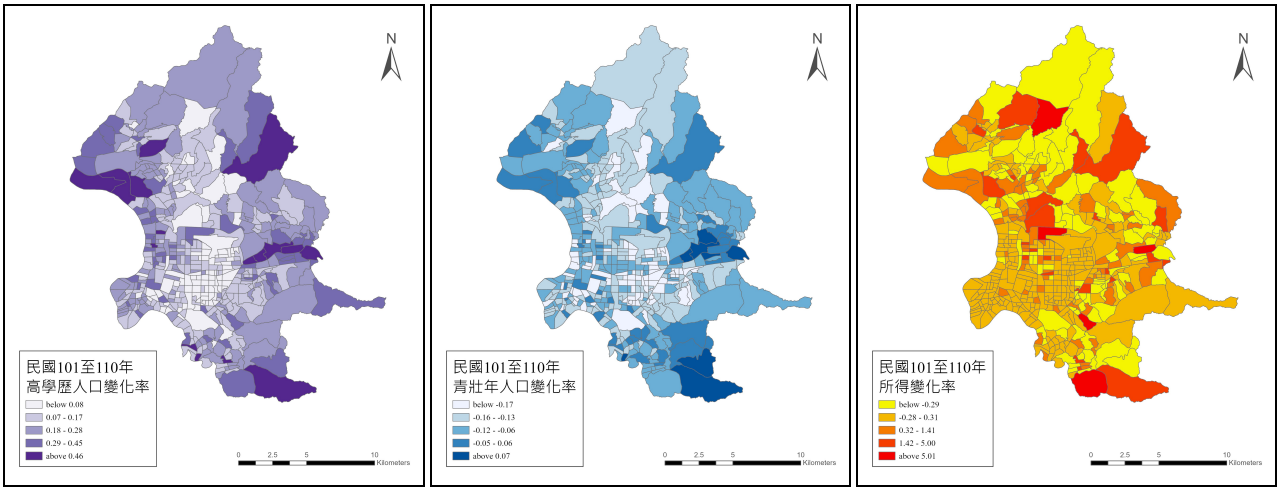

Fig. 3: Rate of change in high degree/Rate of change in working-age/Rate of change in income.

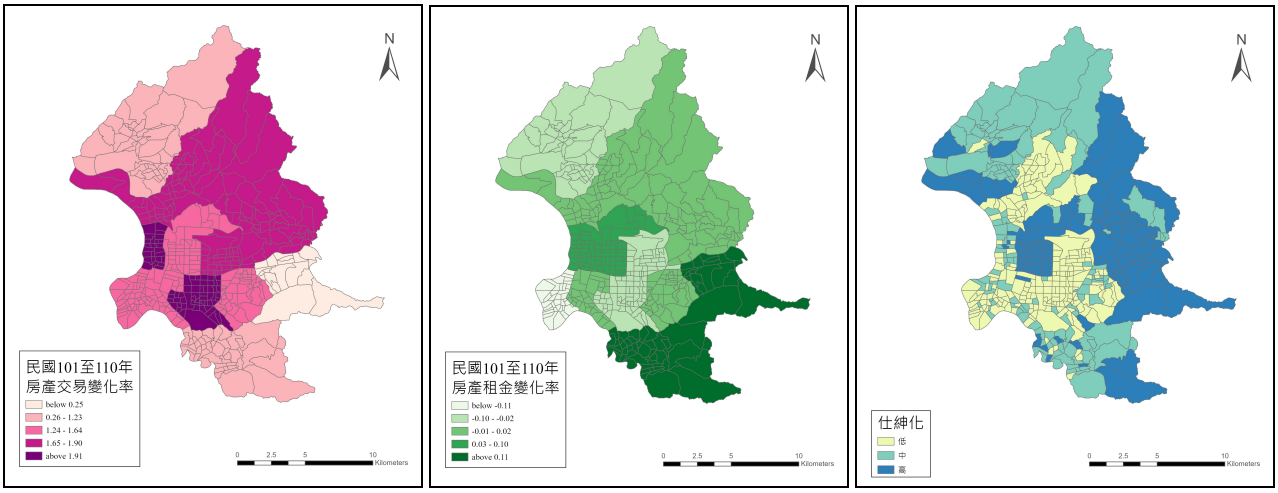

Fig. 4: Rate of change in real estate sales/Rate of change in house rent/Gentrification map.

3.2 Distribution of Social Vulnerability in Taipei City

After standardizing and adding up the values of the social vulnerability indicators (proportion of aged population, proportion of low-income population, and proportion of disability), the highest value (3.42) was found in Changlong Vil., Daan Dist., while the lowest value (-3.63) was found in Chongyang Vil., Nangang Dist. (fig. 5).

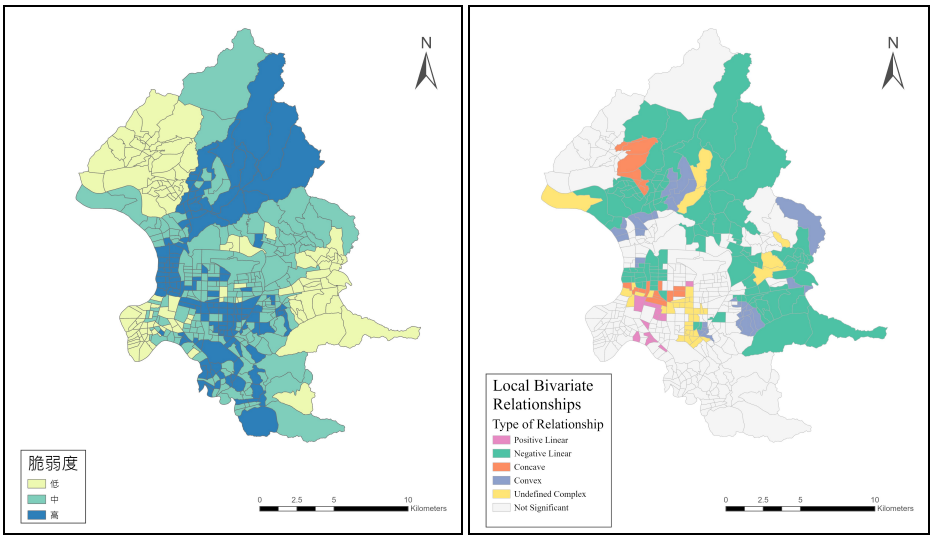

Fig. 5: Social vulnerability map/Result of Local Bivariate Relationships.

3.3 Relationship between Gentrification and Social Vulnerability

Positive linear is mostly found in ZhongZheng Dist., probably due to the fact that it has a smaller population of highly educated and young adults. The rate of change also shows a negative growth trend. The vulnerability level is more in the middle to high range, which results in a positive correlation between gentrification and social vulnerability. 11 of features are not significant, about 2.41%. The negative linear is mostly distributed in Nangang, Shilin, and Beitou Dist. The higher degree of gentrification and lower degree of vulnerability in Nangang District resulted in a negative correlation between the degree of gentrification and the degree of social vulnerability in this district (fig. 5). 107 of features are not significant, about 23.46%. Not significant means that the relationship between two variables are not significant or other explanatory factors need to be considered. 257 of features are not significant, about 56.36%.

4 CONCLUSION

This study synthesizes the relevant literature on the definition, causes, and observable characteristics of gentrification, and identifies the key influencing factors as the basis for analysis. Using Taipei City as the study area, this study utilized a multi-criteria decision-making approach to synthesize the socio-economic indicators. This was then overlaid onto the GIS to identify areas that met the screening criteria for each indicator. To identify the areas of gentrification in Taipei City and to explore the relationship between gentrification and social vulnerability. Provide references for the government to formulate follow-up policies. This study suggests that the government can target the less vulnerable areas and provide substantial social welfare to reduce the impact of gentrification in these areas.

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reviewed paper

Exploring the Role of Urban Identity in Sustainable Development: The Conceptual Framework and Methodological Steps for its Application in Serbia

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1 ABSTRACT

Similar to other regions in Europe, the strategic positioning of medium-sized and small towns in Serbia has not yet been developed to its full extent. At the same time, its potential to contribute to sustainable, balanced territorial development and cohesion at national, regional, and local levels has been recognized through planning documents, strategies, and academic literature. The role of urban identity in the sustainable development of small and medium-sized towns has been especially emphasized. Therefore, there is a need to explore the complex concept of urban identity through analyzing the relevant literature dealing with its definition and practical use in planning. The main goal of the identity analysis is to highlight the specific characteristics of the selected settlements and value them as spatial, material, and immaterial elements that should be at the same time protected and developed. This implies the application of a place-based approach in planning and developing strategies to include the concept of identity as an important parameter for the qualitative assessment of planning solutions. The resulting conceptual framework consists of material and immaterial elements of identity that can be grouped into sets of specific characteristics. Secondly, the sustainable development policy framework for small urban areas in Europe has been investigated, resulting in a set of key thematic fields applicable in general practice and all contexts. The third step subsumes relating the elements of identity with the key thematic fields and creating the framework for measures and strategic directions that would enable simultaneous protection of existing and creation of new place values. This methodology has been applied to the study of identity of five territorially connected municipalities in Western Serbia, that already share a number of common characteristics. Consequently, not only their individual but also their common identity, compared to other regions in Serbia, can be examined. The uniqueness of the individual towns affects the sustainable development policies at the urban level – for regeneration and revitalization of urban centers, their specialization, and positioning. The uniqueness of the common territory opens up possibilities for sustainable development policies at the regional level, for catalyzing economic growth and reinforcing polycentric development at the national level.

Keywords: urban identity, sustainable development, planning strategies, medium-sized and small cities and towns, Serbia

2 INTRODUCTION

Strategic positioning of medium and small towns in Serbia is still not fully developed. At the same time, their potential to contribute to sustainable, balanced territorial development and cohesion at the national, regional, and local levels has been recognized through planning documents (NARS, 2010), strategies (NARS, 2019), and scientific literature (Spasić, 1995, Kokotović Kanazir, 2016, Manić, Niković, 2014). The role of urban identity in the sustainable development of small and medium-sized urban settlements is highlighted in this paper. It explores the complex concept of urban identity through an analysis of relevant literature that deals with the definition and practical application of the urban identity concept in sustainable development strategies and planning.

The position of the urban identity concept in recent European legislation (EUI, EC, 2020, UN, 2017) is examined, as well as in the legal, planning, and strategic documents in Serbia (NARS, 2010, 2013, 2019, 2020, 2023). Key determinants and opportunities for applying this concept in urban planning practice are identified based on a review of theoretical research (Mansour et al., 2023, Duan et al., 2021, Rifaioglu, Güçhan, 2007, etc.). A methodology is proposed that can be applied to study the identity of urban areas with the aim of formulating strategic guidelines for their sustainable development. This methodology has been

used in a study of the identity of five territorially connected municipalities in Western Serbia, which is currently being developed at the Institute of Architecture and Urban and Spatial Planning of Serbia – IAUS (GOA, 2024-2025). Due to their territorial connection, these municipalities already share a number of common characteristics. Therefore, not only can their individual identities be examined, but also their collective identity, in comparison with other regions in Serbia. The implementation of the results of the identity study through strategic projects, using various financial instruments for urban development, contributes to the affirmation of urban areas as active advocates of sustainable and integrated urban and territorial development.

3 THE ROLE OF URBAN IDENTITY IN SUSTAINABLE DEVELOPMENT OF SMALL AND MEDIUM-SIZED TOWNS IN RECENT EUROPEAN LEGISLATION

In 2006, ESPON (European Observation Network for Territorial Development and Cohesion) conducted a study titled "The Role of Small and Medium-Sized Cities," which highlighted the issue of insufficient research and development policies for this type of settlement compared to large cities and metropolises. The role of small and medium-sized cities is defined in relation to: a) two complementary areas: spatial organization and urban governance; and b) three levels of policies: urban policies related to the regeneration of urban centers; regional policies, which focus on opportunities for improving economic development; and spatial development policies, aimed at polycentric urban development, strengthening urban-rural links, and controlling the urban growth of large cities (ESPON, 2006). Research presented in this paper assumes that the network of small and medium-sized cities represents a key framework for achieving the goals of sustainable polycentric spatial development at all levels (Zavodnik et al., 2008, Kokotović Kanazir, 2016).

The concept of identity within the framework of the recent European legislation plays a significant role, whether directly or indirectly mentioned, through policies for sustainable, inclusive, and just cities that must respect cultural and social differences. In this context, identity refers to how cities and communities are recognized and how they connect with their cultural heritage, tradition, and face contemporary global challenges. In addition to social and cultural aspects, the physical aspects of urban identity (spatial organization, public spaces, urban form, etc.) gain a special role within the guidelines for sustainable development in these documents.

The New Urban Agenda (NUA) emphasizes that culture and cultural diversity should play an active and unique role in development initiatives, including the promotion of new sustainable consumption and production patterns that contribute to the responsible use of resources and the mitigation of harmful effects of climate change. The NUA highlights the following transformative commitments to sustainable development: 1) social inclusion and poverty reduction, with a particular role for spatial organization; the structure and arrangement of urban space; 2) sustainable and inclusive urban prosperity and opportunities for all, where urban form, infrastructure, and architectural design play a special role as drivers of efficient and sustainable resource use; urban planning that ensures appropriate compactness and density, polycentricity, and mixed land uses; 3) environmentally sustainable and resilient urban development, where a special role is played by increasing the resilience of urban centers as areas that are particularly vulnerable to the harmful effects of climate change, disasters, and all forms of pollution and environmental degradation; the smart city approach, which takes advantage of digitization, clean energy, technology, and innovative transportation technologies (UN, 2017).

The Territorial Agenda of the European Union until 2030 advocates for territorial cohesion and the use of the specificities/diversities of places (in the context of this study: identity) as a comparative advantage and development potential. The natural and built environment are viewed as parts of territorial capital and identity. Major threats to territorial development are identified as the neglect or degradation of ecological values, environmental quality, and cultural assets, which are exacerbated by urbanization, globalization, and uncoordinated spatial activities. The Territorial Agenda addresses higher spatial levels – regions and functional areas – through a place-based approach, sectoral policy coordination, and multilevel governance. It emphasizes the need for interventions in the areas of: 1) improving quality of life – through access to public services, enhancement of urban mobility and healthcare, creating resilient built environments, and high-quality architecture; 2) improving public services – through accessibility, user-friendliness, affordability, and quality that directly impact higher quality of life and economic development; 3) addressing

demographic and social inequality challenges; 4) digitalization and the 4th industrial revolution; 5) employment and economic development (EC, 2020).

The New Leipzig Charter promotes integrative and sustainable urban development. Like the Territorial Agenda, it advocates for a place-based approach, multilevel governance, and participation (multi-level and multi-stakeholder approach). In the context of urban development, the place-based approach involves recognizing the transformative potential of European cities – small, medium, and large – through their diversity. It emphasizes that cities are unique civilizational creations and key elements of European urban heritage and citizens' identity. This further emphasizes the importance of architectural heritage, the necessity of its protection, and its simultaneous activation as a resource for sustainable development. Special emphasis is placed on the capacity of cities for social interactions at various levels, making them an active part of the polycentric urban system, as well as an adequate platform for social innovations and testing new ways to solve urban development problems. The New Leipzig Charter highlights the need for coordination of measures across three key spatial levels: 1) the neighborhood level – where urban challenges are most prominent, directly relating to local community issues, requiring specific neighborhood policies; 2) the local government unit level – strategic guidelines and specific rules for the entire urban area, serving as a formal link between the neighborhood level and higher spatial levels, and are particularly important for improving the quality of life in small and medium-sized cities, establishing connections with the environment and rural hinterland; 3) the functional area level – regional and metropolitan context based on a complex network of functional interdependencies and partnerships, premised on the idea that cities must collaborate and coordinate development policies and instruments with their rural and suburban environments (EC, 2020).

The European Urban Initiative (EUI) is part of the new EU cohesion policy for the 2021-2027 period. The EUI is a key tool to support cities of all sizes, build capacity, support innovation, and develop solutions for urban challenges, applicable in different environments and scales. The new EU cohesion policy for 2021-2027 sets five main goals that guide investments in urban areas: 1) Smart Europe – innovation, digitalization, economic transformation, and support for small and medium enterprises; 2) Green Europe – implementation of the Paris Agreement on climate change; 3) Connected Europe – strategic transport and digital networks; 4) Europe for Society – support for social rights, quality jobs, education, skills, social inclusion, and access to services; 5) Europe Closer to Citizens – support for local development strategies and sustainable urban development across the EU. Although all the goals are interconnected and inseparable, the concept of identity in this work is most closely related to the fifth goal, which is achieved through territorial instruments: integrated territorial investment (ITI), community-led development (CLLD) (EC, 2021, EUI, https://www.urban-initiative.eu).

4 THE ROLE OF URBAN IDENTITY IN SUSTAINABLE DEVELOPMENT OF SMALL AND MEDIUM-SIZED TOWNS IN LEGISLATIVE, PLANNING, AND STRATEGIC DOCUMENTS IN SERBIA

Recent planning and strategic documents in Serbia define the basic principles of spatial development, in line with the recent European legislation suppoting sustainability, territorial cohesion, strengthening competitiveness, public participation, polycentric territorial development, strengthening urban-rural links, etc. In the context of the research of urban identity discussed in the paper, the following principles are of particular importance: functional specialization, respecting comparative advantages in terms of the development potential of regional units; forming and strengthening networks of cities and settlements (clusters) that can provide the development of complementary functions; improving transportation accessibility as a dominant factor for exploiting territorial potentials and balanced development; developing cultural identity and territorial recognizability; strict adherence to the protection of public interest, public goods, and public spaces; improving and protecting natural and cultural heritage as development resources (NARS, 2010). This chapter examines the role of urban identity advancement and its underlying principles in supranational and national policies relevant to the sustainable development of urban areas in Serbia, to provide guidance on implementing these principles at the local level.

In accordance with European documents reffering to the sources of financing sustainable urban development (EC, 2021) and the application of territorial instruments, the national strategy for sustainable development (NARS, 2019) and several local strategies (GOA, 2023) have been adopted. These strategies emphasize strengthening the identity of urban areas by defining priority areas for urban interventions and directing

financing towards priority projects. The methodology for developing and implementing territorial strategies encourages the application of key principles of good governance in urban and territorial development, such as urban policy as a public good (public interest), integrated approach, participation and co-creation, multilevel governance, and a place-based approach (EC, 2020, UN, 2017).

The Law on Planning and Construction (NARS, 2009-2023) bases the planning, regulation, and use of space on the following principles: 1) Sustainable development through an integrated approach in planning; 2) Balanced territorial development; 3) Rational use of land by encouraging urban and rural renewal and reconstruction measures; 4) Rational and sustainable use of non-renewable resources and optimal use of renewable resources; 5) Protection and sustainable use of natural and immovable cultural goods;... 10) Public participation; 11) Preservation of customs and traditions; 12) Preservation of environmental values, integrity, and the uniqueness of landscapes; 13) Horizontal and vertical coordination (Article 3). Sustainable development, as defined by this law, is "the alignment of economic, social, and ecological aspects of development, the rational use of non-renewable resources, and ensuring conditions for greater use of renewable resources, thus enabling present and future generations to meet their needs and improve their quality of life." (NARS, 2009-2023). Regarding the study of the role of urban identity in this document, the broad definition of sustainable development leaves room for discussion about diverse human needs, including psychological, aesthetic, and so on, as well as quality criteria, which certainly encompass the identity of a place. The law does not specify the term "integrated approach," and terms like "identity," "character," "sense of place," etc., are not mentioned as potentially valuable qualitative parameters, while quantitative parameters are precisely defined. These concepts are only indirectly addressed through the principles of planning, regulation, and use of space.

Through recent amendments and additions to the Law on Planning and Construction, two overarching strategies have been incorporated into spatial and urban planning documents, which provide an opportunity for a more operational interpretation and application of the concept of urban identity in development projects. The Sustainable Urban Development Strategy of the Republic of Serbia until 2030 (NARS, 2019) applies a participatory and integrated approach, considering the spatial dimension of sustainable urban development and the organization of processes that ensure coordination and cooperation. The integrated approach involves the inclusion of relevant thematic areas and tools/resources from various sectoral policies, actors, and institutions at different spatial and administrative levels (local, regional, national, supranational), in order to achieve a comprehensive (holistic) approach to urban development planning and management. The strategy contributes to strengthening the identity of urban areas by defining priority areas for spatial intervention, identifying development issues, and linking them to specific locations. In this way, local integrated urban development strategies are directed toward priority projects for financing. The strategy specifically highlights spatial units with cultural and architectural heritage, which are important landmarks in the cultural and historical development of urban settlements and groups of urban settlements (NARS, 2019).

The National Architectural Strategy for the period 2023-2035 (NARS, 2023) represents a document through which the state establishes a course of action aimed at: creating a high-quality built environment and space, protecting and improving the quality of the living environment, and, within that, preserving natural and cultural heritage. Some of the goals of architectural policy are: the valorization of real architectural values, protection, and improvement of spatial and environmental parts and units, protection of architectural heritage as one of the most important aspects of cultural identity and heritage of a state and its people; affirming the importance of architecture as a key factor in the economic development of the state and the stimulation of overall economic growth; raising awareness among the professional, scientific, and wider public about the significance of architecture and urban planning as one of the most important elements of the quality of life and work (NARS, 2023).

5 THEORETICAL AND METHODOLOGICAL FRAMEWORK FOR EXPLORING THE CONCEPT OF URBAN IDENTITY IN SUSTAINABLE DEVELOPMENT

A review of recent European and national documents indicates the presence and affirmation of the concept of urban identity and its role in sustainable development. However, there is a lack of concretization in the application of this concept, particularly through more precise definition and linking to action points. Comprehensive studies on urban identity highlight its theoretical foundation in psychology, environmental studies, and urbanism (Mansour et al., 2023), as well as its insufficiently precise definition, which calls for

its differentiation from related concepts such as place identity, sense of place, attachment to place, authenticity, and character (Jiven and Larkham, 2003).

5.1 Key Determinants of the Concept of Urban Identity in Theory: Complexity, Multifacetdness, and Dynamic Nature

An analysis of contemporary theoretical contributions on the topic of urban identity reveals three key characteristics of this concept: complexity, multifacetdness, and dynamism.

Complexity: This characteristic implies that urban identity is composed of various elements, which can be identified through content analysis. It is not a simple, singular concept, but rather a combination of many factors acting in synergy. It is emphasized that urban identity is a complex, composite concept containing both material (built and natural environment) and immaterial elements (people, culture, activities etc.), where a specific combination of characteristics produces a spatial and visual effect, i.e., urban identity, which makes places recognizable (Rifaioglu and Güçhan, 2007; Kropf, 1996). We perceive urban areas because they distinctly differ from the surrounding natural or undeveloped environment, or from other places we carry in our memory (Kropf, 1996).

Multifacetdness: This characteristic emphasizes that urban identity can be linked to different aspects of the spatial context. These could include regional, urban, ecological, landscape, social, and other aspects that reflect the diverse layers that constitute the identity of urban space. The extended definition of urban spatial identity becomes a subject of interpretation through three paradigms: landscape, culture, and economy (Duan et al., 2021). In the landscape paradigm, urban spatial identity refers to the cumulative effect of heterogeneous spatial characteristics. In the culture paradigm, the component of cultural values to be protected is added exclusively to the physical component of the landscape paradigm. In the economy paradigm, existing spatial values, comparative advantages, and local resources are viewed as drivers of urban development with positive economic effects. Furthermore, the authors add a fourth, humanistic paradigm, considering the experiences, needs, behaviors of inhabitants, local practices, and culture (Duan et al., 2021).

Dynamism: The concept of urban identity is dynamic, depending on the observer and time, which are not static categories. It constantly changes and develops based on interactions between people and space over time. Urban identity is explained as the relationship between people and their environment; a dynamic interaction of tangible and abstract elements, where the environment encompasses not only built structures but also economic practices and social interactions (Mansour et al., 2023). The relationships between space users and the physical, social, and cultural aspects of that space shape urban identity over time (Rifaioglu and Güçhan, 2007).

5.2 Application of the Concept of Urban Identity in Urban Planning Practice and Sustainable Urban Development Strategies through an Analytical Approach to the Complexity, Multifacetdness, and Dynamism of the Concept

In contemporary research, urban identity is considered a conceptual tool for developing strategic thinking about sustainable urban development, as a response to the processes of globalization, rapid urbanization, and homogenization. Its application is especially significant in historical urban areas, but also in all processes of urban renewal in general (Mansour, 2023; Duan et al., 2021; Rifaioglu and Güçhan, 2007; Appendino, 2017; Salah Ouf, 2001; Taşçioğlu and Sirel, 2020). The application of urban identity in formulating policies and strategies for sustainable development involves addressing the three key determinants of the concept: complexity, multifacetdness and dynamic nature.

The analytical approach to the complexity of the concept involves identifying the elements of urban identity within a specific spatial context: breaking down the complex concept into components, both material and immaterial (Mansour et al., 2023; Rifaioglu and Güçhan, 2007). Complexity is emphasized as a key determinant for describing identity, which underlies every theory of built form. The analysis of complexity involves deconstructing the whole into parts and observing their connections, hierarchy, and patterns of organization (Kropf, 1996).

The analytical approach to multifacetdness involves linking elements of urban identity with various aspects of sustainable development. This includes considering how identity can contribute to or enhance ecological, social, economic, and cultural sustainability in urban areas. The main hypothesis is that every context possesses a unique identity that arises from physical, social, cultural, and historical aspects and elements.

Understanding and taking urban identity into account should be the starting point for policies and decision-making. In urban conservation projects (Rifaioglu and Güçhan, 2007), the identity study encompasses three phases: 1) documentation, which includes literature research, fieldwork, and workshops with local residents; 2) evaluation, which includes conducting a SWOT analysis and selecting identity components for different levels of intervention, considering the goals of sustainable development; and 3) the decision-making phase, which defines several thematic areas to ensure an integrative, sustainable, and manageable conservation process (Rifaioglu and Güçhan, 2007).

The analytical approach to the dynamism of the concept involves stepping out of the comfort zone of an exclusively expert approach – through the engagement of various stakeholders, particularly local residents, to ensure that urban identity is shaped by those who live in the observed area as its direct users. According to Kropf's research, understanding urban identity/character involves a dynamic approach between people and the urban area, namely, the observer and what is observed. Observers are experts who are part of a collaborative study that includes expertise from different fields: spatial planning, demographics, urbanism, urban protection, architecture, environmental protection, sociology, etc. The observed area is the territory on which experts focus, and whose spatial elements are subject of their expertises. The methodological approach balances the perspectives of conservation and planning, protection and development. It includes careful and systematic documentation, analysis, and evaluation of data related to territorial, administrative, ecological, urban, historical, and socio-economic aspects of a given area, to make informed decisions regarding the protection of existing and the creation of new spatial values (Kropf, 1997).

In addition to the analytical approach to the three key determinants of urban identity, to define a particular territory and target population is also important for the application of the concept of urban identity. Although the concept is not solely composed of material factors, its perception is conditioned by the physical framework, as well as by the users of the space. It is not in the observed or the observer, but in the response to a specific place, where conceptual tools are needed to construct the idea of urban identity (Kropf, 1996). Therefore, Duan posits urban spatial identity as a methodology for structural thinking about space as an instrument for planners, conservators, and architects when facing the pressures of globalization (Duan, 2021). The authors propose an integrated, systematic, and consistent methodology for assessing urban identity that addresses the complexity and diversity of urban systems, enabling planners, decision-makers, and communities to develop more resilient, just, and sustainable cities. The main goals are to understand cities as a whole, develop strategies that are economically viable, socially inclusive, ecologically sustainable, and culturally aware. The methodology for exploring urban identity does not use quantification, but rather the analysis of the state-of-the-art and needs assessment through participatory approach, in order to provide a comprehensive understanding of the phenomenon and inform policies and decision-making processes (Mansour et al, 2023).

6 STUDY OF URBAN IDENTITY OF FIVE LOCAL GOVERNMENTS UNITS IN WESTERN SERBIA

Western Serbia is considered one of the regions in Serbia where depopulation and unfavorable demographic structure are particularly evident, which calls for strengthening human and social capital, as well as increasing the attractiveness of the area for living and working. Additionally, Western Serbia faces the serious issue of fragmentation due to the geomorphological characteristics of the hilly and mountainous area, which is interspersed with waterways. Special emphasis is placed on the physical arrangement of space and the protected environment, which should increase the area's appeal to investors and tourists, as well as strengthen the local residents' identification with their living environment. Key priorities include solutions to the problem of illegal construction, urban planning and revitalisation of cities, rural revitalization, and areas with protected, well-arranged, and properly presented cultural heritage as factors of attractiveness (NARS, 2010). The region is marked by significant socio-economic and territorial polarization, primarily between the northern and southern parts of the area. In terms of development, 5 local government units presented in this research are compared to the national average: one is above average (the municipality of Užice); one is between 80-100% (the municipality of Čajetina); two are underdeveloped, at 60-80% (Bajina Bašta and Požega); and one is below average (the municipality of Priboj). The structure of the economy is dominated by the industrial sector, with a preserved competitiveness of several successful companies, agricultural

means of production, along relatively developed tertiary sector activities (trade, transportation, tourism, etc.) (NARS, 2013).

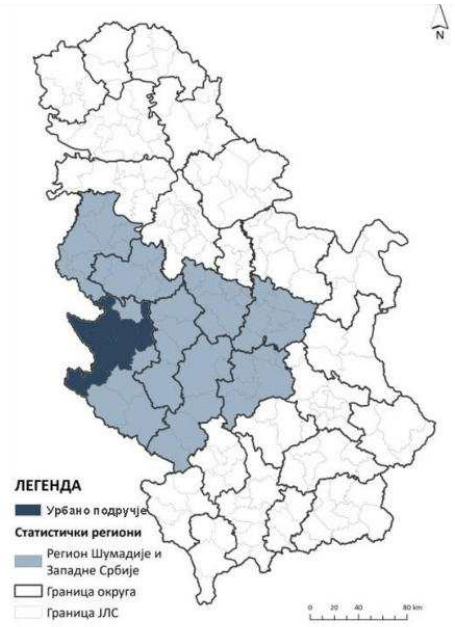

Fig. 1: The position of the targeted territory of five municipalities within Serbia and Western Serbia.

For the integrated territory of the five local government units (Fig. 1), a Development Strategy for the Urban Area has previously been adopted, which defines one of the thematic goals as "strengthening urban identity and the revitalization of the urban area by promoting sustainable and integrated urban development" (GOA, 2023). The Study of the Unique Identity of Urban Environments within the territory of the Development Strategy for Urban Area of Užice, Priboj, Bajina Bašta, Čajetina and Požega local government units (GOA, 2024-2025) elaborates on this goal through three phases/steps: 1) state-of-the-art analysis, 2) defining directions for action, and 3) gathering project ideas. All three phases include expertises from various areas of sustainable urban development and a participatory process. The introductory (zero) step, which is the subject of this paper, covers the initial considerations for the operationalization of the concept of urban identity in order to formulate methodological guidelines, approaches, and steps for the development of the Study.

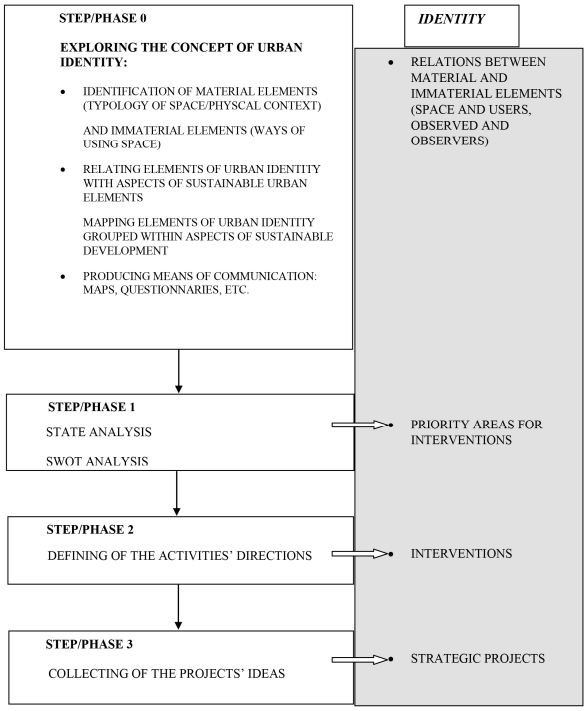

Fig. 2: Steps in the development of the urban identity study.

6.1 Operationalization of the Concept of Urban Identity

6.1.1 Identification of Identity Elements: Analytical Approach to the Complexity of the Concept

In this study, identity is viewed as a complex concept composed of material elements (aspects of the natural and built environment, systematized according to the scope and complexity of spatial organization) and immaterial elements (qualities of space that arise from its interaction with users: the way it is used, perceived, and experienced in real-time and historically) – Table 1. Identity is considered a dynamic concept that depends on the local context and is constructed through the creation of relationships between material (physical environment) and immaterial elements (forms of interactions between physcial environement and users).

Material elements	**Immaterial elements**

Natural Heritage
• City in nature – natural environment and determinants
• Nature in the city
• Routes – connections between settlements
Architectural Heritage (including cultural heritage under institutional protection)
• Archaeological sites
• Industrial and military heritage
• Modern heritage (socialist and post-socialist)
• Monuments
• Fountains
• Bridges
• Public and shared spaces
  • Squares
  • Plazas
  • Passages
  • Urban pockets
  • Streets and sidewalks
  • Roof terraces
  • Shared courtyards
  • Shared spaces in buildings
• Vernacular
  • Private houses and buildings
• Public buildings
  • Municipality
  • Library
  • Theatre
  • Gallery
  • Museum
  • Bus station
  • Railway station
  • Stadium
  • Educational institutions
  • Nursing homes etc.
Partially Built and Unbuilt Areas
• Unbuilt land within construction areas
• Landfills and waste sites
• Agricultural land and farms/land for urban farming
• Infrastructure corridors
	Activities
	• Housing
	• Commercial and Production
	• Education
	• Culture
	• Sports and recreation
	Urban History, Memory, and Perception
	• Notable personalities
	• Significant events
	• Urban landmarks
	• Meeting places/points, hubs
	• Places of memory/demolished buildings, etc., oriental past, etc.
	• Everyday routes/paths
	• Everyday routines/walks, gatherings, etc.
	• Vistas and viewpoints/within the settlement, from the settlement to the surroundings, from the surroundings to the settlement
	• Connection with the wider environment
	Intangible Cultural Heritage (according to official classification, whether or not under institutional protection)
	• Oral traditions and expressions, including language as a bearer of intangible cultural heritage
	• Performing arts
	• Social practices, rituals, and festive events
	• Knowledge and practices related to nature and the universe
	• Traditional craftsmanship

Table 1: Material and immaterial elements of urban identity

6.1.2 Positioning Identity Elements within the Framework of Sustainable Development: Analytical Approach to Multifacetdness of the Concept:

To connect the elements of identity with aspects of sustainable development and to engage the professional capacities of the 18-member IAUS working team in the study's preparation, the following aspects of identity in the context of sustainable development were defined: regional, urban, environmental, social, economic, and governance aspects.

- Regional Aspects: Considers demographic changes, relationships between settlements, infrastructural corridors, and the functional integration of the territory.
- Urban Aspects: Include architectural heritage, including immovable cultural heritage under institutional protection; design guidelines and rules in urban planning documents; the use and performability of public spaces; safety and accessibility of public spaces; the usage modalities of

buildings by function and housing; and the use of shared spaces with a particular focus on multi-family residential buildings.

- Environmental Aspects: Include nature in the city, greenery, water, landscape design, and climate change; natural heritage and tourism infrastructure; waste management and municipal services; environmental quality aspects; underutilized land, agricultural land, urban agriculture, and the circular economy.
- Social Aspects: Manifested through social well-being and the availability and quality of public services.
- Economic Aspect: Refers to recognizing the territory's potential in terms of economic development, employment, and innovation.
- Urban Governance Aspects: Relate to multi-level governance, inter-municipal cooperation, co-creation, participation, and innovative civil governance systems.

Cartographic analyses and presentations of the aspects and factors of identity are important tools for communication throughout the participatory process thoughout all phases of the Study's preparation. On the maps of regional and urban levels, the elements of urban identity have been mapped according to the classification in Table 1 and then linked to the aspects of sustainable development of the territory (Fig. 3).

Fig. 3: Workshop in one of the municipalities (Bajina Bašta). Discussing and mapping.

6.1.3 Participatory Process: Analytical Approach to the Dynamism of the Concept

In line with previous research, the concept of urban identity is dynamic depending on time and observers. By applying a dialectical approach to the analysis of existing elements of urban and physical structures, permanent elements are identified, which testify to the continuity of the existence of settlements and territories, as well as changing elements. Permanent elements are designated as urban landmarks and may or may not be declared cultural heritage sites.

Another powerful tool for addressing the dynamism of the concept is the participatory process, which involves workshops (Fig. 3), surveys, and various forms of communication with a wide range of stakeholders: representatives of local governments, public enterprises, professionals from various fields, especially architects, urban planners, and ordinary citizens.

The foundation for applying participation and co-creation in the development of the Study lies in the theoretical premises of collaborative planning, where participation is based on the belief that social groups

and individuals are capable of learning from one another, and that this knowledge has a positive impact on problem-solving and defining frameworks for activities in space. The main characteristic of these ideas is the view of planning/governance as an active process in which social meanings emerge through discussion, and where social (including professional) practice is formed and gains legitimacy (Healey, 2003).

Planning for sustainable and integrated urban and territorial development involves action, not just a response to problems – it provides a framework for activities. When conducted in a participatory manner, it can contribute to developing the knowledge and relations between actors, fostering joint reasoning, organizing around common issues, and formulating ideas on how to improve the space (Čolić et al., 2021).

In all stages of the development of the Study, a series of events and thematic workshops are organized. Their goal is to transparently and participatively verify, supplement, and rephrase the results of research on the identity of the territory and individual areas, define action directions, and gather project ideas. Informing the broader public about the participatory process of developing the Study is carried out through local media, municipal web portals (Fig. 4), and the Zlatibor Regional Development Agency, as well as social networks used for promoting the project.

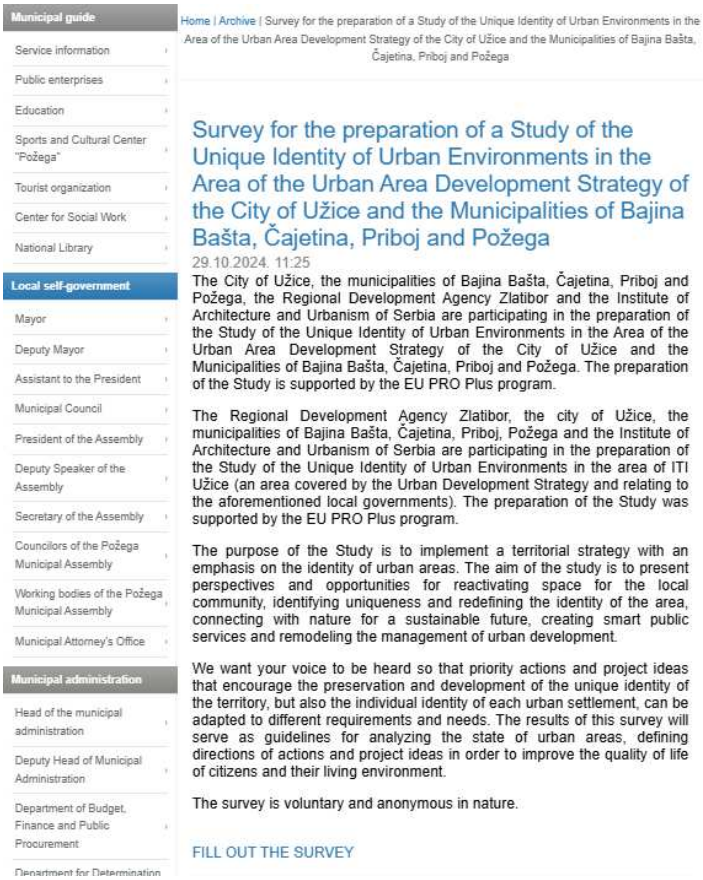

Fig. 4: The survey for citizens "Let Your Voice Be Heard!" on the municipality of Požega's web portal.

7 CONCLUSION

The concept of urban identity has a significant role in strategies for sustainable and integrated urban development. This role is particularly important for the development of small and medium-sized cities, both in the European Union and in Serbia – for their strategic positioning in balanced territorial development and for strengthening territorial and social cohesion (Table 2).

As stated, the urban identity is a complex, multifaceted and dynamic concept that requires an analytical, multidisciplinary and multi-stakeholder approach, which is also place-based, i.e. conditioned by phyical context (Table 3). The synergy of all these approaches produces a conceptual framework for structural thinking and decision-making, which can be aligned with sustainable development aspects.

In the case of the Study on the Unique Identity of Five Municipalities in Western Serbia, the applyied methodology has raised awareness among all participants about the important elements of urban identity that

should be protected and/or used as a trigger for development projects. It has also enhanced the capacitites of local government units to improve strategic thinking, balance between conservation and development, and introduce planning guidelines based on existing territorial and human capital. The up-to-date workshops have shown a lack of awareness among participants regarding the common identity of the entire territory, mostly due to poor traffic connectivity, socio-economic challenges, and territorial polarization. In the next steps of the tudy, by introducing the five key thematic fields of sustainable development – rediscovering uniqueness, reactivating spaces for local communities, reconnecting with nature, reinventing smart public services, and remodelling governance and partnerships (EC, 2023) – a futher wide debate will be opened. This debate should result in specific strategic projects tailored for applying financing instruments, aiming at the creation of sustainable, inclusive, and vibrant urban environments.

Document	**Main points relevant for the urban identity concept**
The New Urban Agenda (UN, 2017)	Relating transformative commitments to sustainable development with: spatial organization, structure and arrangement of urban space; urban form; architectural design; urban planning.
The Territorial Agenda of the European Union until 2030 (EC, 2020)	Refers to the regional level and advocates for territorial cohesion and the use of the specificities/diversities of places (natural and built, with territorial capital and identity) as a comparative advantage and development potential.
The New Leipzig Charter (EC, 2020)	Refers to the urban level and advocates a place-based approach, which involves recognizing the transformative potential of European cities – small, medium, and large – through their diversity.
The Spatial Plan of the Republic of Serbia (NARS, 2010)	Developing cultural identity and territorial recognizability; strict adherence to the protection of public interest, public goods, and public spaces; improving and protecting natural and cultural heritage as development resources.
The Law on Planning and Construction (NARS, 2009-2023)	Public participation; Preservation of customs and traditions; Preservation of environmental values, integrity, and the uniqueness of landscapes; Horizontal and vertical coordination.
The Sustainable Urban Development Strategy of the Republic of Serbia until 2030 (NARS, 2019)	Strengthening the identity of urban areas by defining priority areas for urban intervention, identifying development issues, and linking them to specific locations.
The National Architectural Strategy for the period 2023-2035 (NARS, 2023)	Architectural heritage as one of the most important aspects of cultural identity and heritage of a state and its people; a key factor in the economic development and achieving higher quality of life.

Table 2: The role of the urban identity concept in the recent European and national documents.

The key determinants of the urban identity concept	**A conceptual tool for exploring the urban identity concept in sustainable development**
Complexity	Analytical decomposition of the concept into material and immaterial elements.
Multifacetdness	Multidisciplinary approach – observing the urban identity concept from various aspects of sustainable development.
Dynamism	Multi-stakeholder approach through various channels of communication and participation processes.

Table 3: Analytical approaches to complexity, multifacetdness and dynamism of the urban identity concept.

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Exploring the Socio-Economic and Ecological Impacts of Unlawful Land Use: A Case Study from Louis Trichardt, Makhado Municipality

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1 ABSTRACT

Illegal land use presents intricate challenges with far-reaching socio-economic and environmental implications. This study investigates the dynamics of unlawful land use in Louis Trichardt, Makhado Local Municipality. Employing a mixed-methods approach, the research synthesizes insights from 270 respondents, including municipal employees, supplemented by primary data from comprehensive surveys and community observations. A SWOT analysis revealed key strengths, such as community awareness and potential for localized solutions, but also weaknesses, including insufficient municipal resources and individual resistance to regulations. Identified opportunities include public awareness campaigns, improved housing accessibility, and stronger regulatory enforcement. However, significant threats such as environmental degradation and limited access to formal economic activities pose ongoing risks. The findings highlight unauthorized rental structures, illegal spaza shops, informal shack settlements, and unapproved businesses as prevalent forms of illegal land use. Respondents identified critical drivers behind these practices, including limited access to affordable housing, economic hardships, and unemployment. The study recommends bolstering municipal capacity, enhancing community awareness initiatives, and prioritizing affordable housing programs to address these issues effectively. Suggested areas for future research include examining the long-term impacts of community-driven solutions, evaluating the effectiveness of municipal campaigns, fostering public-private partnerships, advancing sustainable land use planning, and conducting comparative studies with similar municipalities.

Keywords: Land use, spatial, environment, socio-economic, Makhado Local Municipality

2 INTRODUCTION

Illegal land uses, or the unauthorized occupation and use of another person's property, were common worldwide (Machete et al., 2021). This was due to factors like population expansion, urbanization, and poverty, which were especially prevalent in developing nations. Illegal land use was a serious issue in South Africa, impacting both urban and rural areas (eNCA, 2021). The Constitution of the Republic of South Africa 1996, Section 25, only safeguarded a landowner from the arbitrary deprivation of property; it did not provide an absolute property right. One area that felt the negative effects of illegal land use was Louis Trichardt town in Makhado, a local municipality in the Limpopo Province. Like many other South African rural areas, Louis Trichardt struggled with the negative effects of unauthorized land use. Furthermore, according to the South African Human Rights Commission 2000, all citizens could take advantage of their fundamental rights to access land and housing, where necessary and given the available resources. The government also had a responsibility to help private landowners defend their property in cases of widespread invasions, i.e., "Use the Prevention of Illegal Eviction From and Unlawful Occupation of Land Act, 1998 to obtain a swift court eviction order in the event of a trespass on your private property. Alternatively, if the invasion was connected to a requirement for access to agricultural land, ask for help from the Department of Agriculture, Land Reform, and Rural Development" (Carnie, 2022).

Many social, economic, and environmental issues were associated with illegal land use (Masilela, 2022; Mokoena et al., 2017). These issues affected people's livelihoods and general well-being and could have long-term effects on social structures and the environment. In the Makhado Local Municipality, South Africa, there had been an increase in illegal land use over time (Makhado IDP, 2022/23). The area's ecological balance was in danger due to illegal land use, which also affected the socio-economic development of the area. This study aimed to evaluate Louis Trichardt town's illegal land uses from 2017 to 2022 and offer suggestions for addressing this issue.

Firstly, illegal land use was a widespread problem in many South African rural areas and had a significant impact on these places' socio-economic growth and ecological balance (Sinthumule et al., 2020). To create efficient policies and strategies to address it, it was essential to comprehend the scope of this issue and how it affected the study area (Sithole et al., 2021). Secondly, there was a dearth of studies on illegal land use in South African rural areas, especially in Makhado's local municipality. This study added to the body of knowledge on this subject and shed light on the reasons behind and effects of illegal land use in the community (Manakane et al., 2022). Thirdly, the findings of this study could be used by the local government and other stakeholders to develop interventions that addressed the underlying causes of illegal land use, such as poverty and unemployment. This could improve the living conditions of residents in the town and promote sustainable development. Lastly, determining Louis Trichardt's illegal land uses assisted in achieving the Sustainable Development Goals (SDGs) established by the United Nations (Zwane et al., 2020). This research aimed to help achieve SDGs, i.e., "11 and 15". Accordingly, SDG 15 aimed to protect, restore, and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, stop and reverse land degradation, and stop biodiversity loss (Walz et al., 2022); hence, targets 15.9, 15.A, and 15.B of the SDGs aligned with this study because they promoted the protection of biodiversity, investment, and the integration of natural ecosystems into planning, development, and poverty alleviation programs in developing countries. Moreover, SDG 11 aimed to make cities and human settlements inclusive, safe, resilient, and sustainable (Ebbesson et al., 2022). In this case, it was important because inclusive human settlements were being promoted. To address these reaserch gap, the study investigates the dynamics of unlawful land use in Louis Trichardt, Makhado Local Municipality.

3 LITERATURE REVIEW

Illegal land use, also called illegal land occupation, was the taking of land without the required authorisations or legal rights (Khumalo, 2019). Moreover, it could have involved a variety of actions, such as the erection of structures or habitations, the farming of crops, or the unauthorised use of land for other purposes. Hence, it was frequently fuelled by social, economic, and environmental issues like deprivation, unemployment, the lack of affordable housing, and restricted access to land (Palm, 2021).

Furthermore, illegal land use had both good and bad societal, economic, and environmental consequences (Ntshidi, 2020). On the one hand, it provided a way for marginalized groups to gain access to land and shelter when they did not have formal alternatives for obtaining land rights (Dlulane, 2020). It could also have facilitated entrepreneurship, innovation, and societal growth. In addition, it resulted in conflict, bloodshed, and adverse environmental consequences such as deforestation, land degradation, and species loss (Thaw, 2020). It could also have had fiscal consequences, such as lost property tax income and reduced investment in the official real estate market.

Some of the causes included housing shortages, i.e., people turned to occupying land unlawfully to get a place to live in locations where there was a dearth of affordable housing. Another reason was landlessness, that is, people who lacked access to land invaded it to take advantage of resources like agricultural or grazing land (Sakala, 2016, & Adedamola et al., 2022). Additionally, rapid urbanisation led to encroachment and informal settlements due to the need for houses and land. Moreover, poor people invaded other people's land to secure a place to reside, or to engage in illegal activities that brought in money. Weak land governance led to illicit land acquisition and selling, which resulted in conflicts and invasions of private property (Khumalo, 2019).

Theory of Relative Deprivation

According to Neely (2020), this theory stated that people's actions and behaviours were influenced by how they perceived their rights and what they possessed. According to the theory, when people felt their rights to access and own land had been violated, they engaged in collective action, including illegal land use. Longley (2021) stated that when income was insufficient to maintain a standard of living that included food and shelter, absolute deprivation or absolute poverty developed. The theory assisted in explaining why people engaged in illegal land occupation. In South Africa, many people struggled with poverty, unemployment, and a lack of accessible housing (Marutlulle, 2021; Gumbo et al., 2022). According to this theory, individuals felt a sense of relative deprivation about their access to land, especially if they believed that land was being unfairly allotted to others or was being withheld from them.

Furthermore, Ted Robert Gurr's 1970 book, Why Men Rebel, explored the relationship between relative deprivation and political violence. Moreover, the author argued that the frustration-aggression mechanism, triggered by a sense of relative deprivation, was a major contributor to the human tendency for violence (De Kock, 2021). Although not all individuals or groups experiencing relative deprivation engaged in violent acts, Gurr maintained that the longer they endured such frustration, the more likely it was that their anger would escalate into violence (Walker et al., 1984).

The relative deprivation hypothesis also shed light on why urban areas were frequently the scene of illegal land uses (Zulu, 2020). The demand for housing increased because of urbanisation, but many people could not afford the high price of formal housing. People felt relatively deprived because they believed they were entitled to decent housing but could not obtain it (Pillay, 2020). Overall, the relative deprivation theory contended that to combat illegal land use effectively in South Africa, it was necessary to address the root causes of relative deprivation, such as poverty, inequality, and the lack of affordable housing. It might have been possible to lessen illegal land use and encourage a more equitable and sustainable land use method in South Africa by addressing these issues.

4 METHODOLOGY

Employing a mixed-methods approach, the research synthesizes insights from 270 respondents, including municipal employees, supplemented by primary data from comprehensive surveys and community observations. The questionnaires were administered to members of the public who were residents of Louis Trichardt. The researcher utilized Ward's proportional representation to select the respondents. The distribution of the questionnaires was outlined in Table 1:

Total	Population no.	Households no.	NQD	% distributed	NQR	% returned
Ward 21 Louis Trichardt Town	25 360	7 129	379	100%	270	71.2%

Table 1: Questionnaire administration. Sources: Author's Field Data 2023 SA census (2016). Key: NQD = Number of questionnaires distributed, NQR = Number of questionnaires returned.

Table 1 showed that 379 questionnaires were distributed based on population proportions. Only 71.2% of those questionnaires were returned. The appropriate number was determined using the Raosoft sample size calculator online with a margin of error of 5%, a confidence level of 95%, and a response distribution of 50% results.

Purposive sampling was utilized to select key informants. According to Nikolopoulou (2022), this sampling was frequently employed in qualitative and mixed methods research. Seven of the key informants interviewed, were, the Town Planner (processing land use applications and approvals), Geographic Information System (GIS) Officer, GIS Specialist (responsible for capturing and updating all spatial data), EIA Officer (assessment of environmental impacts and authorizations), Town Planner (assess and authorize land uses and issues approvals), Senior Property Administrator (who dealt with municipal land acquisition processes), and Senior Administrative Officer: Valuations (deals with valuation and appraisal of properties land values).

5 FINDINGS AND DISCUSSION

Understanding the varying length of residency within the municipality was crucial in comprehending the perspectives and experiences that informed residents' responses to questions about illegal land use, its consequences, and potential solutions. This diversity in residency duration contributed to a comprehensive analysis of the local community's viewpoints and needs. Figure 1 depicted the years respondents had stayed in Louis Trichardt town.

A significant factor influencing residents' viewpoints regarding various aspects of Louis Trichardt, Makhado Local Municipality was the duration of their residency within the region. The data collected from the respondents revealed a diverse distribution in terms of residency duration, shedding light on the distinct experiences and perspectives of the population. Approximately 11% of the respondents had reported having resided in Louis Trichardt for less than a year. Being relatively new to the area, these individuals might have had a fresh and perhaps less informed perspective on land use and community dynamics issues. Around 17% of the respondents had a residency duration spanning one to five years. This group likely had a somewhat

intermediate familiarity with the municipality, potentially having witnessed changes and developments during their time in Louis Trichardt. The largest cohort, constituting roughly 32% of the respondents, had resided in the area for six to ten years. This population segment likely possessed a more established understanding of the municipality's dynamics and may have witnessed significant changes over their prolonged residency. Finally, 40% of the respondents had been residing in Louis Trichardt for more than ten years. This group, characterized by long-standing residency, was expected to bring a wealth of experience and in-depth knowledge of the region's history and evolution.

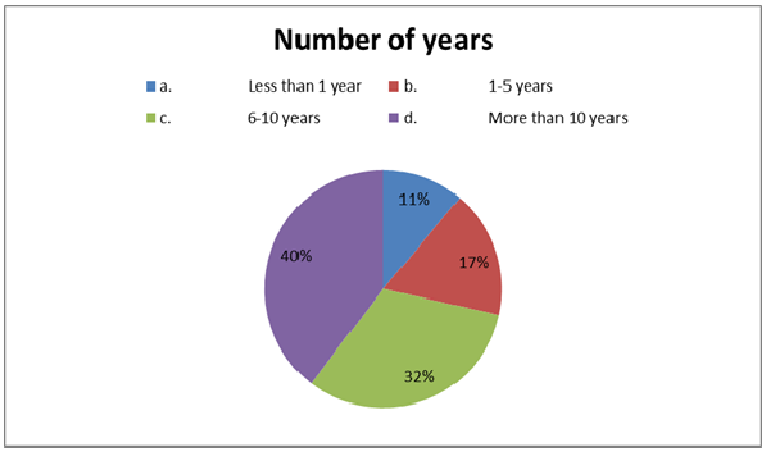

Figure 1: Residency duration. Source: Author's construct/field data (2023)

Awareness of Illegal Land Use in the Vicinity: Perceptions and Observations of Respondents

A substantial majority, comprising approximately 240 respondents, demonstrated a keen awareness of illegal land use. They acknowledged the presence of such issues and offered notable insights into specific instances. Examples of their observations included cases of unauthorized land occupation in residential areas, where individuals had erected structures or established dwellings without following the proper legal procedures. In some instances, respondents pointed to land zoned for specific purposes, such as residential or commercial use, being utilized for purposes that did not align with the designated zoning. These observations reflected a community acutely attuned to the realities of illegal land use, directly impacting their neighborhoods and the broader community. The respondents' ability to identify and provide examples of such instances underscored the significance of addressing this issue to ensure compliance with land use regulations and preserve community well-being. Moreover, key informants "also identified instances of illegal land use, such as unauthorized occupation of residential areas and illegal building conversions''.

Social and Economic Implications of Illegal Land Uses: Insights from Respondents

Respondents' opinions on the social and economic consequences of illegal land use varied. Many (about 72%) expressed concerns about newcomers (less than one year) who might have been unintentionally unaware of zoning regulations. The high demand for housing prompted some residents to occupy land without following proper procedures, resulting in resource and infrastructure strain. Economic hardships and the lack of affordable housing could have driven individuals to engage in illegal land use for survival. Similarly, the study conducted by Mutero and Makwara (2018) revealed that the impetus for illegal land occupation was propelled by the absence of government support in furnishing accommodation for trespassers. Key informants "highlighted the socio-economic consequences of such activities, including reduced property values, increased crime, and potential loss of government revenue''. Additionally, some individuals resorted to illicit land occupation to compel the government to provide them with housing. Furthermore, it was observed that individuals engaging in unauthorized land occupation experienced property loss during an eviction, and the use of force during eviction was identified as a deterrent against subsequent land invasions. In areas with limited access to formal economic activities, joblessness might have made illegal land use seem like a viable alternative. A common thread in their narratives was the belief that the municipality's inadequacy in addressing housing needs might have motivated some to resort to illegal land use.

Perceptions of Ecological Impact: Respondents' Views on Illegal Land Use and the Environment

Respondents generally expressed concerns about the ecological impact of illegal land use. They believed that unauthorized land occupation could lead to deforestation, causing harm to the local ecosystem. In support of this, key informants stated that " The ecological impact included environmental degradation such as land, water, and air pollution, deforestation, and habitat disruption. The municipality's measures to address these issues involved inspections, meetings, contravention letters, warnings, and formal settlement implementation." Issues like improper waste disposal and sanitation in informal settlements were mentioned as factors that could have resulted in the pollution of natural resources, particularly rivers. Land degradation and soil pollution might have resulted from unauthorized activities. The strain on resources due to illegal land use further exacerbated environmental issues. According to Troisi (2022), illegal land use was a noteworthy environmental concern progressively garnering attention.

Impact of Illegal Land Use: Personal Experiences and Community Effects

A significant portion of respondents, roughly 220 out of 270, reported experiencing or observing adverse effects of illegal land use on their community. They mentioned increased congestion and overcrowding in their neighborhoods, which made it challenging to access essential services. Additionally, there was a perceived increase in crime rates in areas with illegal land use, affecting safety and overall quality of life. According to the Makhado IDP, 2022/23, illegal land use was identified as one of the top issues concerning safety and security. The third most frequently reported offenses included property-related crimes such as burglary, stock theft, and similar incidents. Numerous police stations and satellite stations served the study area. Notably, the Makhado police station recorded the highest number of reported crimes, totaling 1,736 cases. Respondents' narratives highlighted a range of consequences, encompassing both tangible and perceived impacts.

Regarding increased congestion and overcrowding, respondents expressed concerns about the palpable effects of illegal land use on their immediate surroundings. They described scenarios where unauthorized land occupation had led to increased congestion and overcrowding in their neighborhoods. The proliferation of informal settlements and structures in areas not designated for housing notably altered the landscape. This, in turn, made it challenging for residents to navigate their local environments and added strain to the existing infrastructure.

Several respondents highlighted difficulties in accessing essential services in areas of illegal land use. These areas often lacked adequate infrastructure, such as roads, sewage systems, and waste management. This resulted in challenges related to waste disposal, safe sanitation, and accessibility to healthcare facilities. Residents in such areas confronted daily obstacles in securing basic services that many others might have taken for granted.

In tandem with the physical transformations brought about by illegal land use, there was a noticeable perceived increase in crime rates in areas with unauthorized land occupation. Respondents pointed to a correlation between the expansion of informal settlements and increased criminal activities within their communities. Examples included theft, vandalism, and general unrest in neighborhoods affected by illegal land use. These observations contributed to a growing sense of insecurity and compromised residents' overall quality of life.

Key informants within the community echoed these sentiments, emphasizing the importance of addressing the adverse effects of illegal land use. They highlighted the need for enhanced security measures, improved infrastructure development, and efforts to mitigate the negative consequences on community well-being. As articulated by respondents and key informants, the impact of illegal land use underscored the urgency of addressing this issue to safeguard the community's quality of life and safety.

Municipal Initiatives to Address Illegal Land Use: Community Awareness and Participation

Unfortunately, the majority of respondents, approximately 210 out of 270, were unaware of any initiatives or programs the municipality undertook to address illegal land use. This indicated a potential lack of public awareness or engagement on the part of the municipality in this regard. Respondents who indicated their lack of awareness suggested that the municipality might not have effectively communicated its initiatives to combat illegal land use. This raised concerns about the need for improved dissemination of information to the public. In their view, the community should have been better informed about the steps local authorities had taken to address this pressing issue.

The absence of public knowledge also underscored missed opportunities for community engagement. Respondents noted that had they been aware of municipal programs, they might have been more inclined to participate actively in initiatives to curb illegal land use. They felt the lack of information had hindered their ability to contribute to the solution. Masenya and Kgobe (2023) argued that land use planning within the municipality held significant implications, particularly in addressing challenges related to human settlement, promoting citizen participation in determining needs and objectives, and rectifying historical spatial inequalities resulting from apartheid spatial planning. Consequently, despite its importance, the implementation of land use planning had encountered various hurdles, such as insufficient collaboration in areas governed by traditional authorities, illicit land occupation, and political interference. In essence, the study posited that achieving spatial justice and rectifying past imbalances in South Africa hinged on effective integration and coordination of land use planning. However, it highlighted persistent discontent within communities regarding their level of engagement. Despite the overall success of many municipalities in fostering citizen participation, an outstanding backlog in civic interaction existed due to unethical practices, financial constraints, a lack of capacity, and misguided targeting.

Key informants echoed these concerns, emphasizing that community involvement was vital in tackling illegal land use effectively. Furthermore, Enaifoghe and Adetiba (2018) uncovered that within most local municipalities, community involvement in decision-making had not been effectively executed. They suggested that the municipality prioritize public awareness campaigns and engage with local residents to encourage active participation. Key informants also highlighted the need for more transparent communication from the municipality regarding its initiatives, fostering a sense of shared responsibility in addressing this critical issue. Moreover, respondents believed that community members could play a pivotal role in preventing and reporting illegal land use. They suggested raising awareness within the community about the legal procedures for land use, encouraging residents to report illegal land use to the authorities, and promoting community engagement and neighborhood watch programs to deter illegal activities.

Community-Driven Solutions: Recommendations to Address Socio-Economic and Ecological Impact

The respondents, cognizant of the challenges posed by illegal land use, offered a spectrum of community-driven solutions to address its socio-economic and ecological impacts in Louis Trichardt, Makhado Local Municipality. These recommendations were rooted in their collective understanding of the problem and their aspirations for a better future.

A common suggestion from respondents was the need for comprehensive municipal awareness campaigns. They believed these campaigns could be pivotal in educating residents about legal land use and the importance of adhering to zoning regulations. By enhancing public understanding, the community anticipated a reduction in illegal land use. Chen et al. (2021) explored the notion that increasing the policing and robustness of land law enforcement contributed to a decrease in the occurrence of illegal land use cases. However, they speculated that this increase in enforcement measures might have prompted offenders to engage in more severe violations out of desperation, thereby increasing the overall degree of illegal land use. In contrast, reducing the difficulty of enforcing land law was associated with significantly reducing the extent of illegal land use.

Furthermore, respondents emphasized the significance of improving access to affordable housing options. According to Yongyang et al. (2018), such informality was a reaction to dysfunctional land institutions, particularly the prohibitively high costs of obtaining land property rights in many developing countries. Mennen (2016) stated that land tenure informality remained one of the most prevalent occurrences, with nearly 75% of the world's population lacking access to formal procedures for registering and safeguarding their property rights. Hence, respondents believed that one of the driving factors behind illegal land use was the lack of accessible and affordable housing. By creating more opportunities for residents to secure suitable housing, they aimed to mitigate the socio-economic consequences of illegal land use.

Respondents identified the critical role of law enforcement in preventing and addressing illegal land use. They stressed the need for stronger enforcement of land use regulations to act as a deterrent and ensure compliance. An effective legal framework would curb illegal activities and contribute to community safety. The community, aware of its collective potential, proposed community-driven initiatives to address the housing and economic challenges that could lead to illegal land use. Examples included forming neighborhood watch programs to enhance security and community projects to provide affordable housing

solutions. Respondents recognized the importance of sustainable land use planning to mitigate the ecological impact of illegal land use. They suggested that comprehensive planning would help allocate land for various purposes, reducing the strain on natural resources and preventing ecological degradation. The community's ecological concerns led to recommendations for conservation efforts. Respondents were keen on initiatives to protect the local environment from degradation. Examples included reforestation programs, waste management solutions, and campaigns to promote responsible land use.

Key informants echoed the community's recommendations, emphasizing the need for community involvement and active participation in implementing these solutions. They highlighted the role of local governance in initiating and supporting these efforts. Additionally, key informants stressed the importance of public-private partnerships to facilitate the creation of affordable housing options.

In summary, the recommendations put forward by the community, coupled with the insights of key informants, highlighted a collaborative and multifaceted approach to addressing the socio-economic and ecological impact of illegal land use. These solutions reflected the community's resilience and commitment to building a more sustainable and secure future for Louis Trichardt, Makhado Local Municipality.

Municipal Respondents Regarding Illegal Land Use

The following sections presented, analyzed, and interpreted the data collected from municipal respondents regarding illegal land use in Louis Trichardt, Makhado Local Municipality. The survey encompassed various aspects, including the roles of municipal employees, instances of illegal land use, socio-economic consequences, ecological impacts, measures taken to address illegal land use, the effectiveness of these measures, challenges encountered, support and resources required, the role of public awareness, and policy recommendations.

Theme 1: Human Settlement

Illegal land use affected the availability of adequate housing in the municipality, as unauthorized occupation reduced the land available for residential purposes. The strain on basic services like water, electricity, and sanitation also led to service disruptions in illegal settlements. Informal land use contributed to overcrowding, straining existing infrastructure. Residents perceived these informal settlements as congested and lacking resources compared to formal housing. The lack of legal land tenure in these areas further led to criminal activities and instability. According to the UN-Habitat 2021 report, "Shelter served as the foundation for personal and familial stability and security. It stood at the core of our social, emotional, and economic experiences, a sanctuary providing a haven for individuals and families to live in tranquility, safety, and respect." Hence, housing played a crucial role in achieving sustainable urbanization, acting as a catalyst for development, peace, and enhanced living standards for everyone.

Theme 2: Informality

Informal land use disrupted the legal and regulatory framework governing land ownership and development, leading to delays in development and a lack of compliance with legal procedures and municipal by-laws. It also affected the formal land market by lowering property values in the vicinity. The informal economy associated with illegal land use might have increased the local economy due to population growth but could have resulted in competition and unsafe working conditions. The provision of public services in informal settlements was often inadequate, affecting healthcare and infrastructure. Moreover, social exclusion was a concern as it could have led to limited access to services and higher crime rates.

Theme 3: Access to Economic Activities

Illegal land use negatively affected residents' access to formal economic activities and employment opportunities, as businesses avoided informal areas, leading to economic instability for residents. The informal economy associated with illegal land use might have stimulated the local economy but often operated under unsafe conditions. The lack of legal land tenure might have made formal businesses less attractive, potentially hindering economic growth. Additionally, illegal land uses affected land available for agricultural and productive activities, increasing poverty levels due to limited opportunities.

Illegal land use not only hampered residents' access to formal economic activities and employment opportunities but also introduced a range of challenges that rippled through various aspects of community life. The reluctance of businesses to establish themselves in informal areas, driven by uncertainties related to illegal land use, not only caused economic instability but also perpetuated a cycle of limited growth and

opportunity for local residents. The informal economy associated with illegal land use, while contributing to local economic stimulation, often operated under unsafe conditions, posing risks to the well-being of those involved.

Moreover, the absence of legal land tenure could have diminished the attractiveness of formal businesses, potentially acting as a deterrent to investment and impeding overall economic growth. The resulting economic disparities might have exacerbated existing social inequalities, affecting the overall prosperity of the community. Beyond the urban landscape, illegal land uses also encroached upon land designated for agricultural and productive activities. This encroachment limited the available space for cultivation and production, subsequently increasing poverty levels by restricting opportunities for sustainable livelihoods. The intricate web of challenges stemming from illegal land use highlighted the need for comprehensive strategies that addressed the immediate issues and contributed to sustainable economic development, social equity, and improved living conditions for affected communities.

Theme 4: Land Uses

Illegal land uses had a negative impact on the availability and conservation of natural resources, including land, water, air pollution, deforestation, and habitat disruption. Unauthorized land occupation disrupted land use planning and urban development initiatives, hindering the implementation of sustainable practices. Such informal land use also contributed to environmental degradation and loss of biodiversity. Residents stressed the importance of fairness and transparency in land resource management. Furthermore, the lack of legal land tenure might have led to land disputes and hindered the implementation of sustainable land use practices in the area.

These responses shed light on the multifaceted challenges and consequences of illegal land use within Louis Trichardt, Makhado Local Municipality. The insights provided by municipal employees offered a comprehensive understanding of the issues at hand and served as a basis for potential policy development and community engagement initiatives to address these challenges.

6 CONCLUSION

The study on illegal land use in Louis Trichardt, Makhado Local Municipality, provides valuable insights into the challenges and potential solutions regarding this multifaceted issue. The community's awareness, concerns, and recommendations, combined with municipal perspectives, emphasize the need for collaboration, community engagement, and effective policy measures. By implementing the recommended strategies and addressing the identified weaknesses, Louis Trichardt can move towards a more sustainable and secure future while ensuring the well-being of its residents and protecting its environment. The findings highlight the economic, social, and environmental consequences of illegal land use, reflecting similar impacts observed in the Lwandle informal settlement in Cape Town. The study also draws parallels with international cases, such as the ongoing struggles with illegal land use and evictions in South Africa and the exploitation of indigenous lands in Brazil.

The community's awareness, concerns, and recommendations, combined with municipal perspectives, underscore the need for collaboration, community engagement, and effective policy measures. Addressing illegal land use requires a multifaceted approach that includes strengthening municipal resources, enhancing public awareness, and improving access to affordable housing. The study underlines the importance of a coordinated effort involving government, civil society, and affected communities to effectively address illegal land use and its repercussions. This approach not only tackles immediate challenges but also contributes to long-term sustainable urban development.

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🏆 reviewed paper

Formalising the Informal: A Multi-Stakeholder Approach to Sustainable Urban Development in South Africa

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1 ABSTRACT

The 21st century is the era of continuous rapid and high levels of urbanisation, particularly in cities of the developing world. Projections show that by 2050, over half of the global population will reside in urban areas. It is estimated by the United Nations (UN) that 71.3% of South Africa's population will live in urban areas by 2030, increasing to nearly 80% by 2050. This study explores the diverse challenges hindering sustainable urban development in South Africa. The paper identifies key barriers through a systematic literature methodology, including the ripple effects of apartheid, the sheer prevalence of urban informal settlements, unemployment, and limited citizen engagement. However, it does not stop at identifying the problems. It also proposes an innovative approach: "Formalising the Informal" through a multi-stakeholder lens. It argues that achieving this goal requires addressing the informal sector's complexities, often viewed as a problem rather than a potential asset. The approach stresses collaboration between government, communities, and the private sector to integrate the informal sector into the urban fabric, supporting secondary cities and further tackling societal concerns such as unemployment and inadequate housing, adversely affect urban sustainable development. The study argues that recognising informal actors' ingenuity and economic contributions can pave the way for more sustainable and inclusive cities in South Africa.

Keywords: urban development, informality, formalising, multi-stakeholder, secondary cities

2 INTRODUCTION

The rapid and high levels of urbanization in the 21st century presents significant challenges and opportunities for sustainable urban development, particularly in South Africa. The United Nations projects that by 2050, over half of the global population will reside in urban areas, with an estimated 71.3% of South Africa's population living in urban centres by 2030 and nearly 80% by 2050 (United Nations, 2018). As urban populations swell, so too do the complexities associated with managing these growing cities, particularly in South Africa's unique socio-political history. South Africa's urban landscape is deeply shaped by the legacy of apartheid, which has left a lasting impact on city planning, housing, and economic opportunities. One of the most visible manifestations of this legacy is the prevalence of informal settlements, which have become a prominent feature in the country's urban areas. These settlements are often characterized by inadequate infrastructure, a lack of basic services, and precarious living conditions, highlight the persistent inequalities within South African society (Harrison, Todes & Watson, 2008).

Despite these challenges, informal settlements are not merely a symbol of urban failure; but represent a complex and dynamic aspect of urban life. The informal sector, which includes these settlements, is often viewed as a problem to be eradicated rather than a potential asset that could contribute to urban sustainability. This study challenges this conventional perspective by proposing a multi-stakeholder approach to "Formalising the Informal." Smit, (2018), argues that sustainable urban development in South Africa can be better achieved by integrating the informal sector into the formal urban fabric, rather than sidelining it. The multi-stakeholder approach involves collaboration between government entities, local communities, and the private sector. This collaborative effort is essential for addressing the diverse challenges faced by secondary cities, which are often overshadowed by larger metropolitan areas yet are crucial to the broader urbanization process. UN-Habitat (2019), formalising the informal sector, there is the potential to tackle critical societal concerns such as unemployment and inadequate housing, which are key barriers to sustainable urban development.

Moreover, this approach recognises the ingenuity and economic contributions of informal actors. These individuals and communities, who operate outside the formal economy, play a vital role in the functioning of cities. Their inclusion in urban planning and policy-making processes can pave the way for more inclusive

and resilient urban environments. As South Africa continues to urbanize, embracing the informal sector through a multi-stakeholder framework may be key to achieving long-term sustainability and equity in urban development. This paper contributes to the ongoing discourse on sustainable urban development by highlighting the importance of a more inclusive approach. Formalizing the informal, South Africa can move towards a future where its cities are not only more sustainable but also more just and inclusive for all its inhabitants.

3 LITERATURE REVIEW

Sustainable urban development is broadly understood as the process of encouraging urban growth while balancing economic, social, and environmental considerations (James, 2024). The United Nations Sustainable Development Goal 11 (SDG 11) stresses making cities and human settlements inclusive, safe, resilient, and sustainable. This entails providing access to adequate housing, improving infrastructure, ensuring participatory urban governance, and stirring economic opportunities while mitigating environmental degradation (United Nations, 2018). However, globally, achieving this vision faces challenges such as urban sprawl, resource depletion, socio-economic inequalities, and inadequate planning frameworks (Kanchana, 2022).

Developing countries often rely on centralised, top-down urban planning frameworks that exclude meaningful participation by local communities (Mokoele, 2023). This approach fails to address the needs of marginalised populations, particularly those in informal settlements, leading to urban environments that are inequitable and unsustainable (Watson, 2009). Without grassroots engagement, urban policies often exacerbate disparities rather than resolve them (Muggah and Wahba, 2020). Informal settlements often lack basic infrastructure and services, yet they house a significant proportion of the urban population (Huchzermeyer, 2011). Similarly, the informal economy provides critical employment opportunities where formal economies fall short, particularly in sectors such as construction, retail, and services (Chen, 2012). Despite their importance, informal settlements and economies are often sidelined in planning processes, further marginalising vulnerable communities. Another prominent feature of impediment to sustainable urban development in the developing world is corruption. Resources intended for infrastructure development and public services are often misallocated, and public-private partnerships may prioritize profit over equity and sustainability (Pattanayak and Verdugo-Yepes, 2020). Corruption undermines trust in governance structures and inhibits the implementation of inclusive urban development policies. Secondary cities, often eclipsed by larger metropolitan areas, play a fundamental role in regional development and can serve as laboratories for innovative urban policies for achieving urban sustainable development. They function as vital hubs that connect local production, movement, and exchange of goods, people, trade, information, and services between various urban systems, demonstrating industry agglomerations, localized supply chains, diverse economic bases, and a range of housing options (Roberts and Hohmann, 2014).

South Africa's urban development strategies have evolved over the years, shaped by the socio-political and economic challenges inherited from the apartheid era. Several policies and frameworks have been introduced to address the deep-seated inequalities in urban areas, improve living conditions, and promote sustainable urban development. Following the end of apartheid in 1994, the South African government introduced the Reconstruction and Development Programme (RDP) as a comprehensive policy framework aimed at addressing the historical inequalities of apartheid. The RDP focused on providing basic services, including housing, water, and sanitation, to previously marginalised communities (Marutlulle, 2021). This was part of the government's broader goal to promote socio-economic integration through infrastructure development. While the RDP made significant strides in improving living conditions for many South Africans, particularly in informal settlements, it also faced criticism. The approach was often seen as insufficient in addressing long-term sustainability and urban planning issues, with a focus on quantity over quality, which sometimes led to poorly planned settlements (Lefuwa, 2016). Additionally, the RDP's focus on the delivery of housing failed to fully integrate other aspects of urban sustainability, such as economic development and environmental resilience. In response to the persistent challenges of informal settlements, the South African government launched the Upgrading of Informal Settlements Programme (UISP) in 2004. This policy aimed to improve the living conditions of residents in informal settlements by providing secure tenure, basic infrastructure, and services. The UISP encouraged a more integrated and sustainable approach to upgrading informal settlements rather than merely demolishing or relocating residents (Maganadisa, Letsoko, and

Pretorius, 2021). However, the program did not fully address the broader socio-economic factors affecting urban sustainability, such as unemployment and local economic development. While not specifically urban-focused, the Integrated Sustainable Rural Development Programme (ISRDP), launched in 2001, aimed to integrate rural and urban development efforts to create more balanced regional development (Public Service Commission, 2010). The Urban Development Framework (UDF), introduced in 1997, sought to address the specific needs of South Africa's urban areas. The framework set out a vision for integrated, sustainable, and equitable urban development by focusing on promoting urban efficiency, social equity, and environmental sustainability (Department of Provincial and Local Government, 2009). The framework underlines the importance of a balance between housing and employment, urban regeneration, and sustainable environmental practices. While the UDF made strides toward these objectives, it struggled to shift the national urban development paradigm away from large-scale, top-down approaches, often failing to fully incorporate informal sector dynamics and local-level participation in urban development. In 2004, South Africa introduced Breaking New Ground (BNG), a landmark policy that sought to transform the country's approach to housing and urban development. The BNG policy emerged as a response to the limitations of previous housing policies, such as the RDP, by highlighting the need for sustainable human settlements rather than just housing provision (Baloyi, 2014). BNG introduced a more holistic approach by considering aspects such as job creation, poverty reduction, and environmental sustainability in housing development. It promoted mixed-use developments, better access to services, and the creation of communities that were more self-sustaining (Osman and Herthogs, n.d.). However, BNG also faced implementation challenges, including slow delivery of services, financial constraints, and the complexity of integrating informal settlements into the formal urban fabric. Despite the significant efforts made through these programs and frameworks, gaps remain in achieving truly sustainable urban development in South Africa.

In response to the challenges posed by informal settlements, the informal sector, and poor engagements, there has been growing interest in multi-stakeholder approaches to urban development. These approaches state the importance of collaboration between government, communities, and the private sector in addressing urban challenges and achieving urban sustainable development. Watson (2009) argues that inclusive urban governance is essential for creating sustainable and equitable cities, particularly in areas with high levels of informality. Multi-stakeholder approaches have been implemented in various forms across the Global South, with varying degrees of success. In South Africa, as already argued earlier, initiatives such as the (UISP) have sought to formalise informal settlements through partnerships between government and communities (Socio-Economic Rights Institute of South Africa [SERI], 2018). However, these initiatives have often been hampered by bureaucratic inefficiencies, lack of resources, and insufficient community engagement.

4 METHODS AND MATERIALS

This section outlines the methodological approach adopted to guide the research process, ensuring a systematic and coherent investigation of the study objectives. The study employed a systematic literature review (SLR) methodology to explore the challenges and opportunities related to sustainable urban development in South Africa. The primary objective is to understand the role of informal settlements and the informal sector in the urbanisation process and to propose a multi-stakeholder approach for integrating these elements into formal urban development strategies.

The SLR methodology is chosen for its robustness in synthesising existing knowledge and identifying gaps in the literature. A comprehensive search of electronic databases, including Scopus, Web of Science, and Google Scholar, was conducted. Keywords that include "sustainable urban development," "informal settlements," "multi-stakeholder approach," "South Africa," and "urban governance" were used to identify relevant literature. The search initially identified 778 documents, which were screened through a two-step process involving title and abstract review followed by full-text assessment. This rigorous selection process, guided by inclusion and exclusion criteria, narrowed the pool to 33 high-quality and relevant studies. The search was limited to peer-reviewed journal articles, conference papers, and relevant policy documents published between 2000 and 2023. To ensure the relevance and quality of the data, specific inclusion and exclusion criteria were applied. Articles were included if they focused on urban development in South Africa, addressed the role of informal settlements or the informal sector, or discussed multi-stakeholder approaches to governance. Articles that did not meet these criteria, were not peer-reviewed, or were focused on regions outside South Africa were excluded.

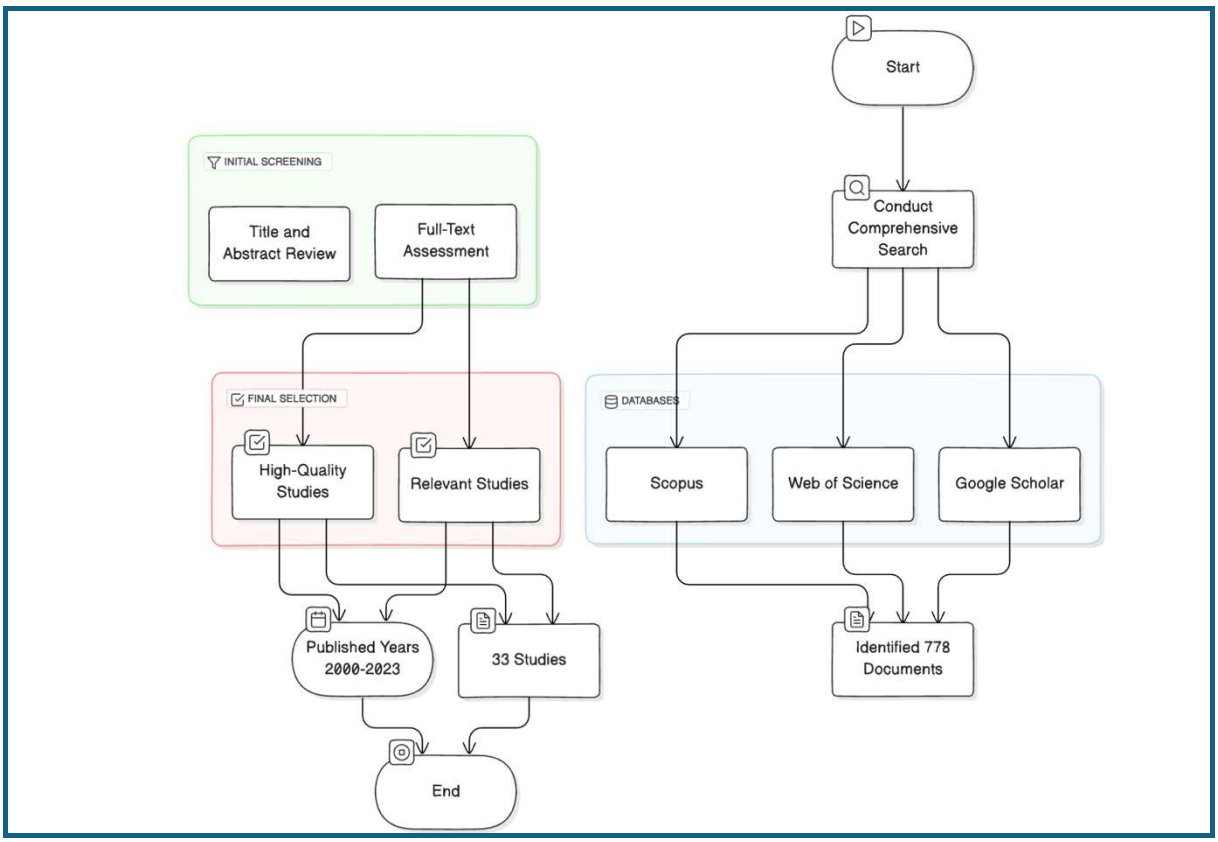

Figure 1: Research Process

5 UNDERLYING OBSTACLES TO ACHIEVING SUSTAINABLE URBAN DEVELOPMENT IN SOUTH AFRICA

5.1 Unsupported Secondary Cities

Urbanisation, the shift of population from rural to urban areas, is a global trend with profound implications for sustainable development. As cities grow, they often face challenges such as increased resource consumption, pollution, and social inequality (Kanchana, 2022). However, South Africa's urbanisation process is complicated by its unique historical and socio-political landscape. South Africa's struggle to achieve urban sustainable development can be equally attributed to its limited support for secondary cities, which plays a crucial role in addressing urbanisation challenges. These challenges, including chronic poverty, unemployment, job creation, infrastructure provision, small business development, and education and skills development, are likely common to most, if not all (Pillay, n.d.). Supporting these cities with targeted investments, infrastructure, and governance reforms would help alleviate urbanisation challenges, reduce inequalities, and promote more balanced development.

5.2 The Legacy of Apartheid on Urban Development

The apartheid era has left an indelible mark on South Africa's urban landscape. Urban planning during this period was characterised by segregationist policies that marginalised non-white populations, pushing them into poorly serviced, overcrowded areas that have since evolved into informal settlements (Harrison, Todes & Watson, 2008). These settlements, often lacking basic infrastructure and services, are a stark reminder of the inequalities entrenched during apartheid. Despite the end of apartheid in 1994, the spatial and economic disparities it created continue to challenge urban development efforts. Several scholars have highlighted the ongoing impact of apartheid on urban development in South Africa. Turok and Borel-Saladin (2014) argue that the spatial legacy of apartheid still influences the distribution of economic opportunities, with informal settlements often located far from urban centres and employment opportunities. This spatial mismatch exacerbates issues of unemployment and poverty, making it difficult for residents of informal settlements to improve their socio-economic conditions.

5.3 Informal Settlements and Urban Sustainability

Informal settlements have become a prominent feature of South African cities, reflecting both the failures of formal urban planning and the resilience of marginalized communities. Huchzermeyer (2011), informal settlements are often viewed as temporary and problematic, rather than as a permanent and integral part of the urban fabric. This perspective has led to policies focused on eradicating or upgrading informal settlements without fully considering the needs and contributions of their residents. The informal sector, encompassing both informal settlements and economic activities, is a critical aspect of urban life in South Africa. Chen (2012) and Mitlin (2014) argue that the informal sector plays a vital role in the economy, providing employment and services where the formal economy falls short. Despite its importance, the informal sector is often stigmatised and excluded from formal urban planning processes, which limits its potential to contribute to sustainable urban development.

5.4 Lack of Public Engagement

Section 152(1) of the Constitution of the Republic of South Africa, 1996, highlights the critical role of public participation by requiring municipalities to promote the involvement of citizens and public organisations in local government affairs and to ensure the sustainable delivery of essential services to communities. Democracies cannot effectively or efficiently address public needs without active public participation. Despite South Africa having a public participation framework and democratic innovations to promote public engagement, challenges persist, including limited resources, low public interest, corruption, ineffective governance, and insufficient feedback from the government (Gumede, 2021). This leads to insufficient follow-up on issues raised by the public, with the absence of feedback mechanisms further undermining participation.

6 TOWARDS A FRAMEWORK FOR MULTI-STAKEHOLDER MODEL FOR SUSTAINABLE URBAN DEVELOPMENT

The discussion on urbanisation, informal settlements, and multi-stakeholder approaches to urban development in South Africa highlights the complexities and challenges of achieving sustainable urban growth. The legacy of apartheid, the prevalence of informal settlements, and the exclusion of the informal sector from formal planning processes all pose significant barriers to sustainability. However, through adopting a multi-stakeholder approach and recognising the potential of the informal sector, South Africa can work towards more inclusive and sustainable cities. The concept of "Formalising the Informal" offers a promising paradigm for addressing these challenges, suggesting that sustainable urban development is not only possible but also achievable through collaborative and inclusive efforts.

Component	Key Actions	Stakeholders Involved
Inclusive Governance	Establish community forums for participatory planning. Ensure transparency and accountability in decision-making.	Government, Local Communities. Civil Society Organizations
Economic Empowerment	Provide microfinance options for informal sector entrepreneurs. Create skill development programs tailored to the informal sector.	Private Sector, Financial Institutions. NGOs, Community Groups
Infrastructure Upgrades	Invest in basic services (water, electricity, sanitation) for informal settlements. Develop affordable housing close to economic hubs.	Government, Development Partners. Private Sector
Capacity Building	Train municipal officials in collaborative urban management practices. Educate residents about their rights and opportunities within formal systems.	Academia, Government Agencies. NGOs, Local Communities

Figure 2: Multi-Stakeholder Model for Sustainable Urban Development. Source: M. Mndzebele (2025)

In addressing the barriers to sustainable urban development, Figure 2, presents a framework that requires inclusive governance and urban planning that engages informal settlement residents, and civil society organisations and recognising their needs and contributions (Isandla Institute, 2014). This approach can

ensures the establishment of sustainable human settlements through development processes that promote human rights, uphold dignity, and ensure equity. Economic empowerment is a crucial component that supports secondary cities and enables balance development – key strategies providing microfinance options to informal entrepreneurs and creating skill development programs to enhance productivity and inclusion, and financial institutions, and NGOs play vital roles in implementation (International Labour Organization, n.d.). These initiatives stimulate economic growth, reduce inequality, and advance urban resilience. The disparities of apartheid are prominent in many South African cities and manifest in substandard informal settlements. There is a need for urban infrastructure upgrades, even though there are efforts done by the government, investments in infrastructure, housing, and economic opportunities in secondary cities are critical to address regional inequalities and reduce the strain on metropolitan areas. The lack of public engagement in urban spaces is an indication of the need for capacity building. Empowering municipal officials with collaborative urban management practices enhances their ability to address complex urban challenges. Training in participatory governance, conflict resolution, and integrated planning encourages inclusive and responsive urban management. This approach aligns with Sustainable Development Goal 16 by promoting institutional efficiency and equity in service delivery United Nations (2015). The proposed multi-stakeholder framework in Figure 2 encourages adaptive governance that leverages the strengths of all stakeholders, creating urban systems that are both equitable and sustainable. Formalising the informal sector and integrating marginalised communities into urban planning processes, South Africa can create cities that are more inclusive, resilient, and prepared to meet the demands of sustainable development.

7 CONCLUSION

This study highlights the critical importance of adopting a multi-stakeholder approach to formalising the informal sector as a pathway toward sustainable urban development in South Africa. The complexities of South Africa's urban landscape, deeply rooted in its socio-political history, have resulted in widespread informal settlements and a vibrant yet marginalised informal sector. These realities present significant challenges but also offer opportunities for inclusive urban growth. The systematic literature review has highlighted the persistent barriers to sustainable urban development, including the legacy of apartheid, unsupported secondary cities, inadequate public engagement, and the marginalisation of informal settlements and economies. However, the findings also reveal that informal settlements and the informal sector are not merely problems to be eradicated but potential assets that, if properly integrated, can contribute meaningfully to the urban economy and social fabric. The proposed multi-stakeholder approach advocates for the active participation of government entities, local communities, and the private sector in urban planning and policy-making processes. Such collaboration is essential to address the multifaceted challenges of urbanisation and to create cities that are inclusive, resilient, and sustainable. Recognising and formalising the contributions of informal actors can lead to innovative solutions that support economic development, reduce unemployment, and improve living conditions in informal settlements.

Moreover, the study stresses the importance of empowering secondary cities as vital hubs in the broader urban network. Through investing in infrastructure, governance, and local economies in these areas, South Africa can alleviate the pressures on major metropolitan centres and promote more balanced regional development. Achieving sustainable urban development in South Africa requires a paradigm shift that moves beyond top-down planning approaches. Embracing the complexities of informality through a multi-stakeholder framework can pave the way for more equitable and sustainable cities. This approach not only aligns with global sustainability goals but also addresses the unique socio-economic challenges facing South Africa, ultimately enhances urban environments that are inclusive, dynamic, and resilient.

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reviewed paper

Formulation of Clean Energy Transition Strategies for Small and Medium Sized Cities

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1 ABSTRACT

The EU project PLENTY-LIFE has developed the Holistic Integrated Spatio-Temporal Energy Planning (HISTEP) framework to help small and medium-sized cities (SMCTs) plan long-term clean energy transitions (CET). Currently, the framework is being tested in seven pilot cities across Austria, Italy, Portugal, and Romania through a collaborative process with local stakeholders. This paper outlines the key steps in CET strategy development and shares initial findings from applying HISTEP to project future energy demand in Fundão, Portugal. The baseline "business-as-usual" (BAU) scenario reflects historical trends and existing policies, with minimal decarbonization efforts and moderate socio-economic and technological changes. In BAU scenario, the projected annual final energy demand by fuel shows a slight increase from 318.8 GWh to 320.0 GWh over the study period (2018-2050), averaging an annual growth rate of 0.01%. During this period, motor fuel remains dominant, where its share decreases from 47% to 43% of total final energy consumption. Electricity's share increases from 30% to 34%, while fossil thermal fuel decreases from 14% to 12%. The final energy by sector shows a dominance of building sectors, its share will rise from 43.8% to 45.9%, the transport sector decreases from 41.8% to 36.5%, and the industry sector increases from 14.5% to 17.6%. The resulting CO_2 emissions within the city boundaries show a slight decline from 48.6 to 43 kt-CO_2. The corresponding per capita indicator indicators reveal an increase in final energy demand from 11.9 to 14.4 MWh/cap and a slight rise in CO_2 emissions from 1.82 to 1.94 t-CO_2/cap. These results illustrate the limited impact of current decarbonization measures concerning energy savings and efficiency improvements, electrification, digitalization, and the transition to clean fuels across all consumption sectors. BAU scenario serves as a benchmark to assess the effectiveness of the forthcoming clean energy transition scenario (CETS), which aims to demonstrate a decarbonization pathway toward a climate-neutral Fundão by 2050. The CET aligns with Fundão's energy and climate goals and is driven by significant enhancements in energy efficiency across all sectors, electrification of end-uses, a shift to clean fuels, and an increase in local RES to decarbonize power and heat supply.

The HISTEP framework's application in Fundão underscores the importance of comprehensive, integrated planning in achieving sustainable energy transitions for SMCTs. Modelling various scenarios following a participatory process engaging local stakeholders and citizens, cities can develop tailored strategies that effectively address their unique challenges and opportunities in the journey toward carbon neutrality.

Keywords: sustainable urban development, spatio-temporal energy planning, city decarbonisation strategy, Co-creation , Clean Energy Transition

2 INTRODUCTION

Achieving climate neutrality requires transitioning to a resource-efficient, sustainable, and low-carbon energy system. Cities, responsible for around 70% of global energy consumption and CO_2 emissions (IRENA, 2020), (UN-Habitat, 2019), (Fuso Nerini et al., 2019) play a crucial role in this shif. With urban populations projected to rise from 55% to 68% by 2050, many European cities have set ambitious decarbonization goals. However, SMCTs often lack the resources for comprehensive strategies, leading to fragmented efforts.

To address this, the EU project PLENTY-LIFE is developing an integrated urban energy planning framework to help SMCTs formulate and monitor long-term CET strategies, aiming for climate neutrality by 2040/2050. The framework is being tested in seven pilot cities across four EU countries, paving the way for broader adoption. Key project areas include:

- HISTEP Framework: A bottom-up urban energy planning approach, modeling future energy demand and supply along CET pathways aligned with socio-economic and technological trends.
- Pilot Cities: Seven case studies in four EU countries demonstrate HISTEP's integration into planning processes.
- Capacity Building: Three training modules enhance local expertise in energy, spatial, and urban planning, targeting policymakers and planners.
- Participatory Process: Engages local stakeholders through co-design, co-creation, and co-learning, including stakeholder mapping, feasibility tools, and workshops.
- CET Strategy Formulation: A five-step approach involving data collection, model calibration for the base year, scenario development, sectoral prioritization, and monitoring, with stakeholder input through workshops and surveys.
- Replication and Scaling: Extracting best practices from pilot cities to support other European SMCTs in developing CET strategies.

This paper presents the CET strategy framework and its application to Fundão[1], Portugal, focusing on projected energy demand by 2050 under a BAU scenario, which serves as a benchmark for future CET scenarios.

3 METHODOLOGY

Transitioning SMCTs to carbon neutrality requires an integrated, cross-sectoral energy planning approach embedded in urban planning. The HISTEP framework, developed within PLENTY-LIFE, combines spatio-temporal energy-demand and supply analysis with advanced urban energy modeling tools to assess flexibility needs (Horak et al., 2022), (Hainoun and Loibl, 2022). It also provides a monitoring framework (KICET) aligned with SDGs 7, 11, and 13.

A co-creation process involving local stakeholders and citizens – through workshops and surveys – guides the development of CET strategies via the following steps:

- Data Collection: Gather current energy balances by sector and fuel, assess RES potentials, and compile socio-economic and technological parameters influencing the city's energy demand and supply.
- Base Year Calibration: Reconstruct and calibrate the base year energy demand and supply to establish a reference point for future projections.
- Scenario Development: Build BAU and CET scenarios through active engagement with key stakeholder.
- Energy Demand-Supply Modelling: Utilize established framework tools MAED-City, CEA, and MESSAGE, to model energy demand and supply, and extract pertinent results.
- Stakeholder Feedback: Refine scenarios to align with city energy and climate targets.
- Key Indicators for CET (KICET): Extract a set of indicators to monitor the progress and effectiveness of the CET strategy.
- Roadmap and Priority of Action: Define a transition roadmap with prioritized actions.

The HISTEP approach ensures CET strategies are data-driven, inclusive, and tailored to city-specific needs, increasing their effectiveness and stakeholder acceptance.

The focus of this paper is on presenting the so far accomplished work of applying the HISTEP methodology to prepare the CET strategy of the pilot city Fundao. Thus, the presented content covers the data collection,

[1] http://plenty-life.eu/portugal/

base year reconstruction and calibration, development of BAU scenario for the final energy demand projection, and elaborating on the conducted work to construct the CETS including related stakeholder and citizen engagement.CASE Study: Fundão city

4 CASE STUDY: FUNDÃO CITY

Fundão, a municipality located in the Castelo Branco District, occupies an area of approximately 700 km² and its population accounts to 26,706 inhabitants (Gabinete de Estratégia e Estudos, 2024). Fundão benefits from its proximity to three important urban areas of polycentrism in the Centre Region, namely Covilhã to north, Guarda to the northeast and Castelo Branco to south (Fig. 1). As a low-density rural territory, agricultural production, complemented by a strong commercial tradition in the city of Fundão, is the region's main sector and has been for centuries. With a population density of approximately 38 inhabitants per km², Fundão's residents are primarily concentrated in urban areas, a common pattern in low-density regions. However, the municipality's population is rapidly declining. While the negative growth rate was only 0.1% in 2001, it had increased tenfold by 2021, and this trend is expected to worsen.

Fundão's economy is heavily reliant on agriculture and a well-established, diverse trade network. Among its agricultural products, the renowned "Cereja do Fundão" stands out, generating over 20 million euros annually and playing a crucial role in the local economy. The sector comprises over 300 producers and employs more than 2,000 seasonal workers each year. Meanwhile, the industrial and trade sectors have diversified in recent years, with notable contributions from the glass, granite, wood, and jewelry polishing industries.

Demographic trends reflect significant shifts. The labor force constitutes approximately 57.4% of the population, but this share is steadily decreasing, while the elderly population (over 65) has risen to 32.5%, a trend that began in the 1960s. Simultaneously, the proportion of younger residents (under 15) declined from 11.8% in 2011 to 10.1% in 2021.

Like demographic changes, the employment landscape is evolving. Agriculture employs a relatively stable 6.5%-6.8% of the workforce, while the industrial and construction sectors have seen a gradual decline, dropping from 27.2% in 2011 to 25.7% in 2021. Conversely, the service sector has grown significantly, from 53.7% in 2001 to 67.4% in 2021, although its growth has slowed in recent years.

Fig. 1: Geographical location of Fundão within the central region of Portugal (Rowe, 2021).

Fundão faces several challenges, typical of landlocked municipalities, which have profoundly affected its demographic and economic landscape:

- An economic downturn due to limited private investment and weak innovation in local industries.
- Population aging driven by declining birth rates.
- Outmigration of younger, skilled individuals to larger urban centers or abroad.

These issues have also led to urban decline, with the historic city center suffering from degradation and a loss of identity. Additionally, rural abandonment and underutilization of the region's natural resources remain significant barriers to economic development.

4.1 Status of Urban Development of Fundão

By focusing on attracting investment, retaining talent, creating jobs, and opening new markets, Fundão's Innovation Plan aims to enhance the region's competitiveness and appeal (Câmara Municipal de Fundão, 2024). Today, Fundão thrives as a hub of open innovation, supported by enterprise hosting facilities, co-working and incubation spaces, a globally certified Fab Lab, a Business and Services Centre meeting top industry standards, an Advanced Training Centre for upskilling and reskilling, the Agrotech IoT Centre, a Temporary Work Reception Centre, and a Software Verification and Certification Centre. This strategy has attracted significant investment, transforming Fundão into a global innovation hub. Over 1,000 technology-sector jobs have been created, and 16 ICT companies have established operations in the region, exporting much of the knowledge produced locally.

Beyond its innovation ecosystem, Fundão, an historic city with roots in trade, features a well-structured street network. The municipality also provides a train station and an intercity bus stop. Due to the city's compact size, it is easily walkable, eliminating the need for an intracity public transport system with a positive implication to the city's CET. However, despite its walkability, 67.7% of the population commutes by car, while only 8.9% use public transport. The new commercial centers have been located outside the city, causing this need to commute by car. Fundão is also well-connected via a highway linking it to three major urban centers: Covilhã (35 km), Guarda (70 km), and Castelo Branco (43 km). This access to key economic hubs is crucial for attracting businesses and supporting their growth in the region. Although Fundão offers good train and intercity bus connections, there are no public transport options within the city itself, leading most residents to rely on cars. Fundão does have a few cycling lanes for recreational activities, and as part of the European project "Mobility Urban Values", plans are underway to expand the cycling network.

In terms of housing, in 2021 the total number of dwellings in Fundão is about 18,882, where the main residences and the secondary residences are included (SPI Technical Team, 2023). Based on these total number of dwellings and the total number of population of approximately 26,700 (SPI Technical Team, 2023), the household size in Fundão is about 1.4 persons per household. In 2011 the household size was about 1.6 persons per household (SPI Technical Team, 2023) and so for the base year 2018 the household size was set up with 1.5 persons per household. Nearly half of these households have been issued an energy certificate of class B or higher (ADENE – Agência para a Energia, 2023). Given the historic nature of the municipality, ongoing renovation efforts have contributed to this significant share of energy-efficient buildings. However, it is important to note that this figure applies specifically to the residential sector.

4.2 Energy and Climate Targets: National and Municipal Commitments

Portugal aims to reduce the greenhouse gas emissions in the order of 45% to 55% from 2005 levels by 2030.

A significant component of this strategy is increasing the share of renewable energy in final energy consumption to 51% by 2030, up from the previous target of 47%. In the electricity sector, the objective is even more ambitious, with plans to generate 93% of electricity from renewable sources by 2030. The overall installed renewable energy capacity will rise to 42.9 GW by 2030. These efforts are part of Portugal's revised National Energy and Climate Plan (NECP 2030), which outlines the country's commitment to enhancing energy efficiency, diversifying energy sources, and reinforcing infrastructure to support the energy transition (European Commission, 2024). By implementing these measures, Portugal aims to reduce its dependence on fossil fuels, enhance energy security, and position itself as a leader in renewable energy within Europe.

The Municipality of Fundão has implemented various sustainability initiatives such as the development of the Sustainable and Intelligent Interurban Development Action Plan (PADISI) in 2018 and Sustainable Energy and Climate Action Plan (SECAP) in April 2023. PADISI promotes a low-carbon economy and energy self-sufficiency in the Alentejo-Centro-Extremadura Euroregion (EURO–ACE). The SECAP outlines goals to reduce CO2 emissions by at least 40% by 2030, increase resilience to climate impacts, and improve energy efficiency through six mitigation sectors (Municipal buildings, non-municipal buildings, residential buildings, industry, primary sector, transport) and thirteen adaptation sectors (buildings, transport, energy,

water, waste, land use planning, agriculture and forestry, environment and biodiversity, health, civil protection and emergency, tourism, education, ICT). Additionally, the plan addresses energy poverty across six macro areas (climate, socio-economic aspects, housing, mobility, regulatory policy, participation/awareness-raising).

Category	Measure
Sustainable Buildings	Enhance thermal comfort, passive resilience, and energy and water efficiency in buildings by prioritizing the use of advanced, efficient technologies. Decarbonise the building stock.
Sustainable Mobility	Foster sustainable transportation by supporting the energy transition in the transport sector and promoting universal accessibility and efficient travel behaviors.
Renewable Energy Production	Facilitate the decarbonization of the municipality and boost energy self-sufficiency by engaging the community as active participants in the energy system.
Sustainable Networks	Improve the efficiency of public infrastructure and resource management to minimize waste and enhance territorial resilience.
Sustainable Natural Assets	Strengthen resilience, value natural capital, and promote a balanced rural economy and environmental sustainability.
Ecological, Just, and Cohesive Transition	Integrate ecological and sustainable principles into municipal policies and practices, raising awareness and encouraging citizen participation in sustainable production and consumption.

Table 2: Qualitative municipality targets (SPI Technical Team, 2023)

Fundão's commitment to sustainability is further reflected in its improving energy efficiency and promoting renewable energy, attracting private investments in clean energy. Fundão now produces more energy than it consumes, with renewable energy production reaching 423 GWh in 2020, far exceeding its own consumption of 92 GWh. This energy surplus is expected to grow with upcoming investments, positioning Fundão as a regional leader in clean energy production.

4.3 Data Collection and Base Year Calibration

The energy consumption presented refer to the main consuming sectors: agriculture, construction, mining, manufacturing, household, service and transportation (passenger and freight).

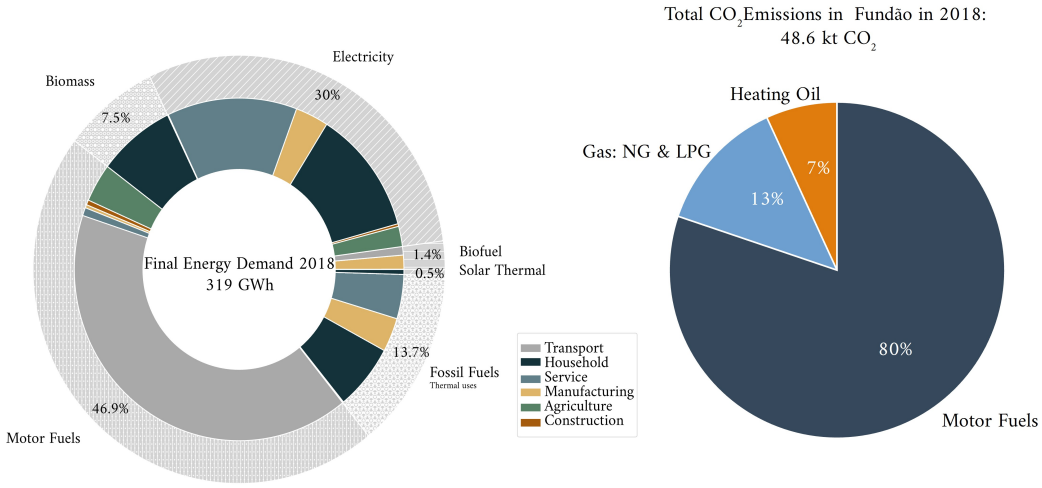

Fig. 2: Final energy consumption by sector and fuel type (on the left-hand side) and CO_2 emissions by fuel type in Fundão in 2018 (on the right-hand side).

4.3.1 Energy Demand of Fundão in the Base Year 2018

When compared to national energy indicators, Fundão's energy intensity and per capita energy consumption are both lower than the national average. In 2018, the total final energy consumption in Fundão reached approximately 318.8 GWh, distributed to 41.8% for mobility (freight 13.6% and passenger transportation 28.18%), 26.1% for households, 17.7% for services, 8.1% for the manufacturing industry, 5.6% for agriculture and forestry, and 0.8% for the construction sector. The energy demand breakdown by fuel highlights the dominance of fossil motor fuels, which account for 46.9%, primarily used in the transport

sector. Electricity makes up 30.0%, mainly consumed by households and the service sector. Fossil fuels for thermal use account for 13.7%, shared between households, services, and manufacturing, while firewood at 7.5%, as shown in Fig. 2.

The resulting direct CO_2 emissions of Fundão reached in the base year 2018 around 48.6 kt CO_2 with the primary source represented by fossil motor fuels, followed by gas (natural gas and LPG) and heating oil as depicted in Fig. 2. The significant share of emissions from fossil motor fuels in the base year 2018 highlights the critical importance of implementing effective mitigation strategies in the transport sector as elaborated later by the development of the CET strategy of Fundão.

4.3.2 Energy Supply of Fundão in the Base Year 2018

Fundão hosts several renewable energy power plants, with the largest being a forest biomass thermoelectric plant, boasting an installed capacity of 15 MW (Power Technology, 2024). This plant generates around 120 GWh of electricity, with a capacity factor of approximately 0.91. In addition, the municipality has 2.38 MWp of installed PV capacity (Observatório Fotovoltaico, 2023). According to GEM (Global solar power tracker, 2023), an additional 110 MW of solar PV is currently under construction. Fundão does not have a district heating network, and all households rely on individual heating systems powered by either fossil fuels or biomass.

4.4 Scenario Development

Following the steps elaborated above in the methodology section the development of CET strategy starts with the modelling of final energy demand which has been conducted using the bottom-up model MAED-City (Hainoun and Loibl, 2022) that constitues a module within the HISTEP framework. The first step dealt with the reconstruction of the base year 2018 to clibrate the relation between sectoral end-use energy consumption and the demographic, socio-economic and technological determinants controlling the useful and final energy demand. Starting from the calibrated base year the future development scenarios are constructed following the expected long-term development of demographic, socio-economic and technological drivers up to 2050.

The expected future trends for these drivers are exogenously introduced based on official references (e.g. city future development strategy and plans, local and nation energy and climate goals), stakeholder workshops, citizen survey, bilateral communications with the city stakeholder and expert judgements. Each scenario starts with a storyline describing the future vision of the perceived development path.

The key aspect in the scenario development is to ensure internal consistency among the different assumptions of the key drivers. Considering that the resulting future energy demand is just a reflection of these assumptions. Two development scenarios have been considered – BAU and CET scenario – describing two pathways of the Fundão's future socio-economic and technological development over the period 2018-2050.

The scenario results of MAED-City are always of the conditional type to project a possible future development trajectory allowing for analyzing the impact of different socio-economic development policies of the city, e.g., different economic growth in industry and service activities, changes in the lifestyle of society like individual car vs. public transport, Impact of technological development reflected in new market penetration rates and related equipment efficiency, new policy targets of clean energy transition. This contribution focuses on the development of BAU scenario.

4.4.1 Development of BAU scenario

The BAU scenario follows historical trends and enacted policy measures characterised by low moderate socio-economic and technological changes and limited decarbonisation measures concerning energy savings and efficiency improvements, electrification, digitalization, and the transition to clean fuels across all consumption sectors. BAU scenario serves as a benchmark to assess the effectiveness of the forthcoming CET scenario, which aims to demonstrate a decarbonization pathway toward a climate-neutral Fundão by 2050.

Fig. 4 represents the resulting development in the BAU secenario of the final energy demand by fuel and sector for the municiplality of Fundão. The total demand will grow by an average annual rate of 0.01% from 318.8 GWh in 2018 to 320.0 GWh in 2050. The consumption of biomass (firewood) recorded the largest

annual increase with 0.71% p.a. followed by biofuel (gasoues, liquid, solid- e.g. wood chips) with 0.43% p.a. The final energy demand will be mainly dominated by motor fuel whose share in final energy consumption will slightly decrease from 47% (2018) to 43% by 2050, followed by electricity that will increase from 30% (2018) to 34% by 2050, and fosill fuel that will decrease from 14% (2018) to 12% by 2050. The results illustrate the trend development of limited penetration of energy efficiency measures and clean fuel usage. This effect is especially pronounced in the building sectors (service and household sector) showing limited switch from fossil fuel to renewable energy sources or showing less energy efficiency measures as set in the CET scenario. The result is that the final energy demand of the household sector increases from 83.1 GWh/a (2018) to 87.6 GWh/a (2050) and of the service sector from 56.4 GWh/a (2018) to 59.5 GWh/a (2050), which are the dominating sectors of the total energy demand of Fundão by 2050. The increase in final energy demand in the building sectors is due on the one hand to the increase in dwelling sizes and heated areas of the different housing types and on the other hand to the use of vacant dwellings. The building sectors (household and service) have in 2050 a share of 46%, followed by the passenger transportation sector with 23% and the freight transportation sector with 14% of the total final energy demand as illustrated in Fig. 4. The corresponding final annual energy demand per capita shows an increase from 11.9 to 14.4 MWh/cap.

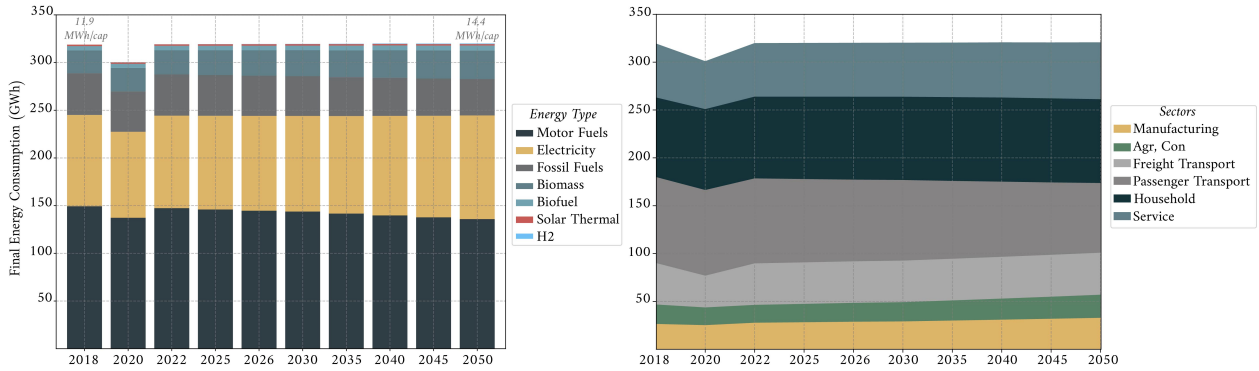

Fig. 4: Fundão's final energy demand projection by fuel type (left) and by sector (right) for the BAU Scenario.

Following the projected final energy demand by sector of BAU the development of energy-related CO_2 emissions within the city boundaries has been calculated as shown in Fig. 5. The results depict the dominance of motor fuel accounting for 80.2% in 2018 and increased to 82.2% in 2050. This trend is primarily driven by fossil fuel consumption in the transportation sector, as well as in agriculture and construction. This illustrates, that to reach climate neutrality by 2050, the municiplaity of Fundão should implement effective decarbonistaion measures in the transportation sector. Strategies include transitioning from fossil-fueled vehicles to EV, promoting a shift from individual to public transportation, and encouraging active modes of transport such as biking and walking within the city.

Furthermore, Fig. 5 highlights that natural gas is predominantly used in the manufacturing sector (52% of total gas consumption), followed by households (24%) and the service sector (23%). Its extensive use in Fundão presents a significant opportunity for decarbonization through the adoption of renewable energy sources and electrification measures. Additionally, heating oil is expected to be phased out in Fundão's BAU scenario by 2040.

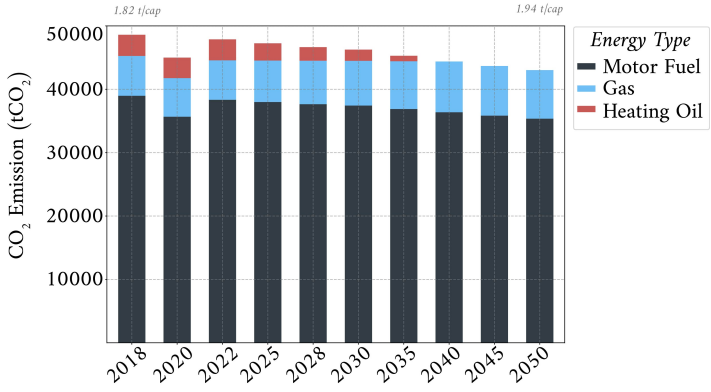

Fig. 5. Projection of the CO_2 emissions for the municipality of Fundão until 2050 (BAU scenario).

The total CO_2 emissions in Fundão decrease by -0.38% p.a. from 48.6 kt CO_2 in the base year 2018 to 43.0 kt CO_2 by 2050. Due to the expected population decline in Fundão of around -0.57% per year from 2018 to 2050, the CO_2 emissions per capita will increase from 1.82 to 1.94 t CO_2 per capita.

4.4.2 Development of Clean Energy Transition scenario (CETS)

The CETS aligns with Fundão's energy and climate goals and is beeing developed based on the results of BAU employing significant enhancements in energy efficiency, electrification of end-uses and a shift to clean fuels across all sectors beside increasing the share of local RES to decarbonize power and heat supply. As a result, significant shifts will occur in city's final energy demand and supply structure, the technological landscape of energy production and consumption, and the changes in related socio-economic and technological determinants. Fig. 3 illustrates the key decarbonisation drivers for developing the CET scenarios.

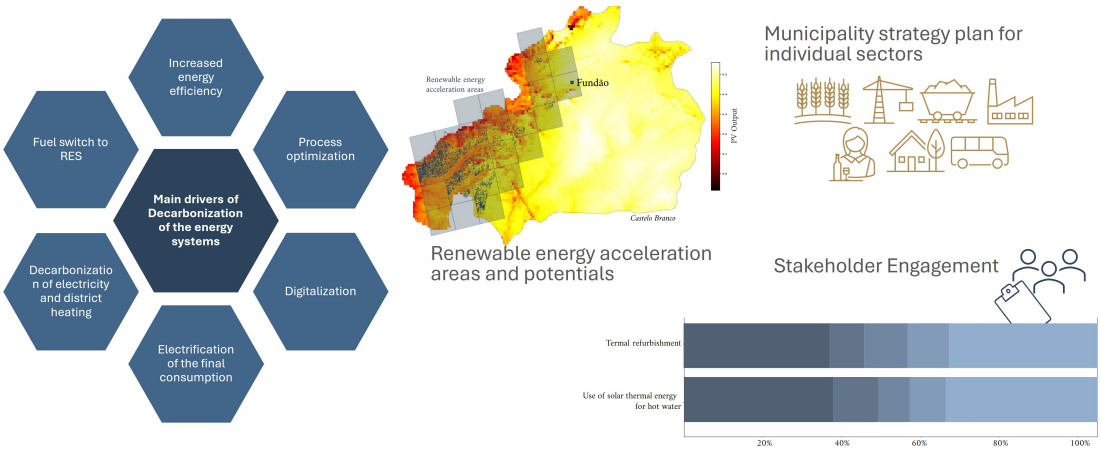

Fig. 3: Framework for Modeling CET scenarios in cities.

Decarbonization across all sectors relies on reducing energy demand, improving efficiency, and integrating renewable energy sources. In the building sector, measures such as thermal insulation, high-performance glazing, energy-efficient appliances, and advanced HVAC systems significantly lower heating and cooling demand, while refurbishment minimizes energy losses. Industrial decarbonization focuses on process optimization and waste heat recovery through technologies like heat exchangers and combined heat and power systems, which enhance energy utilization and reduce emissions. Digitalization plays a key role in improving energy efficiency, with smart meters, AI-driven management, and automated control systems enabling real-time energy optimization and grid stability. The electrification of transport, heating, and cooking – through the adoption of electric vehicles, heat pumps, and induction-based systems – reduces reliance on fossil fuels and shifts energy demand towards renewables. Additionally, expanding district heating networks and increasing the share of renewable energy sources such as solar, wind, geothermal, and biomass further supports the transition to a low-carbon energy system.

To effectively model clean energy transition scenarios, it is essential to assess the spatial and technical potential for renewable energy deployment while aligning sectoral decarbonization strategies with urban planning objectives. Additionally, municipalities must align their strategic plans with the unique needs of different sectors, since each sector has different energy demands, and targeted approaches are needed to decarbonize them.

Equally important is engaging stakeholders in the process. By involving local businesses, communities, and policymakers through surveys and consultations, citizens willingness to invest in clean energy strategies and determine what percentage of them is likely to adopt these solutions can be gauged. This input will provide valuable insights into the practical feasibility and acceptance of proposed measures.

4.5 Citizen Engagement

The clean energy transition are not just technical challenges, they are social ones. A key aspect of the project implementation is strong stakeholder engagement, ensuring the active involvement of key actors in the pilot cities. This facilitates collaboration with local stakeholders who contribute to the development of CET strategies, monitor results, and support the creation of realistic action plans.

To create truly sustainable and livable cities, we must move beyond top-down planning and embrace co-creation, where citizens actively shape the future of their communities. People are not just end-users of policies; they hold valuable local knowledge, and the power to drive change. When citizens are engaged, solutions become more inclusive, effective, and widely accepted, reducing resistance and fostering long-term commitment.

4.5.1 Citizens Survey

This study presents the findings of a citizen survey conducted to assess public perceptions, behaviors, and awareness of energy use and climate change, providing valuable insights into societal attitudes and potential policy implications. The questions asked in different domains cover couple of options for citizens to rank from "not relevant" to "very relevant".

The Fig. 6 illustrates citizens' opinions regarding the domains of buildings energy savings. Most participants ranked thermal insulation as the preferred measure for achieving heating energy savings. For reducing cooling energy demand, the most common response was the installation of a photovoltaic (PV) system to cover their own energy needs.

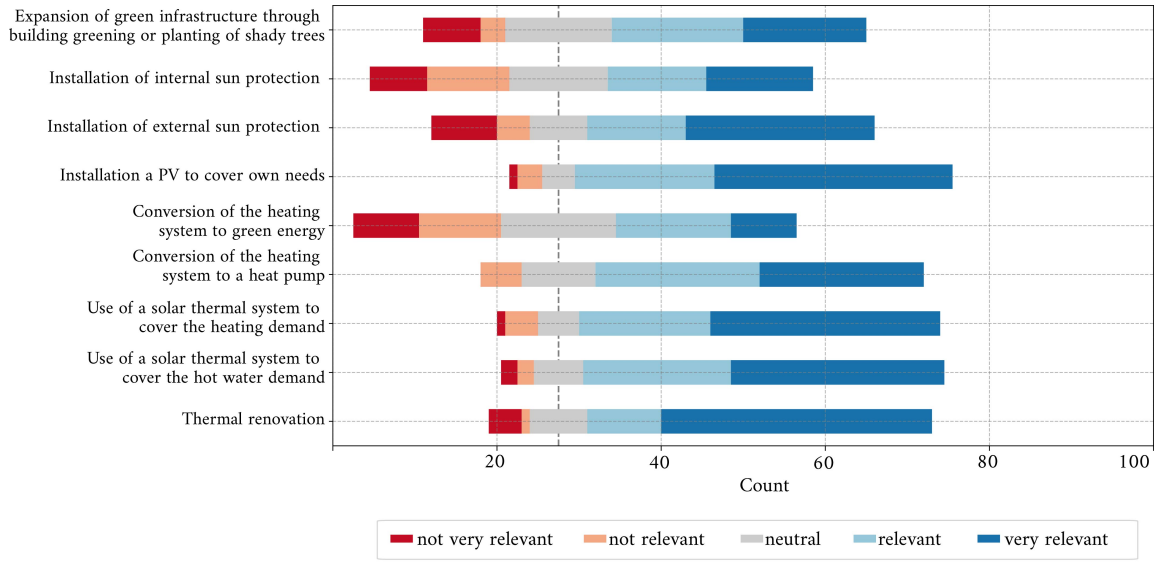

Fig. 6. Citizen ranking on "Which measures would you be most likely to implement to achieve energy savings (heating and cooling) in your own house/apartment?"

The most commonly owned vehicle among participants is a diesel car. In contrast, electric vehicles (EVs) are not prevalent within the surveyed group. The Fig. 7 presents citizens' views on the relevance of mobility. The most participants indicated that the expansion and promotion of public transportation is the most critical area for the improvement.

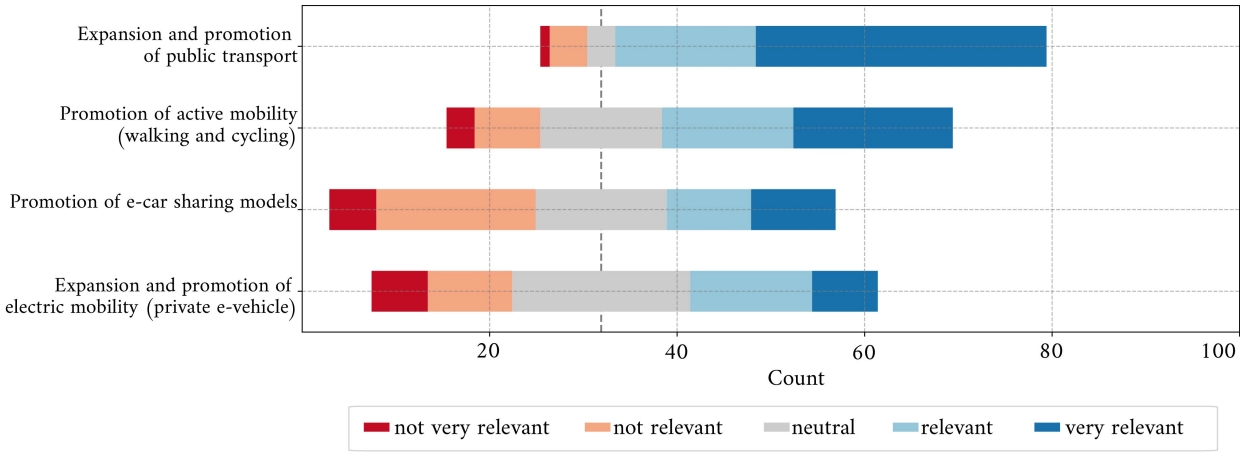

Fig. 7. Citizen ranking on "Where is the greatest need for action to achieve the climate goals of your municipality concerning mobility?".

The Fig. 8 illustrates citizens' opinions on achieving climate goals of municipality. Most of the participant find the consumption of local goods are in greatest need. Walking and cycling follows this.

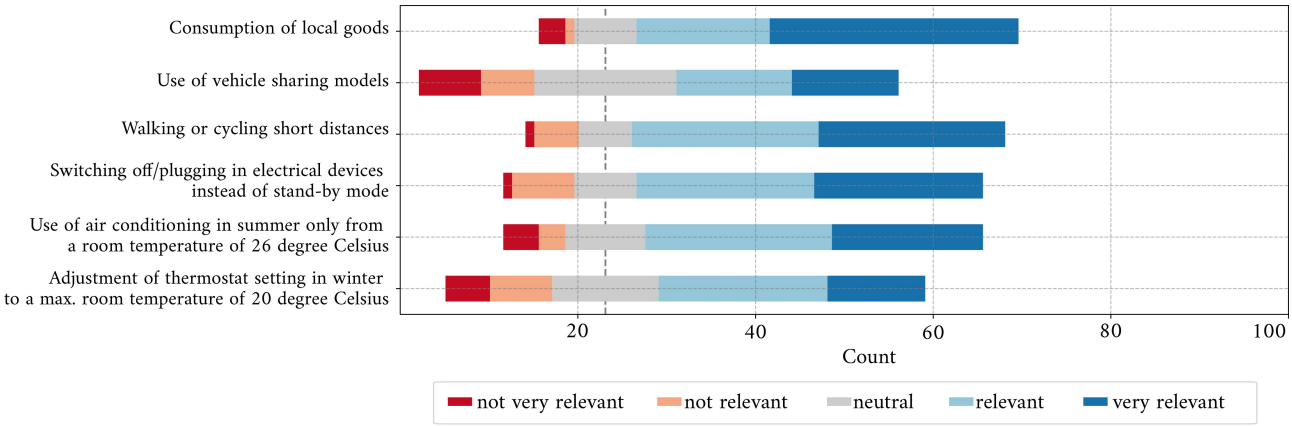

Fig. 8. Citizen ranking on "Where is the greatest need for action to achieve the climate goals of your municipality/city?"

4.5.2 Workshop2 – Ranking the importance of transformation sectors

To collaboratively establish measurable CET targets for the city, a matrix outlining the transformation sectors (agriculture, buildings, cross-sectors, industry/service, and mobility) and the corresponding measures (energy efficiency, fuel switch, socio-economic, and other measures) is generated to rank the importance of these topics for 2030. Fig. 9 displays the heatmap of the result from the ranking processes. According to the citizens the most important measures within the cities are i) fuel switch in the buildings, ii) other measures in the cross sectors, ii) socio-economic measures in industry/service sector.

The lowest-ranked measures are those where development relies heavily on technology, leaving citizens with little influence. As a result, they did not prioritize these measures in their votes. For example, in the mobility sector, energy efficiency received low rankings because citizens have limited control over it, lack awareness, and do not fully understand its impact. Similarly, in the agriculture sector, switching fuel sources was ranked low for the same reasons.

The highest-ranked measures are those where citizens can have a direct influence. For example, in the building sector, fuel switching is a priority, with many new buildings opting for solar thermal water heaters. In the industrial sector, socio-economic measures, such as the expansion of industrial zones to support business growth, ranked highly. Cross-sectoral factors, such as population decline due to an aging population, were also considered significant.

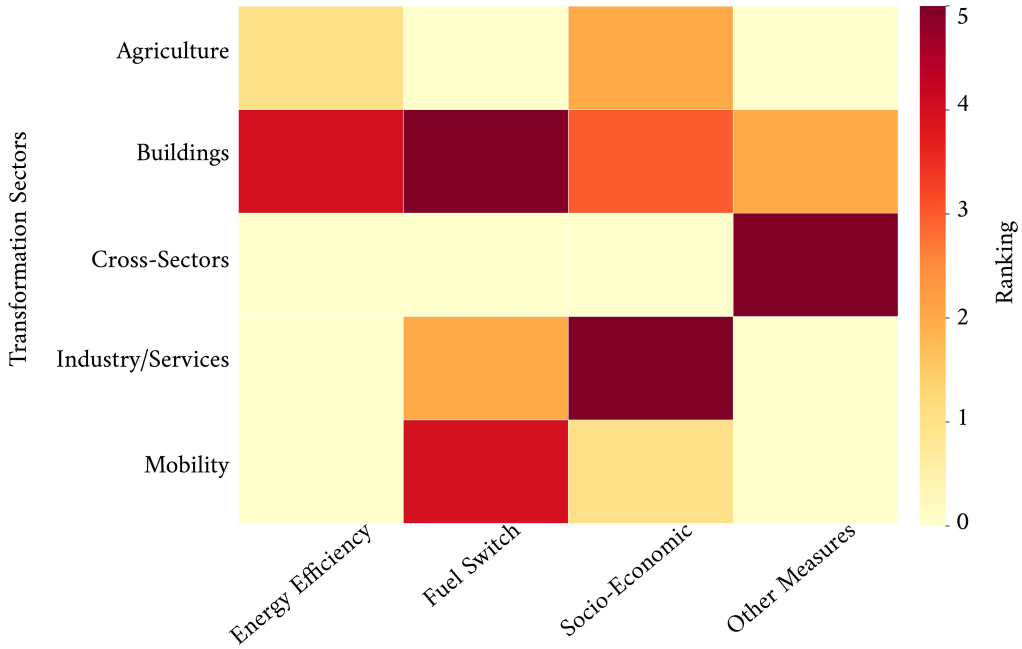

Fig. 9. Citizen workshop results for defining importance of the measures in transformation sectors for 2030.

5 CONCLUSION

The Plenty-Life project demonstrates a comprehensive approach to supporting SMCTs in delivering their clean energy transitions strategies. By integrating integrated urban energy modeling, stakeholder participation, and capacity-building programme, the project aims to empower local authorities to formulate tailored, long-term decarbonization strategies. The case study of Fundão serves as the first example of the framework's practical implementation, addressing critical challenges such as demographic shifts, reliance on fossil fuels, and sectoral inefficiencies in energy consumption.

Key findings of BAU scenario illustrate the limited impact of the embloyed measures concerning energy savings and efficiency improvements, electrification and the transition to clean fuels across all consumption sectors. However, they indicate the high decarbonisation potential, particularly in the transportation and building sectors. Such measures will be realised in the ambitious CETS which is driven be effective decarbonisation measures in all sectors. However, achieving the CET traget will require high investments in infrastructure, intensive deployment of renewable energy sources, and enhanced policy coordination at both municipal and national levels.

Stakeholder involvement and citizen engagement, demonstrated through workshops and surveys, have proven essential for ensuring that energy strategies align with local priorities and are socially accepted. While citizen participation in the development of clean energy transition scenarios provided valuable insights, it also underscored the limitations of relying solely on public input. Effective scenario planning requires a balanced approach that combines citizen perspectives with expert knowledge, socio-economic viability, technological feasibility, and policy frameworks. To strengthen this process, the project aims to actively involve a diverse range of stakeholders, ensuring broader awareness, engagement, and more comprehensive clean energy transition strategies. However, significant challenges remain. Limited funding, ristricted data accessibility, and technological barriers may hinder the implementation of the delivered strategies and their replication in other cities. To address these issues, further research is needed to refine energy planning models, explore innovative funding mechanisms, and assess the long-term impacts of policy interventions.

Overall, the Plenty-Life project underscores the importance of integrated planning frameworks in achieving climate-neutral cities. By fostering collaboration among stakeholders and leveraging data-driven insights, the project provides a replicable model for sustainable urban transformation across Europe. The next phase will focus on finalising the CET strategies for the pilot cities, disseminating best practices and supporting follower cities in implementing tailored strategies for a cleaner, more resilient future.

6 ACKNOWLEDGEMENT

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reviewed paper

From Metropolitan POPS to Medium City Social Spaces: Adapting Public-Private Collaboration for Urban Development

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1 ABSTRACT

Privately owned public spaces (POPS) have emerged as an incentive-based tool for creating and managing public spaces in high-density cities through private developments, facing both criticism regarding their inclusivity and recent adaptations in European cities. This paper examines the translation of public-private collaboration principles for space development and management to medium-sized cities, where traditional density-based incentives and agreements are not applicable. Unlike metropolitan areas where POPS emerged from high land values, shortage of public land for new public spaces, and established regulatory systems, medium-sized cities present a fundamentally different context: higher availability of undeveloped land at lower market values but limited resources. This contextual shift requires a systematic transformation of public-private collaboration approaches in the provision and management of public spaces and amenities, particularly in ensuring these spaces remain truly public, accessible, and inclusive for all user groups despite private involvement.

Through a comparative analysis of public-private collaboration models, this study evaluates the current practices in the Netherlands and their adaptation potential for medium-sized cities, focusing specifically on mechanisms ensuring public accessibility and social inclusion. The paper advances public space governance discourse by examining implementation phases from planning to management and analysing varying scales of private involvement from temporary to permanent arrangements, maintaining public access and social equity. It develops conceptual frameworks for governance model based on different POPSs governance models that align with medium-sized cities' governance capacities while prioritizing inclusive design and management practices. We identify valuable lessons from Dutch experiences that can inform similar practices in other contexts. This research contributes to urban planning and governance in several ways; it proposes context-sensitive approaches that balance public benefit with private interests in private developments. Second, it provides strategies to ensure the creation of inclusive and accessible social spaces that serve diverse community needs in medium-sized urban developments.

Keywords: urban governance, public space management, public-private collaboration, Privately Owned Public Spaces (POPS), social inclusion

2 INTRODUCTION

The provision of public spaces through private sector involvement has emerged as a significant urban development strategy over the past half-century, currently manifesting itself in the global trend of private sector-led urban development (Heurkens, 2012). Privately Owned Public Spaces (POPS) represent a specific model of this involvement, emerging initially in high-density metropolitan areas as an incentive-based tool for creating and managing public spaces through private developments and investment. While POPS have faced both criticism and acclaim regarding their effectiveness and inclusivity in metropolitan contexts, their potential adaptation for medium-sized cities remains largely unexplored. This paper examines how the principles of POPS might be translated for medium-sized cities, where traditional density-based incentives and metropolitan-scale agreements are not applicable. The research addresses a crucial gap in urban development literature and practice. Unlike metropolitan areas where POPS emerged from high land values, shortage of public land, and established regulatory systems, medium-sized cities present a fundamentally different context: higher availability of undeveloped land at lower market values but limited resources for public space development and maintenance. This contextual shift requires a systematic transformation in how we conceptualize private sector involvement in public space provision.

The conceptualization of medium-sized cities has evolved beyond simple population metrics to encompass functional characteristics and regional roles. While population thresholds vary across contexts, with ranges from 50,000 to 500,000 inhabitants commonly cited (Bell & Jayne, 2009; ESPON, 2014), the defining

characteristics of these cities extend far beyond size alone. As Kunzmann (2010) articulates, medium-sized cities are distinguished by their distinct economic, social, and cultural functions within regional urban systems, typically serving as crucial intermediaries between metropolitan regions and rural hinterlands. Several key perspectives enrich the theoretical understanding of private sector involvement in public space provision. Webster's (2007) property rights theory helps explain why traditional POPS incentives that work in metropolitan areas may fail in medium-sized cities. The lower land values and different market dynamics mean that density bonuses alone may not provide sufficient motivation for private sector involvement. Furthermore, Mitchell (2003) and Harvey's (2008) work on spatial justice becomes particularly relevant when considering how to ensure POPS in medium-sized cities remain truly public and accessible.

Servillo et al. (2017) observe that medium-sized cities face what they term a "governance gap" – they lack both the market conditions that make metropolitan POPS models effective and the resources to maintain purely public solutions. This paradox has led to increasing interest in alternative models for public space provision that could work in medium-sized urban contexts. The concept of "territorial capital," introduced by Kunzmann (2010), provides valuable insights into how medium-sized cities might approach public space provision differently. These cities possess distinct advantages in terms of social capital, local networks, and community cohesion that could inform new approaches to private sector involvement in public space provision. As Bell and Jayne (2009) note, medium-sized cities maintain stronger connections to local traditions and community values than their larger metropolitan counterparts. Medium-sized cities face several distinct challenges and opportunities in public space provision:

- Resource Constraints: As Burayidi (2001) notes, while these cities possess "determination and spirit," they often lack systematic approaches and resources for development planning. Kunzmann (2010) further emphasizes how these cities operate with more limited institutional capacity and fewer specialized departments than their metropolitan counterparts.
- Market Dynamics: Kayden's (2000) analysis demonstrates how POPS emerged in response to high land values in dense urban environments. However, as Servillo et al. (2017) observe, medium-sized cities lack these market conditions, making traditional density bonus incentives less effective as tools for generating public spaces through private development.
- Governance Capacity: Bell and Jayne (2009) identify what they term a "significant blind spot" in understanding how governance mechanisms function at different urban scales, with medium-sized cities requiring distinct approaches that match their institutional capabilities.

These cities also present unique opportunities, as identified in the literature:

- Community Networks: Kunzmann (2010) emphasizes how medium-sized cities benefit from what he terms "Übersichtlichkeit" – a transparency and legibility that facilitates social interaction and community engagement.
- Stakeholder Relations: Robertson (2001) demonstrates how medium-sized cities maintain closer connections between stakeholders, with public spaces that are "closely linked to nearby residential neighbourhoods" and feature more independent rather than corporate presence.
- Context-Sensitive Solutions: As Paradis (2000) argues, these cities can maintain what he terms "conceptual small towns" – places where social relationships and community identity are actively maintained through the design and management of public spaces.
- Adaptive Governance: Folke et al. (2005) and Healey (2015) suggest that medium-sized cities can develop more flexible management approaches that accommodate limited resources while maintaining public benefit.

The distinct characteristics of medium-sized cities necessitate a systematic reconsideration of how private sector involvement in public space provision might work. This requires moving beyond simple adaptation of metropolitan POPS models to develop context-appropriate frameworks that reflect local conditions, capacities, and needs. To address this need, we propose a comprehensive analytical framework encompassing 15 key dimensions across planning, implementation, management, and supervision phases. This framework, detailed in the following section, provides a systematic approach to understanding and developing POPS models suitable for medium-sized cities.

2.1 Research Objectives and Questions

This research examines how lessons learned from Privately Owned Public Spaces (POPS) in metropolitan areas can be adapted for medium-sized cities, where traditional density-based incentives may not be applicable. The study specifically focuses on understanding the mechanisms of private sector involvement in public space provision and how these might be reconceptualized for different urban contexts. The research is guided by four interconnected research questions that progressively build understanding from existing POPS implementations toward new models for medium-sized cities:

(1) What motivates and enables private sector involvement in public space provision? This question examines the fundamental drivers behind private sector participation, exploring what unique capabilities private actors bring to public space provision.

(2) What regulatory powers and development rights do public authorities trade to enable private provision of public spaces? This question investigates the spectrum of public sector assets that can be leveraged for public space provision.

(3) What challenges and opportunities emerge from these POPS agreements and governance modelsand opportunitiesand opportunities? Building on existing implementations, this question examines both inherent tensions and practical challenges in private provision of public spaces.

(4) How can effective models be developed for medium-sized cities? The final question focuses on adaptation and innovation, examining how POPS principles can be modified for contexts where traditional density bonus incentives may not be viable.

3 ANALYTICAL FRAMEWORK

The governance of privately owned public spaces necessitates a systematic framework addressing four distinct but interconnected phases that shape their creation and operation. This phased approach emerged from decades of POPS implementation across different urban contexts, reflecting the complex nature of public-private arrangements in urban space provision. The initial policy and planning phase proves fundamental as POPS emerged through specific regulatory mechanisms offering development incentives in exchange for public benefits, first demonstrated in New York's 1961 zoning resolution and later adapted across different cities (Kayden, 2000; Huang and Franck, 2022). The implementation phase became essential as early experiences revealed how translating policy into physical space required careful consideration of design standards and approval processes to ensure meaningful public benefits (Loukaitou-Sideris and Banerjee, 1993; Németh and Schmidt, 2011). The management phase emerged as a critical consideration as studies demonstrated how operational practices significantly impact public accessibility and use patterns, requiring frameworks that balance private control with public access rights (Nemeth, 2009; Leclercq et al., 2020; Manifesty et al., 2022). The supervision phase developed from the recognition that maintaining public benefits over time requires ongoing oversight and accountability, particularly as these spaces evolved from simple plazas to complex urban amenities (Carmona, 2021; Lee and Scholten, 2022). Together, these phases enable comprehensive analysis of how cities structure private sector involvement in public space provision, from initial policy frameworks through long-term operation and oversight. This understanding proves particularly valuable for medium-sized cities seeking to develop context-appropriate approaches to POPS implementation.

Phase A. Planning and Policy Criteria

(1) Policy objectives: What drives cities to involve the private sector in public space provision? It addresses the fundamental cities' reasons and expected outcomes for private sector involvement. Cities' objectives have evolved from a lack of public spaces to complex goals addressing public realm quality and social inclusion.

(2) Urban planning context: Which part of cities and developments are POPS implemented and incentivized as a solution? This ranges from high-density commercial districts where POPS emerged as vertical public spaces to mixed-use environments where they form part of broader urban regeneration strategies.

(3) Planning incentive mechanisms: What encouragements do cities offer to private developers? It represents the core tools for encouraging private sector involvement. While floor area bonuses dominated early POPS development in metropolitan areas, diverse incentive structures have evolved to match different market conditions and development patterns.

(4) Trade-off structures: What rights and responsibilities are exchanged between public and private sectors? It defines the specific agreement structure between public benefits and private rights and responsibilities.

Phase B. Implementation Phase Criteria

(5) Regulatory control mechanisms: How do cities ensure enforcement of POPS agreements? This criterion examines legal tools and compliance frameworks that give public authorities control over private development.

(6) Space type: What types of spaces and amenities must private developers provide? Defines physical requirements for POPS, from outdoor plazas to indoor atriums, and required amenities.

(7) Design and quality standards: What design guidelines and quality benchmarks must POPS meet? It explores specific design criteria and quality standards the city officials provide for public space provision.

(8) Approval process: How are POPS proposals evaluated and approved? It questions the process for reviewing and approving private proposals, from standard applications to case-by-case negotiations.

Phase C. Management Phase Criteria

(9) Management Framework: What are the functional standards and programming obligations for POPS operation? It addresses specific operational duties, programming requirements, and service standards that ensure spaces function effectively for public use.

(10) Access requirements: When and how must POPS be accessible to the public? It defines temporal and physical access conditions, including operating hours, gates, and entry points.

(11) Control Rights: Who has authority over space management and security measures? It examines the specific allocation of management powers between public and private entities, including security arrangements and enforcement rights.

(12) Usage regulation frameworks for users: What specific activities and behaviors are permitted or prohibited? It addresses the explicit rules governing public use, focusing on allowed activities and behavioral expectations.

(13) Maintenance requirements What physical maintenance standards must be met? It focuses specifically on upkeep obligations, including cleaning, repairs, and maintaining physical condition standards.

Phase D. Supervision Phase Criteria

(14) Supervision framework: How is compliance with POPS agreements verified and enforced? It examines specific methods for monitoring operations, inspecting conditions, and enforcing compliance.

(15) Agreement Duration: What are POPS arrangements' temporal conditions and modification provisions? It addresses the timeframes of agreements and processes for reviewing or modifying terms over time.

This framework systematically evaluates POPS implementation across different contexts while recognizing local variations. The analysis of these criteria reveals how cities have adapted their approaches to match local conditions, providing valuable insights for developing context-appropriate models. This is particularly relevant for medium-sized cities seeking to develop POPS frameworks that reflect their specific challenges and opportunities.

4 THE EVOLUTION AND IMPLEMENTATION OF POPS ACROSS URBAN CONTEXTS

The implementation policies of POPS vary significantly across different urban contexts, reflecting distinct regulatory traditions, market conditions, and governance approaches. Since their emergence in 1960s New York, POPS has evolved from bonus plaza mechanisms to complex urban planning tools adapted to diverse cities worldwide. This comparative analysis serves two essential purposes in understanding POPS adaptation for medium-sized cities. First, it provides empirical evidence of how the analytical framework's implementation phases manifest in practice, revealing the diverse ways cities have operationalized public-private collaboration in public space provision. Second, by examining various governance approaches across different urban contexts, it helps identify which elements of POPS frameworks might be most applicable to medium-sized cities' specific characteristics and institutional capacities. This analysis examines POPS implementation based on the proposed analytical framework across multiple cities, from North American origins to European adaptations and Asian models, revealing how different urban contexts have shaped these

spaces' planning, implementation, management, and supervision. The examination of POPS policies and practices across these contexts demonstrates a progression from standardized incentive-based approaches to more mixed models. Drawing from examples in cities including New York, London, Hong Kong, Seoul, and Berlin, this analysis reveals how POPS frameworks have been adapted to address different urban challenges while maintaining their role in public space provision.

4.1 Planning and Policy Framework Elements in POPS Practices

The policy objectives driving POPS implementation reflect cities' evolving understanding of public space provision through private development. Early objectives focused primarily on quantitative space provision in dense urban areas, exemplified by New York's 1961 zoning resolution (Kayden, 2000). This narrow focus has expanded to encompass broader urban goals across different contexts. Asian cities demonstrate particularly complex objectives: Hong Kong combines public space provision with pedestrian connectivity and urban ventilation, while Japanese cities integrate disaster preparedness with public space networks (Dimmer, 2012; Wu et al., 2022). European objectives emphasize social cohesion and urban integration, with German cities focusing on democratic access and community benefits, whereas UK objectives balance urban regeneration with public realm quality (Carmona, 2021). The urban and morphological context fundamentally shapes POPS implementation approaches. High-density Asian contexts have generated sophisticated three-dimensional solutions. Hong Kong's POPS form integral parts of multi-level pedestrian networks, responding to extreme density and topographical constraints. Seoul's system targets commercial districts with buildings over 5000m², creating a hierarchical implementation framework (Jian et al., 2021). European contexts demonstrate more varied applications: UK POPS span from historic centers to regeneration zones, while German implementations emphasize integration with existing urban fabric and historic districts. Dutch approaches specifically target mixed-use areas, focusing on ground-level activation and public realm continuity (Lee and Scholten, 2022).

Regarding planning incentive mechanisms, Cities have developed diverse approaches to incentivizing private sector involvement, moving beyond simple floor area bonuses. Hong Kong's system offers the most generous incentives, with up to 5x floor area bonuses for ground-level provision, complemented by plot ratio exemptions and site coverage relaxations. This contrasts with European approaches, where German cities have abandoned standardized bonus systems in favor of negotiated agreements through building permits and urban development contracts. UK systems combine development rights with long-term management arrangements, while Dutch models emphasize operational flexibility over density bonuses and also consider the protection of historic districts(Leclercq et al., 2020). The effectiveness of different incentive structures varies significantly: research indicates that larger bonuses don't necessarily produce better spaces, with Hong Kong's generous system facing similar quality challenges to more modest incentive structures (Rossini and Yiu, 2020). The same observation can be seen in terms of trade-off structure. The exchange of rights and responsibilities between the public and private sectors reveals distinct approaches to balancing interests. North American models establish permanent requirements through zoning, trading development rights for public space provision and maintenance. Asian cities have developed more complex trade-off structures: Hong Kong combines multiple incentive types with detailed management requirements (Xing 2013). Japanese systems balance public access rights with private operational flexibility. On the other hand, UK systems establish long-term private control through lease arrangements (99-250 years) (Minton, 2006; De Magalhaes and Freire Trigo, 2017). European approaches show greater variation: German cities maintain stronger public oversight through urban development contracts. Dutch models emphasize shared management responsibilities over property rights transfers, reflecting their focus on operational partnerships (Langstraat & Van Melik 2013). The effectiveness of these trade-off structures appears less dependent on the specific rights exchanged than on the clarity of agreements and quality of oversight mechanisms (Dunlop et al. 2023).

4.2 Implementation Frameworks and Mechanisms in POPS Practices

The translation of POPS policies into physical space reveals distinct regulatory and design approaches across different urban contexts. Metropolitan areas that pioneered POPS have developed sophisticated regulatory control mechanisms over time. New York's implementation framework, combines zoning requirements with detailed design guidelines and legal agreements, creating a comprehensive system for ensuring public benefits. This model has influenced other North American cities, though studies reveal varying degrees of

success in maintaining consistent quality standards and public accessibility (Huang and Franck, 2022). Hong Kong employs a multi-departmental system involving Building Regulations Section 22 and Deed of Dedication agreements, reflecting complex urban integration needs (Yu, 2018). This complex regulatory framework responds to the challenges of integrating POPS into high-density, multi-level urban environments. Japanese implementations focus on minimum design standards emphasizing size requirements (minimum 45m²), layout, and connectivity to sidewalks, prioritizing functional aspects like pedestrian circulation and disaster evacuation over social space considerations (Dimmer, 2012). Seoul's system combines elements of both approaches, implementing detailed installation guidelines while maintaining strong district-level oversight (Lee 2022). European regulatory frameworks demonstrate greater emphasis on public sector control and context sensitivity. German cities use legally binding land-use plans and urban development contracts that prioritize integration with surroundings and public accessibility. UK implementations combine planning agreements with property rights and legal covenants, creating comprehensive but complex enforcement frameworks (Carmona, 2021; Lee and Scholten, 2022).

The evolution of POPS typologies reflects increasing sophistication and diversity of form and functions in public space provision. Early implementations in US cities focused primarily on ground-level indoor and/or outdoor plazas and through block connections, mostly in office and commercial tower developments facilitating stationary activities and pedestrian movements. Hong Kong's system includes street-level spaces, elevated walkways, indoor atriums, and rooftop gardens, creating three-dimensional public networks. Japanese POPSs emphasize connectivity to sidewalks and disaster evacuation functions in high-rise buildings. Seoul POPS covers diverse ranges, including plazas, sidewalk widening, through-block connections, and also facilitating connections to transportation facilities. UK systems include open spaces, facilities through-site links, tailored to local needs in mixed-used and large-scale commercial and residential developments. Design requirements range from prescriptive guidelines to performance-based standards. North American cities typically employ detailed design guidelines specifying amenities and accessibility requirements. Asian approaches vary: Seoul's POPS Installation Guidelines provide specific requirements. However, other cities like Hong Kong focus more on circulation and connectivity than on social space design, with no well-established design standards. European design requirements emphasize context-sensitive design. UK systems incorporate design codes and local character requirements, while German approaches focus on public accessibility and urban integration.

The approval process for POPS varies from standardized procedures to case-by-case negotiations. North American cities generally employ as-of-right zoning calculations combined with design review processes, providing clarity but potentially limiting innovation. Hong Kong's multi-stage approval system reflects the complexity of implementing POPS in dense urban environments, while European approaches often emphasize public consultation and democratic approval processes. German cities particularly demonstrate how approval processes can integrate POPS within broader urban development negotiations, allowing for more context-sensitive solutions (Lee and Scholten, 2022).

4.3 Management and Operational Frameworks in POPS Practices

Management practices significantly shape POPS functionality and accessibility. North American cities establish baseline operational requirements while granting management flexibility to private entities. Asian implementations show varied approaches: Hong Kong mandates basic maintenance with limited programming requirements, focusing on circulation and access control. Japanese systems emphasize efficient pedestrian flow and emergency evacuation functions. European models demonstrate greater emphasis on public benefit: German cities require public accessibility with limited restrictions. UK systems balance private management efficiency with public access rights (Németh and Schmidt, 2011).

Access requirements represent a critical aspect of POPS management, with significant variations across contexts. Most Asian implementations link access to building operating hours, reflecting their integration with commercial developments. Hong Kong's system varies requirements by space type, with some elements of the pedestrian network requiring 24/7 access while others follow building hours. Japanese POPS maintain a more basic "generally open to public" requirement, allowing night closure with approval, reflecting their dual role as public spaces and emergency evacuation areas (Dimmer, 2012). European examples generally favor more extensive public access, with UK and German systems often requiring 24/7 accessibility, though some allowances for nighttime closure exist.

Control rights and security arrangements demonstrate how different cities approach the "publicness paradox" in privately managed spaces. UK POPS often grant full private security and management rights within planning conditions, creating effectively self-regulated environments. This contrasts sharply with Dutch approaches, which maintain strong public sector control and limit private security powers. Asian implementations show interesting variations: Seoul grants significant management and security authority to building owners while maintaining public access rights, while Japanese systems focus primarily on maintaining pedestrian circulation and evacuation functions rather than broader public space management (Rossini and Yiu, 2020). Usage regulations and behavioral controls represent perhaps the most contentious aspect of POPS management. North American cities typically establish required permitted uses while limiting activity restrictions, aiming to protect public rights within privately managed spaces. Asian implementations often impose more explicit restrictions, with Hong Kong and Seoul both limiting social gatherings and recreational uses, focusing primarily on circulation functions. European approaches vary significantly: UK systems often employ property management rules controlling commercial activity and behavior, while German cities emphasize protecting public use rights while balancing private management needs (Leclercq and Pojani, 2023).

Maintenance requirements show more consistency across contexts, though with varying levels of specification and oversight. Though standards and enforcement mechanisms differ, most systems place full maintenance responsibility on private owners. UK and Australian implementations typically demand high maintenance standards tied to property management regimes. Asian cities often require annual maintenance reporting, while European continental approaches emphasize regular cleaning obligations under public oversight. The effectiveness of these requirements often depends more on enforcement mechanisms than on the specific standards themselves (Carmona, 2021).

4.4 Supervision and Long-term Oversight Frameworks

Regarding public sector supervision mechanisms, the approaches to oversight of the proper function of POPSs reveal fundamental differences in how cities conceptualize the relationship between public benefits and private management. North American cities, particularly New York, have developed systematic oversight through city planning departments, implementing regular compliance checks and public reporting requirements, for example, every 3 years in New York. However, studies reveal that even these well-established systems face challenges in maintaining consistent supervision. Kayden's (2000) study found that 41% of New York's POPS were non-compliant with public access requirements. Asian cities demonstrate varying approaches to the supervision of POPS, often reflecting broader governance traditions and resource constraints. For example, Hong Kong relies primarily on Buildings Department inspections supplemented by complaint-based supervision. Japanese literature mentions that cities face challenges in comprehensive monitoring due to limited manpower (Dimmer 2012; To 2018). Seoul's system emphasizes district government monitoring with regular inspections, usually every 2 years (Dunlop et al., 2023).

European oversight models show greater variation in approach and effectiveness. UK implementations typically combine planning enforcement with contract compliance and annual monitoring, reflecting their property-based control model (De Magalhaes and Frere Trigo, 2017). This system provides clear mechanisms for enforcement but can lead to what Carmona (2021) describes as "privatization concerns" due to reduced public control. These systems often achieve better public accountability but can face challenges in coordination and resource allocation (Dunlop et al., 2023). In German cities, regular supervision of the public sector over POPS functions is planned to happen through regular inspections of municipal monitoring through district offices. Also, other methods like public reporting requirements and Multi-stakeholder supervision are considered in the supervisory procedure (Dunlop et al., 2023).

Regarding agreement structures, UK implementations choose more long-term arrangements (99-250 years) tied to property rights, providing stability but potentially limiting flexibility. European systems often employ medium-term contracts allowing periodic review. North American and Asian implementations typically establish permanent requirements through zoning, though some cities have introduced modification provisions to address changing needs. Evidence suggests successful frameworks require both clear long-term commitments and mechanisms for adaptation (Leclercq and Pojani, 2023). These variations in supervision approaches demonstrate the complex challenge of ensuring long-term public benefits in privately managed spaces.

4.5 Synthesizing POPS Governance Models and Implications

The analysis of POPS implementation across different urban contexts reveals three categories of governance models shaped by legal traditions and urban development approaches. These models demonstrate how different cities have balanced private sector involvement with public benefit, leading to three primary governance approaches that have evolved through practical experience and policy refinement.

The Zoning-Based Incentive Model, initiated in New York and adopted across Asian cities, operates through pre-established regulatory frameworks and standardized bonus calculations within the city's zoning code. This model implements district-wide regulations that specify the required public space contributions in exchange for additional development rights, particularly in high-density commercial zones. The system uses standardized formulas to calculate public space requirements and development bonuses. The model typically includes specific design and operational requirements codified in zoning regulations, applying uniformly to all developments within designated zones. The zoning-based model creates a more standardized, predictable system for both developers and city officials. The evolution of New York and Japanese POPSs in downtown high-rises since the late 1960s demonstrates how initially quantity-focused systems often require subsequent quality-oriented reforms (Huang and Franck, 2022; Dimmer, 2012).

The Property-Based Control Model, exemplified by UK implementations, establishes long-term private sector involvement through negotiated planning agreements at various development scales. These developments occur both in individual projects and large-scale regeneration schemes, operating within the city's planning system but without standardized incentive formulas like the US model. The form and type of POPS contributions are negotiated between private developers and city officials through the planning process, responding to site-specific conditions and local planning objectives. This model is characterized by property-based management rights, typically secured through extended leasehold arrangements (99-250 years). Examples like Liverpool ONE (42.5 acres) and Canary Wharf demonstrate how private developments can incorporate publicly accessible spaces under private management control. The model operates through case-by-case planning negotiations rather than standardized district-wide or city-wide regulations. German cities approach POPS governance through urban development contracts and legally binding land-use plans, with public sector involvement maintained through planning requirements and oversight (Lee and Scholten, 2022). However, specific arrangements vary by city and project.

The Partnership-Based Model for POPS establishes shared governance arrangements through structured agreements between private owners, public authorities, and community stakeholders. Unlike the property-based model's emphasis on full private control or the zoning model's regulatory approach, this model creates institutional frameworks for ongoing collaboration in space governance. The approach typically involves formal partnership agreements that define shared responsibilities, decision-making processes, and accountability mechanisms, while maintaining private ownership. Examples from UK experiences show how this can work through fixed-term governance agreements alongside long-term ownership rights and defined roles for multiple stakeholders in space management. They also have structured oversight mechanisms, regular performance review processes and flexible adaptation of space uses and programs. This model differs from simple management contracts by embedding partnership principles into the fundamental governance structure of privately owned spaces, creating mechanisms for shared control while respecting property rights.

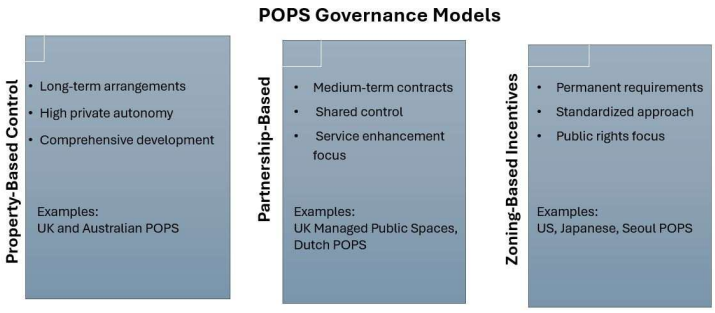

Fig. 1: POPS Governance Models. Source: authors

5 SYNTHESIS AND APPLICATION OF POPS EXPERIENCES TO MEDIUM-SIZED CITIES

This research presents a refined framework for public-private collaboration in medium-sized cities, addressing unique urban challenges through multifaceted public space provision across different implementation phases. It incorporates lessons from global POPS policies and localized urban planning nuances to create context-sensitive models catering to the distinct economic, cultural, and governance structures of medium-sized urban environments.

5.1 Planning and Policy Approach for Medium-Sized Cities

The Planning and Policy phase is crucial for setting the foundational strategies that will guide public-private collaboration in medium-sized cities. This phase integrates adaptive models that respond to less intense market dynamics and limited resource availability, prioritizing sustainable operations and community benefits. The policy objective of the involvement of the private sector in public space provision in midsize cities is proposed to adopt a hybrid model that combines the strengths of the Dutch partnership approach with the UK Business Improvement District (BID) framework. This recommended model is particularly suited to medium-sized cities with less critical density, allowing for more focus on balanced operations and community benefits. This approach supports the creation of partnerships involving local businesses and stakeholders in the planning process, ensuring that developments are not only economically viable but also cater to the community's needs. This aligns with the findings by Healey (2015), who emphasizes the importance of collaborative planning processes for medium-sized cities that engage multiple stakeholders to achieve sustainable urban development. Regarding the urban planning context, the framework proposes adopting the German rights-of-way approach combined with localized UK town center management principles for the urban planning context. This strategy emphasizes the need for broader urban integration rather than focusing solely on central business districts (CBDs), which suit medium-sized cities better where the urban fabric might be more spread out and heterogeneous. By adopting localized management strategies, cities have better opportunities to ensure that planning initiatives are more inclusive and reflect the diverse needs of different urban areas. This recommended method is supported by the work of Kunzmann (2010), who advocates for planning that respects local characteristics and enhances the functionality of all urban areas, not just the economic centers.

The proposed planning incentive mechanism combines operational cost-sharing, similar to the Dutch BIZ model, where businesses in a designated area collectively invest in local improvements. This approach moves away from reliance on floor area ratio (FAR) bonuses, which may not be effective in less dense urban settings of medium-sized cities. Operational cost-sharing allows for distributing maintenance and development costs among local businesses, promoting a vested interest in the area’s success. Lastly, the development of a trade-off structure can involve linking heritage conservation with improvements in the public realm, drawing on models from Australia and Europe. This approach aims to ensure that developments contribute positively to the public space while preserving cultural heritage, which is crucial for maintaining the unique identity of medium-sized cities. It considers sustainable operations over merely extracting development rights and stresses the importance of integrating heritage preservation with urban development to enhance the quality and resilience of public spaces.

5.2 Integrated Design Phase Approach for Medium-Sized Cities

The recommended design phase criteria for public-private collaboration in medium-sized cities address creating multifunctional, context-sensitive public spaces that balance commercial viability and public access. This approach ensures that urban areas effectively meet the diverse needs of their communities while honoring local characteristics and constraints. Multi-functional spaces are essential for maximizing land use in medium-sized cities. The literature of POPS recommended designs that accommodate a variety of activities, from leisure to cultural events, ensuring these areas are vibrant and utilized throughout different times of the day and year. The findings recommend space type requirements in medium-size cities that combine German mixed-use integration standards and UK retail core guidelines. Such variety promotes flexibility in space usage, allowing areas to serve multiple purposes – commercial, recreational, and cultural – thereby supporting a dynamic urban life. This approach addresses what is expressed earlier as the need for adaptable urban environments in medium-sized cities facing diverse developmental pressures (Servillo et al., 2017).

Incorporating context-sensitive design standards can help new developments resonate with the existing urban fabric, honoring the area's historical, cultural, and architectural elements. This approach is reflected in the design & quality standards criteria, which suggest adopting contextual standards alongside quality benchmarks. These standards help avoid prescriptive metropolitan design standards and ensure that new spaces blend seamlessly with their surroundings, enhancing the local character rather than diluting it. As Kunzmann (2010) noted, context-sensitive designs are essential for maintaining the 'Übersichtlichkeit' – the clarity and legibility that fosters community engagement and integration. So It is beneficial to design public spaces that are commercially viable for private sector yet accessible to all. POPSs literture shows commercial activities that complement public access, such as open cafés and retail spaces can enhance public enjoyment without imposing barriers, however overingfilling them may lead to café creep (Mohammadi 2021). The Regulatory Control Mechanism supports this balance by incorporating a simplified version of the Japanese district-level approach with UK management agreements, providing a regulatory framework that emphasizes quality and accessibility without burdening medium-sized cities with complex regulations. This balance reflects findings from Bell & Jayne (2009), who highlight the challenges medium-sized cities face in fostering economic growth while ensuring public space inclusivity.

Finally, the planning phase must be supported by an efficient and democratic approval process. The Approval Process in medium size cities can get insights from democratic review of private involvments in Dutch cities and simplified technical standards used in some asian cities like Hong Kong, ensures that public space projects are both high-quality match with private developments and also community-approved. This process helps maintain design standards while facilitating faster implementation, critical for adapting to the evolving needs of medium-sized cities without extensive bureaucratic delays.

5.3 Integrated Management Approach for Medium-Sized Cities

The management of public spaces in medium-sized cities benefits from balancing professional oversight with active community involvement. The analysis suggests integrating the operational efficiency of the UK BID framework with community-focused Japanese programming approaches. This integration enables efficient daily operations while ensuring spaces are programmed with activities meeting local interests and needs. Such hybrid models facilitate responsiveness to community feedback and changing usage patterns.

Access requirements analysis indicates potential benefits in combining public rights framework with European and UK's flexibility approaches used in large scale developments, allowing for varying access times and uses that reflect local community needs. The control rights framework benefits from integrating Dutch active public oversight principles with successful examples of UK private management capabilities. This balanced approach helps prevent over-commercialization while maintaining operational efficiency. Usage regulations appear most effective when encouraging community engagement while preventing conflicts by few private rules. Maintenance of public spaces must adhere to high standards to ensure safety, cleanliness, and functionality. Combining maintenance standards with community integration practices offers a model where maintenance tasks are performed efficiently while encouraging community involvement in minor upkeep, fostering a sense of ownership and stewardship among local residents.

5.4 Supervision Approach for Medium-Sized Cities

The supervision framework analysis reveals patterns in effective oversight mechanisms for medium-sized city contexts. Evidence from European engagement practices and Asian efficiency metrics suggests that multi-stakeholder monitoring systems can effectively balance oversight needs with resource constraints. The examination of agreement durations indicates that flexible term structures with regular review provisions, as demonstrated in UK and Dutch models, may better accommodate medium-sized cities' evolving needs while maintaining operational stability.

Table 1 synthesizes the findings from our analysis of POPS implementation across different urban contexts and presents a structured framework for their adaptation to medium-sized cities. The table organizes insights across the four implementation phases discussed in sections 5.1-5.4: planning and policy, implementation, management, and supervision. For each criterion within these phases, the table presents two complementary perspectives: 'Potential Adaptation' outlines specific recommendations for medium-sized cities based on our analysis of POPS practices across different urban contexts, while 'Key Literature Considerations' provides supporting evidence from existing research that validates these adaptations' relevance to medium-sized cities'

characteristics and capacities. This dual approach ensures that proposed adaptations are both grounded in successful POPS practices and responsive to the unique challenges and opportunities present in medium-sized urban contexts.

	Potential Adaptation for Medium Cities		Key Considerations from POPS Literature
A. Planning & Policy	Policy Objective	Integration of community value creation with market viability - Focus on sustainable operations and public benefit - Emphasis on local economic development alignment	Evidence from NYC/Hong Kong shows bonus models' ineffectiveness in lower density areas - Dutch partnership models demonstrate success in balanced development - UK town center approaches show effective community integration
	Urban Planning Context	Network-based integration rather than node-focused development - Multi-nodal development supporting diverse centers - Integration with existing public space systems	German rights-of-way integration demonstrates success in medium contexts - Japanese district approach shows effectiveness at local scale - UK town center management proves valuable for local adaptation
	Planning Incentive Mechanism	Operational cost-sharing frameworks - Tax increment financing for improvements - Public-private maintenance partnerships	Traditional FAR bonuses show limited effectiveness (NYC/Tokyo) - Melbourne's mixed incentive system demonstrates adaptability - Dutch BIZ model shows operational success in varied contexts
	Development Trade-off Structure	Focus on operational sustainability - Heritage preservation incentives - Public realm improvement requirements	Australian heritage-linked benefits show effectiveness - European public realm trade-offs demonstrate success - Asian models prove valuable for integrated approaches
B. Implementation	Regulatory Control Mechanism	Simplified frameworks with clear accountability - Performance-based standards - Community oversight integration	Japanese district frameworks demonstrate effective local control - UK management agreements show accountability success - Dutch democratic oversight proves valuable in medium contexts
	Space Type Requirements	Multi-functional design emphasis - Local needs integration - Flexible usage patterns	German mixed-use standards show effectiveness - UK retail integration demonstrates viability - Hong Kong/Singapore models prove value of adaptable spaces
	Design & Quality Standards	Context-sensitive guidelines - Local character preservation - Operational efficiency focus	Melbourne's contextual standards show effectiveness - European quality benchmarks demonstrate balance - Japanese efficiency standards prove valuable
	Approval Process	Streamlined procedures - Community consultation integration - Clear performance criteria	Dutch democratic process shows value in local contexts - Hong Kong technical standards demonstrate efficiency - UK stakeholder engagement proves effective
C. Management	Operational Requirements	Shared management frameworks - Community programming emphasis - Resource optimization focus	UK BID operations show efficiency in medium contexts - Japanese programming demonstrates effectiveness - Dutch partnership models prove valuable
	Access Requirements	Clear public rights framework - Flexible access patterns - Local needs adaptation	Seoul's rights framework shows clarity and effectiveness - European flexibility demonstrates success - UK access management proves valuable
	Control Rights Framework	Balanced oversight mechanisms - Community involvement structures - Clear authority frameworks	Dutch public oversight shows effectiveness - UK private management demonstrates efficiency - Asian models prove valuable for balanced control
	Usage Regulation	Activity support focus - Community programming emphasis - Efficient management systems	German activity support shows success - Japanese management demonstrates efficiency - UK programming proves effective
	Maintenance Requirements	- Shared responsibility models - Community stewardship programs - Quality benchmarking systems	UK standards show effectiveness in medium contexts - Australian community integration demonstrates success - Asian efficiency models prove valuable
D. Supervision	Oversight Mechanism	- Multi-stakeholder monitoring - Regular performance review - Community feedback systems	European engagement shows effectiveness - Asian metrics demonstrate efficiency - UK monitoring proves valuable
	Agreement Duration	Flexible term structures - Regular review provisions - Adaptation mechanisms	UK agreements show stability benefits - Dutch flexibility demonstrates effectiveness - Asian adaptation proves valuable in changing contexts
Conclusions	Primary Characteristics	Partnership-based rather than incentive-driven Local scale integration over metropolitan solutions Community governance with professional management Flexible frameworks with clear standards	
	Strengths	Combines successful elements from Dutch/German democratic processes and UK management efficiency Resource-efficient governance model Clear public accountability Strong community integration	
	Challenges	Balancing community control with professional management Ensuring long-term viability Managing stakeholder expectations European models' coordination issues Asian cities' oversight problems US models' enforcement difficulties	

Table 1: Proposed governance structure for medium-sized cities based on the developed planning and policy framework.

6 CONCLUSION

The analysis of POPS implementation across different urban contexts reveals three distinct categories of governance models that have evolved through practical experience and policy refinement. the Zoning-Based Incentive, the Property-Based Control, and the Partnership-Based models create institutional frameworks for ongoing collaboration in space governance through structured agreements between private owners, public authorities, and community stakeholders, while maintaining private ownership. The identification and analysis of these three models represents a significant contribution to both theoretical understanding and practical implementation of public-private collaboration in medium-sized cities. While traditional POPS emerged from high-density metropolitan areas where land values and market pressures could support density bonus incentives, medium-sized cities present fundamentally different contexts requiring alternative approaches. The research demonstrates that successful adaptation requires moving beyond simple scaling down of metropolitan solutions toward context-sensitive governance frameworks that account for different market dynamics, institutional capacities, and community characteristics.

For medium-sized cities, the findings suggest that elements of the Partnership-Based Model, combined with simplified regulatory frameworks, offer the most promising direction. This approach can leverage the

stronger community networks and social capital typically present in medium-sized cities while accommodating their more limited institutional capacities and different market conditions. The research particularly emphasizes the importance of developing flexible governance frameworks that can support various forms of public-private collaboration while ensuring public benefit and operational sustainability. The practical implications focus on developing context-sensitive incentive structures, clear quality standards, and transparent monitoring mechanisms that match medium-sized cities' governance capacities. This includes creating community-based management models that integrate public space provision with heritage preservation and local economic development objectives. For local governments, the key challenge lies in building institutional capacity for managing public-private partnerships in ways that maintain public benefit while ensuring operational sustainability.

This study has several limitations that suggest directions for future research. The primary limitation lies in the methodology's reliance on secondary literature for POPS policy analysis, rather than direct examination of city policy documents, due to accessibility constraints and language barriers. This methodological constraint suggests the need for more comprehensive primary policy analysis in future research. A second limitation concerns the study's ability to assess the long-term effectiveness of different governance models in medium-sized cities and understand how varying socio-economic contexts influence their success. Future research should address these limitations through direct policy analysis and empirical investigation of of the effectiveness of different governance models, particularly focusing on community engagement mechanisms, the economic sustainability, and public space quality outcomes of various management approaches. Additionally, comparative case studies analyzing actual policy implementation in different urban contexts would provide valuable insights into the practical adaptation of these governance models.

While POPS principles can inform public space provision in medium-sized cities, their successful implementation requires careful consideration of local contexts and governance capacities. The three governance models identified provide a broader framework and continuem for understanding how different institutional arrangements can support public space provision across varying urban contexts. The challenge lies not just in creating public spaces, but in ensuring they remain truly public while being operationally sustainable. This research provides a foundation for understanding how different governance approaches can support this goal while addressing the unique characteristics of medium-sized cities.

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reviewed paper

Gamification in the Smart City: Insights from Participation and Communication Processes

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1 ABSTRACT

The following paper examines how gamification principles can expand citizen engagement and participatory processes in the Smart City. Smart city data in particular can be communicated excellently via digital media, regardless of location and time, due to the way it is technologically generated, stored and processed. Consequently, it makes sense to develop separate digital visualizations and tools for citizens, which on the one hand explain relevant relationships in a generally understandable way and on the other hand can reduce the high technological complexity. Especially in recent times, new formats of digital citizen participation have been emerging, some of which are specially developed between actors in urban development and media agencies (i.e. ZebraLog, Decidim, etc.). It is not uncommon that also the latest technologies such as VR glasses, digital twins, etc. come to use. But despite all the technological innovation, one of the basic problems of classic participation remains unsolved: The mix of participating citizens does not reflect the diversity of society even remotely. Socioeconomically disadvantaged groups in particular are not sufficiently reached and hence not included; instead, it tends to be the educated middle class that participates “who may be passionate about certain issues and ignore larger issues” (Ampatzidou et al. 2018; Akers 2022). Moreover, digital platforms require the decision to actively access it online. Against the background of this challenge, the two research teams of the Institute for Design Strategies at the University of Applied Sciences and Arts Ostwestfalen-Lippe are trying to link digital Smart City techniques with the potential of gamification by building and testing very simple and analog tools and methods. In these the linked digital data tends to take place much more in the background while the joy of playing with tangible elements could support citizen engagement and behavioural changes in an easier way.

This paper looks at a selection of six applied methods and formats that the team has tested in the public spaces of the medium sized city Detmold, Germany, in a completely or partially analog way in 2024. Topics such as urban planning, data security, mobility, climate change and the Smart City itself were discussed in the formats. The methods tested serve as supplementary elements to online participation and as a further development of classic outreach. Categorizations of gamification elements were reviewed for the analysis. In addition, the methods were classified at different levels of participation according to Cardullo and Kitchin based on Arnstein’s work. The paper also takes a critical look at the statement that “Many believe that technological advancements in communication will support a bright new era of political engagement and dialogue“ (Green 2020) and that digitalization is therefore the panacea for participation. Furthermore, it has been examined how power imbalances can be countered and a more inviting environment for participatory practices can be achieved.

Keywords: citizen, smart city, gamification, participation, communication

2 INTRODUCTION

In a time of increasing political polarization, environmental and economic changes, the quality of social interaction has become a critical factor in sustainable governance and community resilience. Crucial for a functioning society is public participation because “Through civic participation we become aware of difficulties, social problems and moral questions in society, and are aware that there are possibilities to change and build stronger community ties.” (Gudoniene et al. 2021). Likewise, participation is considered to increase the productivity of governments, strengthen citizen satisfaction and promote transparency and trust in politics and administration (Halachmi & Holzer 2010). We follow the definition of participation by Karic

and colleagues who describe it as "the involvement and engagement of citizens in planning and decision-making processes at different governance levels." (Karic et al. 2024).

The ladder of participation by Sherry Arnstein, which has been further developed from various perspectives and disciplines in recent decades, forms the basis for the critical examination of the citizen involvement in planning. The concept is based on eight levels, which are corresponding to the extent of citizens' power in determining the final product of a process (Arnstein 1969). At the bottom of the scale are the forms of non-participation ("manipulation" and "therapy"), followed by tokenism ("informing", "consultation" and "placation") and at the highest level citizen power consisting of "partnership", "delegated power" and "citizen control" (ibid.). In 2018, Cardullo and Kitchin specified the forms of participation for use in Smart Cities in a Scaffold structure (Fig. 1). Main contributions to the structure of Arnstein are the addition of "Consumerism" as the second level and expanding the levels by adding description for the corresponding roles, citizen involvement, political discourse/framing and modality (Cardullo & Kitchin 2018).

<table>
<tr><td>Modality</td><td colspan="6">Top-down, Civic Paternalism, Stewardship, Bound-to-succeed</td><td colspan="3">Inclusive, Bottom-up, Collective, Autonomy, Experimental</td></tr>
<tr><td>Political discourse/framing</td><td colspan="2">Stewardship, Technocracy, Paternalism</td><td>Capitalism, Market</td><td colspan="2">Civic Engagement</td><td>Participation, Co-Creation</td><td colspan="2">Rights, Social/Political Citizenship, Commons</td></tr>
<tr><td>Citizen Involvement</td><td colspan="2">Steered, Nudged, Controlled</td><td colspan="2">Browse, Consume, Act</td><td>Feedback</td><td>Suggest</td><td>Negotiate, Produce</td><td colspan="2">Ideas, Vision, Leadership, Ownership, Create</td></tr>
<tr><td>Role</td><td colspan="2">Patient, Learner, User, Product, Data-point</td><td>Resident Consumer</td><td>Recipient</td><td>Participant, Tester, Player</td><td>Proposer</td><td>Co-creator</td><td>Decision-maker, Maker</td><td>Leader, Member</td></tr>
<tr><td rowspan="2">Form and Level of Participation</td><td>Manipulation</td><td>Therapy</td><td>Choice</td><td>Informa-tion</td><td>Consulta-tion</td><td>Placation</td><td>Partnership</td><td>Delegated Power</td><td>Citizen Control</td></tr>
<tr><td colspan="2">Non-Participation</td><td>Consume-rism</td><td colspan="3">Tokenism</td><td colspan="3">Citizen Power</td></tr>
</table>

Fig. 1: Scaffold of smart citizen participation (adapted from Cardullo & Kitchin 2018)

The increasingly implemented Smart City concept, at its core, is defined by the strategic fusion of sophisticated technologies like machine learning or agent based systems and data-driven methodologies across diverse urban sectors (Marukukula et al. 2023). This technological system is intended to address multifaceted urban challenges and, simultaneously, to achieve a more interconnected and efficient urban environment for its inhabitants (Thibault et al. 2021). On the one hand these major transformations have to be accompanied by democratic processes in the society and on the other hand, digitalization offers new promising options for participation technologies and formats. Methods and instruments that evolved in this century are for example crowdfunding and -sourcing, using social media platforms for public purposes, virtual reality visualizations, online surveys and information, hosting events online or e-voting. These methods are becoming increasingly popular for involving stakeholder groups that are otherwise too busy or not interested in existing formats (Ampartidou et al. 2018). Digital tools are used more superficially then traditional settings by citizens, they tend to reduce the citizen power to tokenism (Levenda et al. 2020), "are rooted in stewardship, civic paternalism, and a neoliberal conception of citizenship that prioritizes consumption choice and individual autonomy" (Cardullo & Kitchin 2018) and favor market-oriented technological solutions over solutions from society that are based on common goals (ibid.).

Digital methods do not eliminate the need to address how to reach marginalized groups (Levenda et al. 2020). Moreover, Fredericks states that the understanding of Smart Cities has to evolve to an approach that connects, engages and empowers communities through playful interactions incorporating digital and physical mechanisms (Fredericks 2020). That is why we explore a different approach than the widely used online participatory platforms in this paper. Instead the focus will be on creative implementation of gamification elements in formats on the edge between analog and digital technologies. The term gamification refers to the use of "game elements in nongame contexts" (Deterding et al. 2011). The potentials of gamification in urban planning participation include long-term engagement, inclusion, and empowerment of underrepresented actor groups, as well as more enjoyable participation in general (Ampatzidou et al. 2018). Moreover, they address social values such as joy, agency, and social connection (Altarriba Bertran et al. 2021). Particularly important for effects that go beyond plain information is that gamification can lead to desirable behavioral changes that are supported by emotional experiences (Robson et al. 2015).

The analysed methods are derived from prototypes tested in the mid-sized German city Detmold that currently is facilitating a program of Smart City and data projects funded by the Federal Ministry for Housing, Urban Development and Building called "Modellprojekte Smart City". We understand our tests as a reality check in the wild on the question of which methods and theoretical elements actually work to motivate and raise interest in citizens in the context of Smart City, mobility and climate change mitigation.

Special attention was given to the design of the (physical) participatory spaces to offer structures that make every individual user an equal and (interacting) constituent (Lang 2015). In addition to spatial design, communication and graphic design also played an essential role in the visual communication of content.

3 PRINCIPLES OF GAMIFICATION

Gamification has emerged as a significant approach in various domains, defined as integrating game design elements into non-game contexts to enhance engagement, motivation, and behavioral change (Deterding et al. 2011). While games focus on entertainment, gamification is characterized by a serious purpose like education or behavior changes (Krath et al. 2021). Gamification draws ideas from components of games and applies them to the real environment instead of being a full-featured game (ibid.; Deterding et al. 2011). This chapter explores the theoretical frameworks that inform gamification and examines the principles guiding its application in diverse settings. Because game-related elements are often still loose definitions, we focus on one framework of principles created by Krath et al. in 2021. The researchers ran a systematic literature review about gamification, serious games and game-based learning. Based on 118 different theories mentioned in the meta-review, ten basic principles were derived which help to explain how gamification works (Krath et al. 2021). In later chapters those principles are compared on how participatory methods were implemented within the research project.

Clear and relevant goals. Gamification can transparently illustrate goals and their relevance.

A crucial theoretical framework is Goal-Setting Theory, introduced by Locke and Latham (1990), which emphasizes the significance of clear, specific, and challenging goals in driving motivation and performance. Klein et al. (1999) add that goal-setting increases persistence and performance by providing clear benchmarks. The principle can for example be accomplished by introducing badges, achievements (Gutt et al. 2020) and quests (Klock et al. 2020).

Immediate feedback. Gamification can provide users with direct feedback on their actions.

One of the most influential theories in gamification is Self-Determination Theory, initially developed by Deci and Ryan (1985). The use of immediate and constructive feedback further supports this theory by helping individuals track their progress and adjust their efforts accordingly (Locke & Latham 2002). Immediate feedback can be shown through points, levels or a progress bar (Koivisto & Hamari 2019).

Positive reinforcement. Gamification can reward users for their performance and communicate the relevance of their achievements.

Vroom's (1964) Expectancy Theory provides additional insight into gamification by suggesting that individuals are motivated by the expected outcomes of their actions. This theory underscores the importance of designing reward structures in gamification that align with users' expectations and perceived effort-reward relationships. Rewards can be implemented through badges, trophies (Suh et al. 2018) in-game rewards (Berkovsky et al. 2012) or status symbols (Klock et al. 2020; Rapp 2017).

Guided paths. Gamification can nudge users towards the actions necessary for achieving the goals.

As described in the constructivist learning theory, coaching is crucial to successful learning (Krath et al. 2021) and may include supporting learning through motivational prompts, assistance or reflection (Jonassen & Rohrer-Murphy 1999).

Simplified user experience. Gamification systems are usually easy to use and can simplify content.

Gamification can simplify the user experience by dividing complex tasks and topics into shorter and simpler sub-tasks (Simões 2013) and abstracting real-world problems to less complex scenarios supports learning and understanding (Ranchhod et al. 2014). We also add to this point the game-like design of the gamification concept. As Thiel (2017) mentions, a well-thought-out design is an important part of gamification and ease of use and intuition are crucial for the communication of information.

Individual goals. Gamification can allow users to set their own goals.

The goal-contents-theory states that people have different preferences and strategies to pursue intrinsic and extrinsic goals (Ryan & Deci 2017). To support the individual need for autonomy, users should be given the opportunity to set goals for themselves (ibid.). This can be achieved by the integration of leaderboards

(Chernbumroong et al. 2017), level bosses (Chen et al. 2019), avatars which illustrate the user´s future (Rapp 2017) or tracking and performance stats (Al-Ramahi et al. 2016).

Adaptive content. Gamification can adapt tasks and complexity to the abilities and knowledge of the user.

Csikszentmihalyi's (1990) Flow Theory further contributes to the understanding of gamification by describing an optimal psychological state of immersion and enjoyment that occurs when an individual's skill level is balanced with the difficulty of a task. In gamification, achieving this flow state requires structuring challenges that progressively adapt to users' skill, knowledge and behavioral level, providing clear objectives and immediate feedback to maintain engagement without causing frustration or boredom (Krath et al. 2021).

Multiple choices. Gamification can allow users to choose between several different options to achieve a certain goal.

According to the situated learning theory, conceptual knowledge can only be acquired by application to real-world scenarios and being embedded in realistic contexts (Brown et al. 1989; Dabbagh & Dass 2013). For learning, personal and environmental experiences and making own decisions based on the context are more important than instruction (Kolb 2015).

Social comparisons. Gamification can allow users to see their peer's performance.

Bandura's (1977) Social Learning Theory highlights the role of observational learning, imitation, and modeling in behavior acquisition. In gamification, leaderboards, social comparison mechanisms, and peer recognition (Christy & Fox 2014; Ding et al. 2020) serve as motivators by allowing users to observe and emulate successful behaviors. The incorporation of social interaction elements enhances engagement, as individuals are more likely to participate actively when they perceive themselves as part of a community (Bandura 1977).

Social norming. Gamification can connect users to support each other and work towards a common goal.

This principle refers to the concept that people have the basic psychological need for relatedness which is shown in the need for conformity and proximity with peers (Ryan & Deci 2017). Using the social comparison mechanisms of social pressure and a common goal can therefore help to reach the educational goals of the gamification (Krath et al. 2021). Social norming can be achieved by forming teams, mastering team challenges, collective voting and social networks (Klock et al. 2020).

The above-mentioned aspects of the study thus offer a good starting point for comparing and evaluating different participation concepts, which will be discussed in more detail below.

4 THE RATIONALE FOR GAMIFICATION IN SMART CITIES

The potentials of gamification in urban planning include long-term engagement, inclusion, and empowerment of underrepresented actor groups, as well as more enjoyable participation in general (Ampatzidou et al. 2018) which increases the motivation to participate (Muehlhaus et al. 2023). Moreover, they address social values such as joy, agency, and social connection (Altarriba Bertran et al. 2021; Bowser et al. 2013). Particularly important for effects that go beyond plain information is that gamification can lead to desirable behavioral changes that are supported by emotional experiences (Robson et al. 2015). This is achieved by illustrating complex urban issues in a more tangible way and using mechanisms of social learning (Ampatzidou et al. 2018). While board games have been specifically developed and used for planning purposes for a long time e.g. the game "Paticipology" where decisions on development challenges, place-making and planning issues get discussed and solutions negotiated and serious games and edutainment like SIM City have gained popularity (Robinson et al. 2021), implementing gamification principles rather than games into urban projects is not that widely applied yet.

The approach of gamification assumes particular relevance within the complex landscape of Smart Cities, where the complicated reality of urban infrastructures and data-driven governance models can present barriers to accessibility and may appear disconnected from the daily lives of average citizens (Latifi et al. 2022; Sgueo 2019). The application of gamification in Smart Cities is diverse, spanning numerous urban domains. Thus, in the following a selection of various projects will be presented based in the Smart City context which draw inspiration from the theories and instruments of gamification.

For instance, gamification can be effectively used to encourage pro-environmental behaviors through initiatives such as "Recycle Bank", where people collect points through recycling and can use them to get

rewards from local businesses, which demonstrates how reward systems and friendly competitions can incentivize recycling and waste reduction in the US (Marukukula et al. 2023). In the realm of transportation and mobility, addressing traffic congestion and promoting sustainable transportation choices is a key focus for Smart Cities. Gamified applications, such as "Bike Angels" in New York or gamified ride-sharing apps, can incentivize citizens to utilize public transport, cycling, walking, or carpooling by offering points, discounts, and rewards (ibid.; Sgueo 2019.). With the "Smart Road Sense" game in Italy and carpooling gamification schemes modeled with multi-agent systems people report road and traffic problems, collect points and compare their scores with others (Marukukula et al. 2023). This illustrates how gamification can be used to optimize traffic flow and promote responsible driving behavior (ibid.). Moreover, gamification can enhance citizen preparedness and responsiveness during emergencies. The last gamification examples can educate citizens on safety procedures, emergency protocols, and community support mechanisms (ibid.). Emergency Notification applications redesigned with gamification aim, where the users follow the rules of a typical videogame; users "can get points for sending EN notifications, for accomplishing missions and for attending training courses." (Romano et al. 2016), to improve civic engagement during crises by creating more compelling and informative interfaces for reporting incidents and receiving guidance (ibid.).

The examples show the potential variety in fields of application for gamification in Smart Cities which. In our case, the approaches that can be transferred to topics such as urban climate protection and sustainable mobility are of particular interest, as these are the requirements of the funding line.

5 TESTED METHODOLOGICAL APPROACHES

The focus of the tested methods in the project was on investigating how the above described gamification elements can enhance interaction and engagement among participants. Special emphasis was placed on diversity, real participation, and raising awareness for sustainable mobility and urban resilience. The methods were designed to reach diverse target groups, lower barriers, and promote active participation. This is achieved through multisensory experiences enriched with gamification elements and high-quality design. For each format, a brief profile was created summarizing the essential elements of the respective format.

5.1 Card Game "From A to B"

Description: Participants rethink their mobility habits by using a card game that represents their use of digital tools and modes of transportation (Fig. 2). This workshop invites participants to explore their daily use of digital tools and transportation modes through a card game. Participants describe their day by explaining how they moved from one location or activity to the next, with a particular focus on their choice of transportation and the use of digital tools like a railway transport provider app or a local bus operator app (Fig. 2, r). This process is visually supported by cards that represent each station or mode of transport. The cards are laid out sequentially to create an individual mobility profile, which encourages sharing more information during the conversation and can be added to the profile with pencils. With the participants' consent, the process is filmed or photographed from above, depicting only the hands, to provide a visual documentation of their individual mobility routes. This makes behavioral patterns visible and encourages discussions about alternative transportation concepts. This method was successfully tested at a neighborhood festival in the district Herberhausen and contributes to raising awareness about sustainable mobility options.

Objective: This method addresses key Smart City topics such as sustainable mobility, digital infrastructure, and urban planning. "From A to B" aims to identify barriers to using public transportation, promote alternative mobility options, and inspire behavioral changes towards eco-friendlier transport choices. By making participants more aware of their mobility patterns, the method encourages reflection on how cities can become more sustainable and efficient in terms of transportation.

Gamification Elements: Cooperative interaction, visualization of behavioral patterns, discussion about possibilities for change:

(1) Cooperative Interaction: The card game encourages participants to engage in discussions, share their mobility experiences, and collaborate on identifying patterns and alternative solutions. This fosters a sense of shared learning and collective reflection on sustainable mobility.

(2) Visualization of Behavioral Patterns: The visual representation of each participant's mobility route allows them to see their own behaviors, making abstract mobility choices more tangible and easier to analyze. This dynamic feedback loop sparks self-awareness and discussion about personal mobility habits.

(3) Discussion about Possibilities for Change: By focusing on alternatives to current transportation behaviors, the game creates a space for critical thinking and collaborative dialogue about possible changes in mobility choices, enhancing engagement and promoting sustainable alternatives.

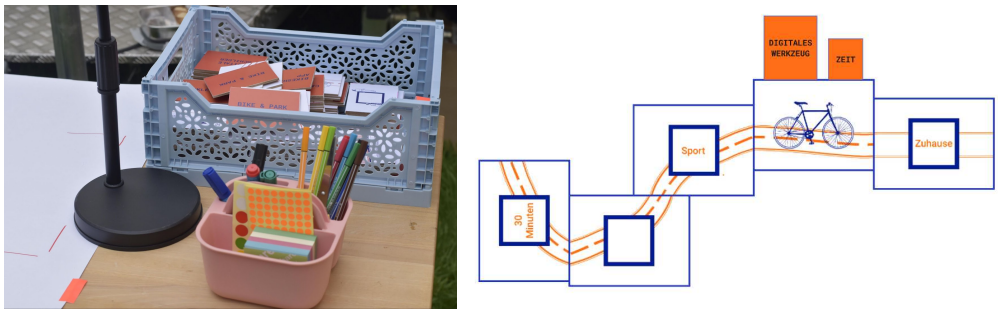

Fig. 2: Crafting materials and example result for "From A to B"

5.2 Model Building "Shape Your Digital/Car-Free City"

Description: A creative format where participants shape their vision of a car-free or digital city. In this interactive format, participants develop their individual vision through playful, engaging questions like "How do you use your phone on the go?" or "How does a car-free city smell?" while using various building materials (e.g., plastic film, wire, cardboard, Fig. 3). The created models are fixed to A3 cardboard and photographed at the end, allowing participants to take personalized postcards with them. This creative approach allows individual future visions to be visualized playfully and discussed afterwards. The questionnaires helped participants structure their ideas, while the photo postcards served as tangible rewards that strengthened engagement. The results of the method were diverse, individual designs and a discussion about future city planning. The interactive environment encouraged exchange, and creative co-creation allowed for a deeper connection to the concepts. In the future, the format should be more flexible in terms of duration and target groups and offered in multiple languages.

Objective: Promote participation, gather ideas and knowledge about digital and car-free cities, and visualize future visions.

Gamification Elements: Creative co-creation, personalized postcards as rewards:

(1) Creative Co-Creation: Participants engage in the collaborative creation of their vision, fostering a sense of ownership and involvement in shaping future urban spaces. The process of co-creating allows participants to see their ideas come to life in a tangible way, fostering greater connection to the activity.

(2) Personalized Postcards as Rewards: The creation of postcards featuring their designs acts as a reward for the participants, providing a tangible artifact that reminds them of their participation and involvement in imagining future cities. These postcards also serve as a form of recognition for their creative input.

Fig. 3: Question-cards, a visitor building their own city at "Shape your Digital/Car-free City" and a result postcard

5.3 Fishing-Game

Description: The fishing game is an interactive activity for Smart City information through playful engagement. As part of the international Parking Day 2024, the parking areas at the central street Rosental in Detmold were transformed into information booths to lounge areas, from clubs, initiatives, and projects. The project space was designed with an exciting, playful, and colorful spatial concept using scaffolding structures

(Fig. 4). Visitors could use wooden fishing rods with magnets to "catch" wooden symbols from a painted pond. These symbols represented different aspects of the Smart City concept and were assigned to corresponding themes in a "Decision-Makers' Corner". The aim of the activity was to actively involve Detmold's residents in learning about key topics such as mobility, saving resources, and social justice. Additionally, the symbols could be taken home as postcards, serving as a reminder of the creative transformation of public space. The fishing game, often known from childhood, is intuitively understood and provides visitors with a lot of fun. The appealing design with organic shapes and bright colors enhances attention and thus participation. Through the playful "fishing", participants engage with topics related to the Smart City and contribute their own ideas. Challenges arise in spatial design and target audience engagement, as the game primarily appeals to children but less so to adults.

Objective: Presenting information in an interesting way and raising awareness of sustainable urban development and Smart City topics.

Gamification Elements: Magnetic fishing game, categorization task, postcards:

(1) Interactive Gameplay: The magnetic fishing rods and symbols offer an engaging and playful interaction. The physicality of fishing creates an immersive experience where participants interact with the environment, leading to greater involvement.

(2) Categorization Task: After catching symbols, participants are tasked with categorizing them into related themes. This task encourages participants to engage cognitively with the different aspects of the Smart City concept, fostering deeper understanding and reflection.

(3) Creative Takeaway: The postcards that participants can take home act as both a reward and a reminder of their engagement, enhancing the emotional connection to the activity and reinforcing the impact of the experience.

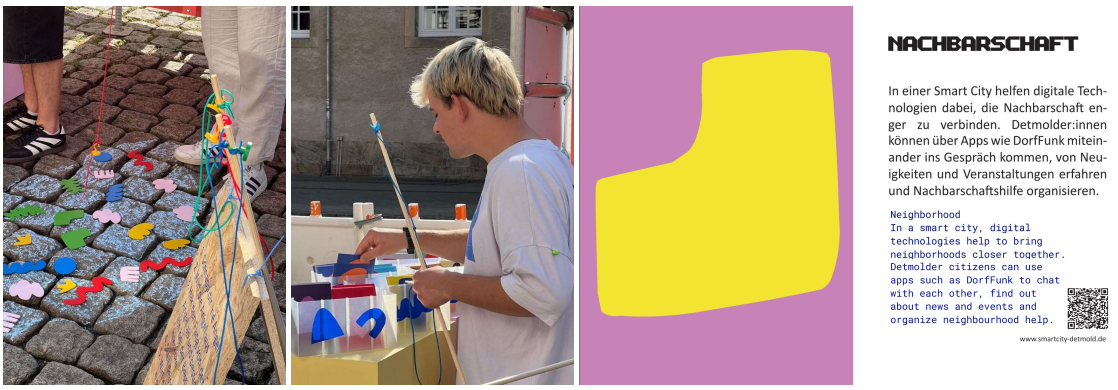

Fig. 4: Visitor at the public Fishing-Game collecting cards with Smart City information, card example "neighborhood"

5.4 Feminist*Parti

Description: The anti-conference "Feminist*Parti", which took place at the university in Detmold, discussed topics of intersectionality in urban contexts of participation. This format deliberately moved away from traditional conference structures and created an inviting and participatory atmosphere with its open room design (Fig. 5). Instead of rigid lectures and hierarchical seating arrangements, different spatial zones were created with open and flexible areas that enabled spontaneous interactions and low-threshold participation. We found that a non-hierarchical spatial arrangement can promote inclusivity, collaboration and active participation by breaking down physical and psychological barriers. This ensures that all participants can equally contribute, are valued and the feeling of shared responsibility is created. The "Feminist*Parti" anti-conference also demonstrated the importance of a well thought-out visual appearance. A consistent and appealing design created clear recognizability, facilitated orientation and visually conveyed the main content of the event. The barrier-free design of the information material and the interactive presentation formats reduced articulation barriers and enabled a low-threshold to interact.

Objective: Testing design approaches for event promotion and the physical space of the interaction, while contentwise discussing intersectional participatory processes.

Gamification Elements: interactive spaces, co-creation zones, spontaneous discussions, and tangible takeaways such as zines and installations.

(1) Playful and Open Interaction Spaces: The spatial concept encouraged spontaneous participation by replacing traditional conference structures with flexible zones, interactive installations, and open co-creation spaces. This made participation feel natural and inviting. Additionally, the event took place in a central, open space – the university foyer – allowing people to join even for just a few minutes.

(2) Collective Challenge & Co-Creation: Participants were encouraged to collaboratively map out intersectional challenges in urban participation through discussion prompts, open discussions, and creative workshop tasks, reinforcing a sense of shared responsibility.

(3) Tangible Insights & Recognition: During the workshops, participants created zines or small installations that they could take home as a keepsake. These also served as a starting point for later presentations and discussions. This approach enhanced engagement and validated their contributions in a playful yet meaningful way.

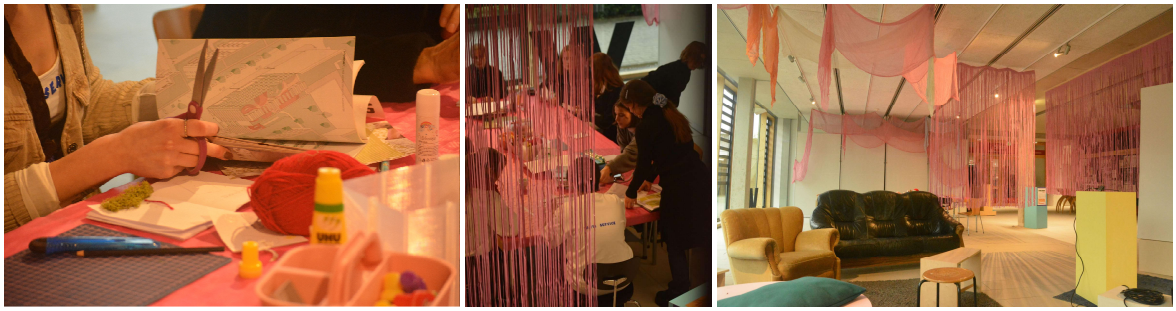

Fig. 5: Input session and workshop in different spaces at the Feminist*Parti

5.5 Mobil-Map – Detmold Design Week 2024

Description: The prototype employs an interactive, map-based interface controlled via a physical joystick and button in Arcade style. Participants utilize this interface to navigate a virtual urban environment, exploring mobility options for traveling from a designated physical location to any point within the map. Users are presented with the choice between utilizing a car or a bicycle for their virtual journey. Upon selecting a mobility option, the system generates a step-by-step visual routing and provides a detailed comparative analysis of the selected car and bicycle routes, highlighting key differences in distance, cost per kilometer, CO2 emissions, and time (Fig. 6). Following this comparative visualization, users are prompted with a decisional query regarding their potential reconsideration of mobility choices in favor of more sustainable alternatives. Upon submitting their response, the prototype generates a physical receipt summarizing the user's choices and key data points from their interactive experience, providing a tangible artifact of their engagement. The map was mainly programmed and designed by our team, within JavaScript and HTML frameworks and Python for user interaction and data handling. Additional mobility options like walking and taking public transport should be added to the map in the future to show a realistic variety.

Objective: The primary objective of this prototype is to enhance user awareness of diverse mobility options available within an urban environment and to actively promote the consideration and adoption of more sustainable transportation choices.

Gamification Elements: The prototype integrates subtle gamification principles primarily through:

(1) Playful and Nostalgic Exploration: The map-based interface and physical joystick control in Arcade style, pixelated fonts and visualizations, and experience identity offer an engaging and easy to interact means of exploring urban mobility options.

(2) Comparative Feedback and Challenge: The detailed visual comparison of car and bicycle routes serves as a form of immediate feedback, highlighting the trade-offs and potential benefits associated with different choices.

(3) Tangible Reward & Summary: The physical receipt functions as a form of reward or takeaway, providing a tangible summary of the user’s interaction and reinforcing the choices and information presented during the experience.

Fig. 6: Example comparison in the Mobil-map interaction, haptic elements and printer with receipt

5.6 Voting Towers – Neighborhood Festival Herberhausen

Description: This prototype was developed to tangibly demonstrate the concept of data physicalization within a playful and intuitively interactive experience. The core of the prototype consists of physical "voting towers" engineered to register user votes through a ball-drop mechanism (Fig. 7). Utilizing a set of 200 small balls, participants physically cast their votes by balls into the designated tower corresponding to their chosen answer option. Each tower is equipped with integrated sensors capable of detecting ball ingress and automatically tabulating received votes. A networked web interface and server infrastructure are implemented to facilitate real-time data acquisition from the voting towers, aggregate collected data, and generate dynamic visualizations of the voting patterns. The system further incorporates a comparative data layer, enabling direct visualization and contextualization of collected voting results against pre-existing national average datasets for Germany, providing a comparative benchmark for participant responses. The question asked was: "Why are you not using the bike more?" with the given options "I'm already using a lot", "I don't own a bike", "weather", "too exhausting", "safety concerns" and "too long distances". The national data included more options which due to limited number of towers couldn´t be shown.

Objective: The user experience is intentionally designed to be both playful and accessible, simplifying the complex process of data visualization and civic participation into the intuitive act of ball-throwing.

Gamification Elements: While not employing complex game mechanics, the prototype leverages inherent playfulness through:

(1) Physical Interaction and Intuitive Control: The act of physically casting votes by throwing balls into designated towers provides a kinesthetic and inherently engaging form of interaction.

(2) Immediate Visual Feedback and Data Representation: The dynamic visualization of aggregated vote data on the web interface, combined with the physical accumulation of balls within the towers, offers immediate and visually compelling feedback on collective opinion, rendering abstract data sets into concrete and understandable representations.

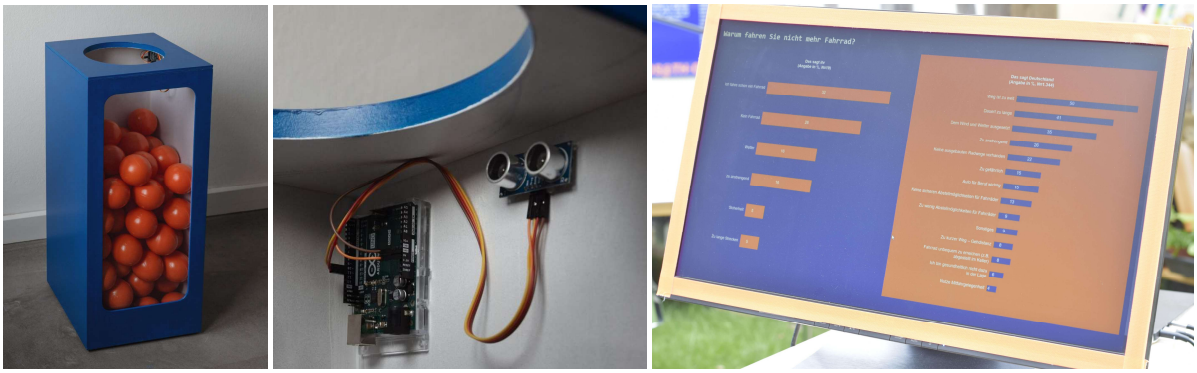

Fig. 7: Voting Towers with sensors and dynamic visualizations.

(3) Comparison and Benchmark (Implicit Challenge): The real-time comparative display of collected data alongside German national averages implicitly introduces an element of benchmark-driven comparison,

subtly prompting users to consider their responses in relation to broader societal trends and collective opinions. While not explicitly competitive, the comparative element introduces a layer of contextual engagement and implicit challenge.

6 FINDINGS AND DISCUSSION: POTENTIAL OF GAMIFICATION IN SMART CITY PROJECTS FOR CITIZEN COMMUNICATION AND PARTICIPATION

To review the newly developed and once tested methods they are brought into comparison on the basis of level of participation (Cardullo & Kitchin 2018) and the principles of gamification (Krath et al. 2018).

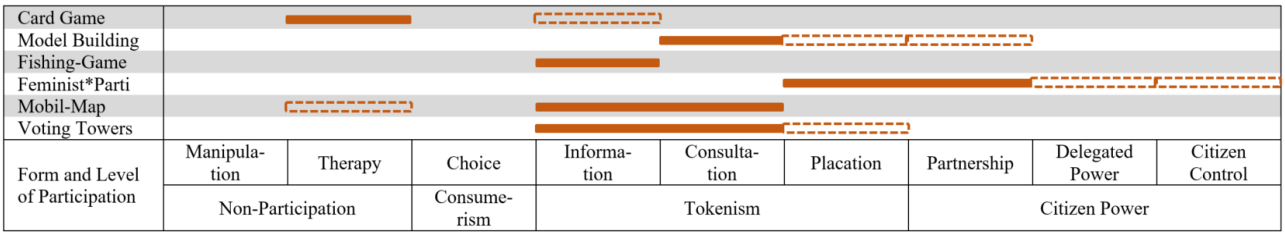

Fig. 8: Level of participation based on the scaffold of smart citizen participation by Cardullo & Kitchin 2018. (dotted = can potentially be used for …)

Looking at the scaffold of participation reveals that our methods focus on data collection (included in "Therapy"), communication and information instead of the higher levels of participatory practices (Fig. 8) which is in line with the distribution of methods carried out by cities (Levenda et al. 2020). This has to do with the fact that the method exploration is part of a research project testing creative information formats and improving outreach to diverse citizen groups. No specific power or budget is therefore allocated to self-organised citizen projects. While this is a specific problem of research in this field, it also reflects a bigger issue in digital participation: technological advancements cannot introduce a "new era of political engagement and dialogue" because the challenges lie in the limitations of power, politics and public motivation (Green 2020). In general the research team can confirm what Thiel (2017) stated: the best way to engage people in urban governance activities is to show that the people in power are listening to citizens input and make it part of their policies. While developing methods for information and outreach is essential, tokenism and power imbalances can only be prevented by transparently sharing from the start what can be achieved and decided by the citizens in the participatory process. This might require a shift in mindset within the administration and politics which again would be part of a wider societal turn.

	Clear and relevant goals	Immediate feedback	Positive reinforcement	Guided paths	Simplified user experience	Individual goals	Adaptive content	Multiple choices	Social comparisons	Social norming
Card Game					•				•	
Model Building	•		•		•		•	•	•	
Fishing-Game			•		•					
Feminist*Parti					•				•	•
Mobil-Map	•	•	•	•	•	•		•	•	
Voting Towers	•	•			•				•	•

Fig. 9: Analysis based on gamification principles by Krath et al. 2019

The analysis of the gamification principles shows that many of the methods fulfill the simplified user experience (Fig. 9) which is due to the emphasis on design and simplifying complex topics. Furthermore, social comparison is found in five of the methods, mainly because of the setting in social and public settings. Unsurprisingly, the Mobil-Map fulfilled the most gamification principles. It also represents the method which had the highest digital development need and hence was closest to an actual (serious) game. User feedback from the applications indicated a positive effect on attracting attention in open participatory formats and the rewards in the different methods particularly promise an improved long-term engagement with the topics presented in the workshops. Detailed feedback by citizens has to be studied in future events including structured monitoring through e.g. questionnaires.

For all methods it has to be said that they were solely developed for the specific event by the research team and included many time resources for content development, coding, printing and especially achieving a high-quality design which included special recognition of the event setting and creating an open and inclusive space where the participation could happen. This reveals a discrepancy between creating new and exciting

participatory methods and what public institutions could often actually achieve with their given resources. Specific skills regarding gamification, design, accessibility etc. are needed in the staff from the public side, especially in comparison to the usual town hall meeting with a slide-presentation or online-publication of information. Due to these reasons real playful urban technology has stayed in research and arts till now and remains unusual in real-world Smart Cities (Altarriba Bertran 2021; Ampatzidou et al. 2018). Moreover, a focus of the described methods was to provide accessibility in color choice, font choice, easy language and offering different languages which did not reflect in the gamification comparison. In the future gamification principles in regard to participation processes should integrate these elements.

7 CONCLUSION

This paper explored how gamification principles are and can be part of participatory processes in Smart Cities. We found that while the studied methods fulfill several gamification principles (Fig. 9) it does not automatically result in perfect participation or that more principles equal better interaction. Creating a surprising and interactive design for the specific context seems to be more important because the most pressing problem is currently the outreach to a representative section of the citizens. We concluded from our results that using gamification can help to fulfill this aim but also entails a need for more budget, time and human resources for the development. Therefore, future research should address these issues by providing guidance or a toolbox for easily implementing engaging participation in public administrations, even in smaller cities with less resources. Furthermore, different methods using gamification e.g. with design probes should be studied in greater detail and should gain importance rather than implementing online-participatory platforms everywhere without questioning their benefits within a diverse society. Indeed, a mix of different digital and analog methods seems to create a robust and useful participatory environment (Akers 2022).

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Gesundheitsversorgung im Wandel – Entscheidungsunterstützung für die Planung in einer alternden Gesellschaft

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1 ABSTRACT

Das Thema Gesundheit ist in den letzten Jahren u. a. aufgrund der COVID-19-Pandemie sowie des im Zuge des demografischen Wandels zunehmenden Fachkräftemangels wieder verstärkt in den Diskurs der Raumwissenschaft und Raumplanung gerückt (siehe u.a. ARL 2023, S.14). Dabei geht es längst nicht mehr nur um den präventiven Gesundheitsschutz (Stichwort gesundheitsbezogene Resilienz) und die Schaffung gesundheitsförderlicher Strukturen im Sinne der Strategie „Health in all Policies“ (HiAP). Diese zielt auf die Verankerung von Gesundheit als gesamtgesellschaftliche Aufgabe in allen Politikfeldern und umfasst u. a. auch die Bereitstellung von Gesundheitsinfrastrukturen als Grundlage für die öffentliche Gesundheit und die gesundheitsbezogene Gleichwertigkeit der Lebensverhältnisse. Wenngleich dieser Ansatz in Deutschland noch am Anfang steht (Köckler und Geene 2022), geht es zunehmend um die wohnortnahe, bedarfsgerechte Versorgung der Bevölkerung mit Gesundheitsinfrastrukturen als Aufgabe der öffentlichen Daseinsvorsorge (ARL 2023, S.14). Deutlich wird dies u. a. auch durch das zuletzt im Referentenentwurf eingebrachte Gesetz zur Stärkung der Gesundheitsversorgung in der Kommune (GVSG), welches in dieser Fassung eine stärkere Beteiligung der Kommune an der ambulanten Gesundheitsversorgung vorsah. Zwar wurde das Gesetz im weiteren Verfahren deutlich gestrafft, dennoch kommt die Frage nach einer stärkeren Rolle der Kommunen in der Gesundheitsversorgung auf: Wie können Kommunen aktiv an der Gestaltung derer vor Ort mitwirken?

Der vorliegende Beitrag stellt vor diesem Hintergrund die Entwicklung und den Stand eines digitalen Decision-Support-Systems (DSS) für politische Entscheidungsträgerinnen und Entscheidungsträger auf kommunaler und überörtlicher Ebene für die ambulante Gesundheitsversorgung vor, welches als Teil eines komplexeren DSS im Rahmen des von der Carl-Zeiss-Stiftung geförderten Projekts „Ageing Smart – Räume intelligent gestalten“ entwickelt wurde (siehe www.ageing-smart.de).

Das DSS umfasst dazu (1) eine datengestützte Analyse der aktuellen Ausgangssituation (Entwicklung und Struktur der Bevölkerung einschließlich der Haushaltsstruktur, Ausstattung mit Einrichtungen der Gesundheitsversorgung sowie jeweils entsprechende Prognosen), (2) eine dynamische, intermodale Erreichbarkeitsanalyse von Gesundheitseinrichtungen (Stiewing et al. 2022, S. 131-141), (3) eine Befragung der betroffenen Bevölkerung zur Versorgungssituation (am Beispiel der Kohorte der Babyboomer in vier Modellkommunen) (Stiewing und Mangels, 2023, S. 404-413) sowie (4) eine strukturierte Sammlung möglicher kommunaler Handlungsoptionen zur aktiven Gestaltung der Gesundheitsversorgung. Perspektivisch soll in dem System zudem die Möglichkeit bestehen, die Auswirkungen der Handlungsoptionen zu visualisieren, um verschiedene Handlungsszenarien diskutieren und bewerten zu können.

Das vorgestellte Instrument ermöglicht damit den Kommunen eine bedarfsgerechte Planung für eine zunehmend älter werdende Gesellschaft und damit eine Möglichkeit zur aktiven Gestaltung des demografischen Wandels. Darüber hinaus wird der Ansatz dem Anspruch Raumplanung gerecht, stärker in die Bereitstellung von Gesundheitsinfrastrukturen steuernd einzugreifen (ARL 2023, S.14).

Keywords: Entscheidungsunterstützung, Gesundheitsversorgung, Daseinsvorsorge, Demografischer Wandel, Raumplanung

2 GESUNDHEITSVERSORGUNG IM KONTEXT DES DEMOGRAFISCHEN WANDELS

2.1 Dimensionen des demografischen Wandels

Der demografische Wandel beschreibt allgemein die Veränderung der Bevölkerung nach Zahl und Struktur, die in Deutschland bereits seit Jahren zu beobachten ist. Diese Entwicklung lässt sich mit den Schlagworten

„älter“, „bunter“ und – regional differenziert – „weniger / mehr“ zusammenfassen (vgl. Gans, 2018, S.376). Bei näherer Betrachtung zeigt sich jedoch, dass es sich um einen mehrschichtigen Prozess handelt, der durch ein Nebeneinander von Schrumpfung und Wachstum der Bevölkerungszahl, die Alterung sowie eine zunehmende Heterogenisierung und Singularisierung der Bevölkerung gekennzeichnet ist. Dabei geht der demografische Wandel mit weitreichenden räumlichen Implikationen für ländliche, suburbane und städtische Räume einher, welche auch hinsichtlich der Gleichwertigkeit der Lebensverhältnisse und der Sicherung der Daseinsvorsorge von Bedeutung sind (vgl. ebd.).

Schrumpfung und Wachstum sind Ausdruck der quantitativen Komponente des demografischen Wandels, welcher hierbei zu einem Rückgang des natürlichen Saldos führt. Ursache sind die seit den 1970er Jahren anhaltend niedrigen Geburtenraten und die damit einhergehende stetige Verkleinerung der potenziellen Elterngenerationen. Demgegenüber steht ein insgesamt positiver Wanderungssaldo (vgl. Statistisches Bundesamt, 2024). Allerdings unterliegen gerade Wanderungsbewegungen vielfältigen Einflussfaktoren (z. B. politisch, ökonomisch), weshalb diese regional differenziert und nicht konstant verlaufen. Die Binnenwanderung innerhalb Deutschlands ist ein Indikator, der, stärker als der Gesamtwanderungssaldo, auf Qualitäts- bzw. Attraktivitätsunterschiede (hinsichtlich Arbeitsmarkt, Bildungsmöglichkeiten etc.) hinweist. Die Außenwanderung über die Staatsgrenze wird hingegen stark durch externe Faktoren wie z. B. humanitäre Krisen und geopolitische Rahmenbedingungen beeinflusst (vgl. Fürst und Mäding, 2011, S.29). Das Ergebnis dieser wechselseitigen Dynamik zwischen natürlicher Bevölkerungsentwicklung und unterschiedlichen Wanderungsbewegungen sind teilräumlich nebeneinander ablaufende Wachstums- und Schrumpfungsprozesse mit ebenso unterschiedlichen räumlichen Ausprägungen und Wirkungen. Die absolute und relative Zunahme älterer Menschen, d.h. die Alterung der Bevölkerung ist in qualitativer Hinsicht das prägende Merkmal des demografischen Wandels und „in Deutschland schon lange kein Zukunftsthema mehr“ (vgl. Statistisches Bundesamt, 2024). Neben dem stetigen Geburtenrückgang und dem Schrumpfen der potenziellen Elterngenerationen („Alterung von unten“) ist dies auf den stetigen Anstieg der Lebenserwartung („Alterung von oben“) zurückzuführen (vgl. Gans 2018, S. 379f.). Zudem wirkt sich die Alterung der geburtenstarken Babyboomer-Jahrgänge als Treiber dieser Entwicklung aus, etwa ein Viertel der deutschen Bevölkerung ist diesen Jahrgängen zwischen 1955 und 1969 zuzuordnen (vgl. Statistisches Bundesamt, 2024 / vgl. Stefan et al. 2022: 1ff.). Konkret äußert sich die Alterung der Bevölkerung in einem steigenden Durchschnittsalter sowie einer Verschiebung der Altersgruppen mit einer Zunahme der Zahl der Senioren und Hochbetagten. So geht die 15. koordinierte Bevölkerungsvorausberechnung von einem starken Anstieg der Entwicklung der Altersgruppe 67 bis 79 bis 2037, gefolgt von einem erneuten Anstieg ab 2050 aus, während die Zahl der Menschen in der Altersgruppe 80 und älter bis 2050 ansteigen wird. Dagegen wird die Zahl der Personen im erwerbsfähigen Alter (20 bis 66 Jahre) bis Mitte der 2030er Jahre zurückgehen und sich – abhängig von der Entwicklung der Zuwanderung – ab etwa 2037 stabilisieren (vgl. ebd.).

Zur Heterogenisierung der Bevölkerung trägt zum einen die Migration aus dem Ausland bei, wobei die Herkunftsländer vielfältiger werden. Auch „das Leben in Deutschland wird durch die größere Vielzahl an ethnischen Gruppen, Kulturen und Subkulturen vielfältiger“ (Friedrich-Ebert-Stiftung, 2015). Zum anderen haben sich in den letzten Jahrzehnten aber auch gesellschaftliche Erwartungen gewandelt, verbunden mit einer gesteigerten Breite an Lebensentwürfen und Familienmodellen wie z. B. Patchwork- und Regenbogenfamilien. Darüber hinaus steigt, teilweise bedingt durch die Alterung der Gesellschaft mit einem höheren Anteil alleinstehender älterer Menschen und teilweise als Folge der Heterogenisierung, der Anteil der alleinlebenden Menschen. Dieser Prozess lässt sich ebenso dem demografischen Wandel zuordnen und wird als Singularisierung bezeichnet (vgl. Thüringer Ministerium für Infrastruktur und Landwirtschaft o.J.).

2.2 Auswirkungen und Konsequenzen für die Raumentwicklung

Wie bereits kurz skizziert, sind die räumlichen Auswirkungen des demografischen Wandels vielfältig und betreffen u. a. Wohnungsmärkte und Siedlungsdichte, Flächeninanspruchnahme, öffentliche Infrastrukturen (Auslastung, Kosten und Ersatzbedarf), Verkehrsströme, Wirtschaftskraft und -entwicklung, Arbeitsmärkte, Angebots- und Nachfragestrukturen, öffentliche Finanzen (Einnahmen, Ausgaben), Segregation, ethnische und soziale Konflikte bis hin zur öffentlichen Sicherheit (vgl. Mayer, K. et al., in Veröffentlichung). Die auftretenden Effekte variieren dabei nach Art und Intensität der demografischen Teilprozesse und werden von einer Vielzahl von Rahmenbedingungen beeinflusst. Die meisten dieser Entwicklungen stellen jedoch

eine Belastung dar und erfordern eine aktive Auseinandersetzung seitens der Raumplanung und der Politik (vgl. Fürst und Mäding, 2011, S. 30).

In quantitativer Hinsicht zeigt sich der demografische Wandel besonders durch einen Bevölkerungsrückgang in strukturschwachen, peripheren ländlichen Räumen (vgl. Maretzke, 2018, S.32). Dieser Rückgang ist häufig mit einer sinkenden wirtschaftlichen Attraktivität und einer sinkenden Nachfrage nach privaten Gütern und Dienstleistungen, Wohnungen und Infrastrukturleistungen verbunden. Als Konsequenz sehen sich die betroffenen Räume mit Herausforderungen wie Leerständen, steigenden pro-Kopf-Kosten und Tragfähigkeitsproblemen bei Infrastrukturen, Schließung von Geschäften und ärztlichen Praxen, wachsenden Einzugsbereichen, dem Rückgang an qualifizierten Arbeitskräften und einer allgemein sinkenden Attraktivität bei gleichzeitiger Unterversorgung mit wichtigen Leistungen der Daseinsvorsorge konfrontiert (vgl. u. a. Fürst und Mäding, 2011, S. 31; Fina et al., 2018, S.14). Dabei können sich diese Entwicklungen „zu Problemkreisläufen verstärken, die die Kommunen bei gleichzeitig sinkenden Steuereinnahmen vor große Herausforderungen stellen." (Fina et al., 2018, S.14). Die Binnenwanderung führt zudem zu einer Abwanderung, insbesondere jüngerer Menschen, in wirtschaftlich prosperierende Ballungsräume und damit zu einer Verstärkung der Disparitäten zwischen schrumpfenden ländlichen Räumen und prosperierenden urbanen Zentren (vgl. BiB, 2023). In diesen Wachstumsregionen kann die Intensität der demografischen Alterung zwar durch Wanderungsgewinne gemindert werden (vgl. Maretzke, 2018, S.32). Dadurch erleben diese Regionen wiederum ein zunehmendes Bevölkerungswachstum, das mit einer steigenden Nachfrage nach Wohnraum, Verkehrsinfrastruktur und sozialen Dienstleistungen verbunden ist (vgl. DIW 2021).

Qualitativ stellen Alterungsprozesse, welche mit unterschiedlicher Intensität und Geschwindigkeit in allen Regionen Deutschlands stattfinden, die zentrale Herausforderung des demografischen Wandels dar. Besonders betroffen sind hierbei ländlich geprägte, periphere Räume mit niedriger Bevölkerungsdichte, sowie verstädterte Räume und Agglomerationen mit wirtschaftlicher Strukturschwäche (vgl. Gans, 2018, S. 382). Während die Zunahme des Altenquotienten gesamtwirtschaftlich primär eine Herausforderung für das Rentensystem darstellt, ist die Alterung aus regionaler und lokaler Sicht vor allem eine Herausforderung für die soziale Infrastruktur. Dies betrifft insbesondere die Sicherstellung einer bedarfsgerechten Gesundheits- und Pflegeversorgung. Ungünstig wirkt sich hierbei die stetige Abnahme des Erwerbspersonenpotenzials auf dem Arbeitsmarkt bei gleichzeitiger Zunahme der Zahl älterer und hochbetagter Menschen aus, was die Schere etwa zwischen Pflegebedürftigen und Pflegekräften zunehmend öffnet. Gleiches gilt auch für die Gesundheitsversorgung, bei der sich eine zunehmende Diskrepanz zwischen der Zahl der Menschen mit Behandlungsbedarf und der Zahl vorhandener Leistungserbringer zeigt. Insgesamt verändern sich mit der Alterung der Gesellschaft aber auch die Anforderungen an die Infrastruktur. Dies umfasst z. B. die Ausstattung mit Einrichtungen der Gesundheitsversorgung, die Infrastruktur zur Sicherung der individuellen Mobilität oder das Angebot von Kultur- und Freizeitangeboten. Dies wurde u. a. im Rahmen projektinterner Workshops in den sieben Modellkommunen des Projektes „Ageing Smart" deutlich.

Gleichzeitig erfordert die Alterung der Gesellschaft eine Anpassung der gebauten Umwelt und bestehender Einrichtungen der Daseinsvorsorge an die Bedürfnisse älterer Menschen. Dies umfasst die Förderung altersgerechter Wohn- und Mobilitätskonzepte, die bedarfsgerechte Ausstattung mit medizinischen und pflegerischen Einrichtungen unter Nutzung alternativer (mobiler, digitaler und hybrider) Versorgungsdienste sowie die Gestaltung öffentlicher Räume, die den sozialen und physischen Bedürfnissen (Barrierefreiheit, Sitzmöglichkeiten) älterer Menschen entspricht (vgl. Körber-Stiftung und SRzG, 2020). Zudem kann in stark schrumpfenden Räumen auch der Rückbau oder die Umnutzung bestehender Infrastrukturen erforderlich werden, um den veränderten demografischen Gegebenheiten gerecht zu werden (vgl. BBSR, 2020).

2.3 Herausforderungen für die Gesundheitsversorgung

Hausärzte fungieren nicht nur als erste Anlaufstelle für medizinische Fragen und stehen oftmals in einem engen Betreuungsverhältnis zu ihren Patienten, sie übernehmen darüber hinaus auch die Koordinierung der weiteren fachärztlichen Versorgung sowie Präventionsmaßnahmen. Deren Bedeutung geht damit weit über die Behandlung akuter Krankheitsbilder hinaus. Besonders gilt dies aufgrund der größeren Entfernungen zu Fachärzten und Krankenhäusern zudem für ländliche Regionen (vgl. BBSR, 2025, S. 8). Gerade dort und in strukturschwachen Räumen ergeben sich aufgrund der strukturellen, demografischen und wirtschaftlichen Gegebenheiten jedoch Herausforderungen bei der Sicherung einer flächendeckenden und bedarfsgerechten Gesundheitsversorgung (vgl. BMWK, 2024, S. 202; Cramer et al., 2022, S. 2). Die entsprechenden Räume

sind dabei gekennzeichnet durch eine geringere Siedlungsdichte, ein daher geringeres Bevölkerungspotenzial und eine eher ungünstige Lage, gemessen etwa an den durchschnittlichen Fahrzeiten zum nächstgelegenen Oberzentrum (vgl. Ried, 2021).

Herausfiorderungen ergeben sich zum einen durch einen zunehmenden Bedarf an medizinischer Versorgung, bedingt durch die stetige Alterung der Bevölkerung. Die in diesem Rahmen ablaufenden Verschiebungen in der Altersstruktur führen zu einer steigenden Zahl der Hochbetagten und einer Zunahme von Multimorbidität und Mobilitätseinschränkungen. Zu erwarten sind daher Nachfrageveränderungen bei altersspezifischen Infrastruktureinrichtungen, insbesondere bei der ambulanten und stationären Gesundheitsversorgung sowie in der Pflege (vgl. Cramer et al., 2022, S. 2; Kuhn und Amelung 2015, S. 16–17). Verschärfend wirken u. a. zudem die vermehrt spürbaren Auswirkungen des Klimawandels (z. B. in Form von Extremhitzeereignissen) auf die menschliche Gesundheit (vgl. Birkmann und Blätgen, 2018, S. 1102).

Ungünstig gegenüber stehen dieser Entwicklung sinkende Behandlungskapazitäten, teilweise bedingt durch den demografischen Wandel und teilweise als Folge einer sinkenden Niederlassungsbereitschaft und dem Trend zur Teilzeit und Tätigkeit im Angestelltenverhältnis, verbunden mit einem Rückgang der insgesamt geleisteten Arbeitszeit (vgl. u. a. Bundesärztekammer, 2023 und Zwierlein et al. 2020). Auch hier wirkt sich wiederum die geburtenstarke Kohorte der Babyboomer aus, da sich gerade die Gruppe der Ärztinnen und Ärzte im Alter von 50 bis 65 Jahren durch hohe Wochenarbeitsstunden auszeichnet, welche sich in diesem Maße nicht von den nachfolgenden Generationen ausgleichen lassen (vgl. Bundesärztekammer, 2023).

Zusätzlich zu diesen quantitativen bestehen auch qualitative und räumliche Herausforderungen. Qualitativ lässt sich hierbei seit längerer Zeit eine fachliche Fehlverteilung feststellen, die durch eine Zunahme von fachärztlichen Spezialisierungen und einem Mangel an (niederlassungsbereiten) Allgemeinmedizinerinnen und -medizinern gekennzeichnet ist. Räumlich zeigen sich Disparitäten zwischen wohlsituierten Stadtteilen mit vielen Privatpatienten und einem hohem sozioökonomischem Status sowie ländlich-periphere und strukturschwache Gemeinden, in denen mitunter bereits die Grundversorgung gefährdet ist (vgl. Gerlach et al. 2014, S. 349 ff. und S. 377 ff.). Gerade die Nachbesetzung offener Sitze und Stellen gestaltet sich hier als schwierig, auch da Befragungen der Jahre 2015 und 2018 zu Folge fast 50 Prozent der jungen Ärztinnen und Ärzte eine Abneigung gegenüber dem Arbeiten im ländlichen Raum angeben (vgl. Zwierlein et al. 2020, S. 2; Jacob et al. 2015, S. 61 f).

Der demografische Wandel setzt die ambulante Versorgung gerade in ländlichen Räumen damit zunehmend unter Druck (vgl. Kuhn und Amelung 2015, S. 18). Auch mit Blick auf die angestrebte Gleichwertigkeit der Lebensverhältnisse ergeben sich daher Handlungserfordernisse bei der Sicherung der Gesundheitsversorgung (Stiewing und Mangels, 2022, S. 410-411). Dabei sind in den betroffenen Räumen umfassende Maßnahmen erforderlich, um den beschriebenen Herausforderungen entgegenzuwirken und eine flächendeckende, bedarfsgerechte Gesundheitsversorgung sicherzustellen. Kommunen sind daher explizit gefordert, integrierte Versorgungs- und Präventionsstrukturen aufzubauen sowie innovative und tragfähige Ansätze zu entwickeln (Böhm und Schönknecht 2020, S. 1). Die Steuerung und Ausgestaltung des öffentlichen Gesundheitswesens ist den Kommunen jedoch weitgehend entzogen und zu einem überwiegenden Teil auf die die gesetzlichen Krankenkassen und die medizinischen Leistungserbringer übertragen worden. Nichtsdestotrotz stellt sich im Kontext des demografichen Wandels aber die Frage nach einer stärkeren Rolle der Kommunen in diesem Bereich: Wie können Kommunen aktiv an der Gestaltung der lokalen Gesundheitsversorgung beteiligt werden?

2.4 Forschungsansatz im Carl-Zeiss-Projekt „Ageing Smart – Räume intelligent gestalten“

Bei den skizzierten Wirkungen und Herausforderungen im Kontext des demografischen Wandels wird deutlich, dass gerade die Kohorte der Babyboomer als Treiber einiger dieser Entwicklungen auftritt. Das von der Carl-Zeiss-Stiftung und der RPTU Kaiserslautern-Landau über einen Zeitraum von fünf Jahren mit 4,3 Millionen Euro geförderte Forschungsprojekt „Ageing Smart – Räume intelligent gestalten“ adressiert diese geburtenstarken Jahrgänge 1955 bis 1969 („Babyboomer“) und führt in einem integrierten Ansatz erstmals raumplanerische und versorgungsseitige Ansätze, Bedarfe der Babyboomer sowie Handlungserfordernisse und -optionen von Kommunen zusammen. Das interdisziplinäre, im universitären Potentialbereich „Region und Stadt“ der RPTU angesiedelte, Forschungsvorhaben gliedert sich in zehn Teilprojekte der Disziplinen

Raumplanung, Stadtsoziologie, Klimatologie, Informatik sowie Mathematik und wird am Fachgebiet Stadtsoziologie unter Prof. Dr. Annette Spellerberg koordiniert.[1]

Insbesondere für die Gesundheitsversorgung haben die Babyboomer dabei als größte Patientengruppe eine hohe Relevanz. Als ein Aspekt der Daseinsvorsorge widmet sich das Teilprojekt „Gesundheitsversorgung", das am Fachgebiet Regionalentwicklung und Raumordnung koordiniert wird, daher der hausärztlichen sowie der allgemeinen fachärztlichen und zahnärztlichen Versorgung in vier ländlich-suburbanen Kommunen – den beiden Verbandsgemeinden Kusel-Altenglan und Nieder-Olm, dem Geisaer Land und der Gemeinde Remshalden. Ein Fokus liegt dabei auf der klassisch standortgebundenen und alternativen, d. h. digitalen, mobilen und hybriden Gesundheitsversorgung (Angebot und Nachfrage), andererseits auf den verkehrlichen Infrastrukturen zur Gewährleistung von individueller Mobilität und Erreichbarkeit der medizinischen Einrichtungen. Ziel ist es, die Bedürfnisse der alternden Bevölkerung, die Raumentwicklung und die Versorgungsmöglichkeiten vor Ort in Einklang zu bringen (Stiewing et al., 2022, S. 132f.)

Ziel des gesamten Verbundvorhabens ist die Entwicklung eines daten-, IT- und KI-basierten Systems zur Entscheidungsunterstützung (Decision Support System = DSS) welches von öffentlichen Akteuren in ihrem Planungs- und Entscheidungsprozess (Kommunen fragen, das DSS antwortet) herangezogen werden kann. Infrastrukturen, Angebote und Dienstleistungen sollen so nachfragegerecht, tragfähig und zukunftsorientiert entwickelt werden können, um die Lebensqualität der Babyboomer und perspektivisch der gesamten Bevölkerung zu sichern und zu fördern.

Bezogen auf die Kohorte der Babyboomer und den Bereich der Gesundheitsversorgung stellen sich Fragen, die u. a. das Angebot an und die Nachfrage nach Infrastrukturen sowie das Wohnstandortverhalten betreffen: Welche Bedarfe sind aktuell und in Zukunft gegeben? Welche Infrastrukturen werden verstärkt nachgefragt? Wie kann die Qualität und Zugänglichkeit der medizinischen Versorgung im ländlich-suburbanen Raum durch Einbeziehung alternativer Dienste verbessert werden? Welche Akzeptanz finden digitale, mobile sowie hybride Angebotsformen der medizinischen Versorgung bei der Babyboomer-Generation? Welche Relevanz hat die medizinische Versorgungsinfrastruktur für die kommunale Entwicklung? Welche Möglichkeiten bestehen, auf die Standortwahl von medizinischen Einfluss zu nehmen? Welche Mobilitätsangebote werden in Zukunft benötigt? Wo und wie wohnen die Babyboomer in Zukunft?

Unter Berücksichtigung von Nachfrage- und Angebotsaspekten wurden die Rolle und Einflussmöglichkeiten der kommunalen Ebene im Bereich Gesundheit analysiert sowie je zwei ländliche und suburbane Kommunen hinsichtlich der Ausstattung und Erreichbarkeit der medizinischen Versorgung untersucht. Darüber hinaus wurde eine Umfrage zur Gesundheitsversorgung unter Babyboomern in diesen Kommunen durchgeführt, um Daten zum Gesundheits- und Wohnstandortverhalten der Babyboomer und den daraus resultierenden Herausforderungen zu generieren. Die Erkenntnisse z. B. zu Versorgungsstrukturen, Nachfragemustern und Bedarfen, dem Wohnstandort- und Mobilitätsverhalten sowie zur Akzeptanz und Relevanz digital-mobiler Angebotsformen medizinischer Dienstleistungen werden genutzt, um konkrete Handlungserfordernisse zu identifizieren und Handlungsoptionen zur Sicherstellung der Gesundheitsversorgung und deren Erreichbarkeit zu formulieren. Diese werden zudem durch die Einschätzung von Experten aus Politik und Verwaltung der Modellkommunen, der ambulanten Bedarfsplanung sowie mit Vertretern der medizinischen Spitzenverbände ergänzt.

3 GESUNDHEIT ALS AUFGABE DER ÖFFENTLICHEN DASEINSVORSORGE

3.1 Ausgestaltung der Gesundheitsversorgung im Selbstverwaltungsystem des Gesundheitswesens

In Deutschland sind Verantwortung und Steuerung der Gesundheitsversorgung nicht staatlich, sondern als Selbstverwaltungssystem organisiert, wobei die Zuständigkeiten gemäß dem föderalen Staatsaufbau auf die Ebenen Bund, Länder und Kommunen verteilt sind. Der Bund definiert dabei u. a. mit dem Sozialgesetzbuch (SGB) die gesetzlichen Rahmenbedingungen, während die genauere Ausgestaltung den Bundesländern und den Trägern der Selbstverwaltung, den Krankenkassen und den Kassenärztlichen Vereinigungen (KVen), obliegt. Oberstes Organ dieses Systems ist der Gemeinsame Bundesausschuss (G-BA), welcher durch die Kassenärztliche Bundesvereinigung (KBV), die Kassenzahnärztliche Bundesvereinigung (KZBV), die

[1] RPTU Kaiserslautern-Landau: „Ageing Smart – Räume intelligent gestalten" unter https://www.ageing-smart.de

Deutsche Krankenhausgesellschaft (DKG) sowie den Spitzenverband Bund der Krankenkassen (GKV-Spitzenverband) als Trägerorganisationen gebildet wird (vgl. G-BA, 2023).

Hinsichtlich der ambulanten Gesundheitsversorgung liegt der Auftrag zur Sicherstellung einer ausreichenden und flächendeckenden ärztlichen Versorgung im Rahmen der gesetzlichen Krankenversicherung (GKV) gemäß § 75 Abs. 1 SGB V bei den medizinischen Leistungserbringenden, vertreten durch die KVen, und den Krankenkassen. Erstere erstellen im Einvernehmen mit den jeweiligen Landesverbänden der Krankenkassen einen Bedarfsplan (§ 99 SGB V), welcher die Anzahl und Verteilung der Arztpraxen anhand von Richtlinien des GBA regelt und die Versorgung gemäß diesem Sicherstellungsauftrag garantiert. Die Bedarfsplanungs-Richtlinie (BPL-RL) macht bundesweite Vorgaben, welche auf regionaler Ebene in den sogenannten Landesausschüssen umgesetzt werden. Die BPL-RL beschreibt damit eine vollumfängliche funktionale Planungssystematik, welche Vorgaben zu u. a. Versorgungsebenen und Arztgruppen mit korrespondierenden Planungsbereichen und Versorgungsgraden formuliert, gleichzeitig aber Raum für regionale Abweichungen zulässt. Jede Arztgruppe (z. B. Orthopäden) ist dabei einer von vier Versorgungsebenen zugeordnet, welche in einer unterschiedlichen räumlichen Auflösung beplant werden: der hausärztlichen Versorgung (Mittelbereiche), der allgemeinen fachärztlichen Versorgung (Kreise), der spezialisierten fachärztlichen Versorgung (Raumordnungsregionen) oder der gesonderten fachärztlichen Versorgung (Landesebene). Die Bewertung der Versorgungslage erfolgt pro Arztgruppe und Region mit dem Versorgungsgrad über einen Abgleich des Einwohner-Arzt-Verhältnisses und dem Soll-Niveau der Verhältniszahl (vgl. KBV, 2025).

Die stationäre Versorgung liegt überwiegend in der Verantwortung der Länder, die den entsprechenden Sicherstellungsauftrag innehaben und demnach eine ausreichende, wohnortnahe Versorgung mit Krankenhausleistungen gewährleisten müssen. Die Finanzierung erfolgt dabei nach dem Prinzip der dualen Krankenhausfinanzierung durch die Länder und die Krankenkassen. Die meisten Bundesländer haben diesen Sicherstellungsauftrag jedoch auf die Kommunen übertragen, weshalb diese in vielen Fällen als Träger von Krankenhäusern agieren und damit auch an der Finanzierung der Krankenhäuser direkt und indirekt beteiligt sind (vgl. Böhm und Schönknecht 2020, S. 12).

3.2 Rolle der Kommunen bei der Gesundheitsversorgung

Wenngleich die Rolle der Kommunen in diesem System beschränkt ist, tragen diese verfassungsrechtlich als Teil der Länderverwaltung dennoch eine Verantwortung für die Gewährleistung der öffentlichen Gesundheit (vgl. Gerlinger 2021, S. 16). Eine effektive kommunale Gesundheitsversorgung ist dabei auch im Sinne einer gesundheitsfördernden Gesamtpolitik und der Strategie „Health in All Policies“ (HiAP). Letztere zielt als Mehrebenen-Ansatz darauf ab, das Thema Gesundheit in allen Politikfeldern zu verankern und darüber eine gesamtgesellschaftliche Verantwortung für die Gesundheit zu etablieren (vgl. Köckler und Geene, 2022). Abb. 1 bietet daher einen Überblick über die Rolle der Kommunen hinsichtlich der Gesundheitsversorgung sowie der Gesundheitsförderung und Prävention.

Zum einen können die Kommunen (d. h. Städte, Gemeinden, Landkreise) explizit als Leistungserbringer auftreten. Der rechtliche Rahmen wird hier u. a. durch das SGB V und das GKV-Versorgungsstrukturgesetz 2012 definiert. Kommunen können dabei – mit Zustimmung der zuständigen KV – in begründeten Ausnahmefällen sogenannte Eigeneinrichtungen zur unmittelbaren medizinischen Versorgung betreiben (§ 105 Abs. 5 SGB V). Zusätzlich gestattet § 95 Abs. 1a SGB V die Gründung kommunaler Medizinischer Versorgungszentren (MVZ) unabhängig von der Zustimmung der KVen (vgl. Gerlinger 2021, S. 70 f.). Seit dem Inkrafttreten des GKV-Versorgungsstärkungsgesetz im Jahr 2015 ist dies auch für arztgruppengleiche MVZ der Fall. Mit dem aktuellen Gesundheitsversorgungsstärkungsgesetz (GVSG), welches auf eine Verbesserung der ambulanten Versorgung zielt, ist zudem eine Vereinfachung kommunaler MVZ geplant. Die Umsetzung dieser Möglichkeit bleibt jedoch eine Herausforderung. Untersuchungen zeigen, dass die Bereitschaft kommunaler Funktionsträger zur Gründung von MVZ niedrig ist. Befragungsteilnehmende bewerteten MVZ in kommunaler Trägerschaft dabei eher kritisch und äußerten Bedenken hinsichtlich der wirtschaftlichen und organisatorischen Machbarkeit (vgl. Gerlinger 2021, S. 54 nach Kuhn et al., 2018; Barthen & Gerlinger, 2016; Kleinschmidt, 2019). Gründe liegen u. a. in fehlenden finanziellen Ressourcen und dem Mangel an fachlicher Expertise in den Kommunen (vgl. Gerlinger 2021, S. 73). Die Zahl der MVZ in kommunaler Trägerschaft ist daher bislang sehr gering (Gerlinger 2021, S. 54).

Zum anderen steht den Kommunen aber auch Handlungsspielraum aufgrund der im Grundgesetz verankerten kommunalen Selbstverwaltungsgarantie (Art. 28 Grundgesetz [GG]) offen. In diesem Rahmen können

Kommunen durch gezielte Maßnahmen Einfluss auf die Gesundheitsversorgung vor Ort nehmen, z. B. durch Beratungsleistungen, die Bereitstellung von Praxisräumen oder finanzielle Anreize für Ärztinnen und Ärzte (vgl. Kuhn und Amelung 2015, S. 18). Darüber hinaus können Kommunen über Gesundheitskonferenzen oder interkommunale und regionale Netzwerke die Zusammenarbeit zwischen lokalen Akteuren fördern, um Versorgungslücken zu schließen und die Versorgung zu sichern (vgl. Böhm und Schönknecht 2020, S. 6-10).

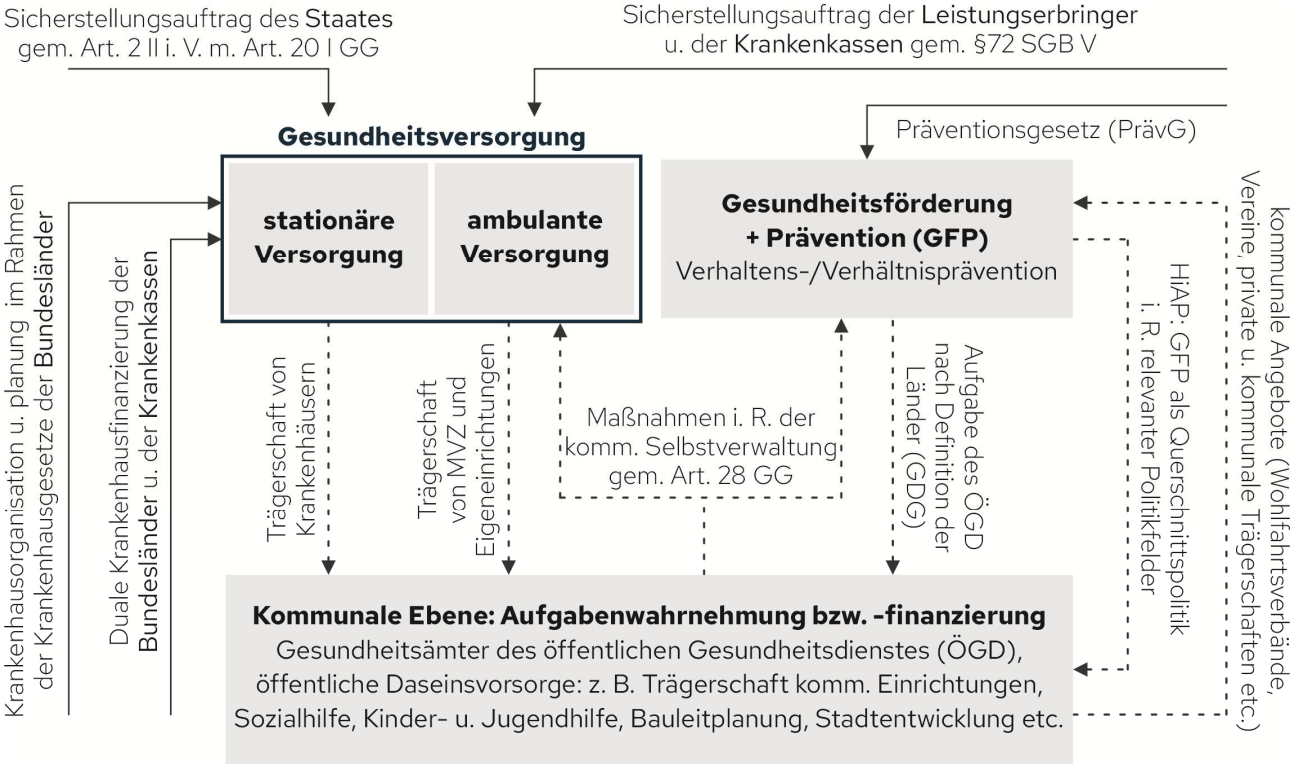

Abb. 1: Rolle der Kommunen im Handlungsfeld Gesundheit (Stiewing & Mangels, in Veröffentlichung).

4 ENTSCHEIDUNGSUNTERSTÜTZUNG IM BEREICH GESUNDHEIT

4.1 Analyse der Ausgangssituation als Baustein zur Entscheidungsunterstützung

Aufgabe der Raumplanung ist u. a. die Erfassung und adressatengerechte Visualisierung unterschiedlicher Entwicklungen sowie deren räumlicher und zeitlicher Zusammenhänge im Rahmen der Raumbeobachtung. Raumplanung schafft damit eine Arbeits- und Diskussionsgrundlage für sowohl politische Entscheidende als auch die Bevölkerung, etwa zur Erarbeitung räumlicher Strategien und Konzepte unterschiedlicher Art.

Im Austausch mit kommunalen Akteuren, u. a. im Rahmen projektinterner Workshops, Vernetzungstreffen und Konferenzen hat sich gezeigt, dass gerade in kleineren Kommunen mit nur wenigen Ressourcen Unterstützungsbedarf besteht. Diese verfügen dabei eher über einen oberflöächlichen Überblick über die vor Ort ansässigen Einrichtungen und zeigen aus Sicht der kommunalen Entscheidungsträger ein eher diffuses Problembewusstsein unter dem Schlagwort „Ärztemangel“. Ein Baustein zur Entscheidungsunterstützung bildet daher die Analyse der aktuellen Situation im Bereich der Gesundheitsversorgung als Grundlage für eine faktenbasierte Entscheidung. Diese umfasst

- allgemeine Indikatoren gängiger räumlicher Strukturanalysen in der Raumplanung,
- die Analyse der Gesundheitsversorgung im engeren Sinne,
- die Analyse der intermodalen Erreichbarkeit der medizinischen Einrichtungen sowie
- die Sichtweise und Einschätzung hierzu befragter Babyboomer im ländlichen und suburbanen Raum.

Ziel dieser analytischen Betrachtung ist die Beschreibung der Ist-Situation der Gesundheitsversorgung sowie die Ableitung von Handlungserfordernissen auf kommunaler Ebene.

Standardmäßig erfolgt die datengestützte Bestandsaufnahme und -analyse für ein bestimmtes räumliches Gebiets (z. B. einem Landkreis, einem Gemeindeverband) im Rahmen einer räumlichen Strukturanalyse. Diese umfasst i. d. R. die Strukturbereiche „Raumstruktur und Siedlungsentwicklung“, „Entwicklung und

Struktur der Bevölkerung“ (einschließlich der Haushaltstruktur), „Entwicklung und Struktur der Wirtschaft und des Arbeitsmarktes“, „Erreichbarkeit und Infrastruktur“ sowie je nach Ziel- und Schwerpunktsetzung z. B. „Gewerbe“ oder „Tourismus“. Innerhalb dieser Strukturbereiche erfolgt dann die Betrachtung und Einschätzung relevanter Indikatoren auf der Basis statistischer Daten auf Gemeindeebene und ggf. im zeitlichen Verlauf (i. d. R. Entwicklung der letzten ca. zehn Jahre). Ebenso können Prognosen und Vergleichswerte herangezogen werden, um einen Vergleichsmaßstab für die Einschätzung der Ist-Situation zu schaffen.

Für den Bereich der Gesundheitsversorgung stellen sich auf kommunaler Ebene zunächst folgende Fragen: Wie stellt sich die Situation der ambulanten Gesundheitsversorgung im Landkreis / dem Gemeindeverband / der Gemeinde bzw. in den Gemeindeteilen aktuell dar? Wie wird sich die Versorgungssituation vermutlich in fünf bis zehn Jahren darstellen? Wo besteht sowohl akut als auch perspektivisch Handlungsbedarf?

Folgende Daten können daher zunächst für eine Analyse der Gesundheitsversorgung herangezogen werden:

- Basisdaten zur Visualisierung, d. h. administrative Grenzen (z. B. auf Landkreis-, Gemeindeverbands- und Gemeindeebene) sowie Siedlungsbereiche bzw. Gebäude,
- Daten zur Raumstruktur und Siedlungsentwicklung, insbesondere Raumtypen und zentrale Orte,
- Daten zur verkehrlichen Infrastruktur, d. h. zum motorisierten Individualverkehr und öffentlichen Verkehr einschließlich Trassen, Haltepunkten, Taktung, Entfernungen und Erreichbarkeiten,
- soziodemografische Daten (z. B. Zensus) zur Beurteilung der quantitativen Nachfrage), insbesondere Stand und Entwicklung der Bevölkerung der letzten zehn Jahre, Bevölkerungsdichte und Bevölkerungsprognose sowie Daten zur Altersstruktur, z. B. Durchschnittsalter, Anteil und Entwicklung der Kohorte der Babyboomer sowie der Altersgruppen ü65/ ü75/ ü85), Lebenserwartung.

Ergänzend hierzu erfolgt die Analyse der Gesundheitsversorgung im engeren Sinne., wobei der Fokus im DSS auf den kleinräumigsten Planungsbereichen der ambulanten Versorgung, d. h. der hausärztlichen, zahnärztlichen und allgemeinen fachärztlichen Versorgung, liegt.

Folgende Daten können hierbei herangezogen werden:

- Rahmenbedingungen und Kennzahlen der ambulanten Bedarfsplanung zur Einschätzung des Angebotes in quantitativer und qualitativer Hinsicht, d. h. insbesondere Planungsbereiche, Versorgungsggrad, offene Sitze, Verhältniszahl von Einwohnern je Arzt,
- Daten zur medizinischen Ausstattung auf Gemeindebene zur Einschätzung des Angebotes in räumlicher Hinsicht, d. h. insbesondere adressgenaue Standorte der ambulanten ((Einzel- und Gemeinschaftspraxen, MVZ) und stationären Versorgung (öffentliche und private Krankenhäuser) sowie Apotheken und ggf. vorhandene mobilde, digitale und hybride Angebotsformen

Vor dem Hintergrund einer veränderten Mobilität im Alter gewinnt die Erreichbarkeit der Standorte für die Einschätzung des Angebotes in räumlich-qualitativer Hinsicht an Bedeutung. Daher wird die Analyse der Gesundheitsversorgung durch eine intermodale Erreichbarkeitsanalyse auf der Grundlage mathematischer Algorithmen ergänzt. Diese bezieht dfabei unterschiedliche Verkehrsträger und Nutzerprodile mit ein und ermöglicht die Identifikation von kleinräumigen Erreichbarkeitsdefiziten und Versorgungslücken innerhalb eines Planungsbereiches (Stiewing et al. 2022, S. 131-141).

Folgende Daten werden hierbei herangezogen:

- adressgenaue Standorte der einzubeziehenden Einrichtungen,
- das Straßennetz,
- aktuelle Fahrplandaten des öffentlichen Verkehrs,
- der Berechnung zugrunde liegende Parameter und Nebenbedingungen (z. B. in Form von zuvor konfigurierten Mobilitätsprofilen) sowie
- angebotsseitige Erreichbarkeitsstandards zur Bewertung und Einschätzung der Ergebnisse.

Abschließend ist zudem die Sichtweise der Babyboomer unter dem Aspekt der Bedarfsgerechtigkeit und Patientenorientierung bei der Einschätzung von Angebot und Nachfrage in quantitativer, qualitativer und

räumlicher Hinsicht von Bedeutung. Anhand von Aussagen zu Nachfrageverhalten und Bedarfen bei der Gesundheitsversorgung, dem (überörtlichen) Wohnstandortverhalten, dem Mobilitätsverhalten sowie der Akzeptanz und Relevanz digitaler und mobiler medizinischer Angebotsformen sollen sowohl für politische Entscheidungsträger als auch für die Träger der Gesundheitsversorgung Handlungsbedarfe aufgezeigt und Handlungsoptionen zur Sicherung der Gesundheitsversorgung und Mobilität formuliert werden (Stiewing & Mangels, 2023, S. 403).

Folgende Daten werden hierbei u. a. herangezogen:

- subjektiver Gesundheitszustand sowie gesundheitliche Einschränkungen, chronische Erkrankungen, Risikofaktoren (Multimorbidität) und soziale Einbindung,
- Zufriedenheiten mit der medizinischen Versorgung und Mobilität am Wohnort,
- Akzeptanz mobilder und digitaler Angebotsformen bei der Gesundheitsversorgung,
- Bedeutung von Gesundheitsversorgung und Mobilität als Standortfaktoren bei der Wohnstandortwahl (Vergangenheit und antizipiert),
- Anforderungen und Wünsche zum Wohnen im Alter.

4.2 Handlungsoptionen zur aktiven Gestaltung der Gesundheitsversorgung

Wie Abb. 2 zeigt, können sich Kommunen unterschiedlich intensiv im Bereich der Gesundheitsversorgung betätigen. Auf einer ersten Stufe umfasst dieses Engagement zunächst die inhaltliche Auseinandersetzung der kommunalen Vertreter mit der Thematik und den Austausch mit den ärztlichen Leistungserbringern vor Ort. Aus einem Problembewusstsein für die spezifische Situation können dann erste Handlungsoptionen erwachsen, welche sich unter „Beratung“, „Unterstützung“ und „Vermittlung“ subsummieren lassen. Ein Beispiel bildet hier etwa die Beratung im Rahmen der Niederlassung. Auf einer zweiten Stufe agiert die Kommune als Partnerin bei der Standortsuche und ggf. Niederlassung. Beispiele bilden die Vermietung bzw. Bereitstellung geeigneter Praxisräumlichkeiten oder der Verkauf von Immobilien oder Baugrundstücken zu günstigen Konditionen. Auf einer dritten Stufe wird die Kommune als Moderatorin bis hin zur Treiberin aktiv, indem sie das Thema Gesundheit in eigene Stategien und Konzepte einbindet und in diesem Rahmen auch die Analyse des Status quo und die Kommunikation darüber zum Gegenstand kommunalen Handelns macht. Beispiele bilden daneben zudem (interkommunale) Strategien und Netzwerke. Das höchste Maß an kommunalem Engagement bildet schließlich die Übernahme eines eigenen Versorgungsauftrags in Form der Trägerschaft eines bzw. der Beteiligung an einem kommunalen MVZ oder dem Betrieb einer kommunalen Eigeneinrichtung in Abstimmung mit der zuständigen KV. Beide Einrichtungen bieten die Möglichkeit, Ärztinnen und Ärzte in einem Angestelltenverhältnis einzusetzen, was gerade bei der jüngeren Ärzteschaft beliebt ist (vgl. dostal & partner management-beratung gmbh, 2019; BMG, 2024; BMG, 2025). Die einzelnen Stufen bauen dabei aber nicht zwangsläufig aufeinander auf, vielmehr bilden sie unterschiedliche Gestaltungsansätze, welche sich in Abhängigkeit von den lokalen Gegebenheiten ergänzen können.

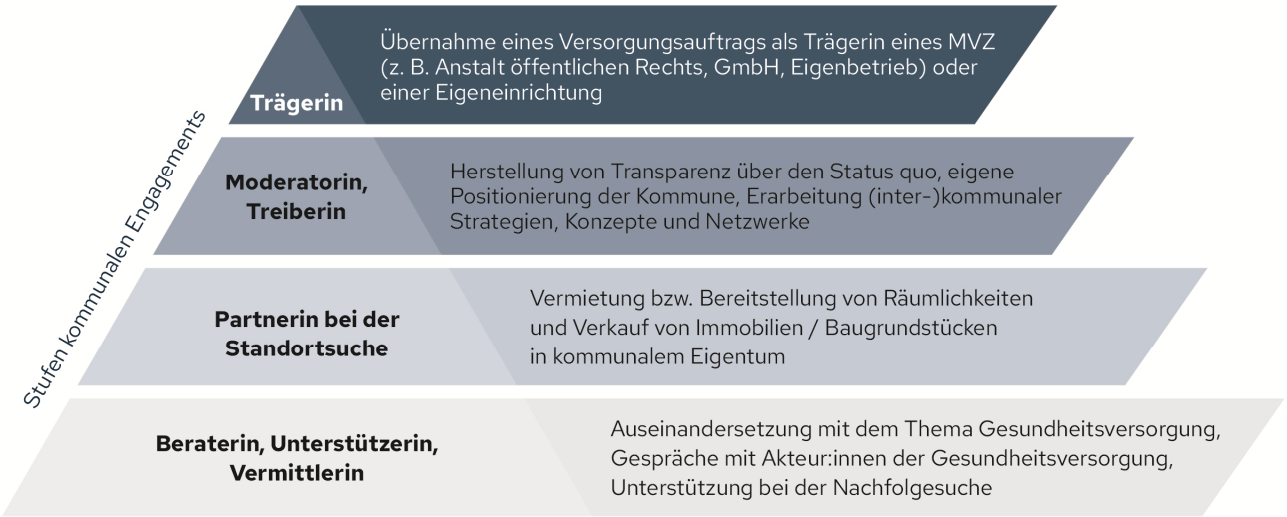

Abb. 2: Stufen kommunalen Engagements bei der Gesundheitsversorgung (Stiewing & Mangels, in Veröffentlichung).

Im Rahmen des DSS sollen mögliche Handlungsoptionen aufgezeigt und durch die Forschungsergebnisse im Teilprojekt systematisiert werden. So ist etwa eine Gliederung nach Engagementstufen ebenso denkbar wie eine rein inhaltliche Gliederung (z. B. Gesundheitsversorgung, Gesundheitsförderung Mobilität) oder eine Priorisierung nach unterschiedlichen Gesichtspunkten (z. B. Befragungswerten). Die Aufbereitung der einzelnen Handlungsoptionen erfolgt in Form von standardisierten Steckbriefen, welche im DSS hinterlegt werden sollen. Darüber hinaus können die Handlungsoptionen als Basis für alternative Szenarien dienen, anhand derer verschiedene Handlungsmöglichkeiten und deren Auswirkungen diskutiert werden können. Ein Beispiel hierfür ist die Standortplanung (z. B. zur Beratung bei der Niederlassung oder der Standortsuche für ein kommunales MVZ), bei der auf Basis des skizzierten intermodalen Erreichbarkeitsmodells verschiedene Standorte und deren Einfluss auf die Erreichbarkeit visualisiert werdem können sollen.

5 AUSBLICK

Das DSS fokussiert zunächst die geburtenstarke Kohorte der Babyboomer und entsprechend auf insbesondere altersspezifische Infrastrukturen, Angebote und Dienstleistungen, wie u. a. auch den Bereich der Gesundheitsversorgung. Die im Rahmen des Projektes entwickelten Use Cases sollen langfristig jedoch auch auf andere Einrichtungen (z. B. Nahversorgung, Einzelhandel, Bildung) übertragbar sein und damit ein breites Werkzeug zur Analyse und Lösungsfindung bieten. Dadurch wird eine sachgerechte und datengestützte Entscheidungsfindung unterstützt (vgl. Stiewing et al., 2022, S.139).

6 ANMERKUNGEN

In diesem Beitrag verwenden wir an einigen Stellen das generische Maskulinum als geschlechtsneutrale Schreibweise. Selbstverständlich wenden wir uns damit ausdrücklich auch an alle Menschen, die sich nicht dem binären Geschlechtssystem zugehörig fühlen, haben uns aus Gründen der Lesbarkeit aber gegen eine gegenderte Schreibweise entschieden.

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🏆 *reviewed paper*

Grünraum als Schlüssel: Anpassungsplanung für Gemeinden im Zeichen des Klimawandels

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1 ABSTRACT

Mit der fortschreitenden (Sub-)Urbanisierung gehen eine zunehmende Flächeninanspruchnahme und Versiegelung durch die Erweiterung und Verdichtung von Städten und Ortschaften einher. Der Rückgang unversiegelter Flächen zusammen mit den Auswirkungen des Klimawandels, wie vermehrten Hitzewellen und zunehmenden Starkregenereignissen, führt zu problematischen Effekten, wie Überschwemmungen und Hitzeinselbildungen. Entsprechende gesundheitliche und wirtschaftliche Schäden für die Betroffenen sind die Folge. Daher spielen die Begrünung und der Erhalt natürlicher Grünflächen eine zentrale Rolle um den Auswirkungen des Klimawandels entsprechend entgegenzuwirken. Für die konkrete Umsetzung von Klimaanpassungsmaßnahmen ist es dabei wichtig auf Ebene der örtlichen Raumplanung anzusetzen.

Die F&E Dienstleistung „RaumGrün & Gemeinden“ erforscht innovative Ansätze zur Verankerung von Klimaanpassungsmaßnahmen in der österreichischen Raumplanung. Aufbauend auf der Vorstudie “Raum & Grün” entwickelt das Projekt konkrete Strategien und Handlungsoptionen, um begrünungsassoziierte Maßnahmen als integralen Bestandteil der örtlichen Raumplanung zu etablieren. Ziel ist es, Gemeinden bei der Bewältigung von Klimarisiken, wie Hitze, Hochwasser, Erosion und Stürmen, zu unterstützen und nachhaltige Lösungen zur Förderung lebenswerter Siedlungsräume zu schaffen bzw. zu erhalten. Neben der technischen Entwicklung liegt der Schwerpunkt auf der engen Einbindung der zuständigen politischen und fachlichen Vertreterinnen und Vertretern von drei Pilotgemeinden sowie weiterer Stakeholder auf Gemeinde- und Bundesländer-Ebene, um die Praxistauglichkeit der Ergebnisse zu gewährleisten.

Für die drei raumtypologisch unterschiedlich ausgewählten Pilotgemeinden Fels am Wagram (Niederösterreich), Weiz (Steiermark) und Zwischenwasser (Vorarlberg) wurde im Rahmen des Projektes eine datenbasierte WebGIS-Applikation entwickelt, über die gebündelt auf aktuelle Daten zu lokalen Klimarisiken inklusive der ÖKS 15 Klimaprognosen und der HORA-Risikodaten zugegriffen werden kann. Darüber hinaus wurde eine neue Methode zur grundstücksscharfen Berechnung eines Risikofaktors für die lokale Überhitzung auf der Basis von Flächennutzungen vorgeschlagen und eine Solarstrahlungs-Analysekarte auf Fußgängerinnen- und Fußgänger-Ebene erstellt. Die Datenplattform ermöglicht die Identifikation von Klimarisikozonen als Entscheidungsgrundlage für gemeindespezifischer Maßnahmen zur Klimawandelanpassung. Auf dieser Grundlage wurde ein Prototyp für ein örtliches Planungsinstrumentarium sowie ein Maßnahmenkatalog mit Handlungsempfehlungen erarbeitet, die sich auf unterschiedlichen Planungsebenen (Örtliches Entwicklungskonzept, Flächenwidmungsplan, Bebauungsplan, Vertragsraumordnung) anwenden lassen. Die Ergebnisse dienen einerseits als Werkzeuge für die lokale Planung und andererseits auch als Grundlage für strategische Überlegungen zur langfristigen und verbindlichen Integration von Klimaanpassungsmaßnahmen auf Gemeindeebene.

Die Studie „RaumGrün & Gemeinden“ bietet zudem eine Roadmap zur Verankerung von Maßnahmen in übergeordneten Rechtsmaterien und Programme sowie Indikatoren zur Evaluierung. Die Ergebnisse des Projekts sind für verschiedene Zielgruppen der Raum- und Landschaftsplanung relevant, um standortspezifische Klimawandelanpassungsmaßnahmen verbindlich zu verankern. Die Pilottests in den drei Gemeinden dienen als Praxisbeispiele, die ein Leitbild für andere Gemeinden bzw. Bundesländer mit ähnlichen Raumtypen und Herausforderungen darstellen können. Mit dem FFG-Folgeprojekt „GreenGEO“ wird die Arbeit an datengestützter Klimawandelanpassungsplanung fortgeführt und weiter vertieft.

Keywords: Raumplanung, Planungsinstrument, Klimawandelanpassung, Stakeholder, integrative Planung

2 ENGLISH ABSTRACT

Progressive (sub-)urbanization is accompanied by increasing land consumption and sealing due to the expansion and densification of cities and towns. The decline in unsealed areas together with the effects of climate change, such as increased heat waves and more frequent heavy rainfall events, leads to problematic effects such as flooding and the formation of heat islands. This results in corresponding health and economic damage for those affected. Greening and the preservation of natural green spaces therefore play a central role in counteracting the effects of climate change. For the concrete implementation of climate adaptation measures, it is important to start at the level of local spatial planning.

The R&D service "SpaceGreen & Communities" develops innovative approaches for anchoring climate adaptation measures in Austrian spatial planning. Building on the preliminary study "Space & Green", the project develops concrete strategies and options for action to establish greening-associated measures as an integral part of local spatial planning. The aim is to support municipalities in coping with climate risks such as heat, flooding, erosion and storms in the future and to create and maintain sustainable solutions to promote liveable settlement areas. In addition to technical development, the focus is on closely involving the responsible political and technical representatives of three pilot municipalities as well as other stakeholders at municipal and provincial level in order to ensure that the results can be put into practice.

As part of the project, a data-based webGIS application was developed for the three pilot municipalities of Fels am Wagram (Lower Austria), Weiz (Styria) and Zwischenwasser (Vorarlberg), which were selected for their different spatial characteristics. This tool provides bundled access to various current data on local climate risks, including future ÖKS 15 climate forecasts and links to HORA risk data. In addition, a new method was proposed for calculating a risk factor for local overheating on the basis of land use and a solar radiation analysis map was created at pedestrian level. The data platform enables the identification of climate risk zones as a basis for decision-making on community-specific climate change adaptation measures. On this basis, a prototype for a local planning toolkit and a catalogue of measures with recommendations for action were developed, which can be applied at different planning levels (e.g. local development concept, zoning plan, development plan, contractual spatial planning). The results serve both as tools for local planning and as a basis for strategic considerations on the long-term and binding integration of climate adaptation measures at municipal level.

Furthermore, the study "RaumGrün & Gemeinden" (loosely translated: SpaceGreen & Communities) provides a roadmap for anchoring measures in higher-level legal materials and programs as well as indicators for evaluation. The results of the project are relevant for various target groups in spatial and landscape planning in order to anchor site-specific climate change adaptation measures in a binding manner. The pilot tests in the three municipalities serve as practical examples that can provide a model for other municipalities or federal states with similar spatial types and challenges. The FFG follow-up project "GreenGEO" will continue and deepen the work on data-based climate change adaptation planning.

3 AUSGANGSLAGE

Der Klimawandel beeinflusst zunehmend unser tägliches Leben. Auch Österreich ist entsprechend betroffen. Hier fiel die Temperaturzunahme in den letzten 170 Jahren stärker als im weltweiten Durchschnitt aus. (Balas et al. 2024, 35 ff.) Der Bodenverbrauch durch Verbauung und Versiegelung ist in Österreich im Vergleich zu anderen europäischen Ländern ebenfalls hoch, was den unwiederbringlichen Verlust biologisch produktiven Bodens bedeutet und die Folgen des Klimawandels zusätzlich verschärft. (Kanonier et al. 2023) Der tägliche Rückgang unversiegelter, grüner Flächen belastet den Wasserhaushalt durch den Verlust versickerungsfähiger Flächen und fehlender Verdunstung sowie Evapotranspiration über Pflanzen. Kombiniert mit klimawandelbedingen Effekten, wie Hitzewellen und Starkregen, werden Überschwemmungen begünstigt und der Urban-Heat-Island-Effekt verstärkt. Daher ist es unumgänglich, den Klimawandel auch bei der Gestaltung unserer Lebensräume insbesondere in der Raum- und Landschaftsplanung gezielt zu berücksichtigen. (Knoll et al. 2022c; Reinwald et al. 2023)

Anpassungsmaßnahmen, die diese Auswirkungen mildern könnten, stoßen oft auf politische, bauliche und finanzielle Hürden. Insbesondere blaue und grüne Infrastrukturen sowie Entsiegelungs- und Begrünungsmaßnahmen werden nicht ausreichend priorisiert. Wenn sie überhaupt vorgesehen sind, werden

sie häufig als ästhetische Verbesserungen öffentlicher Räume wahrgenommen und nicht als notwendige Klimawandelanpassungsmaßnahmen. (Trapp et al. 2020; Reinwald et al. 2021)

Derzeit finden sich Aspekte der Klimawandelanpassung, Entsiegelung und Begrünung nur marginal in den gesetzlichen Grundlagen zur Raumplanung wieder. (Knoll et al. 2022c) Dabei sind Begrünung und der Erhalt natürlicher Grünräume entscheidende Elemente, um den negativen Folgen des Klimawandels entgegenzuwirken. Gemäß der österreichischen Bundesverfassung ist die örtliche Raumplanung eine Aufgabe der Gemeinden, die im eigenen Wirkungsbereich und unter Beachtung bundes- oder landesrechtlicher Vorgaben eigenständig handeln. (Gruber et al. 2018) Da die direkte Planungsbehörde in diesem Bereich der Gemeinderat ist, liegt der Schlüssel zur Umsetzung von Klimawandelanpassungsmaßnahmen, wie Begrünung, Entsiegelung, Bauwerksbegrünungen, Regenwassermanagement und Hangsicherungen, auf der Ebene der örtlichen Raumplanung.

Der vorliegende Beitrag konzentriert sich auf konkrete Maßnahmen und Handlungsansätze zur Klimaanpassung auf örtlicher Ebene für Gemeinden im Rahmen der F&E Dienstleistung „RaumGrün & Gemeinden“, dargestellt und umgesetzt am Beispiel der drei Pilotgemeinden Fels am Wagram (Niederösterreich), Weiz (Steiermark) und Zwischenwasser (Vorarlberg). Am Beispiel dieser drei Gemeinden mit unterschiedlichen räumlichen Strukturmerkmalen wurde herausgearbeitet welchen Beitrag eine vorrauschauende, integrale Raum- und Landschaftsplanung leisten kann um Klimawandelanpassungsmaßnahmen entsprechend verbindlich zu verankern. Zur Umsetzung und Demonstration des Projektes wurde auf die erarbeiteten Ergebnisse der Begleitprojekte „Strasshof 2021“, „Strasshof Klimafit!“ und dem direkten Vorgängerprojekt „Raum & Grün“ zurückgegriffen und entsprechend aufgebaut.

4 VORARBEITEN UND BEGLEITENDE PROJEKTE

Die Projekte „Strasshof 2021“ (gefördert von der FFG – Österreichische Forschungsförderungsgesellschaft unter der Projektnummer 877634) und „Strasshof. Klimafit!“ (gefördert von der FFG – Österreichische Forschungsförderungsgesellschaft unter der Projektnummer 891996) wurden im Rahmen der Smart Cities Initiative des Klima- und Energiefonds Österreich gefördert, um innovative Maßnahmen zur Anpassung an den Klimawandel zu entwickeln und umzusetzen. Beide Projekte werden in der Stadtgemeinde Strasshof an der Nordbahn umgesetzt und dienen als Beispiele dafür, wie klimafitte Lösungen konkret in der Raumplanung integriert werden können, um den Herausforderungen von Hitze und Starkregen-Ereignissen zu begegnen.

Das explorative Projekt „Strasshof 2021“ konzentrierte sich auf die Entwicklung klimawandeladaptierter Planungsinstrumente. Ziel war es, Maßnahmen wie die Begrünung von öffentlichen und privaten Flächen, das Regenwassermanagement und die klimaangepasste Gestaltung von Straßenbegleitgrün in der örtlichen Raumplanung zu verankern. Zudem wurden potenzielle Flächen für grüne Strukturen bewertet und eine Liste klimaangepasster Baumarten erstellt, die sowohl für öffentliche Plätze als auch für private Gärten geeignet sind. Durch die Identifikation von Barrieren und die Entwicklung konkreter Kriterien für eine klimafitte Siedlungsplanung leistet das Projekt einen wichtigen Beitrag zur nachhaltigen Entwicklung der Gemeinde.

Das darauf aufbauende Leuchtturmprojekt „Strasshof. Klimafit!“ geht einen Schritt weiter und setzt resiliente, multifunktionale Lösungen um, die die Lebensqualität der Bevölkerung steigern und gleichzeitig das Mikroklima verbessern sowie die Biodiversität fördern. Besonderes Augenmerk wurde auf das „Schwammstadt-Prinzip“ gelegt, das an die Gegebenheiten in Strasshof (eine Gemeinde ohne Regenwasserkanal) angepasst wurde – etwa die Umsetzung von prototypischen Regenwasser-Sickermulden entlang der Straßen. Maßnahmen, wie EVAPO+ Grünwände, Versickerungsmulden, Sickerflächen und klimaangepasste Bepflanzungen wurden nicht nur in Strasshof implementiert, sondern auch als Best-Practice-Beispiele für andere Gemeinden und Kleinstädte aufbereitet. Über regionale, nationale und internationale Austauschforen werden die gewonnenen Erkenntnisse verbreitet und weitergegeben. Eine Schritt-für-Schritt-Anleitung unterstützt Gemeinden dabei, ähnliche Maßnahmen eigenständig umzusetzen. Die umfangreiche Dokumenatation des Projekts ist unter https://www.b-nk.at/strasshof nachzulesen und unter https://www.b-nk.at/yt-strasshof nachzuschauen. Vor allem die Webinare, verfügbar auf dem YouTube Kanal geben einen detaillierten Einblick in das Projektgeschehen und zeigen auf, wie Gemeinden konkret Klimawandelanpassungsmaßnahmen umsetzen und kommunizieren könn(t)en.

Beide Projekte verfolgen das gemeinsame Ziel, die Raumplanung an die Herausforderungen des Klimawandels anzupassen, die Widerstandsfähigkeit von Gemeinden zu stärken und praxisnahe Lösungen zu schaffen, die auch in anderen Regionen angewendet werden können. Sie machen Strasshof zu einem Vorreiter in der klimafitten Gemeindeentwicklung und setzen wichtige Impulse für nachhaltige und zukunftsorientierte Planungsstrategien.

Die Studie (F&E Dienstleistung, beauftragt vom Klimaschutzministerium) „Raum und Grün“ beschäftigte sich mit der Frage, welche Möglichkeiten es gibt, um das Thema Begrünung in das Regelwerk der österreichischen Raumordnung zu integrieren. Im Fokus standen die Identifikation von Barrieren und die Entwicklung von Handlungsempfehlungen sowie die Erstellung von Textbausteinen für örtliche Planungsinstrumente, um Begrünungsaspekte verbindlich zu berücksichtigen. Durch Analysen nationaler und internationaler Strategien, Fallbeispiele sowie Fachgespräche wurden konkrete Vorschläge erarbeitet. Diese umfassen rechtliche Anpassungen (z. B. Bauordnungen, Bebauungspläne) und Fördermaßnahmen, um Begrünungsmaßnahmen auf lokaler Ebene zu erleichtern. Die Studie betont zudem die Bedeutung gemeindeübergreifender Vorgaben und Bewusstseinsbildung für eine effektive Klimaanpassung und Emissionsreduktion. In der Publikation werden konkrete Lösungsansätze und Empfehlungen aufgezeigt. Besonders sind die Vorschläge im Hinblick auf die Vertragsraumordnung und die Zonenkategorien bzw. Räumliche Festlegungen/ Kenntlichmachung „Klimahain“ zur Bestandssicherung und „Klimawandel-Vorrangzone“ zur Zukunftssicherung zu nennen. Die Studie steht unter https://www.b-nk.at/raum-gruen zum Download bereit.

Alle drei Begleitprojekte ergänzen sich durch ihre unterschiedlichen Schwerpunkte: „Raum und Grün“ liefert die strategische und rechtliche Basis, auf die das hier dargestellte Projekt fundamental aufbaut. „Strasshof 2021“ und „Strasshof. Klimafit!“ knüpfen ebenfalls an dieser Schnittstelle an, entwickeln Maßnahmen und setzen dergleichen für eine klimafitte Raumplanung in der Stadtgemeinde Strasshof an der Nordbahn um. Bei allen drei Projekten stehen Begrünungsmaßnahmen, wie Entsiegelung, Bauwerksbegrünung und Regenwassermanagement im Fokus, die sowohl lokal als auch übertragbar auf andere Gemeinden zu gestalten sind.

5 PROJEKT RAUMGRÜN & GEMEINDEN – PILOTTEST: BEGRÜNUNG ALS INTEGRALER BESTANDTEIL DER ÖRTLICHEN RAUMPLANUNG IN ÖSTERREICH

Die F&E Dienstleistung „RaumGrün & Gemeinden“ ist eine direkte Weiterentwicklung der Vorstudie „Raum und Grün“. Sie vertiefte diesen Ansatz und konzentrierte sich auf die Pilotierung von Begrünungsmaßnahmenplanung in drei Gemeinden. Konkretes Ziel war die Entwicklung eines prototypischen Planungsinstrumentariums, die Integration von Begrünungsmaßnahmen in die örtliche Raumplanung sowie die Schaffung einer niederschwelligen Datengrundlage zur Identifikation von Klimarisiken. Dadurch werden Gemeinden unterstützt, Klimawandelanpassungsmaßnahmen unter Anwendung bestehender, adaptierter oder neuer Planungsinstrumentarien der Raum- und Landschaftsplanung entsprechend umzusetzen. Es geht dabei darum die Räume und ihre entsprechenden Bedarfe zu verstehen und Planungen gezielt im Rahmen eines prozessorientierten Ansatzes zu unterstützen. Wesentlich ist dabei das Aktivieren von Transitionsprozessen in Bezug auf Klimawandelanpassung von Lebens- und Wirtschaftsbereichen in bestimmten Räumen und Gemeinden. Es soll die politische Entscheidungsfindung für örtliche Klimawandelanpassungsmaßnahmen im Sinne von multi-level Governance auf der Ebene von Bund, Bundesländern (Rahmengebung) sowie Regionen und Kommunen (Umsetzungsverantwortung) unterstützt werden.

Die Umsetzung des Projekts erfolgt – wie bereits im Vorgänger-Projekt „Raum & Grün“ – in intensivem fachlichem Austausch mit den zuständigen Stellen der Ämter der Landesregierungen bzw. deren Gremien sowie weiteren wichtigen Stakeholdern. Das Bearbeitungsteam setzt sich aus Mitarbeiterinnen und Mitarbeitern von B-NK GmbH Büro für nachhaltige Kompetenz, Dipl.- Ing. Ralf Dopheide e.U., RaumRegionMensch ZT GmbH und AEE INTEC zusammen. Auftraggeber ist der Klima- und Energiefonds und abgewickelt wird das Projekt über die der FFG – Österreichische Forschungsförderungsgesellschaft unter der Projektnummer 902414. Projektinformationen sind unter https://www.b-nk.at/raum-gruen-gemeinden verfügbar. Die gesamte Studie wird voraussichtlich im Sommer 2025 veröffentlicht.

5.1 Fragestellungen des Projekts

Folgende zentrale Fragestellungen wurden im Projekt bearbeitet:

- Wie kann die strategische Integration von Begrünung/ Vegetation/ Klimwandelanpassungsmaßnahmen im gesamten Siedlungsraum an der Schnittstelle von überörtlicher Raumplanung und örtlicher Raumplanung forciert werden?
- Welche Daten und Szenarienrechnungen sind für die Analysen auf Mikro- und Makroebene notwendig (zeitlich und räumlich) bzw. Basis für politische Entscheidungen? Wie müssen Daten und Modelle aufgearbeitet werden, um in tägliche Praxis der Gemeinden möglichst niederschwellig aufgenommen werden können?
- Wie muss ein örtliches Planungsinstrument (Örtliches Entwicklungskonzept bzw. Räumliches Entwicklungskonzept, Flächenwidmungsplan, Bebauungsplan) ausgestaltet sein, das sektorale Vorgaben in Bezug auf Klimawandelanpassung/Begrünung aufnimmt und auf der Gemeindeebene verbindlich fortgesetzt und verortet?

5.2 Beteilige Pilotgemeinden

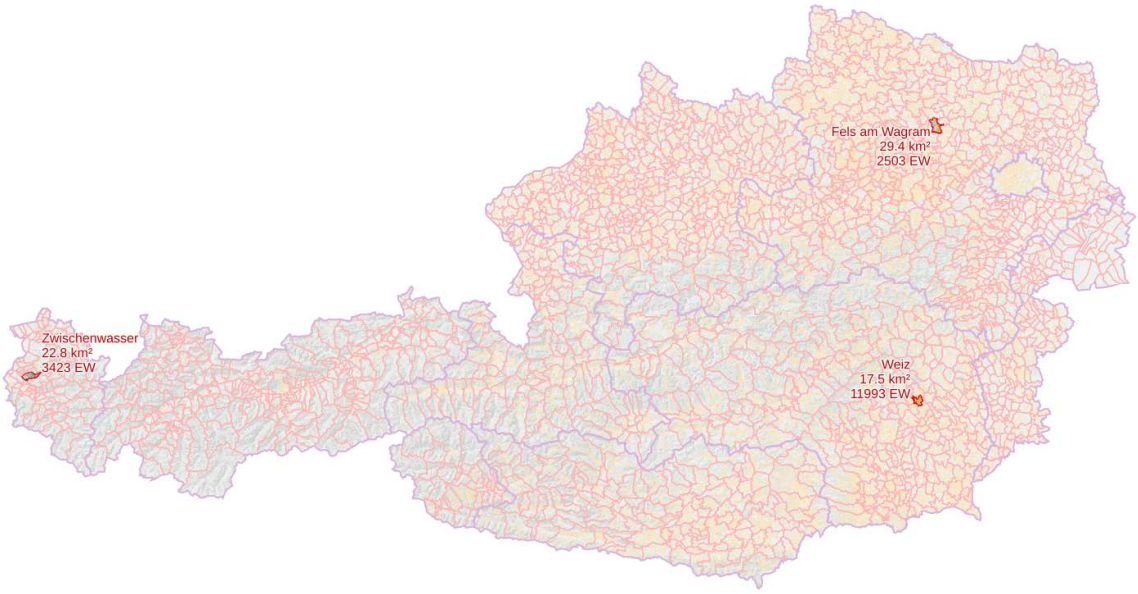


Abbildung 1: Lokalisierung der drei Pilotgemeinden (Eigene Darstellung)

Um das konzipierte prototypische örtliche Planungsinstrument und weitere Empfehlungen aus der „Raum und Grün“ Studie in der Praxis zu testen und für die Gemeinden weiterzuentwickeln und aufzubereiten, werden Pilottests in den drei ausgewählten österreichischen Gemeinden mit unterschiedlichen Charakteristika durchgeführt. Die drei Gemeinden unterscheiden sich grundlegend in ihrer geografischen Lage, demografischen Struktur und ihren Schwerpunkten.

- Fels am Wagram ist eine landwirtschaftlich geprägte Gemeinde mit Fokus auf Weinbau und Tourismus, geprägt von ländlichen und Merkmalen, wie Lösswänden und Weingärten.
- Weiz hingegen ist eine Bezirkshauptstadt mit dicht besiedelter Struktur, Einkaufszentren und Ansiedlungen großer Produktionsbetriebe, wodurch sie stärker urbanisiert ist und weniger Grünraum aufweist.
- Zwischenwasser hebt sich durch seinen Schwerpunkt auf Nachhaltigkeit und Klimaschutz hervor, liegt in alpinem Gebiet am Übergang zum Rheintal und wurde für seine vorbildlichen Energieprojekte ausgezeichnet.

Während Fels am Wagram landwirtschaftlich-touristische Herausforderungen hat, steht Weiz vor Herausforderungen in einem städtischen Kontext, und Zwischenwasser ebenfalls als ländliche Gemeinde mit Anschluss an das urban geprägte Rheintal und an das hochalpine Gelände.

5.3 Datenerhebung und -analyse

Die Methodik des Projekts „RaumGrün & Gemeinden“ basiert auf einem systematischen Ansatz zur Integration von Klimaanpassungsmaßnahmen in die örtliche Raum- und Landschaftsplanung. Der Prozess begann mit einer umfassenden Datenerhebung und -analyse, bei der verfügbare Informationen zu Klimarisiken, Flächennutzungen und topographischen Gegebenheiten gesammelt wurden. Ziel war es, diese Daten in einer praxistauglichen Form aufzubereiten, die für die Gemeinden leicht anwendbar sind. Der Fokus lag dabei auf der Verwendung öffentlich zugänglicher Datenquellen, um einen möglichst niederschwelligen Zugang für die Gemeinden zu ermöglichen.

5.2.1 Datengrundlage und Datenerhebung

Zu den genutzten Datengrundlagen gehören neben den Flächenwidmungs- und Gefahrenzonenplänen aktuelle Klimadaten, wie Tropennächte, Hitzetage, entsprechende Kühlgrad- und Heizgradtage sowie Niederschläge. Zur Beurteilung der zukünftigen Entwicklung von Klimarisiken wurden die ÖKS 15 Klimaprojektionen herangezogen. Die HORA-Risikodaten zu Hochwasser, Hagel, und Wind etc. wurden ebenfalls integriert. Diese umfassenden Datensätze liefern wichtige Erkenntnisse über die langfristigen klimatischen Entwicklungen und ermöglichen es, potenzielle Risiken und Auswirkungen frühzeitig zu identifizieren. Satellitendaten der Europäischen Weltraumorganisation (ESA) liefern Tree Cover Density-Daten, die die Landbedeckung durch Bäume und Waldflächen auf lokaler Ebene darstellen. Sie helfen dabei, bestehende Waldstrukturen zu quantifizieren und deren Bedeutung für die mikroklimatische Regulation innerhalb der Gemeinden zu bewerten. Darüber hinaus wurden regionale Gefahrenzonenpläne ausgewertet, um Risiken, wie Hochwasser- und Erosionsgefahren, gezielt in die Planung zu integrieren. Hierbei wurden insbesondere rote und gelbe Gefahrenzonen für Wildbäche und Hochwasserereignisse übernommen, die wertvolle Informationen über potenziell gefährdete Gebiete liefern. Ergänzend wurden Infrastrukturdaten, wie Informationen über öffentliche Einrichtungen (z. B. Schulen, Kindergärten, Krankenhäuser) eingebunden, um besonders vulnerable Zonen zu identifizieren und priorisierte Handlungsräume zu definieren.

5.2.2 Datenanalyse: Identifikation von Flächennutzungen und der neu entwickelte Heatfactor

Ein wesentlicher Bestandteil der Analyse ist die systematische Erfassung und Klassifizierung von Flächennutzungsdaten. Basierend auf den Erkenntnissen aus Testberechnungen in Zusammenschau mit Temperaturdaten aus Drohnenbefliegungen, wurden die Annahmen bestätigt, dass vor allem Versiegelung und fehlende Vegetation die Hauptursache für lokale Hitzeinselentwicklung sind. Auf dieser Grundlage wurde ein neuer, niederschwelliger Risikofakter unter Nutzung der überall digital vorhandenen Flächennutzungsdaten entwickelt, der sogenannte Heatfactor. Die Flächen wurden dabei gemäß ihrer Nutzung in Hitzebeitragsflächen, wie Bauflächen, Parkplatzflächen oder Straßen, sowie Kühlbeitragsflächen, z. B. Gärten, Wälder oder Uferbereichen gegliedert. Diese Flächenklassifikation bildet die Basis für die Berechnung des Heatfactors, der das Verhältnis von Hitzebeitrags- zu Kühlbeitragsflächen abbildet.

Der Heatfactor wird auf Parzellenebene berechnet und zusätzlich durch Punkt-Raster-Analysen ergänzt, um detailliertere Aussagen treffen zu können. Dabei wurden verschiedene Berechnungsmodelle getestet: Einerseits die Berechnung auf Grundstücksebene inklusive 50 Meter Radius um das Grundstück, andererseits eine Punktrastermethode, bei der möglichst gleichmäßig verteilte Punkte über die Flächen gelegt und die jeweiligen Flächenverhältnisse innerhalb eines 50-Meter-Radius zum Punkt berechnet werden. Die Punktmethode gleicht Verzerrungen aus, die durch stark unterschiedliche Grundstücksgrößen und geometrische Konfigurationen (z.B. extrem langgestreckte Straßengrundstücke) entstehen.

Schließlich wurde eine kombinierte Methode als optimal befunden, die beide Ansätze verbindet. Durch die zusätzliche Verwendung eines Punktrasters konnte eine präzisere Differenzierung der Risikozonen erreicht werden. Diese neue Methode ermöglicht es, auch kleinräumige Hitzeinseln zu erfassen, und grundlegende Aussagen auf Parzellenebene zu treffen, die mit grober aufgelösten Methoden, wie Satellitendaten zu Oberflächentemperaturen, nur schwer zu treffen sind.

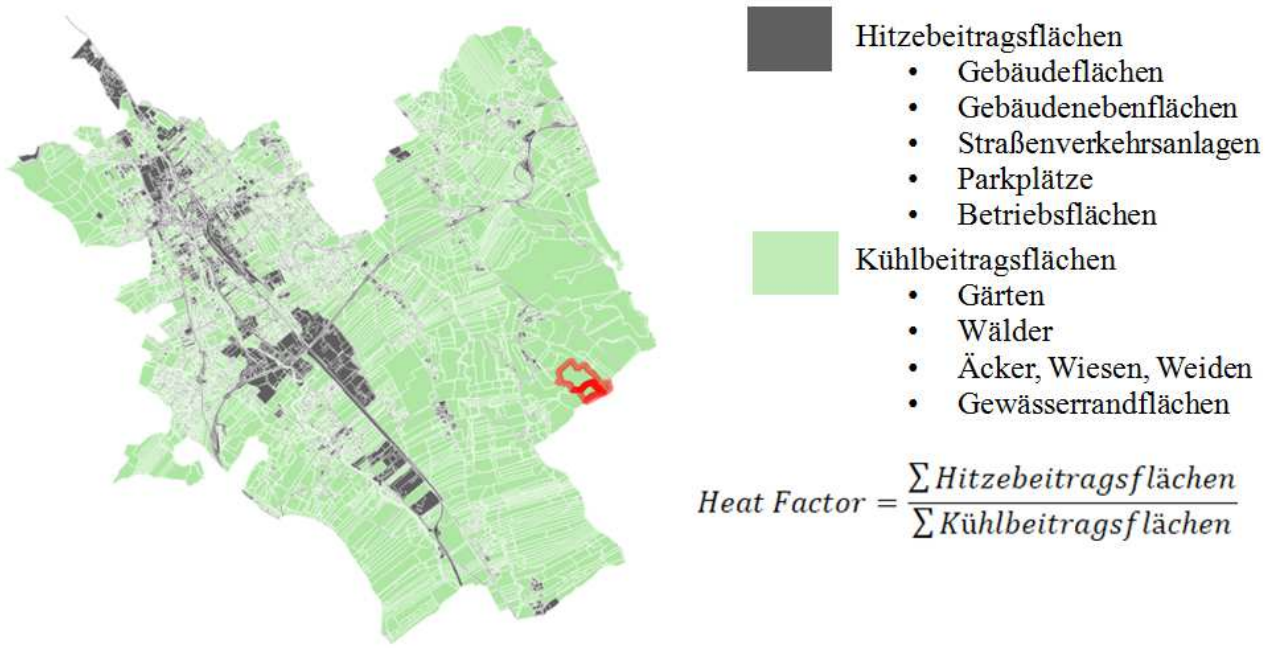


Abbildung 2: Identifikation von Flächennutzungen und Berechnungsformel des Heatfactors (Eigene Darstellung)

5.3 Die WebGIS-Applikation

Aktuell müssen außerhalb von Bezahldiensten viele unterschiedliche Datenquellen zur ganzheitlichen lokalen Klimarisikoanalyse herangezogen werden. Als Antwort auf diese zeit- und wissensintensive Problematik wurde eine neue WebGIS-Anwendung prototypisch entwickelt, die die verfügbaren Datenquallen vereint und so auf GIS-Basis eine präzise Kartendarstellung und quantitative Analyse ermöglicht.

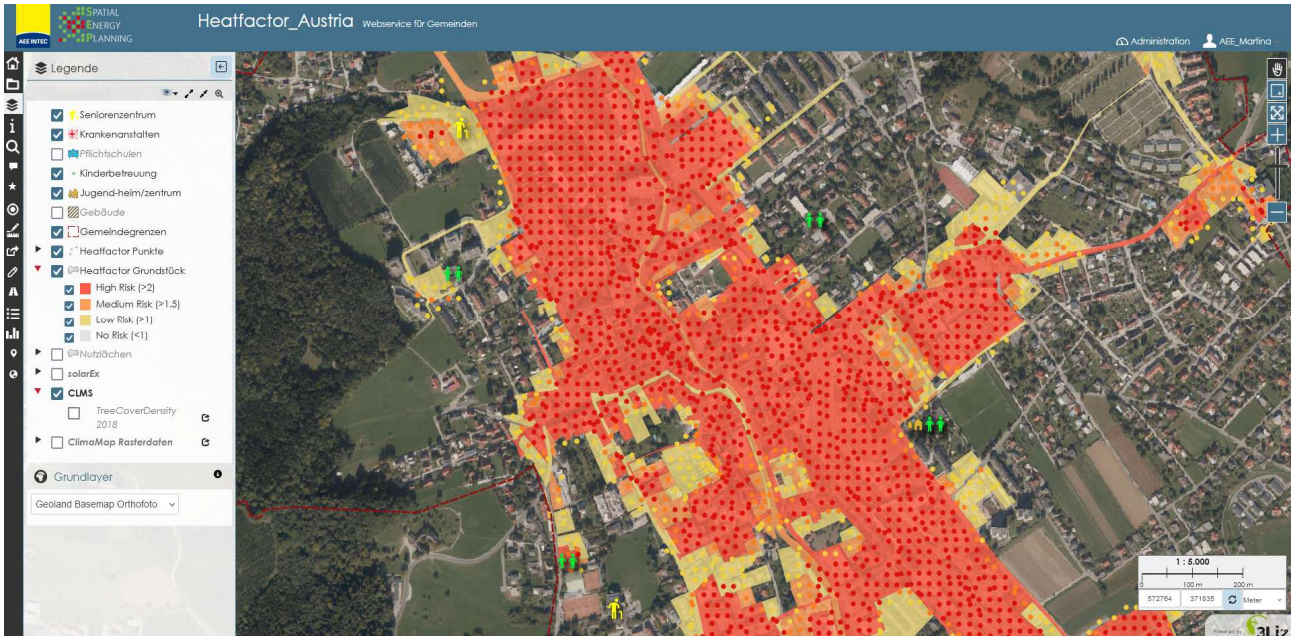


Abbildung 3: Screenshot der WebGIS-Applikation – Veranschaulichung der Risikozonen (Eigene Darstellung)

Dies umfasste die – soweit mögliche – Harmonisierung unterschiedlicher Datenquellen hinsichtlich räumlicher Auflösung, um eine vergleichbare Grundlage für die weitere Planung und Entscheidungsfindung in den Gemeinden zu schaffen. Die Anwendung ermöglicht eine Visualisierung von klimatischen Herausforderungen und bietet den Gemeinden ein detailliertes Verständnis der klimatischen Gegebenheiten ihres Gebietes um auf dieser Basis fundierte, datengetriebene Entscheidungen zu ermöglichen. Sie vereint die unterschiedlichsten Datenquellen in einer gemeinsamen interaktiven digitalen Umgebung und ermöglicht eine intuitive Handhabung für Gemeinden, unabhängig von deren GIS-Vorkenntnissen. Damit wurde den

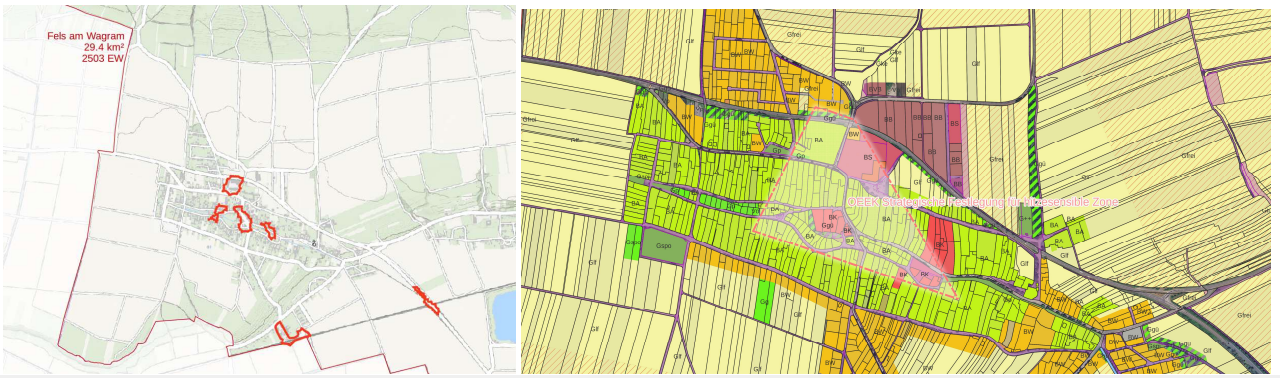
Pilotgemeinden eine benutzungsfreundliche Schnittstelle zur Verfügung gestellt, die es den Planungsverantwortlichen ermöglicht, komplexe Daten einfach abzurufen, zu analysieren und für die kommunale Entscheidungsfindung nutzbar zu machen. Funktion, mit der erstellte Analysen und Kartenansichten als Berichte exportiert werden können, geben den Verantwortlichen ein Werkzeug in die Hand, die Ergebnisse auch nutzungsfreundlich für politische Entscheidungsprozesse oder öffentliche Beteiligungsverfahren zu verwenden.

5.4 Prototypisches Planungsinstrument

Das prototypische Planungsinstrument kombiniert die Ergebnisse der Klimarisikoanalysen, die in der WebGIS-Applikation dargestellt werden, mit einem klar strukturierten Maßnahmenkatalog für den Handlungsbereich örtliche Raumplanung. Der Maßnahmenkatalog umfasst rund 80 Klimaanpassungsmaßnahmen, die die vier zentralen Themenfelder Hitze, Wasser, Erosion und Wind abdecken. Die Maßnahmen sind dabei so konzipiert, dass sie nicht nur auf die spezifischen Bedürfnisse der Pilotgemeinden zugeschnitten sind, sondern auch für andere Gemeinden in Österreich anwendbar und übertragbar bleiben. Der Fokus liegt auch in der Zuordnung von Klimaanpassungsmaßnahmen zu den unterschiedlichen Instrumenten der örtlichen Raumplanung, darunter das Örtliche Entwicklungskonzept (ÖEK)/Räumliche Entwicklungskonzept (REK), der Flächenwidmungsplan (FWP), der Bebauungsplan (BPL) und das Instrument der Vertragsraumordnung.

Die Verknüpfung von Maßnahmen gegen Klimarsiken können damit räumlich verortet werden und bestimmten Instrumenten zugewiesen werden, so dass der Weg der Umsetzung klar vorgezeichnet wird. Durch die Verknüpfung mit dem GIS-basierten Modell zur Erfassung von Klimarisiken können Gemeinden gezielt jene Flächen identifizieren, die aufgrund ihrer klimatischen Belastung besonderer Schutz- oder Anpassungsmaßnahmen bedürfen. Beispielsweise lassen sich Gebiete mit hoher Hitzebelastung durch Maßnahmen, wie Dach- und Fassadenbegrünung oder die Schaffung von Frischluftkorridoren, gezielt auf Bebauungsplanebene steuern. Für hochwassergefährdete Zonen könnten hingegen Maßnahmen, wie die Ausweisung von Retentionsräumen erfolgen – was in den meisten Fällen bereits geschehen ist. Allerdings fehlt bisher die Perspektive der landschaftsplanerischen Ausgestaltung solcher Retentionsräume, die wiederum wirksam sein können im Kampf gegen den Klimawandel.

Das prototypische Planungsinstrument ermöglicht Risikozonen zu erfassen und mit einer Liste an Gegenmaßnahmen zu hinterlegen. Damit werden wichtige Entscheidungsgrundlagen für die jeweilige Planungsbehörde geliefert. Es zeigt zudem auf unterschiedlichen Ebenen Möglichkeiten auf, gegen die Klimarisiken im eigenen Wirkungsbereich vorzugehen. Damit wird ein entscheidender Beitrag geleistet, die Implementierung von Maßnahmen an geeigneter Stelle zu operationalisieren, so dass aus einem abstrakten Sachverhalt eine konkretes Umsetzungsprotokoll abgeleitet werden kann.



fid	fid_m	Risikozone	Instrument	Widmungsstatus	Eigentumsstatus	Massnahme	Anmerkung
1	34	HTL	OEEK	BLB, BLU, VF, GL	P, G, OE	Strategische Festlegung für hitzesensible Zone	Sicherstellung des planerischen Willens für weitere Maßnahmen
2	4	HTL	FLWP	BLU, VF, GL	P, G, OE	Widmung Klimahain-Kühlfläche als Zusatz	Sicherstellung eines zusammenhängenden Grünraums als zentraler Bestandteil
3	62	HTL	FLWP	GL	P, G, OE	Erhalt von Grünlandwidmungen	Berücksichtigung bei Widmungsverfahren
4	63	HTL	KWB	GL	P, G, OE	Erwerb von Grünlandgrundstücken mit besonderer Bedeutung	Aktive Bodenpolitik für Grünraummanagement
5	64	HTL	BBPL	BLU, VF, GL	P, G, OE	Sicherstellung durchgängiger, begrünter Fußwegverbindungen	Angerbereich besondere Bedeutung zukommen lassen
6	10	HTL	FLWP	BLU	P, G, OE	Festlegung einer Grünlandwidmung in größeren Baulandfläch...	Parkanlage als Aufenthaltsraum

Abbildung 4: Veranschaulichung prototypischen Planungsinstrumentariums – Beispiel: Fels: Strategische Ebene (ÖEK) (Eigene Darstellung)

5.5 Stakeholder-Dialoge und Roadmap

In Stakeholder-Dialogen, die ein zentraler Bestandteil des Projekts waren, konnten zentrale Fragestellungen und Herausforderungen der Gemeinden reflektiert und die Erfahrungen von weiteren Fachpersonen berücksichtigt werden. Diese Dialoge, die in verschiedenen Projektphasen stattfanden, dienten dazu, die entwickelten Instrumente praxisnah abzustimmen und sicherzustellen, dass sie den tatsächlichen Bedürfnissen der Gemeinden entsprechen. Die Diskussionen zeigten, dass viele Gemeinden mit begrenzten personellen und finanziellen Ressourcen kämpfen, wodurch Klimaanpassung oft nur schwer umsetzbar ist.

Insbesondere die Notwendigkeit einfacher, praxisnaher Maßnahmen, klare Anreizsysteme sowie die stärkere Integration klimarelevanter Planzeichen in die Raumplanung wurden hervorgehoben. Vertreterinnen und Vertreter der Bundesländer betonten zudem die Herausforderungen durch den hohen Verwaltungsaufwand und sahen Potenzial in neuen Grünlandkategorien sowie der großräumigen Freihaltung von Klimaflächen. Während die Bereitstellung relevanter Planungsgrundlagen auf einer zentralen Plattform begrüßt wurde, gab es Skepsis gegenüber einem österreichweiten Rollout und politischen sensiblen Themen, wie beispielsweise der Rückwidmung von Bauland.

Im Rahmen dieser Beteiligungsprozesse wurde auch eine Roadmap zur Umsetzung von Klimaanpassungsmaßnahmen konzipiert. Diese Roadmap fasst die zentralen Schritte und Empfehlungen zusammen, die erforderlich sind, um die entwickelten Maßnahmen effektiv in den kommunalen Planungsprozess zu integrieren. Sie bietet den Gemeinden eine Orientierungshilfe und zeigt auf, wie sie die erarbeiteten Werkzeuge und Handlungsempfehlungen nachhaltig implementieren können. Ziel der Roadmap ist es, den Gemeinden praxisnahe Leitlinien bereitzustellen, die ihnen helfen, Klimawandelanpassung als festen Bestandteil ihrer Raumplanung zu verankern und gezielt Maßnahmen zu setzen.

6 FAZIT

Die WebGIS-Applikation zur Klimarisikoanalyse und das prototypische Planungsinstrument bietet den Gemeinden eine umfassende Unterstützung bei der systematischen Integration von Klimaanpassungsmaßnahmen in ihre Raumplanung. Durch die Kombination von Klimarisikoanalysen, strategischen Planungsinstrumenten und einem praxisnahen Maßnahmenkatalog erhalten Gemeinden eine datenbasierte Entscheidungsgrundlage, die es ihnen ermöglicht, gezielt auf lokale klimatische Herausforderungen zu reagieren. Besonders für kleinere Gemeinden mit begrenzten personellen und finanziellen Ressourcen stellt das Planungsinstrument eine wertvolle Hilfestellung dar, indem es strukturierte Maßnahmen zur Verfügung stellt und vorhandene Mittel effizient einsetzbar macht.

Ein wesentlicher Vorteil dieses integrierten Ansatzes ist die hohe Flexibilität der Anwendung. Gemeinden können sowohl kurzfristige Maßnahmen zur Schadensbegrenzung als auch langfristige Strategien zur strukturellen Anpassung an den Klimawandel entwickeln. Dies gewährleistet eine nachhaltige und praxisnahe Umsetzung von Klimaanpassungsstrategien, die auf wissenschaftlich fundierten Grundlagen basieren und dennoch an die individuellen Gegebenheiten der Gemeinden angepasst sind. Ein weiterer wichtiger Aspekt der WebGIS-Applikation und des Planungsinstruments ist die transparente und nachvollziehbare Kommunikation der geplanten Maßnahmen mit Stakeholdern, Bürgerinnen und Bürgern. Ein Rollout der WebGIS-Applikation sowie des prototypischen Planungsinstruments in die österreichischen Bundesländer kann maßgeblich dazu beitragen, Klimarisiken in der Raum- und Landschaftsplanung sichtbarer zu machen und auf verschiedenen Planungsebenen gezielte Maßnahmen zu etablieren. Die klare Visualisierung der Klimarisiken fördert zudem das Bewusstsein für die Notwendigkeit von Anpassungsmaßnahmen und unterstützt die aktive Beteiligung relevanter Akteurinnen und Akteure auf Gemeindeebene.

Zusammenfassend lässt sich sagen, dass die im Projekt entwickelten Instrumente den Gemeinden eine praxisnahe, datenbasierte und zukunftsorientierte Unterstützung bieten, um den Herausforderungen des Klimawandels effektiv zu begegnen. Sie helfen nicht nur dabei, klimatische Risiken frühzeitig zu identifizieren und geeignete Maßnahmen zu ergreifen, sondern bieten auch die Möglichkeit, Klimaanpassung als integralen Bestandteil der Gemeindeentwicklung zu etablieren. Die enge Einbindung von Stakeholdern in den Entwicklungsprozess hat dazu beigetragen, praxisrelevante und umsetzbare Lösungen zu schaffen, die auf breite Akzeptanz stoßen und eine nachhaltige Umsetzung begünstigen. Damit leisten die entwickelten

Instrumente einen wichtigen Beitrag zur klimaresilienten Entwicklung österreichischer Gemeinden und bieten ein übertragbares Modell, das auch anderen Kommunen als wertvolle Orientierung dienen kann.

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reviewed paper

hiWALK and hiBIKE: Co-created Indices to Foster Active Mobility for All

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1 ABSTRACT

Current accessibility analyses, which underlie the 15-minute city concept, assume that all streets are equally walkable and bikeable for everyone. This assumption implicitly neglects the needs of people with special mobility requirements, i.e. of the old and very young, people with disabilities, and risk-averse bikers. Stakeholders working to improve urban active mobility, e.g., NGOs such as Radlobby Austria or traffic planners such as PLANUM Fallast & Partner, require detailed information on the bikeability and walkability of the urban path network to lobby and/or plan for infrastructure that promotes active mobility and provides inclusive accessibility to essential services. To address this gap, HeiGIT's climate action team works with practitioners and NGOs to co-create street-level indices of walkability (hiWalk) and bikeability (hiBike) with direct practical applications. Going beyond summary values at the level of cities or neighborhoods, our street-level indicators facilitate integrating bikeability and walkability information into routing engines, thereby supporting accessibility analyses of "15-minute cities for all". Both hiWalk and hiBike incorporate indicators describing the urban street and path network in terms of user-friendliness, attractiveness, and safety. For example, the indicators identify walkable/bikeable paths and analyse their surface quality in terms of smoothness and type of material. hiBike also includes an indicator of "dooring" risk, based on street-side parking information. Both indices rely on open data sets, mainly OpenStreetMap (OSM), and can be tailored and applied across cities worldwide.

Since both hiWALK and hiBIKE are still under development, rather than presenting the indices' results, this paper will discuss the challenges encountered (1) during their application to starkly differing urban environments worldwide, and (2) due to the variability in OSM's data quality and completeness across regions. Additionally, we present our co-creation approach and discuss its benefits for index usability and policy impact. Besides continuing to refine the two indices, future research will also focus on assessing whether the results of our analyses align with the perceived walkability and bikeability in different streets, neighbourhoods, and cities. We conclude that several unique features of hiWalk and hiBike distinguish them from existing indices of active mobility. hiWalk and hiBike prioritise accessibility for all, explicitly considering users with special mobility needs. Moreover, through our plan to integrate our indicators into OpenRouteService (ORS), the mobility needs of the most vulnerable will be effectively captured in accessibility analyses and routing decisions. Finally, and most importantly, our co-creation approach renders feedback from stakeholders during the development process, which ensures the relevance and usability of the indicators in real-world urban planning and advocacy applications.

Keywords: open data, 15-minute city, biking, walking, planning

2 INTRODUCTION: WHY AIM FOR CO-CREATING INDICES FOR ACTIVE MOBILITY?

Cities around the world are grappling with the challenges of reducing carbon emissions, enhancing public health, and improving urban liveability, all while addressing the people's diverse mobility needs. Since the transport sector is a major source of CO_2 emissions and progress in reducing these emissions has been limited (Friedlingstein et al., 2023), advancing sustainable mobility has become a pressing priority. Walking and cycling (collectively referred to as "active mobility") are highly efficient, low-impact urban transport options, making their enhancement crucial for fostering healthier, more liveable cities. Active mobility, together with accessibility to the amenities required in daily life, are the two fundamental characteristics of a "15-minute city", in which daily essential services are within a short (e.g., 15 minutes) walking distance from any location in the city.

Interest in 15-minute cities – a novel framing of older urban planning principles – has exploded in recent years (Mouratidis, 2024). Cities in various continents started implementing initiatives to promote active mobility and local accessibility (Allam et al., 2024; Teixeira et al., 2024). Academics have conducted spatial analyses and developed indicators to assess how walkable and bikeable cities are, and how close they are to being 15-minute cities. So far, however, many of these analyses and indicators fail to consider the needs and perspectives of people with limited mobility, marginalized communities, and other stakeholders (Alves et al., 2020; Rhoads et al., 2023; Willberg et al., 2023).

Including diverse perspectives into mobility analyses is especially important given the potential of data-driven indicators to support urban planning and policymaking (Blečić et al., 2020; Đorđević et al., 2023). By combining a suite of indicators, active mobility indices typically assess one or more aspects of the environment that promote walking and cycling, often summarized as the 5 D's – density, diversity, design, destination accessibility, and distance to transit (Ewing & Cervero, 2010). Thereby, indices can – for example – help identify problematic areas, allocate limited resources to the infrastructure with the greatest potential to improve active mobility, and address social inequities (Su et al., 2019).

Despite their importance and relevance for urban planning and policymaking, active mobility indices are often developed for commercial purposes (e.g., WalkScore and Walkonomics) or academic research (e.g., Alves et al., 2020; Buck et al., 2011; Frank et al., 2005), and rarely incorporate input from actual urban planners or other key stakeholders, potentially limiting their usefulness in practice. At the same time, studies underscore the value of co-creation in research and software development (Abelein & Paech, 2015; Deserti et al., 2021; Stier & Smit, 2021). Co-created walkability and bikeability indices are collaboratively developed by diverse stakeholders, including urban planners, scientists, advocacy groups, associations, and local initiatives, combining data, expertise, and lived experiences. Therefore, co-created indices can be an important tool to support a shift in the urban traffic infrastructure towards sustainable mobility as one building block for healthier, climate-friendly, and more liveable communities.

In this paper we demonstrate our unique approach to co-create open-source indicators of walkability (hiWalk) and bikeability (hiBike). Our partners include non-governmental organisations (e.g., Radlobby Austria and Lagos Urban Development Initiative) and traffic planners (e.g., PLANUM Fallast & Partner). Our indicators' street-level perspective can lead to actionable insights, producing concrete and targeted recommendations for planners that help foster active mobility for all, going beyond generalized metrics of neighbourhood accessibility. While our indicators are still being refined through a continuous feedback loop with our partners and are still not aggregated into indices, we describe our plans for next steps, including the integration of the indicators into an online dashboard with global coverage. We also discuss some of the challenges of using open data such as OpenStreetMap, our scalable, local to global approach, the advantages brought by co-creation, as well as the potential implications for designing 15-min cities.

3 METHODOLOGY

3.1 Co-creation approach

Co-creation describes the process of collaborative problem solving for the design and content of products and services (cf. Prahalad & Ramaswamy, 2000). In the case of hiBike and hiWalk, stakeholders work together with HeiGIT's climate action team to define the respective index, outline its elements, and test and

enhance our prototypes. Specifically, our collaborative approach is based on a prominent co-creation method called "design thinking" (Rösch et al., 2023). This method entails a shift in perspective to prioritize the partner's viewpoint. Rather than perceiving stakeholders as customers, we engage with them in a partnership as equals. This pivotal element of our co-creation approach facilitates the reciprocal exchange of diverse expertise, experiences, and approaches that prove mutually beneficial. Through frequent contact with our partners, our indices undergo short, regular and direct feedback loops, which allow for direct application and checking of the results in practice.

In order to establish a structured environment conducive to active, creative, concrete, and solution-oriented work on the development of indices, we create virtual collaborative workspaces for our partner workshops. The objective is to leverage a variety of viewpoints and competencies to create indices that indeed make a difference, as these indices are intended to be used by a diverse array of stakeholders, including city and traffic planners, administrative bodies, NGOs, citizen initiatives, and other communities of practice. In a series of ideas incubation workshops, our partners work with us to define what we are trying to achieve, how we measure success, define potential indicators, and prioritise them. An important asset is the joint formulation of user stories and a clear definition of the content and the type of data outputs required for a given version of the index, as well as their fitness for purpose.

Whilst the benefits for the respective co-created indices are obvious and foster knowledge growth for all partners, there also is a certain price to be paid. Co-creation means an additional workload, not only because of workshops to incubate indicator ideas, but also meetings to align and manage expectations, usefulness, and feasibilities between all collaborators. Different sources of knowledge, i.e. reaching from "on the ground" and in different urban environments up to theoretical and conceptual research, need to be synchronised and checked for validity. Furthermore, there might be an increased risk of example-based development that might limit the generalisation of results.

In addition to these individual virtual collaborative workshops, we are planning to have one or more in-person sandpit workshops. Sandpit workshops are especially designed to foster collaborative problem solving and idea generation. In comparison with regular workshops, they are more immersive, designed for inter- and multidisciplinary contexts, facilitated by experts, and via iterative ideas incubation highly outcome-oriented (Alber, 2020). In a typical sandpit workshop, participants initially engage in open-ended thinking for the first few days, setting aside their usual disciplinary and institutional boundaries to explore how collaboration could unfold without these constraints. The later stages focus on refining and narrowing down these creative concepts, and transforming them into concrete project ideas, which are further developed in a more conventional manner after the event. A sandpit workshop is an experimental space that allows us to go beyond traditional disciplinary boundaries and to pursue novel research and software development approaches.

3.2 Open data and open source

To maximize the potential impact and usefulness of our indices, we aim to base them on open and, as far as possible, also freely accessible data and software tools. Our primary source of spatial data is OpenStreetMap (OSM), a database of crowdsourced geographic information sometimes referred to as the 'Wikipedia of Maps'. Contributors from around the world can add all types of spatial information to OSM, as long as it is not private information and it can be verified independently on the ground. A distinguishing feature of OSM is the wealth of meta-information in the form of tags that its contributors can add to the OSM data. As such, OSM not only displays the network of cycling paths in a city, for example, but can also show the properties of each path, such as their width, number of lanes, surface material and smoothness.

Since OSM was created with a strong focus on car navigation and routing, it has very complete data on the global street network, but relatively poor and heterogeneous coverage of data relevant for active mobility analyses (Mobasheri et al., 2015, 2018; Vierø et al., 2025). This focus is due partly to the more apparent importance of streets for navigation and transportation, but also to the fact that non-car data means many more paths, complexity, and diversity, so the task of getting a decent database is much bigger than for streets. A particular challenge for hiWalk is the lack of a universally preferred method for mapping sidewalks in OSM. Contributors can either tag sidewalks as attributes of roads or map them as separate ways. The lack of standardisation as well as the sheer complexity of the topic can lead to inconsistencies and

omissions in sidewalk data. However, in well-mapped areas, OSM contains a wealth of information about the presence and quality of infrastructure for walking and cycling, as well as about points of interest, land use, green spaces, and other urban features that affect active mobility. To enrich and complement spatial data in OSM and its meta-information, we use publicly available Sentinel 2 satellite imagery from Copernicus and SRTM (Shuttle Radar Topography Mission) data. In addition, we investigate the potential of street level imagery as well as other community-sourced datasets to improve the database of our indicators.

In the first half of 2025, our indices of bikeability (hiBike) and walkability (hiWalk) will be available to the public through a dedicated online dashboard in which users can conduct tailored analyses for their area of interest anywhere in the world. We use Python for all spatial data processing, analyses, and visualisations and will publish our code under an Open Source license along with the online dashboard. Open source code can be checked, reused, modified, and redistributed by others, increasing our indices' usefulness and impact.

3.3 Indicators

Harnessing the power of open spatial data, and guided by the requirements and experience of our partner stakeholders, hiBike and hiWalk have evolved to include a series of metrics (i.e., indicators) describing aspects relevant to active mobility at the street segment level. To produce inclusive assessments of bikeability and walkability, our indicators take the perspective of the most vulnerable, such as children, the elderly, and people with disabilities.

Note that both hiBike and hiWalk are still work in progress and the description of the indicators below refers only to their current version, and may change in the future. Also, in sake of conciseness, we focus the methods and results of this paper on hiWalk, but similar and equivalent indicators exist in hiBike.

3.3.1 Classifying urban cycling and pedestrian infrastructure: Who do I share this path with?

The first step in our assessment classifies walking or cycling infrastructure by accounting for with which other users a pedestrian or cyclist has to share the infrastructure. This classification and ranking, based on OSM tags, is meant to serve as a proxy for the safety and comfort of road segments for walking and cycling, as well as for the overall quality of a city's walking and cycling infrastructure. For example, previous studies have proposed to classify urban streets based on traffic stress levels (Huertas et al., 2020), which aligns with how we define bikeability categories in hiBike. Table 1 displays the walkable path categories and their explanation. hiBike classifies bikeable paths into equivalent categories, with an extra group for paths where cyclists are required to dismount (e.g., train platforms, certain bridges, and pedestrian zones).

Walkable path category	Description
Designated	Sidewalks, pedestrian streets, and other walkable areas where no motorised vehicles are allowed. They are considered the safest and most comfortable for walking.
Designated, shared with bikes	Paths where both walking and cycling is allowed. These paths are also generally safe, but many walkers feel uncomfortable sharing their path with cyclists.
Shared with motorised traffic low speed (walking speed)	Streets without sidewalks in which pedestrians need to share the street with cars. In these the risk of much more serious traffic accidents and potentially more noise and air pollution is generally higher. Streets shared with cars but with a speed limit up to 5 km/h (e.g., living streets) are still considered safe and comfortable for active mobility.
Shared with motorised traffic medium speed (<= 30 km/h)	Streets without sidewalks in which pedestrians need to share the street with cars. In these the risk of much more serious traffic accidents and potentially more noise and air pollution is generally higher. Streets shared with traffic up to 30 km/h are at the edge of being too dangerous to walk on, depending on their traffic volume.
Shared with motorised traffic high speed (>= 50 km/h)	Streets without sidewalks in which pedestrians need to share the street with cars. In these the risk of much more serious traffic accidents and potentially more noise and air pollution is generally higher. Streets shared with traffic up to 50 km/h are uncomfortable and, most importantly, dangerous for walkers.
Shared with motorised traffic of unknown speed	Streets without sidewalks in which pedestrians need to share the street with motorised vehicles, but where the speed limit is unknown.
Not walkable	Streets shared with traffic faster than 50 km/h are considered too dangerous and grouped as unwalkable, with other streets where pedestrians are not allowed (e.g., due to access restrictions).
Unknown	Streets and paths without enough tag information in OSM to be categorised.

Table 1: Definition and rationale of hiWalk's walkable path categories

3.3.2 Analysing path surface type and smoothness: Who can safely and comfortably walk here?

Even if a street has a sidewalk or a cycle path, other factors may hinder active mobility. Sidewalks and paths can be poorly maintained and too bumpy, muddy, or slippery to be used safely by everyone. A smooth path surface is especially important for people in wheelchairs or requiring walking frames (Pearlman et al., 2013).

The surface quality indicator is based on the values of the OSM tags "smoothness", "surface", and "tracktype" (in order of their evaluation). While the values of "smoothness" correspond directly to the

surface quality, they are only sparsely mapped. We therefore also use “surface” and “tracktype” as a proxy to complement the data. In doing so, we consider that for a given surface type there might be a wide variety in the maintenance status and thus only yield a conservative estimate for the surface quality. This is to reflect our commitment to creating our indicators from the perspective of the most vulnerable, for whom a poor surface quality can become a major obstacle. To highlight the uncertainty of the maintenance status, we add the prefix "potentially" to values of the surface quality that are derived from the surface type. Exceptions are surface types like sand, which can be confidently categorised to be poor in any case. Table 2 presents a full list of the surface quality categories and their explanation.

Surface quality	Description
Good	Relatively smooth surface (e.g., asphalt with minor cracks and holes). Thinly wheeled vehicles – such as wheelchairs, walking frames, and prams – can roll with only minor vibrations.
Potentially good	Surface smoothness is unknown, but inferred based on surface material. For example, asphalt paths are classified as “potentially good”.
Mediocre	Irregular surface where walking and particularly using thinly wheeled vehicles is challenging and uncomfortable. Some surface types, such as cobblestones, are assigned to this category.
Potentially mediocre	Surface smoothness is unknown, but inferred based on surface material. For example, paths covered with gravel are classified as “potentially mediocre”.
Poor	Surface is so bumpy and irregular that walking is very uncomfortable and potentially dangerous.
Unknown	Paths and streets without enough tag information in OSM to be categorised into any of the groups above.

Table 2: Surface quality categories in hiWalk

After developing this indicator for hiWalk and receiving feedback from diverse partners, we decided to disaggregate surface quality in hiBike into its different components: surface smoothness, surface material, and maintenance state. Breaking down surface quality into its components is important to understand the results and find out what interventions are needed to address surface quality issues.

3.3.3 Measuring street connectivity: How big of a detour must I take to reach my surroundings?

Beyond having safe, comfortable, and attractive paths, urban environments fostering active mobility must arrange these paths into a dense and well-connected network, facilitating access to surrounding locations. Since active mobility is typically slower than motorized traffic, detours have a greater impact on travel time. This can be compensated for by dense networks and, in particular, good network connectivity, which gives pedestrians the opportunity to shorten their journey by taking more direct routes. Good connectivity is important to promote pedestrian accessibility to basic services and daily needs (i.e., 15-minute cities).

hiWalk's “detour factor” indicator divides the area of interest into a hexagonal grid and, for each grid cell, it shows how much longer it takes on average to walk to the center of the six neighboring cells compared to traveling in a straight line. The optimal value is 1, meaning that a grid cell is connected with straight paths to all its surroundings. A value of, for example, 2, means that on average one needs to walk twice as long as the straight distance to the surrounding cells.

We plan to implement this indicator in hiBike as well, where it will function in the same way except that the neighborhood of analysis will be much larger in most cases, since cyclists can travel faster than pedestrians can.

3.3.4 Integrating satellite imagery to assess green and blue infrastructure: How “natural” are this street’s surroundings?

Comfort and safety are fundamental for active mobility, but a street might have a smooth sidewalk or cycling lane and still be unattractive for pedestrians and cyclists if the surrounding environment is perceived as ugly, stressful, or uninteresting (Adkins et al., 2012; Borst et al., 2008). One of the most important factors influencing the attractiveness of environments for active mobility is the presence of vegetation, water bodies, and other natural environments (Bialkova et al., 2022; Borst et al., 2008; Yang et al., 2019). Urban vegetation and water bodies also can have positive effects on mental health (Hidalgo, 2021; Sousa-Silva et al., 2025; Völker & Kistemann, 2011), air quality (Kumar et al., 2024; Leung et al., 2011), and heat island mitigation (Lin et al., 2020; Melaas et al., 2016). To quantify the abundance of vegetation on and next to streets, we use Sentinel-2 satellite imagery to measure the annual median Normalized Difference Vegetation Index (NDVI) in a 10-m buffer around each road segment. High values correspond to areas with trees and natural vegetation, such as forests and parks, while low values indicate streets surrounded by built-up areas

with little greenery. While the naturalness indicator is currently only available in hiWalk, we plan to incorporate the exact same metric into hiBike.

3.3.5 Considering topography: How steep is this street?

The slope indicator displays the slope of a street or path as a percentage value, using Shuttle Radar Topography Mission data with a resolution of approximately 90 m. The indicator uses this data to calculate the elevation difference between the two ends of a street segment, and thereby the street's average slope. The indicator categorises inclines from "steep" (greater than 12 % gradient) to "manageable" (less than 6 %). It takes into account research suggesting that a 1 % increase in slope makes walking about 10 % less attractive (Alves et al., 2020; Meeder et al., 2017). Similarly, slope generally has a negative effect on bikeability (Ito et al., 2024), while steep slopes can even endanger cyclists due to higher speeds when descending (Castañon et al., 2024). The slope indicator is currently only available in hiWalk, but will be incorporated in hiBike as well because steep paths can hamper bikeability even more strongly than walkability.

4 RESULTS & DISCUSSION

4.1 Results for different cities and what they can tell us about the fitness for purpose of OSM

As a research institute based in Heidelberg, we usually carry out the first tests of our indicator prototypes in our hometown. One reason for this is our own experience as pedestrians and cyclists in this city. Another reason is the active OSM community in and around Heidelberg, which has created a comparatively complete database on street smoothness (Fig. 1a) that allows us to highlight the potential of OSM for mobility indicators in well-mapped regions. However, in contrast to streets, the smoothness of sidewalks is only sparsely mapped even in Heidelberg. As described above in the methods section, we therefore use "surface" (indicating surface type, such as asphalt or cobblestones) and "tracktype" (indicating maintenance state) as proxies to complement the data. As this information is comparatively frequently available in Heidelberg, our surface quality indicator reveals that most walkable infrastructure in Heidelberg is potentially smooth enough for comfortable walking (Fig. 1c), although there are clusters of paths with poor surface quality near the train station and in the forest area east of the city. In contrast, in Amersfoort, OSM smoothness data is rare for streets and entirely absent for sidewalks (Fig. 1b). Even "surface" data is frequently missing in Amersfoort, and as a result hiWalk categorizes the surface quality of most paths as "unknown" (Fig. 1d).

This paucity of data about the quality of the pedestrian infrastructure highlights the need to use additional data sources to complement OSM and improve the consistency and global coverage of our indicators.

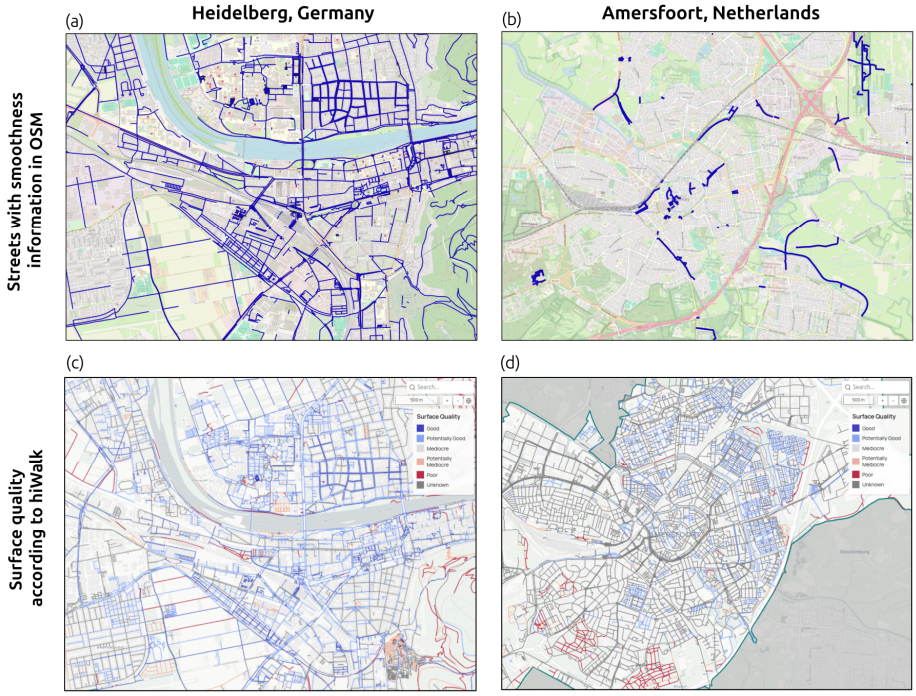

Fig. 1: Map of Heidelberg (a) and Amersfoort (b) showing streets with road smoothness information in OSM (blue lines). Data coverage in well-mapped cities like Heidelberg enables the creation of useful indicators to inform active mobility planning (c), in contrast to sparsely mapped cities like Amersfoort (d).

The same pattern, albeit less markedly, emerges when classifying pedestrian infrastructure according to the users that share the path/street. Information about the presence of sidewalks alongside streets is very important for this indicator, but the coverage of this indicator also varies starkly across different cities (Fig. 2). In its current version, hiWalk assumes that streets without sidewalk tag information in OSM do not have sidewalks in the real world, which is often not true. As a result, hiWalk currently underestimates the quality of walking infrastructure in in poorly mapped cities such as Amersfoort.

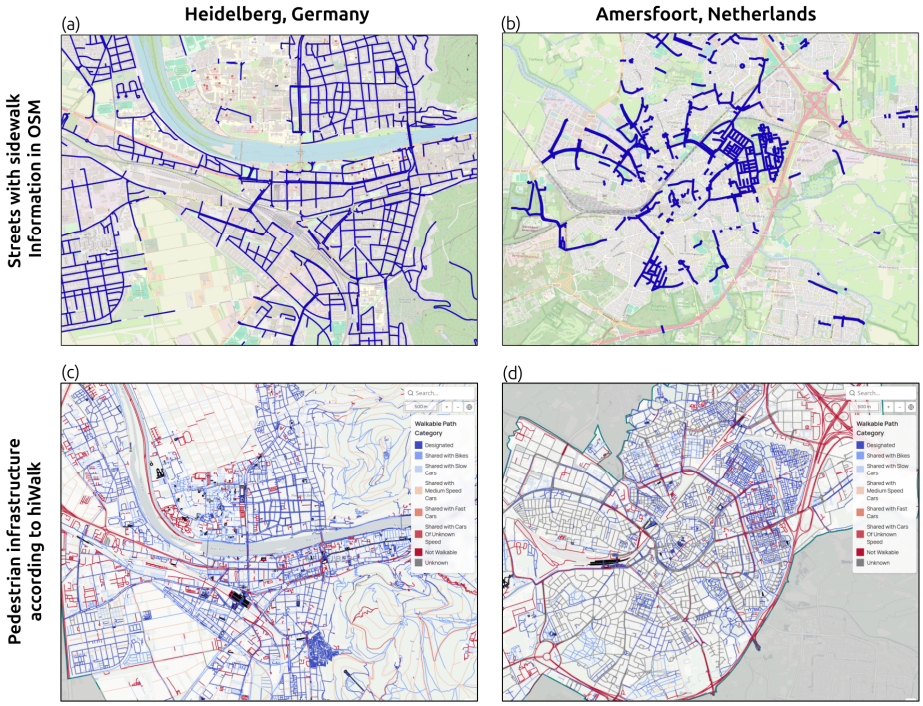

Fig. 2: Map of Heidelberg (a) and Amersfoort (b) showing streets with sidewalk information in OSM (blue lines). More complete sidewalk information in well-mapped cities like Heidelberg results in less uncertain indicators of pedestrian infrastructure (c), in contrast to sparsely mapped cities like Amersfoort (d).

4.2 Results for two extremely different cities: Why transferability matters

Researchers, urban and transport planners, and other stakeholders inadvertently tend to transfer their everyday experiences and realities to other places. Many of the current active mobility indices are applied to cities and regions around the world. However, these indices' underlying assumptions do not necessarily apply to other regions, especially when they have been developed in and for one context and are then transferred to a very different one.

Like many other indices of bikeability or walkability, hiBike and hiWalk aspire to be globally applicable. However, our approach is different in that we work with local stakeholders to adapt our indices regionally. For hiWalk, for example, we were able to collaborate with LUDI (Lagos Urban Development Initiative) in Nigeria, an organisation with a large interest to improve walkability in Lagos. In the following paragraphs, we will demonstrate why our Walkable Path Categories indicator within hiWalk is a prime example for the importance of this approach and for the significant difference it will ultimately make.

hiWalk categorises streets with sidewalks as having designated pedestrian infrastructure – interpreted as safe and comfortable – and streets without sidewalks as requiring pedestrians to share the road with motorised traffic – interpreted as unsafe and uncomfortable. This is based on the assumption that motorised traffic occurs more or less everywhere in a city so that designated pedestrian infrastructure makes a big difference in terms of safety and comfort. However, this assumption does not hold true everywhere. Comparing car density, income inequality, and average income between Heidelberg (Germany) and Lagos (Nigeria) will give us more insight into why this is so.

Car density is the ratio between the number of cars and the number of inhabitants in a given geographical area. In 2021, there were 388 cars per 1000 inhabitants in Heidelberg (Stadt Heidelberg, 2024), and around 322 cars per 1000 inhabitants in Lagos (cf. https://www.ceicdata.com/en/indicator/nigeria/motor-vehicle-registered, https://worldpopulationreview.com/cities/nigeria/lagos; note that the calculation of car density in Lagos is uncertain due to contradicting official population numbers). At first glance, car density seems very similar in both cities. However, differences in income level and distribution, with lower and more unequal incomes in Lagos, also need to be taken into account. Lagos is among the cities with the greatest income inequality, with a Gini coefficient of 0,64 (WorldAtlas, 2019). While there is no Gini coefficient available for Heidelberg, for its federal state (Baden-Württemberg) it is 0,29 (Statistische Ämter des Bundes und der Länder, 2023). Moreover, the average monthly income in Lagos is $207,61 (median income in Heidelberg in 2022: $4250) and by 2026 the city could have a poverty rate of more than 50 % (EARLY, 2024). As a result, the distribution of car ownership within Lagos is very uneven, resulting in congested districts on the one hand and more or less car-free districts on the other. These figures highlight the need for local knowledge when interpreting data: We cannot assume that ‘shared with motorised traffic' means poor pedestrian safety and comfort in those largely car-free districts and areas of Lagos. Therefore, we also cannot assume that the interpretation of hiWalk’s pedestrian infrastructure categories is valid in cities with uneven spatial distributions of car ownership and traffic volume, such as Lagos. We were made aware of our wrong assumptions during our collaboration with LUDI, and are currently co-developing a version of hiWalk tailored to Lagos, which could potentially be applied to other West African cities.

4.3 hiBike and hiWalk results and the 15-min city: Just because a route is short, doesn’t make it good

A future task of HeiGIT’s climate action focus group is to integrate our active mobility indicators into OpenRouteService (ORS, https://openrouteservice.org/), an open-source routing engine built on OSM data. Current routing services and accessibility analyses, which underpin the popular 15-minute city concept (Moreno et al., 2021), typically assume that all streets are equally bikeable and walkable for everyone. As a result, they focus solely on travel time, overlooking not only the diverse experiences and specific needs of different population groups, such as older adults or children, but also that subtle urban design elements influence walkability (Ewing et al., 2006). However, urban planners require detailed insights into how the bikeability and/or walkability of street networks influences active mobility across all citizens to implement effective measures that ensure equitable access to essential services.

Fig. 3: Implementing hiBike and hiWalk into OpenRouteService (ORS) to generate routes optimised for active mobility rather than just the shortest or fastest paths. Considering walkability and/or bikeability in routing can help quantify how close cities are to being a “15-minute-city for all”.

To bridge this gap, we take first steps toward integrating hiBike and hiWalk into a routing engine (cf. Fig. 3). This integration will enable us to generate routes optimised for active mobility rather than just the shortest or fastest paths. By incorporating hiBike and hiWalk into accessibility analyses, it becomes possible to calculate a truly “bikeable and walkable 15-minute city”. To this end, we will adjust the routing algorithm’s cost function to incorporate bikeability and walkability alongside cycling/walking duration, prioritising safer and more pleasant routes even if they are slightly longer. With this enhanced routing service, accessibility

analyses can account for safer and more pleasant active mobility routes when determining access to essential services such as supermarkets or healthcare facilities.

5 CONCLUSIONS

Our findings show the opportunities and challenges of developing active mobility indices that can be applied to cities worldwide. While OSM serves as a good baseline for data-driven active mobility analysis, our results stress that OSM data has to be complemented with other (open) data sources to obtain a more complete understanding of the infrastructure for active mobility. Global analyses of accessibility and active mobility must account for the stark differences in data availability, recency, and completeness in cities around the world.

Another key finding of our work is the influence of regional disparities on the applicability of bikeability and walkability indices. The case of Lagos shows that basic assumptions, such as the impact of pedestrian infrastructure on walkability, cannot necessarily be extended to widely varying urban settings. This underscores the need for co-creation with local stakeholders to ensure the indices are applicable and relevant. Our approach of co-creating hiWalk for West African cities with its consideration of local context illustrates that inclusive and context-aware mobility assessments are needed for sustainable traffic planning in urban areas worldwide. At the same time, these findings raise questions concerning the ethics of transferring data-driven models across different socio-economic and infrastructural contexts. Although universal applicability is desirable, the potential for misinterpretation and misapplication underscores that an iterative validation with local experts is essential.

The integration of hiBike and hiWalk into an open routing service algorithm will be started soon. The current state of accessibility analyses often overlooks the qualitative aspects of walking and cycling experiences, focusing instead on travel time efficiency. By integrating active mobility indicators into ORS, we aim at a more holistic understanding of urban mobility that will enable planners to design truly accessible (15-minute) cities.

hiBike and hiWalk demonstrate the potential of co-created, open-data-informed indices of active mobility. Even more than that, they highlight the challenges in constructing active mobility indices that are applicable worldwide. With the help of local insights and by integrating multiple data sources, we are sure it is possible to create more effective indices to support sustainable and equitable mobility worldwide.

Despite the challenges and limitations that we currently face while developing hiWalk and hiBike, the co-created nature of these pilot indicators offer a unique and important innovation in the field of active mobility analyses. Our co-creation approach renders real-world feedback from stakeholders during the entire development process, from the conception of indicators, to their prioritization, implementation, and refinement. This synergistic transdisciplinary process ensures the development of indicators that are relevant to stakeholders, directly applicable, easy to understand, and based on sound methods and the latest science. Several innovative aspects of hiWalk and hiBike show the early fruits of this co-creation process.They focus on mobility and accessibility for all, explicitly considering people with special mobility needs. They harness high-resolution open geodata to assess mobility at the street-segment level. And last but not least, they will soon be integrated into a routing engine (OpenRouteService) to account for walkability and bikeability in accessibility assessments and routing.

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Innovation in Informal Settlement Upgrading: A Case of Johannesburg

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1 ABSTRACT

Globally, rapid movement from one state to another, mostly from under-developed areas to developed areas takes place. When this movement happen, there is a need for provision of accommodation. Due to lack of proper housing affordability and socio-economic inequalities lead to formation of informal settlements. In Johannesburg there is an increase of informal settlements across the city and now some of these informal settlements developments emerge close to the Central Business District (CBD). Accordingly, the increasing of these settlements create challenges for urban development and service delivery. Traditional approaches to informal settlement upgrading have often fallen short in addressing the complex and dynamic needs of residents. The aim of the study is to explore innovative strategies and technologies being implemented to improve living conditions in Johannesburg's informal settlements, focusing on infrastructure development, housing solutions, and community participation. A case study research approach is deployed to examine key upgrading initiatives, including in-situ upgrades, smart infrastructure, and participatory planning approaches. Consequently, assesses the effectiveness of these interventions in enhancing access to basic services, and promoting social inclusion. Technological innovations stategies have demontrated the ability to improve housing quality and urban resilience, challenges such as land tenure security, policy constraints, and resource limitations persist. The findings of the study aim to provide insights into the evolving landscape of informal settlement upgrading in Johannesburg, offering recommendations for scalable and sustainable solutions that can be replicated in other urban contexts.

Keywords: urban innovation, participatory planning, informal settlements, service delivery, sustainability

2 INTRODUCTION

Accomodation is a need for all individuals. The Republic of South Africa is a developing country working towards being a transitional country. The republic is trying in various aspects to provide high quality infrastucture. There are various housing projects to ensure that there is enough housing in the republic. However, most of these housing developments are not afforded by all South African residents. Therefore, leading to some individuals opting for informal housing. The City of Johannesburg afford various economic opportunities to various individuals which attracts many people to the city. As more people move in, there is a need for accomodation to all these indivisuals whom are from different classes regarding socio-economic status ranganging from low class income, middle class income to high class income. Some individuals afford proper housing accomodations such as apartments and bond housing. Some individuals do not afford proper housing accommodation and to those who do not afford they settle for backyard rooms, backyard shacks and informal settlements. Due to some informal settlements become populated, more formation of informal settlements emerge. The city has struggled for many years to curb the growth of informal settlement formation which in a long run they lead to various challenges in the city straining the available infrastructure. However, due to the informal settlements have emerged and many people are living in these areas. There is a need to upgrade these settlements and provide proper service delivery, and infrastructure to ensure functionality. Accordingly, technological innovations have proved to play a critical role in various disciplines to improve efficiency and functionality.With this, the study aim to identify suitable methods and technologies that coud be used to enhance informal settlements using the City of Johanneburg as case study.

3 BIBLOMETRIC LITERATURE REVIEW

The use of biblometric mapping of literature has been adopted for this study. This is to identify suitable literature for this study and identify most of the common themes researched on related to informal settlement upgrade, technological innovation and South Africa. This provides a summary of themes that are most studied and or that need attention.

Figure 1: Keyword co-occurrence network visualisation

The above figure1 indicates a biblometric mapping of literature about authors keywords. These keywords indicate the most used keywords related to the study. There are 9 items (keywords), 3 clusters, 11 network links, 12 total link strength, and there is a total of 27 occurences by the top 9 keywords selected for this study. The top keywords are Cape Town, informal settlements, South Africa, challenges, informal settlement, off-grid energy, open data, sanitation, and innovative technology. Accordingly, links indicate the connection between various keywords in the biblometric mapping of literature, and the occurences shows how much a keyword has appeared in the networks. Furthermore, the total link strengths highlights that which keywords are most connected to other keywords indicating that most author's studies focuses on such.

The authors keywords formed 3 clusters that are indicated by different colours. Each cluster has subfields that most authors work focuses on. In cluster 1, there are four keywords indicated by red node which include challenges, off-grid energy, informal settlement and innovative technology. This cluster indicates that some of the works done focused on challenges to provide off-grid energy to informal settlements and or deploying innovative technology to provide solutions for informal settlement challenges. In cluster 2, there are three keywords represented by a green node which include Cape town, informal settlements, and open-data. This cluster highlights that various studies focused on trying to push the notion of the provision of open-data of informal settlements in Cape town. In cluster 3 there are two keywords represented by a blue node which include sanatation and South Africa. The cluster indicates that there is a connection of works conducted in South Africa and sanisation, which this highlights that there is a need of proper sanitation for many areas or informal settlements in South Africa. In cluster 4 represented by a yellow node, there are also five keywords such as carsharing, jitneys, micromobility, paratransit, and station cars.

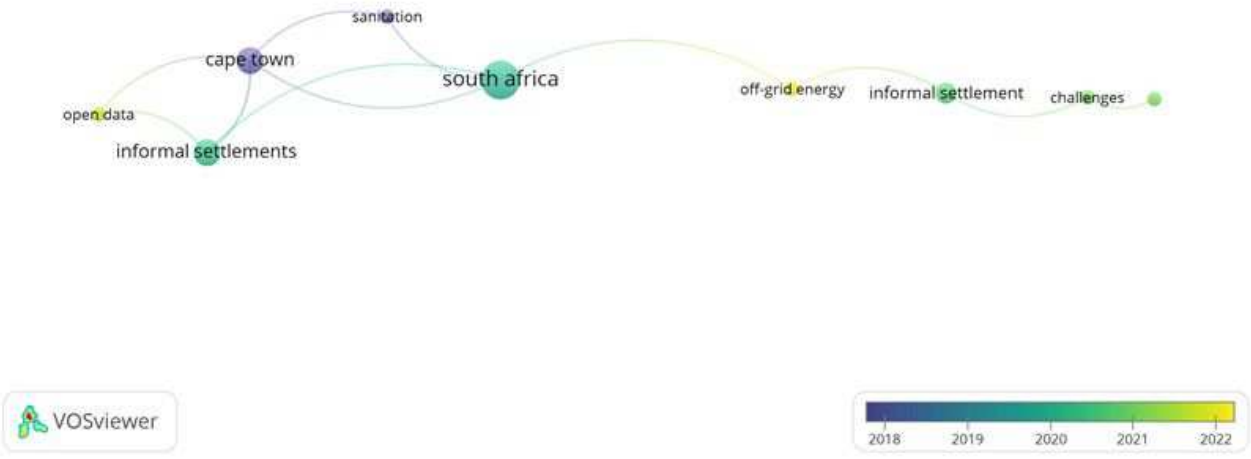

Figure 2: Keyword co-occurrence overlay visualisation

The above figure 2 highlights the publication themes that were most trending from the year 2018 to the year 2022. Consequently, this indicates that studies on informal settlenment upgrading with the use of technological innovations started to gain traction from the year 2018 to date. However, there are very few studies conducted related to this study which highlights that there is more research that could be done in this area. As seen on the above keyword co-occurrence overlay visualisation, there are few keywords that are creating a network of authors keywords, indicating that this research area in South Africa has not been explored sufficiently to assist provide positive impact using this approach of informal settlement upgrading through technological innovations. During 2018, studies conducted related to the study focused on improvements of sanitation in the City of Cape town. Around 2019 and 2020, there was increased of studies focusing on provision of off-grid energy and proper sanitation for informal settlements in Cape town, South

Africa. In 2021, there was a significant boost in moving towards publications that focus on introducing technological innovations to provide solutions for challenges in informal settlements. From 2021 to 2022, more research studies were conducted on the provision of off-grid energy in informal settlements, in South Africa. Consequently, some of the studies focused on the provision of open data for informal settlements in Cape town.

4 APPROACH AND METHODOLOGY

The use of biblometric mapping of literature has been deployed for this study. The use of biblometric mapping of literature assist to identify common research areas related to informal settlements, upgrading, technological innovation and South Africa, and this allow the study to identify a literature gab. 42 publications were downloaded on scopus which included conference papers, journal articles and book chapters. The keywords selected were informal settlement, upgrading, and South Africa. Only three keywords were used to ensure that the researcher obtain most suitable publications and also if more keywords are added no publication is obtained. During the data cleaning process, the abstracts of all publications generated were examined and 8 publications were ommited due to not being relevant to the current study. Therefore, 34 publications were selected and exported to a excel sheet csv document to provide a suitable file that VOSviewer allow for biblometric mapping of literature. Accordingly, the excel sheet was inserted in the VOSviewer to start the process of biblometric mapping of literature. Accordingly, the type of analysis chosen is co-occurrence and the unit of analysis selected are authors keywords. Consequently, the threshold chosen is based on the number of occurrences of a keyword should appear twice. Initially, 142 keywords were generated, and when the threshold was selected, only 9 keywords meet the threshold. These keywords included Cape town, informal settlements, South Africa, challenges, informal settlement, off-grid energy, open data, sanitation, and innovative technology. Therefore, the results produced figure 1 representing keyword of co-occurrence network visualisation and figure 2 representing keyword co-occurrence overlay visualisation.

Further, a case study research design was deployed focusing on the City of Johannesburg informal settlements due to the rising settlements across the city. Accordingly, a qualitative approach was deployed where semi-interviews were conducted with informal settlement dwellers and key officials, as well as the use of biblometric analysis. A non-random sampling was used to selected 60 informal settlement dwellers from 4 different settlements, and in each settlement, 15 semi-interviews were conducted. Consequently, A random and snowball sampling was selected as 5 Town planners were purposively selected and 5 references of Town planners were provided.

5 RESULTS AND ANALYSIS

This section provides the results and analysis of informal settlement dwellers and the key officials responses from the semi-interviews conducted regarding this study.

5.1 Informal settlement dwellers responses

Informal settlements provide accommodation to many individuals in the City of Johannesburg and there are over 312 informal settlements sheltering 7.2% of the city's population (Huchzermeyer et al., 2014). These settlements are associated with the low income class and need interventions of urban innovations to improve the quality of life for individuals occupying these spaces. Below is figure 3 indicating the informal dwellers responses based on the semi-interviews conducted based on the questions related to decisions led to relocating in these spaces, daily leaving experience to understand the routines and conditions, technological innovations capabilities to improve the living conditions, and if whether community members are involve in planning processes of the informal settlements.

The above figure 3 indicates the responses of informal settlement dwellers. 90% of the dwellers have indicated that it is important for them to move in the City of Johannesburg as there are many economic opportunities and resources that could lead to success. However, moving to a new environment, there is need for accommodation and living in formalised settlements is not easy due to affodability, the cost of living in such neighborhoods is expensive and they can not afford decent housing, and rentals due to their unemployment status, and if employed the amount they get paid is not sufficient to cover their montly expenses and rent or pay for bond housing. Therefore, this led most of them ending up relocating to informal

settlements as there are limited options for them. Consequently, 5% of the dwellers indicated that they have moved out from they homes where they grew up living with family to start a new life, and due to high cost of decent housing, opting for moving to informal settlement is not a bad option as they know after sometime the government provide certain informal settlement upgrading projects which could then provide better housing. Accordingly, other 5% of dwellers have indicated that they have always lived in informal settlements and to them it is all they know as some move from one informal settlement to the next, which they feel like its how they suppose to leave they lives.

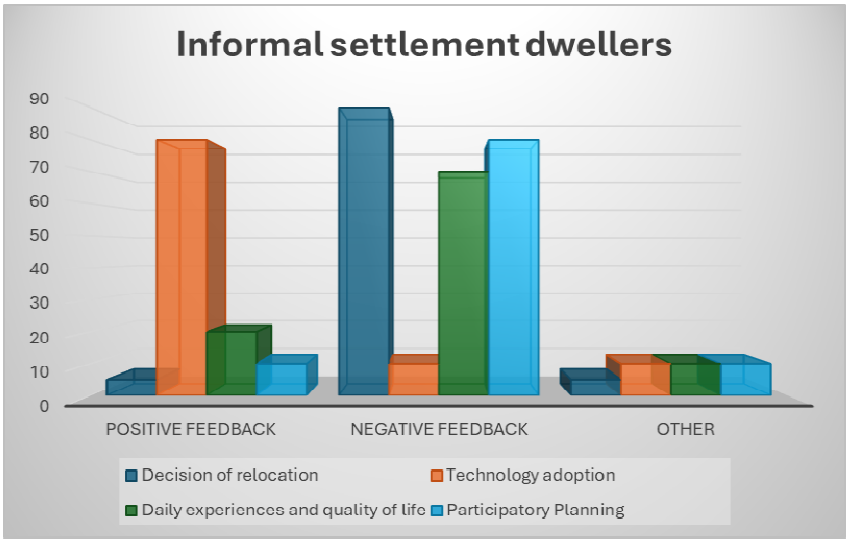

Figure 3: informal settlement dwellers responses

Consequently, 70% of the dwellers have indicated that leaving in informal settlements is hard as they feel like they are not regarded as citizens of the country due to being under treated by the government. Various informal settlements have poor informal settlements basic infrastructure such as proper sanitation, water and electricity. Dwellers indicated that there is a lot of them living in these settlements, however, there is few provision of communal toilets which are then strained at some point leaving them and chidren vulnerable. Accordingly, there is lack of drainage systems making it hard to navigate around the area when its raining, and waste management which makes the environment conditions poor. Consequently, the shared water supply have no proper drains which leads to water run-off making uncomfortable when accessing the taps. Inline, there is lack of proper connection of elctritiry supply which makes them not to have any appliances that needs power and also making areas unsafe at night. Further, in other informal settlements where there is delivery of basic services, dwellers indicated various aspects that are not pleasing in the area.

Further, 80% of informal settlement dwellers responses indicated that they are aware of the capabilities of technological innovations that they bring in urban areas and they could be delighted if these technologies could be deployed as they will provide a positive change in enhancing their areas of habitation. 10% of the responses highlighted the need of sufficient basic service delivery and proper housing development, but less interest in provision of technological innovations. Inline, another 10% of informal dwellers indicated that technology will be good for informal settlement, however, there is a need first for provision of sufficient service delivery. Accordingly, 80% of the informal settlement dwellers have indicated that they are involved in planning stages of projects that are implemented as there are initiatives in various instances. However, 5% highlighted that these projects implemented are already decided by stakeholders who are financing these project, as when a project is to be conducted dwellers are notified that a certain project is to take place rather than what type of project does the settlement need.

5.2 Key officials responses on challenges on in-situ upgrading

Informal settlement upgrading is a difficult project to complete successfully in South Africa without passing through various challenges. These kind of projects include various stakeholders wereby in some instances there are conflicts and decisions takes time to materialise. The below figure 4 indicates the responses received from key officials regarding challenges on in-situ upgrading.

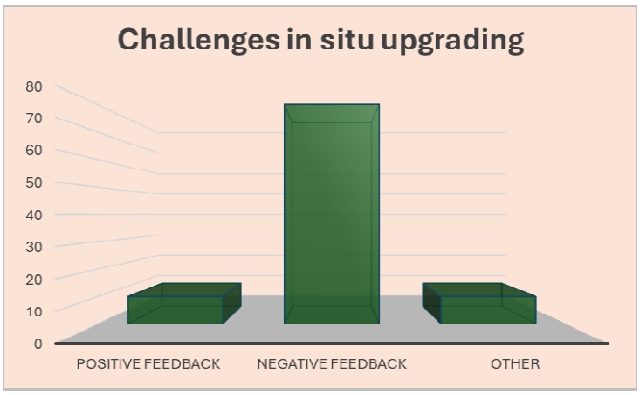

Figure 4:Challenges in situ upgrading

Many of the housing related projects have their own challenges and agendas. 5% of the key officials have indicated that when in-situ upgrading takes place, there is a certain aspect that they focus on and deliver it to a particular informal settlement, and mostly they deliver what is needed by the community. 80% of the key officials indicated that there are various issues with upgrading informal settlements, firstly indicating the issue of many informal settlements that are found across the city and which need similar attention. Secondly, informal settlement dwellers want all services to be developed at the same time, which is difficult to deal with, and a possibility is to deal with one challenge at a time. Consequently, there is lack of sufficient resources to ensure that informal settlements needs are met all the time. When basic services are provided, infrastructure is provided, it get strained due to the increase of the settlements. Accordingly, when a housing project is implement, there is re-development of informal settlement that emerges next to the formal housing that is being developed, population growth increases, and households that get provided with formal housing develop outside informal building in the yards. Further, there are challenges associated with land tenure, and some settlement are to big to provide all individuals with property ownership.

5.3 Key officials responses on strategies and methods for in situ upgrading

The are various strategies and methods to approaches of upgrading informal settlements, and process that need to be followed to ensure successful adoption for this strategies. In the below figure, it is the responses of key officials on strategies and methods on in-situ upgrading.

Figure 5: Strategies and methods on in-situ upgrading

Key officials indicated that there is a need to provide proper services that are required by the community and there is a need to identify first which services need to be provided . Some of the approaches used to know the needs is through conducting pilot studies which provide insights and the needs of the informal settlements. Accordingly, there is a need for public-private patnerships which this brings different contributions and can accelerate productivity. 45% of the key informants responses highlighted that knowing first what needs to be provided in the community assist to provide correct services for a particular community. Accordingly, there is a need to study an area sufficiently. 45% of responses highlighted that some of the strategies that are used might not be successful due to shortage of resources. Mostly, approaches used are similar leading to the same results, and this calls for a need to establish more substantial approach.

5.4 Key officials responses on technological integration

Technology speed up the process of tackling activities and provides support to areas that could be problematic with only the manual operations of activities, and it is important for technology to be integrated in informal settlements development. Below, figure 6 represent key officials responses on the usage of technological innovations in upgrading informal settlements.

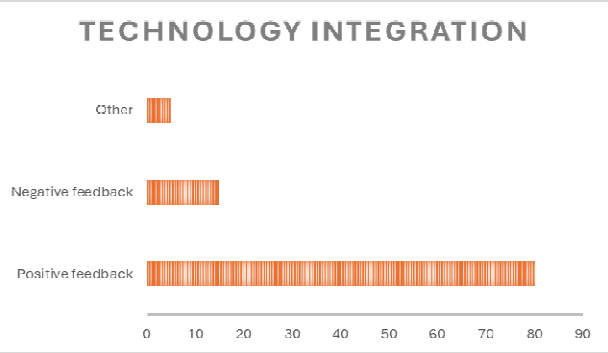

Figure 6: Technology integration

Technology has had a break through in many operation in different fields providing solutions to difficult challenges and circumstances that would seem to be impossible. 80% of the key officials indicated that informal settlements are very difficult to manage and upgrade due to various aspect associated with them and there is a need for accuracy to ensure that they function effectively to avoid many negative impacts that arise from these areas. It has been indicated that there are smart phone applications that infromal dwellers use to share communication about any conditions that need the attention of the government for example if there are damages or infrastructure maintanance required, the community members take photos of such and upload in the online platforms for attention which this also contribute to public participation. Accordingly, there are issues of electricity in many of these communities and there is implementation of solar powered street lights to ensure that the areas are not completely dark which assist with prevention of criminal activities. Consequently, there are smart water meters that are installed which detect the cleanliness of the provision of water to communities which has been an issue in previous years were informal dwellers are exposed to contaminated water. Further, it has been indicated that there is usage of GIS mapping that is used to monitor change, level of concentration and assist with anticipating future condition and be able to take suitable cause of action. 15% of key officials responses have indicated that integration of various technologies in informal settlements is expensive and there is already shortage of resources, and some informal settlements still require basic services. Therefore, this, reduces resources that could be used to provide sufficient basic services.

5.5 Key officials responses on participatory planning

Participartory planning is the involvement of community members in urban development and planning to ensure transparency and inclusion leading to trust between all the involve stakeholders. The figure below indicates the participatory planning responses from the key officials.

Figure 7: Participatory planning

Participartory planning is a critical process in planning and cannot be over looked. 70% of key officials have indicated that for informal settlements upgrading to be successfully developed, there is a need to engage with

the community members. This assist with knowing the needs of the particular community and by showing that views of the community are included in the planning process the implementation becomes easy and there is protection of the infrastructure implemented by the community members. Accordingly, it has been indicated that most of these community engagements are positive and common grounds are mostly met but this differs from one community to the other. However, 20% of the key informants have indicated that in some instances community members become negative towards various projects especially if it is not providing land ownership and housing. Informal dwellers want to dictate the terms of the projects and what needs to happen. Further, 10% of key officials indicated if communities are not involved in the decisions of a project taking place, especially, when the informal dwellers do not see it as a priority, it becomes very difficult to carryout the project and in some instance this becomes unsuccessful. Inline, if such incidents takes place communities end up not wanting to participate in other activities. Consequently, the protests emerge which this destruct functionality of urban areas, areas of protest, and their daily activities that they must carryout as officials. In addition, the key officials highlighted that when there is proper involvement of community members, there is accessibility to these communities, communities comply to government requests and after the completion of a project community members provide a feedback which assists to improve the projects going forward.

6 DISCUSSIONS

There is a need for urban innovations to ensure functional and sustainble informal settlements. Informal settlements provide accommodation to a large number of the population across the city. The living conditions of informal settlements as a whole are very poor. Government is trying various initiatives to ensure that these areas are habitable and functional through the provision of various service deliveries and housing programmes developed. There is a need for implementing various types of technologies to try solve various informal settlement challenges and enhance these areas. Technologies that could be deployed are (i) infrastructure monitoring sensors: this could ensure that the available infrastructuure is not strained or what kind of infrastructure does the area require to provide prompt response before a challenge emerge. For example (a) electricity: if there is a strain in power supply and illegal connections are taking place, and or lack of service provision of power supply creates negative impacts such as crime, (b) waste management: if the environment is experiencing more than what it should regarding proper functioning, the sensors could provide signals for attention and assist plan for locations that could provide a service for future prevention, (c) sensing drainage systems: this could provide awareness of blocked drainages for example by solid waste materials, and could notify the service providers that there is a need of maintanance before heavy storms.

Accordingly, (ii) landscape sensors: the sensors can assist with monitoring areas that could be affected by heavy storms and provide solutions of the types of drainage systems that need to be implemented. Many informal settlements are affected by both minor rains as there is difficulties of moving around in these areas due to flooding and heavy storms which leads to mortality and loss of property. (iii) informal settlement locator sensors: this could provide suitable areas wereby informal settlement development could be established, and these areas are not prone to natural disasters and there is provision of basic service delivery, and control. One may argue that this could promote informality, however, there is a need to realise that informal settlements are growing and are housing many people but are established in poor areas that leads to loss of life. Consequently, when sufficient resources are available such areas could be upgraded. (iv) online platforms: enhanced platforms supporting the current existing one's, which this could allow informal settlement dwellers to log enquiries direct to the department that deals with specific area of location and services, and prompt response provision through communication on the specific challenge or service delivery provision, and however, this will always vary to availability of resources.

Provision of such technological innovations can assist enhance informal settlements across the City of Johannesburg. Such technologies could be improved to function better and provide more, and wider services overtime. The use of technology is playing a critical role in housing development and should not be over looked but a need to fully utilise such innovations as they provide solutions to simple challenges the proffessionals, services providers and individuals face.

7 CONCLUSION

The City of Johannesburg has many informal settlements that have emerged due to many individuals lacking proper housing affordability. Many people live in dire conditions in these settlements, and most of the informal settlement dwellers are permanent residents of these settlements. There is a need for enhancement in various aspects of strategical approaches to enhance informal settlements in the City of Johannesburg. The study advocates for technolocal innovations to be deployed as they provide efficient services in ensuring that informal settlements are sustainable.

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🏆 reviewed paper

Insulation and Packaging with Natural Fibres: Contribution to the Smart City and Waste Reduction

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1 ABSTRACT

The current discussion in the literature on urban development raises the provocative question: are Smart Cities really sufficiently ecologically sustainable? Literature implies the need to re-define the Smart City concept in this context: A synthesis of the two terms ‘Smart or Intelligent Cities’ and ‘Sustainable Cities as ‘Sustainable Smart Cities’ is suggested(Ahvenniemi et al. 2017). This paper agrees to put the synergy between the smart and intelligent ICT Smart city driven concept and the ecologically sustainable city framework higher on national and urban planning agendas. In this context, based on an experiment on ‘Insulation and packaging with natural fibers’, the authors of this paper suggest an innovative ecologically sustainable solution in the context of reducing plastic waste. The work aims to better establish natural materials in the technical foam sector, which is mainly dominated by plastic foams.The experiment is driven bynatural insulation materials instead of conventional materials such as EPS management with a potential high ecological impact for smart city ecosystems and corporate supply chains. The experiment,based on an innovative foaming process,strongly implies that it is possible to find ecological substitutes for current insulation and packaging materials that leave a significantly lower carbon footprint without compromising on quality. Suggestions for startup, ecosystem and marketing implications are provided.

Keywords: Smart City, Natural Fabrics, Insulation Material, Supply Chain, Marketing

2 INTRODUCTION

Amalgamizing the two terms “Smart or Intelligent Cities” and “Sustainable Cities,” some authors (i.e. Ahvenniemi et al., 2017)propagate the term “Sustainable Smart Cities,” shared by the authors of this paper.Albeit differing as to the content of the typologies of smart cities and sustainable cities compared to Ahvenniemi et al. (2017), Almeida, Guimarães, and Amorim (2024) confirm the emphasis on environmental protection in sustainable city frameworks and to the dubbing of the new term “Sustainable Smart Cities”. The implicitly necessary higher public appreciation and intensified integration of protecting the Environment, Climate and Resources as well as highlighting respective objectives as national and community themes is suggested by Keppner et al. (2022) to the ‘BUND’ (Nation of Germany). In addition, and amongst others, latter authors call for an improved networking amongst all relevant stakeholders such as city administration, infrastructure companies, services or citizens in this context.

The careful and sustainable use of our finite resources is a central issue in solving climate and environmental problems. In globalized trade and also in digital retail, transport packaging is needed in large quantities for protection and/or insulation. Even today, packaging material is still largely made of plastics with an unfavorable CO_2 footprint and usually has an extremely short useful life. As a general rule, recycling is logistically far too costly. In Germany alone, 5.20 million tons of plastic waste are produced per year, and the amount of recycled waste is only 15.6% (Jeschke and Heupel 2022). Styrofoam is not considered economically recyclable.

A promising way to sustainably reduce the burden is to use raw materials provided by nature or from waste streams. Here, depending on the product concept, simple environmentally sound disposal can be made possible in addition to recycling. Depending on the intended use of the end material, different material properties come to the fore.

The focus of this work is therefore to develop an alternative to plastic foams based on natural materials. Depending on the use of the end material, different material properties come to the fore. The developments

presented are intended to provide an alternative to expanded polystyrene, which is very popular in the packaging industry mainly due to its low thermal conductivity and low weight. Hence, the crucial product properties of thermal conductivity and density of the manufactured sample sheets are measured first and foremost. In addition, abrasion and material stability will be assessed. In the selection of the raw materials used, it is decisive that the material – as it accumulates – can be processed with the methods presented here without any further process steps.

Bénézet et al. (2012) describes the production and investigation of biodegradable foams to consist of 10 (w) % natural fibers. In his work, the starch foam matrix is the basic framework of the resulting material, and the natural fibers serve to improve the mechanical properties. The foams are produced by extrusion. Glenn and Orts (2001), on the other hand, produce starch foams using a compression-explosion process and investigate the properties of the foams. These also consist of a starch matrix.Bergeret and Benezet (2011) investigate starch and PLA foams produced by melt extrusion. Water and chemicals are used as blowing agents. Lopez-Gil et al. (2015) produce starch foams reinforced with natural fibers in three steps using extrusion, thermoforming and microwave foaming processes, where water acts as plasticizer and blowing agent. They make compostable foams using this process and investigate the mechanical properties. Kraus (2014)investigates microwave-induced expansion in extruded starch-based pellets from different points of view(Kraus, Enke, Gaukel et al., 2014; Kraus, Enke, Schuchmann et al., 2014; Kraus, Enke, Gaukel, et al., 2014).

The process presented in this paper is not yet known in literature. It focuses on the production of insulation materials with a high content of natural fibers or granules using natural binders in two steps, namely mixing or spraying and microwave drying or foaming. Compared to known processes, this procedure offers the significant advantage of using high proportions of residual or recycled materials. In this way, ecologically sustainable and fully compostable insulation materials can be produced cheaply and efficiently without the need for costly processing of the raw materials.

3 THE POTENTIAL IMPACT ON WASTE AND CO_2 REDUCTION

The authors aim to develop an ecologically sustainable solution with a potential high impact to increase cities' or regions' resilience and the wellbeing of their citizens. The reduction of waste plays a central role alongside ecologically sustainable construction. Packaging and insulation materials made from natural fibers offer decisive advantages here compared to conventional materials such as EPS (expanded polystyrene). The volume of 2.5 million tons of lightweight packaging waste per year in Germany (Volk et al. 2021) illustrates the great potential for recycling and avoiding waste and the importance of a functioning circular economy. The main components of lightweight packaging waste are polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polystyrene (PS) and expanded EPS. In contrast, insulation materials made from natural fibers, which can also be used as packaging material, offer a promising ecologically sustainable alternative. Natural foams can be made biodegradable and, therefore, contribute to reducing household waste. Their use also conserves resources and reduces the need for non-renewable raw materials. The potential ecological impact is illustrated in that the use of natural insulation materials such as recycled paper foam instead of EPS in a new urban development area with only 100 house roofs would lead to a reduction in CO_2 emissions of 1039 tons. This corresponds to a saving of over 80% compared to the use of EPS. This significant reduction portrays the positive influence of natural fiber insulation materials on the CO_2 balance in the construction industry and underlines their importance for sustainable urban development. In total, between 300,000 and 400,000 tons of EPS are used for house insulation in Germany every year (Report by the German Polystyrene Society). The production of EPS typically releases between 2.5 and 3.5 tons of CO_2 per ton of EPS. This means that in Germany alone, there is a potential CO_2 saving of 900,000 tons.

According to the International Polystyrene Society (PSI, year of publication; also include in references), around 5 to 6 million tons of polystyrene are produced worldwide every year, Insulation materials account for around 30 to 40% of total EPS production. Consequently, the production of the dominant insulation material EPS alone contributes to around 16 million tons of CO_2.

The hypothetical consideration can also be applied to the packaging industry:the use of 1,000 tons of expanded polystyrene (EPS) of a medium-sized logistics company in Germany for packaging every year, results in around 3,000 tons of CO_2 emissions per year. By switching to natural fiber foam, which has a 70-80% lower carbon footprint, emissions are reduced to 800 tons of CO_2 per year. This corresponds to a saving

of 2,200 tons of CO_2 per year – comparable to the CO_2 absorption of 176,000 trees per year (cf. "Dena-Leitstudie Aufbruch Klimaneutralität" 2021). By their citizens using such materials, cities can actively contribute to climate protection and significantly reduce their environmental impact.

4 THE CURRENT TECHNICAL STATE OF THE ART

As the construction and infrastructure sector accounts for 35% of energy consumption, 35% of emissions, 50% of resource extraction and over 50% of total waste generation, a shift to a circular economy that minimizes the use of raw materials and maximizes recycling processes is urgently needed to reduce environmental impacts in the long term (Berger, Prasser, and Reinke 2013).

Although numerous processes exist to produce technical foams from plant-based raw materials, the end products are often classified as plastics. For example, bio-based polyethylene (bio-PE), which is made from renewable raw materials such as sugar cane, is chemically identical to petroleum-based polyethylene and is therefore not biodegradable (Thielen 2020). Another example is the development of lignin foams. The Fraunhofer Institute for Wood Research (WKI) is working on the production of foams from lignin sulphonate, a by-product of pulp and paper production. Although lignin is a bio-based raw material, this does not automatically mean that the foams produced from it are biodegradable. The decisive difference in the present work, therefore, lies in whether a bio-based plastic consists only of renewable raw materials or whether it is also biodegradable. In practice, this means that not every "bio-based plastic" is automatically more environmentally friendly – especially if it behaves in a similar way to fossil-based plastics at the end of its life.

Fortunately, the use of natural fibers in insulation materials and packaging has made considerable progress in recent years and is gaining increasing acceptance both technologically and in terms of ecological sustainability. In both areas, dry wet and molded fiber processes are used.

Natural fiber-based insulating materials such as hemp, flax, wood fibers and cellulose are increasingly in demand due to their environmentally friendly properties and good insulating performance. They offer advantages such as high moisture regulation, good sound insulation properties and a positive ecological balance. In addition, they are often less energy-intensive to produce and can be disposed of or recycled more easily at the end of their life cycle. The Fachagentur Nachwachsende Rohstoffe e.V. (FNR) has published a comprehensive market overview of insulation materials made from renewable raw materials, which provides detailed information on various materials and their applications(Fachagentur Nachwachsende Rohstoffe e. V. (FNR), 2020).

Natural fiber-based materials are also becoming increasingly important in the packaging sector. In addition to the traditional processes for producing paper and cardboard from cellulose fibers, packaging made from numerous types of natural fibers is already being produced using innovative methods such as thermoforming and dry forming.

In the present work, various natural fibers and binders are combined to form a material structure. The aim here is to offer a natural alternative to expanded polystyrene that can be produced with little effort. Two different approaches are used for production, whereby foamed or cross-linked fiber networks are created via individual points. Both methods used here utilize the microwave drying process. Waste paper, straw, hemp, wood shavings, seaweed, cork and tree bark are used as the material matrix, while starch and methyl cellulose serve as binders and sodium hydrogen carbonate as a blowing agent.

5 THE EXPERIMENTAL METHOD

5.1 Materials

Waste paper, starch and methyl cellulose used in this work are considered chemically converted raw materials, while hemp and wood chips are physically converted; straw and seaweed can be categorized as raw (untreated) raw materials.

Starch and methyl cellulose are used as hydrocolloid binders. Starch is a polysaccharide and exists as a mixture of unbranched amylose and branched amylopectin. The amylose-amylopectin ratio depends on the plant species. The size and shape of the starch grain vary depending on the plant. The rice starch used in this

work has a grain size of 4-5 µm (Behr and Seidensticker, 2018; Trueb 2020).Methyl cellulose is a cellulose derivative that forms a gel with water. The material is used as a thickener and binder.

5.2 Formulation

In formulation, fibers, binders and possibly blowing agents are mixed with pre-tested proportions puruing two different approaches. One is a formulation for foaming and the other is used for cross-linking the fibers. The proportions in the dry material for these different approaches are listed in Table 1.

	Averaged mass fractions foaming %	Averaged mass fractions at cross-linking %.
Fiber	85	85
Binders	10 (Methyl cellulose)	15 (starch suspension w/w)
Blowing agent	5	-

Table 1: Proportions of fiber, binder and blowing agent in dry matter

The required water amount was determined in preliminary tests based on fiber type and production method. For foaming, optimal viscosity ensures maximum volume expansion, with an average water content of 200% (dry mass). In fiber cross-linking, water content is reduced to 120% to maintain sprayability while minimizing excess moisture.

Foaming with sodium bicarbonate, binding with Methyl cellulose

The fibers are mixed – as indicated in Table 1 – and water is added. Mixing produces a paste-like mass. The mass is dried in the microwave in a homemade Teflon mould with the dimensions 16 cm x16 cm x 4 cm.

Spraying with starch suspension

A 15 % (w/w) starch suspension is sprayed onto the fibers during the mixing process. The fibers are then dried in the Teflon mould in the microwave.

6 ANALYSIS

Microscopy

The microscopic images were created with a Keyence VHX-700 3D microscope.

Thermal conductivity

Thermal conductivity is measured using a guarded hot plate apparatus. The temperature gradient applied to the samples is maintained by means of a hot plate. The thermal conductivity of the material can be calculated via the heating power required for this(Sonnick et al. 2019). The SRM 1453 (Expanded Polystyrene Board) from NIST (National Institute of Standards and Technology) serves as a reference for all measurements (Zarr and Pintar 2012)

Density

The density of the material is determined by the dimensions and weighing.

Three-point bending test

For specimen preparation, reference points are taken from the standards DIN EN ISO 14125 (Deutsches Institut Für Normung. Faserverstärkte Kunststoffe – Bestimmung Der Biegeeigenschaften (14125)) and DIN 51902 (Bestimmung Der Biegefestigkeit Nach Dem Dreipunkt-Verfahren – Feststoffe (51902)). The testing machine complies with the requirements of DIN EN ISO 7500-1.

7 RESULTS AND DISCUSSION

In the following, the samples produced and the important key points in the entire process are described quantitatively, and the results of the microscopic examinations, thermal conductivity and density measurements as well as the three-point bending tests are presented.

Qualitative assessment

In addition to the haptic description, the qualitative description of the manufactured samples includes the naming of the most important points in the processing of the starting materials. The following statements also encompass knowledge from preliminary investigations. In general, it should be noted that the finer the

fibers are ground, the lower the density of the samples produced. The fiber length plays a major role in fiber cross-linking. The longer the fibers, the more elastic the resulting sample. The samples produced show different abrasion behaviors. The sample with cork and bark is most prone to abrasion, followed by wood foam, seaweed, hemp, straw and finally waste paper (see figure 1). Waste paper haptically resembles pulp and shows hardly any abrasion. The foamed samples show clear shrinkage behavior, whereas this is not the case with cross-linked fibers. Different levels of thickness can be produced with all samples.

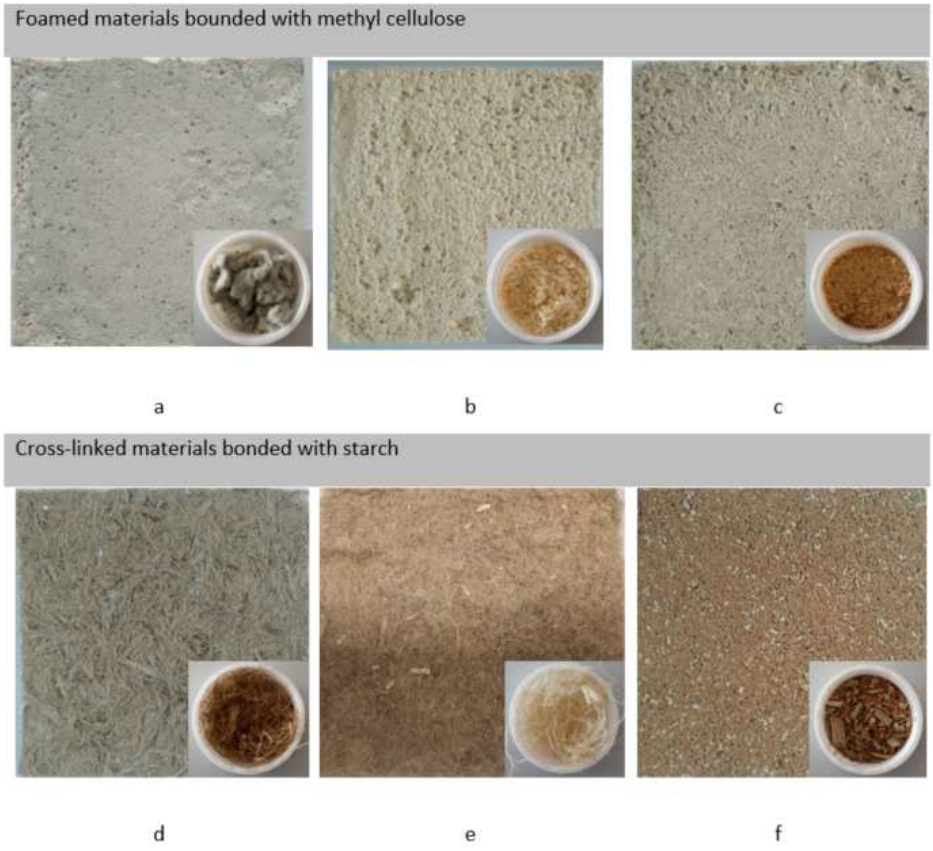

Figure 1. Samples: a: wastepaper; b: wood shavings, c: straw; d: seaweed; e: hemp; f: cork bark

Microscopy

The starch adhesive is observed as a cross-linking point in many samples and appears as a shiny transparent layer (best seen in Figure 2 h and l). The cross-linking points are irregularly distributed over the sample surface. While some of them are connected by long arms, others are present as isolated points. The adhesive is visible to the naked eye as a transparent layer. Microscopy shows that the adhesive layer has many interruptions and is dotted with pores of different sizes (cf. Figure 2 e, f, g, h, k, l). Among the foamed samples, the waste paper sample has the finest structure compared to the cork bark sample and the wood chip sample. The cork bark samples have the coarsest structure and, as granules, have the most irregular surface structure. The coarser the material, the deeper the pores that are visible to the naked eye. The material's own porosity and hygroscopicity probably also plays an important role in the distribution and absorption of the adhesive. In the cork bark sample, the individual granules are almost completely covered with the adhesive, while in the seagrass sample individual cross-linking points can be observed. In the hemp samples, neither cross-linking points nor a glue view are visible.

Thermal conductivity, density and mechanical stability

For this investigation, plates are produced in a Teflon mould with dimensions 16 cm x 16 cm using the formulations and production methods from 5.2. The thermal conductivity of the samples is determined at atmospheric pressure at an average temperature of 30 °C (hot plate 45 °C, cold plate 15 °C). The measurement is carried out with a guarded hot plate apparatus; the more precise specificationscan be taken from Sonnick et al. (2019). The volume is determined by multiple measurements of length, width and height (thickness) along the edges of the material. The weighing is carried out three times per sample. The density is calculated via the average values. The results of the three-point bending test are given in Table 2 based on

the maximum force at break related to the material thickness with the standard deviation. In addition, the averaged thermal conductivities, densities and material thicknesses are listed in Table 2.

Figure 2. Microscopic images at 20x (left) and 100x (right) magnification with Keyence digital microscope. (a), (b): wastepaper; (c), (d): wood shavings, (e), (f): straw, (g), (h): seaweed, (i), (j): hemp, (k), (l): cork bark

Sample	Thermal conductivity	Density	Breaking stress	Standard deviation breaking stress
	mW/mK	kg/m³	MPa	MPa
Polystyrol (EPS)	37	43,2	0,82	0,02
Waste paper	36	105,3	0,16	0,06
Wood shavings	47	156,3	0,18	0,03
Straw fine	37	112,6	0,40	0,04
Seaweed	43	145,6	0,17	0,03
Hemp	51	105,6	0,74	0,20
Cork + bark	42	166,2	0,39	0,10

Table 2: Thermal conductivities, densities and mechanical stability of the manufactured samples.

EPS, which serves as a reference material here, is a very light material with low thermal conductivity and low density. The material properties are, as already mentioned, optimal for use as insulation and packaging material. The material shows hardly any abrasion, is dimensionally stable and has a homogeneous pore structure. The measured thermal conductivity of 37 mW/mK and the density of 43.2 kg/m³ (Table 2) confirm the previous statements on the suitability of the material as packaging and insulation material. By means of the maximum force leading to breakage, the breaking stress is calculated and given in Table 2. The stress value includes the geometric influences, e.g., the material thickness and, thus, the material consumption. At this level, the highest degree of material stability can be determined for EPS. None of the samples can reach the low density of EPS. The lowest density of 105.3 kg/m³ is achieved by the wastepaper sample. The hemp fiber sample follows with 105.6 kg/m³. The coarse-grained cork bark sample has the highest density of 166.2 kg/m³. The wastepaper sample has the lowest thermal conductivity of 36 mW/mK, and the straw sample also has low thermal conductivity of 37 mW/mK. Wastepaper and straw samples also perform best in the three-point bending test.

The results showthat it is possible to produce boards from natural fibers or granulates and natural binders by means of microwave drying. The samples from wastepaper and straw come closest to the reference material EPS in terms of thermal conductivity, density and abrasion. The somewhat higher densities of the new insulation materials do not necessarily have to be seen as a disadvantage, since in the shipping industry in particular one is basically dealing with transient heat transfer processes. Here, it is not thermal conductivity but the thermal diffusivity that is decisive. Due to the resulting inclusion of a storage term, materials with a higher density and the same thermal conductivity even perform better in this comparison. The advantage of being able to produce the panels at low cost without having to process the raw materials should also be emphasized again at this point. Costly processes such as extrusion can be bypassed. The high water content in the two proposed formulations must be removed during microwave drying. There is a need for optimization here. For both the optimization of the foam properties for insulation purposes, as well as for the energetic optimization, optimal fiber-binder-blowing agent-water proportions can be developed in further work through parameter studies.

Implications for a startup ecosystem and marketing

Once the aforementioned still pending optimization processes are completed, the commercialization and roll-out of the research comes to the fore. After the patent has been assured, the research is suggested to be marketed by startups due to their higher ability to test the marketand higher level of flexibility for innovation.Later, for the end of the life cycle, for scaling purposes, co-operation with or acquisition by big companies can be envisioned. At the birth stage of the startup, a Minimum Viable Product (MVP) must be developed. According to Tripathi et al. (2019), supporting startups to find the fundamental problem-solution fit and to facilitate the learning process during the MVP process, improves their chances to successfully manage and survive the MVP stage within the difficult first two years. In this context, the previous authors suggest a supportive startup ecosystem being in line with the authors of this papers. In the following, some possible supportive activities of respective startup ecosystem stakeholders are schematized (see Westphal et al. (2022) for an applied best case example of the ecosystem of the city of Mannheim)). First of all, a strong ecologically sustainable engagement of the city/region reflected, for example, by a commitment to the smart city movement in general and to the climate neutrality in particularprovides a fertile ground.Furthermore, the resources of a network of experienced representatives of successful local companies might be approached to support in the production of the ‘physical product’ such as plates or packaging material. To approach potential entrepreneurs, university spin-offs transferring their invention to graduates or private local companies, might be a viable option. In addition, graduates from undergraduate or postgraduate university courses, or information, networking and educational eventsby local universities, incubation centres or accelerators, city departments/joint ventures or entrepreneurship associations(especially also female ones) and/or business angelsarepromising routes for recruiting entrepreneurs. Very important is the initial educational support of startups and their human capitalin terms of technology applied (in this case, for example, biodegradable natural fabrics application and knowledge on material properties) and entrepreneurial education; latter refers, for example, to sustainable business development and startup/entrepreneurial competences provided, for example, by universities and/or consultants. Including the future market, in this case the citizens, construction, packaging or logistics companies, architects, as well as city representatives (especially in the case of the existence of city quarters to be energetically and

ecologically redesigned) in co-creating the problem-solution-fit is suggested.Later, achieving a market-product fit and quickly implementing and continuously reflecting and improving on the suggestions of the co-creators is regarded another key success factor. Paramount is, of course, the support in terms of financial resources, i.e. from business angels and venture capitalists for seed and growth capital, city departments, banks, accelerators, philanthropistsor via crowdfunding. After having successfully found a market-product fit, further mentoring and educational support is proposedto find a best channel-product and communication fit. As, after this stage, increased growth resources are required, the development of a detailed sustainable business model, including, for example, concepts such as networking, value proposition canvas, sustainable value mapping (Bocken, 2021) or sustainable supply chain are suggested, to convince potential investors at this stage.Regarding the latter, the minimum possible transport distances seem a given, simply because most of the raw materials are usually available in the region, in turn leading to enhanced support for the local economy. Moreover, the faster local access to raw materials is, the more efficient and sustainable the supply chain planning will be: this is supported by corresponding certifications of these available raw materials, i.e. FSC for wood. As fewer other additives are required when processing natural insulation materials, regardless of whether these are chemical or synthetic in nature, a further reduction in the entire supply chain, and, importantly, a health benefit might occur. It is obvious that increased CO_2 neutrality or biodegradability will have a lasting influence on corporate communication and, hence, an effective sustainable marketing or business model impact (Bocken, 2021). Storytelling in the channel-product-fit stage on innovative natural materials, i.e. via social media, might strike a balance to the often prevalent perception of the building materials industry as an ‘energy waster’.

In order to establish the optimal marketing of sustainable insulation materials made from natural materials, the choice of which material can best be marketed, where must also take a geographical component into account. Regional differences and their raw material deposits are highly diverse. Thus, it does not make much sense, even ecologically, to use insulation materials made from seaweed in regions thousands of kilometers away from coasts with access to the sea.

We also see that the use of different raw materials has a strong influence on the entire marketing of the respective products, sales markets, distribution channels and much more.

Recycled paperas insulation material is illustrated in the following, geographically the least critical, case (Naturanum, n.d.; Koala Insulation, n.d)

Recovered paper as a raw material for insulation material is sustainable, cost-effective and in high demand in the construction industry. It can be processed into cellulose insulation (blow-in insulation, mats) or innovative composite materials. Here are two of the possible business models that could be considered:

(1) Licensing to building materials manufacturers, through recycling companies that work directly with insulation manufacturers. The advantages here are obvious, with the development of an innovative and smart insulation technology (cellulose-based) from recycled paper. Further advantages of this form of technology sales are the very fast market access via existing and well-established companies, as well as the zero production costs, which also leads to very fast and high scalability. The sales challenges on the other hand are manageable and are only referring to the investment for material development, and to the dependence on the possible licensees, who are ultimately responsible for the sales success.

(2) Engaging in high-tech construction projects such as eco-friendly buildings in the luxury and high-end sector, based on high-performance cellulose insulation with a technical add-on, such as a hydrophobic coating, to ensure increased protection against moisture. Likewise, with the appropriate coating, one can argue much better on the subject of fire protection, especially with the raw material “cellulose”. Another component could be an additional coating with “aerogel” insulating materials to make the good insulation values even more efficient, in order to achieve a far better market positioning as a so-called premium building material. This in turn leads to the marketer, be it, for example, the high-quality building materials dealer with significantly higher yields and also less local competition, carrying out more attractive marketing through the premium positioning. This is now also becoming an increasingly important topic for property developers an architects with regard to sustainable construction projects. The challenges associated with this lie here again in the extensive and costly material development and the necessary certifications/ standards for the market-ready product, which requires a high investment budget and certainly correspondingly higher marketing funds.

Contrarily, the example of seaweed as an insulating material is juxtaposed: geographically highly critical, since only certain regions worldwide are suitable (Building Centre, 2017).

Seaweed as a raw material for insulation material is both sustainable and innovative, although the sustainable extraction of seaweed as an insulating material is certainly more difficult than with other natural materials. Here, too, two possible business models demonstrate the diversity of marketing:

1.To somewhat counteract the geographical restriction in this case, the first concept would be quite suitable. In this case, long-term co-operation with agricultural and/or aqua-farm operators would serve as a source of raw materials, because local independence is a given here; in the case of both "raw material producers" such as agricultural operations or aqua-farm operators, proximity to the lake is not absolutely necessary. With aqua-farms, sustainable raw material production can take place with special aquacultures. Further marketing remains in the hands of the "producers" and can be sold directly to the processing company. Thus, very low production and manufacturing costs go hand in hand with the greatest possible support measures, e.g. from environmental organizations. Short distances from production to final use are thus ensured and do their part to reduce the carbon footprint. The positive aspects in this distribution model are counterbalanced by only a few, albeit important and sometimes difficult to calculate factors. These include the certainly fluctuating harvest volumes influenced by environmental factors, as well as a seasonal challenge, which goes hand in hand with strong dependencies and few flexible options with regard to production partners and ultimately also distribution partners in the long term.

2.A business model in which the recycling approach can be implemented quite well, in addition to the use of the natural material as an insulating material, is, in principle, also referred to here as the cradle-to-cradle model (Streich and Hartje, n.y). Here, the development and production of fully biodegradable seaweed would come first, in order to pursue the approach mentioned from the ground up. This would be accompanied by the development of an efficient take-back and recycling process for these insulation materials, which would add immense value to a circular economy in the positive argumentation. A clear differentiation from classic and sustainably produced insulation materials underlines the sustainable marketing model. This requires specialized building materials dealers who can also provide well-founded advice. In addition to funding from environmental funds, for example, or investors from the environmental, social or ESG sectors, there is another exciting approach to marketing to the end consumer, namely selling CO_2 certificates, to name another possible source of income. The longer time to market for such a model is certainly more of a challenge at present, due to the need to set up and implementproduction and take-back processes, which will balance out in the long run.

Market development

To provide a better overview of the rapid and positive global development and the overall market potential, we have zoomed inglobal economic forecasts on some aforementioned examples of natural materials (. The market for sustainable insulation materials made from natural materials will grow significantly in the next 10 years. This is driven by stricter environmental regulations, rising energy prices, growing awareness of CO_2 reduction in the construction industry and technological advances.

- The global market for sustainable insulation materials is expected to grow from USD 15–18 billion (2024) to over USD 30–40 billion (2034) (GMI, 2024)
- This corresponds to a compound annual growth rate (CAGR) of 6–9 %.
- Natural insulation materials (e.g. hemp, wood fiber, cellulose, sheep's wool, seaweed, straw) could increase their market share from the current 5–8% to up to 15–20%.

Insulation material market development (2024–2034) in more detail (FairWell, n.d)

Hemp:Very strong growth due to improved availability and correspondingly lower costs of approx. 6–8 %

Wood fiber: Well established, and will continue to grow steadily and solidly at approx. 8–12 %

Cellulose: Inexpensive raw material & efficient, high growth expected at approx. 10–15 %

Straw: can be easily integrated into the circular economy, but is associated with scaling problems approx. 2–5 % growth

Seaweed: highly innovative natural material, an absolute niche with great future potential, currently at approx. 1–3 % growth.

We therefore see three major growth markets worldwide (FNR, 2019; GVE, n.d)

The EU as the leading market for natural insulation materials, with the strongest growth due to stricter environmental laws such as the EU taxonomy or the so-called Green Deal Initiative. Countries such as Germany, France, Scandinavia or the Netherlands are playing the absolute pioneering role here, which, due to the high demand for CO_2-neutral insulation materials, significantly increases the market opportunities for wood fibers, cellulose and seaweed Materials.

The USA shows a growing demand but also faces challenges still remaining on the acceptance side. It is now being presented to a wider audience through standards in the green building sector or through energy efficiency programs. Hemp and cellulose have the greatest potential here, while seaweed is currently still considered a niche product.Which is actually not quite understandable, since the US has a relatively long and geographically extensive coastline.

The third growth market is the People's Republic of China, with a huge market potential at the start of the development. However, the first major pilot projects have already been launched that recognize the place of hemp and cellulose as insulation materials in sustainable urban development. With its rather long coastal regions, seaweed as another natural material that could quickly increase in acceptance.

In terms of their use as insulation materials, the naturall materials we have discussed are indispensable, and the same applies to other applications and rapidly growing markets. In addition to medical and chemical products, the most demanded product groups are temperature-sensitive products such as food and beverages and the requirements of their“cold chain” during the storage and transportation of these temperature-sensitive product groups. This also requires refrigerators and freezers, as well as the trucks, railway carriage or airfreight containers in which the insulating materials made of natural materials are also finding their way in.

Based on this paper, there are also two fundamental directions in the construction industry that offer immense market opportunities. However, these need to be differentiated as to basic marketing. Classic residential construction, which also includes the entire spectrum of renovation, and the construction industry for commercial use of factory buildings or halls. In the broadest sense, this can also include warehouses and, for example, greenhouses, whether in industry or agriculture, all of which require temperature sensitivity as a must in planning, construction and operation over decades as a common thread.

8 CONCLUSIONS

The development of the sample materials of the experiment provided shows that it is possible to find ecological substitutes for current insulation materials that leave a significantly lower carbon footprint without compromising on quality. The materials presented can also be produced and applied decentral in third world countries without the need to build huge factories. The findings imply that the samples from waste paper and straw come closest to the reference material EPS in terms of thermal conductivity, density and abrasion. The findings of this research in progress suggest scope for optimization. For both, the optimization of the foam properties for insulation purposes, as well as for the energetic optimization, optimal fiber-binder-blowing agent-water proportions can be developed in further work through parameter studies. Once this optimization steps are finalized, however, commercial success – based on successful startup life cycle design and sustainable business modelling- can be envisaged due to the high potential impact of the innovative product on waste and CO_2 reduction.

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reviewed paper

Integrated Urban Planning: An Example of the Historic Centre of the City of Zagreb

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1 ABSTRACT

The processes of transformation of the spatial and functional structure of city centers are driven by global demographic, social, technological, economic, cultural, political, and environmental changes, especially natural disasters whose intensity of reflection on the city depends on the interaction with the character and specifics of local conditions.

Faced with the increasingly intense development and resilient challenges of cities, traditional sectoral spatial planning, which is focused on location, intensity, form and balanced growth, is transforming its (over)regulated bureaucratic approach towards a strategic development approach, which offers a more coordinated and coherent spatial logic and the integration of economic, social and environmental dimensions of urban programming, planning and implementation. Traditional urban plans are becoming increasingly inefficient because they cannot be a timely guide through urban transformation processes.

Encouraged by the consequences of the 2020 earthquake, the City of Zagreb has implemented a new urban paradigm that ensures the possibility of transformation through the harmonization of different disciplines, as opposed to traditional urban planning – a static image of the physical dimension of space, and the City of Zagreb has started programming a comprehensive renovation of the Historical unit of the city of Zagreb, which proposes a strategic, process-based approach to creating urban space ("place-making") that enables dynamic transformation possibilities to anticipate possible challenges, threats and opportunities with a pro-active planning system and thus (strategically) plan future development, and/or reconstruction (ex-ante), instead of responding to unexpected events (ex-post) with a reactive planning system.

With the method of thematic modeling of the space of the center of the city of Zagreb and interdisciplinary programming of spatial values, limitations and sustainable urban potentials, a new platform was created – urban planning agenda – principles, as well as recommendations and guidelines that aim to achieve the development goals of comprehensive urban renewal, as well as the preconditions for their realization.

By parallel management of multisectoral processes through the proposed participatory platform consisting of all active participants in the City planning process, a comprehensive pattern/model has been generated according to which integrated urban renewal activities are carried out following the most advanced European policies.

This paper provides a framework for a sustainable way of use, conditions for the use, and protection of space and management. It is an expert basis for the development of a new generation of spatial planning documents, especially the urban and conservation plan of the Historic Urban Core of the City of Zagreb, which will unite urban and conservation guidelines and be the initiator of urban changes in the center of the historic city, directed towards the Green Center 2050.

Keywords: integrated urban planning, historic center, interdisciplinary programming, comprehensive urban renewal, urban and conservation plan

2 INTRODUCTION

Already in the early 1990s, Zagreb had a multi-generational and sensibility diverse "house" for spatial planning with European knowledge and eager for new knowledge, with a technically and digitally supported system of strategic spatial planning, digital orthophotos, a photo library of aerial photographs of Zagreb and the proposal for the New Urban Strategy of Zagreb, transformed into a package of the new city spatial and urban plan Zagreb 2000+: Spatial Plan of the City of Zagreb and General Urban Plans of the City of Zagreb and Sesvete, with a proposal for a comprehensive spatial planning system (Gradski zavod za planiranje, 2000). Institute for Physical Planning of the City of Zagreb, the largest and strongest public urban planning

professional and scientific institution in Croatia, the successor and follower of the institutions responsible for spatial and urban planning of the City of Zagreb and the Zagreb region, focused on professional and scientific research work on sustainable spatial and urban planning, has been particularly active through work on European projects in exploring the possibilities improvement of the planning system and modernization in terms of content and procedure.

The strong earthquakes that hit Zagreb in 2020 pointed to the long-term neglect and vulnerability of the city center (Fig. 1), raised awareness of the high risk of earthquakes, and additionally pointed out the need to find different planning tools and instruments for its renewal. Facing local challenges and solving them with the ultimate goal of long-term improvement of the physical, social, economic, and environmental factors of the wounded area under the continuous threats of the process of gentrification and pauperization (Svirčić Gotovac, 2010) was the imperative of sustainable urban renewal.

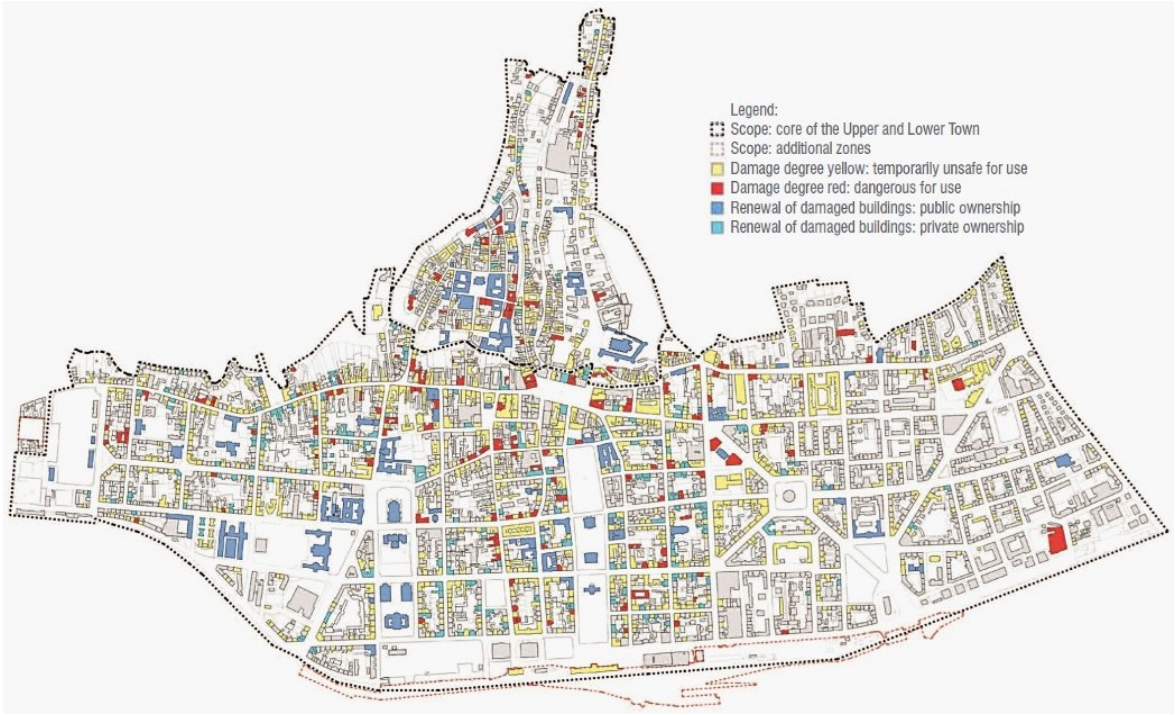

Fig. 1: Comparison of damaged buildings (acc. to the register of the Institute for Physical Planning GIS June 2020) and those undergoing renewal (public and socially-owned buildings, and privately-owned buildings); Source: Identity Topography of the Historic Urban Core of the City of Zagreb, Faculty of Architecture, University of Zagreb/for the purpose of the Comprehensive Renewal Programme of the Historic Urban Core of the City of Zagreb, Zagreb, 2023.

As a response to the accelerated changes in contemporary urban development and planning from urban entrepreneurship, through neoliberal (Swyngedouw et al., 2002) to globalization urbanism, all the way to social justice as the development challenges of cities and planning, a change from a regulated bureaucratic approach to planning and a step from traditional sectoral planning to a strategic approach driven by implementation, development, monitoring and improvement, i.e. integrated spatial planning, was necessary. The fundamental principles of integrated planning in the process of urban renewal are therefore: 1. detailed multidisciplinary analysis of all components of the existing state and local conditions of blocks and insulas; 2. defining development problems and needs with sustainable and efficient use of natural, economic and human resources; 3. establishment of clear and measurable goals of the process; 4. compliance of goals with the principles of sustainable development; 5. inclusion and interaction of different groups of stakeholders; 6. coordination of all levels of government from national to local, all to improve the physical condition of buildings, social structure, economic and environmental conditions for more precise guidance of the urban renewal process (UNDP, 2023).

Programming and planning of urban renewal is also an opportunity to improve the network of public spaces and systematic transition from grey to green infrastructure, which is especially important concerning the high population density of the city center as a prerequisite for adapting to the increasingly pronounced effects of climate change. Although the methodology for the urban renewal process is almost the same, integration into the historical urban entity is crucial.

In the process of integrated planning, special importance has the participation of relevant stakeholders – prominent representatives of the four main social actors ("quadruple helix"), whose synergistic effect ensures a balanced platform for a multidisciplinary innovative approach to integrated development, and consists of: representatives of different areas and fields of science – higher education institutions, scientific and research centers, representatives of the economy, administration and civil society organizations – citizens (Varmland county, 2019). Recently, the "quintuple helix" model has been introduced, which introduces the natural environment as the fifth component, which enables social-environmental interactions, including application to sustainable development, including climate change (Veselić Bruvo, 2023).

3 INTEGRATED VS. TRADITIONAL PLANNING

New development processes in cities are resulting in the need for new forms of urban management (Albrechts, 1991; Salet, 2008). Traditional (sectoral) spatial planning focused on location, intensity, form and balanced development, which lacks the aspect of active encouragement and synergy with other policies, needs to be harmonized with strategic documents that include a large number of stakeholders and that, through a long-term vision, measures, activities and means of implementation, establish the form and framework for the transformation of strategically key areas and focus on decisions, activities, monitoring and evaluation of results (Veselić Bruvo, Jakovčić, 2019).

The new urban paradigm in the form of integrated planning represents the provision of transformation opportunities through the harmonization of different disciplines (Medeiros et al., 2020), in contrast to traditional urban planning – a static picture of the physical dimension of space. Traditional spatial and urban plans are becoming more and more ineffective, because they cannot be a timely guide through the processes of urban transformation (Carta, 2014) and an integrated, process-based approach to the creation of urban space ("place-making") is proposed, which enables dynamic transformations (Ellin, 2013).

Although spatial and urban plans are extremely complex interdisciplinary spatial documents, they should be part of a comprehensive system of spatial planning and, as such, are only sectoral urban planning documents since procedural and institutional solutions are based on the partnership of the basic participants in spatial management. Integrated spatial and urban planning with its holistic approach is a powerful tool for ensuring ecologically sensitive and socially just urban development which refers to the practice of integration and synergy of environmental, social, cultural and economic aspects in order to create a sustainable and high-quality environment (ECTP-CEU, 2013). From the focus on static images of the physical dimensions of space in the traditional approach to planning and the primary goal of capacities, ways and conditions, integrated planning focuses on accessibility and quality of life (including social justice and equality, health and environmental quality and economic viability) with a shift towards sustainable mobility and strong integration of infrastructure, markets, legal frameworks, databases and their accessibility, information and promotion (European Commission, 2020).

The political platform of the proposed new generation of integrated spatial and urban plans should be subsidiarity and participation of all social actors in decision-making, and the technical platform – openness for greater financial sustainability and public space for the community, acceleration of the procedure, transparency and reduction of administrative and legal procedures and obstacles with greater respect for the profession of urban planners and architects.

With an integrated approach, traditional plans cease to be sectoral plans and effectively address the complexity of urban development. They are linked to other development areas and include a long-term vision and strategies, and are developed by interdisciplinary planning teams, stakeholders, and citizens who are involved in the process from the very beginning, who are at the heart of the planning process, which is transparent and collaborative. Impact is also systematically assessed to enable learning and improvement. The multidisciplinary approach ensures resilience to unexpected development challenges and flexibility to adapt to change. It also involves a wide range of stakeholders, urban planners, and other experts to develop comprehensive solutions, which is a strong support for the implementation of urban development projects.

At the heart of integrated planning is cooperation between sectors, rather than negotiations between them – since cooperation is not focused on averages, but to maximum values (Ovink & Boeijenga, 2018). The interconnectedness and complexity of the challenges mean that the added value of these solutions leads to multiple benefits for different sectors and at different planning levels. The key element for achieving

integration is a thorough assessment of the current situation (baseline) and future trends (scenarios, planning is always a process of choosing between different images of the future) aligned with a widely accepted common vision with strategic goals (Blyth, 2005) and a package of legal, promotional, financial, technical and infrastructural measures to achieve these goals – the implementation of which must be accompanied by systematic monitoring and evaluation (Veselić Bruvo, 2023).

4 HISTORIC URBAN CORE OF THE CITY OF ZAGREB IN STRATEGIC AND URBAN PLANS

The existing strategic, spatial, and urban planning documentation for the centre of the City of Zagreb is an indispensable starting point for considering and proposing a new planning framework.

In the development strategy of the City of Zagreb – ZagrebPlan (Gradski ured za strategijsko planiranje, 2012), the historical core of the City of Zagreb and its urban revitalization, especially the block structure of the Lower Town, is considered as an area of special significance for the identity of the City and for a balanced process of urban development. In accordance with the ZagrebPlan, the 168 blocks of the Lower Town urgently need to redefine their own identity and purpose and the necessary protection and restoration of the architectural heritage. The most pronounced challenges of the Lower Town are: the withering away of the existing way of using and the facades of city streets, the interior of the blocks and the built fabric as a whole, the spatial reduction of zones and the representation of trade and services with the concentration of public and social life, and the saturation of traffic, especially that at rest. In addition to the above challenges, potential obstacles to the revitalization of the Lower Town are complex property relations, lack of cross-sectoral cooperation, population stagnation, changes in consumer habits, and possible resistance of residents to change.

The last detailed plans for the Historic Urban Core of the City of Zagreb were designed almost 40-45 years ago: Implementation Urban Plan for the Development and Revitalization of the Upper Town and Kaptol (UZGZ, 1979) and Implementation Urban Plan for the Lower Town (UZGZ, 1989). Most of the development challenges that occupied urban planners forty years ago are still present today. However, a completely different social platform, economic and ownership system, a more cautious attitude towards space, new standards and requirements, as well as the application of modern technological solutions, with an integrated approach and the increasingly important role of the participation of residents and users from the very beginning of the programming and planning process, and coordination of all levels of government, call for a different approach and a new planning paradigm (UN-HABITAT, 2009), and the area of the Historic Urban Core has not been fully assessed in the form of a spatial planning document.

In 2003, a new General Urban Plan for the City of Zagreb was developed for the urban area of the City of approximately 220 km² (with several cycles of amendments and supplements – Zavod za prostorno uređenje, 2003; 2007; 2009; 2013; 2016). The General Urban Plan (Master plan), although ambitiously prepared and created (as part of a comprehensive spatial planning system, with all the necessary tools for implementation), is adopted as a generated and hybrid spatial planning document at a scale of 1:5000, which is an implementing document for most situations, and a guiding document for the remaining transformation zones or new regulations on undeveloped areas. The General Plan defines the areas of the Historic Urban Core of the City of Zagreb (Lower Town, Upper Town and Kaptol) as highly consolidated with the established urban rule "Protection, development and extension in historic architectural entities" as well as general and detailed urban planning guidelines, and enables direct implementation through location and construction permits, while only exceptionally for some of the blocks (due to the potential of the interior of the blocks) is the preparation of more detailed urban plans mandatory. The overall scope of the Historic Urban Core of the City of Zagreb is an immovable cultural asset (Fig. 2) and as such is subject to special conditions of conservation protection by the competent administrative body for the protection of cultural monuments, and following the sectoral study "Conservation documentation – Conditions for the Protection and Preservation of Immovable Cultural Assets" (Gradski zavod za zaštitu, 2004; 2008; 2012; 2015), which are not integrated with the general and detailed urban planning guidelines of the General Plan.

5 COMPREHENSIVE RENEWAL PROGRAMME FOR THE HISTORIC URBAN CORE OF THE CITY OF ZAGREB (2023.)

The urban renewal of the existing protected urban fabric of the Upper Town and Kaptol and the Lower Town, the most valuable historical, cultural, urban, and identity heritage of the City of Zagreb, is the greatest

challenge in recent city history. The medieval part of the city and the city of the late 19th and early 20th centuries need to be secured for the highest possible seismic loads while preserving its physiognomy and making it the most attractive part of the city for living, working, and visiting.

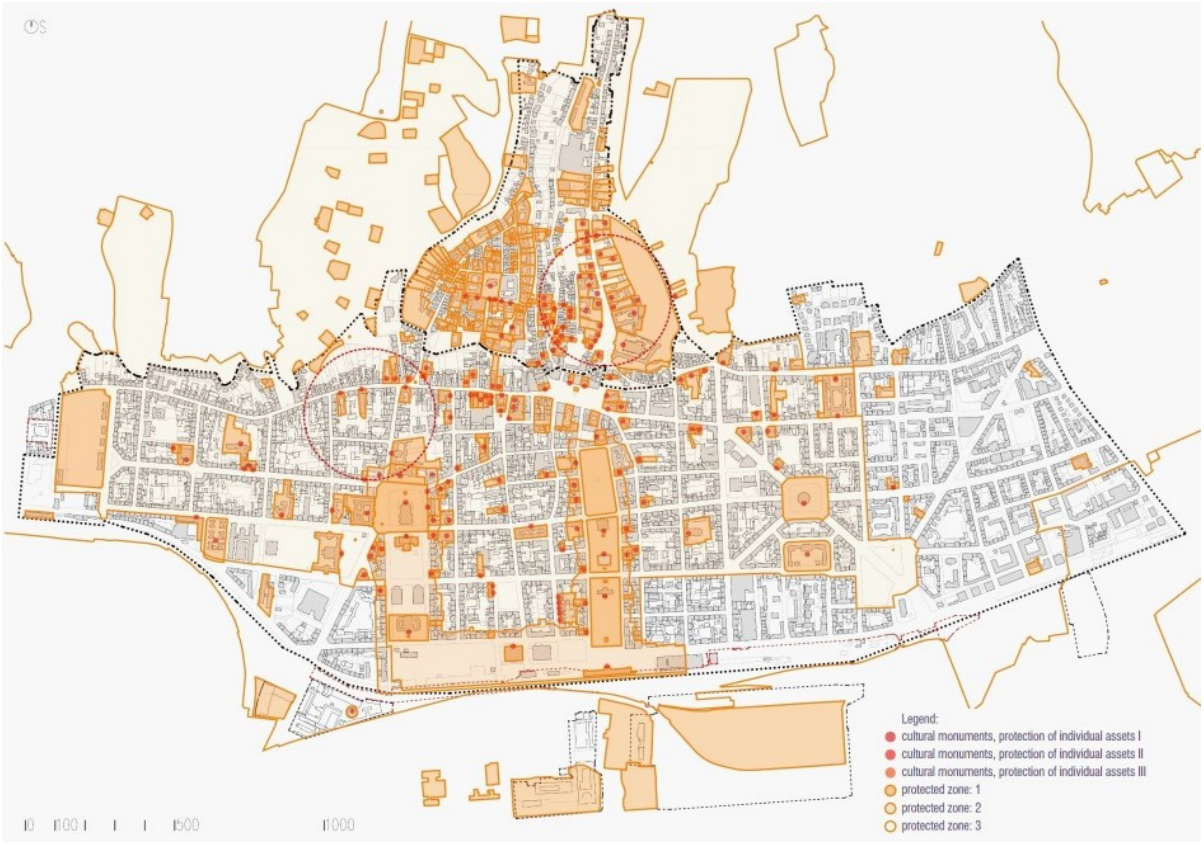

Fig. 2: Cultural monuments and protected zones (according to GIS, Ministry of Culture and Media); Source: Identity Topography of the Historic Urban Core of the City of Zagreb, Faculty of Architecture, University of Zagreb, Zagreb, 2023.

5.1 Design methodology and process: an innovative urban approach

The layering and complexity of space of the Historic Urban Core of the City of Zagreb required a new planning paradigm and instruments for finding integrated spatial solutions aimed at a high level of earthquake hazard insurance and a high standard of energy efficiency, while preserving the unique ambience and architectural value, retaining residents and preserving the socio-demographic vitality of the city center, and finding a sustainable organizational and financial-economic framework. To this end, the Institute for Physical Planning of the City of Zagreb gathered a multidisciplinary platform consisting of fifteen expert working groups of scientists and professionals who, within the framework of their professions and in mutual coordination, worked on research, and studies together with the Institute's urban planners.

Through the creation of the Programme (Zavod za prostorno uređenje, 2024), the Institute inaugurated an urban/planning breakthrough by introducing several new (and forgotten) topics that were not an integral part of the spatial planning regulatory framework or urban practice, aligned with the EU Green Plan (European Commission, 2020), such as early participatory processes, connection of urban and strategic planning, earthquake hazard and stability of the existing building stock, energy efficiency, energy transition and decarbonization, adaptation and mitigation of the impact of climate change, sociological analysis and quality of life, economic and property law possibility of implementation, principles of the 15-minute city and super-blocks and circular management of buildings and space, taking into account horizontal and vertical links.

The focus of the work on the Comprehensive Renewal Programme for the Historic Urban Core of the City of Zagreb is the interaction between urban planning and strategic economic development, i.e., the results that are created through interdisciplinary cooperation in situ and have implications for urban space. Development scenarios in time dynamics – spatial planning documents, by their nature, provide frameworks for action in space but do not determine the sequence or priorities, only the planned framework for action. Thus, urban plans do not include any emphasis on strategy, prioritization, or steps in spatial interventions, and different

solutions or alternative options are, by definition of unambiguity, difficult to implement without changing the plan.

5.2 A balanced hierarchical approach to sectoral research

For the realization of such a task, experts from all disciplines (Fig. 3) were mobilized, united in a single professional platform for a comprehensive systematic renewal of the center of Zagreb based on preserving the urban identity of the Historical Urban Core of the City of Zagreb, its ambience and views, improving housing and preserving the neighborhood, carefully programming the contents and activities of the blocks, improving mobility and the use of public space, establishing a green infrastructure system, energy transition and adaptation to climate change, designing a strategy for the seismic preservation of cultural heritage buildings and implementing a comprehensive earthquake-resistant rehabilitation of the valuable building stock of the City of Zagreb and reviewing financing options. In doing so, the synergy of science and profession, administration and economy, with timely participation of citizens, was of immense importance. The renovation/restoration of historical parts of the city requires effective and concrete, professionally relevant, and scientifically based activities.

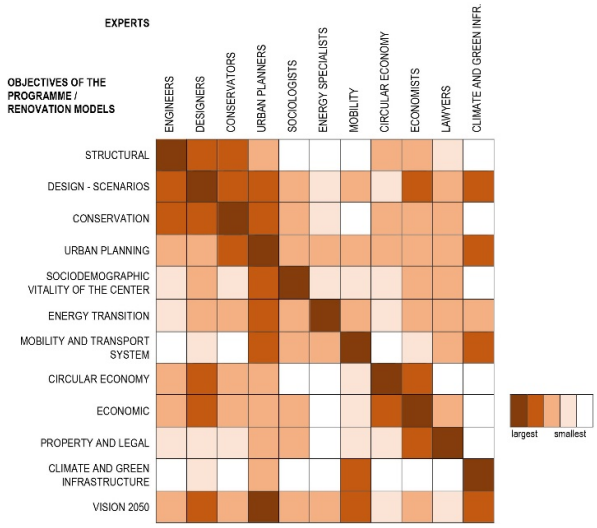

Fig. 3: Proposal of the necessary experts/studies related to the goals of the Comprehensive Renewal Program. Source: Institute for Physical Planning of the City of Zagreb, July 2020.

The Institute for Physical Planning of the City of Zagreb has developed a working framework together with the organizational structure and determined the dynamics of work on the Programme through two main stages: work on the Pilot Project Block_19 and work on the entire scope of the Historical Urban Core. Working groups were formed, work tasks were defined, and they were all carried out through research and the preparation of studies and expert papers and integrated into a comprehensive study through intensive inter-sectoral coordination (Fig. 4). A financial plan was drawn up. As a "project" in the project, an interoperable digital (GIS) database is being developed in which data from all relevant sectors is collected in a way that they can be grouped or aggregated and integrated for research and analysis, and the proposal of spatial solutions.

Work on the Programme was carried out simultaneously with activities on multiple levels: in parallel, detailed sectoral research was conducted at the level of the (selected) Pilot Project Blok_19, which was dealt with by most expert groups, at the level of the Historical Urban Core of the City of Zagreb, but also research that crosses the borders of the Historical Urban Core and has much wider zones of influence than the block/insula unit (mobility and transport systems, macroeconomic analysis and energy concept, identity). At the same time, attention was also paid to the dynamics of possible solutions, which were divided into short-term, medium-term and long-term frameworks.

5.3 Participatory process

Workshops and communication with residents and users were continuously conducted, as well as familiarization with the activities in their environment, surveys about their needs, ideas, suggestions and proposals about the space where they live and work. Sociological research was conducted in a mixed way –

partly “face to face”, partly in direct contact with respondents, and partly with the help of an online service/Online Survey (lockdown period due to the COVID-19 pandemic), i.e. qualitative sociological research on the quality of life and complete urban renewal and revitalization through focus groups with residents and through interviews with experts and actors of special importance for the urban renewal of that part of the historic urban complex.

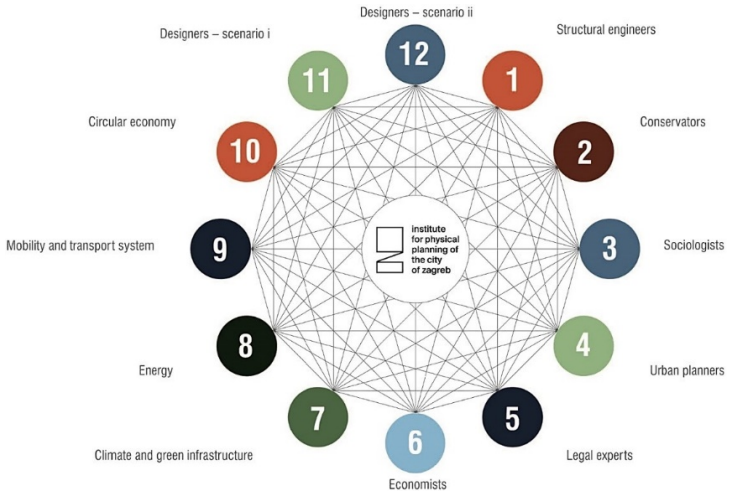

Fig. 4: Inter-sectoral coordination in developing the Comprehensive Renewal Programme. Source: Institute for Physical Planning of the City of Zagreb, July 2020.

During the work, the first results of sectoral research were presented, and the basic starting points, directions and visions, the main goals of the research, intersectoral connections, sectoral recommendations and directions for improving further work, as well as the guidelines of the new planning paradigm for an innovative urban approach – green urban renewal were determined.

The Comprehensive Renewal Programme proposal was presented throughout the process in various phases, with workshops, thematic discussions and public forums to the executive and representative authorities of the city, representatives of state and city administrative bodies, representatives of the Croatian Academy of Sciences and Arts and other scientific and professional institutions, representatives of professional and non-governmental organizations, citizens and representatives of the media, with constant coordination and harmonization of the work of 15 expert working groups.

5.4 Spatial scope of the Programme Development

The spatial scope of the Programme includes 168 lower city blocks and 36 insulas of the Upper Town and Kaptol, which is a total coverage of over 400 hectares with approximately 31,000 inhabitants (DZS, 2022), compared to approximately 45,000 inhabitants in 2001. The area of the thoroughly researched area of the pilot project Block_19 (the area of the block bounded by Ilica, Frankopanska, Dalmatinska, and Medulićeva streets, for which two scenarios of a possible design model of renovation were developed in order to explore spatial possibilities) is 3.3 ha.

5.5 Vision of comprehensive urban renewal and goals

According to the Vision of Urban Renewal and Development_GreenCenter 2050, the Historic Urban Core of the City of Zagreb in 2050 is a part of the city that, through the joint efforts of the city and state administration, the scientific and academic community, business people, residents and users of the space, is: organized and safe, attractive and lively, a multifunctional area of the city, with ensured socio-demographic vitality, inclusiveness and consideration, has experienced a new level of modernization and transformation, has been renovated and transformed circularly and innovatively, is a leader in energy transition, digitalization and economic development, has achieved climate neutrality, is relieved of transit automobile and freight rail traffic, has been redefined in terms of content and is the most desirable place to live among all city districts, and is an example of a competitive renovated city center.

After researching development problems and needs and defining the long-term Vision for the urban renewal of the Historic Urban Core of the City of Zagreb – GreenCenter 2050, five goals for comprehensive urban renewal were set and within them 54 appropriate measures were defined to achieve the given goals: 1.

innovative/circular renewal of the perimeter and structural transformation of the interior of the blocks/ insula; 2. sociodemographic vitality, social cohesion and fairness; 3. identity, ambient characteristics and recognizability of the city center; 4. resilience to climate change and climate neutrality through the use of nature-based solutions (NBS); 5. energy transition and improvements to the circular economy of a smart and green city based on digitalization.

5.6 Thematic modeling of space

Using the method of thematic modeling of the space of the Historic Urban Core of the City of Zagreb and interdisciplinary programming of spatial values, limitations and sustainable urban potentials, a new platform has been created – an urban planning and programming agenda – principles, recommendations and guidelines that aim to achieve the development goals of the comprehensive urban renewal of the Historic Urban Core and the City of Zagreb as a whole. After collecting thematic data and conducting basic analyses, identifying development problems and needs, and establishing strategic goals to be achieved, projects, measures, and activities have been proposed to implement them, and the prerequisites for their realisation have been highlighted.

Fig. 5: Assessment of usability of buildings in Block_19 after the Zagreb earthquake; Structural Models of Renewal (part of the comprehensive renewal of the protected Historic Urban Core of the City of Zagreb – Lower Town); Source: Faculty of Civil Engineering, University of Zagreb, Zagreb, 2021.

The components of thematic spatial modeling are: seismic hazard and stability of the existing (age and maintenance) building stock – structural models of renovation (Fig. 5), protection and preservation models – conservation models of renovation, affordable housing and sustainable mixed-use facilities – design models of renovation (Fig. 7), models of improving mobility and transport systems/sustainable mobility, models of preserving identity systems, models of improving the quality of life – sociological analyses, models of energy efficiency, energy transition and decarbonization, models of adaptation (and mitigation) to climate change (Fig. 6), models of circular management of buildings and space, models of quality planning and management of the development of green infrastructure by introducing the NBS system (Nature-Based Solutions) in the part of pluvial water drainage, property law models and feasibility of solutions, and models of possible financing.

Fig. 6 (left): Proposed green infrastructure solutions for Block_19; Adaptation to Climate Change Impacts and Green Infrastructure Usage – Block_19 Pilot Project; Source: North-West Croatia Regional Energy Agency – REGEA, Zagreb, 2021. Fig. 7 (right): Block_19 SCENARIO I: Planned construction – floor plan of the roof; Design Models of Renewal – Block_19 Pilot Project – SCENARIO I, Hržić; Source: Architecture Atelier, Zagreb, 2021.

By conducting multi-sector processes in parallel through a participatory platform consisting of all active participants in the City planning process, a comprehensive form/model was generated according to which activities are carried out to determine principles and develop recommendations and guidelines aimed at achieving the development goals of comprehensive urban renewal, as well as determining criteria for prioritizing/evaluating projects and activities (short-term and long-term), and ultimately determining performance indicators for monitoring implementation and evaluation.

5.6.1 Urban models of renewal

Through research conducted during the development of the Comprehensive Renewal Programme, key spatial aspects for the implementation of the comprehensive renewal of a historic urban core were identified: built structure, protection and preservation, facilities, housing, sustainable mobility, green spaces, nature-based solutions, property aspects, identity, modernization and urban safety, as recommendations, guidelines and prerequisites at the level of short-term and long-term measures, regardless of whether they relate to urban spatial planning or spatial management.

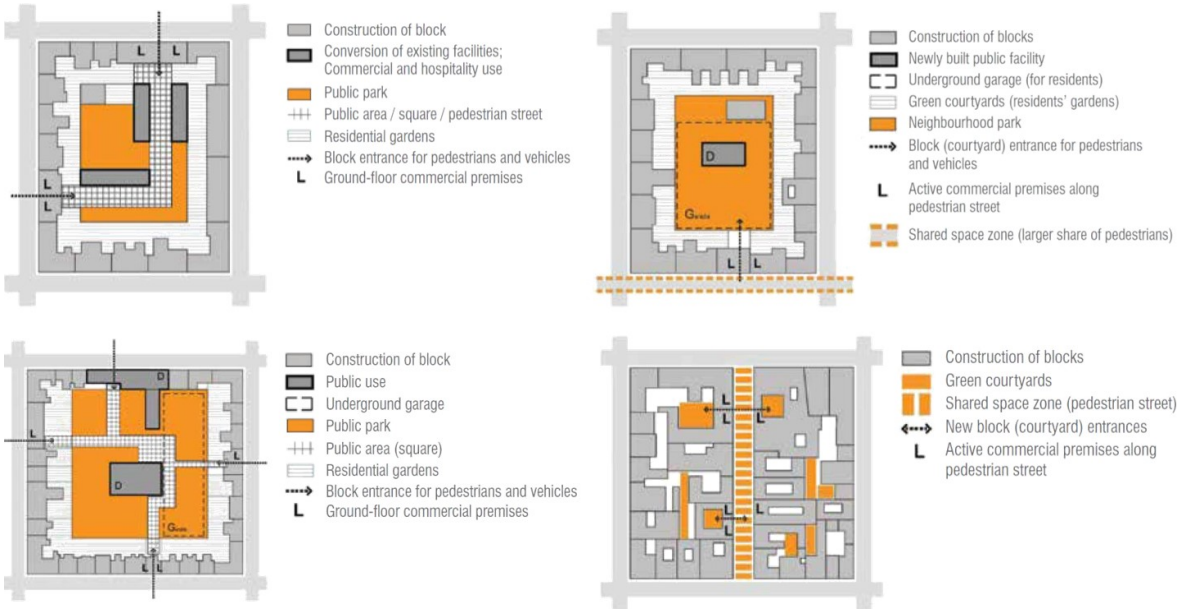

Fig. 8: Four proposed basic block renewal/transformation types/models for the Lower Town area: 1. Open block design – a new neighborhood sub-center; 2. Open block design, highly public character – public use, square, park; 3. Closed block design – garden with public amenities and underground garage; 4. Closed block design with a pedestrian street; Source: Urban Renewal Models, Faculty of Architecture, University of Zagreb/for the purpose of the Comprehensive Renewal Programme of the Historic Urban Core of the city of Zagreb, Zagreb, 2021.

Thus, four characteristic types of renovation (Fig. 8) are proposed for the area of the Lower Town and its 168 blocks based on the typological classification of blocks with the same or similar characteristics of the blocks and considering their structural and functional transformations and the possibility of property law implementation: a block of open character as a new sub-center of the neighborhood (1), a block of open, distinctly public character with a public purpose, square and park (2), a block of closed character as a park with public facilities and an underground garage (3), and a block of closed character with a pedestrian street (4), designed within the framework of the Comprehensive Renewal Programme for the Historical Urban Core (AF, 2021; 2022).

For the area of the Upper Town and Kaptol and the 36 insulas in its scope, the basic guidelines proposed by the Programme are: ensuring different intensity of use of individual parts, better connection with the Lower Town, balancing tourist facilities and relocating part of the Government facilities (Upper Town), harmonizing further activities of the City and the Zagreb Archdiocese and opening individual manor courtyards for public use (Kaptol), and avoiding commercialization and unification of catering facilities (area between Tkalčićeva – Nova Ves streets).

5.6.2 Conservation models of restauration

Based on architectural and photographic recording, archival and historical research, analysis of the existing condition, interpretation and detailed conservation valorization of the Historic Urban Core of the City of

Zagreb to propose conservation guidelines – the characteristic Lower town block – Block 19, the Upper town insula – Insula 11 and the Kaptol – Opatovina (within the framework of the Comprehensive Renewal Programme for the Historical Urban Core) conservation models of renewal have been proposed that include the conservation and restoration of historical structures, but also new urban and architectural interventions (IPU, 2021; 2022). In addition to the renovation of building structures, the revitalization of the historic core also requires the retention of key public functions and the population. In addition to conservation rehabilitation, the vision of the city's renewal should certainly include modern interventions, both urban and architectural.

The research proposed conservation models of renewal and conservation guidelines for the area of the Historic Urban Core of the City of Zagreb. Conservation models of renewal range from the model of complete protection of historical buildings (1), which is applied to the group of the most valuable historical buildings – individually protected cultural assets entered in the Register of Immovable Cultural Assets of the Republic of Croatia and the most prominent buildings erected along the perimeter of the block for which a final decision on renovation and restoration will be made only based on conservation studies that include restoration sounding of the facade, main parts of the interior and detailed architectural survey. As a rule, buildings from this group are preserved in their entirety, with the modernization of secondary interior spaces. Furthermore, the conservation model of partial protection of historical buildings (2) is applied to all buildings categorized lower than the previous two groups, for which it is proposed to preserve and restore street facades and roofs and representative common parts of the interior, while the design of other parts is free. The demolition and replacement with facsimile model (3) is applied if the degree of damage to the building is such that the building cannot be restored – partial facsimile reconstruction – a facsimile of the facade and possibly communication spaces, the rest is free design for lower categories of conservation protection or complete facsimile reconstruction for the highest level of conservation protection. The demolition and replacement with new construction model (4) is applied for buildings of the lowest architectural value, and the character of interpolation and design is taken over (conditioned by) the overall image of the block or neighboring buildings on the plot.

6 CONCLUSION: RECOMMENDATIONS AND GUIDELINES FOR THE DEVELOPMENT OF AN URBAN PLANNING AND CONSERVATION PLAN

The strong earthquakes that hit Zagreb in 2020 pointed to the long-term neglect and endangerment of the city center, made people aware of the great risk of earthquake hazard, additionally pointed to the need to find different planning tools and procedures to speed up the process of urban renewal – functional and qualitative changes to the economic, social, cultural and environmental deficiencies of the degraded central historical part of the city. In addition to the renovation primarily aimed at achieving the highest possible level of safety of the building stock, while respecting the preservation of morphology, ambience, atmosphere and achieving socio-demographic balance, the Institute's urban ambitions were also aimed at modernization in the form of green development and accelerated energy transition towards renewable energy sources and climate neutrality.

A total of 15 interdisciplinary teams with almost 200 scientists and experts participated in the research and task of developing the vision of urban renewal – GreenCenter 2050, as well as in defining the program models of renewal. Given the wide range of topics and sectors covered by the Programme, its role in directing planning activities through a high degree of respect and consensus of different professions, the involvement of local residents throughout all phases of the program-planning process, and a high degree of cooperation between all levels of government, is also evident. The focus of the work is the interaction between urban planning (spatial-urban plans) and all strategic development guidelines (strategies), i.e. the results that are created through interdisciplinary cooperation in situ and have implications for urban space. Historical urban entities require additional attention directed towards cultural heritage, which is one of the key components of the identity of the space (Hosagrahar et al., 2016). Planned activities for the preservation and sustainable development of historic urban core (Miele, 2005) therefore necessarily require the integration of cultural heritage into spatial planning documentation (Bandarin et al., 2012) in the form of the development of an integrated Urban Conservation Plan – by combining conservation guidelines with urban planning guidelines for optimal inclusion in development activities/programs (Ministarstvo kulture, 2022).

The program does not have an implementation character, but the program-plan synthesis of individual recommendations, guidelines and prerequisites developed by the Institute, in cooperation with the main social actors – the "quadruple helix" (which, with their synergistic effect, provide a balanced platform for a multidisciplinary innovative approach to integrated development) is also the starting point for the elaboration of the Urban Planning and Conservation Plan of the Historic Urban Core of the City of Zagreb (Kerr, 2013; Kropf et al., 2023) according to the following thematic areas:

1. Built structure – the importance of ground floor content/interaction with public space, removal of neglected substandard construction inside the blocks, functional additions/extensions/superstructures in order to improve the quality of life (elevators, public and social facilities, neighborhood garages, etc.), structural changes in the interior of the blocks, modernization of existing construction in accordance with special regulations, connection of open public spaces to achieve recognizable systems of undeveloped public space (existing and newly realized);

2. Facilities – improving the quality, number, and distribution of facilities important for the daily life of residents (kindergartens, daily consumption shops, recreation and sports, culture) to retain existing and attracting new residents, a harmonized relationship between residential and business purposes;

3. Housing – improving existing and planning new facilities important for daily life, encouraging the modernization/transformation of blocks – complete renovation with functional and structural transformation, removing substandard construction inside the blocks, arranging the interior of the blocks;

4. Green infrastructure – increasing the share and quality of green areas at the block level, encouraging comprehensive concepts of arrangement, affirmation and functional transformation of green courtyards at the level of several blocks, by implementing elements of green infrastructure, increasing the attractiveness of the street system and encouraging citizens to actively use public spaces, ensuring at least 20% of natural soil for new construction;

5. Sustainable mobility – encouraging the development of the center according to the "15-minute city" traffic model, improving and adapting the parking/garage concept in the city center, exploring the spatial and financial possibilities of building block garages to eliminate parking spaces along the street network;

6. Nature-based solutions – using nature-based solutions to mitigate heat islands and drain pluvial waters (in situ stormwater drainage solution, retention and gradual release of water into the underground, increasing natural terrain, green roofs);

7. Modernization/transformation – enabling adaptation to modern life needs, in accordance with new requirements, standards and technological achievements (with respect for the architectural and cultural-historical heritage and the improvement of inherited identity values), ensuring and encouraging the application of new technical and technological solutions while maintaining the ambiance, encouraging and implementing energy renovation, reducing energy consumption, green construction, mobility and decarbonization (smart, resilient and creative city).

From the presented thematic spatial modeling and interdisciplinary programming of spatial values, constraints and sustainable urban potentials in the development of the Comprehensive Renewal Programme for the Historic Urban Core of the City of Zagreb, with the cooperation of all stakeholders participating in the development of the city and different levels of government, it is clear that the interconnectedness and complexity of the challenges provide added value and that it leads to multiple benefits for various sectors and at different levels of planning. Therefore, the development of an integrated Urban Conservation Plan by unifying conservation guidelines with urban guidelines for optimal inclusion in development activities/programs requires a transformation/transition from traditional, "static" approaches to plan development towards an integrated, "dynamic" process that includes the interaction of all relevant stakeholders to recognize the character and specificity of local conditions for the purpose of developing a resilient city that can respond to current and future challenges (UN-HABITAT III, 2016).

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Introducing a Financial Twin App for Exploration and Comparison of Municipal Financial Patterns

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1 ABSTRACT

The availability of financial resources determines the extent to which municipalities can proactively manage critical aspects such as sustainable urban planning, infrastructure development, public service improvement, and regional development (Zimmermann, 2018). The foresighted management of these financial resources is, therefore, crucial for municipal decision-making. This project introduces a decision-support tool designed to analyze and visualize financial patterns among municipalities in North Rhine-Westphalia, Germany.

Drawing on municipal financial data and population records for the 22 urban municipalities in North Rhine-Westphalia from 2009 to 2022, the application is built on a Flask-based web framework integrated with Python libraries, including pandas, scikit-learn, and GeoPandas. These libraries enable robust data processing, analysis, and visualization. GeoPandas facilitates geospatial analyses and visualizations, which are integral to understanding spatial trends in municipal finance (Jordahl et al., 2014). The system identifies "financial twins" – municipalities exhibiting comparable financial behavior in terms of income and expenditures across domains such as education, public safety, and infrastructure. The inclusion of population records allows for per-capita and absolute value analyses, ensuring contextual relevance.

The tool provides a list of financial twins for all 22 urban municipalities based on cosine similarity and Euclidean distance. It offers corresponding data for each year from 2009 to 2022, with the flexibility to analyze twins either with or without factoring in the population of each municipality for a given year. The application also employs the k-means clustering technique to group municipalities into intuitive categories, highlighting shared financial characteristics.

The tool can serve as a resource for:

- Benchmarking and Collaboration: Identifying peer municipalities to share successful financial strategies.
- Exploration and Comparison: Highlighting similarities and differences, and their impacts on financial decision-making.
- Policy Development: Offering actionable insights into resource allocation and prioritization.

This initiative underscores the critical role of data-driven approaches in addressing the complexities of urban financial planning in public administration. By making sophisticated clustering and visualization accessible to planners, the tool bridges the gap between raw data and actionable policy insights. Future work will explore predictive modelling and integration with socio-economic data to further enhance its relevance for strategic urban development.

Keywords: big data, financial twin app, decision support, financial data, clustering

2 MOTIVATION

The analysis of municipal financial data is crucial for effective governance and sustainable community development. Municipalities are responsible for providing essential services such as education, public safety, infrastructure, and health care. Understanding the financial health of a municipality enables decision-makers to allocate resources efficiently, ensuring that these services are delivered effectively and equitably (Bahl & Linn, 1992). One of the primary reasons for analyzing municipal financial data is to identify trends and patterns that can inform policy decisions. By examining revenue sources, expenditure patterns, and debt levels, municipal leaders can gain insights into the fiscal sustainability of their communities. This analysis helps in forecasting future financial conditions, allowing municipalities to prepare for economic fluctuations

and demographic changes (Mikesell, 2013).Moreover, the analysis of financial data fosters transparency and accountability. Citizens have a right to know how their taxes are being spent. By making financial data accessible and understandable, municipalities can build trust with their constituents. Engaged citizens are more likely to participate in local governance, advocate for necessary changes, and support initiatives that enhance community well-being (National League of Cities, 2018).Additionally, financial data analysis aids in strategic planning. Municipalities can identify areas where efficiencies can be gained or where investments are needed most. For instance, analyzing data on infrastructure maintenance costs can highlight the need for preventive measures, ultimately saving money in the long run (Gordon, 2015).

Amid growing challenges from demographic shifts and economic pressures, leveraging financial data is essential for navigating the complexities of modern governance (Bourdeaux, 2008).This study applies clustering and similarity analysis approaches to enhance the understanding of municipal financial data and enable policymakers in making better-informed decisions. First, an overview over existing research in the field of digital twins in municipal policymaking is provided,followed by a detailed description of the dataset used for this approach. Before presenting insights into the application, the methodological approaches are outlinedin greater detail. The study concludes with an outlook on potential future research steps.

2.1 Existing research approaches in the field of municipal financial data analysis

Municipal financial data analysis is essential for maintaining transparency, accountability, and efficient resource allocation in local government operations in Germany. Local governments are responsible for key public services, including education, infrastructure, social welfare, and public safety, all of which require significant financial oversight. By analyzing municipal financial data, local governments can ensure that their expenditures align with budgetary constraints, forecast future revenue streams, and monitor the long-term sustainability of investments (Löffler & Hoffer, 2015).

Research highlights that municipal financial analysis plays a crucial role in ensuring fiscal discipline and effective governance. For instance, Lehtonen (2017) emphasizes that financial transparency at the local level improves public trust, while Feld &Kirchgässner (2009) argue that rigorous financial management practices contribute to reducing public debt and avoiding fiscal crises. Such analysis also aids in identifying inefficiencies, prioritizing public spending, and assessing the economic health of municipalities (Scharpf, 2003). Furthermore, studies like Homburg (2010) suggest that financial data analysis provides a foundation for evidence-based policy decisions, enabling municipalities to navigate challenges such as economic downturns or demographic shifts. By making financial information accessible to citizens and stakeholders, municipalities foster greater civic participation and accountability (Bovens, 2005).

While most digital twin application focus on providing additional insights and scenario-based planning approaches by creating a hypothetical twin model of the real subject, our approach focuses on identifying an existing financial twin using approaches from similarity analysis. With this approach we not only aim to identify existing patterns but to also enable municipalities to discuss strategies and policy options based in similarities in very specific areas of responsibilities.

In the context of enhancing the understanding of municipal financial data, the introduction of the financial twin application serves a dual purpose: (1) applying clustering approaches to reveal patterns across municipalities based on financial data, and (2) utilizing similarity analysis approaches to provide deeper insights into the specificexpenditure categories causing financial similarity. This clustering approach extends beyond traditional approaches in grouping municipalities, which predominantly focus mostly on regional structure, overall resource availability and by demographic factors such as youth quotient. The proposed approach uses financial data to an extent to which learning processes can be deducted from the initial analysis and with furthering this research important factors influencing changes in clustering patterns can be identified. The approaches with similarity measures takes those insights further in enabling the identification of product groups and detailed levels of municipal expenditure data that drive similarities between municipalities.

3 DATA SOURCE

The municipal structure in Germany plays a crucial role in the federal system of governance, with municipalities (known as "Kommunen") being the local level of government responsible for various administrative, social, and economic functions. Municipalities in Germany vary in size, scope, and

population, from small rural villages to large cities. Despite their differences, they all share a basic framework of responsibilities and governance structures. The responsibilities are vast, ranging from social welfare and public safety to urban planning, education, and infrastructure management. For each municipal responsibility expenditure (payouts) and income (payin) data can be attributed. The structure thereby is designed to promote local autonomy, ensuring that municipalities can tailor their services to the specific needs of their residents. The municipal responsibilitiesand the corresponding expenditure and income data can be sorted into many categories (see Figure 1).

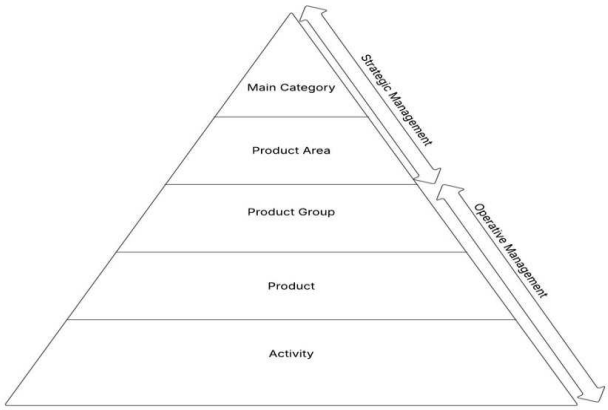

Fig. 1: Product pyramid of municipal accounting

Examples can be local government and administration, public services and infrastructure, social services, public safety and emergency services, culture, sports and leisure, economic development and local business support. Each of those main categories can be specified even further. Social services, for example, includeproduct areas such as childcare and specifying again even further children day care centers. In our data set we analyze the expenditure and income data for 102 product groups.

Municipal structures in Germany generally differentiate between (district-free) cities, towns and districts.While (district-free) cities and districts share a similar level of responsibility, towns and smaller municipalities have fewer obligations to fulfill. The partition of responsibilities between states, (district-free) cities, districts and smaller municipalities varies across federal states. For the initialimplementation of the financial twin app, the focus is therefore set on the state of North-Rhein Westfalia (NRW)to ensure comparability under uniform responsibilities and similar expenditure potentials. The study analyzes a newly composed dataset consisting of time series data from 22 urban municipalities in NRW, covering the period from 2009 to 2022. The dataset includes the cash inflow and cash outflow of those municipalities. Since the objective of this research is to identify common expenditure and income patterns, we are not focusing on overall expenditure and spending but rather on the expenditure and income within individual product groups.Focusing on the level of product group, this analysis is observing both strategic management decisions and a more detailed level of operative management decisions on how to provide sufficient service to the public. Toadd another level of depth to the analysis population data is incorporated to enable analysis of per capita values. This enhances an even better comparability of financial behaviors across municipalities.

4 METHODOLOGY

To measure the similarity between the financial structure of two municipalities based on the provided data, several preliminary steps are required. First, it is necessary to identify the relevant attributes and determine an appropriate weighting strategy. Secondly, the user needs to be provided with a preselection of the most suitable distance metrics for this specific application. The chosen clustering technique is also described in detail. Moreover, this section presents a detailed explanation of the system design of the tool, outlining its structure, key components, and their interactions to ensure a well-organized and effective implementation.

4.1 Data Preparation and Analytical approaches

The datasets available, which have been explained in detail in Section 3, provide a wealth of information that needs to be meaningfully correlated. To achieve this, the datasets themselves must be prepared, and appropriate techniques for analysis must be selected.

4.1.1 Identifying key parameters

It makes a significant difference when considering whether to analyzethe absolutefigures of a municipality or the per capita values. Therefore, the total population of the municipality provides valuable information. The idea of selecting or aggregating individual accounts to simplify understanding and enhance clarity was discarded, as it could, under certain circumstances, hinder detailed comparability by experts. Instead, users are given the option to select the accounts relevant to their specific analysis. In the default mode, a comprehensive view of all accounts is always provided. Inflows and outflows are considered separately. The user can choose whether to focus on one or the other.

The option to assign greater weight to individual accounts has not yet been implemented. It is also conceivable to take the age distribution of the population into account. In the first version of the application, municipalities are also only compared within the same year, even though multiple years are available, and the comparison could be extended.

4.1.2 Selection of distance measures

To measure the similarity between two municipalities, pairwise distances based on either relative or total figures are utilized. Depending on the calculated value, one can make a statement about the proximity and therefore similarity of the respective municipalities. This can be done in different ways, leading to varying results. Therefore, the choice of an appropriate metric is crucial, and the correct interpretation of the results is of utmost importance. Two measures[1] have been identified as relevant:

For two given cities, P and Q, with the values of their respective accounts (in absolute or per capita values)$p = (p_1, p_2, \ldots, p_n)$ and $q = (q_1, q_2, \ldots, q_n)$, their *Euclidean Distance* is calculated as:

$$d_{eucl}(p, q) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2 + \ldots + (p_n - q_n)^2}$$

Based on the pairwise differences in the amounts of individual accounts, an overall distance is calculated. The smaller the results, the closer and thus more similar the two municipalities are.It must be noted that accounts with very high amounts can generally have a significantly greater impact. This, along with the fact that there are many zero entries, leads us to the second approach, which utilizes Cosine Similarity. In this case, the magnitude of expenditures does not matter; rather, the focus is on the pattern of accounts that are nonzero.

Again,the n-dimensional vectors p and q as above are being used, this time to first define the *Cosine Similarity*:

$$\cos(p, q) = \frac{p * q}{\|p\| \cdot \|q\|},$$

where * denotes the dot product of two vectors.

This results in the *Cosine Distance*:

$$d_{cos}(p, q) = 1 - \frac{p * q}{\| p \| \cdot \| q \|}$$

Since only non-negative entries occur in this use case, the values of$d_{cos}(p, q)$range between 0 and 1. A value of 0 indicates that the vectors are identical in terms of direction, while a value of 1 signifies the maximum possible difference between them.

The two measures are not completely independent of each other, but in this case, they may lead to very different interpretations. Additionally, two municipalities may be close to each other when using one measure while exhibiting a large distance when using the other (see example in Figure 2).

[1]The Python library used (scipy.spatial.distance.pdist) employs the parameter name "metric", even though Cosine Distance is not a metric in the mathematical sense, as it does not fulfill the conditions of the triangle inequality.

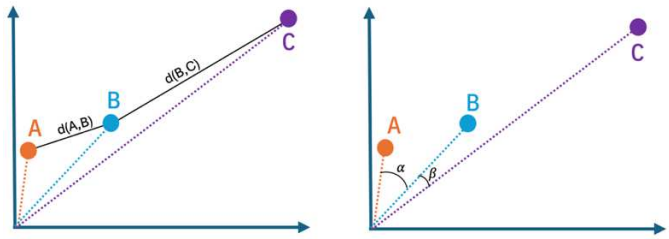

Fig. 2: The Euclidean distance d(A,B) is smaller than d(B,C) (left), whereas the cosine distance α between points A and B is greater than the cosine distance β between B and C (right). Own illustration.

4.1.3 Clustering technique and optimal number of clusters

With the aim of partitioning the given municipalities into a predefined number of disjoint groups, the well-established k-means algorithm was employed. The algorithm is provided with the desired number of clusters and, through an iterative process based on the concept of centroids, assigns municipalities to groups in a manner that minimizes their variance as much as possible.[2]

In a practical context, there is no single, universally defined true number of clusters. The optimal number of clusters must be determined based on data-driven criteria and an understanding of the specific objectives. To determine an optimal number of clusters, Silhouette Scores (Rousseeuw, 1987) were used. They provide an indication of the quality of the clustering results by calculating, for each data point, the average distance to all other points within the same cluster and comparing it to the shortest average distance to points in the nearest neighbouring cluster. The Silhouette Score is then derived by computing the ratio between these distances, resulting in a value between -1 and 1, where higher values indicate better-defined clusters.By comparing Silhouette Scores for different numbers of clusters, the optimal number of clusters can be identified (see Figure 3). In this use case, the optimal number of clusters may depend on the chosen year, the selected accounts, and whether absolute or per capita values are considered.

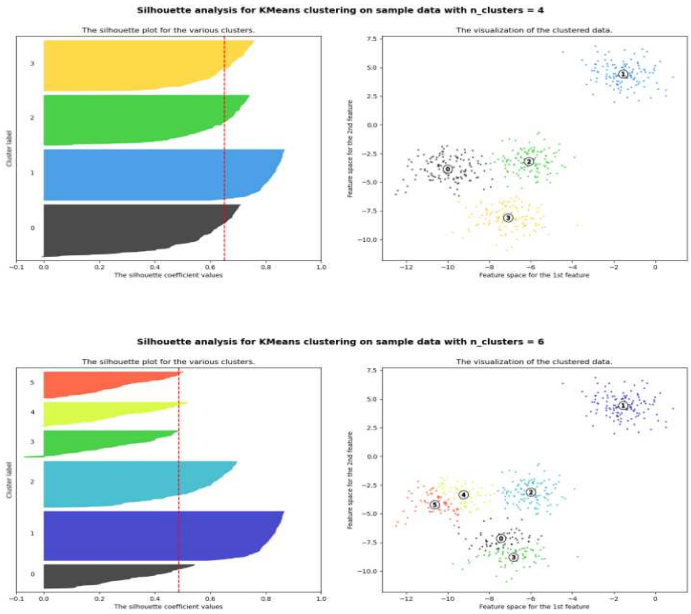

Fig. 3: Example results of two k-means clustering applications with 4 and 6 clusters. The Silhouette Score is indicated by the red dashed line. It can be observed that the 4-cluster solution achieves a higher score (Pedrogosa 2011).

Since the algorithm depends on the pairwise distances between vectors, different metrics can again lead to different results. By default, the Euclidean distance is used in the Python library scikit-learn (Pedrogosa 2011), and this is also the case here.

[2] Since k-means is a heuristic algorithm, it may only find a locally optimal solution.

4.2 Architecture and User Interaction

The architecture of any web application serves as the foundation that supports scalability, performance and maintainability. A well-structured system facilitates seamless interaction between backend and frontend components which enables efficient data processing and subsequent visualization of the results. The decision to develop a web application was driven by the ease of use for end users and the simplicity of distribution, ensuring accessibility without the need for complex installations. This section highlights the key architectural design adopted in this Flask-based web application.

4.2.1 Overview of the Flask-Based Web Application

The application is designed with a modular and scalable architecture, ensuring efficient financial analysis for municipalities in NRW. It integrates backend processing for data computation and financial insights with an interactive frontend for clear visualizations and user-friendly interaction. Figure 4 displays the interaction between the various architectural components of the application.

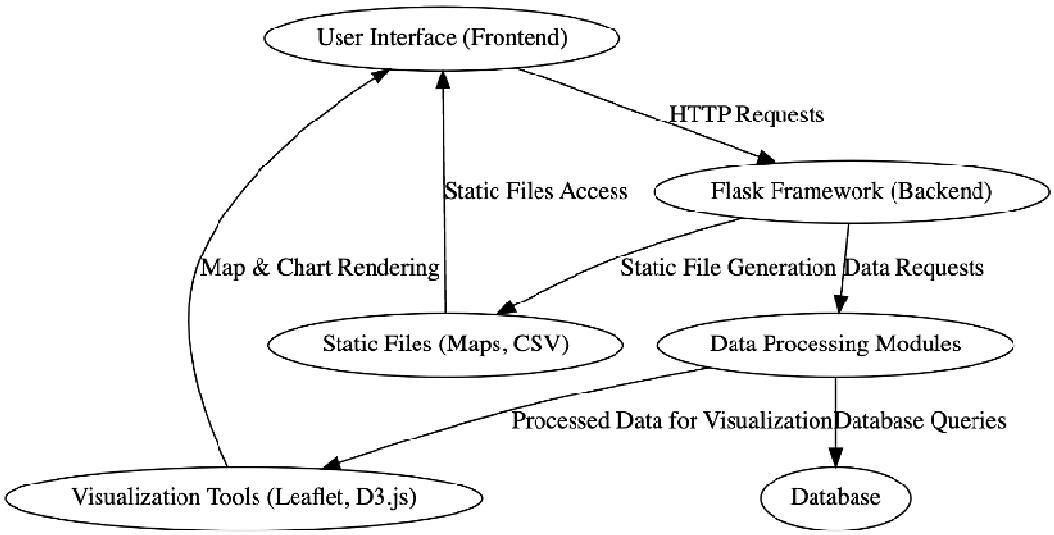

Fig. 4: Architectural representation: Illustration of the interaction of the different components of the application.

The key components of the architecture can be broadly categorized into Backendand Frontend. The Frontend components can be further differentiated between the interactive, User Interface, Flow of User Interaction and Visualization.

4.2.2 Backend: Flask Framework and Data Processing Modules

The backend forms the core of the application and is built on Flask, a lightweight yet efficient Python framework. It processes user requests, manages data interactions, and dynamically delivers results. The framework handles HTTP request management, user session control, and error handling, ensuring system reliability. Additionally, it employs the Jinja2 template engine to render dynamic content,which seamlessly integrates with the frontend.

The data processing modules utilize Python libraries such as pandas, NumPy, and SciPy to perform advanced calculations, including cosine similarity and Euclidean distance measures. Clustering algorithms like k-means from scikit-learn are applied to identify financial twin clusters. A custom module normalizes and aggregates datasets, generates insights, and prepares data for visualization. The application dynamically retrieves and processes financial data from Excel files and geospatial shapefiles, ensuring real-time updates based on user interactions with municipal and financial parameters.

4.2.3 Frontend: Interactive User Interface, Flow of User Interaction and Visualizations

The frontend is designed to provide a user-friendly and interactive environment for financial data exploration. The Jinja2 template engine dynamically renders HTML content, while Bootstrap and CSS frameworks ensure responsive and visually appealing layouts. Users can input parameters such as municipality selection, financial years, and clustering attributes through intuitive forms. The system presents results in structured tables and interactive charts, allowing users to analyze financial insights effectively.

Export options are available for downloading analysis results in Excel or ZIP formats containing maps. Navigation across the application is seamless, with dedicated pages for Startup, Analytics, and Map Generation. Users can explore financial data dynamically by selecting relevant options, and the system processes these inputs in real time, providingimmediate feedback.

The interaction begins with input parameter selection. Users choose a municipality from the Startup page by clicking on a financial twin displayed in the table. The system then selects the corresponding financial metric automatically. Additional parameters such as the year and population metric (inclusion or exclusion of per capita value in analysis) can be adjusted via dropdown menus. Once the parameters are set, the backend processes the selection to compute financial similarities, generate clustering results, and produce financial twin comparisons. The results include detailed twin pairs, key differences, and distance metrics.The visualization phase presents these findings in the form of interactive tables and maps, allowing users to explore financial twin clusters with ease. The system enables iterative refinements, allowing users to modify parameters and analyze new results dynamically. Additionally, users can export data and visualizations for offline analysis.

The application integrates various visualization tools to ensure clear and actionable financial insights through geospatial representations. Leaflet.js, a lightweight JavaScript library, enables dynamic and interactive maps, with distinct colors representing financial twin clusters for enhanced differentiation. D3.js supports custom visualizations, including graphs, sliders, and trend charts that help analyze financial patterns over time. Geospatial data integration is achieved using GeoPandas, ensuring accurate mapping of financial clusters based on municipal shapefiles. The system also includes export features that allow users to download maps as images or CSV files for further analysis.

5 IMPLEMENTATION DETAILS

The implementation of this application follows a structured approach which facilitates seamless flow during the financial twin analysis. It details the key features and functionalities, highlighting how different components work together. The following subsections describe the core features of the application and their roles in ensuring efficient financial data exploration.

5.1 Application Features

The application features are designed to provide meaningful insights in the context of financial twin analysis. The following subsections summarize the role of each page of the web application. It highlights the functionality and significance of each component.

Municipality	Payins Cosine Twin	Payins Euclidean Twin	Payouts Cosine Twin	Payouts Euclidean Twin
Düsseldorf, krfr. Stadt	Münster, krfr. Stadt	Hagen, krfr. Stadt	Köln, krfr. Stadt	Köln, krfr. Stadt
Duisburg, krfr. Stadt	Herne, krfr. Stadt	Leverkusen, krfr. Stadt	Münster, krfr. Stadt	Wuppertal, krfr. Stadt
Essen, krfr. Stadt	Mülheim an der Ruhr, krfr. Stadt	Mülheim an der Ruhr, krfr. Stadt	Hamm, krfr. Stadt	Mülheim an der Ruhr, krfr. Stadt
Krefeld, krfr. Stadt	Köln, krfr. Stadt	Köln, krfr. Stadt	Herne, krfr. Stadt	Leverkusen, krfr. Stadt
Mönchengladbach, krfr. Stadt	Dortmund, krfr. Stadt	Dortmund, krfr. Stadt	Oberhausen, krfr. Stadt	Oberhausen, krfr. Stadt
Mülheim an der Ruhr, krfr. Stadt	Essen, krfr. Stadt	Essen, krfr. Stadt	Gelsenkirchen, krfr. Stadt	Solingen, krfr. Stadt
Oberhausen, krfr. Stadt	Mönchengladbach, krfr. Stadt	Mönchengladbach, krfr. Stadt	Mönchengladbach, krfr. Stadt	Mönchengladbach, krfr. Stadt
Remscheid, krfr. Stadt	Münster, krfr. Stadt	Duisburg, krfr. Stadt	Münster, krfr. Stadt	Hagen, krfr. Stadt
Solingen, krfr. Stadt	Hamm, krfr. Stadt	Wuppertal, krfr. Stadt	Herne, krfr. Stadt	Köln, krfr. Stadt
Wuppertal, krfr. Stadt	Hamm, krfr. Stadt	Münster, krfr. Stadt	Münster, krfr. Stadt	Münster, krfr. Stadt
Bonn, krfr. Stadt	Bielefeld, krfr. Stadt	Bielefeld, krfr. Stadt	Hagen, krfr. Stadt	Hagen, krfr. Stadt
Köln, krfr. Stadt	Krefeld, krfr. Stadt	Krefeld, krfr. Stadt	Herne, krfr. Stadt	Düsseldorf, krfr. Stadt
Leverkusen, krfr. Stadt	Düsseldorf, krfr. Stadt	Hagen, krfr. Stadt	Krefeld, krfr. Stadt	Krefeld, krfr. Stadt
Bottrop, krfr. Stadt	Oberhausen, krfr. Stadt	Oberhausen, krfr. Stadt	Gelsenkirchen, krfr. Stadt	Oberhausen, krfr. Stadt

Fig. 5: Startup Pageof the application, displaying financial twin analysis in a tabular format

5.1.1 Startup Page

The startup page (Figure5) serves as the entry point to the application and provides an overview of the financial twin analysis in a tabular format. It displays financial twins based on different mathematical models, namely cosine and Euclidean similarity (refer to Section 4.1.2). The table also includes payins and payouts, representing allocated funds and incurred expenses, respectively (refer to Section 3). By default, the displayed data corresponds to the year 2019, with per capita data as basis for the calculations. Users can modify these settings through a dropdown menu, selecting a different year or opting to exclude population data from the analysis. Additionally, the startup page features interactive action buttons that enhance user navigation. The "Check Clusters on NRW Map" button redirects users to a page displaying financial twin clusters on a map, providing a geospatial perspective. The "Check Financial Twin of Individual Municipalities" button allows users to retrieve detailed financial twin data for a specific municipality each year, facilitating comparative financial analysis.

5.1.2 Analytics Page

The analytics (Figure 6) page allows users to dive deeper into the financial twin analysis by examining the closest and farthest financial parameters between municipalities.

The analytics module provides a detailed comparison of financial parameters between a municipality and its financial twin. It highlights both the closest and farthest parameters, allowing users to identify areas of similarity and divergence. By default, the analysis considers five parameters, though users have the flexibility to adjust this range between one and ten. To facilitate further exploration, an "Export as Excel" option enables users to download the results for offline analysis.

Additionally, the interface supports interactive exploration, allowing users to click on the differences displayed in the table to expand and view a detailed breakdown of the individual values contributing to the computed differences.

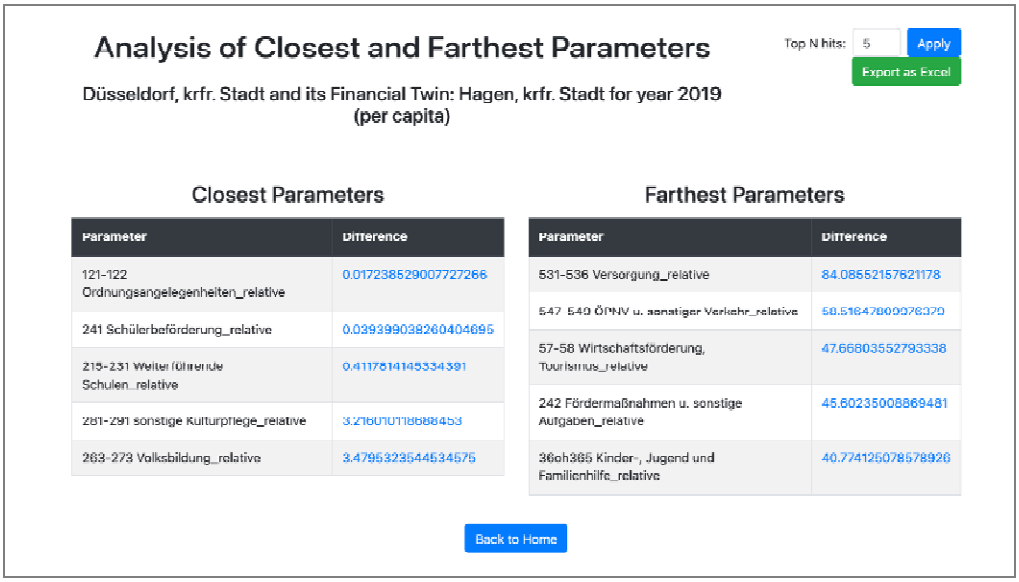

Fig. 6: The analytics page showing the closest and farthest financial parameters between a municipality and its financial twin.

5.1.3 Generate Maps Page

The generate maps page (Figure7) allows users to create visual clusters of municipalities based on specific input parameters.

The clustering module provides users with a flexible interface to customize financial data analysis. It includes input fields for selecting the financial data type, allowing users to choose between payins or payouts for clustering. The number of clusters can be defined manually, with a default value of four, or calculated dynamically based on historical data (2009–2022) using a built-in calculation function. Users can further refine their analysis by enabling the "Check Per Capita" option, which incorporates population metrics into the calculations. Additionally, a dropdown menu allows the selection of specific expense fields for clustering, with the default setting including all fields.

Upon submission, the "Generate Maps" button processes the selected parameters and visualizes the resulting clusters on an interactive map. A dedicated section enables users to compute the ideal number of clusters for a given year, considering all specified parameters. This feature is particularly useful for those seeking to explore financial distributions in greater detail and optimize cluster selection for more meaningful insights.

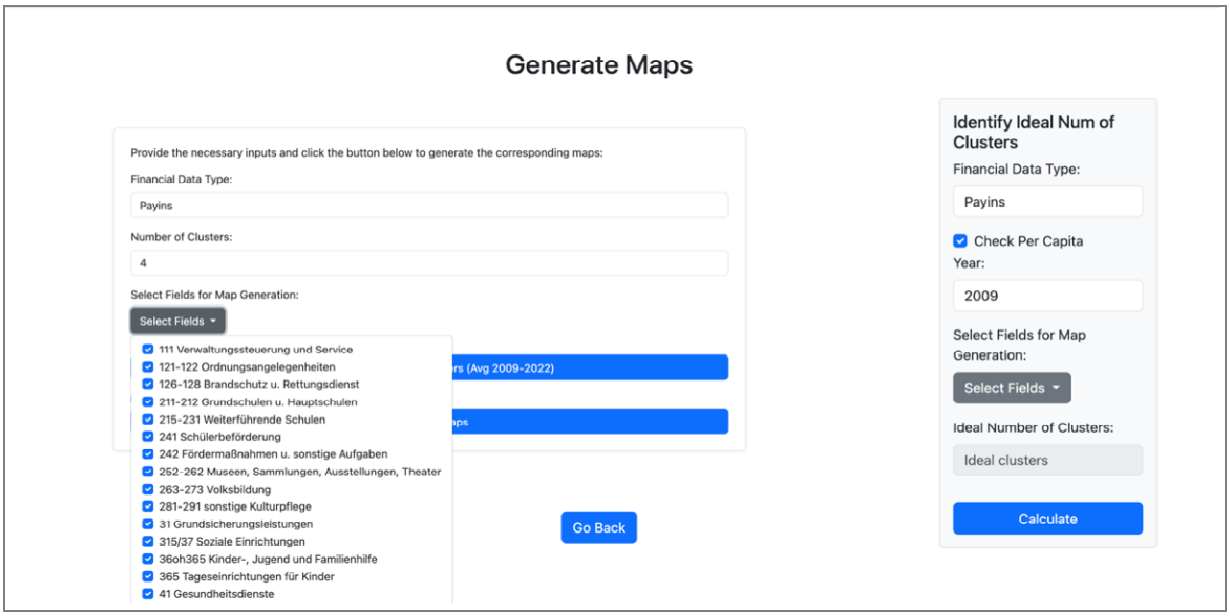

Fig. 7: The map generation interface – selecting financial data, clustering parameters, and calculating the ideal number of clusters.

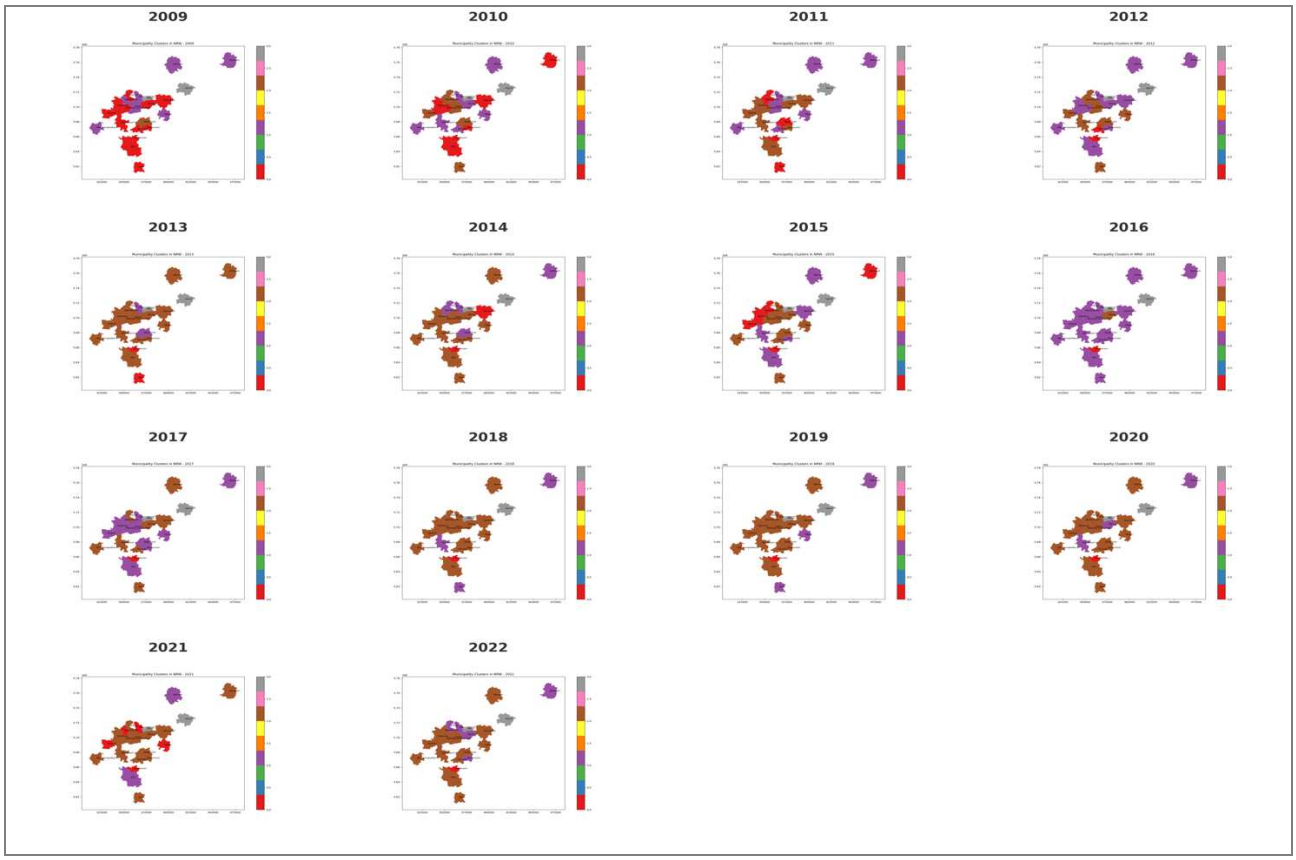

Fig. 8: Generated maps displaying municipality clusters in NRW for 2009 to 2022, with distinct colors representing different financial similarity groups.

5.1.4 Generated Maps Page

The generated maps page visualizes the financial twin clusters for NRW municipalities for all years (2009 to 2022) via a scrollable carousel display.This page provides an interactive visualization of clustered municipalities based on financial similarity, with each cluster represented by a distinct color for easy

differentiation (see Figure 8). Users can navigate through different years using a slider, enabling comparative analysis over time. Additionally, the page offers export options, allowing users to download maps as images in a ZIP file or export map data as CSV files for further analysis and offline use.

6 RESULTS AND DISCUSSION

This section presents the key findings of the study, focusing on the identification of financial twins among municipalities in the German federal state of North Rhine-Westphalia (NRW) and the observed trends in financial clustering over time. The results demonstrate how demographic factors and different similarity measures influence financial analysis outcomes.

6.1 Key Insights from the Application

By leveraging mathematical models such as cosine similarity and Euclidean distance, the application effectively identifies financial twins – municipalities with comparable income and expenditure patterns. The ability to analyze financial similarity with and without population metrics allows for a more nuanced understanding of demographic influences on municipal financial structures. By implementing similarity analysis and clustering approaches the study enables both the identification of a singular twin as well as a cluster of similar municipalities.

6.1.1 Identification of Financial Twins in NRW

The application successfully pairs municipalities with similar financial behavior based on both income (payins) and expenditure (payouts). The inclusion or exclusion of population in these calculations significantly impacts the results, demonstrating the role of demographics in financial patterning.

Observations from the financial twin analysis reveal stable patterns across multiple methods. Several municipalities consistently appear as financial twins irrespective of the similarity measure used. For example, Düsseldorf is frequently linked with Leverkusen, Duisburg shares financial similarities with Herne, and Essen aligns closely with Mülheim an der Ruhr. The consistency of these twin pairings suggests robust financial similarities that persist over time.The impact of population inclusion by analyzing per capita values further refines these observations. When population metrics are incorporated, municipalities with comparable per capita income and expenses are grouped together. Conversely, when population is excluded, financial clustering is driven by absolute revenue and expenditure, leading to the grouping of larger municipalities. An example of this effect is observed in Düsseldorf, whose Euclidean twin shifts from Dortmund to Leverkusen when population is factored into the calculation. The analysis of per capita financial data is most often used since biases due to large overall spending can be neglected by focusing on per capita values. Since most of the comparative research to date focuses on using per capita values, the results presented by this study correspond in data structure with existing approaches.

6.1.2 Trends Observed in Cluster Maps

The clustering maps generated by the application provide a visual representation of financial similarities across municipalities from 2009 to 2022. These maps help identify patterns in financial behavior and highlight key trends over time.

Impact of Population on Clustering: The consideration of per capita values significantly affects cluster formation. When population is considered, clusters display a more balanced distribution, with municipalities grouped based on financial efficiency rather than sheer size. This leads to smaller municipalities forming distinct clusters that reflect their financial management practices. In contrast, when population is not considered, clusters become dominated by larger municipalities, overshadowing smaller ones. Financially strong cities such as Düsseldorf, Cologne, and Dortmund consistently form distinct clusters under this approach, reinforcing the influence of absolute financial metrics in cluster formation.

Evolution of Financial Clusters Over Time: Financial clustering is not static; municipalities shift between clusters over different years, reflecting changing economic conditions. These shifts may be influenced by factors such as industrial growth, policy changes, or economic fluctuations. Certain municipalities, however, display persistent clustering behaviors. For instance, Düsseldorf and Leverkusen frequently appear in the same financial cluster across multiple years, suggesting long-term financial stability and structural similarity. The evolving nature of financial clusters highlights the need for continuous monitoring of municipal

finances. Understanding these trends allows policymakers and analysts to anticipate economic shifts, optimize resource allocation, and develop strategies that enhance financial resilience at the municipal level.

7 OUTLOOK AND FUTURE WORK

This study advances existing research on municipal financial data analysis by demonstrating how clustering and similarity analysis approaches can uncover valuable insights into the financial structures of municipalities. By identifying broader groups with financial similarities through clustering and pinpointing singular financial twins using similarity analysis, the proposed methods offer practical support for various urban stakeholders in their decision-making processes.

The current research focuses on urban municipalities in the German federal state of North Rhine-Westphalia, allowing for in-depth comparative analysis within a uniform framework of responsibilities. Expanding the scope of the study to include municipalities from other federal states requires the availability of data in a comparable structure. Only with standardized and harmonized financial data across states can the analysis maintain its validity and enable meaningful comparisons.

Future research should address inter-state differences in municipal responsibilities, enabling a broader dataset and facilitating more comprehensive analyses through data assimilation strategies. Additionally, future work will explore intertemporal comparative approaches to help decision-makers identify financial twins over time. Such longitudinal analysis can foster a learning process and serve as a catalyst for communication among municipal financial decision-makers.

Beyond its analytical applications, the financial twin app could also serve as a practical tool to demonstrate to municipalities and statistical offices the potential benefits of well-structured financial data. By showcasing concrete use cases and analyses, the app can highlight how structured financial data can optimize decision-making processes and promote data-driven strategies. This approach would not only enhance the transparency and comparability of municipal financial data but also emphasize the added value of systematic and structured data collection.

Expanding the methodological toolkit to include alternative clustering techniques and involving experts in evaluating these methods will further strengthen the robustness of the analysis. This approach will help mitigate potential technical limitations of specific methods, ensuring that the most suitable approach is applied to the given data.

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reviewed paper

Investigating the Barriers to Successful Rural Development Projects: Bibliometric Analysis of Trends and Insights from South Africa (2014-2024)

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1 ABSTRACT

Rural development projects are crucial for improving the livelihoods of rural populations and enhancing overall economic growth, serving as a potential solution to socio-economic challenges in these areas. Previous studies suggest that targeted investments and policies can address rural issues effectively. However, many rural development initiatives, particularly in developing countries like South Africa, often fail to achieve their intended outcomes. This paper conducts a bibliometric review to identify and analyze the key factors hindering the success of rural development projects. This paper conducts a bibliometric review to identify and analyze the key factors hindering the success of rural development projects. A comprehensive bibliometric analysis was conducted using the Web of Science database. The search strategy focused on keywords such as “rural development” “project failure”, “success factors” and “barriers”. The exported data was then analysed using Vos Viewer software to illustrate the main keywords around the study area through network maps. Articles published between 2014 and 2024 were included to capture recent trends and insights. The analysis involved identifying publication counts, citation analysis, and keyword frequency in the literature. The findings highlight the need for a multi-faceted approach in project planning and implementation to overcome these barriers and enhance the efficacy of rural development initiatives.

Keywords: rural development, project failures, success factors, barriers, planning

2 INTRODUCTION

Income sources in the rural areas of the former Bantustans of South Africa have always been a subject of study. There is poverty in most parts of the country, proving the effects of colonialism and apartheid regimes and the lack of adequate measures by the new democratic state to eradicate it (Khumalo, 2013). Rural areas in South Africa are characterised by a lack of social and economic infrastructure and poor maintenance of existing infrastructure (Sigwela et al., 2017). Some of the effects widely associated with them include poor standards of roads, houses made of mud, land decline and efficient uses of the same. Yet, a few rural development projects have been initiated and they touched upon the economic and social development needs of rural communities and are crucial for bridging the gap between urban and rural regions (Everatt and Ebrahim, 2020). Evaluating both the poverty and vulnerability research area, it can be noted that both a very long history of research and a vast number of development interventions have not helped the problem sufficiently (Eriksen et al., 2021). All these lead to the loss of resources and negative impacts on the societies that such agency seeks to benefit. The main reasons for this failure in development in rural areas are inadequate consultation with the community, poor needs analysis, economic considerations, and problems associated with governance and institutions.

The government to reduce the challenges that faced social and economic infrastructure in rural regions begun formulation of the rural development projects such as Comprehensive Rural Development (CRDP) of which was piloted in Muyexe village in 2009 (Bila, 2013). Greater Giyani Municipality IDP (2022/23) on the economic development of Greater Giyani Local Municipality notes that this village was a raw village with very little basic infrastructures, such as water and housing; electricity; economic infrastructure such as schools and recreational centres. Based on the provision of infrastructure, it was expected that the projects would result in employment, hence better livelihoods as well as poverty reduction in the community. However, the expectations were not met due to another fact that it did not manage to fulfil all of its goals. Therefore, this study analyses Web of Science to identify the publication trends and further employs Vos Viewer software to analyse the keyword relationships and dominant research themes.

3 RESEARCH QUESTIONS

How has the number of publications and citations in a specific field changed over the past decade?

What are the key themes and topics in the literature, and how have they evolved over time?

4 LITERATURE REVIEW

This section will discuss the literature related to the study, unpacking the origin of rural development, the implemented rural development projects in South Africa and the common challenges leading to the failure of rural development projects.

4.1 The Origin of Rural Development in South Africa

It is postulated that three historical factors underpinned rural development in South Africa, mainly arising from colonial land deracialisation, therefore resulting in apartheid policies for separate development in areas that were rural (Hebinck and Shackleton, 2011). After the displacement of indigenous people, there was much capital directed towards the expansion and development of the white controlled commercial farmer community. Stock farming and control of food production in the African reserves led to overcrowding because of natural growth of the population and also because people were removed from the so-called 'white areas' to live in Bantustans (Nongogo, 2016). The Mission Stations Act of 1909, the Coloured Rural Areas Act (Act 9 of 1987), and the Coloured Persons 'Betterment Scheme 'as outlined in the 1963 Act all affected areas deeded as 'coloured rural areas' in the Western Cape.

These origins are connected and are based on historical systemic processes of discrimination. Unfortunately, it was not until the promulgation of a three-tier government structure in 1994 that municipalities were able to enter into discussions about what a national rural development strategy might entail. This strategy therefore has to inconveniently address poverty and unequal development inherited from previous historical periods and seek to reduce on-going social and economic ramifications of such disparities (Phuhlisani Solutions, 2009).

4.2 Strategies For Rural Development in South Africa Since 1994

For the last two decades, the South African government has sought to do so through different strategies in its Rural Development Framework aimed at eradicating rural poverty and redressing socio-economic inequality that apartheid regime fostered (Kativhu and Netshandama, 2024). Among these is the Reconstruction and Development Programme (RDP) that was initiated in 1994, and it sought to bring socio-economic renewal and empower that coupled with good planning, agriculture diversification and availability and utilization of social necessities. These ambitious goals were self-defeating because the RDP had been criticized for focusing on the production of deliverables, while not doing enough to improve the lives of the rural poor who continue to experience high unemployment and earning inequality (Moselane, 2015). The Growth, Employment and Redistribution (GEAR), an economic plan that was put in place in 1996 to propel the economy forward and create employment impedes poverty and unequal distribution of wealth inadequately (Ndhambi, 2015). The Rural Development Framework (1997) builds on RDP objectives, and the Integrated Sustainable Rural Development Strategy (ISRDS) (2000) aimed at integrated service delivery but failed due to inadequate implementation and finance (Ndhambi, 2015). Accelerated and Shared Growth Initiative of South Africa (ASGISA) launched in 2006 was designed to address emergent socio-economic issues but again implementation was not sustained. The last is the CRDP – Comprehensive Rural Development Programme launched in 2009 where policy makers focus on participation of the communities and infrastructure development to tackle rural poverty and food insecurity (Bila, 2013). In general, these strategies indicate a persistence of dealing with apartheid's aftermath; however, many of them have been implemented with difficulties and have varying success.

4.3 Common Factors Leading to Failure

It can be learnt that most rural development projects are critically developed top-down and implemented imperfectly without enough consultation and involvement of intended beneficiaries (Joshi and Rao, 2018). Another adverse effect of this low participation in the process is resistance or lack of support for the initiatives, which leads to inferior results. A needs assessment approach is crucial to discover the specific difficulties and opportunities typical for rural areas (Kapur, 2019). Situations where objectives and goals are

not analysed in detail may mean ignoring some essential problems while the proposed solutions may also be quite irrelevant or ineffective. As a result, the resources can become misplaced, and this will mean that such initiatives will not be effective either. Also, the approaches toward sustainable growth in the context of the rural development of the country often seem to be hardly economically viable in many cases (Purvis and Robinson, 2019). Projects that have not factored in the local economic climate and possibly the new business opportunities may find it extremely difficult to sustain themselves after some time (Van der Ploeg et al., 2017). Hence, it is necessary for the projects to be planned with an adequate knowledge of markets and resources and available economic conditions to become sustainable after getting funding.

Additionally, there are challenges such as political instability, corruption and general unwillingness and/or inability to develop appropriate and sufficient institutions to support project implementation (Živojinović et al., 2019). Proper administration is very important for the available scarce resources to have accountability and to increase the trust of the community. Where institutions are feeble, rural development projects may not achieve their intended goals because the projects are conducted in a ineffective and unrestrained environment. Likewise, the rural development concept also requires flexibility; projects that were set for implementation but not willing to change directions or improvise where there are changes in community dynamics, physical environment or economic situation can fail to succeed (Kypengren, 2017). For a long-term goal, there must be a great deal of flexibility with the possibility to evaluate the process and adjust if necessary.

4.4 Strategies for Effective Town Planning in Rural Development

Different strategic urban planning methods must be employed because they will help overcome the challenges in rural development initiatives. Rural development becomes effective when authorities organize land planning while taking into account area resources along with landholding systems and environmental variables. Sustainable development land use policies can make land utilization more efficient by limiting land disputes according to Everatt and Ebrahim (2020). Rural economic development hinges on investments in key infrastructure – roads, water, and energy. Planning that meets community requirements as well as guarantees economic longevity must form the basis for achieving long-term community benefits (Bila, 2013).

Getting communities involved is essential to achieve successful projects and make them feel like owners.The involvement of local stakeholders in decision-making under participatory governance platforms helps create projects that match actual population needs which leads to sustainable outcomes (Kapur, 2019). The plans need to shift their direction according to both changes within the community and adjustments in wider environmental influences. Examples of adaptable projects which adjust their operations based on updated information or changed community needs perform better in attaining their extended objectives (Kypengren, 2017). The development of effective town planning and management requires local institutions to receive essential capacity-building to function properly. Through training programs for local leaders in governance and resource management communities gain the ability to steer their own development paths and build trust internally (Purvis and Robinson, 2019).

5 METHODOLOGY

In undertaking this research, the bibliometric analysis approach was used. This methodology has been found to be quantitative as a means of examining large data sets. This enables one to measure productivity and impact of scientific outputs of any researcher, an institution, or a country. It has been useful across disciplines in a field to get a snapshot of the field and watch for details and evolution (Donthu et al., 2021). The authors employ this approach to investigate the knowledge landscape and to visually represent and analyze the field of ‘rural development’ in the developed, transition and developing countries. The term “rural development” was exported using Web of Science with data dating from between 2014 and 2024. The search strategy focused on keywords such as "rural development," "project failure," "success factors," and "barriers. The exported data was then analysed using Vos Viewer software to illustrate the main keywords around the study area through network maps. Articles published between 2014 and 2024 were included to capture recent trends and insights. The analysis involved identifying publication counts, citation analysis, and keyword frequency in the literature. The overall purpose of this study is to assess research failures of rural development projects in developed, transitional, and developing countries.

Therefore, the study has been designed to unpack the publication trends, research themes and topics and the co-authorship patterns of the field by using the following research questions: How has the number of publications and citations in a specific field changed over the past decade?

6 RESULTS, ANALYSIS AND DISCUSSION

This section will discuss the results and analysis.

6.1 Publication Trends:

Knowing publication trends is thus useful for identifying areas of growth or contraction and as such, potential areas of growth or demise. The trends can reveal which topics are getting raised, which might be related to their growing popularity among scholars, where they are cited For this study, the researchers used bibliometric data over 10 years between 2024 and 2024. According to Figure 1 below, in the year 2014, the publications relating to the study of rural development were fewer, with 33 publications and 24 citations, as compared to the year 2015, which had around 46 publications with 165 citations. However, the subject gained popularity during the year 2016. The publications increased from 46 to 53 within the years. This shows that there was interest in the topic. There is growing awareness of the assignment of rural development areas towards coping with challenges such as poverty, hunger and sustainable development. This increased attention may cause more research to be performed, and although the increase in published articles points to an increased concern with the problematics of rural development, it also means that more solutions can be developed. Thus, more change can be brought to the field. During the years 2019 and 2020, the publications decreased, from 50 to 43. Given the situation created by COVID-19 disruptions in early 2020, the onset of the pandemic disrupted many research activities, funding sources, and collaboration opportunities. Many researchers shifted their focus to health-related topics or faced delays in fieldwork, leading to a decrease in rural development publications. However, during the year 2021, there was a slight increase in publications, which increased from 43 to 44. As the situation stabilized in 2021, there may have been a renewed focus on rural development, especially as the pandemic highlighted vulnerabilities in rural areas. This could have led to increased publications as researchers sought to address the challenges rural communities face. From 2021 to 2024 there was a deep decrease in publications, from 44 to 1. Researchers may have moved towards more pressing issues, such as urbanization, climate change, or economic recovery, especially in the aftermath of the pandemic.

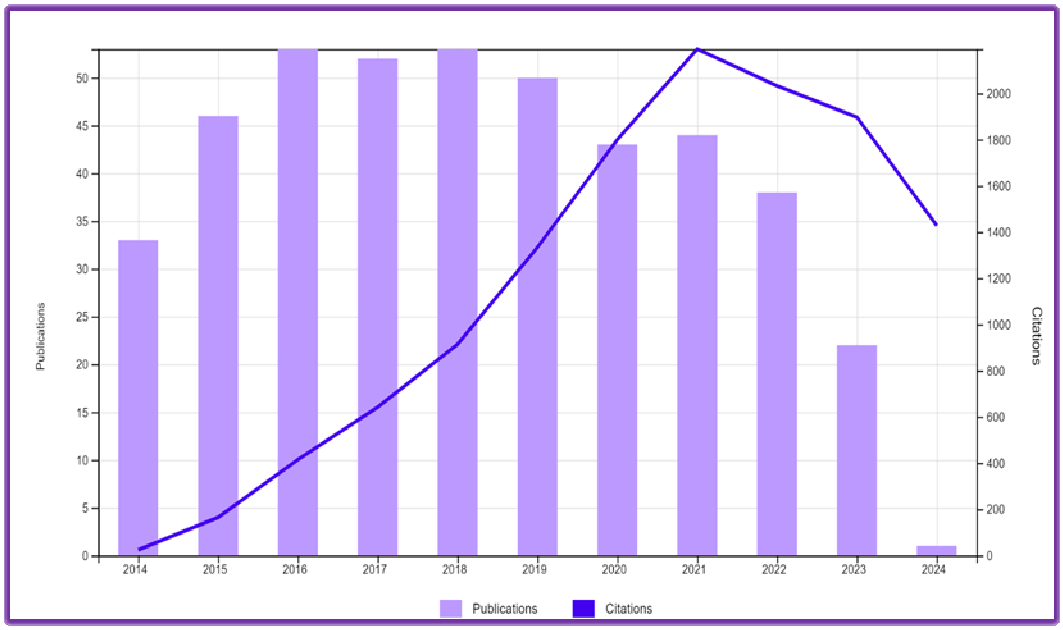

Figure 1: Publication Trends

6.2 Research themes and topics

The second set of data analysed for this study consisted of a keyword frequency analysis. Drawing from the upward trend in research publications from the first data set, it is critical to analyse which research areas are

in high demand within the keyword variables, answering the first research question. When the data was imported to VOS Viewer from the Web of Science database, a minimum of 5 term occurrences were selected. Of the 1766 terms, 50 met the threshold. 29 items were created, which were grouped into 5 clusters and contained 78 links with a total link strength of 101. To investigate the pertinent topics in this field further, a network map was created in VOS Viewer with a temporal overlay (2014-2024) to understand the research trend.

Analysing the research themes highlights that studies focus on real-world problems and health-related consequences of unsuccessful rural development projects, especially in South Africa. The study focuses on rural South Africa for specific reasons to analyse the particular barriers that stand in the way of development in that region therefore supporting the examples with local projects such as Muyexe village. Research interest in actual obstacles during project execution stands out through the links between "implementation" and "impact" as well as "barriers", thus reflecting the reason why projects might fail. The combination of health keywords "obesity" and "mortality" demonstrates studies analysing the harmful effects which

implementation failures have on the wellness of rural populations beyond monetary impacts and into the facets of physical health.

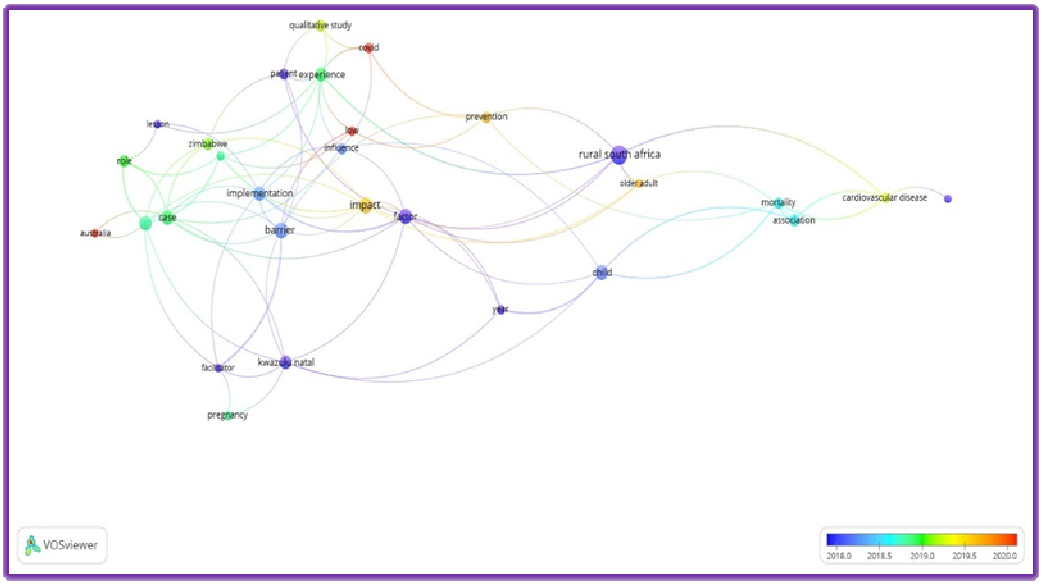

Figure 2: Research themes and topics

6.3 Co-authorship Analysis

To map the research field further, the authors opted to conduct an author co-citation analysis to identify the prominent authors in the field. The selected maximum number of authors per document was 25. The selected minimum number of documents of an author was 2, and of 2303 authors, 183 met the threshold.

The authors further used VOSviewer to create a co-authorship network map (see Figure 3) that displays intellectual research structures relevant to rural road infrastructure, which matches the development emphasis of the study. The figure presents authors working together on research. Research about infrastructure access associated with socioeconomic effects targeting healthcare and education services serves as the main focus of "Kahn, Kathleen" research group in accordance with the essential service access emphasis of the study. The research group that centres on "Tansen, Frank" studies public transportation together with connectivity, which directly responds to concerns about rural population compactness. The cluster regarding "Vandermotten, Alain" advances research into economic effects resulting from infrastructure investment, which directly connects to the development analysis of the study. Figure 3 shows interconnected clusters, which reflect the paper's recommendation for integrated solutions because they implement connecting lines to represent cooperation among experts examining the multiple issues of rural road infrastructure.

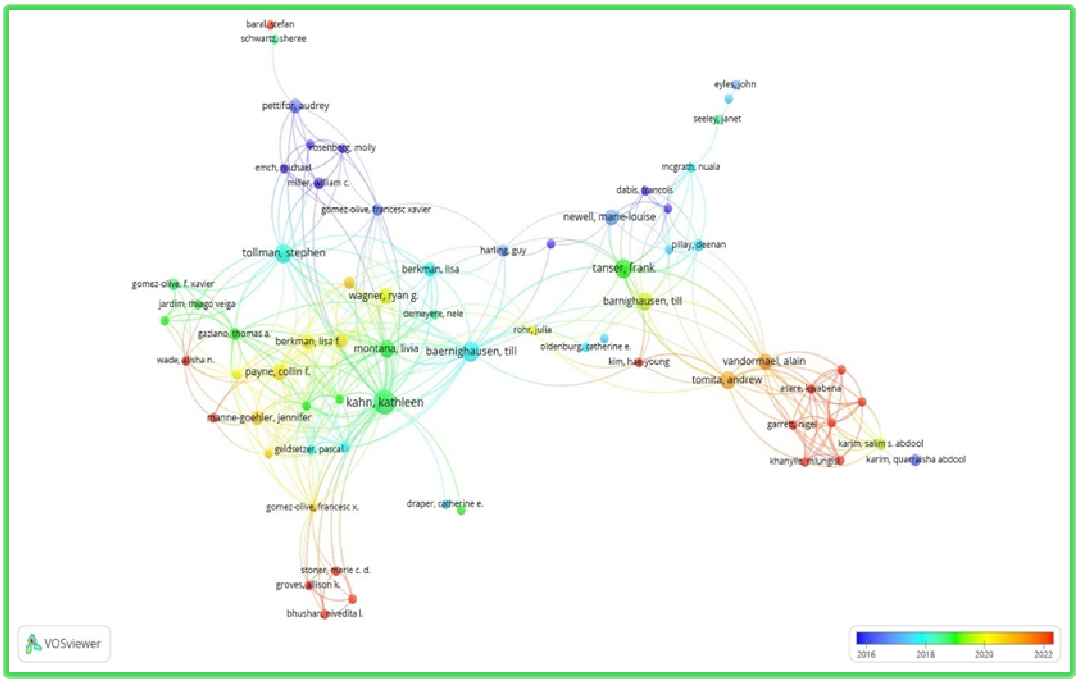

Figure 3: Co-authorship Analysis

From Table 2, shown below, Khan Kathleen has the highest total link strength; therefore, it is the most influential in this study area. This means several other published works are closely related to the work of Khan Kathleen, are often cited, or the author is included in many other related studies. Montana Livia has well-established ties to the research network and has significant link strength, with many more links than documents. This implies that contributions made by Montana Livia are well-absorbed in the field and probably involved in the discussion on the research keywords that are under analysis. Tollman Stephen also demonstrates relatively high connectivity and, therefore, bears a somewhat lower connectivity level than Montana Livia. Baernihausen Till has moderate betweenness centrality, which means the work is somewhat related to other studies but not as close and tied as the authors mentioned above. Like Baernihausen Till, Tomita Andrew has moderate connectivity. Payne Collin F has the least total link strength of all these authors. This indicates that although Payne Collin is present in the literature to some extent, his work can be less referred to and linked to other influential studies as compared to others.

#No	*Author*	*Documents*	*Total link strength*
1	Kahn Kathleen	12	65
2	Montana Livia	6	42
3	Tollman Stephen	7	38
4	Baernihausen Till	8	31
5	Tomita Andrew	6	31
6	Payne Collin F	5	30

Table 1: Co-authorship analysis with the total link strength

7 CONCLUSION

The paper presents a comprehensive bibliometric analysis of rural development projects, focusing on their failures and the factors contributing to success. Understanding publication trends is essential for identifying areas of growth or decline in research, particularly in rural development. To analyse the level of interest by year for this study, the bibliometric data used covered a period of ten years from the year 2014 to 2024; the observation indicated that interest in rural development was rather cyclic. In the first period (2014), a total of 33 publications were reported, while in the second period (2015), this number rose to 46, with a rise in citation rates as well. The number of publications reached its highest point in 2016 while interest elevated during 2019 and 2020; however, it hit a decline in the following year because the COVID-19 pandemic shifted the focus to health-related research only. Interest in rural issues rose slightly in 2021 to five articles before dropping to only one in 2024, as scholars focused on topics such as urbanization and climate change. Third, it was also found that frequency analysis of keywords resulted in a more focused study of rural development with other emerging themes. Co-authorship analysis was used to determine the leading

influential authors in the field; the most influential author was found to be Kahn Kathleen, who emphasises collaboration and knowledge networks in promoting the advancement of rural development science.

In conclusion, addressing the barriers to successful rural development initiatives requires a multifaceted approach that encompasses effective town planning strategies. The importance of integrated land use planning, sustainable infrastructure development, participatory governance, flexibility in project implementation, and local capacity building cannot be understated. These factors are critical for enhancing project efficacy and ensuring that rural development interventions are relevant, sustainable, and beneficial to the communities they aim to serve.

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Konzeption einer Entscheidungshilfe für resiliente Wasserwirtschaft und effektive Klimaanpassung

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1 ABSTRACT

Die Wasserwirtschaft wird durch den Klimawandel besonders herausgefordert, da Anzahl und Intensität von (Sturz-)Fluten und Dürren zunehmen. Die Bewältigung dieser Herausforderungen durch Klimaanpassung erfordert komplexe und interdisziplinäre Ansätze, die mit unsicheren Prognosen einhergehen. In den derzeitigen Planungsprozessen sind notwendige Betroffenheits- und Wirksamkeitsanalysen noch nicht vollständig etabliert. Entscheidungen werden häufig von externem Fachwissen geleitet, ohne dass eine individuelle Analyse erfolgt. Dies schränkt die Umsetzung von wirksamen Klimaanpassungsmaßnahmen und damit die Resilienz der Wasserwirtschaft im Hinblick auf Hochwasser und Dürren ein.

Dieses Forschungsvorhaben befasst sich mit der Frage, wie Maßnahmen im Hinblick auf die Resilienz der Wasserwirtschaft und die Klimaanpassung gleichzeitig und niederschwellig ausgewählt werden können. Es wird untersucht, wie Kommunen mit diesen Herausforderungen umgehen, und welche Maßnahmen dazu beitragen, die Vulnerabilität für den Klimawandel zu verringern und die Resilienz der Wasserwirtschaft zu erhöhen. Um Kommunen bei der Verbesserung der Resilienz und der Anpassung an den Klimawandel zu unterstützen, wird eine Entscheidungshilfe vorgeschlagen, welche die betroffenheitsorientierte und standortgerechte Entscheidungsfindung fördert. Ein Pilotprojekt zur Umsetzung von Baumrigolen in der Stadt Koblenz (Rheinland-Pfalz, Deutschland) dient – mit einem Vergleich zu anderen Kommunen – als Erfahrungsgrundlage.

Klimaanpassung und Klimaresilienz in der Wasserwirtschaft stellen, im Hinblick auf die sich schnell verändernden Bedingungen aufgrund der Komplexität und Unsicherheiten des Klimawandels, große Herausforderungen für Entscheidungsträger dar (IPCC, 2014). Bei der Bewertung möglicher Maßnahmen müssen nicht nur Kosten oder physikalische Kriterien wie Überschwemmungsgebiete berücksichtigt werden, sondern auch Kriterien der Verwundbarkeit, die sowohl wirtschaftliche als auch soziale Situationen der Betroffenen berücksichtigen. Solche interdisziplinären Kriterien werden in die vorgeschlagene Entscheidungshilfe integriert.

Die Stadt Koblenz führt derzeit ein innovatives blau-grünes Infrastrukturprojekt durch. Durch die Installation von Baumrigolen und die Entsiegelung von Flächen soll die Widerstandsfähigkeit der Stadt hinsichtlich des Klimawandels verbessert werden, indem das städtische Mikroklima verbessert, Hitzestress reduziert und die Auswirkungen von Starkregen gemildert werden. Bei der Umsetzung sind verschiedene Herausforderungen zu bewältigen, z. B. interdisziplinäre Planungsprozesse, fehlende Bodendaten oder Platzmangel. Als Pilotprojekt beruhte die Auswahl der Maßnahmen (Baumrigolen, Entsiegelung von Flächen usw.) eher auf Expertenwissen als auf einer eingehenden Bewertung der Wirksamkeit und Eignung. Zu letzteren drei Aspekten werden Informationen während und nach der Umsetzung ergänzend gesammelt und bewertet.

Anhand der gewonnenen Informationen aus Koblenz und anderen Städten werden geeignete Maßnahmen ausgewählt, die sowohl Resilienz in der Wasserwirtschaft als auch Klimaanpassung fördern (z. B. Baumrigolen). Die Analyse ist der Ausgangspunkt für einen integrierten Bewertungsrahmen. Mit diesem können die Kommunen künftige Entscheidungen und die praktische Umsetzung verbessern, um die Anfälligkeit für den Klimawandel zu verringern und die Widerstandsfähigkeit der Wasserwirtschaft zu verbessern.

Keywords: Resilienz, Unterstützung, Planung, Entscheidung, Konzept

2 EINFÜHRUNG UND PROBLEMSTELLUNG

Mit dem 2024 veröffentlichten Klimaanpassungsgesetz sowie der Deutschen Klimaanpassungsstrategie (2009) ist Klimaanpassung als Ziel definiert. Gleichzeitig nimmt die Bedeutung von Klimaresilienz im wissenschaftlichen Diskurs zu. Dadurch entsteht Handlungsdruck für Entscheidungsträgerinnen und

Entscheidungsträger in Kommunen. Dabei sind die übergeordneten Konzepte schwer greifbar und die Messbarkeit für Kommunen begrenzt. Dies überträgt sich auf die Umsetzungskonzepte auf kommunaler Ebene. Begrenzte Datenverfügbarkeit erschwert das Vorgehen. Indikatoren und Wirkungsketten, welche den Prozess erleichtern sollen, sind häufig nicht ohne Weiteres auf die eigene Kommune übertragbar. Die Hürden für eine standortgerechte Ausrichtung von Maßnahmen zur Klimaanpassung und Klimaresilienz erscheinen somit meist hoch. Dies führt häufig dazu, dass sich die Auswahl der Maßnahmen eher an zugänglichen Erfahrungswerten (von Nachbarkommunen, Planern o.ä.) oder Expertenwissen orientiert als an transparenten, datenbasierten Betroffenheits- und Wirksamkeitsanalysen.

Hier zeigt sich ein Spagat: Einerseits müssen die komplexen Zusammenhänge und Wirkungsketten berücksichtigt werden, andererseits ist eine Vereinfachung dieser Zusammenhänge notwendig, um eine praktische Umsetzung unter Berücksichtigung der Betroffenheit zu ermöglichen. Hier limitieren oftmals Aspekte wie finanzielle und personelle Ressourcen die Umsetzung von nachweislich wirksamen Klimaanpassungsmaßnahmen. Die Schwierigkeit für Kommunen liegt darin, integrierte und standortgerechte Lösungsvorschläge für die Herausforderungen der Klimaresilienz und Klimaanpassung zu identifizieren sowie in die vorhandenen Planungsprozesse integrieren zu können (Stadt Koblenz, 2025). Um die Auswahl der Maßnahmen passgenau auf die Betroffenheitsindikatoren zu übertragen, gibt es bisher keine übergreifend anerkannte Methodik.

Um dies zu erleichtern, wird ein Bewertungsrahmen entwickelt. Dabei werden messbare Indikatoren identifziert, welche mit kommunal erfassbaren und zugänglichen Daten betrachtet werden können. Es soll so eine Entscheidungshilfe entwickelt werden, welche bei der Auswahl von geeigneten Maßnahmen anhand von Betroffenheitsindikatoren unterstützt, um die identifizierte Betroffenheit zu reduzieren. Es ist eine erste Prüfhürde zur Identifizierung und cross-checking von möglichen baulichen Maßnahmenvarianten. Kommunen sollen in einem weiteren Schritt die Bewertung dann an ihre jeweiligen Bedingungen anpassen. So soll die zielgenaue Auswahl von Maßnahmen zur Steigerung resilienter Wasserwirtschaft und Klimaanpassung verbessert werden. Außerdem werden potentielle Synergieeffekte in den Konzepten der Resilienz und Klimaanpassung sichtbar gemacht. Letztlich gilt es den größten gemeinsamen Nenner zu finden und die Verbindung von gemessenen Herausforderungen und standortgerechten Maßnahmen zu vereinfachen. Hierbei wird sich auf bauliche Maßnahmen in Bezug auf Wasser und Temperaturentwicklung konzentriert.

3 HINTERGRUND

3.1 Konzeptionelle Gemeinsamkeiten von Klimaresilienz und Klimaanpassung

Um mit möglichst wenigen Maßnahmen einen möglichst breiten Effekt zu erzielen, werden insbesondere die Gemeinsamkeiten von Klimaresilienz und Klimaanpassung betrachtet. Klimaanpassung definiert sich durch die Verminderung der Verletzlichkeit bzw. dem Erhalt und der Steigerung der Anpassungsfähigkeit natürlicher, gesellschaftlicher und ökonomischer Systeme gegenüber den Auswirkungen des Klimawandels (Deutsche Anpassungsstrategie an den Klimawandel, Bundeskabinett 2008). Die Vulnerabilität gegenüber Klimawirkungen bestimmt im Wesentlichen die Notwendigkeit von Anpassungsmaßnahmen. Fuchs et al. (2011) definieren das Ausmaß der Klimavulnerabilität mit den Komponenten des erwarteten Naturereignisses (Betroffenheit), der biophysikalischen Sensibilität einer Region sowie der Anpassungskapazität. Effektive Klimaanpassungsmaßnahmen führen zu einer Reduktion der Vulnerabilität (Exposition, Anfälligkeit und Bewältigung) (Birkmann et al., 2012). Ziel ist es weniger vulnerabel zu sein und damit die Anpassung der Region zu steigern.

Klimaresilienz hingegen hat kein einheitliches Verständnis in der Literatur (Fekete et al., 2014; Camacho et al., 2024; DWA T2/2024), was die „Übersetzung“ in die Praxis zusätzlich erschwert. Grundsätzlich beschreibt die Resilienz den Umgang mit disruptiven Ereignissen. Zu den drei übergeordneten Bestandteilen – Widerstandsfähigkeit, Adaptionsfähigkeit und Transformationsfähigkeit – gibt es Übereinstimmung in der Literatur. Dabei definiert Widerstandsfähigkeit die Fähigkeit, disruptiven Ereignissen standzuhalten, ohne grundlegende Identität, Struktur oder Funktion einzubüßen. Es herrscht ein enger Zusammenhang mit der Kapazität eines Systems, Belastungen zu absorbieren und sich davon zu erholen, ohne dass tiefgreifende Veränderungen notwendig sind (Walker & Salt, 2006). Die Adaptationsfähigkeit beschreibt die Anpassungsfähigkeit an sich verändernde Umstände und Reaktion auf neue Herausforderungen, unter

Aufrechterhaltung der grundlegenden Funktionsweise (Adger, 2000). Transformationsfähigkeit stellt die Transformation als die Fähigkeit dar, bestehende Rahmenbedingungen, die möglicherweise die Resilienz einschränken, zu überwinden und radikal neue Wege zu beschreiten, die nachhaltigere und widerstandsfähigere Systeme schaffen (vgl. Pelling 2011; Folke et al. 2010). Das Kernkonzept der Resilienz ist „die Anerkennung unserer Unwissenheit; nicht die Annahme, dass zukünftige Ereignisse erwartet werden, sondern dass sie unerwartet sein werden". (Mentges et al., 2018). So ist Resilienz mehr als die Kehrseite der Vulnerabilität, jedoch gibt es Überlappungen (Modaressi, 2013).

Was Klimaanpassung und Klimaresilienz verbindet, ist das Vorhandensein von unterschiedlichen, teils abstrakten Konzepten, die Ziele definieren, welche nur schwer greifbar sind. Sie zielen auf den Umgang mit Unsicherheit („Welches Klimaszenario wird wann Realität?") und mehreren Gefährdungen (Hitze, Sturzfluten etc.). Vulnerabilitätsanalysen und Klimawirkungsketten bilden die Basis der Handlungsanalysen (UBA, 2017 & 2022).Weiterhin wird ein prozessuales Verständnis benötigt, da keine ad-hoc Lösungen zu definieren sind. Mit „scale-, place- und system-specific" erläutert Keating et al. (2017) die standortspezifische Abhängigkeit von Resilienz. Das Vorkommen von zahlreichen Indikatoren (z. B. City Resilience Water Approache by Saika et al., 2021 oder Baseline Resilience Indicators for community (BRIC) by Cutter et al., 2010) als teilweise normative Grundlage ist vor dem Hintergrund der damit notwendigen komplexen Datensammlungen und Analysen lokal schwer umzusetzen. Somit stellen sie auf dem Weg zur standortgerechten und zielgerechten Umsetzung für kommunale Entscheidungsträgerinnen und Entscheidungsträger eine enorme Herausforderung dar.

3.2 Kommunale Planungsprozesse hin zu klimaresilienter Wasserwirtschaft und Klimaanpassung

Um das aktuelle Vorgehen und gegebenenfalls Defizite in kommunalen Planungsprozessen zu Klimaanpassung und klimaresilienter Wasserwirtschaft identifizieren zu können, werden zunächst die bestehenden Prozesse betrachtet.

Die Leitfäden zu kommunalen Planungsprozessen sowie die Literatur empfehlen als ersten Schritt eine Vulnerabilitäts- und/oder Betroffenheitsanalyse zu den jeweiligen Klimawirkungen.

Im Anschluss daran sollen klare Ziele mit messbaren Indikatoren formuliert werden. Dabei ist die Sachebene (d.h. die die Veränderung von Niederschlagsereignissen) stets von der Wertebene (d.h. die politische Entscheidungsebene) zu trennen und eine konsistente Struktur zu wahren (UBA, 2015). Auch soll die Analyse valide und verlässlich sein. Weiterhin sind die Betroffenen und Beteiligten möglichst in einem partizipativen Prozess zu berücksichtigen (UBA, 2015 & 2017 & 2022). Darauf aufbauend sollen dann passgenaue Maßnahmen identifiziert und umgesetzt werden.

In der Praxis ist es für kommunale Entscheidungsträgerinnen und Entscheidungsträger unter Berücksichtigung der vorhandenen personellen und sonstigen Ressourcen eine Herausforderung die Analysen durchzuführen, unter anderem da die Datenverfügbarkeit und -zugänglichkeit oftmals schwierig ist (Scharte et al., 2016). Gleichzeitig stehen die Kommunen unter einem enormen Handlungsdruck.

Eine grundsätzliche Herausforderung stellt auch die Greifbarkeit und Operationalisierung der Konzepte zur Klimaresilienz und Klimaanpassung dar. Folglich wird häufig auf Erfahrungswerte zurückgegriffen, welche zumeist keinen Schaden anrichten und ggf. auch wirksam in Bezug auf die Konzepte sind. Oftmals bleibt die Frage aber offen, ob es weitere, möglicherweise wirksamere Maßnahmen gegeben hätte.

3.3 Derzeitige Bewertungsschemata von Resilienz und Klimaanpassung

Klimaresilienz und Klimaanpassung stehen als übergeordnete, erstrebenswerte Ziele im Raum – teilweise mit normativem Charakter. Die Messbarkeit und Bewertung zum Erreichen der Ziele macht eine Operationalisierung notwendig. Aufbauend auf dem in der Literatur fehlenden Konsens einer Definition von Resilienz ist auch die Operationalisierung komplex (Birkmann et al., 2009). So umfasst Resilienz nicht nur bauliche Maßnahmen, sondern auch Fragen der Governance und politischen wie gesellschaftlichen Handlungsfähigkeit.

Damit stehen die Konzepte im Spannungsfeld zwischen den Herausforderungen der Messbarkeit auf der einen und der Notwendigkeit der Messbarkeit auf der anderen Seite. Um die Konzepte als Grundlage der Entscheidungsfindung nutzen zu können, ist eine Evaluierung und Messbarkeit notwendig (Bertilsson et al., 2019).

Birkmann et al. (2012) sehen das „Leitbild der umfassenden Resilienz [als] kaum hilfreich“ an (ebenda, S. 97). Resilienz bzgl. einzelner Ereignisse ist leichter messbar als langfristige schleichende Prozesse. Folglich wird eine Operationalisierung für eine Gesamtresilienz als schwer umsetzbar angesehen. Anders ausgedrückt ist die Definition generischer Indikatoren schwierig und die Erfassung dieser wiederum nochmals schwieriger (Laurien et al., 2022). Der in der Literatur prominente Ansatz von Cutter „Resilience of what? To what? For whom?“ nimmt die Grenzen der Messbarkeit des abstrakten Konzeptes der Resilienz auf und stellt Systemgrenzen und Funktionen in den Vordergrund.

Diesem Ansatz folgend stehen die einzelnen Funktionen eines Systems der Operationalisierung im Vordergrund. Diese wiederum können als Subsysteme zur Resilienz des Gesamtsystems zusammengefügt werden. Definierte Subsysteme können kritische Infrastruktur, die Ökonomie, Governance oder Lieferketten sein (Carlson, 2012). Aufgrund der Komplexität des Resilienzbegriffs gibt es Stimmen, dass die Operationalisierung lediglich eine Annäherung darstellen kann. Auch wird die externe Validierung und damit die Vergleichbarkeit erschwert (Camacho, 2024).

In der Konsequenz existieren mittlerweile viele verschiedene Bewertungsansätze zwecks Messbarkeit der Resilienz. Gemäß Sharif (2016) folgen diese überwiegend fünf Herangehensweisen:

- Bewertung anhand der Ausgangsbedingungen
- Bewertung anhand von Schwellenwerten orientiert an Programmzielen
- Bewertung anhand von Grundsätzen der ausgeprägten Resilienz
- Bewertung im Vergleich zu Gleichartigen
- Bewertung anhand von Erholungsgeschwindigkeit

Dem Ansatz Cutters folgend wird dabei thematisch meist zwischen fünf Dimensionen unterschieden (Sharif, 2016):

- Umwelt
- Soziales
- Ökonomie
- Geschaffene/bauliche Infrastruktur(-einrichtungen)
- Institutionen

Auch das Umweltbundesamt folgt dem Ansatz, dass Resilienz nicht als Gesamtheit gemessen werden kann, und definiert für Klimawirkungs- und Risikoanalysen sog. Cluster mit untergeordneten Handlungsfeldern (UBA, 2021). Die Cluster sind teilweise deckungsgleich mit den von Sharif (2016) identifizierten Dimensionen:

- Land (z. B. biologische Vielfalt, Boden, Landwirtschaft)
- Wasser (z. B. Wasserhaushalt, Wasserwirtschaft, Fischerei)
- Infrastruktur (z. B. Bauwesen, Energiewirtschaft)
- Wirtschaft (z. B. Industrie und Gewerbe)
- Gesundheit (Menschliche Gesundheit).

Die Deutsche Anpassungsstrategie (DAS) (2009) ist in 13 Handlungsfelder untergeordnet, thematisch decken sie sich mit den Handlungsfeldern des Umweltbundesamts. So nehmen beim UBA untergeordnete Themen in der DAS eigene Handlungsfelder ein, wie z.B. die biologische Vielfalt, welche beim UBA dem Handlungsfeld Land zugeordnet ist.

Zahlreiche Leitfäden und Anwendungshilfen zur Anpassung an den Klimawandel sind bereits veröffentlicht. So ist das Vorgehen für Kommunen mehrfach systematisch beschrieben und ein überwiegend übereinstimmendes Verfahren (Klimawirkungs- und Betroffenheitsanalyse, Ziele formulieren, Maßnahmen identifizieren, Monitoring) beschrieben (vgl. Klimalotse).

Die Validierung einzelnder Indikatoren gestaltet sich bezüglich der Datenverfügbarkeit und Methodik als schwierig (Feldmeyer et al., 2021). Zudem wird die Gewichtigung kontrovers diskutiert (Camacho, 2024).

Auch soziale Aspekte sind für das System relevant, aber in derzeitigen Statistiken oft nicht oder nicht ausreichend reflektiert (Feldmeyer et al., 2021).

In Interviews mit Fachämtern einer Stadtverwaltung gewonnene Erkenntnisse bestätigen diese Beobachtungen. Die Vielzahl an vorhandenen Leitfäden und Rahmenwerken zur Klimaanpassung, die jedoch keine verbindlichen gesetzlichen Vorgaben enthalten, kann zu bürokratischen Herausforderungen führen. Insbesondere besteht Unklarheit darüber, welche Dokumente und Empfehlungen für die praktische Umsetzung bevorzugt herangezogen werden sollen. Klimaanpassung erfordert eine interdisziplinäre Herangehensweise. Die vorliegenden Leitfäden sind häufig nicht gezielt auf die spezifischen Anforderungen der für bauliche Maßnahmen zuständigen Fachämter ausgerichtet, sondern übergreifend formuliert. Dadurch werden sie vorrangig von den für Klimawandelthemen zuständigen Stellen rezipiert, während ihre Relevanz und Anwendbarkeit für die bauausführenden Fachämter begrenzt bleibt. Infolgedessen kann es zu einer gewissen Zurückhaltung oder Skepsis gegenüber der Nutzung dieser Instrumente kommen, insbesondere wenn sie nicht hinreichend auf die spezifischen lokalen Rahmenbedingungen zugeschnitten sind (Stadt Koblenz, 2025). Folglich führen generisch formulierte Leitlinien oder Rahmenwerke häufig zu Zurückhaltung in interdisziplinärer Zusammenarbeit. Eine Brücke zwischen Theorie und Praxis kann hier ein Ausgangspunkt für mögliche Umsetzungen schaffen.

Insgesamt sind Bewertungsschemata vorhanden und damit ist eine Vereinfachung der Umsetzung von Klimaanpassung und Resilienz in Kommunen angestoßen, allerdings nicht komplett. Insbesondere die integrierte und standortgerechte Auswahl von Maßnahmen und Lösungen für größere Resilienz und Klimaanpassung ist weiterhin herausfordernd.

4 VORGEHENSWEISE/METHODIK

Um eine Entscheidungshilfe für die Maßnahmenauswahl zu entwickeln, sollen Potentiale für Klimaanpassung und Klimaresilienz niederschwellig sichtbar gemacht werden. Zur Maßnahmenidentifikation wurden Kriterien aus Sicht der Anwenderinnen und Anwender identifiziert (siehe Kapitel 4.1).

Bei der Ausgestaltung der Entscheidungshilfe lag der Fokus auf den Klimastimuli Hitze und Wasserhaushalt, da diese als besonders relevante Klimawirkungen in den spezifischen Planungsbereichen in deutschen Kommunen gelten.

Um eine Übertragbarkeit in die kommunale Praxis zu erreichen, wurden die Kriterien zur verbesserten Anwendung aus Sicht der lokalen Entscheidungsträgerinnen und Entscheidungsträger ausgewählt. Darauf aufbauend wurden die Kriterien Datenverfügbarkeit, räumliche Planung auf Quartiersebene, Betroffenheitsanalyse und Wirksamkeitsanalyse sowie bauliche Maßnahmen im Bereich Hitze und Wasserhaushalt ausgewählt.

Die Herausforderung der Datenbeschaffenung ist ein essenzielles Kriterium, da es Ressourcen bindet, unter zeitlicher Dringlichkeit steht, Analysefähigkeit fordert, Verfügbarkeit annimmt oder finanzielle Mittel für mögliche externe Analysen und weiteres voraussetzt. Dies ist in kommunalen Verwaltungen oftmals nicht gegeben, weshalb die Daten leicht beschaffbar sein sollten oder es eindeutig kommuniziert wird, welche möglichen externen Untersuchungen notwendig wären, um die Daten zu beschaffen bzw. zweckorientiert auszuwerten.

Räumliche Planungsverantwortung soll gegeben sein, damit Kommunen aktiv eingreifen können und die Befugnis haben entspechende Maßnahmen umzusetzen. Als Entscheidungshilfe zur ersten Identifizierung von Maßnahmen ist dies in einem späteren Schritt stets mit einer überregionalen Betrachtung (z. B. des Einzugsgebietes) zu ergänzen.

Anhand einer Literaturrecherche mit diesen Kriterien nach oft genannten Folgen, Auswirkungen und Betroffenheiten durch Kopplung mit Vulnerabilität, wurden häufige Betroffenheiten von Kommunen identifiziert. Neben Klimaanpassungskonzepten inkl. Betroffenheitsanalysen der Städte Bielefeld, Kleve und Koblenz wurden Literaturwerke wie bestehenden Analyseinstrumente (z. B. Cutter et al., 2010, UBA, 2015 & 2017), das Bundes-Klimaanpassungsgesetz (KAnG) 2023 sowie weitere einschlägige Gesetze (z. B. Wasserhaushaltsgesetz 2009) betrachtet. Ebenfalls wurde die DIN EN ISO 14091:2021 | Anpassung an den Klimawandel – Vulnerabilität, Auswirkungen und Risikobewertung berücksichtigt. Weiterhin wurden Interviews mit drei Fachämtern der Stadt Koblenz durchgeführt, welche Einblicke in die Planungsprozesse,

die Begriffsverständnisse und Datenverfügbarkeit ermöglichten. Mit den entwickelten Kriterien wurden anschließend Indikatoren identifiziert.

Darauf folgte der Einbezug von Maßnahmen zur Stärkung der Klimaresilienz und Klimaanpassung, welche auf Schnittmengen aus Leitfäden des Umweltbundesamtes und der Bundesländer sowie bestehenden Forschungsvorhaben wie beispielsweise dem KURAS-Leitfaden basieren (Matzinger et al., 2017). Auch hier wurden Informationen aus Klimaanpassungskonzepten und Interviews mit der Stadt Koblenz ergänzt. Die so ausgewählten Maßnahmen sind auf bauliche Maßnahmen eingegrenzt und bedienen zudem ebenfalls die erarbeiteten Kriterien. Für die Erarbeitung der Entscheidungshilfe wurde die Wirksamkeit der Maßnahmen auf Basis der Literaturrecherche bewertet.

Um zu vermeiden, dass Handlungen von externer Expertise geleitet und Maßnahmen so möglicherweise nicht optimal ausgewählt oder umgesetzt werden, zielen die Indikatoren auf eine Ermöglichung von standortgerechter Planung ab. Dies geschieht durch die Einbindung von Betroffenheitsanalysen und Wirksamkeitskontrollen. Die Betroffenheit des Raums sowie die Wirksamkeit der Maßnahmen sollen möglichst gleichermaßen über die Indikatoren messbar sein. Dies ist eine Voraussetzung für die Auswahl der Indikatoren.

Die Maßnahmensammlung ist begrenzt auf bauliche Maßnahmen mit Hitze und Wasserhaushalt als Querschnittsthemen. Da Maßnahmen u. U. mehrere Wirkungen haben können, sind Überlappungen bzw. Mehrfachzuweisungen möglich.

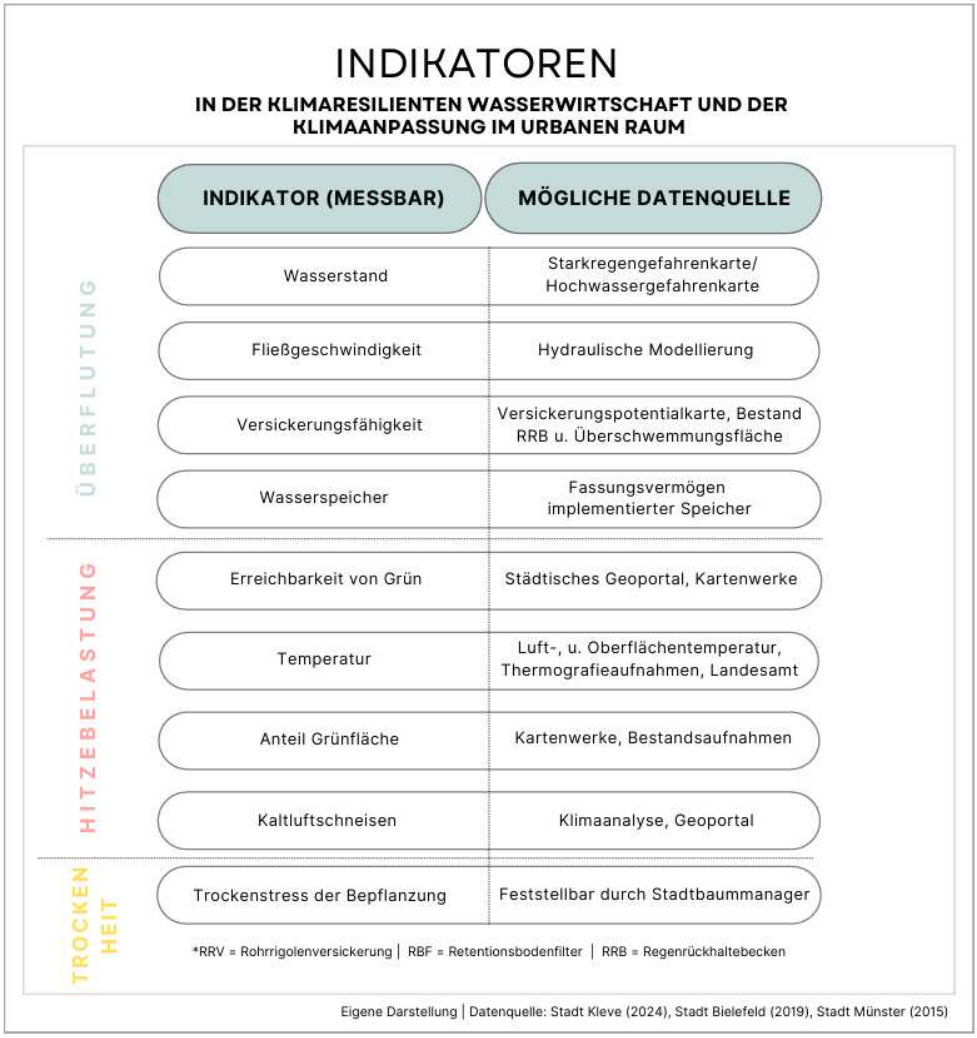

Abbildung 1: Indikatoren der klimaresilienten Wasserwirtschaft und der Klimaanpassung mit möglichen Datenquellen

5 ERGEBNISSE/IDENTIFIZIERTE INDIKATOREN UND MAßNAHMEN

Unter Berücksichtigung der zuvor definierten Kriterien wurden neun Indikatoren identifziert, welche sich den Klimawirkungen Überflutung, Hitzebelastung und Trockenheit zuordnen lassen. Die Indikatoren

gleichen jeweils einer Messgröße, welche in der Praxis erfassbar und somit bewertbar ist. Außerdem wird darüber die Verlässlichkeit des Rahmens sichergestellt. Dafür sind zum einen die Auswirkungen des Klimawandels wie bspw. steigende Temperaturen, zum anderen aber auch entsprechende Empfindlichkeiten einzubeziehen, die eine lokale Betroffenheit zur Folge haben. Einflussfaktoren der Empfindlichkeit können beispielsweise eine dichte Bebauung oder ein Mangel an Schattenflächen sein (Klimalotse). In Tabelle 1 sind die genannten Klimawirkungen mit zugehörigen Indikatoren und möglichen Datenquellen aufgelistet.

Im nächsten Schritt erfolgt die Erarbeitung möglicher Maßnahmenansätze für die Reduzierung der Betroffenheit, d. h. es erfolgt eine Identifikation geeigneter Maßnahmen.

Es gibt Anpassungsmaßnahmen, die unabhängig von den Unsicherheiten der zukünftigen Klimaveränderungen vorteilhaft sind. Maßnahmen, die auch dann positive Effekte haben, wenn keine oder sogar entgegengesetzte Klimaveränderungen eintreten, gelten als sogenannte „Win-Win-“ oder „No-Regret“-Ansätze. Dazu gehören beispielsweise Maßnahmen, die zugleich anderen Zielen wie dem Klimaschutz und somit auch der Kostenreduktion dienen.

Ein weiterer Ansatz besteht in Anpassungen, die durch geringe zusätzliche Investitionen realisiert werden können. Ein Beispiel hierfür ist die Installation größerer Rohrdurchmesser bei der Erneuerung eines Abwassersystems, um zukünftige Starkregenereignisse besser bewältigen zu können. Ebenso relevant sind Maßnahmen, die flexibel und reversibel gestaltet sind. Dazu zählt unter anderem der Verzicht auf Bebauung in Kaltluftschneisen, um die natürliche Belüftung eines Stadtgebietes zu erhalten. Ebenso können Maßnahmen sinnvoll sein, die eine spätere Anpassung ermöglichen, ohne dass hohe Folgekosten entstehen.

Kurz- bis mittelfristig wirksame Maßnahmen können zudem dazu beitragen, Investitionsentscheidungen hinauszuzögern und somit einen erweiterten Planungshorizont zu schaffen. Durch eine solche Strategie bleibt mehr Zeit für eine umfassende Analyse und die Entwicklung geeigneter Schutzkonzepte (Umweltbundesamt, 2022).

Anhand ausgewählter Leitfäden (insbesondere Matzinger et al., 2017; Hörnschemeyer et al., 2023) wurden die folgenden baulichen Maßnahmen mit Wirksamkeit in den Auswirkungen Hitze, Trockenheit und Wasserhaushalt ausgewählt:

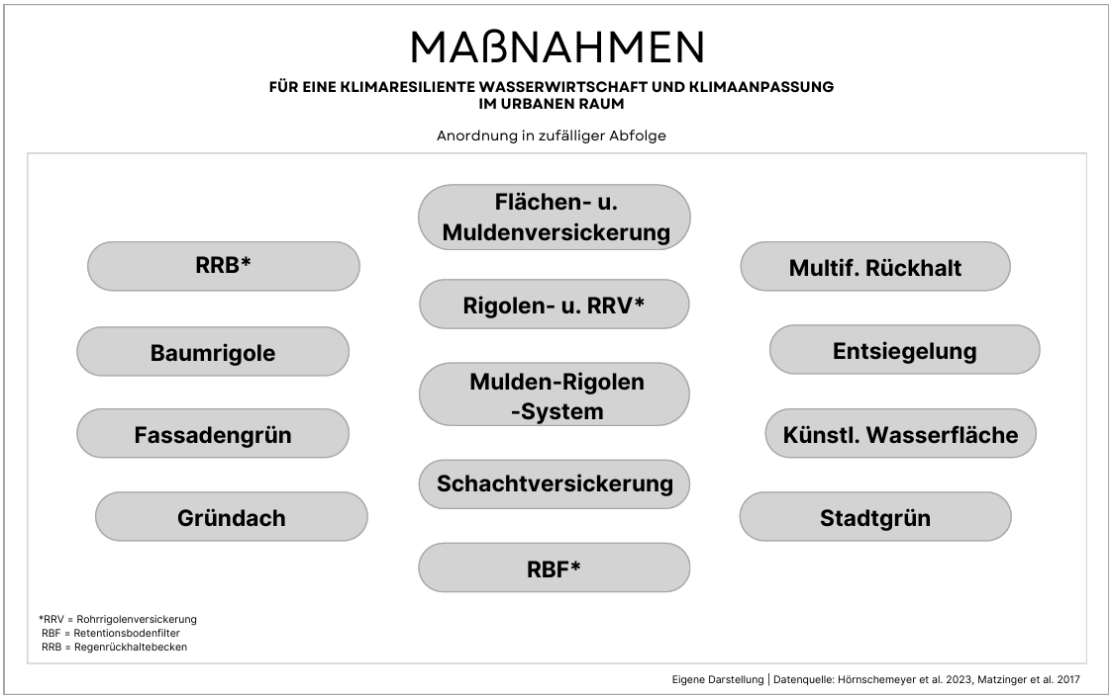

Abbildung 2: Bauliche Maßnahmen, die zu klimaresilienter Wasserwirtschaft wie zu Klimaanpassung beitragen

Die gefilterten Maßnahmen stammen fast ausschließlich aus Ansätzen der blau-grünen Infrastruktur.

Um die Maßnahmenauswahl zur Milderung der Folgen des Klimawandels und zur Stärkung der Klimaresilienz zu fördern, wird nachfolgend die Entscheidungshilfe vorgestellt.

5.1 Zuordnung der Indikatoren und Maßnahmen

In kommunalen Entscheidungsprozessen kann eine Übersicht an möglichen Maßnahmen für ihre regionale Betroffenheit einbezogen werden. Auch können Alternativen zu einer überlegten Maßnahme identfiziert werden, um neben der Wirksamkeit weitere Faktoren wie u. a. Finanzierung, Robustheit oder positive Nebeneffekte betrachten zu können.Die Zuordnung von Indikatoren und Maßnahmen erfolgt über den potentiellen positiven Beitrag zu den Indikatoren, wie er in anderen Studien festgestellt wurde (Matzinger et al., 2017;, Hörnschemeyer et al., 2023, DWA, 2024). Die Wirksamkeit spielt eine wegweisende Rolle, allerdings ist das priorisierte Ziel der Entscheidungshilfe, Potentiale zu identifizieren und zwar bezogen auf alle Einwirkungen (Überflutung, Hitze und Trockenheit). Da die Wirksamkeit stark von der Ausgestaltung der einzelnen Maßnahmen sowie der Randbedingungen abhängt (z. B. Substratstärke eines Gründachs, Versickerungsfähigkeit des Bodens), bedarf die Feststellung dieser einer detaillierteren Analyse. Tabelle 2 zeigt die Zuordnung von Indikatoren und Maßnahmen und lässt Wirksamkeitspotentiale erkennen. So sind mögliche Wirkungen einzelner Maßnahmen zu erkennen und potentiell geeignete Maßnahmen können gewählt werden, je nach gewünschter Wirkung.

Ein nächster möglicher Analyseschritt ist ein Katalog mit Ausschlusskriterien sowie notwendigen Randbedingungen der einzelnen Maßnahmen. So können mögliche Maßnahmen identifiziert werden, aber auch unmögliche ausgeschlossen werden.

5.2 Anwendung der Entscheidungshilfe

Die vorgestellte Entscheidungshilfe zielt auf die Vereinfachung von kommunalen Planungsprozessen. Oftmals beginnt die Entscheidungsfindung mit dem Ergebnis – mit der Identifzierung von Maßnahmen aufgrund von Förderungen, Erfahrungen aus Nachbargemeinden oder von Ingenieurbüros. Mit der hier vorgestellten Entscheidungshilfe können kommunale Entscheidungsträger eine Voranalyse treffen. Anhand der Indikatoren können sie mögliche Betroffenheiten von Gebieten in Bezug auf die Klimawirkungen Wasser und Temperatur identifizieren und im selben Schritt mögliche Maßnahmen hierzu identifizieren. Um grundlegende Informationen zu analysieren, ohne auf finanzielle oder personelle Mittel angewiesen zu sein, bringt der Entscheidungsrahmen Abhilfe, da die Wirksamkeit von Maßnahmen mit der Betroffenheit des Standorts oder des Quartiers abgeglichen wird. So kann eine Kommune örtliche und thematische Betroffenheiten der Gemeinde identifizieren und schnell feststellen, welche Maßnahmen zur Schließung der Lücke in Frage kommen. Außerdem können so mögliche Alternativen zu bekannten Maßnahmen in Erwägung gezogen werden. Dabei sind die einzelnen Maßnahmen neben der Wirksamkeit, auch in Bezug auf Flexibilität, Robustheit, Umsetzbarkeit, finanzielle Tragbarkeit, positive Nebeneffekte und Nachhaltigkeit (UBA, 2022) zu analysieren.

Durch die einfache Identifizierung von Maßnahmen anhand von wissenschaftlich belegten und zugänglichen Daten sowie der Verknüpfung mit der Betroffenheit können potentielle Maßnahmen identifiziert werden. Die abstrakten Konzepte von Klimaresilienz und Klimaanpassung bekommen somit mögliche konkrete Ausgestaltungen und berücksichtigen gleichzeitig die Interdisziplinarität. Anschließend sind diese potentiellen Maßnahmen in der weiteren Planung bzw. im weiteren Entscheidungsprozesse näher zu beleuchten. Es ist im Einzelnen zu untersuchen, wie welche Potentiale der Maßnahmen bestmöglich ausgestaltet werden können. Zu dieser Betrachtung gehört auch der Umang mit Unsicherheiten.

6 PRAXISBEISPIEL KOBLENZ „KLIMARESILIENTE VERKEHRS- UND QUARTIERSENTWICKLUNG KOBLENZ-RAUENTAL“

In Reaktion auf extreme Wetterereignisse initiierte die Stadt Koblenz in Kooperation mit der Hochschule sowie der Universität Koblenz ein Pilotprojekt, das der Adaptation an den Klimawandel gewidmet ist. Dieses Vorhaben, gefördert im Rahmen des Programms „Anpassung urbaner Räume an den Klimawandel“ des Bundesinstituts für Bau-, Stadt- und Raumforschung im Bundesamt für Bauwesen und Raumordnung (BBSR), trägt den Titel „Klimaangepasste (-resiliente), integrierte Verkehrsraum- und Quartiersentwicklung am Beispiel der Moselweißer Straße im Stadtteil Koblenz-Rauental“. Ziel ist die klimaresiliente Umgestaltung eines Teilabschnitts der Moselweißer Straße im Stadtteil Rauental, um daraus Schlussfolgerungen für zukünftige Verkehrs- und Quartiersentwicklungen abzuleiten.

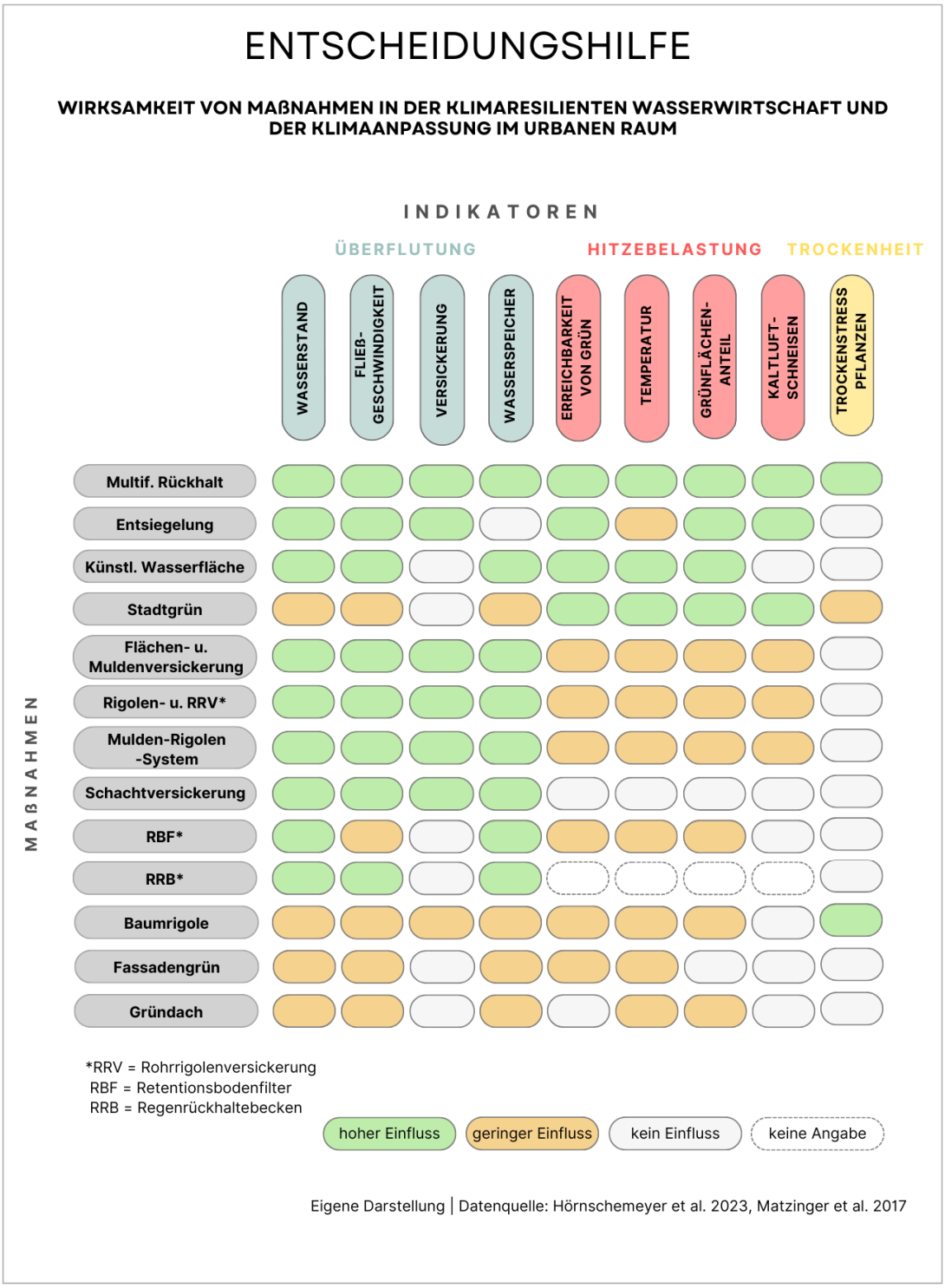

Abbildung 3: Entscheidungshilfe zur Identifizierung von Maßnahmen anhand von Indikatoren zur Wirksamkeit

Im Fokus des Projekts stehen die Installation von acht Baumrigolen im Straßenraum sowie die Teilentsiegelung eines Kirchenvorplatzes. Hier fand die Maßnahmenauswahl durch einen internen Abstimmungsprozess über mehrere Monate statt. So wurde eine Straße im innerstädtischen Überwärmungsbereich zur Begrünung mit Stadtbäumen gesucht. Das Grünflächenamt der Stadt wählte mögliche Standorte v.a. in Anbetracht mangelnder Begrünung, ausreichender Breite des Straßenraums und der Baumpflanzungen ohne Konflikte mit Leitungstrassen aus. Eine detaillierte Betroffenheitsanalyse der möglichen Standorte wurde nicht durchgeführt. Letztendlich fand eine Einigung auf die Moselweißer Straße statt. Die Entscheidung für den finalen Abschnitt ergab sich aus mehreren Faktoren: der Fokussierung auf öffentliche Flächen, dem Ausschluss gewerblicher Areale durch den Fördergeber sowie den spezifischen Gegebenheiten des ausgewählten Bereichs – einer Straße in Verbindung mit einem Kirchenvorplatz, wo sich

zudem eine Jugendbegegnungsstätte befindet. Da ein Interesse an der Erprobung verschiedener Baumrigolensysteme bestand, erfolgte die Auswahl nicht ausschließlich nach der Betroffenheit, sondern maßgeblich unter Berücksichtigung der räumlichen Gegebenheiten und der baulichen Machbarkeit.

Anhand dieses Beispielprojekts wird die Entscheidungshilfe angewandt, um festzustellen, ob die gewählten Maßnahmen in Retrospektive zum Standort passen oder ob äußere Faktoren die Auswahl dahingehend beeinflusst haben, dass die Eignung des Ortes für die geplanten Maßnahmen nicht gesichert ist. Es soll weiterhin abgeschätzt werden, ob die Anwendung Vorteile bietet wie Zeitersparnis, verbesserte Priorisierung und damit verbesserte Zielerreichung zu Klimaresilienz in der kommunalen Wasserwirtschaft/Klimaanpassung.

Dies wird erreicht, in dem Maßnahmen mit Wirkungen bei den selben Indikatoren gesucht werden. So werden durch die Baumrigolen die Indikatoren „Anteil Grünfläche“, „Temperatur“, „Wasserspeicherung“ und „Erreichbarkeit kühlender Grünflächen“ begünstigt. Die Entsiegelungsmaßnahme unterstützt die Indikatoren „Anteil Grünflächen“, „Temperatur“ sowie „Versickerungsfähigkeit“. Da eine zu einem späteren Zeitpunkt durchgeführte Betroffenheitsanalyse im Projektgebiet insbesondere einen aufgeheizten Straßenraum durch hohe Versiegelung, wenig Grün und fehlende Verschattung beschreibt sowie mögliche punktuelle Überflutung bei Starkregen, sind die ausgewählten Maßnahmen als geeignet einzustufen. Die Entscheidungshilfe bietet den Vorteil, dass auch mögliche Alternativen in Betracht gezogen werden können. So stellen die Maßnahmen „Flächen- und Muldenversickerung“ sowie „Rigolen- und Rohrrigolenversickerung“ mögliche alternative Maßnahmen dar mit ähnlicher Wirkung wie „Baumrigolen“ und „Entsiegelung“. Im Koblenzer Projekt war ein weiteres Ziel, neue Standortsysteme für Bäume zu testen, um mögliche Speichersysteme zu entwickeln. Diese Erkenntnis ist für die Übertragbarkeit in andere Stadtgebiete von Bedeutung, da nicht überall die Kosten für teure Baumrigolen gedeckt werden können. Durch das Aufzeigen von Alternativen können auch weitere Aspekte wie beispielsweise Umsetzungs- und Betriebskosten, Synergien oder Robustheit der Maßnahme in den Fokus genommen werden.

7 SCHLUSSFOLGERUNGEN

Die Entwicklung einheitlicher Rahmenbedingungen, die eine effiziente Maßnahmenauswahl für Klimaresilienz und Klimaanpassung ermöglichen, ist von großer Wichtigkeit. Trotz vieler Leitfäden und Anwendungsrahmen ist eine praktikable Übertragbarkeit noch immer eine Herausforderung. Durch den erstellten Entscheidungshilfe wurde dieser Aspekt weiter angestoßen, sodass kommunale Entscheidungsträgerinnen und Entscheidungsträger niederschwellig eine erste Betroffenheitsanalyse verknüpft mit Potentialen baulicher Maßnahmen vornehmen können. Der Rahmen bietet ein Angebot in der unerlässlichen interdisziplinären Zusammenarbeit einen gemeinsamen Nenner zu finden und datenbasiert Alternativen zu betrachten. Er ermöglicht damit eine Richtungsvorgabe auf Sachebene unabhängig von politischen oder sonstigen Rahmenbedingungen. Gleichzeitig erhöht er die anfängliche Transparenz für die Entscheidungsträgerinnen und Entscheidungsträger wie für die weiteren Beteiligten. Der Rahmen ist damit ein erster Schritt in der Planung, ohne weitere detailliertere Analysen zu ersetzen. Die Indikatoren ermöglichen gleichermaßen ein Monitoring der Wirksamkeit der Maßnahme.

Durch die Anwendung der Entscheidungshilfe am Koblenzer Projektbeispiel konnten dessen Anwendbarkeit und Vorteile aufgezeigt werden. Er zeigt mögliche Alternativen, welche eine vergleichbare potentielle Wirksamkeit hervorrufen, sodass die Betroffenheit auf Hitze und Überflutung in die Bewertung miteinbezogen werden können.

Eine zukünftige Weiterentwicklung der Entscheidungshilfe ist geplant. Die Wirksamkeit der Maßnahmen kann spezifiziert werden, sodass eine Parametrisierung nach Standort erfolgt. Weiterhin wurde begonnen, die Entscheidungshilfe um einen Ausschlusskatalog der einzelnen Maßnahmen in Bezug auf lokale Gegebenheiten zu erweitern. Ebenso sind soziale Aspekte noch stärker mit einzubeziehen, insbesondere in der Vulnerabilitätsanalyse. Für ausgewählte Kommunen sollen beispielhafte Indikatoren erfasst werden, um die Entscheidungshilfe mit konkreten Daten zu hinterlegen.

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reviewed paper

Krisensicher und lebendig: Die Rolle resilienter öffentlicher Räume für die zukunftsfähige Stadt

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1 ABSTRACT

Die zunehmenden Herausforderungen des 21. Jahrhunderts stellen Städte weltweit vor komplexe Aufgaben. Klimawandel, Pandemien, sozioökonomische Umbrüche und militärische Auseinandersetzungen erfordern neue Ansätze in der Stadtentwicklung (BBSR 2018: 9). In diesem Kontext gewinnt das Konzept der urbanen Resilienz zunehmend an Bedeutung. Ursprünglich aus der Ökologie stammend, beschreibt urbane Resilienz die Fähigkeit städtischer Systeme, auf Krisen und Katastrophen zu reagieren, sich an die veränderten Rahmenbedingungen anzupassen und hinsichtlich eines besseren Schutzes der Bevölkerung zu transformieren (UN Habitat o.J.). Eine resilienzorientierte Stadtentwicklung ist entscheidend für die Zukunftsfähigkeit von Städten in einer von Unsicherheit geprägten Welt. Öffentliche Räume spielen dabei eine Schlüsselrolle, da sie als Puffer und Katalysator urbaner Resilienz fungieren. Sie bieten Potenzial für flexible Nutzungen in Krisensituationen und fördern zivilgesellschaftliche Interaktion, da sie unmittelbar vom öffentlichen Sektor administriert werden und das Potenzial für eine beschleunigte Transformation durch demokratisch legitimierte Planung aufweisen. Diese Transformation ermöglicht Experimente und eine zeitnahe Reaktion auf Herausforderungen, während gleichzeitig die Kernfunktionen des öffentlichen Raums erfüllt werden.

Öffentliche Räume prägen das Bild einer Stadt und tragen maßgeblich zu ihrer Identität bei. Sie sind Orte der Erinnerung und des kollektiven Gedächtnisses, die das Stadtbild unverwechselbar machen. Sie bieten Platz für Begegnungen und Interaktionen zwischen verschiedenen Bevölkerungsgruppen und fördern den sozialen Zusammenhalt. Zudem ermöglichen sie Freizeitaktivitäten und unterstützen die Integration unterschiedlicher sozialer Gruppen (BSBK 2020: 26). Öffentliche Grünflächen tragen zur Klimaanpassung bei, indem sie die Luftqualität und Temperatur regulieren. Sie bieten Lebensräume für Flora und Fauna und fördern die biologische Vielfalt. Öffentliche Räume beeinflussen die wirtschaftliche Attraktivität einer Stadt, indem sie durch eine gute Gestaltung nicht nur Touristen, sondern auch Unternehmen anziehen. Sie bieten Raum für Demonstrationen, Versammlungen und andere Formen der politischen Partizipation und Meinungsbildung (Berding, Selle 2018: 1643).

Öffentliche Räume befinden sich in einem dynamischen Wandel und unterliegen bezüglich ihrer Herstellung, Verfügung, Nutzung und Gestaltung einem fortwährenden Prozess. Hierbei bedingen sich räumliche Entwicklungsprozesse und gesellschaftliche Rahmenbedingungen einander und führen zu einer Vielschichtigkeit und Veränderlichkeit (Breuer 2003: 8–10). In den letzten Jahrzehnten scheinen jedoch die Ansprüche an öffentliche Räume immer komplexer und multipler zu werden. Sich verändernde Lebenskonzepte, Arbeitsformen und Konsumverhalten werden zu globalen Herausforderungen und führen zu unterschiedlichen Anforderungen an die Nutzung und Gestaltung, entsprechend zu einem hohen Transformationsdruck (Walther 2024:20).

Die Widerstands- und Anpassungsfähigkeit öffentlicher Räume wird in diesem Beitrag unter dem Aspekt unvorhersehbarer Ereignisse, wie Naturkatastrophen und militärischen Auseinandersetzungen betrachtet. Es wird dabei der Frage nachgegangen, wie resiliente öffentliche Räume flexibel gestaltet, durch sichere Infrastrukturen ausgestattet und Prinzipien urbaner Resilienz in die Entwicklung und Gestaltung resilienter öffentlicher Räume integriert werden können. Dazu werden sowohl der aktuelle Forschungsstand als auch Analysen und Voruntersuchungen des durch die Gesellschaft für Internationale Zusammenarbeit (GIZ) geförderten Projekts„Strengthening of urban resilience (SUR) in the Areas of Supply Infrastructure and Housing in the Ukraine“ eingeordnet und innovative Ansätze zur Entwicklung und Gestaltung resilienter öffentlicher Räume vorgestellt.

Keywords: Transformation, Öffentliche Räume, Resilienz, Stadtentwicklung, Planung

2 URBANE RESILIENZ UND IHRE BEDEUTUNG FÜR DIE PLANUNG

Krisen, Katastrophen und disruptive Ereignisse stellen die räumliche Planung vor immer größere Herausforderungen (BBSR 2018: 9). Klimawandelinduzierte Extremwetterereignisse, die noch immer nicht vollkommen überwundene Corona-Pandemie sowie der Krieg gegen die Ukraine zeigen, wie anfällig unsere urbanen Lebensräume für schwerwiegende Schocks sind. Sie verdeutlichen aber auch, wie wichtig ein koordiniertes Handeln der relevanten Akteure und eine frühzeitige und umfassende Beschäftigung mit Risiken ist, um die Folgen dieser Krisen bestmöglich zu bewältigen. Planung kommt als „Tochter der Krise" (Kaiser 1968: 7) damit eine besondere Rolle zu, da sie aufgrund des interdisziplinären Ansatzes, der Auseinandersetzung mit verschiedenen Zukunftsszenarien und der partizipativen Ausrichtung in besonderer Weise geeignet ist, die Vorbereitung auf Krisen in konkrete Handlungsstrategien zu überführen.

Ein Kernkonzept in der Auseinandersetzung mit Krisen in der Planung ist das der Urbanen Resilienz. Das Konzept legt die Verantwortung der Planung für eine sichere und lebenswerte Zukunft zugrunde. Ursprünglich aus der Ökologie stammend, beschreibt urbane Resilienz die Fähigkeit städtischer Systeme, auf Krisen und Katastrophen zu reagieren, sich an die veränderten Rahmenbedingungen anzupassen und hinsichtlich eines besseren Schutzes der Bevölkerung zu transformieren (UN Habitat o.J.). Der Urbanen Resilienz immanent ist demzufolge ein Dreiklang aus den Dimensionen Widerstandsfähigkeit, Anpassungsfähigkeit und Transformationsfähigkeit. Die beiden letztgenannten Aspekte verdeutlichen, dass Urbane Resilienz über den reinen Wiederaufbau zerstörter Strukturen und das Verständnis im Sinne einer reinen Robustheit hinausgeht. Vielmehr sind resiliente Strukturen einer Stadt jene, die sich flexibel an veränderte Rahmenbedingungen anpassen können. Die Notwendigkeit hierfür ergibt sich bereits aus der Vielfalt möglicher disruptiver Ereignisse. Urbane Resilienz ist dabei kein Zustand der je abgeschlossen sein kann, sondern sie ist ein dynamischer Prozess, der insbesondere durch die Lernfähigkeit und das Potenzial zur Veränderung gekennzeichnet ist (Kegler 2022: 145).

2.1 Resilienz in der Planung

Die Agenda 2030 verpflichtet die Mitgliedsländer der UN, die 17 globalen Ziele für eine bessere Zukunft (Sustainable Development Goals – SDG) anzuerkennen und ihren individuellen Beitrag zur Erreichung dieser Ziele zu leisten (Bundesregierung o. J.). Das Ziel elf bezieht sich dabei auf nachhaltige Städte und Gemeinden und verpflichtet die Mitgliedsländer, diese „inklusiv, sicher, resilient und nachhaltig" zu machen (United Nations o. J.). Die Verankerung von Resilienzaspekten in den SDGs verdeutlicht die besondere Bedeutung, die Städten und Gemeinden für die Sicherheit der Bewohnerinnen und Bewohner zukommt. Dies gilt auch für deutsche Kommunen. Resilienz ist dabei als Querschnittsthema der Stadtentwicklung Teil der erweiterten Daseinsvorsorge und elementar, um die Grundfunktionen der Stadt zur Versorgung der Bevölkerung auch während Störereignissen aufrechterhalten zu können (Fekkak u. a. 2016: 10). Deutsche Städte und Gemeinden befinden sich hierfür in einer besonderen Ausgangslage, denn ihr Stadtwachstum ist in großen Teilen bereits abgeschlossen (Sieverts 2013: 319). Die Ziele einer resilienten Stadtentwicklung beziehen sich somit insbesondere auf den Umgang mit dem Bestand und die Implementierung von Lösungsansätzen innerhalb gegebener Grenzen. Dies stellt Städte und Gemeinden vor eine besondere Herausforderung, denn Lösungen können nicht einfach „auf der grünen Wiese" gefunden werden, sondern müssen sich stets dem individuellen Aspekt der Exposition anpassen.

Dabei kann es nicht Ziel der planerischen Auseinandersetzung mit einer resilienten Stadtentwicklung sein, sämtliche Störereignisse verhindern zu wollen. Stattdessen sollten städtische Systeme so ausgerichtet werden, dass ein proaktiver Umgang mit potenziellen Krisen und Schocks erfolgt und diese bei Eintritt zu möglichst wenig Schäden führen. Die Planung ist gefordert, über die bisherigen Denkmuster hinauszugehen, neue und kreative Formen der formellen wie der informellen Planung zu entwickeln und städtische Räume so zu gestalten, dass sie lebenswert bleiben. Hierzu kann es auch gehören, Räume neu zu ordnen und Bereiche zu etablieren, die der Resilienz besonders zuträglich sind. Hierzu zählen beispielsweise (Aufzählung teilweise nach Kegler 2022: 149 f.):

- Pufferzonen,
- Regenerationsbereiche,
- Schutzzonen für die Sicherung unbekannter Entwicklungen,
- Vorhaltebereiche […] für Notfälle,

- Neue (sozial-) kulturelle Identitätsorte.

Diese neu zu schaffenden Orte ergänzen bereits existierende Orte, die für eine resiliente Entwicklung von ebenso großer Bedeutung sind, denn in ihnen manifestieren sich Störungen und machen sie dadurch zu potenziellen Transformationsräumen der Zukunft. Zu diesen zählen (Aufzählung teilweise nach Kegler 2022: 149):

- Ortszentren,
- Dezentrale, funktionale Knoten,
- Siedlungsnetze […],
- Anthropogen belastete Räume,
- Kritische Infrastrukturen.

Um gemachte Fehler in der planerischen Auseinandersetzung mit Gefahren und Risiken nicht erneut zu begehen, sollten sämtliche planerische Handlungen auf die Vereinbarkeit mit Aspekten der Resilienz überprüft werden.

2.2 Aspekte urbaner Resilienz

Urbane Resilienz umfasst verschiedene Aspekte der städtischen Auseinandersetzung mit disruptiven Ereignissen. Diese Ereignisse manifestieren sich im Zyklus einer Stadt als langfristige Krisen oder abrupte lokale Katastrophen. Beide Erscheinungsformen wirken auf die Stadt ein als Risiken, denen es sich zu stellen und auf die es sich vorzubereiten gilt (vgl. Abb.1). Risiken sind dabei nicht immer gleich wahrscheinlich, sondern hängen unmittelbar von den Komponenten der Vulnerabilität einer Stadt oder des betrachteten Teilsystems, ihrer Exposition und der Gefahr ab. Vulnerabilität kann verstanden werden als „die durch physische, soziale, wirtschaftliche und ökologische Faktoren oder Prozesse bestimmten Bedingungen, die die Empfindlichkeit eines Gemeinwesens gegenüber den Auswirkungen von Gefahren erhöhen“ (NKS 2019: 10). Dabei muss Vulnerabilität nicht immer negativ konnotiert sein, sondern sie kann auch als Möglichkeit

gesehen werden, positive Veränderungen herbeizuführen (Christmann u. a. 2018: 185). Die Exposition beschreibt das Maß, in dem Menschen, Infrastrukturen oder sonstige städtische Systeme einem potenziellen Gefahrenereignis ausgesetzt sein können (IPCC 2014: 4). Sie hängt von der geographischen Lage, der räumlichen Verteilung der betrachteten Schutzgüter und deren Anfälligkeit ab. Eine hohe Exposition bedeutet, dass ein Gebiet oder eine Population direkt von einem Risikoereignis betroffen sein kann, was die potenziellen Schäden und Verluste erheblich erhöht. Die Komponente der Gefahr beschreibt einen Zustand, Umstand oder Vorgang, durch dessen Einwirkung ein Schaden an einem Schutzgut entstehen kann (BBK o. J.).

Von besonderer Bedeutung bei der Prävention von und Reaktion auf disruptive Ereignisse sind im Kontext der Urbanen Resilienz die drei bereits genannten Dimensionen der Widerstandsfähigkeit, Anpassungsfähigkeit und Transformationsfähigkeit. Widerstandsfähigkeit beschreibt die Fähigkeit des Systems Stadt, äußeren wie inneren Stressfaktoren nur in geringem Maße nachzugeben und die Stabilität der Teilsysteme auch in Krisensituationen beizubehalten. Anpassungsfähigkeit beschreibt demgegenüber die Fähigkeit einer Stadt, sich an die veränderte Situation während und nach einem disruptiven Ereignis anzupassen, ohne dabei jedoch die Erfüllung der Kernfunktionen aufzugeben. Unter Druck geratene Prozesse werden angepasst, um negative Folgen künftig zu minimieren (Adger 2000). Transformationsfähigkeit steht für die Fähigkeit, städtische Teilsysteme grundlegend zu verändern, auch in ihrer Identität. Sie umfasst dabei mehr als die Anpassungsfähigkeit, da sie etablierte Muster und Strukturen kritisch hinterfragt, grundlegend erneuert und für die Zukunft transformiert, um langfristig bestehen zu können (Pelling 2011).

Ergänzt werden die Dimensionen urbaner Resilienz um Prinzipien, die einer Operationalisierbarkeit des Konzepts in der Praxis dienen sollen. Sie wirken dabei zugleich handlungsleitend und als überprüfbare Variablen zum Status Quo. Redundanz betont die Bedeutsamkeit, städtische Strukturen abzusichern, indem alternative Systeme bereitstehen, die im Krisenfall Ausfälle kompensieren können (Meerow u. a. 2016). Dies gilt insbesondere für den Bereich der kritischen Infrastrukturen. Effizienz gewährleistet die ressourcenschonende Nutzung urbaner Systeme, wobei die Abwägung zwischen nachhaltigen und resilienten Lösungen bisher noch schwerfällt. Die Robustheit urbaner Strukturen schützt vor physischen und funktionalen Beeinträchtigungen durch externe Schocks, während Flexibilität es Städten erlaubt, Flächen zu

sichern, freizuhalten und schnell zu aktivieren. Schließlich trägt Diversität zur Innovationsfähigkeit urbaner Systeme bei, indem sie unterschiedliche Akteure, Nutzungsformen und Infrastrukturlösungen kombiniert um die Sicherheit der Menschen zu erhöhen (Vale und Campanella 2005).

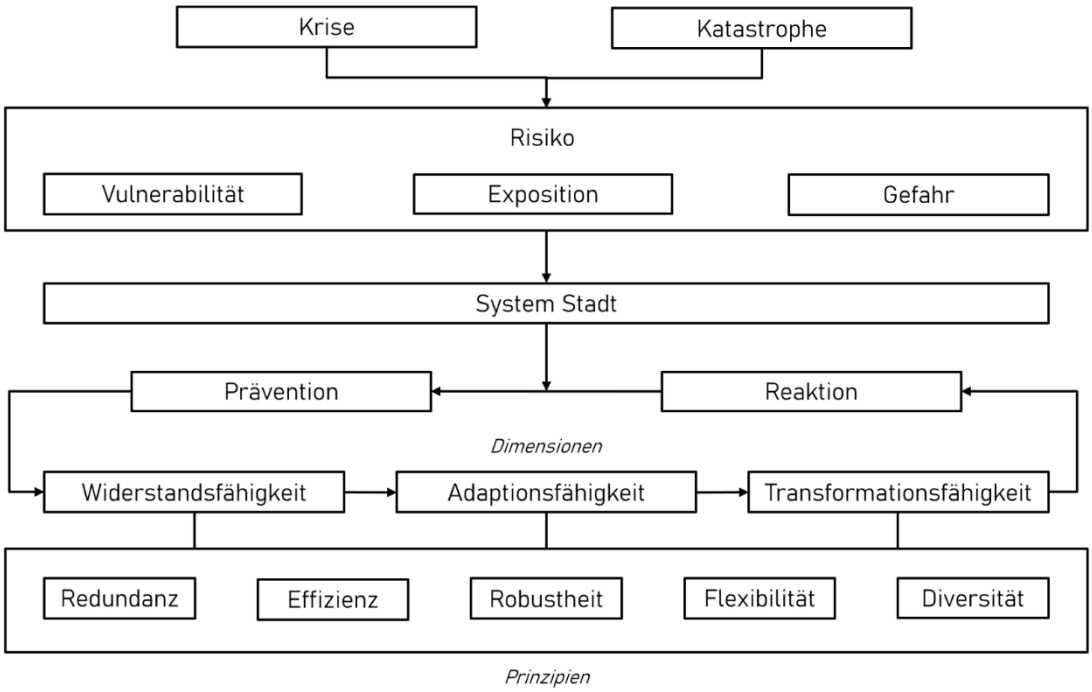

Abb. 1: Resilienzkonzept in der räumlichen Planung, Quelle: Lennart Bruß

3 RESILIENTE ÖFFENTLICHE RÄUME

Öffentliche Räume prägen das Bild einer Stadt und tragen wesentlich zu ihrer Identität bei. Sie sind Orte der Erinnerung und des kollektiven Gedächtnisses, die das Stadtbild unverwechselbar machen. Sie bieten Raum für Begegnungen und Interaktionen zwischen verschiedenen Bevölkerungsgruppen und fördern den sozialen Zusammenhalt. Darüber hinaus ermöglichen sie Freizeitaktivitäten und unterstützen die Integration unterschiedlicher sozialer Gruppen (Baukulturbericht 2020/21: 26). Öffentliche Grünflächen tragen zur Klimaanpassung bei, indem sie die Luftqualität und Temperatur regulieren. Sie bieten Lebensräume für Flora und Fauna und fördern die Biodiversität. Öffentliche Räume erhöhen auch die wirtschaftliche Attraktivität einer Stadt, indem sie durch eine gute Gestaltung nicht nur Touristen, sondern auch Unternehmen anziehen. Als Orte, an denen Meinungen in die Öffentlichkeit getragen werden, bieten sie zudem Raum für Demonstrationen, Versammlungen und andere Formen der politischen Partizipation und Meinungsbildung (Berding/Selle 2018: 1643).

Die Rolle einer verantwortungsvollen Planung öffentlicher Räume ist sehr wichtig: Einerseits hat die Planung die Handlungshoheit über die Gestaltung öffentlicher Räume und kann daher bei hohem Handlungsbedarf schnell durch die Regulierung und Gestaltung dieser eingreifen. Gleichzeitig ist die Planung nur durch einen demokratischen Prozess und durch die eigene Bevölkerung handlungsfähig und legitimiert, muss also verantwortungsvoll vor allem zugunsten der Öffentlichkeit, also zugunsten von Bewohnerinnen und Bewohnern planen.

3.1 Öffentliche Räume in Krisenzeiten

Öffentliche Räume befinden sich stets in einem dynamischen Wandel und sind hinsichtlich ihrer Herstellung, Verfügbarkeit, Nutzung und Gestaltung einem kontinuierlichen Prozess unterworfen. Dabei bedingen sich räumliche Entwicklungsprozesse und gesellschaftliche Rahmenbedingungen gegenseitig und führen zu einer Vielschichtigkeit und Wandelbarkeit (Breuer 2003: 8–10). In den letzten Jahrzehnten scheinen die Herausforderungen an öffentliche Räume jedoch immer komplexer und vielfältiger zu werden. Veränderte Lebenskonzepte, Arbeitsformen und Konsummuster führen zu unterschiedlichen Nutzungs- und Gestaltungsansprüchen und damit zu einem hohen Transformationsdruck(Walther 2024:20).

In Zeiten von Krisen und Katastrophen kommt dem öffentlichen Raum eine besondere Rolle zu, wie es in der jüngsten Vergangenheit die Covid-19-Pandemie verdeutlichte: Öffentliche Räume wurden zu Risikoräumen, die durch Lockdowns, strikte Reglementierungen, Grenzen und Absperrungen das Nutzungs- und Bewegungsverhalten bestimmten. Gleichzeitig stieg ihre Bedeutung vor allem in jenen Teilen der Stadt, in denen die Wohnverhältnisse beengt und derAnteil an privaten oder wohnungsnahen Erholungs- und Aufenthaltsräumen gering waren. Durch die Schließung von Kultur-, Gastronomie- und Freizeiteinrichtungen wurden öffentliche Räume, wie Parks, Plätze und Gehwege umso intensiver genutzt und verdeutlichten dadurch ihre gesellschaftliche Relevanz in Krisenzeiten (dvmP/SP 2022:12 ff; Schicketanz 2024:228). Viele Städte nahmen diese Ausnahmesituation zum Anlass, auf den hohen Bedarf an aneignungsfähige öffentliche Räume zu reagieren und diese durch kurzfristige und temporäre Maßnahmen wie dieEinrichtung von Pop-Up-Radwegen, die Umwidmung von Stellplätzen oder eine flexiblere Handhabung von Sonderregelungen, wie der gastronomischen Nutzung, sowohl als Aufenthalts-, als auch als Bewegungsraum der Bevölkerung zur Verfügung zu stellen. Gleichzeitig wurde deutlich, dass langfristig eine Transformation der öffentlichen Räume notwendig ist, die sich unter anderem in Konzepten wie der 15-Minuten-Stadt von Paris widerspiegelt.

Auch die fortschreitende Klimakrise stellt öffentliche Räume vor wachsenden Herausforderungen. Hohe Temperaturen führen durch wärmespeichernde Materialien und hohe Versiegelungsgrade vor allem in urbanen Räumen zur Bildung von Hitzeinsel-Effekten. Dies erhöht nicht nur die Gesundheitsrisiken insbesondere für ältere Menschen, Kinder und Personen mit Vorerkrankungen, sondern führt bei hohen Hitzebelastungen auch zu einer eingeschränkten Nutzbarkeit öffentlicher Räume.Zudem nehmen Häufigkeit und Intensität von Starkregenereignissen zu, die Entwässerungssysteme überlasten und zu Überschwemmungen und Sturzfluten führen können (Riechel/Wiemer 2022:6-7).Aus der Klimaanpassung lernen wir bereits, dass eine klimagerechte Gestaltung öffentlicher Räume kühle Orte im urbanen Raum schafft und dadurch nicht nur die Lebensqualität steigert, sondern Hitzestress im lokalen Maßstab reduziert und somit vor allem vulnerable Bevölkerungsgruppen vor bioklimatischer Belastung schützt(Stadt Freiburg i.Br. 2019:30). Durch Anpassungsstrategien wie Entsiegelung, blau-grüne Infrastruktur und dezentrales Regenwassermanagement wird auch das Hochwasserrisiko reduziert und die Widerstandsfähigkeit gegenüber Hitzewellen erhöht(Walther 2024:21; Dickhaut 2022:5 ff).

3.2 Relevanz resilienter öffentlicher Räume

Es wird deutlich, dass öffentliche Räume neben den eingangs genannten Funktionen auch eine Schutzfunktion für vulnerable Bevölkerungsgruppen haben. Eine Auseinandersetzung mit schleichenden Krisen und Herausforderungen, wie der zunehmenden Hitzebelastung, werden bereits in die Planung öffentlicher Räume integriert. Herausfordernder ist jedoch die Qualifizierung öffentlicher Räume hinsichtlich ihrer Schutzfunktion gegenüber der Bevölkerung und wichtiger kritischer Infrastrukturen im Kontext komplexer und sich überlagernder Krisen sowie disruptiver, unvorhersehbarer Ereignisse, wie plötzlich auftretende Naturkatastrophen oder militärische Konflikte. Im Sinne der urbanen Resilienz ist daher zu klären, wie widerstands-, anpassungs- und transformationsfähige öffentliche Räume entwickelt und zu sicheren öffentlichen Räumen ausgestattet werden können und wie Prinzipien der urbanen Resilienz in die Gestaltung resilienter öffentlicher Räume einfließen können.

4 RESILIENTE QUARTIERSENTWICKLUNG IN UKRAINISCHEN STÄDTEN

Urbane Resilienz als zentrales Planungskonzept im Umgang mit Krisen und Katastrophen gewinnt insbesondere in ukrainischen Städten zunehmend an Bedeutung. Die Stärkung urbaner Resilienz stellt ukrainische Städtevor dem Hintergrund des anhaltenden russischen Angriffskrieges vor besondere Herausforderungen. Einerseits müssen unter sich täglich ändernden Bedingungen kurzfristige Lösungen gefunden werden, um die Bevölkerungvor akuten und anhaltenden Bedrohungen zu schützen. Gleichzeitig gilt es, Szenarien und Strategien für eine mittel- bis langfristige Planungsperspektive zu entwickeln, die sowohl die lokalen Auswirkungen des Kriegesals auch alle weiteren globalen Herausforderungen und Krisen, wie den fortschreitenden Klimawandel, zunehmende Urbanisierungsprozesse oder eine verändernde Demografie berücksichtigen.Das von der Deutschen Gesellschaft für Internationale Zusammenarbeit (GIZ) geförderte Forschungsprojekt Strengthening of urban resilience (SUR) in the Areas of Supply Infrastructure and Housing in the Ukraine geht der Frage nach, wie resiliente Quartiere in ukrainischen Städten entwickelt

werden können und lässt erste Rückschlüsse auf die Gestaltung und Ausstattung resilienter öffentlicher Räume zu.

Abb. 2: Methodik zur Stärkung urbaner Resilienz auf Quartiersebene, Quelle: Poliksen Qorri-Dragaj

4.1 Identifizierung von Critical Spots, den besonders gefährdeten Bereichen eines Quartiers

Um ein möglichst vollständiges Bild der Risiken zu erhalten, denen ukrainische Städte ausgesetzt sind, ist es notwendig, die potenziellenGefahren, Expositionen und Vulnerabilitäten in einer kurz- bis mittelfristigen Perspektive zu identifizieren, indem verschiedene Kriterien untersucht werden (Vgl. Abb. 2).

Der russische Angriffskrieg gegen die Ukraine stellt ein externes disruptives Ereignis dar, das aufgrund der Unvorhersehbarkeitder täglichen Angriffe und Zerstörungen eine akute Gefährdung ähnlich einer Natur- oder technogenen Katastrophe bildetund unterschiedliche Auswirkungen haben kann: Die Zerstörung sensibler und kritischer Infrastrukturen führt zu grundlegenden Versorgungsengpässen; die Zerstörung ganzer Wohnblöcke und Quartiere erhöht den Bedarf an Notunterkünften und Schutzräumen;militärische Schadstoffe haben enorme ökologische Auswirkungen, kontaminieren Boden und Wasser undführen zuweiteren Störungen des Ökosystems; Angriffe in der Nähe von Atomkraftwerken stellen ein enormes Risiko für technogene Katastrophen wie eine Nuklearkatastrophe dar.

Neben den akuten Gefahren sind auch Kriterien der Exposition in die Risikoanalyse einzubeziehen. Kritische und militärische Infrastrukturen in Wohnquartieren als mögliche militärische Angriffsziele erhöhen z.B. das Gefährdungspotenzial für die Zivilbevölkerung durch Fehleinschläge von Raketen oder Kontaminationen durch Altlasten.

Die Vulnerabilitätsanalyse schließt die Bereiche einer Stadt ein, in denen viele sensible Bevölkerungsgruppen, wie ältere Menschen, Kinder und Säuglinge sowie Menschen mit eingeschränkter Mobilität leben. Darüber hinaus werden sensible Infrastrukturen als Kriterium einbezogen, da sich dort sensible Bevölkerungsgruppen dauerhaft oder über den Tag verteilt aufhalten, wie z.B. Krankenhäuser, Kindergärten, Schulen, Altenheime, Traumazentren/psychiatrische Kliniken, Unterkünfte für Binnenvertriebene oder Menschen, die ihr Zuhause durch den Krieg verloren haben. Weitere Kriterien sind kritische und militärische Infrastrukturen, die die Versorgung der Bevölkerung sicherstellen und daher besonders geschützt werden müssen, wie Infrastrukturen in den Bereichen Energie, Wasser, Ernährung, Informationstechnologie und Telekommunikation, Gesundheit, kommunale Abfallentsorgung etc. Schließlich werden in die Vulnerabilitätsanalyse die Bereiche eines Quartiers einbezogen, die ein Defizit an erreichbaren und zugänglichen Schutzräumen, wie Bunker, Notunterkünfte, Sammelstellen oder unterirdische Bahnhöfe aufweisen.

Die Überlagerung der aufgeführten Kriterien ermöglicht die Identifizierung von Critical Spots. Dies sind Bereiche einer Stadt, die im besonderen Maße Risiken ausgesetzt sind und daher eine hohe Handlungspriorität bei der Entwicklung resilienter Quartiere haben.

4.2 Entwicklung resilienter Quartiere

Zur Entwicklung widerstandsfähiger, anpassungsfähiger und transformationsfähiger Quartiere können Planungsziele anhand räumlicher Prinzipien urbaner Resilienz formuliert werden, die eine Überprüfbarkeit in der Praxis ermöglichen.

Redundanzen stellengleiche Funktionen mehrfach zur Verfügung, um Reservekapazitäten für unvorhersehbare Risiken vorzuhalten und bei Bedarf abrufen zu können. Beispiele für redundante Systeme sind redundante Straßennetze, die im Notfall alternative Versorgungs- und Evakuierungswege darstellen. Natürliche Freiraumstrukturen könnenals redundante Retentionsräume entwickelt werden. Die Stromversorgung einer Stadt kann in mehrere redundante, räumlich voneinander getrennte Quellenaufgeteilt werden, um Defizite im Schadensfall auszugleichen.

Effizientes Planen im Bestand schont Ressourcen, indem z.B.Quartiere kompakt, grün und nutzungsgemischt entwickelt werden und die Innenentwicklung der Außenentwicklung vorgezogen wird. Eine klimasensible und multifunktionale Gestaltung von Freiräumen fördert die Mehrfachnutzung von Flächen. Quartiere der kurzen Wege verdrängen den dominierenden motorisierten Individualverkehr und ermöglichen soeine Neuaufteilung der Straßenräume. Ressourcen werden zudem durch dezentrales Wassermanagement effizient genutzt und für Notfälle verfügbar gehalten.

Robuste Systemehalten Auswirkungen extremer Bedingungen stand, indem sie Ausfälle antizipieren und Vorkehrungen treffen, um im Notfall autark agieren und Krisen eigenständig bewältigen zu können. Dies kann z.B. durch die Aktivierung lokaler und regionaler Produktion geschehen, um eine autarke Versorgung mit Gütern des täglichen Bedarfs sicherzustellen. Im Bereich der Sicherheit sind gut erreichbare Schutzräume und Versorgungseinrichtungen durch kontinuierliche Instandhaltung und Entwicklung zu einem Netz von sicheren Räumen zu entwickeln.

Flexible Systeme sind in der Lage sich zu verändern, sich weiterzuentwickeln und sich veränderten Umständen anzupassen. Polyzentrische Strukturen stellen ein flexibles System dar, da sie im Notfall unabhängig funktionieren und eine dezentrale Versorgunggewährleisten. Der Aufbau modularer und dezentraler kritischer Infrastrukturen sichert beispielsweise Versorgungsnetze auch bei vereinzelten Störungen durch externe disruptive Ereignisse. Die flexible Gestaltung öffentlicher Räume ermöglicht temporäre Nutzungen oder kann im Notfall schnell Platz für Transport oder Evakuierung schaffen. Auf der Bebauungsebene können ausgewählte geeignete Gebäude flexibel zu Notunterkünften umgebaut und für Schutzsuchende zugänglich gemacht werden.

Das Prinzip der Diversität ermöglicht die Bereitstellung verschiedener Alternativen bei Teilausfällen. Polyzentrische, nutzungsgemischte Strukturen ermöglichen eine gute Erreichbarkeit aller notwendigen Funktionen in einem kurzen Radius und reduzieren Abhängigkeiten im Störungsfall. Vielfältige Typologien ermöglichen die Integration unterschiedlicher Wohn- und Arbeitsformen im Quartier. Ein differenziertes Mobilitätsangebot sichert Ausweichmöglichkeiten bei Ausfall eines einzelnen Verkehrsmittels. Mobility-Hubs können als gut erreichbare Bausteine eines Quartiers durch multifunktionale Gestaltung vielfältige Funktionen übernehmen – für einen möglichen Katastrophenfall können sie so ausgestattet werden, dass sie eine gewisse Grundversorgung sicherstellen oder auch Schutzräume aufweisen.

Durch die Entwicklung von Szenarien können schließlich erste Möglichkeitsräume für die Entwicklung resilienter Quartiere ausgelotet werden, die neben globalen Herausforderungen, wie den Auswirkungen des Klimawandels, der zunehmenden Urbanisierung oder desdemografischen Wandels vor allem auch mögliche mittel- bis langfristige Folgen des Krieges, wie den Umgang mit Schrumpfung oder Wachstum von Städten als Folge von Zerstörung, Vertreibung, (Binnen-)Migration und Rückkehr umfassen. Die Integration urbaner Resilienz zur Bewältigung lokaler und globaler Risiken eröffnet ukrainischen Städten die Möglichkeit zur Transformation, ganz im Sinne des Building-Back-Better-Ansatzes.

5 BEST PRACTICES

Die Übertragung des Konzepts der urbanen Resilienz auf die Quartiersebene zeigt bereits, dass öffentliche Räume eine entscheidende Rolle bei der Bewältigung von Krisen und Katastrophen spielen. Durch die Betrachtung ausgewählter Best Practices können wertvolle Erkenntnisse gewonnen werden, wie diese zu resilienten öffentlichen Räumen weiterentwickelt werden können.

5.1 „Common Spaces“ Drohobych – Binnenflüchtlinge gestalten resiliente öffentliche Räume

Der brutale Angriffskrieg Russlands gegen die Ukraine führt zu Vertreibungen der Bevölkerung und zu massiven Zerstörungen in den Städten, wobei gezielt soziale, kulturelle und kritische Infrastrukturen wie Schulen und Kraftwerke bombardiert werden. Infolgedessen stehen vor allem westukrainische Städte vor enormen Herausforderungen bei der Bereitstellung von Wohnraum und Infrastruktur für mehr als sechs Millionen Binnenvertriebene (Internal Displaced Persons – IDPs) bereitzustellen.

Neben der Umsetzung baulicher Maßnahmen ist jedoch vor allem die Integration der IDPs in den Zufluchtsstädten wichtig. Öffentliche Räume eignen sich besonders, um den Austausch zwischen Alteingesessenen und den neuen Bewohnerinnen und Bewohner sowie die Aneignung des neuen Wohnortes zu ermöglichen. Eine multifunktionale und flexible Gestaltung integriert in einen inklusiven Planungsprozess kann öffentliche Räume als Orte der Solidarität stärken. In ihnen kann sich eine widerstandsfähige Zivilgesellschaft Ausdruck finden, die in der Krise neue Narrative entwickelt und gleichzeitig ihr Selbstverständnis bewahrt.

Unter dieser Prämisse haben über 30 Studierende und Dozentinnen und Dozenten der Universitäten TU Lviv, KNUBA Kyiv und RPTU Kaiserslautern-Landau während des Sommersemesters 2023 am Projekt „Common Spaces“ zur Qualifizierung öffentlicher Räume in der westukrainischen Stadt Drohobych zusammengearbeitet. Das Studienprojekt wurde durch das Programm „Ukraine digital“ des Deutschen Akademischen Austauschdienstes (DAAD) sowie durch die Stiftung Erinnerung, Verantwortung und Zukunft (EVZ, Programm Meetup) gefördert.

Abb. 3: Gestaltung resilienter öffentlicher Räume in Drohobych, Quelle: Anna Kuzyshyn

Öffentliche Räume sind das Wohnzimmer einer Stadt, in denen sich jeder Bewohner, unabhängig von Alter, Geschlecht oder Status, eingebunden fühlt und mit denen er sich identifiziert. Ausgangspunkt des Projekts war die These, dass die IDPs in Drohobych durch die Nutzung gemeinsam gestalteter Räume, die Beteiligung an Workshops und die Umsetzung der Projekteauch in der Ankunftsstadt eine Heimat finden. Indem sie ihre Ideen und Ressourcen gemeinsam mit den alteingesessenen Bewohnerinnen und Bewohnern in die Umgestaltung öffentlicher Räume einbringen, schaffen sie einerseits ein Umfeld, das Teil ihrer neuen Geschichte wird. Gleichzeitig entsteht durch die Einbindung aller Akteure in die Entwicklung gestalterisch hochwertiger öffentlicher Räume eine resiliente Zivilgesellschaft.

Das Projekt wurde in drei Phasen umgesetzt: Die erste Phase umfasste eine Bestandsaufnahme mit Skizzen, Kartierungen, Fotografien und Sozialforschung zur Geschichte und Sozioökonomie der Stadt, um Orte für Interventionen zu identifizieren. In der zweiten Phase wurden zwei Workshops mit lokalen Akteurinnen und Akteuren durchgeführt, um Standorte und Projektvorschläge für den öffentlichen Raum zu ermitteln. In der dritten Phase stellte die Studierenden gemeinsam mit den Bewohnerinnen und Bewohnern von Drohobych die Stadtmöbel vor Ort her und installierten sie an drei Modellstandorten.

Die realisierten Modellprojekte verfolgen verschiedene Ziele. Der erste Modellstandort „Kamenyar“ befindet sich vor einer ehemaligen Buchhandlung im historischen Stadtzentrumvor dem Hintergrund des Fassadenmosaiks „Mädchen mit Buch“ im Stil des sowjetischen Realismus. Die Installation des Stadtmöbels soll eine Rückbesinnung auf das historische Gedächtnis des Ortes initiieren und damit nicht nur seine soziokulturelle Funktion stärken, sondern auch und die Aufenthaltsqualität des Ortes verbessern. Am Modellstandort "Park der Kultur" kreuzen sich wichtige Fußwegeverbindungen aus dem Stadtzentrum in der Nähe des Volkshauses, des Hauses der Kultur, des Krimtatarischen Zentrums und der Staatlichen Pädagogischen Universität. Hier war es wichtig, klassische Gestaltungsansätze zu überdenken und durch die Ausrichtung und Ausstattung des Stadtmobiliars unterschiedliche Nutzungsszenarien zu ermöglichen.

Durch die Um- und Mitgestaltung öffentlicher Räume unter Beteiligung der lokalen Bevölkerung, der neu zugezogenen IDPs und der vor Ort agierenden Studierenden wurden wichtige Impulse für die Neugestaltung des öffentlichen Raums in Krisenzeiten gesetzt. Es wurden Orte geschaffen, an denen sich IDPs und lokale Bewohnerinnen und Bewohner begegnen und das Bild und die Identität ihrer Stadt neu prägen. Die Beteiligten haben sich nicht nur theoretisch mit dem Thema auseinandergesetzt, sondern auch vor Ort diskutiert, selbst Stadtmöbel gebaut und dadurch öffentliche Räume gemeinsam neu gestaltet, die nachhaltig das Stadtzentrum aufwerten und beleben. Gleichzeitig entsteht eine neue Generation ukrainischer Architektinnen und Architekten, Stadtplanerinnen und Stadtplaner, die gemeinsam mit den lokalen Akteuren ihre Städte resilient umbauen, hin zu einem lebenswerten, demokratischen und freien Gemeinwesen innerhalb Europas.

5.2 Disaster Prevention Parks, Japan

Japan war in den letzten 100 Jahren mehrfach verheerenden Erdbeben ausgesetzt, die in der Folge Tsunamis und Brände auslösten und zahlreiche Todesopferforderten. Als Reaktion auf diese Katastrophen wurde 1978 das Prinzip der Disaster Prevention Parks angestoßen und bis heute kontinuierlich weiterentwickelt – einer systematischenEinrichtung von Freiraumsystemen, die im Katastrophenfall vor allem als Evakuierungsorte und -routen, Brandschneisen und Stützpunkte für die Wiederherstellung und den Wiederaufbau dienen(Tashiro 2025). Die Disaster Prevention Parks werden hierbei in unterschiedliche Typen gegliedert, u.a.:

- Parks, in denen die Polizei und die Feuerwehr, ein weiträumiges Hilfsteam und ein Rettungsteam stationiert sind
- Parks und Grünanlagen als ausgewiesene Evakuierungsgebiete
- Mit einem Hubschrauberlandeplatz ausgestattete Parks in der Nähe medizinischer Einrichtungen, um Patienten und medizinische Güter transportieren zu können.

Die Parks sind mit Katastrophenschutzeinrichtungen wie einer als Bad nutzbaren Pergola, solarbetriebener Beleuchtung, zu Öfen umfunktionierbaren Sitzgelegenheiten und Wasserpumpen ausgestattet. Hubschrauberlandeplätze befinden sich auf Sportplätzen und ausgewiesene Wegenetze in den Parks sind so dimensioniert, dass Rettungsfahrzeuge darauf fahren und Evakuierungsrouten eingerichtet werden können (Tokyo Metropolitan Park Association, o.J.). Die einzelnen Funktionen sind entsprechend der Größe der Parks, des zeitlichen Rahmens sowie des Bewältigungsprozesses seit Eintritt des Ereignisses kategorisiert (Vgl. Abb. 4), wobei übergeordnete Schutzzonen (Large-Scale Refuge-Areas) alle 2 km vorhanden sind und eine Fläche von mindestens 2 m² / Person vorsehen sollten (Masuda 2014:55).

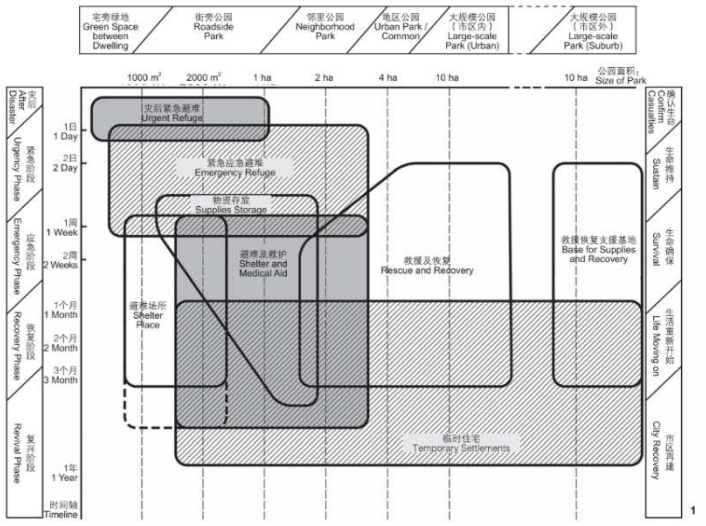

Abb. 4: Systematik Disaster Prevention Parks, Quelle: Disaster Refuge and Relief Urban Park System in Japan (Masuda, 2014)

Neben dem Katastrophenschutz haben die Disaster Prevention Parks aber auch die Funktion, eine kollektive Erinnerung an das disruptive Ereignis aufrechtzuerhalten und dadurch das Risikobewusstsein in der

Gesellschaft durch lokale Evakuierungsübungen oder die Besichtigung von Katastrophenschutzeinrichtungen zu schärfen. Auf diese Weise verbinden Parks Orte der Erholung und Freizeitgestaltung mit planerischen Sicherheitsstandards zu multifunktionalen Zufluchtsorten (Tashiro 2025).

5.3 Milan 2020 Adaptation Strategy

Mailand gehörte zu den ersten Städten Europas, die im besonderen Maße von der Covid-19-Pandemie betroffen waren und als unmittelbare Reaktion umfassende Lockdowns einführten. Trotz der Krise erkannte die Stadtverwaltung aber auch die Chance, auf der Basis eines unmittelbaren Krisenmanagements Transformationen anzustoßen, um sich an die neue Normalität anzupassen. Dies mündete in der Milan 2020 Adaptation Strategy, die die Lehren aus der Pandemie zieht, um auf künftige Krisen und Katastrophen besser vorbereitet zu sein (Pinto/Akhavan 2022:373).

Eine Anpassungsstrategie ist die Rückeroberung öffentlicher Räume. Die Nutzung von Straßen und Plätzen soll überdacht werden, um eine sanfte Mobilität zu fördern, aber auch Einzelhandel, Freizeitaktivitäten und kulturelles Leben unter Einhaltung von Abstandsregelungen zu ermöglichen. Die Entwicklung von „Piazze Aperte / Open Squares“ ermöglicht es durch die Aneignung von Verkehrsflächen, vor allem in Quartieren mit einer geringen Verfügbarkeit an Grünräumen und in der Nähe von Schulstandorten, Aufenthaltsräume zu schaffen und Spielstraßen für Kinder einzurichten. Darüber hinaus erleichtern die Einrichtung von Tempo-30-Zonen und die Lockerung rechtlicher Regelungen die Nutzung öffentlicher Räume für Einzelhandel, Gastronomie und kulturelle Veranstaltungen(Comune di Milano, o.J.). Durch eine breite Öffentlichkeitsbeteiligung konnten die Einwohnerinnen und Einwohner Vorschläge zu den Themen Fußgängerzonen, Radwege und Bikesharing, öffentlicher Nahverkehr, Wasser und Stadtgrüneinreichen, die in einer Karte verortet wurden und eine erste räumliche Perspektive für die Entwicklung des öffentlichen Raums aufzeigen. Maßnahmen zur Aneignung öffentlicher Räume konnten durch Tactical Urbanism kurzfristig und kostengünstig umgesetzt werden. (Pelizzaro:2021).

6 LEARNINGS

Es wird deutlich, dass öffentliche Räume vor dem Hintergrund zunehmender disruptiver Ereignisse insbesondere die Aufgabe haben, die Bevölkerung zu schützen und das Selbstverständnis und die Identität des Lebensumfeldes auch unter besonders herausfordernden Bedingungen zu bewahren. Diese Funktionen kommen nicht nur bei militärischen Angriffen zum Tragen, sondern können auch auf Naturkatastrophen und andere unvorhersehbare Schocks übertragen werden, die den Schutz der Bevölkerung erfordern. Öffentliche Räume können durch die Anwendung folgender Prinzipien zu krisenfesten und resilienten Räumen qualifiziert werden:

- Die Entwicklung redundanter Straßennetze ermöglicht die Einrichtung von Evakuierungsrouten und Versorgungskorridoren auch bei Teilausfällen wie Sperrungen oder Zerstörungen.
- Flexibel gestaltete öffentliche Räume ermöglichen eine temporäre Umnutzung, um im Notfall und bei fehlender Redundanz schnell Platz für Flucht- und Versorgungswege zu schaffen.
- Gut erreichbare und multifunktionale Safety-Hubs können Schutz vor Starkregen und Hochwasser, aber auch vor Raketeneinschlägen bieten.
- Die Integration der Schutzfunktion in die Entwicklung übergeordneter Freiraumsysteme bietet im Notfall Reserveflächen und Ausweichräume sowohl für die Unterbringung der Bevölkerung als auch für die Stationierung verschiedener Rettungseinheiten.
- Die planerische Entwicklung krisenfester öffentlicher Räume und deren Umsetzung fördert das Risikobewusstsein und -verhalten der Bevölkerung. Sie wird für mögliche Gefahren sensibilisiert.

Gleichzeitig müssen im Sinne der urbanen Resilienz neben einer vorausschauenden Planung bezüglich akuter Risiken auch langfristige Krisen in die Entwicklung lebendiger und lebenswerter öffentlicher Räume einbezogen werden. Dabei spielt dieKlimaanpassung eine entscheidendeRolle. Gut erreichbare, multifunktionale und klimasensibel gestaltete öffentliche Räume erhöhen nicht nur die Widerstandsfähigkeit eines urbanen Systems gegenüber dem Klimawandel. Sie erhöhen auch die Qualität öffentlicher Räume als Räume des Aufenthalts, Verweilens und des Bewegens. Die Förderung des Langsamverkehrs und des öffentlichen Verkehrs reduziert die Luftverschmutzung, ermöglichteine gerechte Umverteilung des bisher

vom motorisierten Individualverkehr dominierten Straßenraums und erhöht damit die Aneignungsfähigkeit öffentlicher Räume durch die Bewohnerinnen und Bewohner einer Stadt.

Neben der strategischen Entwicklung resilienter öffentlicher Räume ist auch die Einbindung der Bevölkerung von besonderer Bedeutung. Risikobewusstsein und adäquates Verhalten bei plötzlich eintretenden Ereignissen müssen trainiert werden, damit Schutzfunktionen überhaupt greifen können. Durch die Beteiligung der Bevölkerungen können aber auch kurzfristig dringende Handlungsbedarfe und -prioritäten identifiziert werden, wie dies in Mailand geschehen ist. Gleichzeitig kann über die Entwicklung und Gestaltung öffentlicher Räume durch die Partizipation unterschiedlicher Akteurinnen und Akteure die gesellschaftliche Resilienz gestärkt werden, indem durch gemeinsames Handeln ein neues Selbstverständnis entsteht, öffentliche Räume im Verständnis als gemeinsames Gut verankert und somit als lebendige und lebenswerte öffentliche Räume erlebt werden.

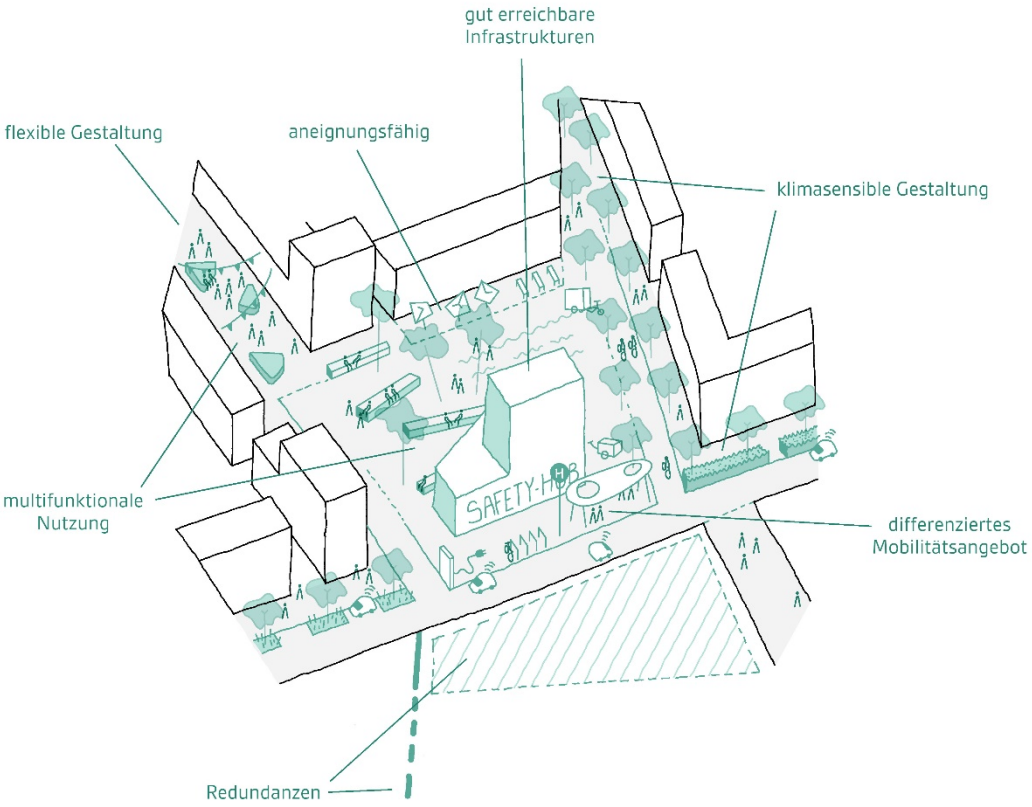

Abb. 5: Schlüsselthemen resilienter öffentliche Räume, Quelle: Poliksen Qorri-Dragaj

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1 ABSTRACT

Die Mobilitätsforschung konzentriert sich bislang hauptsächlich auf städtische Gebiete und die spezifischen Mobilitätsbedürfnisse ihrer Bevölkerung – der ländliche Raum wurde dabei oft vernachlässigt. Die urbanen Mobilitätslabore (UML) der österreichischen Mobility Lab-Initiative befassten sich bislang auch in erster Linie mit Städten und dem Stadtumland. Genau hier setzt das land.mobil:LAB an: Als Brückenbauer zwischen Forschung und Praxis treibt es Mobilitätsinnovationen für ländliche Regionen voran. Das Mobilitätslabor für den ländlichen Raum orientiert sich an bestehenden Strategien wie der Open Innovation Strategie 2025 (BMWFW & BMVIT 2016), dem Masterplan Mobilität 2030 (BMK 2021) und dem Mobilitätskonzept Niederösterreich 2030+ (Amt der Niederösterreichischen Landesregierung 2015). Durch seinen Co-Creation-Ansatz und die Prinzipien der offenen Innovation (Schuurman 2015) schafft das Mobility Lab einen neuen Standard für alle Projekte unter seinem Dach.

Als Modellregion für das land.mobil:LAB dient das Waldviertel (Niederösterreich). Zwei zentrale Ziele stehen dabei im Fokus: die Reduktion von Treibhausgasemissionen im Rahmen der Mobilitätswende und die Verbesserung der sozialen Teilhabe durch Mobilität. Um dies zu erreichen, entwickelt das LAB ein tiefgreifendes Verständnis für die verschiedenen Mobilitätsbedürfnisse der Bevölkerung im ländlichen Raum durch Bildung von mobilitätsrelevanten (Proto-)Personas (Nielsen et al. 2013, Dangschat 2020).

Als Teil des FTI-Förderprogramms des BMK für die Mobilitätswende zielt das Projekt darauf ab, zukunftsweisende Mobilitätsinnovationen in der Praxis zu testen. In einem breiten Netzwerk aus Land Niederösterreich, Waldviertler Gemeinden, Mobilitätsdienstleistern, Unternehmen, Veranstaltenden und Bürgerinnen und Bürgern werden innovative Mobilitätslösungen erprobt. Dies stärkt nicht nur die Mobilitätswende im ländlichen Raum, sondern auch die gesamte Forschungslandschaft in diesem Bereich (BMK o.J., online).

In der vorangegangenen Fallstudie „KulturMobil“ ließen sich wichtige Erkenntnisse für die erste Phase des land.mobil:LABs gewinnen: Gerade im Bereich der Freizeitmobilität zeigt sich ein besonderes Potenzial für Verhaltensänderungen, da Menschen in ihrer Freizeit offener für alternative Mobilitätsformen als im Alltag sind (Sodl-Niederecker et al., 2022). Die Studie identifizierte mehrere zentrale Handlungsfelder, die nun im land.mobil:LAB aufgegriffen werden: Die Integration von Kultur- und Veranstaltungsmobilität in die ÖV-Planung, die Entwicklung einer regionalen Mitfahrzentrale sowie die zielgruppengerechte Kommunikation von Mobilitätsangeboten bilden wichtige Ansatzpunkte (Grinzinger et al. 2024). Besonders vielversprechend erscheint die Verknüpfung von Kulturangeboten mit innovativen Mobilitätslösungen wie Schnuppertickets oder die Ergänzung der NÖ-Card um zusätzliche Mobilitätsangebote. Diese Erkenntnisse fließen nun, neben den Schwerpunkten Flex-ÖV und der Einbindung regionaler Mobilitätsdienstleistender, in die erste Arbeitsphase des land.mobil:LABs ein. Das Ergebnis sind übertragbare Methodensets für strukturähnliche Regionen in Österreich und Europa.

Keywords: co-creation, Waldviertel, rural mobility, living lab, transport innovation

2 PROJEKTEINBETTUNG UND THEORETISCHER RAHMEN

2.1 Die österreichische FTI-Mobilitätsinitiative zum Aufbau von Mobilitätslaboren

Im Rahmen des Programms "Mobilität der Zukunft (MdZ)", wurde seitens des österreichischen Bundesministeriums für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK) eine Mobilitätsinitiative ins Leben gerufen, die den Aufbau und Betrieb von Mobilitätslaboren zum Ziel hat

(BMK, o.J.). Die Erreichung der europäischen und nationalen Klimaziele bedingt die Förderung von technischen, sozialen und organisatorischen Innovationen im Bereich der Mobilität, die zur Generierung neuer Geschäftsmodelle beitragen und somit eine nachhaltige Transformation des Mobilitätssektors ermöglichen. Ein signifikanter Eckpfeiler der Maßnahmen des BMK stellt die finanzielle Förderung von Forschung, Technologie und Innovation zu übergreifenden Grundsatzfragen einer nachhaltigen Mobilität dar. (Österreichische Forschungsförderungsgesellschaft mbH (FFG), o.J.)

Die 2014 initiierte Sondierungsphase für urbane Mobilitätslabore fungierte dabei als Ausgangspunkt für die Errichtung eines umfassenden Wissenspools. In einer zweiten Phase, die von 2017 bis 2021 andauerte, wurde der Aufbau und Betrieb von sechs Mobilitätslaboren gefördert. Die Laufzeit der Mobilitätslabore in der zweiten Phase endete im Jahr 2021. Aufbauend auf der im Jahr 2020 durchgeführten externen Wirkungsprüfung der Mobilitätslabore wurde im Frühjahr 2021 die dritte Phase der Mobilitätslabore ausgeschrieben. Vier urbane Mobilitätslabore und das Center for Mobility Change werden seitdem weitergeführt und -entwickelt. Seit 2018 werden das Centre for Mobility Change und seit 2022 das Policy Lab vom BMK gefördert. Im Jahr 2023 startete u. a. die Sondierungsphase für Regionale Mobilitätslabore. Seit 2024 werden weitere vier Regionale Mobilitätslabore gefördert. Durch eine mobilitätslaborübergreifende "Kooperations- und Austauschplattform Mobilitätslabore Österreich" (KAMÖ), wird mit Unterstützung der AustriaTech ein Lern- und Austauschprozess realisiert, durch den Synergien zwischen den einzelnen Mobilitätslaboren genutzt und Kompetenzen zu experimentellen Umgebungen im Mobilitätskontext fortlaufend erweitert werden. (BMK, o.J.)

2.2 Eine Verknüpfung der Reallaborforschung mit dem Open-Innovation Ansatz

Die österreichischen Mobilitätslabors greifen Ideen und Methoden auf, die im wissenschaftlichen Diskurs unter dem Begriff „Reallabor“ behandelt werden. Der gemeinsame Nenner dieser beiden Begriffe beschreibt die Tatsache, dass in den letzten Jahren zahlreiche vielversprechende Lösungen – nicht nur im Bereich der Mobilität – entwickelt wurden. Diese sind aber meist in den Schubladen verschwunden und somit nicht oder nur im geringen Umfang mit den Menschen und ihren tatsächlichen Bedürfnissen in Berührung gekommen. Die österreichischen Mobilitätslabore fokussieren sich auf die Unterstützung von Forschung und Entwicklung, mit dem Ziel, das vorhandene Potenzial der vorliegenden, regional diversen, Mobilitätsstruktur, im Sinne eines sozial- und klimagerechten Angebots, in einer realen Umgebung zu maximieren. Zu diesem Zweck wird u. a. eine enge Verzahnung von Wissenschaft und Praxis bereits in der Ideenfindungsphase angestrebt. Menschen mit unterschiedlichem Hintergrund tragen zur gemeinsamen Verbesserung von Innovationen bei. Schließlich erfolgen Praxistests in verschiedenen Alltagssituationen, um die Eignung von neu entwickelten Mobilitätsangeboten zu ermitteln. Der Fokus liegt somit auf der Generierung attraktiver Ideen, Maßnahmen und Angebote, um eine Transformation hin zu mehr Nachhaltigkeit und Teilhabegerechtigkeit in der Mobilität zu ermöglichen. (BMK, o.J.) Eine Kombination des Reallaboransatzes mit dem Open-Innovation-Ansatz, soll die Entwicklung und (kommerzielle) Implementierung von Innovationsvorhaben basierend auf „internen und externen“ Ideen ermöglichen und damit eine marktreife gewährleisten. Dies bedeutet, dass Kundinnen und Kunden sowie externe Partnerinnen und Partner „in die Innovationsphasen der Ideenfindung und Entwicklung sowie teilweise in die Vermarktung mit einbezogen und integriert“ werden. (Pohl & Engel, 2020)

Im Reallabore-Kontext, ist festzuhalten, dass verschiedene Ansätze, wie beispielsweise die transdisziplinäre Forschung, Nachhaltigkeitsforschung und Transformationsforschung zur Anwendung kommen. Dies bietet ein Methodenset mit innovativen Möglichkeiten für die (mobilitäts)planerische Prozessentwicklung und Maßnahmenimplementierung. „Als ‚Reallabor‘ bezeichnet man eine transdisziplinäre Forschungseinrichtung, um in einem räumlich abgegrenzten gesellschaftlichen Kontext Nachhaltigkeitsexperimente durchzuführen, um Transformationsprozesse anzustoßen und um entsprechende wissenschaftliche wie gesellschaftliche Lernprozesse zu verstetigen“ (KIT – Institut für Technikfolgenabschätzung und Systemanalyse, 2016). Um das volle Potenzial dieses Forschungs- und Praxisformats auszuschöpfen, sind sieben Charakteristika für eine praxisorientierte Durchführung zu beachten: Forschungsorien¬tierung, normative Orientierung an Nachhal¬tigkeit, Transdisziplinarität, Transformativität, zivilgesellschaftliche Orientierung, Langfris¬tigkeit und Laborcharakter. (ebd.)

Die Reallaborforschung versteht sich als iterativer Lernprozess im Wechselspiel von Forschung und Praxis, wobei dies durch folgende Elemente gekennzeichnet ist (ebd.):

- Förderung einer nachhaltigen Raum- und Mobilitätsentwicklung
- Generierung von Wissen durch gemischte Teams aus regionalen Praxisakteurinnen, Praxisakteuren, Wissenschaftlerinnen und Wissenschaftlern: Reallabore als Orte des Austauschs und der Bildung
- Integration der Charakteristika von Forschungs-, Governance- und Planungsprozessen: transdisziplinäre Betrachtung der Perspektiven aus Forschung und Praxis
- Ort der Reflexion und Co-Produktion von Wissen und Maßnahmen
- Weist die Programmatik eines langfristigen Partizipationsprozesses auf
- Partizipationskontinuum: Wechselspiel diverser partizipativer Formate: Verbindung mehrerer Beteiligungsstufen im Arbeitsprozess
- Der Fokus liegt auf einen langfristig ausgelegten und mehrdimensionalen Transformationsprozess, auf Basis von Handlungs- und Transformationswissen
- Entwicklungsfortschritte begleiten, bewerten und weiterentwickeln (Monitoring)

3 MOBILITÄT UND DER LÄNDLICHE RAUM

3.1 Klassifikation „ländlicher Raum“

Der Begriff des ländlichen Raums und seine Definition stellen sowohl Forschung als auch Praxis vor komplexe Herausforderungen. Während traditionelle Ansätze den ländlichen Raum hauptsächlich in Abgrenzung zu städtischen Gebieten definieren, setzen sich neuere Konzepte für ein differenzierteres Verständnis ein, das ein Kontinuum zwischen urbanen und ruralen Gebieten beschreibt. Die Klassifizierung erfolgt dabei anhand verschiedener siedlungsstruktureller und sozioökonomischer Merkmale, wobei die Vielfalt ländlicher Räume zunehmend in den Fokus rückt. Besonders problematisch erweist sich dabei die häufig defizitorientierte Betrachtungsweise ländlicher Räume, die diese vorrangig als "strukturschwach" charakterisiert. Diese Perspektive vernachlässigt jedoch die spezifischen Potenziale und Besonderheiten ländlicher Regionen. Zentrale Herausforderungen liegen in der territorialen Ungleichheit, der Gefahr der Abkopplung von Agglomerationsräumen sowie Problemen wie Abwanderung und mangelnden Teilhabemöglichkeiten. Die Forschung steht vor der Aufgabe, Ansätze zu entwickeln, die über simple Stadt-Land-Vergleiche hinausgehen und die lokalen Besonderheiten und Lebenswelten der ländlichen Bevölkerung adäquat erfassen (Kühn et al., 2023).

Ein zeitgemäßes Verständnis des ländlichen Raums erfordert daher einen differenzierteren Blick, der die spezifischen Qualitäten und Entwicklungspotenziale ländlicher Regionen in den Vordergrund stellt, anstatt sie lediglich als Gegenpol zu städtischen Räumen zu definieren (Barlösius & Neu 2007).

Die österreichische Urban-Rural-Typologie stellt ein erweitertes Klassifizierungssystem zur internationalen OECD/EU-Methodik dar, das speziell auf österreichische Verhältnisse ausgerichtet ist. Basierend auf einer 1km² Rasteranalyse unterscheidet sie vier Hauptkategorien: Stadtregionen, Regionale Zentren, Ländlicher Raum im Umland von Zentren und Ländlicher Raum. Die Klassifizierung erfolgt anhand eines "Bevölkerungspotentials", das neben der Wohnbevölkerung auch Nebenwohnsitze und Tagesbevölkerung berücksichtigt. Zusätzlich werden die Gemeinden nach ihrer Erreichbarkeit in zentral, intermediär und peripher eingestuft und können mit einem Zusatzkriterium "Tourismus" gekennzeichnet werden. Diese differenzierte Methodik ermöglicht eine präzisere Darstellung der Vielfalt des ländlichen Raums und dient als einheitliche, regelmäßig aktualisierte Grundlage für raumrelevante Analysen in Österreich (STATISTIK AUSTRIA, 2021). Allerdings weist diese Form der Klassifizierung auch potenzielle Schwächen auf: Die stark quantitative Ausrichtung anhand von Bevölkerungsanteilen könnte wichtige qualitative Aspekte der Regionen übersehen. Auch die festgelegten Grenzwerte von 50 % und 80 % könnten zu einer vereinfachten Kategorisierung führen, die der komplexen Realität der Übergangsformen zwischen städtischen und ländlichen Räumen nicht vollständig gerecht wird.

3.2 Mobilitätsbedürfnisse im ländlichen Raum

Die Mobilität im ländlichen Raum ist durch besondere Herausforderungen geprägt, die sich aus der räumlichen Struktur und den damit verbundenen Lebensbedingungen ergeben. Grundlegend ist die Notwendigkeit, größere Entfernungen zu überwinden, da das Angebot an Arbeitsplätzen sowie die

Erreichbarkeit von Gütern und Diensten der Daseinsvorsorge deutlich schlechter sind als im urbanen Raum (ÖROK 2006: 74ff). Dies führt zu einer starken Abhängigkeit vom motorisierten Individualverkehr, was sich in überdurchschnittlich hohen Motorisierungsraten widerspiegelt. Das Waldviertel weist laut VCÖ den höchsten Motorisierungsgrad in ganz Österreich auf (Stand 2023). Die Bezirke Waidhofen an der Thaya mit 767 PKW pro 1.000 Einwohnerinnen und Einwohner, Zwettl (741), Horn und Gmünd (je 727) belegen die ersten vier Plätze im österreichweiten Vergleich und verzeichneten dabei alle einen Anstieg gegenüber 2022. Diese Zahlen liegen deutlich über dem Bundesdurchschnitt von 566 PKW pro 1.000 Einwohnerinnen und Einwohnern (VCÖ, 2024).

Die Beweglichkeit, die das Auto verspricht und in der Regel auch leistet, ist dabei zu einem unverzichtbaren Aspekt der Lebensqualität im ländlichen Raum geworden. Gleichzeitig sind etwa 15-20 % der Bevölkerung zeitweise oder dauerhaft nicht motorisiert und damit auf Alternativen angewiesen (Tamme, 2013). Dies betrifft insbesondere Jugendliche, ältere Menschen und Personen mit Mobilitätseinschränkungen. Das öffentliche Verkehrsangebot kann diese Bedürfnisse jedoch oft nicht ausreichend erfüllen, da es sich vielerorts auf den Schülerinnen- und Schülerverkehr beschränkt. Die disperse Siedlungsstruktur und geringe Bevölkerungsdichte machen dabei eine flächendeckende und wirtschaftliche ÖV-Versorgung besonders herausfordernd – der Kostendeckungsgrad liegt im ländlichen Raum bei nur 15-20 %. Dies führt zu einer „Mobilitätsfalle“ für nicht-motorisierte Bevölkerungsgruppen, die für die Befriedigung ihrer grundlegenden Mobilitätsbedürfnisse auf externe Hilfe wie Mitfahrgelegenheiten im Familien- und Freundeskreis angewiesen sind. Die Situation wird zusätzlich verschärft durch die fortschreitende Ausdünnung der Versorgungsinfrastruktur im ländlichen Raum, wodurch sich Wege weiter verlängern und die Abhängigkeit vom Auto noch verstärkt wird (Tamme, 2013).

Gleichzeitig haben sich verstärkte Veränderungen im Arbeitsalltag durch die Möglichkeit mobilen Arbeitens ergeben.

4 LAND.MOBIL:LAB MOBILITÄTSLABOR FÜR DEN LÄNDLICHEN RAUM

4.1 Das Waldviertel (NÖ) als Fokusregion für ländliche Mobilitätskultur

Das Waldviertel liegt im nordwestlichen Gebiet Niederösterreichs, grenzt im Norden an Tschechien und ist hinsichtlich der Siedlungs- und Mobilitätsstruktur als „ländlich“ zu definieren. Abb. 1 zeigt die Einordnung der Gemeinden in die Urban-Rural-Typologie der Statistik Austria. Es fällt auf, dass der überwiegende Teil der Kommunen ausschließlich dem ländlichen Raum zuzuordnen ist, während fünf Gemeinden als intermediäre regionale Zentren eingestuft werden, welche hinsichtlich der Daseinsvorsorge wichtige Funktionen für die Region erfüllen.

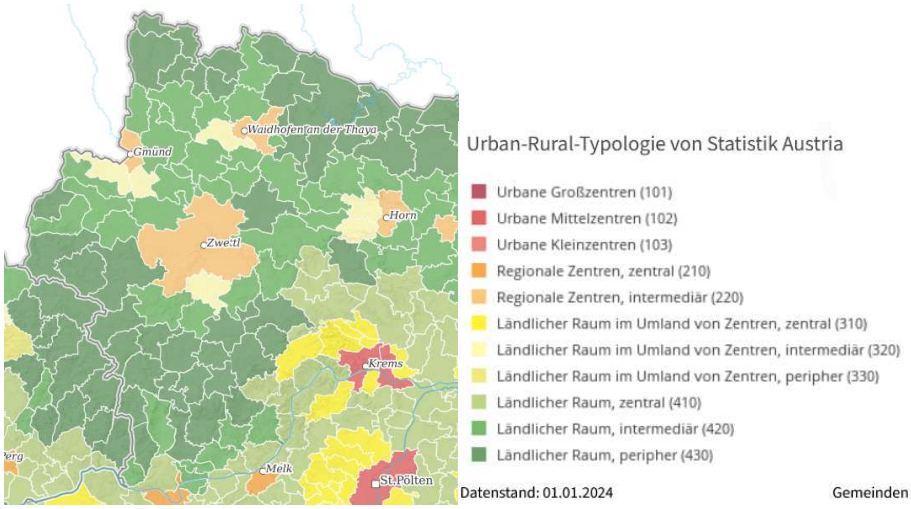

Abb. 1: STATatlas Urban-Rural-Typologie österreichischer Gemeinden (STATISTIK AUSTRIA, 2024b)

Auf der Ebene von Gebietskörperschaften kann die Fokusregion des Mobilitätslabors durch die Bezirke Gmünd, Waidhofen a. d. Thaya, Horn, Zwettl, sowie Teile der Bezirke Melk und Krems (Land) abgegrenzt werden, da die Donau die physische Grenze zum Übergang ins Mostviertel bildet, wie der Karte in Abb. 2 zu

entnehmen ist. Im Betrachtungsraum sind 121 Gemeinden mit einer Gesamtfläche von rund 4.878 km² und ca. 232.000 Einwohnerinnen und Einwohner zu verorten (STATISTIK AUSTRIA, 2024a).

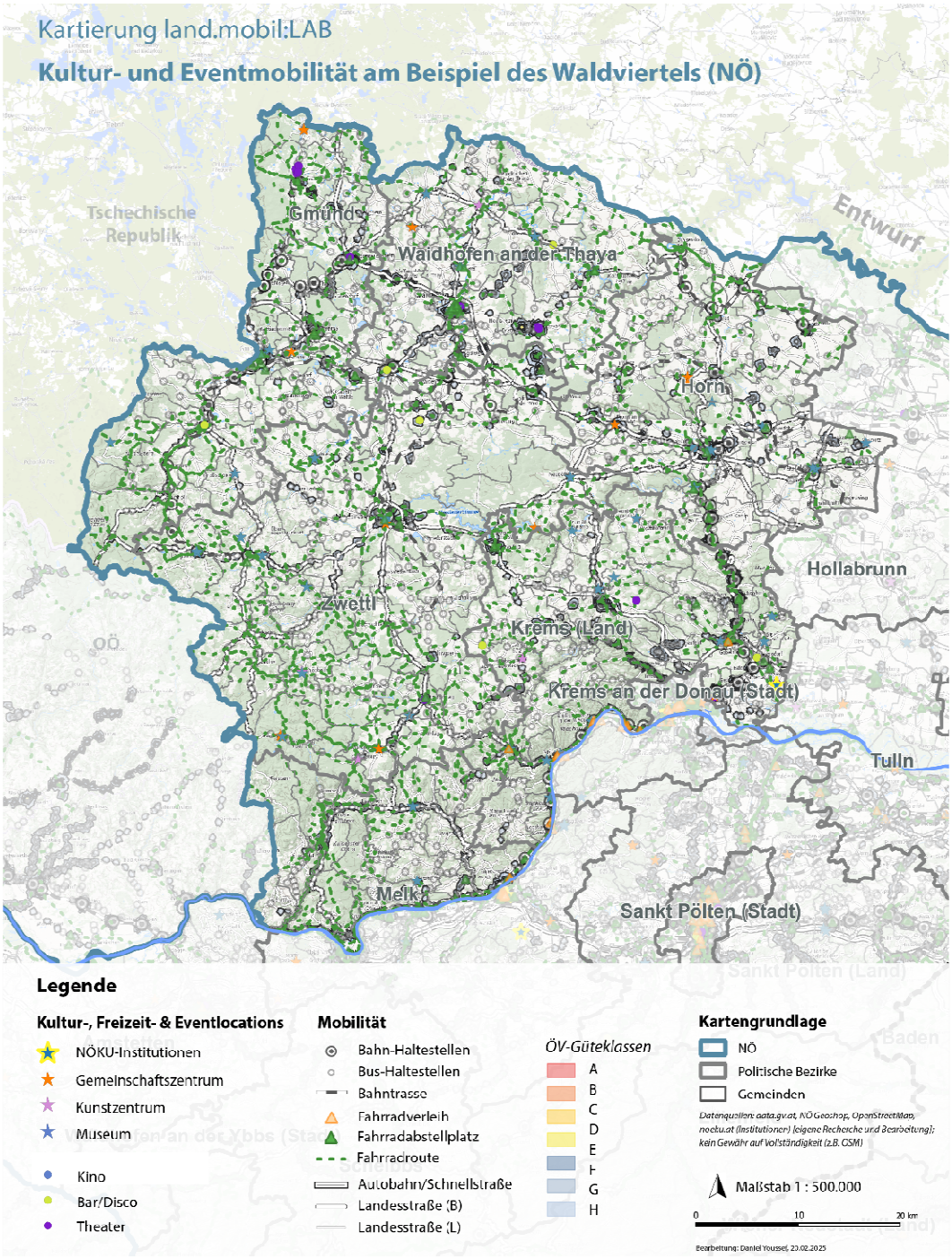

Abb. 2: Kartierung land.mobil:LAB, Ebene Kultur- und Eventmobilität (eigene Darstellung)

Wie Abb. 3 zeigt, leben österreichweit 41,4% der Bevölkerung in Gemeinden, die als „ländlich“ eingestuft werden (STATISTIK AUSTRIA, 2021). Für die Erkenntnisse, die mit Unterstützung des Mobilitätslabors in der Fokusregion Waldviertel gewonnen werden, wird von einer Transferierbarkeit in andere ländliche Regionen ausgegangen, die vor ähnlichen Herausforderungen stehen, d.h. strukturähnliche Räume. Dazu zählen auch die als zentral eingestuften, ländlich geprägten Gemeinden.

4.2 Forschungsinfrastruktur des Mobilitätslabors

Das land.mobil:LAB bietet auf die Projektlaufzeit von fünf Jahren befristet sowohl kostenlose Beratungs- und Unterstützungsangebote als auch kostenpflichtige Forschungsinfrastruktur an, mittels derer die Umsetzung von mobilitätsbezogenen Innovationsvorhaben mit Pilotcharakter durch Dritte ermöglicht bzw. vereinfacht und so die Mobilitätswende im ländlichen Raum vorangebracht werden soll. Die Bandbreite

reicht von Erhebungs- und Analysemethoden sowie Vermittlungsformaten über ein laufend um die Ergebnisse abgeschlossener Innovationsvorhaben erweitertes Angebot an Mobilitätsdaten und -informationen bis hin zur Unterstützung bei der Projektanbahnung und Konsortialbildung für die Umsetzung von Innovationsvorhaben.

Klasse	Bezeichnung	intermediär	peripher	ländlich	Wohnbevölkerung (1.1.2021)
220	Regionale Zentren, intermediär	●	○	○	188 050
310	Ländlicher Raum im Umland von Zentren, zentral	○	○	●	1 224 817
320	Ländlicher Raum im Umland von Zentren, intermediär	●	○	●	72 213
330	Ländlicher Raum im Umland von Zentren, peripher	○	●	●	52 136
410	Ländlicher Raum, zentral	○	○	●	1 374 955
420	Ländlicher Raum, intermediär	●	○	●	444 581
430	Ländlicher Raum, peripher	○	●	●	532 155

	intermediär	peripher	ländlich	Summe
Summe Wohnbevölkerung (1.1.2021)	704 844	584 291	3 700 857	3 888 907
Anteil Wohnbevölkerung (1.1.2021)	7,9%	6,5%	41,4%	43,5%

Abb. 3: Bevölkerung 2021 nach Urban-Rural-Typologie (eigene Darstellung, Daten: Statistik Austria)

Das Mobilitätslabor ist eine offene Plattform und richtet sich entsprechend an alle Akteurinnen und Akteure, die Interesse an der aktiven Ausgestaltung des Mobilitätsangebots in der Fokusregion Waldviertel haben. In Anbetracht des hohen Selbstorganisationspotenzials ländlicher Mobilitätsnachfragerinnen und Mobilitätsnachfrager, das aus dem stark regional differenzierten öffentlichen Verkehrsangebot und den räumlich bedingt teilweise weiten Pendeldistanzen resultiert, greift das land.mobil:LAB sowohl Top-down- als auch Bottom-up-Ansätze auf, überträgt sie in neue Kontexte (z.B. Kulturevents) und evaluiert sie. Top-down organisierte Mobilität umfasst die von einer Gebietskörperschaft administrierten Mobilitätsangebote, allen voran dem für öffentlichen Personenregionalverkehr verantwortlichen Land Niederösterreich, aber auch von Gemeinden und Gemeindeverbänden, die lokal angepasste Mobilitätslösungen betreiben. Bottom-up organisierte Mobilität bezieht sich auf Initiativen von Privatpersonen, Vereinen oder Unternehmen, die zum Ergänzen des öffentlichen Mobilitätsangebots respektive Füllen wahrgenommener Angebotslücken dienen, wie etwa Nachbarschaftsautos bzw. vereinsbasiertes Autoteilen (Peer-to-peer-Carsharing), Mitfahrbörsen oder betriebliches Mobilitätsmanagement. Die TU Wien als Betreiberin des Mobilitätslabors hat zudem Interesse an der Verbesserung der Forschungslage zur ländlichen Mobilität und bringt dementsprechend auch inhaltliche Schwerpunkte zum Anstoßen von Innovationsvorhaben in das LAB ein. Die Gesamtheit der beteiligten bzw. eingebundenen Akteurinnen und Akteure zählt zur sogenannten LAB-Community.

Aufgrund der heterogenen Mobilitätsbedürfnisse der im ländlichen Raum mobilen Akteurinnen und Akteure wurde zur inhaltlichen Strukturierung der vom land.mobil:LAB unterstützten Innovationsvorhaben eine Perspektivenansatz gewählt. Dadurch soll der Spagat zwischen der thematischen Spezifität des Mobilitätslabors in Abgrenzung zu vergleichbaren Infrastrukturen bei gleichzeitiger Berücksichtigung der enormen Breite an lokal relevanten Herausforderungen gelingen. Die Perspektiven (siehe Abb. 4) beinhalten erfassbare und kommunizierbare Vorgaben, gleichzeitig wird ihre inhaltliche Ausgestaltung nicht vorweggenommen, sondern punktuell in den Prozess integriert. Eine Auswahl an Fokusfeldern wurde im Zuge der Sondierung gemeinsam mit Stakeholdern identifiziert und priorisiert:

- Die Perspektive Mobilitätsmodus umfasst unter anderem flexible ÖV-Angebote (regionaler Bedarfsverkehr), sowie bewegungsaktive Mobilität und Mitfahrnetzwerke.
- Bei der Perspektive der Mobilitätszwecke steht Mobilität bei Kulturveranstaltungen sowie Alltags- und Freizeitmobilität im Fokus.
- Im Bereich der Akteurinnen und Akteure werden verstärkt (potenzielle) Mobilitätsdienstleister (Wohnbauträger, Mobilitätsvereine), sowie Infrastrukturbetriebe (Tankstellen, Autohäuser) betrachtet.

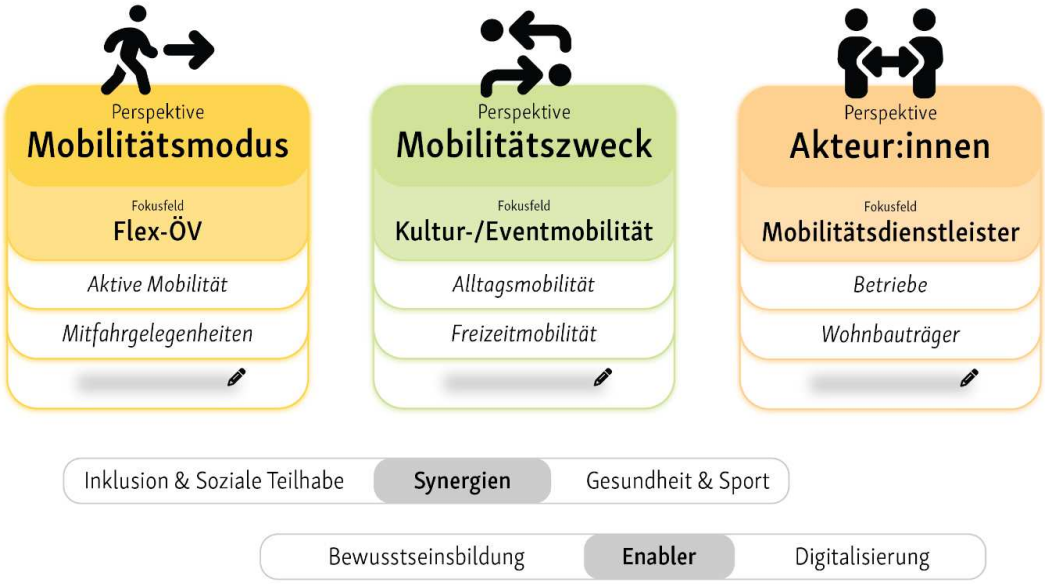

Abb. 4: Innovationsperspektiven land.mobil:LAB (eigene Darstellung)

Bei der Umsetzung von Innovationsvorhaben setzt das Mobilitätslabor auf Synergien mit sozialer Teilhabe und öffentlicher Gesundheit, die beide in engem Verhältnis zum Mobilsein der Bevölkerung stehen. Darüber hinaus sind Bewusstseinsbildung sowie Digitalisierung treibende Kräfte für die erfolgreiche Gestaltung und Durchführung von Innovationsvorhaben.

Das Mobilitätslabor versteht sich vor diesem Hintergrund als forschungsinfrastrukturelles Angebot entlang dreier Säulen:

- Beschleuniger der Mobilitätswende im ländlichen Raum durch das Angebot an Strukturleistungen
- Nährboden für innovative Mobilitätslösungen durch die Begleitung von Innovationsvorhaben
- Multiplikator der Ideen und Erkenntnisse infolge der Anwendung von Kommunikations- und Partizipationsformaten

4.3 Methoden

Im Zuge des Kapazitätsaufbaus und in weiterer Folge zum Zwecke der Erweiterung des Angebotsportfolios im Mobilitätslabors werden Methoden entwickelt, mit denen die angebotenen Leistungen aus eigenen Stücken durchgeführt werden können. Dies betrifft insbesondere zwei Aspekte: einerseits den Bereich der Erhebung und Analyse, um spezifisches Mobilitätswissen sowie Daten über die Fokusregion zu generieren, und andererseits den Bereich der Vermittlung von Inhalten und Kompetenzen, sowohl in der Fokusregion als auch in strukturähnlichen Regionen im österreichischen und europäischen Kontext.

Ein gewählter Ansatz ist die Entwicklung von sogenannten „Personas“ oder „Protagonistinnen und Protagonisten“. Es handelt sich dabei um archetypische Mobilitätsnachfragerinnen und Mobilitätsnachfrager, denen auf Basis von Befragungen, Interviews oder vergleichbaren Untersuchungen ein Bündel an Eigenschaften, Bedürfnissen und Zielen zugeschrieben wird (Nielsen et al., 2013). Diese Eigenschaftsbündel sind im Unterschied zu einer rein an Durchschnittswerten orientierten Repräsentation der Gesamtheit an Mobilitätsnachfragerinnen und Mobilitätsnachfragern realistisch und werden daher insbesondere für die Entwicklung von zielgruppengerechten Mobilitätsangeboten im Rahmen des Mobilitätslabors für geeignet befunden. Durch die Evaluation der Akzeptanz von unter Einbeziehung von Personas entwickelten Angeboten lässt sich deren methodische Eignung in weiterer Folge überprüfen. Diese Vorgangsweise dient dazu, ein tiefgreifendes Verständnis für die vielfältigen Mobilitätsbedürfnisse der Menschen, die sich im ländlichen Raum fortbewegen, zu entwickeln und auf dessen Basis ein realistisches Bild der gegenwärtigen ländlichen Mobilitätskultur zu zeichnen.

Grundlage für die Entwicklung von Personas sind die bereits erwähnten empirischen Untersuchungen. Diesbezüglich ist im land.mobil:LAB die Durchführung von Mobilitätserhebungen und darauf aufbauend die Einrichtung eines Mobilitätspanels in der Fokusregion geplant. Panelerhebungen sind eine Methode zur

Untersuchung von Veränderungen durch die wiederholte Erhebung von Daten aus derselben Stichprobe, um etwa Veränderungen im Mobilitätsverhalten über die Zeit nachvollziehen zu können und Rückschlüsse auf den Einfluss von Veränderungen der Lebenssituation oder bestimmten Lebensereignissen auf Mobilitätspräferenzen kausal erklären zu können (Bäumer & Forschungsgesellschaft für Straßen- und Verkehrswesen, 2012).

4.4 Zeitplan

Das Mobilitätslabor ist auf einen Zeitraum von fünf Jahren angelegt (siehe Abb. 5). Auf eine sechsmonatige Aufbauphase folgen drei Arbeitsphasen zu je 18 Monaten. Durch strategische Planungsmethoden (Backcasting) werden Ziele für die bevorstehende Phase gesteckt. Im Zuge einer Retrospektive werden Lessons Learned abgeleitet.

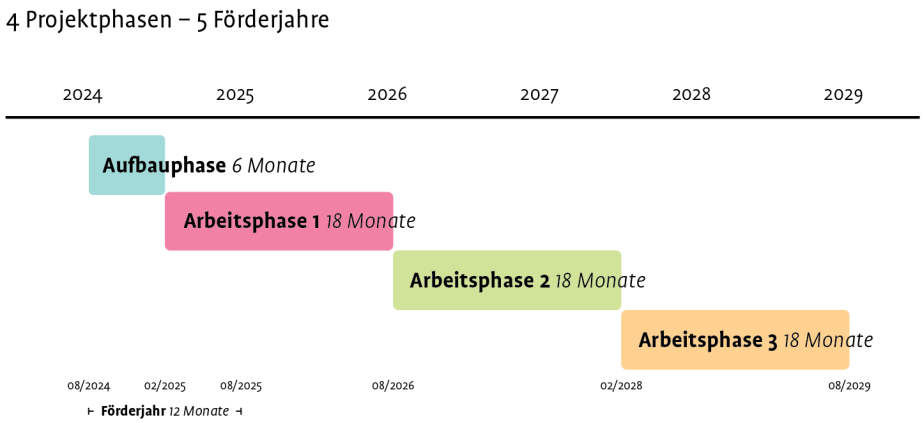

Abb. 5: Zeitplan land.mobil:LAB (eigene Darstellung)

Diese agile Vorgangsweise erlaubt es dem Mobilitätslabor, bei einer Projektlaufzeit von 60 Monaten, trotz veränderlicher Rahmenbedingungen und unwägbarer technologischer Fortschritte handlungsfähig zu bleiben, adaptiv (re-)agieren zu können, im Hinblick auf Innovationsvorhaben, aber auch auf strategischer Ebene. Das Mobilitätslabor befindet sich aktuell unmittelbar vor Beginn der ersten Arbeitsphase.

4.5 Erste Erkenntnisse und Ausblick

In der vorangegangenen Fallstudie „KulturMobil“ (Grinzinger et al. 2024) wurden zentrale Handlungsfelder identifiziert, die im Mobilitätslabor in der Innovationsperspektive Mobilitätszwecke im Fokusfeld Kultur- und Eventmobilität aufgegriffen werden. Im Bereich der Freizeitmobilität zeigt sich ein besonderes Potenzial für Verhaltensänderungen, da Menschen in ihrer Freizeit offener für alternative Mobilitätsformen als im Alltag sind (Sodl-Niederecker et al., 2022). In der Studie wurden exemplarisch für vier Veranstaltungsorte bzw. -formate in Niederösterreich die folgenden Aspekte erhoben: (1) Räumliche Einbettung des Standortes, (2) Verkehrliche Anbindung des Standortes, (3) Veranstaltungsformate, (4) Zielgruppen und (5) Informationsformate und -kanäle. Zu den identifizierten Handlungsfeldern, die im land.mobil:LAB aufgegriffen werden sollen, zählt die Integration von Kultur- und Veranstaltungsmobilität in die ÖV-Planung, die Entwicklung von Mitfahrangeboten zu Kulturveranstaltungen und die Verbesserung der zielgruppenspezifischen Kommunikation von Mobilitätsangeboten. Dass Besucherinnen und Besucher teilweise nicht über das vorhandene Mobilitätsangebot Bescheid wissen trägt unter anderem dazu bei, dass diese geringer ausgelastet sind und damit eine geringere Wirtschaftlichkeit aufweisen. Auf die als „Abmilderungseffekt“ (Betsch und Haberstroh 2005, nach Konrad & Scholl 2009) bezeichnete verringerte Berücksichtigung von Informationen, die den eigenen Handlungsroutinen wie der Verkehrsmittelwahl entgegenstehen, gilt es aus verschiedenen Perspektiven einzuwirken. Besonders vielversprechend erscheint darüber hinaus die Verknüpfung von Kulturangeboten mit bestehenden innovativen Mobilitätslösungen wie dem Schnupperticket (KlimaTicket, das kostenlos bei der Gemeinde ausgeliehen werden kann), aber auch die Ergänzung der NÖ-Card (Vergünstigungskarte für Ausflugsziele in Niederösterreich) um zusätzliche Mobilitätsangebote.

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reviewed paper

Levee Effect and Urban Development under Climate Change: Land-Use Strategies for Managing Residual Flood Risk in Taiwan

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1 ABSTRACT

Urban flooding has become an increasingly severe challenge due to rapid urbanization and climate change, particularly in regions like Taiwan. The combination of steep rivers, mountainous terrain, and frequent typhoons heightens the risk of flooding. Traditional flood control measures, such as levees and drainage systems, have provided protection, but they have also led to unintended consequences. One notable consequence is the Levee Effect, where flood protection infrastructure encourages urban expansion into flood-prone areas, ultimately increasing long-term exposure to extreme flood events.This issue underscores the importance of addressing Residual Flood Risk, which remains even with existing flood control measures, especially regarding land-use dynamics.In this study, we integrated CA-Markov and SOBEK 1D-2D models to evaluate land-use changes and flood risk under different levee heights (6 meters and 10 meters) in Wugu District, Taiwan. Preliminary results indicate that land-use change is closely linked to flood inundation. While flood protection measures reduce inundation areas, urban expansion driven by these measures can still lead to increased flood risk under extreme rainfall events due to changes in land use patterns.In the event of a 650 mm rainfall over 24 hours, unrestricted development significantly raised flood risk and potential economic damages. Conversely, imposing development restrictions effectively reduced potential damages. These findings emphasize the necessity of land-use controls in managing residual flood risk.While levees can lessen flooding under typical conditions, they also promote land development that increases vulnerability to extreme events.This study highlights the need for a hybrid flood risk management strategy that balances structural defences with spatial planning and adaptive policies to improve climate resilience and support sustainable urban development.

Keywords: levee effect, residual flood risk, land use management, CA-Markov, SOBEK model

2 INTRODUCTION

Urban flooding has become a significant challenge in the 21st century, primarily driven by rapid urbanization and climate change (Merz et al., 2021; O'Donnell & Thorne, 2020). Taiwan, characterized by steep rivers, mountainous terrain, and frequent typhoons, is particularly vulnerable to flood disasters. Traditionally, flood risk management has relied on structural interventions such as levees, embankments, and drainage systems (L. Wang et al., 2022). However, the increase of impervious surfaces due to urbanization has worsened stormwater runoff, while climate change has intensified extreme precipitation events, often surpassing existing flood protection standards (Davenport et al., 2021; Li et al., 2024). These factors highlight the limitations of conventional flood control methods in addressing evolving flood risks (Butcher et al., 2023; Kim et al., 2023).

Additionally, the paradoxical relationship between land development and flood risk, known as the Levee Effect, poses a major challenge in flood-prone areas (Fusinato et al., 2024; White, 1958). Research indicates that flood control infrastructure can create a false sense of security, leading to accelerated urban expansion in floodplains and increased exposure to flood hazards (Di Baldassarre et al., 2018; White et al., 2001). When rainfall exceeds the protection threshold, the consequences can be devastating, resulting in significant socioeconomic losses (D'Angelo et al., 2020; Ferdous et al., 2019; Ludy & Kondolf, 2012). This Levee Effect perpetuates a cycle in which flood protection measures encourage more land development, inadvertently increasing long-term flood risk (Ding et al., 2023; Ferdous et al., 2019).

As illustrated in Fig. 1, this cyclecan be worsened by climate change and urban expansion. The figure shows that flood protection standards reduce damage within their design thresholds, but residual flood risk persists when rainfall exceeds these standards (Roberto et al., 2015). Moreover, changes in land use after the construction of flood defences can significantly elevate flood exposure and potential damage (Breen et al.,

2024).Unregulated urban development, coupled with intensifying precipitation, can create a dangerous feedback loop in which rising flood risks necessitate additional structural interventions, ultimately exacerbating long-term vulnerabilities.

In light of these challenges, recent discussions in flood risk management have underscored the importance of Residual Flood Risk – the risk that remains despite protective measures (Serra-Llobet et al., 2022). Existing studies have primarily focused on rainfall events that exceed design standards, often overlooking the impact of post-construction land-use changes that further increase flood risks. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) emphasizes the need to integrate both structural and non-structural flood mitigation strategies, particularly focusing on spatial planning as a means to manage flood risks effectively.

Given these considerations, this study aimed to explore how spatial planning and land-use management strategies can effectively mitigate residual flood risk in rapidly urbanizing flood-prone regions. To achieve this, we employed the CA-Markov model to simulate future land-use scenarios and analyze the impact of urban development on flood exposure. The study incorporated flood inundation models to assess changes in flood risk before and after levee heightening. Additionally, we evaluated the effectiveness of various land-use management strategies, including floodplain zoning, low-impact development (LID) measures, and green infrastructure, underclimate change-induced extreme precipitation scenarios. Through flood risk assessment with the estimated direct flood damage, this research aimed to establish a framework that balances urban development with effective flood risk management, ultimately contributing to resilient urban planning in the face of climate change. This study provided empirical insights into the interaction between land-use policies and flood risk dynamics, offering valuable guidance for policymakers in developing adaptive, risk-informed spatial planning strategies.

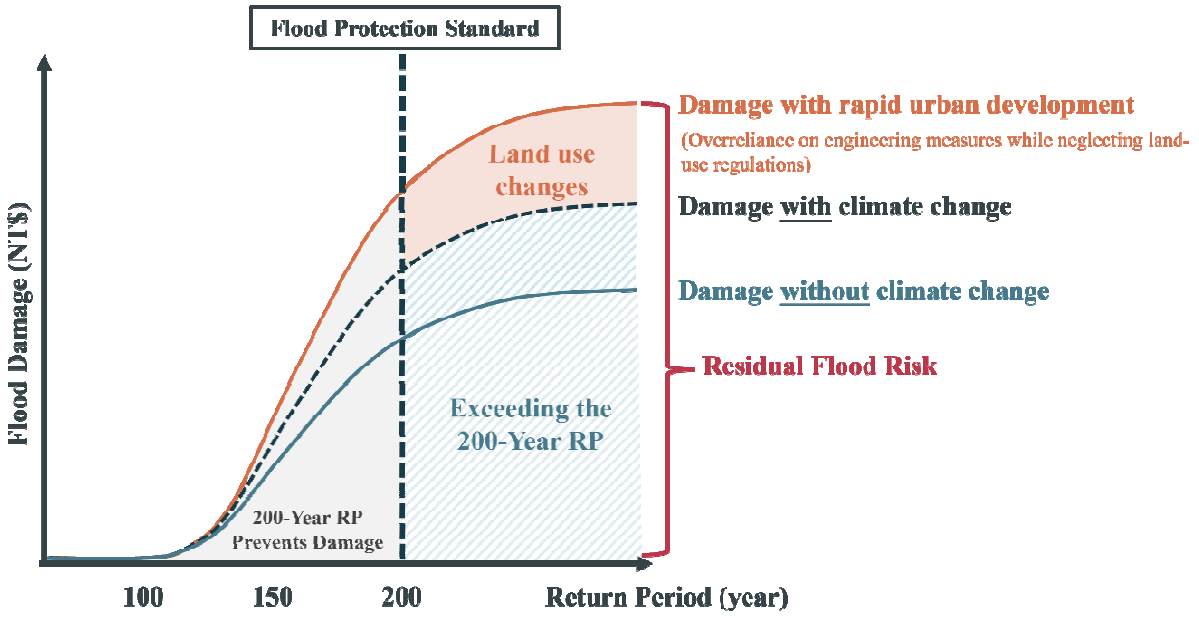

Fig. 1: Impacts of Land Use Changes and Climate Change on Residual Flood Risk Beyond Structural Protection Measures. Modified from Tanoue et al. (2021)

3 METHODOLOGY

3.1 Research Framework

This study combined flood risk management with urban development planning by analyzing the effects of flood inundation and structural flood control measures on land-use changes. The research framework consisted of four main phases: (1) simulating land-use changes using the CA-Markov model, (2) modeling floods with the SOBEK 1D-2D coupled model, (3) developing land-use management strategies for different scenarios, and (4) assessing flood risk through direct flood damage analysis.This integrated approach allowed for a comprehensive evaluation of residual flood risk and the effectiveness of land-use strategies in reducing flood risk.The first phase utilized the CA-Markov model to simulate land-use changes under 6M and 10M levee conditions, incorporating flood inundation data as a key driver. The second phase applied the

SOBEK 1D-2D model to simulate flood inundation across various return periods (10, 25, 50, 100, and 200 years) for both 6M and 10M levees.The third phase assessed land-use management strategies for residual flood risk mitigation, examining six scenarios: business-as-usual (BAU), flood risk regulations, Low-Impact Development (LID), Green Infrastructure (GI), and integrated strategies. The final phase conducted a flood risk assessment, estimating flood direct economic losses across residential, commercial, industrial, and agricultural areas.This study aimed to explore the impact of land-use management strategies on residual flood risk in the context of the levee effect and climate change.

3.2 Study Area

This study focusedon Wugu District in New Taipei City, Taiwan, as shown in Fig. 2. Its low-lying terrain and poor drainage make it highly susceptible to flooding during typhoons and heavy rainfall. Currently, the levee height is 6 meters, protecting for a 20-year return period, which is inadequate for extreme hydrological events. Plans are in place to raise the levee to 10 feet (3.05 meters) to meet the 200-year return period standard, aligning with the Greater Taipei Flood Control Plan. Land use in Wugu is regulated by the Tamsui River Floodplain Control Regulations, requiring municipal approval for construction and modifications. Future development will focus on the Wugu New Town Comprehensive Development Plan to enhance land value and urban growth. This study assessed how the levee height enhancement impacts land use and flood risk under various management scenarios, providing insights for improved flood control strategies and sustainable urban planning in Wugu.

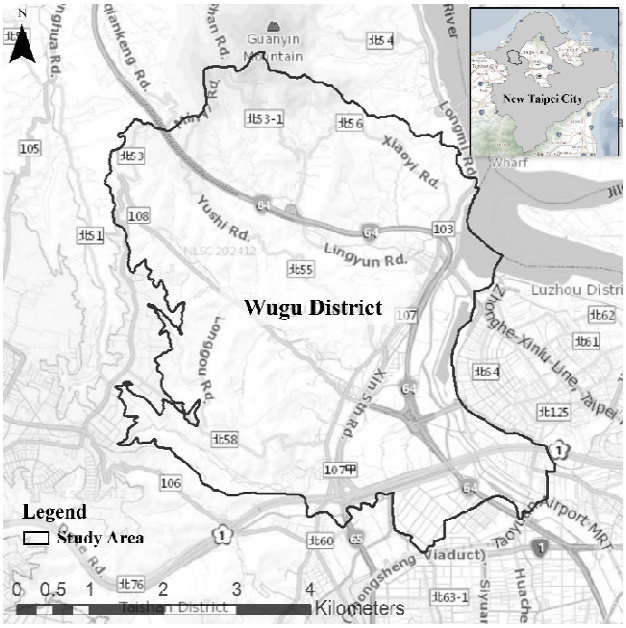

Fig. 2: Location of study area.

3.3 Land Use Change Simulation with CA-Markov Model

3.3.1 Overview of CA-Markov model

This study aimed to examine the relationship between changes in flood inundation areas and future land use transitions after the implementation ofstructural flood control measures. We used the CA-Markov model, which integrates the Markov Chain（MC） model and the Cellular Automata (CA) model, to stimulate future landuse changes. This model has been widely applied and validated in urban growth modeling and landuse change analysis for its accurate and realistic results (Chakraborty et al., 2022; Tan et al., 2024). The MC model estimates land use transition probabilitiesbased on historical trends, generating a Transition Probability Matrix to predict the likelihood of land conversion between different land use categories in the target year (S. Wang & Zheng, 2023). However, the MC model only qualifies changes between land use types and does not account for spatial variations (Moghadam & Helbich, 2013). Given this, the CA model, which has been widely applied in Spatially Explicit Models (SEMs) to capture the dynamics of geographical phenomenasuch as land use changes (Tong & Feng, 2020), was combined with the MC model. The CA modeloperates on a cell-based structure,where each cell's future state is determined by neighborhood effects

and a local transfer function based on the current state of adjacent cells (Al-sharif & Pradhan, 2014; Chakraborty et al., 2022; Liu & Feng, 2012). Additionally, this study built on the work of Lu et al., (2018) and Wang & Zheng (2023) by integrating Multi-Criteria Evaluation (MCE) to generate suitability maps for different land use types, incorporating key environmental and socioeconomic factors along with spatial constraints.We integrated the CA-Markov model with MCE to provide a comprehensive approach to land use simulation, incorporating flood inundation areas as a key factor in land use changes and urban development.

The structure of the CA-Markov model included four phases. In Phase 1, the MCmodel was first applied to calculate land use transition probabilities based on historical land use data. The 1995 and 2015 land use maps are classified and standardized into a grid-based format, forming the basis for computing the Transition Probability Matrix (TPM). In Phase 2, the study integrateddriving and constraint factors into a MCEframework to generate suitability maps that refine spatial land use allocation. First, a review of previous studies informs the selection of environmental and socioeconomic factors, which are standardized using fuzzy membership functions to ensure comparability across variables. Cramer's V correlation coefficient was then used to measure the association between each factor and land use transitions. The Weighted Linear Combination (WLC) method is applied to systematically determine factor weights, avoiding subjective assignments. The resulting MCE-WLC model produces suitability maps for all land use categories, guiding the spatial distribution of land use changes.In Phase 3, the CA-Markov model integrates transition probabilities from the MC model with suitability maps from MCE, allowing for spatially explicit land use simulation. To assess model accuracy, the study simulates the 2021 land use map and compares it with observed data. Kappa Index statistics (including Kstandard, Kno, Klocation, and KlocationStrata) are used to evaluate the model's agreement with real-world land use distributions. If the validation results demonstrate high consistency, the model proceeds to predict the 2035 land use scenario.

3.3.2 Data Collection and Preprocessing

The CA-Markov model required multiple datasets, including land use maps, driving factors, and constraint factors (e.g., Digital Terrain Model (DTM), population density, and flood inundation areas). In this study, we utilized 1995 and 2015 land use maps from the National Land Surveying and Mapping Center of Taiwan to simulate future land use changes, while the 2021 land use map was used to validate the projected 2021 land use scenario. The original land use maps contained approximately 50 land use categories, with classifications varying across different years. To ensure consistency in analysis, we reclassified the 1995, 2015, and 2021 LULC maps into 11 standardized categories: agricultural land, forest land, transportation land, water bodies, commercial land, residential land, industrial land, green space, recreational land, vacant land, and other land uses.Since the TerrSet model operates exclusively on raster data, all LULC maps were converted from vector to raster format, with a spatial resolution of 10 × 10 m grid cells. Additionally, most driving factors were derived from the 2015 LULC map, except for DTM, slope, land with slope greater than 30%, population density, and flood inundation areas, which were obtained from separate datasets. Notably, this study incorporated flood inundation maps under different rainfall scenarios, produced by the Water Resources Agency (MOEA) in Taiwan, as a crucial factor influencing future land use changes.

3.3.3 Markov Chain (MC) Model

TheMCmodel is a stochastic process model that describes the probability of a state transitioning into another (Jokar Arsanjani et al., 2013). In LULCanalysis, the MC model quantifies transition rates between different land use types and has been widely applied in spatial forecasting (Sang et al., 2011). Since the MC model assumes that future transitions depend solely on the current state, it is particularly effective in predicting LULC changes under stable policy conditions, where past trends provide a basis for estimating future transitions (Wang & Zheng, 2023).The model employs a transition probability matrix to determine the likelihood of one land use type changing into another over a specified period (Lu et al., 2018). However, as the MC model does not incorporate spatial distribution patterns, it is often integrated with the CA model to improve spatial accuracy and predictive performance (Aburas et al., 2016; Adnan et al., 2020).LULC changes within the MC framework are predicted using the following equation (Adnan et al., 2020; Sang et al., 2011):

$$S(t+1) = P_{ij} \times S(t) \quad (1)$$

where S (t)andS (t+1) represent the system status at time t andt+1, respectively; the transition probability matrixP_{ij} is defined as follow:

$$P_{ij} = \begin{bmatrix} P_{11} & P_{12} & \dots & P_{1n} \\ P_{21} & P_{22} & \dots & P_{2n} \\ \dots & \dots & \dots & \dots \\ P_{n1} & P_{n2} & \dots & P_{nn} \end{bmatrix} \quad (2)$$

$$\left(0 \leq P_{ij} < 1 \text{ and } \sum_{j=1}^{n} P_{ij} = 1, (i,j = 1,2,3,\dots n) \right)$$

where P_{ij} represents the likelihood of transitioning from status i to status j; n refers to the total number of land use categories.In this study, the transition probability matrix was derived from LULC changes observed between 1995 and 2015 to predict the 2021 LULC map for validation and the 2035 LULC map as the target projection.

3.3.4 Cellular Automata (CA) Model

The CAmodel is a cell-based simulation approach that captures spatiotemporal dynamics through local interactions, where each cell's future state is influenced by adjacent cell states and governed by predefined transition rules (Chakraborty et al., 2022; Lu et al., 2018). This model has been widely applied in land-use change and urban dynamics studies and has been integrated into various simulation tools, including CA-Markov in IDRISI, UrbanSim, and SLEUTH (Tong & Feng, 2020).The CA model consists of four key components, formally expressed as Eq. (3): lattice (L), state space (Q), neighborhood template (δ), and local transition function (f) (Adamatzky, 2018). When combined with the Markov Chain (MC) model, the CA-Markov model enables cells to transition independently based on neighbourhood transition rules and assigned transition probabilities, enhancing spatial continuity and predictive accuracy.

$$A = [L, Q, \delta, f] \quad (3)$$

3.3.5 Driving and constraint factors for land use changes

Land use changes are driven by a combination of environmental, socioeconomic, and policy-related factors (Dewan & Yamaguchi, 2009). The integration of Markov Chain (MC) and Cellular Automata (CA) models provides a robust framework for incorporating both environmental and socioeconomic variables, while simultaneously considering various spatial factors for simulating land use changes (Adnan et al., 2020). Environmental factors, such as topography and amenities, determine land suitability, with flat terrain facilitating development (Aburas et al., 2016). Socioeconomic factors, including population density and real estate values, are essential drivers of urban densification (Chakraborty et al., 2022). Similarly, built environment and infrastructure factors, such as accessibility to roads and highways, establish the connection between development causes (e.g., transportation networks) and their subsequent effects (e.g., urbanization) (Aburas et al., 2016).Furthermore, flood risk variability has been identified as a critical determinant of land use patterns, as areas subject to frequent flooding often undergo land use transitions. Research on the levee effect suggests that flood engineering structures can effectively reduce flood inundation areas, subsequently altering land development trends (Lu et al., 2018). Given this dynamic relationship, this study incorporates flood inundation areas as a key factor to examine the interactions between flood extent changes and land use transitions, thereby contributing to a better understanding of flood risk dynamics.

Cramer's V values were also employed to assess driving factors' significance and explanatory power in predicting future land use changes. A higher Cramer's V value signifies stronger explanatory strength, indicating that the corresponding variable plays a more substantial role in LULC change projections (Islam et

al., 2018; Sisay et al., 2023).This study selects driving and constraint factors based on previous literature and their relevance to land use change modeling within the CA-Markov framework. As shown in Table 1, the driving factors encompass environmental variables, including DTM, slope, proximity to rivers, and flood inundation areas, which influence land suitability based on physical geography and hydrological conditions. Socioeconomic and built factors include population density and proximity to public facilities, roads, residential, commercial, and industrial areas, reflecting the impact of accessibility and urban infrastructure on land use patterns.

For constraint factors, this study considers transportation land, forest land, water bodies, and areas with slopes greater than 30%, as these regions have limited transformation potential in real-world scenarios, thereby enhancing the accuracy of land use change modeling.To further explore the relationship between flood inundation areas and land use changes, this study initially utilizes flood inundation maps under four different rainfall scenarios, provided by the Water Resources Agency (MOEA), Taiwan. Subsequently, the SOBEK model is employed to simulate flooded areas under varying return periods, providing a more comprehensive understanding of flood impact on land use transitions.

Driving Factors		**Constraint Factors**
Environmental Factors	**Socioeconomic and Built Factors**	
DTM	Population density	Transportation land
Slope	Distance to public facilities	Forest land
Distance to river	Distance to roads	Water bodies
Flood inundation areas	Distance to residential areas	Land with a slope greater than 30%
N/A	Distance to commercial areas	N/A
N/A	Distance to industrial areas	N/A

Table 1: Driving factors (environmental, socioeconomic, and built) and constraint factors selected in the CA-Markov model

3.3.6 Fuzzy membership for driving factors and Boolean values for constraint factors

This study employed fuzzy membership functions and Boolean values to evaluate land suitability based on various driving and constraint factors. Constraint factors were assigned Boolean values (0 or 1) to restrict land use transitions, while driving factors were standardized using different fuzzy membership functions, including linear, sigmoidal, and J-shaped functions – based on their characteristics to assess the suitability of land use variations (Lu et al., 2018). The fuzzy membership function quantifies the degree to which a data point belongs to a fuzzy set, with values ranging from 0 to 1 or 0 to 255 (Bianchini et al., 2019).

As illustrated in Fig. 3, distance-related driving factors (e.g., proximity to roads and public facilities) were standardized using the Sigmoidal membership function with an S-shaped curve, where suitability monotonically decreases as distance increases. Conversely, non-distance-related driving factors (e.g., slope and population density) were standardized using the linear membership function with an S-shaped curve, where suitability gradually decreases as factor values increase.The selection of fuzzy membership functions for driving factors and Boolean values for constraint factors was informed by a comprehensive review of previous studies, as summarized in Table 2.

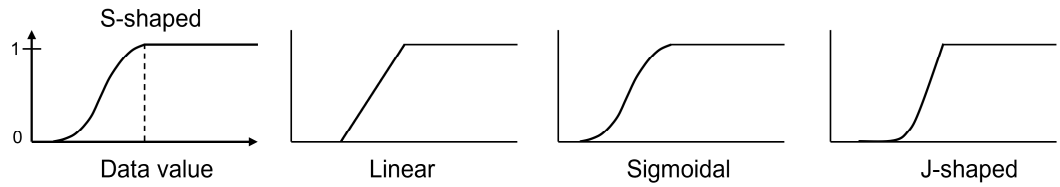

Fig. 3: Types of S-shaped Fuzzy Membership Functions: Linear, Sigmoidal, and J-shaped.Modified from (Bianchini et al., 2019)

3.3.7 Multi-Criteria Evaluation (MCE) for Suitability Maps

In the CA-Markov model,MCEintegrates multiple driving and constraint factors to generate suitability maps, which indicate the suitability of land use change for a specific land use category at each pixel. The suitability values range from 0 (no suitability) to 255 (highest suitability) for land use change (Lu et al., 2018).MCE encompasses three primary approaches: Weighted Linear Combination (WLC), Boolean Intersection, and Ordered Weighted Average. This study adopts WLC due to its flexibility and ability to incorporate various factors with weighted trade-offs (Eastman, 2015). Accordingly, MCE-WLC was applied to generate suitability maps for all land use types, where WLC is computed using Eq. (4) (Wang & Zheng, 2023):

Factors	Functions	Influence Distance (meter)
DTM	Linear (S-shaped)	N/A
Slope	Linear (S-shaped)	N/A
Distance to river	Sigmoidal (S-shaped)	150
Flood inundation areas	Linear (S-shaped)	N/A
Population density	Linear (S-shaped)	N/A
Distance to public facilities	Sigmoidal (S-shaped)	150
Distance to roads	Sigmoidal (S-shaped)	100
Distance to residential areas	Sigmoidal (S-shaped)	100
Distance to commercial areas	Sigmoidal (S-shaped)	100
Distance to industrial areas	Sigmoidal (S-shaped)	100
Transportation land	Boolean values (0 or 1)	N/A
Forest land	Boolean values (0 or 1)	N/A
Water bodies	Boolean values (0 or 1)	N/A
Land with a slope greater than 30%	Boolean values (0 or 1)	N/A

Table 2: Standardization of Driving and Constraint Factors Using Fuzzy Membership Functions and Boolean Values.

$$S = \sum w_i x_i \tag{4}$$

where S represents the suitability outcome, w_i denotes the weight assigned to factor i, and $x_i x_i$ is the standardized value of the respective parameter.Furthermore, unlike the Analytic Hierarchy Process (AHP), which relies on expert judgment and may introduce subjectivity, this study employs Cramer's V values to determine the weight of each driving factor in MCE-WLC. Cramer's V quantifies the statistical association between each factor and land use change, ensuring a data-driven and objective weighting approach.Finally, the suitability maps of all land use classes were integrated into theCAmodel to guide spatial allocation and regulate land use transitions, ensuring that changes occur in areas with higher suitability.

3.3.8 Model Calibration and Validation

To establish the scientific significance of the model in real-world applications and ensure its predictive accuracy, calibration and validation are essential processes (Chakraborty et al., 2022). The Kappa index is a widely used statistical measure for evaluating the agreement between observed and simulated land-use change maps, accounting for chance agreement. The Kappa value typically ranges from 0 to 1, where higher values indicate stronger agreement between predicted and actual data (Aburas et al., 2016; Mitsova et al., 2011; Tong & Feng, 2020). The Kappa coefficient is defined as follows (Pontius, 2000):

$$\text{Kappa} = \frac{(Po - Pc)}{(Pp - Pc)} \tag{5}$$

where Po represents the observed proportion of correctly classified data, Pc denotes the expected proportion of agreement by chance, and Pp corresponds to the proportion of perfect agreement.To refine classification accuracy assessments, Pontius (2000) introduced five extended Kappa indices: Kstandard, Khisto, Kquantity, Klocation, and Kno. Kstandard measures overall reliability, Khisto evaluates category distribution accuracy, Kquantity assesses quantity correctness, Klocation focuses on spatial accuracy, and Kno compares the model's predictive performance against a null model assuming random classification. Furthermore, Kappa values are categorized into five levels: 0.00–0.20 (slight agreement), 0.21–0.40 (fair agreement), 0.41–0.60 (moderate agreement), 0.61–0.80 (substantial agreement), and 0.81–1.00 (almost perfect agreement) (Gwet, 2014; Landis & Koch, 1977; Tong & Feng, 2020).In this study, the VALIDATE module in IDRISI was used to assess the agreement between the observed and simulated 2021 land-use maps, ensuring model calibration. Subsequently, the calibrated model was employed to predict land-use changes for 2035, allowing for an evaluation of the model's long-term predictive performance.

3.4 Flood Modeling with Sobek Model

This study employed the SOBEK model, developed by the Water Resources Agency (MOEA) of Taiwan in collaboration with WL | Delft Hydraulics in the Netherlands, to conduct hydraulic simulations. SOBEK is a comprehensive numerical modeling system widely used for river management, urban drainage, and watershed hydrology analysis. It integrates multiple hydrological and hydraulic components, making it suitable for applications in rural drainage, urban drainage, and river systems.The model features several key hydraulic modules, including the Rainfall-Runoff (RR) module, Channel Flow (CF) module, and Overland

Flow (OF) module, enabling both one-dimensional (1D) and two-dimensional (2D) hydrodynamic simulations for flood analysis. To enhance flood modeling accuracy, particularly for overtopping scenarios, this study utilized the Hydraulic Digital Elevation Model (HyDEM), a high-resolution (1-meter) dataset incorporating overtopping lines, seawalls, and floodgates.Overall, a 1D-2D coupled SOBEK model was applied to simulate flood inundation areas under various rainfall conditions, providing a detailed assessment of flood risks and hydrodynamic behavior.

3.5 Land-Use Strategies for Flood Risk Management

This study first examined the relationship between changes in flood inundation areas and land use transitions following the implementation of flood control engineering measures. The enhancement of flood protection standards may stimulate urban land development. However, given the limitations of flood control infrastructure, overtopping events may still occur, ultimately increasing residual flood risk. Furthermore, residual flood risk is expected to rise with climate change. Spatial planning plays a critical role in flood risk management, particularly through land use planning, which can prevent settlements in high-risk areas, thereby reducing vulnerability.To address this challenge, this study developed six land use management strategies to provide a comprehensive approach to flood risk management and evaluate associated flood risk changes. Previous research has demonstrated that risk-oriented land use planning, such as flood regulation zoning, can effectively mitigate flood risk. Additionally, Low-Impact Development (LID) and Green Infrastructure (GI) measures enhance stormwater storage capacity, reducing surface water accumulation and alleviating flood risk. Therefore, these approaches were selected as land use strategies for evaluating their effectiveness in residual flood risk management. To achieve this, we integrated the CA-Markov model for land use change analysis and the SOBEK model for flood inundation simulation, incorporating hydrological measures such as LID and GI under different rainfall scenarios.

The study considers seven land-use strategy scenarios to evaluate residual flood risk management. Type I (BAU) serves as the baseline, maintaining the existing 6M levee without additional flood control measures. Type II increases the levee height to 10M without land use restrictions, allowing unrestricted development. Type III applies development restrictions in flood-prone areas where inundation exceeds 0.3 meters. Type IV introduces LID measures in flood-prone areas to mitigate surface runoff, while Type V incorporates GI strategies, including permeable water facilities and additional flood retention spaces in parks, green spaces, and agricultural areas. Type VI combines development restrictions (Type III) with GI (Type V) to assess the joint effect of regulatory and green infrastructure strategies. Type VII integrates LID (Type IV) and GI (Type V) to evaluate their combined effectiveness in flood risk reduction. To comprehensively evaluate these scenarios, simulations were conducted under six different rainfall return periods: 10, 25, 50, 100, and 200 years, ranging from normal conditions (10RP or 25RP) to extreme flooding events (200RP). Given the unique characteristics of each scenario, the CA-Markov and SOBEK models were applied accordingly to assess the implications of land use transitions and flood risk changes.

3.6 Flood Risk Assessment Based on Direct Flood Damage Analysis

This study employs direct flood damage analysis to quantify and assess flood risk under different land-use management scenarios. Using the SOBEK 1D-2D hydrodynamic model, we simulated seven land-use strategies under six rainfall return periods (20, 50, 100, 150, and 200 years) within the RCP 6.5 climate change scenario to analyze flood inundation extent and depth.As summarized in Table 3, the assessment focused on residential, commercial, industrial, and agricultural land uses, utilizing flood damage functions derived from previous studies in Taiwan. Direct flood damage was estimated based on flood depth-damage relationships and spatial overlays of land-use maps and flood hazard zones. The study also considered potential land-use transitions and their effects on flood exposure, integrating land-use change projections to evaluate future flood risk under different urban development patterns.

Direct Flood Damage Estimationper 100 m² (NTD × 10k)				
Flood Depth (m)	Residential	Commercial	Industrial	Agricultural
0.3-1.0	0.21	22.08	16.94	0.03
1.0-2.0	0.31	44.47	45.98	0.03
2.0-3.0	0.38	46.59	53.85	0.03
3.0+	0.43	61.45	75.03	0.03

Table 3: Estimated Direct Flood Damage per 100 m² for Different Land Uses and Flood Depths.

4 RESULTS AND DISCUSSION

4.1 Land Use Change Simulation

4.1.1 Land Use Transition Analysis

This study employed the MC model to analyze land use transitions from 1995 to 2015. As shown in Table 4, the transition areas and probability values were calculated to quantify the likelihood of one land use type converting into another over this period.The results showed a significant increase in industrial, transportation, and commercial land, accompanied by a notable decrease in agricultural and forest land. A closer examination revealed that a large portion of agricultural land was converted into industrial and transportation uses, while much of the forest land was transformed into agricultural, industrial, and transportation areas, likely due to urban growth.

Class	AG	FR	TR	WT	CM	RS	IN	GR	RC	VA	OT
AG	0.2143	0.3112	0.0680	0.0088	0.0151	0.0273	0.0857	0.0063	0.0011	0.0592	0.2030
FR	0.2072	0.5500	0.0462	0.0038	0.0043	0.0160	0.0317	0.0040	0.0021	0.0177	0.1170
TR	0.0331	0.0809	0.4541	0.0182	0.0523	0.1158	0.1095	0.0109	0.0031	0.0720	0.0500
WT	0.0289	0.0370	0.1703	0.2370	0.0084	0.0144	0.0385	0.2683	0.0251	0.0318	0.1404
CM	0.0016	0	0.0692	0	0.1944	0.3871	0.3097	0.0033	0	0.0214	0.0132
RS	0.0411	0.1112	0.1493	0.0072	0.0445	0.4590	0.1078	0.0068	0.0018	0.0308	0.0404
IN	0.0429	0.0335	0.1344	0.0081	0.0856	0.1169	0.4939	0.0101	0.0121	0.0305	0.0320
GR	0	0.1853	0.0309	0	0	0.0772	0	0.4904	0	0	0.2162
RC	0	0	0.1671	0	0	0	0	0.0026	0	0.6214	0.2089
VA	0.2143	0.3112	0.0680	0.0088	0.0151	0.0273	0.0857	0.0063	0.0011	0.0592	0.2030
OT	0.2072	0.5500	0.0462	0.0038	0.0043	0.0160	0.0317	0.0040	0.0021	0.0177	0.1170

Table 4:Land use transition probability based on Markov Chain model from 1995 to 2015.

4.1.2 Driving Factors and Their Influence

Land use changes are driven by environmental, socioeconomic, and built factors, and this study selected relevant factors based on their significance. To evaluate their explanatory power, we employed Cramer's V value, which measures the strength of the correlation between each factor and the observed land-use transitions. This study incorporated flood inundation areas as key factors influencing changes in land use. We utilized flood inundation maps produced by the Water Resources Agency of Taiwan, which cover four rainfall scenarios: 200 mm, 350 mm, 500 mm, and 650 mm within 24 hours.

As shown in the Table 5, the results indicated that the overall Cramer's V values for all selected driving factors exceeded 0.1, demonstrating their significant influence on land use changes.Although the Cramer's V value for flood inundation areas was lower than that of other driving factors, it still exhibited a notable association with land use transitions, likely due to Wugu district's location in a floodplain and previous frequent flooding events. Given the comparative analysis of different rainfall scenarios, we selected the 650mm/24hr scenario as the primary flood inundation factor, as it yielded the highest Cramer's V value.

Environmental Factors	OverallCramer's V value	Socioeconomic and Built Factors	Overall Cramer's V value
DTM	0.2285	Population density	0.2293
Slope	0.2329	Distance to public facilities	0.2473
Distance to river	0.2004	Distance to roads	0.2184
Flood inundation areas (200mm/24hr)	0.1341	Distance to residential areas	0.2363
Flood inundation areas (350mm/24hr)	0.1351	Distance to commercial areas	0.2625
Flood inundation areas (600mm/24hr)	0.1414	Distance to industrial areas	0.2699
Flood inundation areas (650mm/24hr)	0.1490	N/A	N/A

Table 5:Cramer's V values for all driving factos.

4.1.3 Suitability Mapping Using MCE-WLC

This study first applied fuzzy membership functions to driving factors and Boolean values to constraint factors.The MCE-WLC wasemployed to generate suitability maps for all land-use types, using Cramer's V as the weighting factor for each variable. As illustrated in Fig. 4, the suitability maps of all 11 land-use types were subsequently integrated with the CA model to enhance the accuracy of future land-usepredictions.

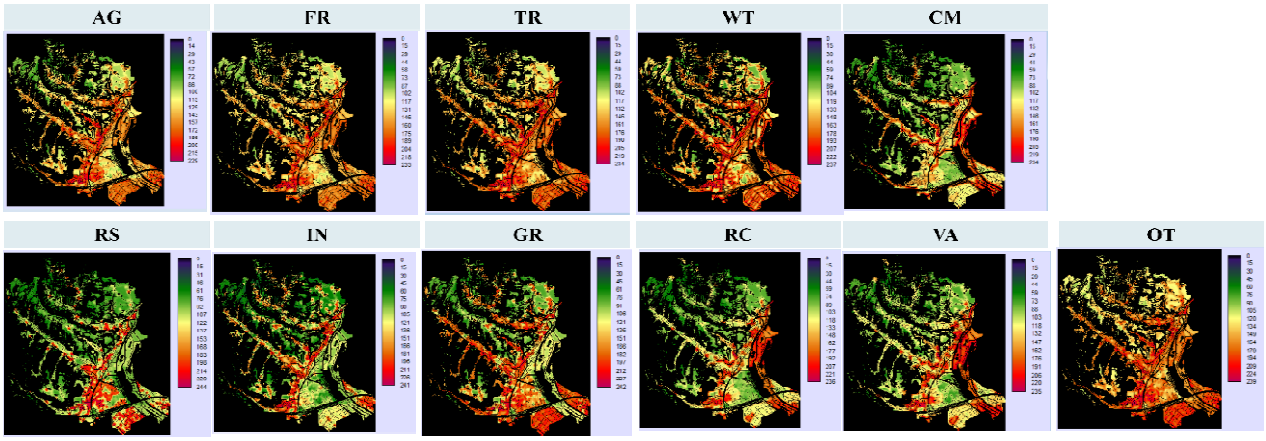

Fig. 4: Suitability Maps for All Land Use Types.

4.1.4 Model Validation and Performance Assessment

The CA-Markv model's accuracy was assessed using the Kappa coefficient, showing high values (Kstandard = 0.7601, Kno = 0.7958, Klocation = 0.8458, and KlocationStrata = 0.8458). Alough the values were slightly lower than 80%, they still indicated a moderate to strong agreement between the observed and projected LULC maps. Following validation, the model was deemed suitable for predicting 2035 LULC map.

4.2 Land Use Scenarios and Flood Risk Assessment

4.2.1 Land Use Change under Different Scenarios

This study preliminarily considered two rainfall scenarios, 200 mm and 650 mm over 24 hours,as key driving factors influencing flood-prone areas to analyze the relationship between flood inundation and land use transitions. The 650 mm/24 hr scenario represented extreme flooding, whereas the 200 mm/24 hr scenario reflected reduced flooding.For the preliminary analysis, we utilized flood inundation maps provided by the Water Resources Agency of Taiwan. Additionally, we restricted land use changes in areas where flood depths exceeded 0.3 meters, aligning with land use regulations for flood risk management. As illustrated in Fig. 5 , projected2035LULCmaps under the three scenarios revealed some spatial variations.

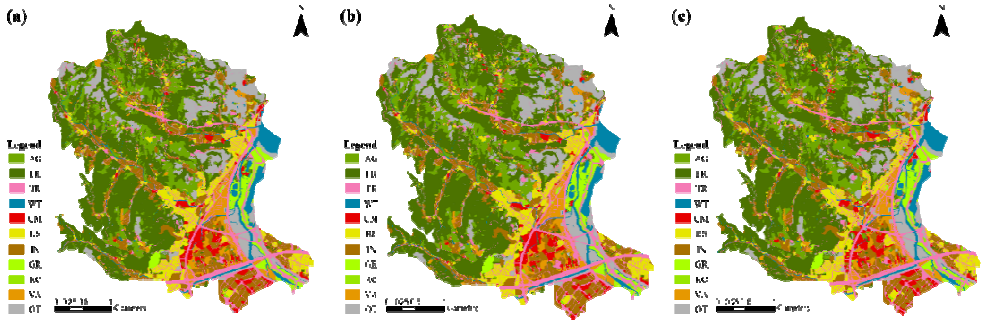

Fig. 5: Projected LULC Maps for 2035 under Different Scenarios: (a) 650mm/24hr, (b) 200mm/24hr, and (c) Restricted Flood Zones.

4.2.2 Impact of Land Use Change on Flood Risk

We overlaid the projected 2035 LULC maps under three scenarios withflood inundation areas for a 650 mm/24-hour rainfall event to compare flood risk. The results showed that under the scenario where 650 mm/24 hours was the key driver, the estimated direct flood damage amounted to 12.4056 billion New Taiwan Dollars (NTD). Under the scenario where 200 mm/24 hours was the key driver, the damage increased to 13.0125 billion NTD. Conversely, when flood-prone areas were effectively restricted, the damage was reduced to 12.0763 billion NTD.The analysis revealed that despite a reduction in flood inundation areas, the flood damage under the 200 mm/24-hour scenario was higher than under extreme rainfall conditions. This phenomenon exemplified the levee effect, where urban expansion accelerated following flood control measures. However, in the absence of effective flood risk management strategies and land use regulations, the overall flood risk still increased. Furthermore, the findings highlighted that controlling flood risk areas was an effective measure to mitigate flood risk. Consistent with previous studies,

these results emphasized the critical role of flood risk-oriented land use planning in ensuring urban resilience, particularly in the face of climate change (Adnan et al., 2020; Pinter et al., 2016).

5 CONCLUSION

This study examined the interplay between the levee effect, residual flood risk, and urban development under climate change, utilizing the CA-Markov model and SOBEK hydrodynamic simulations. The findings reveal that while structural flood control measures, such asreducing flood inundation under normal conditions, they also encouraged land-use changes that inadvertently increase long-term flood risk. The results highlighted the paradox of the levee effect, where enhanced flood protection leads to intensified urban expansion, ultimately exacerbating flood exposure when extreme events exceed design thresholds.The projected land-use scenarios further confirmed that unrestricted urban expansion can elevate direct flood damages despite enhanced flood control infrastructure. Given these insights, policy recommendations emphasize the need for a shift from traditional structural flood control towards a hybrid approach incorporating spatial planning and nature-based solutions. Authorities should implement stricter floodplain development controls, promote sustainable urban design, and enhance public awareness of residual flood risks. Additionally, integrating climate adaptation considerations into land-use policies will be crucial in fostering long-term urban resilience.

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🏆 reviewed paper

Mobilfunkdaten-gestützte Analyse des Mobilitätsverhaltens infolge extremer Wettersituationen

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1 ABSTRACT

Extreme Wetterbedingungen, wie starke Regen- oder Schneefälle, aber auch Hochwasserereignisse und einhergehende Überschwemmungen, können sowohl direkte als auch indirekte Auswirkungen auf das Verkehrsverhalten und die Mobilitätsmuster, sowie auch auf die Nutzung der Verkehrsinfrastruktur und des urbanen und ruralen Verkehrsangebotes haben. Die Auswirkungen von extremen Wetterbedingungen auf die Mobilität können sowohl kurzfristig und temporär während eines akuten Ereignisses beobachtet werden, aber auch langfristige Veränderungen in den Mobilitätsgewohnheiten durch nachhaltige Verhaltensanpassungen bewirken. Gerade im Zuge des akuten Auftretens eines extremen Unwetterereignisses steht die Sicherheit der Bevölkerung an erster Stelle. Damit ist ein Monitoring der stationären Aufenthaltsorte und auch der Bewegungsströme der Bevölkerung während dieser kritischen Zeiträume von zentraler Wichtigkeit, um zeitnah sicherheitsrelevante Maßnahmen im Verkehrsmanagement treffen zu können. Neben einer zeitnahen Vulnerabilitätsanalyse, spielt auch die gezielte Analyse der Infrastrukturresilienz eine wichtige Rolle. Zudem ermöglicht ein Monitoring des Mobilitätsverhaltens infolge extremer Wettersituationen auch eine datengetriebene Krisenkommunikation und ermöglicht die Ableitung von eventuell notwendigen Evakuierungsstrategien.

Um die zu setzenden Maßnahmen im Extremfall mit einer ausreichend genauen Datengrundlage unterstützen zu können, bieten sich flächendeckend verfügbare Mobilfunkdaten an, die bereits regelmäßig für die strategische Verkehrsplanung genutzt werden. Diese Daten ermöglichen die Analyse der Aufenthaltsstandorte und Mobilitätsmuster der Bevölkerung in hoher räumlicher und zeitlicher Auflösung, siehe Dujardin et al. (2020). Die anonymisierten Handysignalisierungsdaten werden dabei durch die aktive und passive Nutzung des Mobilfunknetzes erhoben. Durch die Analyse der Mobilfunkdaten können die Bewegungsströme und Bevölkerungsdichten überwacht und bei extremen Wettersituationen entsprechende Maßnahmen zur Verkehrslenkung, wie beispielsweise Straßensperren und gezielte Umleitungen, angeordnet werden. Zudem ermöglicht die Mobilfunkdatenanalyse eine Überwachung der Evakuierungsbewegungen und kann die Effektivität der Sicherheitsmaßnahmen durch ex-post Analysen erhöhen. Behörden können überprüfen, wie Menschen auf Warnungen und Evakuierungsbefehle reagieren und ob Evakuierungen effizient, zeitgerecht und zielgerichtet durchgeführt werden. Mithilfe der Analysemethodik können zudem auch Muster der täglich stattfindenden Bewegungen untersucht und die Änderungen und Anomalien bei extremen Wettersituationen durch den Vergleich mit historischen Daten in Normalwetterlagen analysiert werden, um frühzeitig Anzeichen von Überlastungsanzeichen der Infrastruktur zu erkennen.

Der Beitrag behandelt die Entwicklung einer mobilfunkbasierten Near-Real-Time-Anwendung und analysiert die Bewegungsströme und Bevölkerungsdichten an neuralgischen Standorten im Zuge der Hochwasserereignisse in Österreich im September 2024. Near-Real-Time ermöglicht es, das Personenaufkommen an spezifischen Standorten kritischer Infrastrukturelemente (Brücken, Staudämme, etc.) mit nur wenigen Minuten Verzögerung zu analysieren. Fast in Echtzeit kann damit beantwortet werden, wie viele Personen sich an einem kritischen Standort aufhalten und es können sicherheitsrelevante Maßnahmen getroffen werden. Die entwickelten Mobilfunkdaten-gestützten Analysen setzen damit einen Meilenstein bei der Etablierung einer dynamischen Expositionsanalyse und bieten wertvolle Einblicke in die Auswirkungen von Wetterereignissen, indem sie Bewegungsmuster und Aufenthaltsorte in Echtzeit analysierbar machen. Darauf aufbauend lassen sich entsprechende Vulnerabilitäts- und Expositionskarten der bewegenden und stationären Bevölkerungsdichten im Sinne einer Risikokartierung dynamisch und ohne lange Latenzzeiten aufbereiten. Die Analysen können somit wichtige Informationen liefern, um Städte besser auf extreme Wetterereignisse vorzubereiten, den Verkehr zu optimieren und die öffentliche Sicherheit zu erhöhen.

Keywords: Vulnerabilitätsanalysen, Mobilitätsverhalten, Mobilfunkdaten, Expositionskarten, Infrastrukturresilienz

2 EINLEITUNG

Die Anpassung von Städten an die Auswirkungen des Klimawandels ist von großer Bedeutung, denn städtische Gebiete sind aufgrund ihrer Bevölkerungskonzentration sowie ihrer Schlüsselrolle in wirtschaftlichen, politischen und sozialen Prozessen besondere Hochrisikozonen. Der Diskurs über die Anpassung von Städten an den Klimawandel hat jedoch erst in jüngster Zeit in Politik und Wissenschaft an Dynamik gewonnen. Die Europäische Kommision widmet sich intensiv dem Thema zur „Bewältigung von Klimarisiken – Schutz der Menschen und des Wohlstands“ in deren Mitteilung der Kommision an das europäische Parlament, den Rat, den europäischen Wirtschafts- und Sozialausschuss und den Ausschuss der Regionen.[1] In der Studie von Birkmann et al. (2010) wurden bereits Anpassungsstrategien an den Klimawandel in neun ausgewählten Städten untersucht und hinsichtlich ihrer allgemeinen Vision und Ziele, der verwendeten Ausgangsdaten, der direkten und indirekten Auswirkungen, der vorgeschlagenen strukturellen und nicht-strukturellen Maßnahmen sowie der Einbeziehung formeller und informeller Akteure analysiert. Die weiterführende Studie von Birkmann et al. (2012) vertiefte die Vulnerabilität verschiedener gesellschaftlicher Gruppen gegenüber Hochwassersituationen im vietnamesischen Mekong-Delta, das stark von den Risiken des Klimawandels betroffen ist. Die Studie leistete einen zentralen Beitrag zur Methodenentwicklung und einzuhaltende Datenqualität für eine umfassende Vulnerabilitätsbewertung, die als Grundlage für zukünftige Anpassungsstrategien dienen kann. Sie verbindet zudem die bestehenden Diskurse zu Katastrophenvorsorge und Anpassung an den Klimawandel.

Die Technologie zur Bestimmung des geografischen Standorts von Mobiltelefonen und anderen tragbaren Geräten wird zunehmend verfügbarer. Nach Ratti et al. (2006) ermöglicht sie eine Vielzahl von Anwendungen, die unter dem Begriff Location Based Services (LBS) zusammengefasst werden und sich zu einem mächtigen Werkzeug für die Stadtanalyse entwickeln können, um aggregierte Daten in Städten abzurufen. Auch Mateos und Fischer (2007) haben schon früh auf die Bedeutung einer ausreichenden raum-zeitlichen Genauigkeit bei der Lokalisierung von Mobiltelefonen in diesem Zusammenhang hingewiesen. So wurden in der Studie von Pulselli et al. (2008) Verkehrsdaten, die von Mobilfunkantennen aufgezeichnet wurden, verwendet, um eine Echtzeit-Überwachungstechnik für die Bevölkerungsdichte in einem städtischen Gebiet zu entwickeln. Dabei wurde davon ausgegangen, dass die Intensität der Aktivität in einer Mobilfunkzelle direkt proportional zur Anwesenheit von Mobilfunknutzern ist.

Deville et al. (2014) zeigte, dass Daten von Mobilfunknetzbetreibern genutzt werden können, um genaue und detaillierte Bevölkerungskarten zu erstellen. Diese Daten bieten laut der Studie eine wertvolle Ressource für die Planung von Maßnahmen in Bereichen wie Gesundheit der Bevölkerung, Klimawandel, Konflikte und auch Naturkatastrophen.

Insbesondere in einkommensschwachen Ländern, in denen Daten zur Bevölkerungsverteilung spärlich vorhanden, veraltet und unzuverlässig sein können, ermöglicht die Verwendung von Mobilfunkdaten eine gute Schätzung der Bevölkerungsdichte, vgl. Tatem und Linard (2011). Der Zugang zu anonymisierten Mobilfunkdaten ermöglicht dabei die schnelle und kostengünstige Erstellung von Bevölkerungskarten in Notfallsituationen oder bei bestehender Datenknappheit. Dieser Fortschritt in der Datennutzung bietet somit einen wertvollen Baustein zur Verbesserung von Folgenabschätzungen und zur gezielten Maßnahmenplanung in Extremsituationen.

Bengtsson et al. (2011) beschreiben diesbezüglich Ergebnisse, die auf Positionsdaten von SIM-Karten eines Mobilfunkanbieters in Haiti basieren, um Bevölkerungsbewegungen nach Katastrophen zu verfolgen und konkret das Ausmaß und die Trends von Mobilitätsbewegungen nach dem Erdbeben und der Cholera-Epidemie in Haiti im Jahr 2010 abzuschätzen. Järv et al. (2012) stützten ihre Studie ebenfalls auf Mobilfunkdaten, wobei hier leidglich die Aufzeichnungen von Handygesprächen (CDR – Call Detail Records) verwendet wurden, um das Mobilitätsverhalten abbilden zu können. Auch in der Studie von Wesolowski et al. (2013) wurde der Zusammenhang zwischen Telefonbesitz und Mobilität in Kenia anhand von Mobilfunkdaten untersucht. Hier wurde festgestellt, dass der unterschiedliche Telefonbesitz in verschiedenen Bevölkerungsgruppen zwar die Interpretation von Mobilitätsmustern erschwert, die Analyse

[1] https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:52024DC0091 [Stand: 06.02.2025]

ergab dennoch, dass die Mobilitätsschätzungen erstaunlich robust sind und nur geringfügig von den Verzerrungen durch den Telefonbesitz unterschiedlicher Nutzergruppen beeinflusst werden.

Lu et al. (2016) untersuchten die Auswirkungen des Klimawandels auf die Migration von Menschen in umweltbelasteten Gebieten. Dazu wurden Mobilfunkdaten von sechs Millionen Nutzern in Bangladesch analysiert. Konkret wurden anhand von Mobilfunkdaten, die während eines Zyklons im Jahr 2013 gesammelt wurden, Migrationsmuster während und nach extremen Wetterereignissen beschrieben. Die Analyse der Daten ermöglichte es, die Beziehung zwischen den grundlegenden Parametern der Migrationsmuster auf nationaler Ebene zu untersuchen.

3 FORSCHUNGSGEGENSTAND

Im Rahmen des Projektes „Flood-Activity-Risk-Monitor“ wurde eine dynamische Expositionsanalyse auf Basis von Mobilitätsanalysen angestrebt. Die Mobilitätsanalysen basierten dabei auf der Datengrundlage der technisch anonymisierten Mobilfunksignalisierungsdaten der A1 Telekom Austria, die vorverarbeitet, aufbereitet und analysiert wurden. Diese Datenbasis stellt eine repräsentative Stichprobe von über 40 % der österreichischen Bevölkerung dar. In dieser Kundenbasis sind auch virtuelle Mobilfunkmarken (MVNOs) und Roamingkunden internationaler Mobilfunkbetreiber enthalten. Die Datenerhebung erfolgt automatisch durch die aktive und passive Nutzung des Mobilfunknetzes, ohne zusätzlichen Aufwand und ohne Beeinträchtigung der Untersuchungsobjekte, wie z. B. durch Feldpräsenz, spezielle Geräte, Apps oder Software. Die Daten werden flächendeckend, zeitgleich und rund um die Uhr erhoben, was räumlich und zeitlich flexible Analysen mit gleichbleibender Qualität und damit Vergleichbarkeit ermöglicht. Da die Mobilfunkdaten eines einzelnen Anbieters nur einen Teil des Mobilfunkmarktes abdecken, werden die Daten mit den regionalen Marktanteilen in den verschiedenen soziodemografischen Gruppen des Netzbetreibers kalibriert und auf die Grundgesamtheit hochgerechnet. Internationale Besucher werden ebenfalls auf Basis regionaler Nächtigungsstatistiken entsprechend der vorherrschenden Roamingverträge hochgerechnet, um auch den Einfluss touristischer Personenbewegungen und insbesondere auch den Transitverkehr abbilden zu können. Damit wird sichergestellt, dass die Analyseergebnisse repräsentativ für die einheimische Gesamtbevölkerung und auch Personengruppen aus dem Ausland sind, auch wenn die erhobenen Daten nur einen Teil des länderspezifischen Mobilfunkmarktes abbilden.

Das Hauptziel der Analysen bestand darin, mit Hilfe von anonymisierten Mobilfunk-Signaldaten Personen zu identifizieren, die einem potentiellen Hochwasserrisiko besonders ausgesetzt sind. Die Arbeiten zielten darauf ab, Gebiete zu untersuchen, die von Hochwasserereignissen (z. B. HQ 100 oder HQ 300) besonders betroffen sind. Dabei sollte auf Basis der Analyse von Mobilfunk-Signaldaten auch der zeitliche Aspekt des menschlichen Verhaltens berücksichtigt werden, da davon auszugehen ist, dass die Anzahl der Personen in exponierten Lagen sowohl im Jahresverlauf als auch im Tagesverlauf schwanken. Bisherige Statistiken von Gemeinden oder Ländern erlauben in der Regel eine gute Abschätzung der vor Ort gemeldeten Personen (z. B. Hauptwohnsitzmeldungen) bzw. eine Abschätzung der in einem Gebiet übernachtenden Personen (über Nächtigungszahlen). Diese Statistiken sind jedoch zu statisch und können daher unter anderem den zeitlichen Aspekt der kritischen Frage nicht beantworten: Wie viele Personen halten sich zu einem bestimmten Zeitpunkt tatsächlich in einem gefährdeten Gebiet auf oder wie viele Personen nutzen eine gefährdete Verkehrsinfrastruktur während extremer Wetterereignisse?

Damit ist auch die übergeordnete Vision der bearbeiteten Fragestellungen definiert, die eine Analyse von durch Naturkatastrophen gefährdeten oder betroffenen Gebieten in nahezu Echtzeit (Near-Real-Time) verfolgt. Die Arbeiten ließen sich sinnvoll in zwei inhaltliche Komponenten gliedern.

- In einem ersten Schritt wurde die Datenvorverarbeitung und Analyse des Füllstands und der Durchfahrer pro Gebiet/Zone ermittelt. Dabei wurden im Rahmen der Analysen drei spezifische Modellregionen rund um die Flussläufe der Leitha, Ziller und des Rheingebietes definiert, um entsprechende Vulnerabilitäts- und Expositionskarten der bewegenden und stationären Bevölkerungsdichten im Sinne einer Risikokartierung aufzubereiten und deren Zeitreihen zu analysieren.
- In einem zweiten Schritt wurde das inhärente Potential einer Near-Real-Time Analyse erarbeitet, um darauf aufbauend das Risiko spezifischer Gefahrenbereiche in nahezu Echtzeit analysierbar zu machen. Hier wurde das Betrachtungsgebiet auf das Stadtgebiet von Wien gelegt, um neuralgische

Stellen entlang des Wienflusses näher zu untersuchen, wobei hier aktuelle Daten des Hochwasserereignisses vom September 2024 betrachtet wurden. Unter Near-Real-Time wurde im Projekt eine minutengenaue Datenbereitstellung mit einer Verzögerung von 15 Minuten definiert.

4 DATENGRUNDLAGE UND -VORVERABEITUNG

Aktuelle Indikatoren zur Beschreibung der Mobilität aus Erhebungen sowie deren Weiterentwicklung sind für Politik und Planung auf allen Ebenen unverzichtbar. Bisher basieren solche Indikatoren vor allem auf empirischen Primärdaten, wie sie in Mobilitätserhebungen gewonnen werden. Solche Erhebungen sind sehr aufwändig, da sie nicht kontinuierlich, flächendeckend und regional differenziert durchgeführt werden können. Gleichzeitig eröffnet der Zugang zu innovativen Datenquellen wie Mobilfunkdaten neue Analyse- und Erkenntnismöglichkeiten, insbesondere im Bereich der räumlichen und zeitlichen Erfassung von Informationen, vgl. Horn et al. (2017). Datenschutz und Ethik spielen dabei eine wichtige Rolle, um sicherzustellen, dass die Daten verantwortungsvoll genutzt werden und die Privatsphäre der Menschen gewahrt bleibt. Caceres et al. (2008) haben bereits sehr früh die Vor- und Nachteile von Mobilfunkdaten für verschiedene Anwendungsfälle untersucht und bewertet. Die Arbeiten konzentrierten sich dabei auf die Auswertung von Quelle-Ziel-Beziehungen, Verkehrsströmen, Reisezeiten und -geschwindigkeiten und daraus abgeleitet auch Stauerscheinungen bzw. Verkehrsdichteanalysen auf Basis von Mobilfunk-Signalisierungsdaten. Mobilitätserhebungen auf Basis von Mobilfunkdaten sind bereits seit einigen Jahren ein intensiv beforschtes und auch umgesetztes Feld, siehe Cik et al. (2017). Die verwendeten Daten werden automatisch und kontinuierlich generiert, da mobile Endgeräte ständig mit dem Mobilfunknetz verbunden sind, auch wenn sie nicht aktiv genutzt werden. Dabei wird einerseits versucht, über die technische Verbindung die aktuell am besten geeignete Basisstation zu ermitteln und andererseits dem Netz mitzuteilen, über welche Basisstation das Endgerät aktuell erreichbar ist. Da diese technischen Daten auch räumlich zuordenbar sind, eignen sie sich sehr gut für die Erstellung von Mobilfunktrajektorien und daraus ableitbaren Mobilitätsanalysen. Schlaich et al. (2010) haben bereits vor geraumer Zeit ein Verfahren vorgestellt, das durch die Analyse von Daten aus dem Mobilfunknetz raum-zeitliche Trajektorien von Reisenden generiert. Die Methode nutzt im Wesentlichen die Daten der Standortaktualisierung, die von jedem Mobiltelefon im Standby-Modus und damit passiv aufgezeichnet werden, und erfordert daher keine aktiven Handlungen wie Telefonate oder Handynutzung.

Zusammenfassend bieten innovative Datenquellen wie Mobilfunkdaten eine neuartige Möglichkeit, unser Verständnis komplexer Phänomene zu vertiefen und neue Erkenntnisse zu gewinnen, die dazu beitragen können, bessere Entscheidungen zu treffen und Problemstellungen effektiver und globaler berücksichtigen zu können. Im Folgenden wird die grundlegende Methodik der Mobilitätsanalyse auf Basis anonymisierter Mobilfunk-Signalisierungsdaten beschrieben, wobei sowohl auf die absolute Datenbasis als auch auf die Datenvorverarbeitung im Detail eingegangen wird.

Die im Rahmen dieser Studie durchgeführten Mobilitätsanalysen von Verkehrsströmen basieren auf anonymisierten, rein technischen Diagnosedaten (Mobilfunksignalisierungsdaten) des Netzbetreibers A1 Telekom Austria AG. Diese Datenbasis bildet eine repräsentative Stichprobe von ca. 40 % der österreichischen Bevölkerung (ca. 3,2 Mio. Mobilfunkgeräte) und setzt sich aus der Mobilfunkkundenbasis von A1 zusammen. Diese Kundenbasis umfasst unter anderem die Marken Bob, Yesss und Red Bull MOBILE sowie andere MVNOs (Mobile Virtual Network Operators) und Roamingkunden internationaler Mobilfunkbetreiber, die das A1 Netz in Österreich nutzen. Die Datenerhebung erfolgt automatisch durch die aktive und passive Nutzung des Mobilfunknetzes und wird für das gesamte Land gleichzeitig und rund um die Uhr erhoben. Die Methoden basieren auf modernen statistischen Algorithmen und maschinellen Lernverfahren, um aus den Millionen von gesammelten Datenpunkten, die als Rohdaten zur Verfügung stehen, Erkenntnisse über die menschliche Mobilität zu gewinnen, ohne dabei Rückschlüsse auf das Mobilitätsverhalten einzelner Personen ziehen zu können und damit auch dem Datenschutz zu entsprechen.

Bei der technischen Kommunikation mobiler Endgeräte mit dem Mobilfunknetz fallen sowohl bei aktiver Nutzung, z. B. bei Anrufen, SMS-Nachrichten oder einer aktiven Internetverbindung, als auch bei passiver Nutzung, z. B. bei der ständigen Suche nach der besten Basisstation durch das Endgerät, fortlaufend Mobilfunk-Signalisierungsdaten an. Für diese technische Kommunikation werden zu Diagnosezwecken Mobilfunk-Events erzeugt, die einen Zeitstempel besitzen und durch die Zuordnung zu einer Basisstation in gewissem Umfang georeferenziert sind. Durch die Aneinanderreihung verschiedener Mobilfunkereignisse

eines Endgerätes entstehen Bewegungsdaten bzw. Mobilfunktrajektorien, aus denen sich die Tagesroutinen der mobilen Endgeräte rekonstruieren lassen. In der Regel ist ein Endgerät jedoch nicht nur mit einer, sondern mit mehreren Basisstationen gleichzeitig verbunden. Dabei werden die in einem Gebiet gleichzeitig auftretenden Ereignisse von verschiedenen Basisstationen empfangen und durch Trilateration die Lokalisierungsgenauigkeit der Mobilfunkereignisse deutlich verbessert. Durch diesen methodischen Ansatz ist eine Orientierung an den eigentlichen Mobilfunkzellen nicht notwendig und die zu analysierenden Gebietseinteilungen, Zonierungen oder Raster können frei und sehr kleinräumig definiert werden (z. B. Geohash7-Raster mit einer Genauigkeit von rund 4.94 Bogensekunden oder umgerechnet 101.7m x 152,6m auf der Höhe von Wien).

Aus Datenschutzgründen werden die Mobilfunk-Signalisierungsdaten alle 24 Stunden zu Beginn jedes Tages nach dem Zufallsprinzip neu anonymisiert. Dadurch können Bewegungsmuster nur auf einen Tag bezogen werden.

In der Trajektorienvorverarbeitung werden in einem ersten Schritt Ausreißer aus den Datenpunkten entfernt und anschließend die (Mobilfunk-)Rohtrajektorien geglättet. Anschließend wird die Trajektorie in stationäre Aufenthalte sowie in bewegende Segmente dazwischen unterteilt. Ein stationärer Aufenthalt liegt vor, wenn ein Endgerät sich für mindestens 15 Minuten an einem anderen Standort als dem Heimatstandort aufhält, wobei hier die Definition eines stationären Aufenthalts je nach Anwendungsfall unterschiedlich und flexibel gestaltet werden kann. Für die stationären Aufenthalte werden neben der geografischen Verortung auch die Anfangs-, Endzeit und Dauer des Aufenthalts ermittelt. Auf Basis der stationären Aufenthalte pro Tag lässt sich auf die bewegenden Segmente dazwischen schließen. Für die bewegenden Segmente werden neben der geografischen Verortung der Trajektorie auch die Abfahrts- und Ankunftszeit, die Reisezeit, die Reisedistanz (Fahrtweite) und die Durchschnittsgeschwindigkeit der Reise ermittelt. Die durchschnittliche Anzahl der Wege pro Person und Tag bildet hier auch einen elementaren Kennwert, welcher bei der Validierung der Ergebnisse der Gesamtpersonenfrequenzen herangezogen wird.

Nach der Segmentierung wird für jedes Endgerät ein Heimatstandort (Wegezweck Wohnen) ermittelt. Dieser Heimatstandort ist definiert als der erste Standort, an dem sich das Endgerät nach der Re-anonymisierung im Zeitraum zwischen 02:30 Uhr und 05:30 Uhr für mindestens 30 Minuten aufhält. Liegt in diesem Zeitfenster kein Aufenthalt vor, wird der Standort der ersten Beobachtung nach der Re-anonymisierung verwendet.

Da die Mobilfunkdaten aus dem Netz der A1 Telekom Austria nur einen Teil des Mobilfunkmarktes abdecken, werden die Daten mit den regionalen Marktanteilsverhältnissen in den verschiedenen soziodemographischen Gruppen des Netzbetreibers kalibriert und auf die Grundgesamtheit hochgerechnet. Damit wird sichergestellt, dass die Analyseergebnisse repräsentativ für die Gesamtbevölkerung sind, auch wenn die erhobenen Daten nur einen Teil des Mobilfunkmarktes abbilden. Die Kalibrierung ermöglicht eine genaue Schätzung und Hochrechnung der Mobilitätsmuster auf die Gesamtbevölkerung. Die auf diese Weise ermittelten Wohnstandorte stimmen nach Hochrechnung auf die Grundgesamtheit sehr gut mit den Erwartungswerten überein, die sich aus einer Kombination der Zahlen des amtlichen Melderegisters bzw. der Übernachtungsstatistik und z. B. der Krankenhausbettenbelegung ergeben.

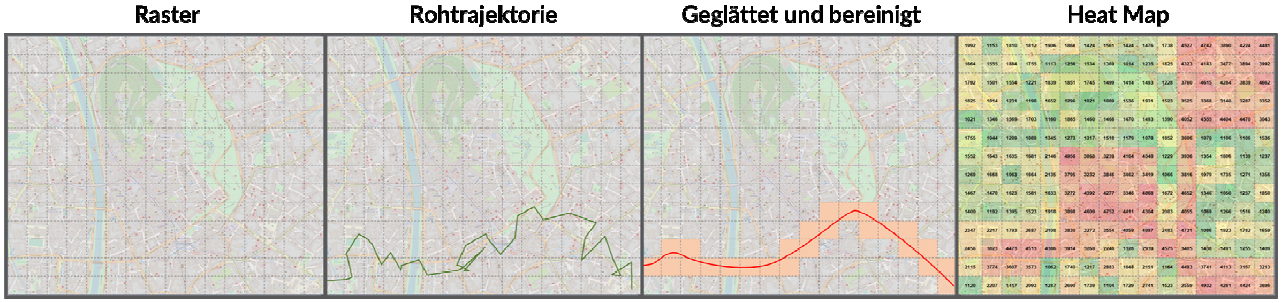

Fig. 1: Zuordnung von geglätteten und bereinigten Trajektorien zu Rasterdaten bewegender Segmente

Ein entscheidender Schritt der Vorverarbeitung der Mobilfunktrajektorien stellt eine belastbare Bestimmung der stationären und bewegenden Segmente dar, um hier Signalsprünge und Messungenauigkeiten von den tatsächlich stattfindenden Bewegungen zu detektieren und zu trennen. Sowohl die stationären als auch die bewegende Segmente können dann je nach Anwendungsfall einer Zelleneinteilung wie z. B. sehr kleinen Rasterelementen zugeordnet werden und ergeben schließlich Heat Maps der stationären bzw. bewegende

Segmente, siehe Fig. 1. Schließlich besteht über Map-Matching-Verfahren prinzipiell die Möglichkeit, kantenbasierte Routenverläufe aus den Mobilfunkbewegungsdaten zu extrahieren und hierfür auch eine Verkehrsmittelerkennung durchzuführen, um die Datensätze mit zusätzlichen Informationen anzureichern.

Die aus den Analysen resultierenden Verkehrskennziffern werden anhand von Referenzwerten aus dem Mobilitätsbereich, wie z. B. Ergebnissen lokaler Verkehrserhebungen (mittlere Anzahl der Wege pro Tag und Person), Fahrgastzahlen oder Belastungszahlen aus Verkehrsdetektoren, validiert. Bei der Validierung ist zu beachten, dass durch die wesentlich feinere räumliche und zeitliche Granularität der Analysen auf Basis von Mobilfunkdaten ortsspezifische sowie zeit-, tages-, wochen- oder saisonabhängige Besonderheiten sichtbar werden, die bei einer größeren räumlichen oder zeitlichen Aggregation nicht erkennbar wären. Ein Qualitätsmonitoring der Mobilfunkrohdaten läuft automatisch im Hintergrund und warnt bei starken, unplausiblen Abweichungen in Anzahl und Auftreten von regionsspezifischen Mobilfunkereignissen und Mobilfunktrajektorien und gibt tagesgenau einen entsprechenden Qualitätsindex regionalspezifisch aus. Dieses Tool stellt sicher, dass nur validierte und plausibilisierte Datensätze in die Mobilfunkanalysen einfließen und keine Artefakte durch Mastausfälle auf Seiten der physikalischen Infrastruktur oder Datenausfälle im Datenstream selbst die Analyseergebnisse beeinflussen.

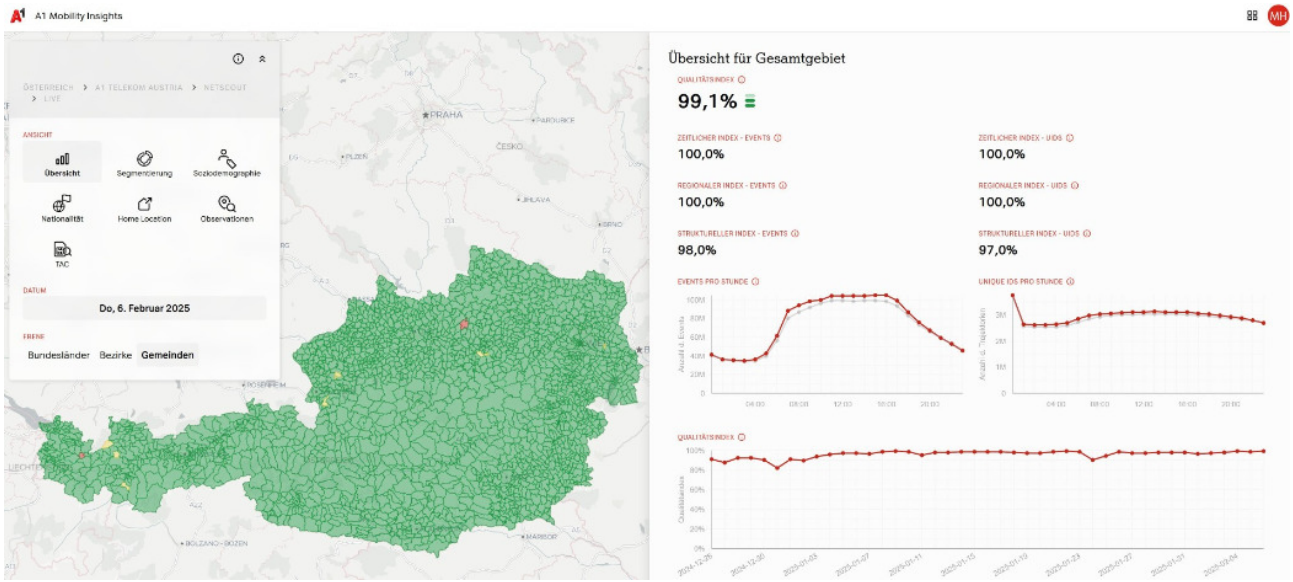

Fig. 2: Data Quality Monitoring System der Mobilfunksignaldaten

5 METHODIK UND ANALYSEERGEBNISSE

Im Rahmen des Projektes „Flood-Activity-Risk-Monitor FARM“ wurde eine dynamische Expositionsanalyse auf Basis von Mobilitätsanalysen durchgeführt, wobei die Mobilitätsanalysen auf der Verarbeitung und Aufbereitung anonymisierter Mobilfunkdaten basierten. Die Projektarbeiten wurden zweckmäßigerweise in drei Teile gegliedert, die in den folgenden Abschnitten erläutert werden.

5.1 Vorverarbeitung und Aufbereitung der Mobilfunk-Rohdaten

In einem ersten Schritt wurden die zu untersuchenden neuralgischen Überflutungsflächen festgelegt. Neben den Überflutungsflächen entlang des Rheins wurden auch Flächen der Ziller und Leitha räumlich festgelegt. Hierfür wurden jeweils zwei volle Kalenderwochen im Jahr 2023 (17.4-23.4.2023 bzw. 19.6-25.6.2023) als Analysezeitraum definiert. Für diese raum-zeitliche Einteilung wurden die anonymisierten Mobilfunkdaten erhoben und für die nachfolgenden Mobilitätsanalysen softwaretechnisch vorverarbeitet. Dabei wurde eine möglichst kleinräumige räumliche Auflösung auf Basis eines 500x500m Rasters gewählt und mit den Überflutungsflächen verschnitten, für die die Datenbereitstellung von stationären und mobilen Entitäten festgelegt wurde.

Die Signalisierungsinformationen von ca. 10.000 Mobilfunkstationen des A1-Netzes mit einer zugrunde liegenden Kundenbasis von mehr als 3,2 Mio. Mobilfunkkunden wurden im Invenium-Rechencluster gesammelt. Die Mobilfunk-Rohdaten wurden für die räumlichen Untersuchungsgebiete und die vereinbarten Zeiträume vorverarbeitet und regionsspezifisch hochgerechnet. Durch Triangulationsmodelle wurden die Positionsgenauigkeiten verbessert und mit intelligenten KI-Algorithmen (Mapmatching, Machine Learning,

Clusteranalyse) Bewegungsverläufe und -profile erstellt, die die Grundlage für die weiteren Analysen der stationären und bewegenden Segmente bildeten.

5.2 Analyse des Füllstandes und Durchfahrer pro Zelle

In einem zweiten Schritt wurden die in den Untersuchungsgebieten erhobenen anonymisierten Mobilfunkdaten für die entsprechenden Analysezeiträume in stationäre und bewegende Segmente segmentiert. Auf Basis der segmentierten Trajektorien wurden für jede Rasterzelle der Füllstand Auslastung (stationäre Segmente) sowie die Durchfahrer (bewegende Segmente) in den einzelnen Rasterzellen stundenscharf für den gesamten Zeitraum über die zwei Analysewochen im Jahr 2024 berechnet und entsprechende Heat Maps aufbereitet. Fig. 3 zeigt hier die Analyse des Füllstands (linke Seite) und der Durchfahrer (rechte Seite) im Zusammenhang mit den Überflutungsflächen des Rheingebietes für die Morgenspitze im Zeitraum von 7 bis 8 Uhr für einen ausgesuchten Tag (19.4.2024). Hierbei wurden die 500m Raster mit den Überflutungsflächen des Rheins verschnitten und die Rasterelemente gezielt analysiert. Für die Durchfahrer wurden die gesamten Trajektorien mit Schnittstellen in das Überflutungsgebiet berücksichtigt, weswegen hier auch ein größeres Gebiet durch die Rasterelemente im Zuge der Analysen abgedeckt ist, als vergleichsweise für die stationären Füllstandanalysen. Während die höchsten Rasterzellwerte der stationären Segemente im Bereich der Stadt Lustenau erkennbar werden, verzeichnen die Rasterzellen im Bereich Götzis und Hohenems sehr hohe Rasterzellwerte der bewegenden Segmente, welche die Durchfahrer in diesem Bereich repräsentieren.

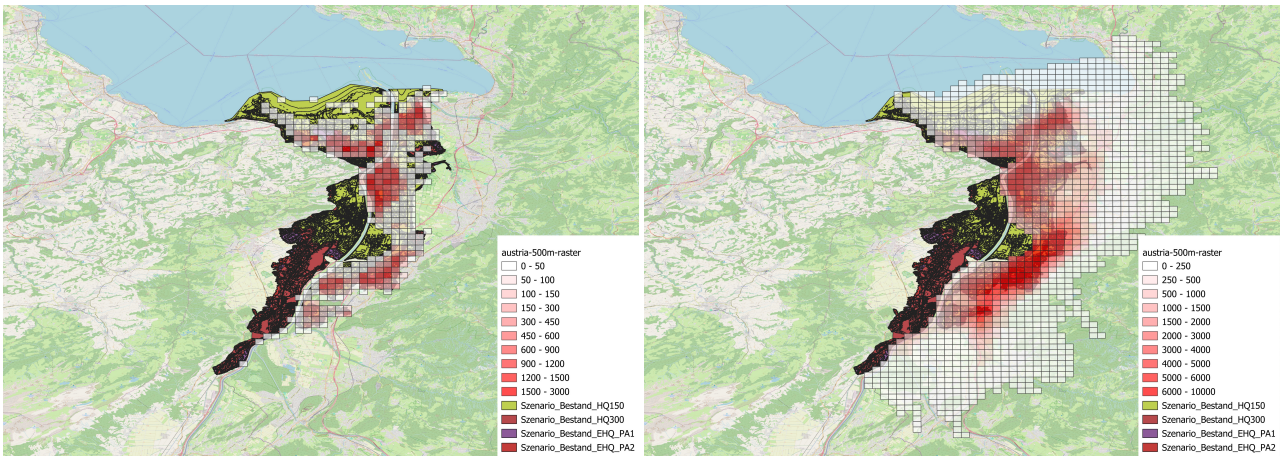

Fig. 3: 500x500m Raster für die Überflutungsfläche des Rheingebiets zur Analyse des Füllstands (links) und der Durchfahrer (rechts)

Im Hinblick auf eine dynamische Expositionsanalyse können auf Basis der stundenfeinen Füllstände und Durchfahrer, die risikoreichsten Zeiträume auf Basis der maximalen Anzahl gefährdeter Personen ermittelt und weitere Kennzahlen abgeleitet werden. Die Ergebnisse zeigen hier, dass die Anzahl der gefährdeten Personen sowohl pro betrachtetem Wochentag als auch pro betrachteter Tageszeit für die drei Untersuchungsräume des Rheintals, entlang der Ziller und der Leitha unterschiedlich sein kann. Durch die Verschneidung der vorliegenden Überflutungszonen mit den stationären und bewegenden Mobilfunkdaten ergibt sich hier eine gute Abbildung des Gefährdungspotentials. Weitere Entwicklungen hinzu einem Gefährdungs-Score, welcher sowohl die Anzahl der gefährdeten Personen als auch die unterschiedlichen Überflutungszonen (z. B. HQ100 vs. HQ300) miteinbezieht sind hier in weiterer Folge zu entwickeln.

Anhand der Verkehrsstärke der Durchreisenden können die Einflüsse auf die bestehende Verkehrsinfrastruktur betrachtet werden, die aufgrund ihrer Exposition gegenüber verschiedenen Naturereignissen wie Hochwasser, aber auch Lawinenverschüttungen einem erhöhten Ausfallsrisikopotenzial ausgesetzt sind. Dabei sollten insbesondere jene Verkehrsinfrastrukturen betrachtet werden, die für eine Region unverzichtbar sind. Als Beispiel sei die einzige Zufahrtsstraße zu einer Ortschaft in einem Tal genannt, deren Unpassierbarkeit die Ortschaft von der Außenwelt abschneiden würde. Unter Verkehrsstärke wird die Anzahl der Personen pro Stunde verstanden, die sich auf dem betrachteten Abschnitt der Verkehrsinfrastruktur bewegen und die aus den Rasterergebnissen der Mobilfunkdaten abgeleitet werden kann.

5.3 Analyse in Near-Real-Time

Die Hochwasserereignisse der letzten Jahre haben gezeigt, dass selbst aufwändige Hochwasserschutzbauten bei Extremereignissen keine absolute Sicherheit bieten können. Diese Erkenntnis der Verletzlichkeit durch Naturkatastrophen hat für viele Menschen das Thema Naturgefahren stärker ins Bewusstsein gerückt. Darauf aufbauend wurden die Eckpfeiler für ein integrales Hochwasserrisikomanagement in Österreich und auf EU-Ebene erarbeitet und schrittweise mittels der EU-Hochwasserrichtlinie (2007/60/EG)[2] umgesetzt.

Vom 12. bis 20. September 2024 ereignete sich ein massives Hochwasserereignis infolge einer sogenannten Vb-Wetterlage in Österreich. Vb (sprich: Fünf-B) bezeichnet dabei die Zugbahn eines Tiefdruckgebietes, das vom Atlantik kommend über das westliche Mittelmeer zieht und dann nach Norden abdreht. Ein Blick in die Vergangenheit zeigt deutlich, dass ähnliche Wetterlagen, wie sie zum Hochwasser im September 2024 geführt haben, in Mitteleuropa immer wieder zu außergewöhnlichen Niederschlagsmengen und Hochwasserereignissen geführt haben, wie beispielsweise auch im August 2002 und im Juni 2013. Je nach Zugrichtung und Ausdehnung der Niederschlagsgebiete bei diesen Vb-Wetterlagen und je nachdem, wo sie eventuell länger stationär bleiben, können der südliche Alpenrand oder die nördlichen Staulagen der Alpen, aber auch die Staulagen der mitteleuropäischen Mittelgebirge in den Nachbarländern betroffen sein.

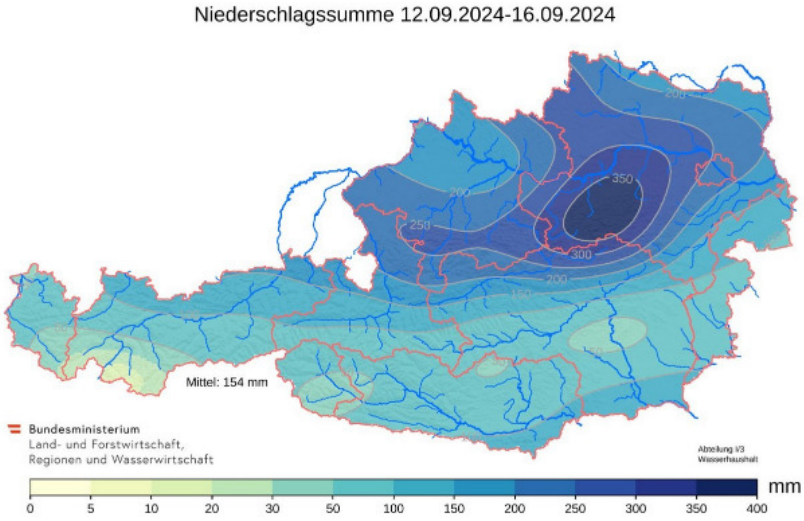

Fig. 4: Niederschlagssummen in Österreich zwischen dem 12.09.2024 und 16.09.2024 (Datengrundlage: Hydrographie Österreich)[3]

Zur Veränderung von großräumigen Starkniederschlägen im Klimawandel liegen bereits umfangreiche Studien wie WETRAX und darauf aufbauend WETRAX+ vor, an denen Meteorologen und Hydrologen gemeinsam gearbeitet haben, vgl. Hofstätter et al. (2015). Im Projekt WETRAX wurde insbesondere die Veränderung großräumiger Starkniederschläge im Zuge des Klimawandels für den Zeitraum 1951 bis 2100 untersucht. Diese Niederschläge haben das Potenzial zu großräumigen, extremen Flusshochwassern zu führen, wie z. B. im August 2002 oder im Mai 2013 an Donau und Elbe. Das Untersuchungsgebiet dieser Studien umfasste Süddeutschland, Österreich und angrenzende Teile der Schweiz sowie Tschechien. Als innovativer Ansatz wurden die für Starkniederschläge relevanten atmosphärischen Zirkulationsmuster mit zwei verschiedenen Verfahren bestimmt und ausgewertet. Die Ergebnisse zeigen, dass viele großräumige Starkniederschlagsereignisse in Mitteleuropa mit nur wenigen Zugbahnen und Zirkulationstypen („Wetterlagen“) erklärt werden können. Das wichtigste Muster ist ein persistentes Höhentief über dem Alpenraum in Verbindung mit einem Bodentief, das von Oberitalien nach Polen zieht. Die Ergebnisse können dazu beitragen, hochwasserrelevante atmosphärische Prozesse besser zu verstehen und Entscheidungsträger im Hochwassermanagement bei der Entwicklung von Anpassungsstrategien an den Klimawandel mit belastbaren Fakten zu unterstützen. So groß die Schäden und so tragisch die Auswirkungen solcher Extremereignisse sind, so wichtig ist eine genaue Analyse der Ereignisse. Sie hilft, die natürlichen Prozesse besser zu verstehen und Schlussfolgerungen für geeignete Maßnahmen zu ziehen.

[2] https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Binnengewaesser/richtlinie_management_hochwasserrisiken.pdf [Stand: 06.02.2025]

[3] https://info.bml.gv.at/themen/wasser/wasser-oesterreich/hydrographie/chronik-besonderer-ereignisse/hochwasser-september-2024.html [Stand: 06.02.2025]

Im Zuge des Hochwasserereignisses vom 12. bis 20. September 2024 wurden in einem Gebiet zwischen Mostviertel und Wienerwald Rekordmengen von 300 bis über 400 mm in 5 Tagen (12.9.2024 – 16.9.2024) registriert (Fig. 4). Dort fiel in 5 Tagen mehr als das 5,5-fache der langjährigen mittleren Monatssumme eines Septembers. In den Flussgebieten unterhalb von 1.000 bis 1.200 m Seehöhe führten die intensiven und lang anhaltenden Niederschläge zu einer raschen Sättigung der Böden, sodass ein Großteil der Niederschläge sehr rasch abflusswirksam wurde. Dies führte vor allem in den Schwerpunktgebieten in Niederösterreich und Wien zu markanten Anstiegen der Wasserführungen und Ausuferungen der Fließgewässer (siehe Fig. 5). Auch viele landwirtschaftlich genutzte Flächen standen unter Wasser, da das Niederschlagswasser aufgrund der hohen Niederschlagsintensität und der Sättigung der Böden nicht mehr versickern konnte. In weiterer Folge führten Dammbrüche zu zusätzlichen Überschwemmungen. So wurden in Niederösterreich in weiten Teilen des Bundeslandes 30- bis 100-jährliche Ereignisse beobachtet. An vielen Gewässern traten extreme Hochwasserspitzen mit Eintrittswahrscheinlichkeiten von deutlich mehr als 100 Jahren auf, wobei die bisher gemessenen Höchstwerte vielfach überschritten wurden. Am Pegel Zwettl-Bahnbrücke am Kamp wurde erneut ein mehr als 100-jährliches Hochwasserereignis registriert, die Durchflussmenge blieb jedoch unter den Höchstwerten von 2002. Die damaligen Hochwasserscheitel hatten eine Eintrittswahrscheinlichkeit von einmal in 1.000 bis 1.500 Jahren am 7. August 2002 und von 500 Jahren am 13. August 2002. Extreme und deutlich über einem 100-jährlichen Ereignis liegende Werte wurden auch in Wien an der Liesing und insbesondere am Wienfluss registriert.

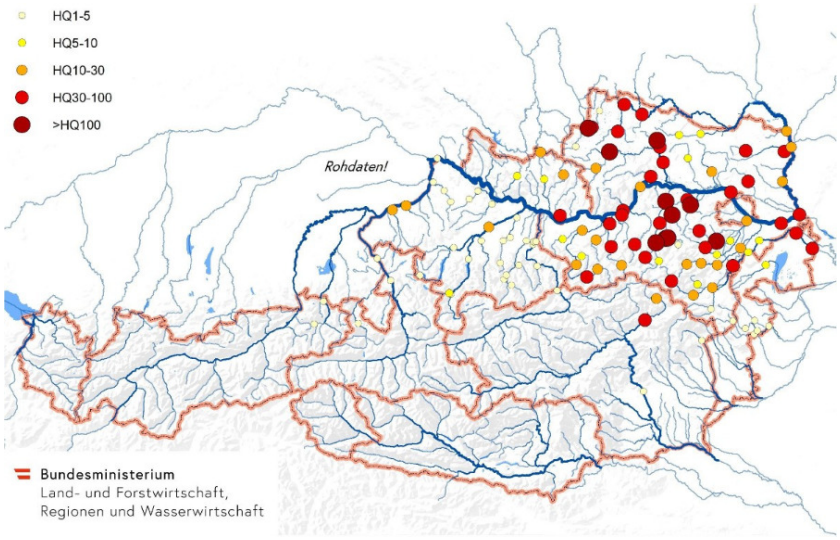

Fig. 5: Maximale erreichte Jährlichkeiten der Hochwasserscheitel an ausgesuchten Pegeln im Zeitraum 14.09.2024 bis 20.09.2024 (Datengrundlage: Hydrographie Österreich)[4]

Der innerstädtische Bereich rund um den Wienfluss wurde hier auch als prototypischer Anwendungsfall für die Near-Real-Time Analyse gewählt, um die Personendichte im Zuge des Hochwasserereignisses des September 2024 analysieren zu können.

Im Zuge der Erweiterung des Mobilfunk-Datenstreams konnten so Analysen für eine Near-Real-Time Anwendung mit einem Zeitverzug von 15 Minuten erarbeitet werden. Mit der Weiterentwicklung hin zu einer Near-Real-Time Anwendung können die bislang tagesaktuellen, stündlichen Expositionsdaten noch schneller und zeitnäher aufbereitet werden. Near-Real-Time ermöglicht es, das Personenaufkommen an bestimmten Standorten und kritischen Infrastrukturen (Brücken, Staudämme, etc.) mit nur wenigen Minuten Verzögerung zu beobachten und zu analysieren. Nahezu in Echtzeit kann so die Frage beantwortet werden, wie viele Besucher sich gerade an einem kritischen Ort aufhalten und im Notfall, z. B. im Zuge eines Hochwasserereignisses, kann auf dieser Datengrundlage zeitnah reagiert und entsprechende, zielgerichtete und sicherheitsrelevante Maßnahmen ergriffen werden. Diese Entwicklungen begünstigen zudem auch eine zeitgerechtere Trendbestimmung des Personenaufkommens, fundiertere Entscheidungsfindung in Ausnahmesituationen und ein nachhaltigeres Ressourcen- und Risikomanagement.

[4] https://info.bml.gv.at/themen/wasser/wasser-oesterreich/hydrographie/chronik-besonderer-ereignisse/hochwasser-september-2024.html [Stand: 06.02.2025]

Fig. 6 zeigt das Real-Time Dashboard. Hier wurden die Personendichten in einem 150x150m Raster im Bereich des Wienflusses auf Höhe des Donaukanals in Near-Real-Time analysiert. Dieser Bereich war neben mehreren anderen Stellen in Wien entlang des Wienflusses akut vom Hochwasserereignis im September 2024 betroffen. Die ausgewählte Rasterzelle umfasst hier den Bereich der Aspernbrücke und weist eine Personenanzahl von 3.630 Personen (bereits auf Zehnerstellen gerundet) auf. Die Anzahl der Personen kann auch als Ganglinie über die letzten 24 Stunden aufgetragen werden. Dabei ist zu beachten, dass im Zeitbereich zwischen 0 Uhr und 4 Uhr morgens täglich eine Neuanonymisierung der Handy-IDs erfolgt. Hier sink die Ganglinie kurzfristig auf den Wert 0. Aus Anonymisierungsgründen werden Rasterzellen mit weniger als 20 Personen nicht weiter spezifiziert und hier nur der Wert <20 für die jeweilige Rasterzelle ausgegeben. Die hier dargestellten Raster entsprechen einer Kantenlänge von 150m. Je nach Anwendungsfall ist auch eine Rasterdarstellung von 300x300m oder eine bezirksfeine Gebietseinteilung möglich.

Neben der Ausgabe der Personendichte existiert im Hintergrund für jede Rasterzelle auch ein historischer Datensatz. Mit Hilfe von Differenzberechnungen können diese historischen Mittelwerte der Rasterzellen mit der aktuellen Personendichte derselben Rasterzelle verglichen und darauf aufbauend bei Überschreitung bestimmter Schwellwerte eine Anomaliedetektion durchgeführt werden. Diese Anomaliedetektionen bieten ein hohes Potential in Zeiten extremer Wetterlagen bei der Beobachtung von zu evakuierenden Gebieten und können gezielt in die akute Maßnahmen- und Einsatzplanung einfließen.

Neben der hochgerechneten absoluten Anzahl der Personen in diesen einzelnen Rasterelementen können auch soziodemografische Datensätze einbezogen werden, die aus den Vertragsdaten der Mobilfunkdaten hochgerechnet werden. Die Hochrechnung erfolgt regional nach dem Wohnort der einzelnen Entitäten. Die soziodemografischen Informationen der Personen umfassen dabei neben der Altersstruktur auch das Geschlecht der Personen. Aus den Informationen der Roamingkunden lassen sich auch die Herkunftsländer klassifizieren und werden mit ausgegeben. Aus Anonymisierungsgründen wird auch hier die Anzahl der Personen immer auf die Zehnerstelle gerundet.

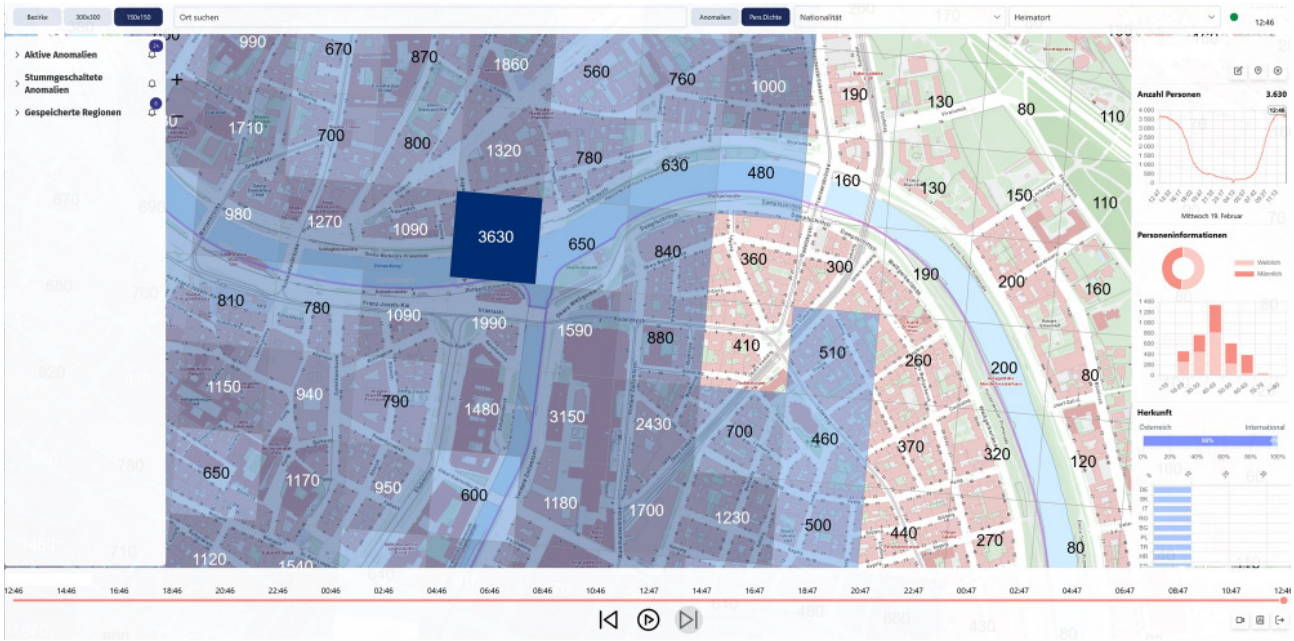

Fig. 6: Analyse der Personendichte in Near-Real-Time in 150x150m-Raster im Bereich Aspernbrücke (Donaukanal/Wienfluss).

Die neuen Near-Realtime-Analysen stellen einen Meilenstein in der Etablierung einer dynamischen Expositionsanalyse für die akute Betrachtung von Personenansammlungen in neuralgischen Zonen im Zuge von Extremwetterereignissen dar. Darauf aufbauend können in weiterer Folge entsprechende Vulnerabilitäts- und Expositionskarten der mobilen und stationären Bevölkerungsdichten im Sinne einer Risikokartierung dynamisch und ständig aktuell ohne lange Latenzzeiten erstellt werden. Darüber hinaus bieten die Analysen auch die Möglichkeit einer historischen Zeitreihenanalyse der Bevölkerungsdichten. Ob hier die Auflösung eines 150m Rasters eine ausreichende Genauigkeit gewährleistet, muss in weiterer Folge für unterschiedliche Gebiete mit unterschiedlichen Geländedynamiken und Bebauungsdichten evaluiert werden.

6 ZUSAMMENFASSUNG UND AUSBLICK

Gerade die Hochwasserereignisse im September 2024 haben die Notwendigkeit einer dynamischen Expositionsanalyse gezeigt. Mit den in Near-Real-Time verfügbaren Mobilfunkdaten steht dafür eine panoptische, passive Datenquelle zur Verfügung, die die notwendige räumlich-zeitliche Detailschärfe und eine permanente Verfügbarkeit für ganz Österreich aufweist. Aufbauend auf den gewonnenen Erkenntnissen und Weiterentwicklungen im Bereich der Near-Real-Time Analysen von Personendichten konnten mit der passiven Datenquelle der Mobilfunksignalisierungsdaten wichtige Lücken in der Aufbereitung von dynamischen Expositionsanalysen geschlossen werden. Durch die österreichweite, lückenlose Verfügbarkeit von Mobilfunkdaten ist auch ein flächendeckender Rollout und eine kontinuierliche Auswertung von Personendichten in Near-Real-Time für das gesamte Bundesgebiet Österreichs einfach realisierbar.

Die vorgestellte Methodik basiert auf den täglich verfügbaren Mobilfunksignaldaten, die nun auch in Near-Real-Time mit einer Zeitverzögerung von 15 Minuten analysiert werden können. Die Ausführungen beziehen sich ausnahmslos auf den Anwendungsfall der Hochwasserrisikoanalyse, die hier sehr kleinräumig auf Rasterbasis mit Zellgrößen von 500x500m bzw. 150x150m durchgeführt wurden. Neben dem Anwendungsfall der Analyse von Extremwetter- und Hochwasserereignissen sind zahlreiche weitere Anwendungsfelder denkbar, die durch eine kleinräumige und zeitnahe Analyse von Personendichten und Bewegungsströmen besser analysierbar werden. Diese Anwendungsfelder können von der Personenlenkung bei Großveranstaltungen bis hin zur Planung von Sofortmaßnahmen bei terroristischen Anschlägen reichen.

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reviewed paper

Moving from Pilot to Scale: a comparative Study of Innovate Shelter and Settlements Response Project for Urban IDPs in Mekelle and Adigrat, Tigray, Ethiopia

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1 ABSTRACT

Globally, more than half of internally displaced peoples (IDPs) have lived in urban areas as the influx exacerbated by natural and man-made shocks/disasters. Following the two-year war (2020-22) in Tigray (Northern Ethiopia), more than 2 million have internally displaced, hosted in collective centres and makeshift shelters. They are still struggling to access basic services in cities and towns that have scarce resilient and sustainable capabilities. To respond to urban IDPs for shelter and settlement provision, an innovative pilot area-based (neighborhood) approach (ABA) has been implemented in Mekelle city with a scaling up a year later in Adigrat town. This paper aims to gain insight into the scale-up type, paths, process, and management of ABA humanitarian project by comparing the performances of two experiences with the help of a selected literature review on related topics. The study is conducted using a comparative case study approach using available data from primary and secondary sources and from a quick meta-analysis. Four types of scaling-up patterns have been identified: qualitative, functional, political and organizational, each with its own dynamics and degree of context sensitivity. Three scale-up pathways include expansion, replication and spontaneous diffusion. The comparative assessment reveals that both pilot and scale-up projects attempted to apply the principles of ABA model in urban post-disaster recovery (Sanderson and Sitko, 2018), exploit the vernacular architecture system of hidmo houses, the building code and planning local culture, as well as the strong sociocultural family tie. The scaled-up project benefited from lessons learned from the pilot, such as implementation of a multi-sector approach and household-tailored shelter response, though it faded out on inclusion and exclusion criteria, selection and targeting of beneficiaries that highly contribute to the effective ABA implementation in urban settlements where a large gap between need and response still exists.

Keywords: Ethiopia, Tigray, urban IDP, area-based approach, scale-up

2 INTRODUCTION AND BACKGROUND

Every year, millions of people are forced to leave their homes with conflict and disasters as the main drivers. In 2023, a record 75.9 million people are forcibly displaced internally across the globe. Of the total, 68.3 million were displaced by conflict and violence and 7.7 million by disaster. Almost nearly half (46 percent) live in sub-Saharan Africa. Some 34.8 million people were displaced in 2023 which is up from the previous year. The biggest increase came from Sudan, currently in the midst of a bloody and disruptive civil war, followed by DRC,Somalia and Ethiopia. Ethiopia, in particular, had 2.85 million conflict and violent induced IDPs at the end of 2023. (IDMC, 2024). Tigray region, in the top north of Ethiopia, hosts the highest number of IDPs, primarily due to the 2020-22 conflict with the Federal Government: 80% were living with host communities mainly in urban areas such as Abi Adi, Adigrat, Adwa, Axum, Mekelle, Sheraro, and Shire. (UNOCHA, Ethiopia – Situation Report, 1 Mar 2024, 2024) (IOM, Ethiopia – Site Assessment Round 33 – Tigray, 2023). According to the UNOCHA, when the war intensified in 2021, 5 million Tigray people needed an urgent humnaitarian assistant and 63,110 did flee to Sudan as refugees (UNOCHA, Ethiopia – Tigray Region Humanitarian Update, 2021). Out of them, 2,036,398 become IDPs (432,358 households) in Tigray (IOM, Emergency Site Assessment: Northern Ethiopia Crisis 7, 2021).

Urban centers around the world have become a destination for millions of internally displaced people (IDPs) seeking short, medium, or long-term refuge. The international community and local governments prefer to focus on IDPs in camps and collective centres: schools, public building, disused buildings, and alike. And that, despite the fact that urban settlements become a preferable home for 6 out of 10 refugees (Crawford, 2015) and slightly half of all IDPs. (IDMC, 2015)

2.1 Area-based approaches (ABA): a shift in shelter and settlement humanitarian response

In 2010 the Inter-Agency Standing Committee (IASC) called for a 'paradigm shift in humanitarian assistance in urban areas based on a district or community-based [approach], rather than an individual beneficiary approach, so as to forge partnerships for assistance delivery and recovery with actors on the ground.' (IASC, 2010). A World Bank review on ABAs, following the 2010 Haiti earthquake, concludes that 'area-based interventions led by local authorities or communities can have wide-ranging benefits and should be encouraged' (IRC, 2015). The International Rescue Committee (IRC) also recommended that humanitarian responders should adopt "an area-based approach".And that is to coordinate the delivery of services in urban areas, to ensure coordination devices as a complement to existing governance systems, and accommodate a suitable multisectoral and multi-stakeholder approach that crises require (IRC, 2015). According to the IRC, ABA is defined as an area, or better a space, rather than a mere sector or target group. All stakeholders, services and needs are mapped and assessed, and relevant actors mobilised and coordinated with (IRC, 2015). In 2013, the global shelter cluster (GSC) called for a 'wider acceptance of a settlement approach in humanitarian responses' in its 2013-2017 strategy and ran a session called 'Towards a settlement approach: discussion on integrated programming of humanitarian responses and the role of the GSC'.

2.2 Scaling up

The concept of 'scale' is used in various scientific disciplines that attribute different meanings to it. The term 'scale' concerns the spatial, temporal, quantitative, or analytical dimensions used by scientists to measure and study objectives and processes and often understood in terms of hierarchy (Gibson et al., 2000) (Gillespie, 2004). In geography and spatial analysis, scale is a dimensional relationship between a cartographic representation and a physical reality. In our case, scale represents a biunivocal translation between two practices or contexts. It becomes a tool that allows us to conceptualize and compare two settlement patterns as responses to emergency.[1]

To achieve the vision of scale, projects develop a strategy referred to as a scaling up. Scaling up refers to efforts to bring more benefits to people over a wider geographic area: in short, more quickly, more equitably, and more lastingly. (IIRR, 2000) (Hartmann and Linn, 2008) define upscaling as "expanding, adapting, and sustaining successful policies, programs, or projects in different places and over time to reach a greater number of people." According to the scale up taxonomy adopted by (Uvin and Miller, 1994) and (Korten, 1980), essentially four different types of scaling up processes are differentiated: qualitative, functional, political, and organizational.

Types and paths of scale up
Qualitative:
spread: increasing numbers of people spontaneously adhere to the organization and its programs **replication:** a successful program (methodology and mode of organization) is repeated elsewhere **nurture:** a well-staffed and well-funded outside agency, using a specific incentive-based methodology, nurtures local initiatives on an increasingly large scale **horizontal aggregation:** a number of distinct organizations or programs combine their resources or merges **integration:** a program is integrated into existing structures and systems and in particular government structures, after it has demonstrated its potential
Functional:
horizontal (sectoral) integration: unrelated new activities are added to existing programs, or new programs are undertaken by the same organization **vertical (factoral) integration:** other components related to the same chain
Political:
information and mobilization: an organization's members or local communities are stimulated to participate in the body politic **networking:** non-permanent collaboration is created between various political organizations on political issues of joint interest **vertical aggregation:** federative structures are created to influence policy making **direct entry into politics:** grassroots organizations, or their leaders, either create a political party or join an existing one
Organizational:
diversify funding **sources** increase degree of **self-financing** through consultancy, sub-contracting, service for fee. etc. promote **skill** development develop procedures and structures allowing for **organizational learning** create **institutional variety**, both internally and externally maintain participation and accountability

Table 1: Scale up type and paths

(Larry Cooley and Richard Kohl, 2005) propose a framework for scaling up innovations, distinguishing between expansion, replication, and spontaneous diffusion:

[1] Conversation with D Patassini (research tutor), Iuav University of Venice (February 2025).

- Expansion: Scaling up within the original organization by extending services to new locations or increasing the number of beneficiaries served.
- Replication: Scaling up by other organizations, where the original model or intervention is adopted and implemented elsewhere.
- Spontaneous Diffusion: The informal spread of ideas or practices without coordinated efforts, often through networks and word-of-mouth. These categories, referred to as organizational paths for scaling up, highlight different strategies for broadening the impact of interventions.

In the context of humanitarian responses, the term “scale” or "scaling up" is used variably, encompassing aspects of development and emergency post-crisis interventions. This variability contributes to a limited body of literature specifically addressing scaling up in humanitarian emergencies, which may differ in concept and approach from development-focused scaling up. Notable contributions to this field include works by the (WHO & ExpandNet, 2010), (Edwards, M. and Hulme, D., 2002), and (Uvin, 1995).

Furthermore, the United Nations Development Programme's 2013 guidance note on scaling up development programmes presents three distinct scenarios for scaling up, as illustrated in the accompanying figure.

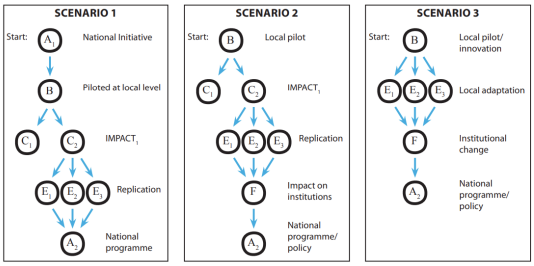

Figure 1:scenarios for scaling up (UNDP,2013)

Literature reviews and studies show that different definitions of the concept, type, and phases of the term scale up exist. However, many definitions have one centrality: that it is a move from pilot to new project in different ways/approaches.[2] The table below shows a list of summaries of the evolution of interpretation, meaning, and type of the scale-up.

Sources	Definition and/or type of scale
Korten (1980)	scaling up process as three successive stages – effectiveness (developing a solution that works), efficiency (finding a way to deliver the solution at an affordable cost), and expansion (developing a way to provide a solution on a larger scale)
Berg (1987)	organizationally, management-wise, and financially
Clark (1991)	three types of scaling-up: project replication, building grassroots movements, and influencing policy reform.The first two are linked to expansion.
Hyden (1992)	differentiates between scaling-up organizationally and functionally or activity-wise.
Howes and Sattar (1992)	"intensification" refer to addition of new activities to existing programs.
USAID,1992	scale-up as expansion of membership or target group
Fisher (1993)	scaling-up as a process of influencing policy and the term "scaling out" to describe expansion
IIRR (2000)	scaling up as effort to bring more quality benefits to more people over a wider geographic area more quicly,more equitably and more lastingly.
IIRR (2001)	scaling-up refers to vertical and horizontal interactions
Uvin 1995	four different types of scaling up process are differentiated-qualitative,functional,political and organizational
Consultative group on International Agricultural Research (CGIAR), 2000	scaling up referes to efforts to bring more quality benefits to more people over a wider georapgic area more quicly,more equitably and more lastingly.
World Bank 2003	Scaling-up: efficiently increase socioeconomic impact from a small to a large scale of coverage.
Hartmanm and Linn (2008)	Scaling up means expanding, adapting and sustaining successful projects, programs or policies in different places and over time to reach a greater number of people (originally proposed by the World Bank, but explicitly endorsed by the authors).

Table 2: Literature review and previous studies (Scale definition and types)

Following the two-year war (2020-22) in Tigray, more than 2 million have internally displaced, hosted in collective centres and makeshift shelters, exposed to struggling to access basic services in cities and towns that have less resilient and sustainable capabilities. In Tigray, 8 out of 10 IDPs are presently living in host communities, most of them in urban areas (UNOCHA, Ethiopia-Situation Report, 1 Mar 2024, 2024). In such cases, a one-size-fits-all approach to emergency shelter responses that includes standard kits such as

[2] Combinations of patterns, pathways and scenarios might draw a variety of scaling up practices (Conversation with D Patassini (research tutor), Iuav University of Venice – February 2025).

tarpaulins becomes less practical. When displacement becomes prolonged, urban IDPs attempt to transit from relief to recovery, in which an innovative and context-driven humanitarian response becomes crucial. Area-based approaches (ABA) is an alternative shelter and settlement response. It can be defined as "supporting people after a natural or manmade disaster in a given specific locations, such as a neighborhood, that help to transition effectively from relief to recovery." (Sanderson and Sitko, 2018) The innovative shelter and settlement responses so-called "an area-based approach" or "neighborhood approach" or "settlement approach" implies a similar definition and can be used interchangeably.

In 2022 and 2024, the International Organization for Migration (IOM) Ethiopia implemented both pilot and scaled-up Area-Based Approach (ABA) shelter and settlement response projects in the Tigray region, specifically in Mekelle city and Adigrat town. This study conducts a comparative analysis of these projects, aiming to assess the transition from pilot to scale-up phases and to provide insights into the types and pathways of scaling up. The analysis offers a detailed examination of the project processes, management, and performance of the ABA or neighborhood projects. The study emphasizes humanitarian response initiatives in the shelter and settlement sector, focusing on the often-overlooked internally displaced persons (IDPs) residing in urban areas within host communities.

3 NEIGHBORHOOD APPROACHN (NA) PROJECT

The neighborhood approach (NA) project is an innovative shelter and settlement response targeting IDPs who are living in host community houses. The response includes in-kind shelter construction kits and cash for skilled labor. The intent of NA project is to increase social cohesion between IDPs and host families, avoid protection-related risks, create economic opportunities, and improve access to services, such as reopening of schools occupied by IDPs. In other words, the main purpose of NA project intervention was to favor the assimilation of IDPs in the host communities. Host communities (families) would accommodate IDPs as members of their family, relatives, or friends without expecting any compensation or reward. Living together was part of the socio-cultural habit, and expected to reinforce affection and give care to each other. NA project was initially implemented as a pilot in Mekelle city by IOM Ethiopia and funded by EHF (Ethiopian Humanitarian Fund). The project work was completed within a year in 2022. On the other hand, the scale-up project in Adigrat town was also implemented by the same partner, IOM Ethiopia, but funded by BHA (Bureau for Humanitarian Assistance/USAID, now suspended). The project work was completed within a year in 2024. Both consist of the project life cycle, including initiation, planning, execution, monitoring, and closure, which is not common to emergency shelter projects during active conflict and relief (recovery) period.

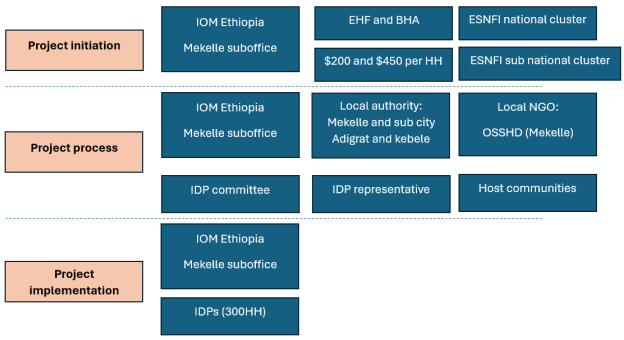

Figure 2: Project structure and flow including the stockholders mapping (illustration by: author)

Unlike other emergency shelter provision projects, which are very standard in response mode, NA pilot project implementation passed through rigorous feasibility study, house-to-house verifications and tests, demand identification and then resulted in a tailored household (HH) shelter response. NA implementation was supported by active engagement of different actors such as local authorities (mainly municipality and Bureau of labour and social affairs (BOLSA) office), local NGOs such as Organzation for social services,health and development (OSSHD), host community, IDP representative, and selection committee (which is gender-balanced). Participation level, size of committee members, and city/town administrative structure vary greatly. Stakeholders support the project in awareness creation, including providing valuable information to IDPs and host communities on project nature, response type, selection criteria, kit distribution, shelter construction, monitoring and supervision.

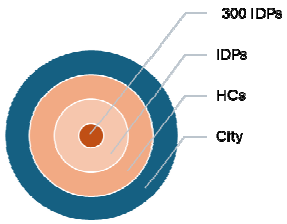

Figure 3: Project hierarchy: city, host community (HC), urban IDPs and target IDPs (abstraction: author)

Project information of the two case study:		
Project location	Mekelle	Adigrat
Implementing partner	IOM	IOM
Project title	Neighboring Approach Piloting Project	Scale up of Neighboring Approach Project
GPS coordinates	13° 29' N and 39° 28' E	14° 16' N and 39° 27' E
Project country	Ethiopia	Ethiopia
Region (province)	Tigray	Tigray
Zone	Mekelle special zone	Eastern zone
Subcity/Kebele	7 subcity	6 kebele
Donor	EHF	BHA
Budget initial	$60,000.00 ($200 per HH)	$135,000.00 ($450 per HH)
Number of beneficiaries	300 HH	300 HH
Project commencemnet date	January 2022	January 2024
Project ending date	December 2022	December 2024
Target population	Urban IDPs	Urban IDPs
IDP place of origin	Western Tigray	All zones except western Tigray

Table 3: Case study basic information

According to Sanderson and Sitko (2018), an area-based approach (ABA) or neighborhood approach (NA) do help the transition from relief to recovery. They work with existing structures and can be scaled up. (Sanderson, 2018) Five key elements of ABA are:

(1) People-centered, as meaningful engagement with affected population is essential.

(2) Focus on a defined area, such as a neighborhood.

(3) Take time, spanning relief to recovery.

(4) Can be scaled up to other areas, which emphasizes the need for local ownership.

(5) Rely on strong collaboration between sectors and key actors.

Based on the context-led project management cycle, the principles are intended by humanitarian aid agencies for naturally triggered disasters responses in urban areas. However, in this study, neighborhood pilot and scale up project have been evaluated using Sanderson and Sitko's criteria in post-war emergency and protracted displacement context.

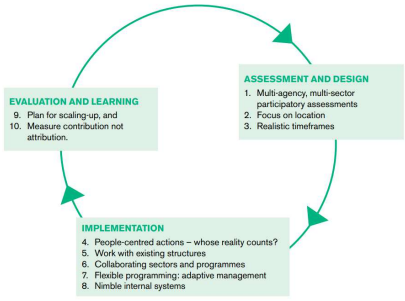

Figure 4: Core principles and criteria applied to Urban ABA in post-disaster context (Sanderson, 2018)

4 METHOD AND APPROACH

Both case study projects have been implemented as a pilot in Mekelle city in 2022 and then scaled up a year later in Adigrat town in 2024. As a result of the two-year war between 2020-22, a large number of IDPs have been influxed into different parts of the Tigray region. According to the metro area population prior to the 2020 war, Mekelle city has a population of 524,000 with an annual growth rate of 3.76 percent, and in 2022 was 565,000 with a 3.86% increase from 2021. On the other hand, Adigrat has a population of 121,776 in 2022 with an annual population growth rate of 5.1%.

Figure 5: Map of study area: Mekelle and Adigrat in Tigray region, Ethiopia (source: UNHCR via AP)

A comparative case study involves comparing multiple cases to develop explanations or generalizations. In this research, both case studies were selected based on their new nature of response, such as the pilot project in Mekelle, followed by the scale-up project in Adigrat town. Both case study projects have the same size of beneficiaries (300 HH IDP population), but different geographic locations. Mekelle is the capital city of Tigray regional state, whereas Adigrat is a town and administrative capital of an eastern zone of Tigray. The case study method explores a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time through detailed, in-depth data collection using multiple sources, reports and case themes (Creswell, 2013). The objective of comparative analysis focuses on similarities and differences in the values of variables, the shape of relations among variables, and the occurrence of events or patterns of events. In our case, the comparative analysis within the experimental framework includes the project management processes and ABA principles (assessment and design, implementation and evaluation, and learning).

According to Yin 2014 and related literature, when dealing with an extreme or a unique case, it is useful to design an empirical inquiry able to link the phenomenon with its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2014). In a multiple case study, research involves the study of several cases within a particular research framework or setting. This approach can help uncover patterns, similarities, and differences among the cases, leading to deeper insights and a more comprehensive understanding.

In case study research, data collection is a critical process that involves gathering comprehensive and contextually rich information about a specific case within its real-life setting. The objective is to achieve a deep understanding of the phenomenon under investigation. Various data collection methods are employed, including literature reviews, interviews, surveys, field notes, document and artifact analysis,focus group discussion (FGD) ,archival research, reports, and case files. Triangulation – the use of multiple data sources and methods – is applied both in data collection and analysis to enhance the credibility and depth of the findings. This approach facilitates cross-case comparisons, highlighting similarities and differences across cases.

For cross-case analysis, researchers compare data across multiple cases, employing techniques such as categorization, pattern matching, thematic analysis, constant comparative methods, and the use of comparison matrices and typologies. These methods aid in identifying generalizable patterns while also exploring the unique characteristics of each case. By systematically organizing and analyzing the data, researchers can draw meaningful conclusions and develop logical strategies that inform both theory and practice. This comprehensive approach to data collection and analysis ensures that case study research provides valuable insights into complex issues, contributing to a nuanced understanding of the cases under study.

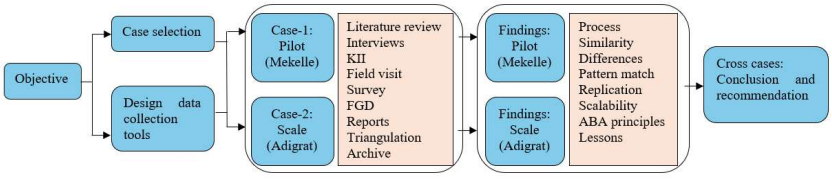

Figure 6: Research methodology (source: authors)

5 RESULT AND DISCUSSIONS

During the emergency and post-war period, the need for alternative shelter and settlement solutions, such as the NA project, is immense in Tigray, as a significant portion of IDPs live within host communities. The

transition from a pilot project to a scaled-up approach in various geographic areas by the same organization represents an expansion strategy (Larry Cooley and Richard Kohl, 2005). Each project supports 300 households (more than 2,700 individuals), consisting of urban IDPs and their paired host families.

5.1 The pilot project

The pilot project was implemented in seven sub cities of Mekelle and targeted 300 households (HH) of IDPs, comprising more than 1,500 individuals. Of the 300 households surveyed, 175 were female-headed. The age of the survey participants ranged from 18 to 75 years, with an average age of 47, and the average family size was 5. All the interviewed households shared a house with a host family. Regarding housing typology, 76% of the floors were made of cement or concrete, 50% of the walls were constructed from stone, and 90% of the roofs of CGI sheets. Mekelle is divided into seven sub cities: Adihaki, Ayder, Hadinet, Hawelti, Kedamay Weyane, Semen, and Quiha. Each subcity contains different numbers of tabiya/kebele (the smallest administrative unit in a town, lower than a subcity or woreda), with a total of 27 kebeles. According to the Key Informant Interviews (KII), the 300 beneficiaries were distributed across the seven subcities and kebeles proportionally, based on the number of IDPs, in consultation with the local government. A large number of IDPs are found in Ayder sub city, followed by Adihaki and Quiha. This distribution means that 20% of the beneficiaries are from Ayder, as it hosts the highest number of IDPs and is one of the largest sub cities in terms of surface. All the respondents (100%) stated that the durable solution for prolonged displacement is to return to their place of origin and begin recovery efforts, even though 40% of the region remains inaccessible.

The sex disaggregation in households and individuals is shown in the table below.

Indicators	Male	Female	Total
Households (HH) head	125	175	300
Individuals/total family size	718	805	1523

Table 4: Gender

The shelter response types/methods include both in-kind kits and cash. The in-kind kits consist of CGI (corrugated galvanized iron), cement, poles, nails (for structural and roofing purposes), locking systems (for windows and doors), and hinges (for windows and doors). Cash support for labor is determined based on the individual household's (HH) Bill of Quantities (BoQ), but it is aligned with three scenarios of response. According to the survey of 300 households, 25% of the households require expansion of a new shelter within the host family's house, while 45% of the households have shelter within the host family's home but need renovations, such as replacing the roof, doors, and windows. The remaining 30% of households share a house with host families, but they require rehabilitation of worn-out house components.

The three scenarios were developed based on a house-to-house survey and tailored into kits according to the available space within the host family's plot of land and the building materials. According to the Post-Distribution Monitoring (PDM) conducted in September 2022, with a 20% sample of households, the success rate of the project was only 40%. However, no further monitoring was conducted to assess the entire population after the PDM.

The pilot project's implementation process and design were innovative in their approach and showed potential for scaling up. Documents such as the project working manuals, Standard Operating Procedures (SOP), distribution reports, final project reports, and lessons learned sessions, along with presentations conducted by the implementing partner, paved the way for scaling up the project.

5.2 Scale up project

Like other towns in Tigray, most of the IDPs in Adigrat town were found in collective centres (primary and secondary schools), host communities (across six kebele), and a planned camp called the Ex-UNMEE (United Nations Mission in Ethiopia and Eritrea) camp. Following the 2022 pilot project in Mekelle, IOM conducted the first scale-up of the ABA project in Adigrat town, located about 120 km north of Mekelle. The scale-up project began with a feasibility study and followed the same project management process as the pilot project.

The project targeted 300 households (HH) of IDPs, or 1,200 individuals, who were living with host families. The age of the survey participants ranged from 18 to 100 years, with an average age of 59, and the average family size was 4. According to the house-to-house survey, the housing typology, size, and required shelter

interventions were identified. Regarding housing typology, 70% of the IDPs lived in host family houses, with plot sizes ranging from 175 to 250 square meters. The houses were predominantly made of stone walls, concrete floors, and CGI (corrugated galvanized iron) roofs. Similar to the pilot project, all respondents (100%) stated that the durable solution for prolonged displacement was to return to their place of origin and begin recovery efforts.

The sex disaggregation of households and individuals is shown in the table below.

Indicators	Male	Female	Total
Households head	161	139	300
Individuals/total family size	590	610	1200

Table 5: Gender.

Adigrat is divided into six kebele. The allocation of the 300 households (HH) was based on the number of IDPs and the size of each kebele. Kebele 04 received 30% of the beneficiaries, the highest allocation, followed by kebele 05. Adigrat's local authorities, the IDPs' representative committee, and the selection committee were actively involved in implementing the project from the outset.

Both the pilot and scale-up projects used similar response types/methods, which included in-kind assistance and cash support. The in-kind shelter kits contained CGI (corrugated galvanized iron), cement, nails (for structural and roofing purposes), hinges (for doors and windows), and locking systems (for doors and windows). Cash support for labor was determined based on the individual household's Bill of Quantities (BoQ).

Unlike the pilot project, the scale-up project included an additional sector focused on WASH (water, sanitation, and hygiene), with components such as dignity kits and latrine slab cover. Tailored responses were provided for each household to ensure that the interventions were unique and context-specific, in contrast to the pilot project, which primarily focused on three scenarios: expansion, renovation, and rehabilitation.

5.3 Similarities and differences

Comparative analysis examines the similarities found in different situations or cases that share common elements, while also highlighting the differences between them. Comparative project analysis:

Project objective	To provide an alternative emergency shelter and settlement solution for IDPs who are being hosted by or sharing accommodation with host communities in urban areas.
Target	Urban IDPs found in host family and/or host community.
Implementation tools used	Feasibility study, project plan and schedule, intention survey, various meetings, official correspondence, notices, formats, templates, and scenario/kit development were all part of the process. In the scale-up project, Google Maps was also used to georeference each household's location, which later facilitated monitoring and supervision activities.
Project structure	The project's structure includes the implementing partner, donor, ESNFI cluster (both national and subnational), IDPs (beneficiaries, representative committee, and selection committee), local authorities (municipality, subcity, and kebele), and the host community, all of whom were actively involved during the project initiation and implementation process. In the pilot project, a local NGO called OSSHD was also engaged during the first phase of the project to support grassroots awareness creation and sensitization on the project's nature and response types.
Shelter responses type/methodology	Both in-kind shelter kits and cash-based intervention (CBI) for skilled laborers.
Project management process	Includes following milestone activities: Local authority, IDP & host community engagement Intention and housing typology survey Conception of individual typologies of responses HLP (housing, land, and properties) verification, beneficiary sensitization, and grouping Distribution of kits and cash Post-distribution monitoring (PDM) Shelter construction Supervision and monitoring
Challenges	Operational challenges such as delay of procurment, industrial materials inflation and inconsistent support from local authorities.

Table 6: Similarities.

The scaled-up project primarily benefited from lessons learned during the pilot phase, such as the implementation of a multisector approach encompassing shelter, settlement, and WASH sectors, as well as household-tailored shelter responses. However, it faced challenges in the selection and targeting of beneficiaries, which are crucial for the effective ABA implementation in urban settlements, where there is a

significant gap between needs and responses. The pilot project targeted IDPs in urban areas originating from inaccessible regions, mainly Western Tigray.

ABA principles application and and project management process	Pilot project-Mekelle	Scale up project-Adigrat
Multi-agency and multi-sectoral sectoral participation	One main partner (IOM), one local partner (OSSHD), and one sector (shelter and settlement)	One partner (IOM) and multi-sector (shelter and settlement and WASH)
Focus on location	Geographical area / area-based /neigborhood responses rather than individual IDPs (Mekelle)	Geographical area / area-based /neigborhood responses rather than individual IDPs (Adigrat)
Responses nature and type	Cluster-based scenarios have been developed for the expansion of new shelters, renovation of existing shelters, and rehabilitation of worn-out shelters.	Tailored and contextual responses have been provided based on household demand, including new shelter construction, renovation, and rehabilitation scenarios.
In-kind shelter response	Based on three scenarios	Based on individual household (HH) BoQ
Cash response	Unconditional, one-time cash payments have been provided for the purpose of skilled labor.	The cash response comprises two phases: the first involves unconditional cash transfers, and the second provides conditional cash transfers based on pre-agreed performance criteria related to shelter construction.
Use of local building materials and constructions	Stone and hollow concrete blocks (HCB) are the dominant building materials for house construction.	Stone, hollow concrete blocks (HCB), and mud blocks are the dominant building materials for house construction.
Settlement type	IDPs are found in planned settlements with host families and communities plot.	IDPs are found in both planned and informal settlements in urban and peri-urban areas.
Impact of IDP returnee exercises	No returnee exercises were conducted during the blockade and siege in 2022.	Two rounds of returnee exercises led by partners and the government affected the project.
Inclusion and exclusion criteria for beneficiaries	Only IDPs from inaccessible areas, primarily from West Tigray, are included.	None
Selection and targeting of beneficiaries	IDPs with vulnerability.	IDPs from both accessible and inaccessible areas, including those with vulnerabilities.

Table 7: Differences

Figure 7 (left): A mud block shelter constructed by IDP on a host family's plot in Adigrat (source: author 2024). Figure 8 (right): A CGI shelter constructed by IDP on a host family's plot in Mekelle (source: author 2022)

6 CONCLUSION

The study offers a comprehensive understanding of innovative shelter and settlement response projects for urban IDPs in Mekelle city as a pilot and scaled-up initiative in Adigrat town. It aims to compare the implementation processes of both projects and examines the transition from pilot to scale. Scaling up seldom occurs as a one-dimensional process; rather, it involves multiple dimensions. Consequently, four distinct types of scaling-up processes – qualitative, functional, political, and organizational – have been identified, each associated with different organizational pathways: expansion, replication, and spontaneous diffusion.

The findings of this study indicate that both qualitative and functional scaling-up processes were implemented during the transition from pilot to scale in the NA projects. These processes involved adding beneficiaries in new geographical locations, executed by the same organization using the same methodological approach. Strategies such as spread, replication, and horizontal integration were employed to facilitate the smooth scalability of the projects. The scaling scenarios revealed that local innovation projects typically commence at the grassroots level, followed by local adaptation and institutional change, eventually evolving into national programs or policies. The comparative assessment of the process and implementation of ABA model for urban post-disaster recovery (Sanderson and Sitko, 2018) indicates that both projects endeavored to apply ABA principles, though there were challenges in fully implementing all aspects. The scaled-up project benefited from lessons learned during the pilot phase, such as the integration of a multisectoral approach, including WASH, and tailored responses based on comprehensive house-to-house assessments. Both projects leveraged the sociocultural family ties among IDPs and host families, which enhanced social cohesion. The ABA responses capitalized on the advantages of vernacular architectural

systems, notably the use of locally available building materials like mud blocks in Adigrat and the traditional "hidmo" construction method for shared stone walls. Additionally, adherence to building codes and proclamations, such as regulations governing the built-to-open-space ratio on plots and building footprints, was observed.

This paper offers valuable insights for humanitarian partners in the shelter and settlement sector, as well as for program and policy makers involved in emergency and post-crisis periods. Shelter partners can draw lessons from the innovative pilot project and its subsequent scaling-up strategy, processes, and pathways. Many projects fail to scale up after the pilot phase due to inadequate planning tools and the absence of structured steps, such as developing a scale-up plan, establishing preconditions for scaling up, and effectively implementing the scaling-up process. This study achieves its objectives by collectively addressing project management processes and ABA principles (Sanderson and Sitko, 2018), including assessment, design, implementation, and evaluation and learning. These insights directly contribute to the paradigm shift needed in shelter and settlement responses in urban areas, as advocated by the Inter-Agency Standing Committee (IASC), the Global Shelter Cluster (GSC), and donors.

The comparative study is limited to two projects – a pilot project and its subsequent scaled-up version – implemented in different towns. Therefore, the findings may not be broadly generalizable. Future research could expand the number of case studies to enhance the robustness of the conclusions. Despite this limitation, the study offers significant contributions. The pilot project introduced innovative approaches in post-war crisis shelter and settlement sectors, providing valuable lessons for humanitarian shelter partners, program managers, cluster coordinators, and policymakers. By employing a comparative study approach, the research highlights similarities and differences in variables and patterns, enriching the understanding of effective strategies in this field.

7 ABBREVATIONS

ABA	Area-based approach
BHA	Bureau for humanitarian assistance
BOLSA	Bureau of labour and social affairs
BoQ	Bill of quantities
CGI	Corrugated galvanised iron
EHF	Ethiopian Humanitarian Fund
ESNFI	Emergency Shelter and Non-Food Items
FGD	Focus group discussion
GSC	Global shelter cluster
HH	Households
IDP	Internally displaced people
IOM	International Organization for Migration
IRC	International Rescue Committee
IASC	Inter-Agency Standing Committee
KII	Key Informant Interviews
NA	Neighborhood approach
NGO	Nongovernmental organization
SOP	Standard Operating Procedures
OSSHD	Organzation for social services,health and development
PDM	Post-distribution monitoring
WASH	Water, sanitation and hygiene

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reviewed paper

Navigating the Margins: The Interrelationship between Public Urban Open Spaces and Homelessness

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1 ABSTRACT

Open spaces, such as parks and streetscapes, play a vital role in fostering social interaction, environmental sustainability, and community well-being. However, in developing countries, these spaces are increasingly intersecting with the complex and persistent issue of homelessness. This study explores the interrelationship between public urban open spaces and homelessness, focusing on spatial, social, and policy dimensions. The study employs a mixed-method approach, combining interviews and spatial datasets. Key findings reveal that open spaces serve as vital refuges for the homeless community, providing temporary shelter and opportunities for social interaction. Scavenging and intermittent aid are crucial components of survival strategies, highlighting the pressing need for consistent support. However, these spaces have become contested sites, as seen through the implementation of anti-homeless design elements by various stakeholders, such as municipal authorities and local businesses, often to the detriment of the homeless population. In conclusion, the study emphasizes the need for collaborative efforts involving governments, businesses, charitable organisations, and the community to address the multifaceted challenges faced by homeless individuals in urban spaces. It provides critical insights for urban planners, policymakers, and social advocates aiming to reconcile competing demands in public spaces, thereby contributing to more sustainable and equitable urban environments.

Keywords: homelessness, sustainable, Open space, spatial, social

2 INTRODUCTION

There has been an increase in conflict between homeless people and those who are housed about the use of public areas, which led to attempts to restrict the public space usage of homeless people (Addo , 2018). The use of open spaces by the homeless such as plazas, streetscapes, and parks is often viewed as an issue of social concern (Kingery & Brown, 2019). Homeless people spend most of their lives on the streets without access to basic needs like potable water and sanitary facilities. For homeless individuals, maintaining personal hygiene can be difficult because clean water is scarce (Padgett & Priyam, 2019). As a result, homeless persons who do not have access to basic amenities like toilets may end up pissing in public areas (Mahlangu & Kgadima, 2021). According to the body of research, homelessness-related issues like begging and littering among housed residents frequently worsen when homeless persons are visible on the streets and in public urban spaces. This creates discomfort and affects general safety in addition to posing aesthetic and environmental problems.

There are no reliable statistics available regarding homelessness (Speak , 2019). It is estimated that at least 150 million people, roughly 2% of the world's population, are homeless. (World Economic Forum , 2021). The statistical data highlights a remarkable population increase for Pretoria of 36.28% from 2001 to 2011 (Statistics South Africa, 2023). The most recent statistical data indicates a substantial 38.33% population growth from 2011 to 2022 (Statistics South Africa, 2023). Specifically, in 2001, the population of the City of Tshwane was 2,143,869, which increased to 2,921,488 in 2011 (Statistics South Africa, 2023), and then surged to 4,040,315 by 2022 (Statistics South Africa, 2023). This transformation has brought about various urban issues, with homelessness being one of the most visible and socially significant.

3 LITERATURE REVIEW

The issue of homelessness in South Africa has roots that stretch back to the apartheid era. To truly grasp the complexities of homelessness in the country, one must delve into its historical context and understand how policies enacted during the apartheid regime, have played a significant role in shaping its current state (Mashau, 2019; Mhlongo et al., 2024). As those who were displaced resisted the apartheid attempts to

enforce compliance, the result was additional forced removals and increased sulering among the dispossessed.

While the inception of homelessness in the country can be linked to policies enforced during the apartheid era, it also finds its roots in social and economic factors (De Beer and Vally, 2021). Divorce, domestic violence, health problems, disabilities, and drug addiction are examples of contributing societal factors. Furthermore, migration from rural to urban areas, which is frequently motivated by a desire to escape poverty, can result in homelessness. It is imperative to emphasize that a strong correlation exists between homelessness and poverty, mostly resulting from joblessness (Mabona, 2023).

The pathways in and out of homelessness have been considered by scholars to come from a multitude of structural and personal factors (Hodgetts and Stolte, 2016). The issue is compounded by rising unemployment rates, a shortage of alordable housing, social breakdown, and the impact of social and economic policies. Addressing homelessness begins with meeting basic needs such as food and clothing, then progresses to providing support for drug and alcohol rehabilitation (De Beer, 2015). The journey culminates in a life-change programme that nurtures an individual's personal and vocational skills, while also focusing on relapse prevention (Musakwa and Moyo, 2020).

Housed citizens perceive the homeless as a threat to public safety and the economic vitality for their cities (Toolis and Hammack, 2015). Homeless individuals find safety in public spaces, such as parks, through interaction with others experiencing the same issue (Rennels and Purnell, 2017). The presence of homeless individuals in public spaces not only alects the local residents who have homes but also places a strain on local governments responsible for overseeing those parks.

Park policies and code enforcement by local law enforcement and public safety departments are often utilised to criminalise the homeless, leading to additional legal and budgetary challenges. Rather than instituting new regulations in public parks that criminalise homelessness, policymakers should engage with the homeless population within these spaces. Listening to their concerns and collaborating to find more positive and elective solutions would be a more constructive approach (Addo, 2018). The impact of homelessness spans far beyond the individual experiencing it.

In 2021, the World Economic Forum disclosed that a staggering 150 million people faced homelessness globally (Henry, 2021). Nigeria held the unfortunate distinction of having the highest number of homeless individuals worldwide. Meanwhile, in South Africa, the homeless population was estimated to be around 200 000 (Homeless World Cup Foundation, 2020). A survey counted 4 177 homeless people in the City of Tshwane (Mabona, 2023). As many as 1.6 billion people lacked adequate housing (UN-Habitat, 2015).

Place-making theory

Place-making represents an urban design approach that places emphasis on prioritizing people over infrastructure. The primary objective is to develop public spaces that transcend mere functionality, aspiring to be environments that inspire and facilitate social interaction and cultural interchange (Urban Design Lab, 2023; Tabane et al., 2021).

The success of urban open spaces relies on the consideration of several interconnected criteria. To create vibrant urban environments, one must assess their quality using four fundamental attributes from the place-making theory thus: Access and linkages, Comfort and image, Uses and activities and Sociability (Eltarabily., 2022).

Access and Linkages: This attribute encompasses both physical access to a place and its connectivity to different transportation options. Linkages refer to the clear connections between the place and its surroundings that should encourage people to enter without obstacles (Surico, 2023). A section of Church Street in Pretoria, leading to Church Square, has been closed to vehicular traffic in order to prioritize pedestrian access and allow people to walk freely.

Comfort and Image: "Comfort" pertains to the feeling of safety, achieved through pedestrian-friendly design. It also involves providing adequate seating options, some of which should be located in areas with both sun and shade. "Image" is related to the overall aesthetic and unique qualities of a place that create a positive first impression and offer an enjoyable social experience.

Uses and Activities: A successful urban space should offer a variety of interesting activities that cater to different age groups throughout the day. The presence of a diverse range of activities and effective

management contribute to the vibrancy of a place. When a place lacks activities that engage people, it tends to become deserted and unused (Peinhardt, 2023).

Sociability: Sociability is enhanced when a place has features that encourage community connectivity. "what attracts people most is other people" underscores the importance of designing spaces where individuals can meet friends, engage in group conversations, and use the area frequently. A strong sense of adaptation to the place contributes to a pleasurable experience when interacting with both friends and strangers.

Competing interests for the same space

In many parts across the country, the legal system treats beggars and individuals compelled by their circumstances to sleep in the streets and public areas as offenders (Killander, 2019). The conflict between citizens with homes and those without has persisted for many years, and the issue of utilizing public areas remains a contentious subject. Alternative approaches employed by homeless individuals to sustain themselves are frequently categorized as unlawful actions and subject to legal penalties, including activities like loitering, trespassing, sleeping on public property, or scavenging (Halton, 2022). When individuals believe that parks are linked to activities with elevated risk factors that could potentially pose dangers, they often choose to stay away. (Slater, Christiana, & Gustat, 2020).

While bylaws function effectively for those with homes, they prove wholly inadequate when applied to homeless individuals (United Nations, 2023). Homeless individuals not only inhabit public spaces like the general "public," but they essentially live within these shared spaces (Bergamaschi, Castrignanò, & De Rubertis, 2014). The choice to stay in public open spaces is a rational decision and such rationality is based on the reality of the individual's situation.

The control of public space

The sight of homeless individuals in urban areas is often viewed as a disruption. It can create the impression that an "ideal city" is one devoid of homeless people loitering in the streets and public urban spaces. This perspective is particularly evident in cities such as Cape Town. 11 homeless individuals took the city of Cape Town to court, contesting the City's bylaws related to Streets, Public Spaces, and the Prevention of Noise Nuisances as well as Integrated Waste Management (Damons, 2021). The City of Cape Town proposed an amendment to fine homeless people, according to the stipulations of the "Streets, Public Places and the Prevention of Noise Nuisances By-Law (Nkhoma, 2021). In the year 2022, the City of Cape Town allocated R142 million to operate and expand the City-run safe space "facilities to accommodate homeless people" (City of Cape Town, 2022)

Homelessness carries a strong social stigma and is frequently met with punitive measures, violence, and assertive policies that infringe upon the rights of individuals rather than protecting them (Mahlangu, 2021). The multifaceted socio-cultural, economic, political, and environmental conditions in each nation significantly shape the factors contributing to and the encounters of homelessness, as well as the attributes of homeless individuals and the strategies and initiatives aimed at tackling homelessness (de. Beer & Vally, 2017).

Exploring the lived experiences of homelessness in a Cape Town suburb by Kerry-Lee Black The themes that emerged from the data clarified the complex nature of the process that leads to homelessness. Numerous causative factors interacted in a sophisticated way to impact each participant's journey towards homelessness. In a similar vein, a variety of circumstances intersected throughout their difficult effort to break free from homelessness, leading to a vicious circle of entrapment. These elements covered several societal levels, ranging from the individual to the community, the family unit, and society at large.

4 METHODOLOGY

Using qualitative research techniques, the researcher set out to explore the relationship between homelessness and public urban open spaces. Key participants comprising a total of twenty-seven (27) were interviewed. Thirteen (13) homeless people who volunteered to participate made up this number, while six (6) businesses/vendors were interviewed. Due to their frequent encounters with homeless people and the fact that they spend most of the days in Pretoria's Church Square, these vendors were recognized as prominent participants. As key participants four (4) organizations that work with the homeless population were interviewed. These organizations have years of experience working with homeless people and have frequent

interactions with them. During the data-gathering phase, other important participants were interviewed, including City of Tshwane Municipal officials, Four (4) prominent officials were interviewed.

Participant No. 1: Thirteen Homeless People

The homeless people who participated in the interview indicated that they stayed at Church Square for more than 3 years. The homeless people at Church Square, Pretoria indicated that Unemployment, Trauma, Drugs and Alcohol Use, Housing , Domestic Violence and Mental Health.

The following criteria were used to guide interviews with homeless people: how long they had been staying in Church Square; what had caused them to become homeless; their access to basic services; their ability to get food; their sense of security; their interactions with visitors; and any potential actions that could be taken to improve their stay in Church Square.

Participant No.2: Businesses operating at Church Square Pretoria

Prominent participants for this study were identified among businesses operating at Church Square Pretoria, given their significant presence in the study area. Six street vendors were interviewed. The church serves as their primary business location, with established permanent spots. Additionally, mobile vendors were also observed, such as individuals selling Maize mealies on a trolley. The interviews with vendors were conducted based on the following criteria: the selected location for their operations, their access to basic needs, the duration of their business activities, their interactions with homeless individuals, their observations of interactions among homeless people, and their interactions with visitors. The participation of those approached for interviews depended on their willingness, as the researcher sought input from individuals who were open to participating.

Participant No.3: Institutions for homeless people.

Four institutions catering to homeless individuals were interviewed, as their day-to-day experiences with the homeless were considered essential for gaining insight into the subject. Many studies have shed light on the issues of stigmatization faced by homeless individuals. The interviews with these institutions, aimed at assisting the homeless, were conducted with a focus on the following parameters: the perspective on the interrelationship between public open space and people experiencing homelessness, the types of accommodations that can ensure the dignity of homeless individuals, the facilities that should constitute public open spaces, the factors contributing to homelessness, and the perspective on whether the presence of homeless individuals causes problems.

Participant No.4: City of Tshwane Municipal Officials

Four key municipal officials responsible for overseeing the management of Church Square in Pretoria were interviewed. The purpose of these interviews was to ascertain the existence of an effective plan for maintaining the square. The interviews with representatives from the City of Tshwane were conducted with a focus on the following parameters: the establishment of the municipality's plan for managing the square, the commitment of the municipality to addressing homelessness, the strategies employed by the city to tackle homelessness, and the municipality's perspective on the interrelationship between public open space and homelessness.

5 FINDINGS AND DISCUSSION

In Church Square, Pretoria, thirteen people who were homeless were interviewed for the research. The majority gave their prolonged stay as a result of having few options, being unemployed, and having disrupted family ties. One of the challenges was getting access to basic amenities like food and restrooms. For survival, participants had to rely on scavenging, sporadic help, and piece work. The researcher found that over the course of the interviews, the homeless people were with their belongings. The majority of the homeless individuals found in Church Square were sleeping, tired and hungry. Safety problems were highlighted, particularly throughout the night, and social services were not always constant. The participants begged for empathy from the general public, stressing that stereotypes about them should not be based on their financial situation.

Institution for the homeless

In order to determine how urban open spaces and homelessness are related, the study conducted interviews with four different institutions. The results brought to light the difficulties that homeless people encounter,

such as maltreatment, a lack of trust, and a lack of municipal help. NGOs were urged to be involved, as well as to treat the homeless with decency, provide basic amenities, and deal with the underlying causes of homelessness, which include abuse, unemployment, and mental health problems. The organizations stressed how crucial it is to provide everyone with access to public areas and give homeless people the tools they need to reintegrate into society. In general, the research recommends all-encompassing enhancements to tackle the intricate problem of homelessness.

Business/vendor at the Church Square

Six Church Square businesses were interviewed and the results showed that the presence of homeless people presents serious issues. Businesses complained about how dirty the Square was and raised worries about safety, citing violent conduct from certain homeless people among other issues. As a result, foot traffic and sales decreased. In order to address the economic impact on companies and provide a safer atmosphere for both enterprises and the homeless population, the businesses stressed their everyday anxieties for personal safety and advocated for government engagement, notably the development of shelter facilities for the homeless.

City of Tshwane Municipality

Four municipal officials from the City of Tshwane were interviewed for the research about homelessness in Pretoria's Church Square. The results show that there are homeless people in the area, that there are problems with money and personnel that lead to inadequate management of urban open areas, and that these concerns are being addressed by the Adopt-a-Spot initiative. Historical and economic variables were found to be among the elements that contribute to homelessness, and there were both positive and negative dynamics in the interaction between homelessness and public places. The difficulties experienced by those who were homeless included being vulnerable to extreme weather, having little access to healthcare, and feeling unsafe. In order to solve the issues encountered by the homeless population in metropolitan areas, the study's conclusion emphasizes the need for comprehensive methods that address both immediate and underlying reasons. It also advocates for cooperative efforts including the government, communities, and companies. The image that goes with it shows a municipal worker cleaning with a high-pressure pipe because of issues including a persistent stench and human faeces.

Existing Secondary Data

The documentation that is now in existence shows how Church Square has changed over time. The Paul Kruger statue was accessible to everyone in the 2009 picture. In 2017, the City of Tshwane launched a landscaping project that significantly altered the square. This involved erecting concrete seats, trash bins, paths, and fences around the Paul Kruger statue. Trees were also planted to provide shade. Furthermore, a significant infrastructure shift was signalled by the installation of Areyeng bus lanes, which are not shown in the 2009 photo.

It is evident from the most current image, taken in November 2023, that the City of Tshwane has kept up its efforts to improve Church Square's usability. As a result of a conscious effort to meet a range of requirements, the square today provides opportunity for different people. This development points to a dedication to improving the square's use and visual attractiveness while bringing it into line with modern urban planning ideas. The continual modifications highlight the square's versatility and its function as a dynamic public area that transforms to suit the needs of the modern world.

6 RECOMMENDATIONS AND CONCLUSION

The study recommends establishing partnerships with non-profit organisation to provide steady assistance for basic necessities like clothing, food, and water. It is crucial to deal with the underlying causes of homelessness by putting policies in place that provide chances for work, drug rehab, and mental health assistance. The study recommends the installation of free, conveniently located bathrooms in public spaces and emphasizes working with local government officials to make this happen. It also recommends collaborating with governmental and non-governmental groups to locate mobile bathrooms in convenient locations.

To counteract cultural stigma, increasing knowledge and awareness of homelessness is another crucial suggestion. The study promotes media engagement, community forums, and educational activities as means

of raising public awareness. The goal is to dispel myths about the difficulties experienced by the homeless people and to promote empathy. The study proposes that in order to solve homelessness, land development policies need to be changed. It is important to include policies that help to lessen homelessness in urban planning and development initiatives and urges for the identification of homelessness in land development regulations.

Comprehensive government interventions for shelter shelters are firmly supported by the literature as a critical way to reduce homelessness. It promotes vigorous support and advocacy of broad government programs targeted at giving homeless people a somewhere to live. In order to provide resources and expertise for the development and implementation of these initiatives, collaboration with local authorities is stressed. It is suggested that the state think about allocating funding for building and land in order to support the efforts to house the homeless people.

The study emphasises the significance of education and career opportunities, the research recognizes the variety of reasons why people may become homeless. It implies that giving jobs and education can play a significant role in assisting people in moving away from homelessness by addressing both the root causes of homelessness and the urgent need for housing.

Establishing a balance between the demands of the homeless community and economic interests is crucial, and legislation that does this is recommended. It is advised to work with local government officials to promote the building of cost-free and conveniently located bathrooms in public spaces. Additionally, the study recommends collaborating with governmental and non-governmental groups to deploy mobile bathrooms in key locations for convenient accessibility.

The study emphasizes that adequate funding is required to carry out plans for cleanliness and the supply of basic services, and it suggests assigning enough staff and cash to guarantee the management of public urban open spaces. It emphasizes the value of space maintenance and community involvement initiatives like Adopt-a-Spot and argues in favour of their growth and enhancement to encourage more community involvement in improving public spaces. The study also emphasizes how crucial it is to work with businesses and non- governmental organizations to provide workable, long-term solutions to homelessness. In order to develop comprehensive and long-lasting solutions. A collaboration between the City of Tshwane, businesses, non-governmental organizations, and local stakeholders is recommended.

In order to guarantee that interventions are efficient, adaptable, and capable of meeting the ever-changing requirements of the community, the study suggests creating frequent channels for coordination and communication. This suggestion attempts to make it easier for everyone participating in the fight against homelessness to continue collaborating and coordinating, so that interventions are effective and responsive to the community's changing needs. In conclusion, the study underscored the need for collaborative efforts involving government, businesses, charitable organisations, and the community to address the multifaceted challenges faced by homeless individuals in urban spaces. Comprehensive solutions that prioritise the dignity and well-being of homeless individuals, while considering the concerns of businesses, are essential for creating a more inclusive and supportive urban environment.

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reviewed paper

Navigating the Qualitative Research Landscape: Methodological Insights from a Study on Gentrification in Johannesburg

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1 ABSTRACT

Any academic inquiry involves the application of appropriate investigative methodologies. Research methodology serves as a vital tool in understanding and addressing research problems. It is the art of exploring, explaining, and envisioning phenomena by connecting ideas, uncovering meaning and making sense of complex realities. Whilst there are several research methodological approaches , this paper explores the applicability of qualitative methodology employed in a study examining gentrification and urban sustainability in Johannesburg's Braamfontein area. Grounded in an interpretive research paradigm, the study adopted a case study research design and used applied purposive and snowball sampling to gather diverse perspectives from participants. Data collection methods included in-depth interviews, field observations, aerial photographs analysis, photographic surveys and spatial analysis, with analysis conducted through Nvivo qualitative data analysis software. The paper discusses the rationale behind methodological choices, the challenges encountered during data collection, and the strategies employed to ensure trustworthiness, including credibility, dependability, and confirmability. By examining the methodological processes used in this study, this paper aims to contribute to the broader discourse on qualitative research, offering practical insights for researchers navigating complex urban studies.

Keywords: Gentrification, qualitative research methodology, case study design, interpretive research paradigm, data collection methods

2 INTRODUCTION

Every academic inquiry requires the application of research methods and methodologies. Research methodology serves as a vital tool addressing research problems. It is the art of exploring, explaining, and envisioning phenomena by connecting ideas, uncovering meaning and making sense of complex realities (Khan et al., 2023). Every research needs to follow a clear, structured and systematic approach to ensure reliable and meaningful results. Research methodology provides the logical foundation for this process, serving as the procedural framework that guides the development of theory and the overall conduct of the study (Haradhan, 2018). The concept of gentrification can be traced back to nearly half a century, with urban geographer Ruth Glass first coining the term in the 1960s to describe the influx of upper-middle-class households purchasing and renovating properties in London's impoverished East End (Holland, 2016). Initially, gentrification was mainly observed in cities of the Global North. However, with the onset of globalization, this phenomenon has increasingly manifested in cities across the Global South (Ah Goo, 2018). Over time, a rich body of literature has emerged, documenting the extent of change and its impact on gentrified neighbourhoods. While much of this research focuses on the processes and consequences of gentrification, there remains a notable gap in works that examine the methodologies used to study this phenomenon (Loukaitou-Sideris et al., 2019).

This paper examines the applicability of qualitative methodology employed in a study on gentrification and urban sustainability in Johannesburg's Braamfontein area. The study is analysed in relation to its key objectives: (1) To assess physical changes that have taken place in the form and structure of Braamfontein over the past 20 years; and (2) To investigate the socio-economic and institutional developments emanating from gentrification processes and practices in Braamfontein neighbourhoods. This study adopts a structured and systemic approach to inquiry, drawing on the analysis of underlying assumptions (Hancock et al., 2007).

It further assesses whether gentrification, as a consequence of urban renewal, effectively contributes to urban sustainability in its broader dimensions – environmental, socio-economic, and institutional development.

This paper explores the qualitative research methodologies employed in studying gentrification and urban in Braamfontein. It begins by contextualising gentrification within broader urban transformation processes, highlighting ket theoretical debates. The discussion then shifts to a comparative analysis of research methodologies used in gentrification studies, examining the strengths and limitations of various qualitative and quantitaive approaches. The paper further delves into the interpretive research paradigm that underpins this study, explaining ist alignment with the research objectives. Following this, the research design, sampling strategies, and data collection methods – including interviews, field observations, and spatial analysis are detailed, providing insight into the study's empirical foundation. The data analysis section outlines how thematic analysis using Nvivo was applied to interpret qualitative findings, complemented by GIS-based spatial analysis to assess land use changes. Finally, the paper reflects on the challenges encountered with methodological choices and their implications, this paper contributes to broader discussions on qualitative inquiry in urban studies.

3 COMPARATIVE ANALYSIS OF RESEARCH METHODOLOGIES IN GENTRIFICATION STUDIES

While this study employed a qualitative case study approach to examine gentrification in Braamfontein, gentrification research globally has utilised a range of methodological approaches, each with distinct strengths and limitations. The choice of methodology is often shaped by the research objectives, data availability, and the sociopolitical context in which the study is conducted. Studies in the Global North and South frequently employ qualitative methodologies to capture the lived experiences and socio-cultural transformations associated with gentrification. For example, Brown-Saracino (2009), through interviews and ethnographic research in Chicago, categorizes gentrifiers into three distinct groups based on their goals and motivations: urban pioneers, social homesteaders, and social preservationists. While Loretta Lees (2003) uses ethnographic methods to examine displacement in London. In contrast, Hammel and Wyly (1996) note that most quantitative studies on gentrification take a broad, census-based approach, focusing on large-scale demographic and economic trends rather than the lived experiences of those affected. Such studies offer measurable indicators of gentrification but may overlook the nuanced experiences of affected communities. Some researchers integrate qualitative and quantitative techniques to provide a more comprehensive analysis. For example, Hwang and Sampson (2014) explore gentrification in Chicago by combining qualitative and quantitative data, drawing from census records, police reports, community surveys, city investment data, and google street view observations to capture both statistical trends and neighbourhood-level changes. While Atkinson (2019) employs both policy analysis and resident interviews to assess the intersection of governance and urban changes. The case study research design used in this research offers deep, context-specific insights into gentrification, particularly in cases driven by policy interventions and commercial redevelopment. For instance, similar qualitative research approaches have been used in studies of state-led gentrification in Shanghai (He, 2010) and Johannesburg's Maboneng Precinct (Murray, 2020). However, its broader applicability is limited for large-scale comparative studies, which could benefit from integrating spatial modelling or longitudinal demographic analysis to capture wider trends.

4 PARADIGMS ADOPTED IN THIS STUDY

This study is grounded in the interpretive paradigm, a philosophical approach that is naturalistic, anti-positivist, humanistic, and constructivist, emerging as a response to positivism in the study of human and social reality (Shah & Al-Bargi, 2013). The interpretive paradigm is particularly concerned with understanding context-dependent phenomena, emphasizing how different elements of complex environment shape what is observed and experienced. In this study, it informs the analysis of structural and physical changes that have occurred in Braamfontein over the past 20 years (Rubin & Rubin, 2011). A core assumption of the interpretive paradigm is that reality is accessed through social constructs such as consciousness, shared meaning, language, and social interactions (Myers, 2008). To capture these diverse perspectives, interviews were conducted with participants from various linguistic, racial, age, and professional backgrounds. This diversity influenced how each participant interpreted and made sense of gentrification. The study highlights how different individuals perceive the same reality – namely, the

structural and physical transformations in Braamfontein – through distinct personal lenses, shaped by their experiences and motivations (Alharahshel & Pius, 2020; Bhattacherjee, 2012).

From an ontological perspective, this study adopted a relativist stance, recognizing that multiple realities exist. The interpretivist approach supports qualitative inquiry, allowing for an in-depth examination of Braamfontein as a case study area. Within this paradigm, understanding is inherently subjective, as participants were encouraged to interpret reality based on their own experiences. This approach facilitated a rich, descriptive analysis using qualitative techniques. Furthermore, the study acknowledged the monistic relationship between the researcher and participants, where their interactions contributed to the co-construction of knowledge. Subjective engagements allowed deeper access to participants' lived realities, reinforcing the idea that the world does not exist independently of human perception but is instead shaped through experience and simultaneously encounter and influenced the reality under study (Shah & Al-Bargi, 2013; Grix, 2010).

5 RESEARCH DESIGN EMPLOYED IN THIS STUDY

This study adopted an exploratory research design to investigate a topic with limited prior research, allowing the researcher to gather new insights. The main purose of exploratory research is to develop a deeper understanding of an issue or situation. It helps lay the foundation for more detailed and structured studies in the future (Davis, 2000; Zikmund, 2000; Cooper & Schindler, 2006)This approach ensures that the evidence collected directly addressed the research question – whether gentrification as a means of urban renewal had achieved urban sustainability in Braamfontein in the environmental, socio-economic and institutional development sense. The exploratory research was conducted using a case study design, where persons with diverse experiences – those who felt the impact of change, were involved in it, or lived in Braamfontein area were interviewed through in-depth interviews. This design ensured that the issue is not explored from one lense but is rather explored through a variety of lenses, allowing for a deeper understanding and revealing various aspects of the phenomenon (Sileyew, 2019).

6 RESEARCH APPROACH

Since the study examines whether gentrification practices as a means of urban renewal are working to bring about and achieve urban sustainability in terms of environmental, socio-economic, and institutional development; a qualitative approach was adopted, where different features of qualitative data were collected.

Qualitative research takes an informative and naturalistic approach, meaning that the research often studies phenomena in their natural settings. The aim, even in this study, is to understand and interpret these phenomena through the perspectives and experiences of the people involved (Denzin & Lincoln, 2003). This study is subjective in nature and seeks to understand the social changes that have occurred in Braamfontein as a result of gentrification. Since qualitative research does not follow a rigid methodology or belong to one particular discipline – in this study, the data was presented through a variety of forms, including images, words, and sounds (Askarzai & Unhelkar, 2017). Data was collected over a long period in a real-world setting, allowing for a deeper understanding of that would not be possible through other research methods (Gay & Airasian, 2000). The data collected in this qualitative study, which will be presented in the finding's chapters, was textual, highly detailed and rich in information (Moriaty, 2011).

7 SAMPLING METHOD

A sample represents a group, where each selected component typically reflects the characteristics of a specific number of individuals in the population (Lohr, 1999). For this study, purposive and snowball sampling methods were used, which are explained in the following subsections.

7.1 Purposive sampling – its used to identify and pick on the appropriate research participants

The researcher employed purposive sampling to select participants who could provide valuable insights into the gentrification processes in Braamfontein. Participants were chosen based on specific criteria, including their involvement in the area for 10-20 years (between 2001 and 2021), such as municipal officials, business owners, residents, employees, estate agents, and developers. The purposive sampling method ensured that participants participats had relevant firsthand experience and knowledge of Braamfontein's urban transformation. This approach was both time and cost-efficient, allowing the researcher to focus on key

stakeholders directly involved in the gentrification process. Interviews were conducted primarily through virtual platforms like Zoom or Microsoft Teams, with afew in-person meetings requested by particiapnts who preferred face-to-face interaction. Before each interview, participants were informed of the study's purpose and gave their informed consent, either written or verbal. All interviews were recorded, and confidentiality was maintained by using pseudonymous and securely storing the recordings. The flexible approach to interview scheduling, taking into account participants' availability and preferences, ensured a comprehensive understanding of their perspectives on the ongoing urban changes in Braamfontein (Lewis & Sheppard, 2006).

7.2 Snowball sampling

Snowballing sampling was another method used to identify participants. As an ongoing process snowball sampling depended on time, and the selection / identification of partcipants continued until saturation was reached, meaning no new information was emerging (Naderifar et al., 2017). In snowball sampling, one participant refers the researcher to another, who then suggests a third, and so on, creating a chain of referrals (Vogt, 1999 cited in Letlape, 2018). In this study, the researcher was referred to various participants who met the criteria for the interviews. For instance, Participant A, a resident of Braamfontein, referred the researcher to Participant B, another resident of Braamfontein. In turn, Participant B referred the researcher to Participant C, a business owner in Braamfontein. Snowball sampling leveraged the social connections of the selected participants, providing the researcher with an expanding list of potential contacts. The researcher chose snowball sampling because it helped gain access to key informants who might have been difficult to locate through other sampling methods. This approach was also cost-effective, as most of the individuals referred to the researcher could be easily contacted directly via phone or email.

8 DATA COLLECTION METHODS

The primary and secondary data collected for this study provides a bridge between theory and practice, enriching ongoing debates and discourses on urban transformation while offering insights into strategies for enhancing urban sustainability in the city. Primary data was collected through in-depth interviews with key stakeholders, complemented by direct and indirect observations. Observations were conducted through site visits, systematic walking tour of the study area and remote analysis using Google Earth alongside photographic surveys to capture spatial and environmental dynamics. The interviews followed an open-ended, semi-structured format, allowing respondents to articulate their experiences, perspectives, and insights in their own words. Saturation was reached after interviewing 23 participants (see Table 1 for a summary).

Secondary data was drawn from a wide range of documentary sources, including books, scholarly articles, research papers, policy documents and urban development frameworks. Additionally, spatial data from the South African National Land Cover (SANLC) datasets were utilised to create land use maps for the years 2001, 2013 and 2021, providing a visual representation of changes in land use over two decades. These maps were instrumental in identifying shifts in land use patterns, intensification of development, and potential drivers of gentrification within the study area. Aerial photographs were also used to trace the changes from a bird's eye view of changes in structures that have occurred in Braamfontein over a period of two decades (2001, 2012 and 2021). The data collection approach functioned as a guiding framework, enabling the researcher to strategically plan and execute tasks, identify key stakeholders, and allocate time and resources efficiently (Degu & Yigzaw, 2006).

Category	Number of participants
COJ Spatial transformation official	3
COJ Land use Planner	1
COJ GIS official	1
Business owners	3
Employees	4
Residents	9
Estate agent/developer	2

Table 1: Categories of interviews

8.1 In-depth interviews

Gentrification has unfolded in different ways and at varying speeds. To understand its impact, the researcher conducted a preliminary investigation to identify key stakeholders who have directly experienced these

changes. The researcher gathered qualitative data through in-depth interviews with individuals who have been involved in local government and other relevant sectors. After conducting 23 interviews, saturation was reached, meaning no new insights were emerging. These conversations explored a range of themes, including physical, economic, social and cultural changes, as well as broader transformations in Braamfontein due to gentrification. The categorisation of interviewees is detailed in Table 1.

8.2 Field observations and photographic surveys

This study used field observations during off peak hours on weekdays, to examine the environmental, socio-economic and institutional transformations in Braamfontein driven by gentrification. By walking through selected streets, the researcher engaged directly with the evolving urban landscape, documenting physical and structural changes in a journal and capturing them through photography. To contextualise these transformations, historical photographs of Braamfontein were sourced from online archives, offering insights into the area's urban evolution. These were complemented by contemporary photographs taken during site visits, highlighting key shifts in urban space, architecture, and spatial configuration. Additional images retrieved from various online sources further enriched the visual narrative, illustrating the patterns and processes shaping gentrification in Braamfontein.

9 DATA ANALYSIS

Thematic analysis was conducted using Nvivo to systematically organise and interpret interview data. The process unfolded through the following stages:

9.1 Step1: Establishing analytical categories

The researcher developed a structured set of categories to guide the organisation and analysis of the data. These categories were identified by examining recurring themes, patterns, and concepts within the interview transcripts. The analytical categories were derived inductively from the data, allowing themes to emerge organically rather than being imposed based on pre-existing theoretical frameworks. This approach ensured that the analysis remained grounded in participants' perspectives, but it also introduced the possibility of researcher bias in the inditification of themes. The absence of a predetermined theoretical framework may have allowed for richer data interpretation, but it risks overlooking important concepts that could have emerged from an alternative, more structured approach (e.g. deductive analysis) (Braun & Clarke, 2006; Creswell, 2014). Additionally, the inductive method's open-ended nature could have led to a narrower focus on immediate patterns rather than a broader exploration of complex underlying dynamics.

9.2 Step 2: Coding and Data Organisation

Using Nvivo, the researcher manually coded the data by applying the predefined categories as labels to relevant excerpts from the transcripts. While this method ensures systematic organisation, it also introduces potential subjectivity in coding. To enhance reliability, an intercoder reliability check was conducted, where a second researcher review a subset of the transcripts to verify consistency in category application.. This reliability check improves the transparency of the coding process but relies on the assumption that coders shared similar interpretve lenses. It would have been valuable to clarify how disrepancies between coders were resolved and whether the coding process involved iterative refinement (Miles & Huberman, 1994). Additioanlly, the reliance on predefined categories may have constrained the depth of thematic discovery, especially if categories were too rigidly applied.

9.3 Step 3: Thematic Analysis

Once the data was categorized, the researcher engaged in an in-depth analysis, examining the relationships between themes, identifying underlying meanings, and tracing broader social dynamics reflected in the data. Nvivo played a crucial role in synthesising complex narratives by highlighting connections across different categories. One key example was the ability to cluster co-ocurring themes, proving a clearer understanding of economic pressures within Braamfontein. However, the software's algorithmic clustering may not fully align with human interpretation, as it lacks the nuanced judgment of a researcher familiar with the local context. This raises the question of whether Nvivo's categorisation could potentially obscure more subtle or comlex relationships, which might emerge through manual or alternative forms of analysis (Bazeley, 2007).

9.4 Step 4: Interpretation and Conclusion Drawing

In the final stage, the researcher synthesized the findings, drawing on theoretical insights to interpret the data within its broader sociological context. This involved making sense of participants' perspectives, exploring the implications of identified themes, and formulating conclusions that contribute to a deeper understanding of the research phenomenon. Acknowledging the interpretive nature of qualitative analysis, steps were taken to mitigate researcher bias, including triangulation with multiple data sources (for example interview transcripts, policy documents, and spatial data). However, as with all qualitative research, findings are shaped by the researcher's lens, and alternative interpretations may exist. While triangulation is a valuable tool to strengthen the validity of findings, its effectiveness depends on the degree of congruence between soures. In this study, contradictions across data types could have been explored more explicitly to identify underlying tensions between different perspectives or data sets (Flick, 2018).

Lastly, spatial data retrieved from the South African National Land Cover (SANLC) datasets were used to generate land use maps for the years 2001 and 2021. These maps were then analysed using ArcGIS to assess changes in land use patterns over time. While SANLC datasets provide valuable longitudinal land data, limitations include variations in resolution and classification methods across different years. These discrepancies may influence the accuracy of land-use classifications, especially when comparing data from two distinct time periods (Longley et al., 2005). To address this, spatial cross-verifications was conducted using historical aerial imagery and municipal zoning records. While this approach strengthens the validity of the spatial analysis, it would benefit from a more detailed discussion of how discrepancies between SANLC and aerial imagery were addressed. Furthermore, supervised classification and change detection analysis techniques, while powerful, can be influenced by user input and assumptions, which may affect the final outcomes (Jensen, 2005).

10 FIELD WORK REFLECTIONS

Conducting photographic surveys in Braamfontein presented significant challenges, particularly regarding the researcher's personal safety, as they were not intimately familiar with the study area when navigating it on foot. Additionally, historical visual documentation of Braamfontein proved difficult to source, as there was limited recorded literature detailing the physical and structural transformations that have taken place over the past two decades (2001-2021). Scheduling interviews was another logistical difficulty, as aligning mutually convenient times with participants was often constrained by the researcher's full-time employment and demanding schedule, as well as the time constraints of the interviewees. Furthermore, identifying long-term residents who had lived in Braamfontein for the past 10 to 20 years was particularly challenging. This difficulty stems from Braamfontein's historical function as a predominantly commercial district, where individuals commute for work rather than reside permanently. Additionally, the area's high concentration of student housing means that many residents are transient, relocating once they complete their studies. To mitigate these challenges, some interviews were conducted virtually via Zoom or Microsoft Teams – an approach that was further necessitated by the COVID-19 pandemic – while others took place telephonically, including through WhatsApp calls. Interview scheduling was adapted to accommodate participants' availability, with one interview conducted as late as 8pm and others arranged over weekends. Regarding photographic data, the study relied on a combination of images sourced from various online platforms, archival materials, and photographs taken directly by the researcher.

11 TRUSTWORTHINESS

Ensuring rigor in qualitative research necessitates establishing trustworthiness within the study. To achieve this, strategies for enhancing trustworthiness were incorporated from the early stages of the research and sustained throughout the research process (Bradshaw & Stratford, 2005). A key methodological approach employed was triangulation, which involved the use of multiple data sources, investigators, methods, and theoretical perspectives. This approach serves as a procedural mechanism through which both the interpretive and participant communities could evaluate the study's credibility and validity (Kennedy, 2015). Qualitative analysis played a crucial role interpreting the collected data by generating meaningful insights, addressing the study's central research questions, identifying thematic patterns, and recognising emerging trends (Patton, 2015). The study relied on multiple data sources to ensure a comprehensive understanding of Braamfontein's transformation over the past two decades. In addition to in-depth interviews that captured the

participants' lived experiences, land use maps and aerial photographs were analysed to identify structural and land use changes in the area. This multi-method approach enhanced the study's depth by providing both subjective narratives and spatial evidence of urban transformation.

11.1 Credibility

Credibility in this study was ensured through in-depth interviews, allowing participants to share their knowledge and lived experiences. To further strengthen credibility, interview transcripts were carefully constructed to be immediately recognisable to those familiar with the phenomenon while remaining comprehensible to outsiders (Kennedy, 2015). The study upholds credibility by ensuring that findings authentically reflect participants' perspectives and provide an accurate analysis of their experiences. Triangulation was achieved by incorporating diverse viewpoints on the physical, economic, social, and cultural transformations brought about by gentrification in Braamfontein, Gauteng.

11.2 Dependability

Dependability in research is established when future researchers can replicate the study's processes and potentially arrive at similar findings (Shenton, 2004). This study maintains methodological rigor by ensuring transparency in data collection and analysis. All interview recordings were transcribed using Otter.ai, preserving the integrity of participants' responses. Additionally, the researcher upholds academic and ethical standards by making all relevant research documents available as required by the university and ethics committee.

11.3 Confirmability

Confirmability ensures that the research findings are rooted in the data rather than the researcher's assumptions or biases. By incorporating triangulation and direct excerpts from interview transcripts, the study mitigates subjective interpretation and enhances the trustworthiness of the analysis. To uphold transparency and accountability, the researcher will make all necessary documents available as required.

11.4 Transferability

Transferability speaks to the extent to which a study's findings can be applied beyond its specific context. In the case of Johannesburg's Braamfontein there is a notable gap in the literature on whether gentrification as a means of urban renewal strategy fosters urban sustainability, particularly in terms of environmental, socio-economic, and institutional development. This gap often leads to misconceptions about the effectiveness of gentrification in achieving sustainable urban transformation. By exploring the lived experiences of those affected, this study contributes to a deeper understanding of the physical, economic, social, and cultural shifts shaped by gentrification, offering insights that may be applicable to similar urban contexts.

11.5 Ethical considerations

Ethical integrity is essential at every stage of the research process (Creswell, 2013). Ethical concerns may arise during data collection, analysis, and the presentation of findings, requiring careful attention to ensure the study's validity and credibility (Miles, et al., 2014). To uphold ethical standards, the researcher sought and received permission from the City of Johannesburg's metropolitan municipality to conduct research in municipal areas, obtaining a Gatekeeper's consent letter. Ethical approval was also secured from the University of Johannesburg's ethics committee, valid for 12 months. Participants were fully informed about the study's purpose, voluntary nature of their involvement, and their right to withdraw at any time without penalty. Consent was obtained for interview recordings, and anonymity was safeguarded using pseudonyms. Additionally, participants granted permission for verbatim excerpts to be used in the study, were informed of the expected interview duration, and were made aware that no monetary compensation was provided for participation. The researcher also sought consent to capture photographic surveys of buildings and streets where individuals might be present and obtain approval from the individual who posted the historical photographs of Braamfontein on the web for their use in the study. Through these measures, the study upheld ethical principles of transparency, confidentiality and respect for participants.

12 CONCLUSION

This study has provided a comprehensive exploration of the qualitative methodology employed to investigate gentrification and urban sustainability in Johannesburg's Braamfontein. Grounding in an interpretive research paradigm, the study adopted a case study approach, utilizing multiple data collection methods – including in-depth interviews, field observations, and spatial analysis – to capture the complexities of urban transformation. Through the lens of lived experiences, the research has highlighted the socio-economic, cultural, and institutional shifts associated with gentrification, offering a nuanced understanding of its implications for urban sustainability. By ensuring credibility, dependability, confirmability, and transferability, the study has contributed to methodological rigor in urban research, demonstrating how qualitative approaches can uncover the multifaceted nature of gentrification. The findings underscore the importance of contextualized, human-centered inquiry in assessing urban change, emphasizing that gentrification's impact extend beyond physical alterations to influence community dynamics and governance structures. Moving forward, further research should expand on these insights, exploring how policy interventions and community participation can shape more inclusive and sustainable urban renewal processes.

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reviewed paper

Planning is Local: A Systematic Review of Decentralised Urban Planning Research and Practise in the SADC Region

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1 ABSTRACT

Urban planning is vital for enhancing sustainable development and addressing urbanisation challenges. However, in the Southern African Development Community (SADC) region, planning frameworks often overlook local realities, resulting in ineffective outcomes. This study critiques the tension between utopian aspirations in urban planning, marked by idealised, standardized models, and the grounded realities of local settings. Using a systematic review methodology, the research synthesises existing literature on decentralised urban planning practices within the SADC region. The findings reveal increasing recognition of participatory planning and local governance but identify persistent gaps, such as limited incorporation of indigenous knowledge and reliance on generic models unsuited to local settings. The paper highlights the importance of localising planning processes through participatory governance, indigenous knowledge integration, and context-sensitive approaches. The work proposes a SADC Contextual Urban Planning Framework, stressing participatory planning, collaborative governance, capacity building, and sustainability. This framework aims to bridge the gap between utopian ideals and local realities, advocating inclusive, contextually relevant urban planning that aligns with regional socio-economic, cultural, and environmental conditions.

Keywords: Systematic Review, Indigenous Knowledge, Decentralisation, Localised Urban Planning, SADC Region

2 INTRODUCTION

Urban planning is a critical tool for enhancing sustainable development and addressing the complex challenges of urbanisation. However, within the Southern African Development Community (SADC) region, many planning frameworks fail to adequately reflect local realities, resulting in ineffective and unsustainable outcomes (World Bank, 2022). Urban planning has long been driven by visions of ideal cities – utopias where infrastructure, society, and the environment coexist in perfect harmony (Mihaylov & Sala, 2022). These utopian ideals often manifest in grandiose projects and standardized frameworks that, while ambitious, may overlook the nuanced realities of local settings. In the SADC region, such approaches have frequently clashed with on-the-ground socio-economic, cultural, and environmental conditions, leading to ineffective and unsustainable urban development outcomes (Cinnamon, 2023; Guma & Monstadt, 2021). This paper contends that while utopian aspirations can inspire progress, they must be balanced with pragmatic, community-centered approaches that prioritise local knowledge and participatory governance. The paper begins by exploring the historical and conceptual foundations of utopian ideals in urban planning and their influence on local settings. It then critiques the gap between these aspirations and the realities on the ground, illustrated through global and regional case studies. The paper concludes by proposing a SADC Contextual Urban Planning Framework.

3 UTOPIA IN LOCAL URBAN PLANNING

A review of global and regional urban planning models reveals a spectrum of approaches, from centralized, top-down frameworks to decentralised, participatory systems. The concept of utopia, derived from Sir Thomas More's 16th-century work, represents an idealised society where perfection is achieved in law, politics, and social conditions (Fisher, 2023). In urban planning, utopian ideals have historically driven the design of cities that aspire to embody perfect order, efficiency, and beauty (Ma, 2017). However, the imposition of such idealised models often fails to account for the complex, dynamic, and diverse nature of real-world urban settings. This work adopts a conceptual framework that critiques the uncritical application of utopian ideals in urban planning. Ebenezer Howard (1898) introduced the Garden City concept, a planned settlement featuring a central business district (CBD) at its core, surrounded by concentric rings of greenbelt

and residential areas. The design ensures accessibility through an integrated network of roads and railways along its periphery. Howard's vision aimed to merge the benefits of both urban and rural living. However, Jane Jacobs (1961) criticised the Garden City model for its rigid and detached planning approach. She highlighted the significance of community interaction, advocating for neighborhoods where people actively engage with and support one another in the planning process. In the 1890s, Daniel Burnham highlighted the importance of grand-scale planning, focusing on orderliness and harmonious design. He is renowned for advocating ambitious and visionary urban plans, believing that only bold ideas have the power to inspire and endure. His famous quote reflects this philosophy:

"Make no little plans; they have no magic to stir men's blood and probably will themselves not be realized. Make big plans; aim high in hope and work, remembering that a noble, logical diagram once recorded will not die."

He firmly believed that great plans, rather than small ones, have the potential to ignite passion and drive meaningful progress. However, based on Jacobs, and Howard; it is easy to conclude that there is no definite definition, design, or concept of a utopia, which forces us to explore utopian aspirations and realities in local settings.

3.1 Utopian Aspirations vs. Local Realities

In an attempt to explore the gap between local realities and utopian aspirations, the study focuses on the cases of Songdo City in South Korea, Sentosa Island in Singapore, and Sejong in South Korea as shown in Figure 1 below.

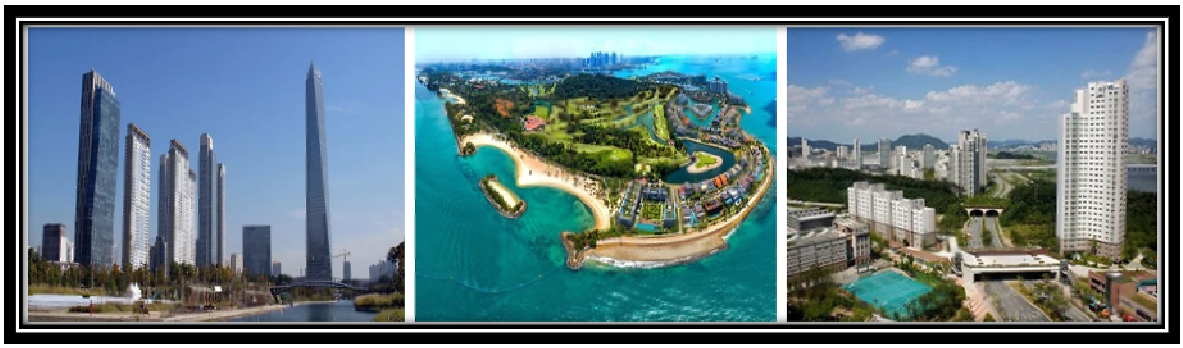

Figure 1: Case Studies. Left: Songdo City Skyline, South Korea. Centre: Sentosa Island, Singapore. Right: Sejong, South Korea.

According to Tura and Ojanen, (2022), Smart cities incorporate cutting-edge urban planning, utilising advanced technologies and sustainable practices to improve the quality of life for residents. Designed free from the limitations of existing infrastructure, they offer a blank slate for developing futuristic urban environments that transform modern living. As depicted in Figure 1, Sejong, South Korea, was designed as an administrative capital and a model city for 500,000 residents. It features cutting-edge technology, including extensive CCTV surveillance, electric buses, and autonomous vehicles. The city's master plan integrates eco-friendly initiatives such as solar-powered homes and zero-waste systems. Additionally, Sejong offers natural scenic elements, highlighted by a 1.9-square-mile central park encircling an artificial lake, which serves as a communal gathering space (Zahran, 2024). Also, in Figure 1, Sentosa, Singapore's resort island, was developed as a premier leisure and entertainment destination to attract tourists worldwide. Boasting over 240 attractions – including hotels, amusement parks, and nature trails – Sentosa offers a diverse experience tailored to families and corporate travellers alike (TTG Asia Media, 2015). Conversely, Songdo, as shown in Figure 1, aspired to be a futuristic model city, attracting a global community of residents and businesses. However, its top-down planning approach struggled to present a genuine sense of community. Despite its green buildings and technological innovations, the city was often perceived as sterile and overly corporate (Zahran, 2024). Unlike Sejong, which stressed collaborative governance, Songdo lacked meaningful public participation in urban planning, leading to a disconnect between the city and its residents. The cases in Figure 1 and the discussion above present the contrast between utopian aspirations and the limitations of local realities that include a lack of participation and collaborative governance, which can result in failed developments.

3.2 Local Knowledge as an Alternative to Utopia

In contrast to top-down, utopian planning models, approaches that value local knowledge and participatory processes have shown greater effectiveness in achieving sustainable urban development. The innovative methodological approach, known as participatory utopian sketching is conceptually grounded in a utopian framework that encourages imaginative and speculative thinking about the future. It challenges citizens to reflect on "the kinds of people [they] want to become and [the] different forms of society [they] will promote or inhibit" (Levitas, 2013). This process unfolds through four interdependent stages: 1) Experiencing the Space, 2) Sketching Utopias, 3) Sharing Utopias, and 4). The framework's key strengths include collaboration, inclusivity, creative experimentation, and an iterative process of reflection (Törnroth et al., 2022).

4 METHODOLOGY AND MATERIALS

This study uses a systematic review methodology to examine decentralised urban planning practices in the SADC region, selected for its capacity to synthesize diverse research, identify gaps, and provide a comprehensive overview of trends and challenges (Mengist, Soromessa & Legese, 2020). As shown in Figure 1 below, the review process involved three phases: a structured literature search using Scopus, Web of Science, and Google Scholar, with keywords like "decentralised urban planning," "participatory planning," and "SADC region," covering sources from 2000 to 2024.

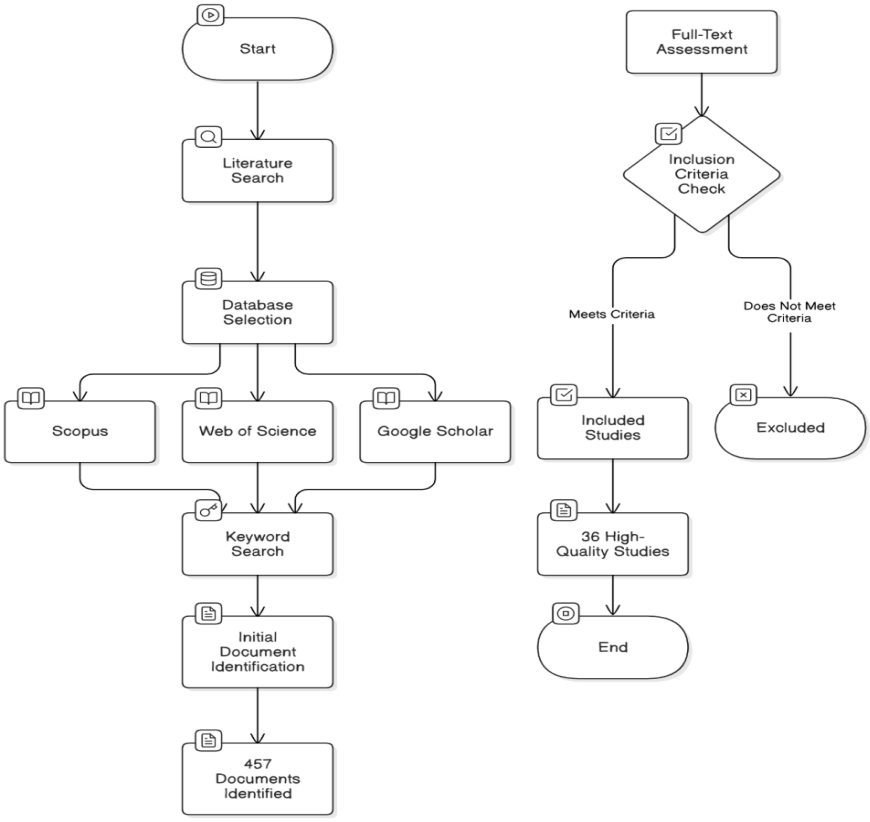

Figure 2: Research Process

The research initially identified 457 documents, which were screened through a two-step process involving a title and abstract review followed by a full-text assessment. This rigorous selection process, guided by inclusion and exclusion criteria, narrowed the pool to 36 high-quality and relevant studies. Studies were included if they focused on decentralised planning models, participatory governance, or capacity building within the SADC region, excluding those that lacked regional relevance. Thematic analysis, utilising coding techniques, was then applied to the selected studies to identify key concepts such as participatory planning, collaborative governance, and capacity building, evaluated concerning sustainable urban development principles.

5 FINDINGS AND DISCUSSIONS OF SELECTED CASE STUDY EXPERIENCES IN SOUTHERN AFRICA

The tension between utopian aspirations and local realities is evident in several urban development projects within the SADC region. Grand plans, often influenced by international models, have sometimes resulted in projects that are misaligned with the needs and capacities of local communities.

A case in point is the N2 Gateway Housing Project in Cape Town, South Africa, which was envisioned as a large-scale solution to housing shortages. However, it faced significant criticism for inadequate consultation with affected communities, leading to social unrest and legal challenges. The project was described as a "beautification project" for the 2010 FIFA World Cup, prioritising aesthetics over the needs of displaced residents (Centre on Housing Rights and Evictions, 2009). The N2 Gateway project was an initiative by the Cape Town government to upgrade the Joe Slovo informal settlement along the N2 freeway. Launched in 2004, it served as the pilot project for the Breaking New Ground Housing Plan introduced by the National Department of Housing (now the Department of Human Settlements) (Baptist, 2009). Intended to be the first of many informal settlement upgrades, the project faced significant challenges. The government adopted a top-down approach rather than a community-driven, bottom-up strategy, leading to poor communication with residents. This lack of engagement resulted in mistrust and misunderstandings about the community's needs in the upgrading process (Tissington, 2009).

In another case in 2016, the Bulawayo City Council (BCC) signed a build-operate-transfer (BOT) agreement with Terracotta to redevelop the Basch Street terminus into a multi-purpose mall (The Standard & NewsDay, 2021). There has been political discord and external interference (Zichire, 2022). Moyo (2021) also alleges that councilors mismanaged and embezzled project funds. The project's failure indicates the importance of contextualizing master plans to local contexts and involving all affected stakeholders.

In the case of the city of Manzini, Eswatini, a new taxi rank called satellite was proposed, and over E3.5 Million for the facility was paid, about 95 per cent of that amount came from ratepayers (Times of Swaziland, (2009). According to Sibisi (2012), the failure of the project was the result of not engaging community stakeholders, including commuters whose interests should have been central to the whole proposal.

In South Africa, BusinessTech, (2019), in 2014, Zendai Developments, a Chinese development firm, unveiled plans for an $8 billion (about R84 billion) smart city in Modderfontein, east of Johannesburg. The 1,600-hectare development aimed to rival Sandton with nine functional zones, including a central business district, entertainment hub, and residential and educational districts. Scheduled for completion by 2030, the project was expected to house 30,000 families and create up to 200,000 permanent jobs, contributing significantly to local economic growth and urban expansion. The project faced setbacks due to divergent visions between the developer and the City of Johannesburg. Reboredo and Brill (2019), Zendai's vision for an upscale, mixed-use development diverged from the City of Johannesburg's priorities. Instead of a luxury global hub, the city sought a more inclusive project aligned with the principles of its 2014 Spatial Development Framework. Furthermore, these spatial patterns conflicted with the objectives of South Africa's new democratic government and its efforts to address the impacts of apartheid-era planning (Reboredo and Brill 2019). The findings provide a clear need for a framework in the SADC region that advises and guides critical development in urban areas.

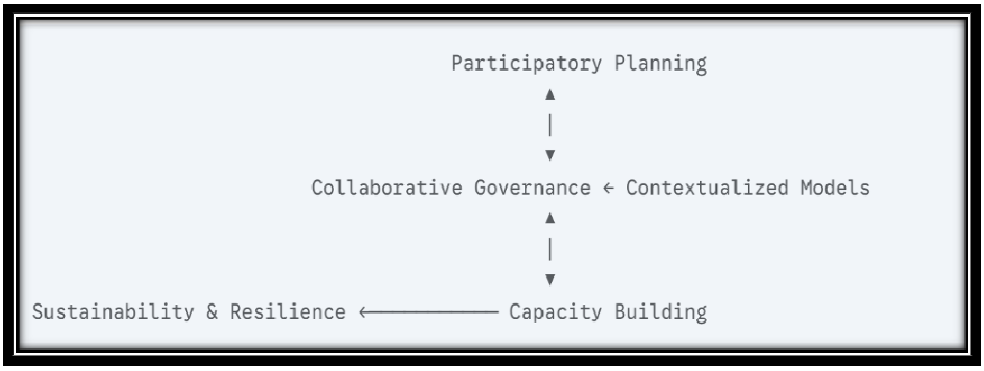

Figure 3: Hierarchical relationship between different concepts related to planning and development. Source: M. Mndzebele (2025)

6 TOWARDS A SADC CONTEXTUAL URBAN PLANNING FRAMEWORK

The SADC Contextual Urban Planning Framework is designed to guide urban development within the SADC region by prioritising local knowledge, participatory governance, and adaptive planning models. It is grounded in insights from the study's findings, which highlight the critical importance of engaging local stakeholders and aligning projects with regional priorities.

The proposed framework in Figure 2 integrates essential components essential for achieving effective, locally driven urban planning projects in the SADC region. At its core, participatory planning enhances inclusive engagement by incorporating local knowledge and community input into urban development processes, ensuring that planning initiatives align with local needs and priorities (Sebunya & Gichuki, 2024). Building on this, collaborative governance and partnerships between local governments, community organizations, and stakeholders facilitate shared decision-making, thereby enhancing transparency, trust, and accountability in the planning process (Njezula, 2024). Complementing these participatory mechanisms, contextualized models promote locally tailored urban frameworks that address unique socio-economic, cultural, and environmental conditions, enabling solutions that resonate with community realities and mitigate project failures Chang (2017). To support these efforts, Capacity Building is critical, as it strengthens local government competencies and empowers community-led initiatives through knowledge sharing, technical training, and institutional development Ndou and Sebola (2016). Together, these components drive sustainability and resilience, ensuring that urban planning frameworks address environmental challenges, promote social equity, and create long-term, adaptable urban solutions that can withstand socio-economic and environmental shocks. This integrated approach forms a robust, locally grounded framework for advancing sustainable urban development in the SADC region.

6.1 Future Research

Comparative studies across different African regions could also help identify best practices and challenges in implementing contextualized urban models, enhancing knowledge-sharing and regional collaboration for sustainable urban development.

7 CONCLUSION

The systematic review highlights the importance of localising urban planning initiatives within the SADC region through participatory approaches, collaborative governance, contextualised models, capacity building, and a focus on sustainability and resilience. The findings stress that urban planning frameworks must prioritise local knowledge, inclusive decision-making, and modified solutions to address the unique socio-economic, cultural, and environmental conditions of the region. Case studies from the SADC region further illustrate the consequences of neglecting community participation and local contexts in urban development projects. Therefore, the proposed framework in Figure 2 offers a pathway for creating more sustainable, inclusive, and resilient urban environments.

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reviewed paper

Positioning Planning: Faculty Placement and Curricular Divergence in South African Planning Schools

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1 ABSTRACT

The effectiveness of urban and regional planning education hinges on a comprehensive understanding of the complex and interconnected challenges facing contemporary cities. The institutional context within which planning programmes are situated significantly influences the perspectives and knowledge emphasized in the curriculum. This study investigates the diverse institutional placements of urban and regional planning programmes within South African universities, examining how their location within different faculties (e.g., Engineering, Humanities, Natural Sciences) shapes their curricular focus and ultimately impacts the skills and knowledge acquired by graduating planners. By analysing the relationship between institutional positioning and curriculum design, this research aims to contribute to a deeper understanding of the factors that influence the quality and relevance of planning education in South Africa. A qualitative research methodology is applied to determine possible differences between the programmes of schools in different faculties. Secondary data sources include institutional online resources and available programme overviews of respective programmes. This enables the grouping of planning schools per faculty and a curricula analysis in relation to themes inherent to SACPLAN competencies. After the application of specified criteria, four planning schools form part of the sample, two situated in the Engineering and Built Environment faculties of their institutions, and two in the faculties associated with Natural Sciences and Agriculture. The findings of the comparative analysis indicate intra- and inter-group differences and similarities in programme focus, technical emphasis, consideration of urban and rural contexts, and integration of themes like sustainability. However, factors other that faculty position may also influence said differences between planning schools, including the institutional history and spatial context. Recommendations include the implementation of a more flexible approach to programme formulation and accreditation, considering the unique institutional, historical, and spatial contexts of planning schools in South Africa. This may enable the development of competitive advantages in respective planning schools to catalyze ongoing growth and improvement in the sector.

Keywords: Urban and Regional Planning Education, South Africa , Faculty Placement, Curriculum Design, Future of planning

2 INTRODUCTION AND BACKGROUND

The twenty-first century is defined by unprecedented urban growth and complexity (UN-Habitat, 2016). Across the globe, cities are grappling with interconnected challenges, from climate change and resource scarcity to social inequality and rapid technological transformation. In this dynamic landscape, the role of urban and regional planning has become increasingly critical. As Hurlimann, et al. (2020) opine effective planning is therefore essential for creating sustainable, resilient, and equitable urban environments that can meet the diverse needs of their populations. Consequently, the field of urban planning education is undergoing a period of significant evolution. This comes as educational institutions are striving to adapt their curricula to reflect the changing demands of the profession, incorporating interdisciplinary approaches, cutting-edge technologies, and a greater emphasis on social justice (Frank and Silver, 2018). Furthermore, the diverse institutional settings in which planning programmes are situated play a substantial role in shaping their pedagogical approaches and the knowledge they impart. Whether housed within engineering faculties, social science departments, or schools of design, the dominant disciplinary viewpoints and research interests of their host faculties and institutions typically have an impact on planning programmes and their curricula. This institutional context inevitably shapes the skills and competencies of graduating planners, influencing their ability to address the complex challenges of contemporary urban life (Chen et al., 2020).

Within this global context, it is crucial to examine the particularities of planning education in South Africa. South Africa's urban landscape is marked by the enduring legacy of apartheid spatial planning, which has

resulted in deeply entrenched patterns of inequality and segregation (Letsoko et al., 2022). Furthermore, the country faces rapid urbanization, coupled with significant socio-economic disparities, creating unique challenges for urban development (ibid, 2022). Therefore, scholars such as Watson and Odendaal (2013) posit that the education of urban planners in Sub-African countries such as South Africa must be tailored to address these specific contextual factors. Consequently, the capcity for planning schools to generate graduates who can successfully negotiate the intricacies of the South African urban environment is directly tied to the caliber and applicability of their curricula, making their efficacy crucial for promoting inclusive and sustainable urban development in South African cities. This leads to the central question of how the institutional positioning of planning programmes within South African universities influences their curricular focus and, ultimately, the skills and knowledge acquired by future planners. This paper, seeks to contribute to a deeper understanding of these dynamics. By examining the diverse institutional placements of planning programmes across South African universities and analyzing corresponding curricular variations, this research aims to shed light on the factors that shape the quality and relevance of planning education in this critical context. Understanding the influences of faculty placement upon curriculum design will allow for suggestions to improve the quality of planning education and, therefore, the quality of future planners within South Africa.

3 LITERATURE REVIEW

3.1 Urban Planning education

The origins of city planning can be traced back to the earliest human settlements in most societies. However, the formal education of professionals equipped to strategically transform urban spaces is a more recent development (Frank and Silver, 2018). In the Global North, the emergence of formal planning education aligned closely with the rise of the modern city planning movement in the early 20th century (UN-Habitat, 2009). This movement was largely driven by growing anxieties surrounding the overcrowded and unsanitary conditions prevalent in rapidly industrializing European cities. A key milestone in this development was the establishment of the first-degree programme in Town Planning and Civic Design at the University of Liverpool in 1909 (Roy et al., 2015). This programme, with its emphasis on urban health and sanitation, represented the first dedicated effort to formally train urban planners. The significance of this development was further underscored by the launch of the Town Planning Review in 1910, which played a crucial role in establishing urban planning as a recognized academic discipline (Davoudi and Pendlebury, 2010). The establishment of this journal not only provided a platform for scholarly discourse but also catalyzed the development of similar programmes elsewhere, including the urban planning course initiated at the Massachusetts Institute of Technology (MIT) in the United States in 1912 (Vale, 2018). While the initial focus of the first town planning degree was specifically on town planning related issues, its nature was inherently multidisciplinary. The early pioneers of the field often came from a variety of professional backgrounds, including civil engineering, architecture, landscape architecture, surveying, public health, and law (Haghani et al.,2023). These professionals brought their existing disciplinary knowledge and experience to the field of planning, contributing to the development of interventions that drew upon a range of perspectives and as graduates of these programmes entered the workforce, they integrated their prior training with newly acquired planning knowledge, leading to innovative approaches to urban problem-solving (Silver, 2018). This served as a foundation for the evolution of planning curricula in the decades that followed. From these relatively modest beginnings, urban planning gradually emerged as a distinct discipline in the early 20th century. This took place as dedicated and standalone planning programmes began to emerge in many Western countries due to the increasing demands for specialized expertise in addressing the multifaceted problems of rapidly urbanizing societies (Silver, 2018).

In the Global South, particularly in most African cities, urban planning was introduced as a colonial imposition.This history has had a lasting impact on higher education institutions, national planning systems, and the specific urban problems faced by planners (Watson & Odendaal, 2013; Sami et al., 2022). A current debate within the field questions whether existing planning curricula are suitable for addressing the unique challenges of urbanization in the Global South given its origins. Academics have argue that the enduring influence of colonialism on planning education is evident not only in the structure of degrees and curricula, but also in the underlying values, philosophies, and teaching methods (Diaw et al. 2002; Denoon-Stevens et al. 2022; Sami et al. 2022). This colonial legacy, it is suggested, leaves graduates ill-prepared to effectively

address the realities of urban life in the Global South and to promote meaningful social and urban change within their communities. Most universities across various African nations, were largely established as a reuslt of the colonial project and inturn planning was used to service the colnoial ideologies hrough extending control over colonial territories and the planning-enabled spatial segregation of urban settlements (Njoh 2009). Thus, planning and planning education in the African continent has to be viewed against a background of the continent's colonial and post-colonial past (Sawyer 2004). Watson and Odendaal (2013) argue that South Africa's apartheid history and resources often position it as an outlier. However, its universities are not necessarily better resourced than others in Africa, and its planning system, though recently reformed, still grapples with poverty and service delivery issues common to neighboring countries. South Africa's stronger institutional capacity in planning and higher education, coupled with a more complete decentralization of local government, facilitates research funding and municipal-level planning reform, a distinction from many other African nations where decentralization efforts remain incomplete (ibid, 2013).

3.2 Curriculum Frameworks and Divergence

Given the dynamic higher education around the globe, curriculum development and reform are ongoing imperatives (Luckett and Shay, 2020). A curriculum encompasses the organized content of courses and degree programmess, the lived experiences of students, and the interactive relationship between teaching and learning (Fraserand Bosanquet, 2007). It is both a planned entity, reflecting the intended learning outcomes of courses and programmes, and a dynamic activity, encompassing the actual implementation and resulting effects of those courses and programmes (Clarence-Fincham and Naidoo, 2013). The historical record shows a strong connection between planning and planning education, and the specific institutions and societies in which they exist (e.g., Frank et al., 2014; Keller et al., 1996). Planning educators have consistently sought to update curricula to reflect evolving societal and professional needs. European urban planning education is characterized by a wide range of approaches and curricula (UN-Habitat, 2009). Frank et al. (2014) categorized these approaches into three models: planning as a specialized discipline within architecture or engineering (e.g., Spain, Italy, Netherlands, Greece); planning as an extension of social sciences, producing specialists in areas like political or applied geography (e.g., UK, Germany, Switzerland); and planning as an independent, interdisciplinary field focused on policy development (e.g., Netherlands, France, Italy, UK). These models often overlap, reflecting a trend towards multidisciplinary education. Canadian and Australian planning curricula share similar foundations due to their shared British colonial history. However, Canadian programmes, particularly in Ontario, emphasize multiculturalism and ethnic diversity (Goonewardena et al., 2004), while Australian programmes prioritize environmental sustainability (Hurlimann, 2009). In the case of the United States, Anacker (2024) highlights that in 2017, the US Planning Accreditation Board accredited 72 master's and 16 bachelor's degree programmes in planning in the US, with approximately 38 additional universities offering related, non-accredited programmes. These programmes are housed in various academic departments and colleges, including those focused on architecture, design, construction, planning, urban planning, and public affairs. While providing a general planning foundation, these programmes also allow students to specialize in areas like land use, transportation, environmental planning, small town and rural development, housing, community and economic development, historic preservation, urban design, and international development.

African planning education faces challenges related to curriculum development and research funding due to rapid urbanization, poverty, and inequality (UN-Habitat, 2009). While many sub-Saharan African countries share similar, colonial-era influenced approaches, South Africa's apartheid history and resource availability create some distinctions. Nevertheless, rapid urbanization and its associated problems are reshaping the demands placed on planners across the continent (Watson & Odendaal, 2012). Watson and Odendaal (2013) further analyzed 46 African planning schools within the Association of African Planning Schools (AAPS), revealing diverse curricular orientations. One category emphasizes technical design and physical planning, often at the undergraduate level and linked to architecture or engineering (e.g., University of Botswana, Ethiopian Civil Service College, Sudanese universities). A second category, exemplified by the Ardhi Institute (Tanzania) and Kwame Nkrumah University of Science and Technology (Ghana), has evolved from a physical planning focus to include policy and management at the postgraduate level, often retaining a design component. The most common category is a geographically, regionally, or environmentally focused approach, typically at the postgraduate level (e.g., Kenyan universities like Kenyatta, Maseno, and Nairobi,

and numerous Nigerian institutions). South Africa's eleven planning schools have diverse histories and influences, including British-influenced programmes (e.g., University of the Witwatersrand), those shaped by apartheid-era planning, and more recent "human-centered" or "developmental" approaches. Post-apartheid, South African programmes have incorporated elements of American social science planning, maintained traditional physical planning approaches, or focused on development (ibid, 2013). This indicates that The curriculum of planning education is influenced by faculty placement, which determines the focus on either technical, policy-driven, or participatory aspects of planning. In South Africa, planning curricula are aligned with SACPLAN that outlines the competency frameworks to standardize planning education however, institutional positioning affects how these competencies are interpreted and taught (Pretorious et al. 2021; Pillay et al. 2021). This suggest that while accreditation ensures baseline proficiency, faculty placement can create disparities in student competencies across universities thus curricular divergence presents challenges in standardizing planning education while ensuring diverse knowledge perspectives.

4 METHODOLOGY

A qualitative research approach is applied to achieve the objectives of the research. Inherent hereto is the analysis of available secondary data from planning schools, in the form of programme overviews and module information, to be able to determine possible differences between the programmes of schools in different faculties. The central instrument in this regard is a comparative analysis of the programmes informed by the themes associated with the South African Council for Planners (SACPLAN) competencies. This includes functional and core competencies (SACPLAN, 2014). A deductive reasoning approach is applied in this context, where the researchers' background knowledge of the various planning schools is utilised to support the interpretation of the findings (Fife & Gossner, 2024). This may contribute to the mitigation of potential limitations in the publicly available secondary data. The criteria utilised in the selection of planning schools to include in the sample are the following:

(1) Programmes at National Qualification Level (NQF) 7 and 8. This ensures a comparison of programmes at a similar level.

(2) The minimum secondary data is publicly available. This includes an overview of the faculty and programme, as well as module names.

(3) Programmes are specifically focussed on urban and regional planning, rather than a sub-field of the discipline.

(4) Programmes are accredited by SACPLAN.

The planning schools that meet these criteria are included in the sample and grouped according to faculty positioning to enable the analysis of inter- and intra-group differences. The planning schools remain anonymous throughout the analysis and discussion. Artificial Intelligence (AI) software (ChatGPT, developed by OpenAI) is employed in the initial scoping of the secondary data sourced from the various institutions and planning schools. A subsequent process of thorough verification and elaboration is applied by the researchers within the scope and context of the study.

5 FINDINGS AND DISCUSSION

This findings and discussion section is centred on the comparative analysis of planning school groups as well as a discussion on the factors that may influence programme differences between planning schools.

5.1 Comparative analysis of planning school groups

Data availability considerations and adherence to the criteria culminated in the selection of four planning schools in South Africa to form part of the secondary data analysis. Planning School A and B (Group 1) are positioned within their tertiary institutions' Engineering and Built Environment faculties, while the primary disciplinary focus of the faculties of Planning School C and D (Group 2) are associated with Natural Sciences and Agriculture. These two groups thus constitute the sample in the comparative analysis central to this paper. Based on the available secondary data on programmes overviews and modules, Table 1 provides an overview of the comparative analysis between the two planning school groups centred on their comparative focus and themes relevant to SACPLAN competencies. The latter includes the technical focus,

urban and rural focus, infrastructure and land use considerations, governance and policy, and sustainability and environmental planning.

With reference to Group 1, and as indicated in Table 1, the available data may be indicative that Planning School A is more focussed on the technical aspects of planning, including spatial analysis, as well as regulatory planning, with limited consideration for urban design components. The potential strength of the programme is centred on its emphasis on GIS, land use management, urban infrastructure, and quantitative analysis and techniques. The relative strength of Planning School B, on the other hand, may be in its focus on policy aspects with reference to economic governance, as well as aspects related to urban design. Urban governance and spatial transformation may set this programme apart from the other planning schools in the sample. Planning School B, however, potentially illustrate a limited focus on technical infrastructure development and planning. Possible intra-grouping differences may be based on the divergent focus on technical planning aspects (Planning School A) and policy, governance, and design components (Planning School B); the one potentially focussing more on spatial modelling and the other on policy development; one with somewhat limited focus on the regional scale and the other highlighting spatial transformation; as well as engineering and infrastructure interventions compared to land use and urban economics. The common features of the Engineering and Built Environment group may be its focus on the urban context, with specific reference to urban governance. Inherent to the latter is a differing technical and policy focus.

Focus	Engineering and Built Environment (**Group 1**)	Natural Sciences and Agriculture (**Group 2**)
1. Comparative focus	Primarily focussed on urban and spatial planning with specific reference to technical and policy aspects.	Comparatively focussed on land use, environmental governance, and regional development.
2. Technical focus	Comparatively strong emphasis on Geographic Information System (GIS) and design (AutoCAD), which is considered in the context of spatial planning and infrastructure development	Moderate emphasis on GIS applied potentially more in the context of land sustainability and environmental planning
3. Urban and rural focus	Significant focus on urban development, with themes that emphasise urban infrastructure and economic development.	A comparatively greater focus on the rural context, which may be reflected in the apparent focus on land governance, rural development, and environmental policy.
4. Infrastructure and land use planning	Potentially significant consideration of land use planning and infrastructure development in the context of policy and governance.	Comparatively strong emphasis land use planning in the context sustainable development in a primarily rural context.
5. Governance and policy formulation	Potentially significant focus on governance and policy development and implementation in the urban context.	Data may reflect a focus on land governance and associated policy considerations.
6. Sustainable development and environmental planning	Potential consideration of related elements in infrastructure development and policy development and implementation.	Potential consideration of related elements in land management and associated policy.

Table 1: Comparative analysis of programme focus. Source: Authors (2025).

In terms of Group 2, the available data on Planning School C may be indicative of the relative importance of land use planning, sustainable development, and environmental planning in this programme, while reducing the emphasis on urban infrastructure planning. The unique offering of this programme may be centred on environmental planning and policy. Planning School D is comparatively focussed on rural development, land reform, and regional planning. The competitive advantage of this programme may be linked to rural development and land governance. Potential differences within the Natural Sciences and Agriculture grouping are that Planning School C may be more focussed on regional and environmental planning; applies GIS in the context of sustainability; includes reference to the urban scale; and applies policy in the context of environmental management. This is compared to the relative focus of Planning School D on the rural context, with reference to rural development and land policy and governance. Similar aspects within the group may potentially be centred on their incorporation of the regional and rural spatial development context, and environmental sustainability.

In the context of inter-grouping similarities, the findings of the preliminary analysis indicate the potential for numerous similarities between the two groups. This includes the central positioning of spatial planning within the programmes as an instruments toward alleviating societal challenges, with focus on the South African built environment. Both groups include the core elements of spatial analytical techniques, including GIS, while applying said tools in different contexts. The latter may vary from land management to urban infrastructure. Urban and regional planning themes are integrated in the programmes of both groups, while different in scale and developmental milieu. The two groups both integrate aspects related to governance and

policy, while the prominence of these themes and their application are divergent. Group 1 seems to apply these competencies in the context of urban transformation, while Group 2 is more focussed on rural development. A possible difference between the groups may thus be their varied urban and rural focus, which possibly translates in divergent consideration of themes such as urban infrastructure, land use, environmental planning, and sustainable development between the planning schools of each group. This may also be reflected in the integration of themes such as sustainability in the respective programmes, which is applied in the context of urban planning in the case of Group 1, while considered in the context of land and resource management in Group 2.

5.2 Factors in curriculum differences between Planning School Groups

The discussion of the factors that may influence differences within and between planning schools in the sample is centred on their faculty positioning, as well as the respective history and spatial context of their institutions.

5.2.1 Faculty positioning

The objectives of the faculty in which planning schools are positioned in their institutions may influence their respective programmes. With regard to the Engineering and Built Environment group, the available data may be indicative that the faculty relevant to Planning School A specifically emphasises engineering, the incorporation of advanced technology, applied science, and problem-solving as outcomes of its programmes. This is possibly reflected in the planning school's technical, analytic focus and incorporation of technological applications. Based on the faculty objectives, spatial and built environment challenges may be seen as problems to be solved through the application of specific technical interventions. The faculty emphasises strong industry collaboration, which may influence the focus on practical planning applications and skills to increase the employability of graduates. The faculty of Planning School B is comparatively more focused on socio-economic and spatial transformation that has and ought to take place and planning's response thereto. This may explain the apparent focus of the programme on urban policy, economic development, and governance in this context. Providing innovative solutions relating to climate change and sustainable development is also reflected in the faculty's objectives. While Planning School A places this in the context of technical interventions, Planning School B may consider these elements in the framework of social justice and transformation.

The positioning of Planning School C in its institution's Natural Sciences and Agriculture faculty may contribute to it being environment-centred and focussed on sustainability and sustainable development. This is also reflected in the incorporation of an urban ecology component in its programme. The available data potentially indicates that Planning School D highlights the need for interdisciplinary, transdisciplinary, and multidisciplinary research, which may bring about a broader thematic focus in the programme. The faculty seeks to ensure graduate competencies are relevant to the local rural context.

5.2.2 Institutional history and spatial context

Faculty positioning, however, may be one of various potential factors that may influence differences in planning programmes. One factor of particular importance may be the context of the difference institutions, which may holistically influence teaching and learning (Hiller & Laird, 2021). Relevant in this regarding may be the history of the institution, which may continue to influence institutional resource availability and constraints (Thompson et al., 2021). This is a prominent feature of the post-apartheid tertiary education sector in South Africa, where the function of "previously disadvantaged universities" and institutions is affected by historical unequal access to finance and development (Nyahodza & Higgs, 2017:42). The related effects on teaching and learning are initially explored by Singh (2004), highlighting lasting disparities in access to resources and information and communication technology (ICT) in the sector. Respective institutions of the sample planning schools may be categorised as previously disadvantaged or now include such institutions in their organisation.

Another potential factor that determines the differences between the planning schools and the two groupings may be their divergent spatial contexts. Both Planning School A and B are situated in metropolitan areas, which may inform their propensity to focus on the urban scale, and associated considerations of economy, governance, and policy. Planning School C and D, on the other hand, are located – to a differing extent – in rural areas. This context may precipitate a more nuanced focus on rural development considerations, with

specific reference to the question of land resources, sustainability, and environmental aspects. The inherent differences in socio-economic and spatial conditions influence local development objectives and public and private sector expectations of graduate attributes. This may manifest in different forces that shape and inform the composition of and content in the various programmes in the two sample groups.

Accordingly, it is possible that the institutional history and spatial context, in addition to a planning school's faculty positioning, may influence the local interpretation, viability, and relevance of SACPLAN competencies and their subsequent incorporation in the programme of each planning school. Historic and current financial constraints may, as an example, influence the viability of the holistic incorporation of functional competencies where advanced infrastructure and resources are required. The urban or rural spatial context of the planning school may influence the relevance of certain core competencies, including environmental planning and management, land economics, regional development and planning, and land use and infrastructure planning. The faculty positioning of planning schools may also influence the institutional interpretation of these competencies and subsequent manifestation in planning programmes.

6 CONCLUSION AND RECCOMMENDATIONS

This study has explored the diverse institutional placements of urban and regional planning programs within South African universities, examining how their location within different faculties shapes curricular focus and, consequently, the skills and knowledge acquired by graduating planners. The comparative analysis of planning schools situated in Engineering and Built Environment faculties versus those in Natural Sciences and Agriculture faculties revealed potential intra- and inter-group differences and similarities in program focus, technical emphasis, consideration of urban and rural contexts, and integration of themes like sustainability. These variations, which are potentially associated with the different faculty positions of the planning schools, in addition to faculty positioning, may be attributed to the unique institutional history and spatial context of each university. The findings of the comparative analysis may be indicative of these intra- and inter-grouping differences and similarities. The study highlights the complex interplay of factors influencing curriculum design and the need for a nuanced understanding of their impact on planning education in South Africa.

A key limitation of this research lies in the limited and inconsistent availability of secondary data regarding program and module content. This constraint affected the depth and scope of the comparative analysis, influencing the detail and quality of the findings inherent to the comparative analysis, and limiting the ability to draw more definitive conclusions about the precise impact of faculty placement on specific learning outcomes. Future research is required to support the robustness of the findings and further investigate the diversity and influence of various factors in planning program composition and focus. Such research should prioritize access to more comprehensive and standardized data to strengthen the robustness of findings and further investigate the diverse factors influencing planning program composition and focus. Such research could explore student and faculty perspectives, analyze graduate outcomes, and examine the influence of professional accreditation requirements in greater detail. Based on the findings of this study, it is recommended that SACPLAN adopt a more flexible approach to accreditation and program formulation, considering the unique institutional, historical, and spatial contexts of planning schools in South Africa. The offering of planning programs ought to reflect the diversity of its institutions, all contributing to maintaining quality planning outcomes inherent to SACPLAN competencies, while enabling the development of competitive advantages in respective planning schools to catalyze ongoing growth and improvement in the sector. Recognizing these unique contexts is crucial. SACPLAN should consider these factors when evaluating programs, allowing for diversity in program offerings while ensuring adherence to core competencies. This approach would enable planning programs to reflect the specific strengths and specializations of their respective institutions, contributing to a richer and more relevant educational landscape. By fostering a system that values both quality assurance (through adherence to SACPLAN competencies) and institutional distinctiveness, South Africa can cultivate a dynamic planning education sector that produces graduates equipped to address the complex and evolving challenges facing its diverse urban and rural environments. This would encourage innovation and specialization within planning schools, ultimately contributing to the ongoing growth and improvement of the planning profession in South Africa.

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Reconnecting Academia and Practise: Curriculum Improvement in Urban and Regional Planning Education

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1 ABSTRACT

In contemporary academia, institutions of higher learning are experiencing an ideological shift as they strive to align with the Sustainable Development Goals (SDGs) while maintaining relevance within professional planning practices. Research and innovation in community-based projects have emerged as pivotal strategies to enhance planners' engagement with real-world challenges. However, curriculum improvement remains a significant undertaking, particularly as institutions aim to secure accreditation for their academic programs from professional bodies. At the University of Johannesburg, a critical gap has been identified in exposing students to real-world projects, which was previously addressed in the National Diploma program through in-service training and mentorship by professional planners – a feature not retained in the transition to the Degree program. This study examines curriculum improvement as a strategy for program accreditation, using the Department of Urban and Regional Planning at the University of Johannesburg as a case study. A qualitative research approach was employed, drawing on university documents, a literature review, and semi-structured interviews. Content and thematic analyses were applied to interpret the data. The findings highlight the potential for partnerships, such as memorandums with municipalities, to reintroduce professional mentorship for students. This mentorship program, leveraging innovative and transformative approaches, promises to achieve outstanding outcomes in teaching, learning, and research, thereby bridging the gap between academic training and professional practice. This study underscores the necessity of continuous curriculum evaluation and the adoption of innovative, inclusive, and sustainable practices. It concludes with recommendations for implementing a dynamic, future-oriented curriculum that prepares graduates to excel within the planning professional while addressing societal and global challenges.

Keywords: curriculum improvement, planning, sustainable, transformation, innovation

2 INTRODUCTION

Globally, higher education is under pressure to reinvent and transform itself. Urban planning education has faced many challenges over the last two decades, and offering education with limited resources carried this problem to another level, increasing concerns among scholars about the quality of the education and the learning outcomes a planner should possess at graduation (Mpofu et al., 2013); Carrim, 2019). While planning schools in South Africa deal with the issues above, global debates in planning education revolve around integrating topics such as digitalisation, climate change, informality, and decolonisation into the curriculum (Ndlovu & Gumbo, 2018; Xing et al., 2018; Wallin, 2010). The acknowledgment of the need for higher education to be a catalyst for sustainable development has provided the foundation required for curriculum transformation and the actual experiences and lessons learned. Seemingly, Naicker (2016) opines that decolonising university curricula and academic culture will lead to desired social transformation at the institutions.

Urban and Regional planning is a complex area of education and practices that seeks to respond to emerging social, environmental, economic and technical aspects of the built environment. Traditionally Urban and Regional planning at the core is interdisciplinary, however over the years it has emerged to become technocratic emphasising practically and quantitative approaches over critical thinking and qualitative approaches (Dawkins, 2016, Makoni, 2020). Sletto (2021) has also raised concerns about how planning is being taught in higher education institutions and how it impacts the practice of the profession in the real

world when students graduate. Similarly, Pojani et al. (2018) have articulated that teaching and learning are mainly traditional, with limited usage of emerging technological tools.

In South Africa, since the demise of apartheid, the education policy terrain has shifted remarkably fast and policies have required that higher education institutions respond to the national plan that commits universities to become cost-effective, massified institutions opening access to all who were historically excluded due to apartheid's policies of educational exclusion (Musakwa and Moyo, 2020). Furthermore student-led protests around the high cost of higher education have also introduced a new kind of pressure point on universities. The aftermath of the #FeesMustFall movement in South Africa has left higher education institutions with numerous challenges with a decrease in government funding and an increase in government control (Ajani and Gamede, 2021). To address these challenges, two contemporary concepts have emerged to inform higher education transformation discourses, namely decolonization and digital transformation. Given that curriculum transformation is not static, it may encompasses any number of themes.

Currently at the forefront are the themes of the decolonisation of teaching, learning and curriculum; and enhanced awareness of the Sustainable Development Goals (Ramrathan, 2016; Roithmayer, 1999); Bloom, 1956; Fataar & Badroodien, 2020). The depth of the emphasis in each of these varies depending on the initiatives of each university. In South Africa, decolonisation has been against the backdrop of the need to address historical, educational segregation that excluded, marginalized, stigmatized, and 'othered.' Digital transformation has aimed to address key competencies for the development of the Fourth Industrial Revolution and 21st century skills in graduates (Musonda et al., 2025; Chikukwa et al., 2025). This has led to universities in the higher education sector being required to generate strategies that broaden awareness, training, and uptake of emerging Fourth Industrial Revolution technologies such as big data, the internet of things, mixed reality, digital twin, and building information modeling. In view of the importance and urgency of transformation within post-colonial educational settings, this study examines curriculum improvement as a strategy for program accreditation, using the Department of Urban and Regional Planning at the University of Johannesburg as a case study. It specifically discusses how concepts of digital transformation and decolonisation are reimagined to meet the urban planning profession's competencies.

3 LITERATURE REVIEW

The decolonial theory understands that Western Modernity keeps imposing itself through a triple mutually reinforcing and shaping imprisonment. Decolonisation within the scope of universities is grounded on decentring using three critical concepts namely coloniality of power in education, coloniality of being focusing on the lasting impact of colonialism on a person's identity and self-perception, coloniality of knowledge focusing on knowledge production discourse. Scholars have articulated that bottom-up and top-down decolonization of higher education can be made complementary (Yang, 2012; Shivji, 1993; Venter, 2018; Moalosi, et al., 2017). Makoni (2020) advocated for a shift in understanding power relationships and conceptions of being and knowing. Additionally, lessons from Wa Thiong'o, N. (1993) writing reveal "moving the center from its assumed location in the West to multiple spheres." This then opens up dialogue from ingenious knowledge systems to be incorporated into higher education spaces. Transformation of higher education will involve unlearning traditional approaches to urban planning in order to relearn news of designing urban spaces and reimagining inclusive utopian registers.

Le Grange (2016) claims that decolonising higher education entails liberation of the present curriculum that is epistemic into "a fusion of both Ubuntu (I am because we are) and the active force of currere into the oneness of decolonised minds". This shift acknowledges the ecological importance of curriculum rather than the subjectivity of being individuals. Lessons learned reveal a shift from 'subjectivity' or individuality to a focus on the embracement of embedded learning, skills development, and critical thinking infused with indigenous knowledge systems. Thus, the curriculum becomes anchored on the attainment and promotion of respectful representation, relational accountability, rights and regulation and reciprocal appropriation.

Rediscovery and reformation of the Urban and Regional planning discipline is essential to ensure the profession remains relevant. The continuing lag in technology adoption within the planning practice is emerging as a growing concern amongst developing countries (Sayed et al., 2017; Zembylas, 2018; Turnbull, 1997). This digital divide within planning poses a considerable obstacle to fostering resilient and inclusive growth. Gumbo (2023) has articulated that the lack of deliberate focus on the digital transition in higher

education institutions in developing countries is evident in the limited adoption, use, and experimentation with technology. Conversely, the industry-driven or bottom-up approach to digitalisation relies less on government intervention, with the industry taking a proactive role in technology implementation. Additionally, professional bodies that do not have mandates for digital skills as part part of competency standards do not experience high adoption of emerging technologies. Bakama (2022) argues higher education institutions that do not have a mandate aligned with digitalisation hinder curriculum transformation and technology adoption.

In an effort to bridge the technology adoption gaps in higher education previous studies have highlighted the crucial role of government oversight, alongside financial and technical support, in fostering technology adoption rather than solely relying on mandates. Additionally, bridging the gap in access to information and communication technology is essential for enhancing adoption, which can be achieved through investments, education, and regulation (Olaitan, et al., 2024). Direct government involvement includes providing subsidies or assistance to higher education institutions and implementing specific programs to engage relevant stakeholders (Armah et al., 2002; Mudau, 2016; Carrim, 2019). Indirectly, higher education institutions can facilitate adoption by establishing policies and regulations that create an environment conducive to innovation. In South Africa the COVID-19 pandemic precipitated significant changes to higher education. Several reformulations were implemented to enable distant learning, these ramifications continue to impact and shape digital transition. Post the pandemic, many higher education institutions have continued to increase investment in digital platforms (Mustapha, 2021). Thus digital transformation in higher education has implied the involvement of sustainable management to adapt to the changes imposed by new technologies (Vázquez-Cano et al., 2020). This result leads to higher education students' development of interpersonal competencies when using Information and Communication Technologies for digital innovational learning and outcomes (Abad-Segura, et al., 2020).

4 METHODOLOGY

A qualitative research approach was employed, drawing on university documents, a literature review, and semi-structured interviews. Table 1 summarises the demographic details of the participants in the focus group discussion. Semi-structured interviews were conducted with staff within the Urban and Regional Planning Department at the Univerity of Johannesburg. The interview duration was between 65 mins and 85 mins. Additionally a focus group of postgraduate Urban and Regional planning students with experiences from the National Diploma and Btech program and the new Bachelor of Urban and Regional Planning program were considered valuable in sharing their insights for the study. This is because focus groups are a popular technique for gathering data since they take advantage of team dynamics to examine interprofessional perspectives. In a focus group, participants are chosen as a deliberate, though not necessarily representative, selection of a certain community and the interviews are "focused" on a specific issue (Takashima et al., 2020). A focus group was employed to collect in-depth answers to questions from a diverse set of participants spread out geographically and to take advantage of group interaction (Blake et al., 2021).

Participants	Urban Planning Qualification	Gender	Position	Years of Employment Experience
Participant 1	Diploma	Female	Student	3
Participant 2	Btech Degree	Male	Student	5
Participant 3	Diploma	Female	Student	9
Participant 4	Btech Degree	Female	Student	4
Participant 5	Bachelors (Hons) degree	Male	Student	1
Participant 6	Bachelors (Hons) degree	Female	Student	0
Participant 7	Masters	Female	Student	2
Participant 8	Masters	Male	Student	6
Participant 9	Bachelors degree	Male	Student	2
Participant 10	Masters	Male	Student	4
Participant 11	Phd	Female	Lecturer	8
Participant 12	Phd	Male	Lecturer	7
Participant 13	Phd	Male	Lecturer	10

Table 1: Demographic Details of the Focus Group Participants.

Three researchers transcribed the audio file using online Microsoft Word for accuracy. The data was analysed using Atlas.ti. The study adopted a thematic analysis approach for coding the major themes and

checking for consistency. To analyse the participant responses thematically, the procedures adopted include; familiarisation with the data, developing initial codes, generating themes, reviewing the themes, and defining and naming the themes. This approach was coded using Atlas ti. Coding the themes involved checking the assessment of the interviewees' feedback to the group and tagging the responses in line with the code to facilitate easy retrieval. The responses from the respondents of this study were coded in nodes (themes) by identifying patterns in them. These themes are discussed and supported by verbatim extracts from the data to highlight important issues

5 FINDINGS AND DISCUSSION

P13 outlined that in developing the improvement plan the Department of Urban and Regional Planning has prioritised analysis of the planning profession accreditation findings. These insights provided invaluable guidance that highlighted areas requiring immediate attention and enhancement. These are part of efforts to ensure the current planning programs are robust and adhere to regulatory standards. Additionally, P12 articulated the need for actively engaging with the evolving needs of students, industry, and society at large. Therefore, the central tenet of the improvement strategy is a commitment to fostering a learning environment that is reflective of contemporary challenges in urban planning, while also ensuring that our graduates are equipped with the skills and competencies necessary to excel in their careers

Transformation is structured around several key initiatives designed to strengthen program marketing, enhance student engagement with industry practices, improve research output, and foster robust connections with alumni and stakeholders. To effectively implement these initiatives, the Department of Ubran and Regional Planning at UJ have established specific actions scheduled for execution over the next two years. By creating a dynamic learning environment with the aim of preparing students to confront the complexities of urban planning today and in the future.

Decolonial Theory Perspectives

The global south discourse on decologinalisation of the built environment has largely enabled transformation to streamline the curriculum, providing a more effective and efficient approach to handling urban challenges. The participants outlined the Department of Urban and Regional Planning boasts of several colleagues who are at the forefront of decolonial thought. There is a call for planning theory which reflects the realities in our urban, regional and rural spaces; hence, decolonisation of knowledge is the only solution that promotes understanding and appreciation of our realities in the African context. Through these efforts, the department has led the quest to decolonize planning education. As part of this exercise, module content is being reviewed to infuse more Global South perspectives and knowledge. This was confirmed by P11 who outlined,

“Interventions to be implemented in the Bachelor of Urban and Regional Planning programme include removing Western-centric theories such as the Garden City model, replacing them with a more Global South perspective (PLNTRA1); incorporating Global South and decolonial perspectives in policy discussions and development planning (RADTRA3); and focussing on decolonising content by integrating Global South approaches to land management and governance (LDCTRB2).”

Makoni (2020) also noted a similar trend, outlining that decolonizing planning education would require radical approaches. Some of the participants indicated that the seminar series has created a platform for advancing the decolonization of the planning agenda. The department has organized multiple conversations with professionals from around the world, giving both postgraduate and undergraduate students the chance to engage with international experts. These events contribute to marketing the programme on an international scale. P12 outlined the seminar series explores the following themes: Decolonial perspectives on smart townships within African contexts, Critical examinations of the ‘smartness’ concept in smart townships and smart cities conceptual frameworks, Gendering Smart Townships, Smart Township and environmental green sustainability, Smart Township and Township Economies, Smart Township and Employment, Smart Townships, surveillance and community safety, Ethical implications of Smart Townships, The interconnections between creatives, creative industries and Smart Townships, and Smart Townships and their Educational implications. This initiative provides intellectual support for academia and the industry to engage in decolonial thought.

Transformative learning is achieved through the use of seminars as a method of teaching urban and regional planning concepts. According to Gibbs (1999), seminars are a method of teaching that brings together small groups of students to discuss a common concept. Through seminars, students focus on a particular theme, thus enabling them to participate actively in the learning process. Seminars set a platform for many students operating at various levels to come together to discuss urban and regional planning issues holistically, raise questions, and debate on critical concepts in the discipline. What remains important is to isolate individual concepts from the seminars presented and link them to various lecture presentations (P11). Tasks that require students to develop and manuscripts assist in transforming my students and prepare them for lifelong learning

Strategies Enabling Digitalisation

In higher education institutions, digital transitioning holds immense potential to revolutionize traditional education practices, drive efficiency gains, and spur sustainable development. The choice and adoption of any teaching method are determined by an array of factors in the urban and regional planning discipline and institution I serve (Briggs and Wager, 1989). For Urban and Regional planning adopting digital technologies offers a pathway towards addressing the unique challenges the profession faces while capitalising on emerging opportunities in the digital age. Figure 1, presents a drone demonstration collecting aerial data. In such contexts, the integration of geographic information systems and building information modelling presents a transformative opportunity to leapfrog conventional methods, accelerate progress, and bridge the gap between aspiration and realisation (P8). At the heart of this curriculum transformation lies the need for the development of tailored solutions for the specific needs and dynamics of the urban and regional spaces.

Figure 1: Data collection with drone

Authentic and effective assessments play the critical role of influencing students' learning behaviours if properly embedded within the curriculum. It is therefore important to ensure that all the different parts of assessment are integrated, that they fit well within a module as a whole, and that students actively participate in providing feedback (Biggs, 1996). Several case studies have proved that lecturers can manipulate the way students learn through the use of assessment in various strategic and tactical ways. P13 outlined "drawing from relevant assessment concepts and theories, strategies and tactics to inform the several ways that I adopt and implement to make learning activities productive. I ensure that assessment tasks and feedback are built in my learning guides and promote the involvement of students at all stages". Consequently, integrating various assessment opportunities with the learning outcomes and other critical components of curricula (Biggs, 1999; 2012).

The University of Johannesburg is not only implementing but is also at the centre of popularising and influencing the adoption of the Fourth Industrial Revolution in all teaching and learning as well as assessment activities. For example, the University is creating awareness of the 4IR among students and the general public through a free and fully online Short Learning Programme in Artificial Intelligence which highlights what technology can do, how it's used and some of its implications, ethically and productively. Consequently, P12 outlined "I intensively and extensively use blended and hybrid systems to apply the ever-

evolving technology in my teaching, learning and assessment". This is particularly true in teaching materials development and packaging, delivering lectures online and hybrid formats and assessing and communicating with my students.

Specifically, staff utilise both interactive and non-interactive platforms such as Blackboard Collaborate Ultra; MS Teams; WhatsApp; Email; Lecture slides (PowerPoint) and Voice-narrated lecture slides (PowerPoint). Students are also taught to use software packages such as the Statistical Package for the Social Sciences (SPSS) in data analysis as well as eographic Information Systems (GIS). P13 added, since the outbreak of the Covid 19 pandemic and the subsequent lockdown in 2020, "I have refined and intensified my skills to use technology in my teaching and assessment."

Limited digital infrastructure, skill gaps, and institutional barriers were described as the key aspects hindering the widespread adoption of digital technologies (P12). Moreover, cultural factors and staff resistance, concerns further complicate the landscape. The urban and regional planning programmes and modules are multi-disciplinary in nature, and the student population in the department is largely from previously disadvantaged communities (P13). Moreover, applying the deductive teaching approach that is informed by the essentialism and constructivism teaching philosophies ensures that the core concepts of the discipline are imparted. Students are enabled to connect them well whilst applying the inductive teaching approach that is informed by the progressivism teaching philosophy. This promotes students' critical thinking and problem solving skills and leads to co-creation of knowledge. The hybrid teaching philosophy thus facilitates students' lifelong, transformative and meaningful learning. Despite these challenges, the imperative for digital transformation remains clear. The benefits extend beyond mere efficiency gains to encompass broader socioeconomic impacts, including job creation, economic growth, and improved quality of life for communities

Innovative Teaching Strategies linked with industry

P11 has outlined although the staffing resources for this component are sufficient as outlined in the primary actors, the department requires budget allocations for marketing campaigns, promotional materials, and event hosting. Figure 2 presents Urban and Regional planning students at a student excursion to Mpumalanga. This includes expenses for travel, advertising, and outreach activities to ensure that this concern continues to be effectively addressed as part of the departmental marketing initiatives. "Undergraduate and Postgraduate students have participated in various excursions, including the SACPLAN Indaba, the Alexandra project, and a Municipal Planning Tribunal (MPT) hearing in Midvaal Municipality" expressed P5. This was echoed by P6, who described the experiences as being positive as they exposed students to industry practices and fostered program awareness.

Figure 2: Student excursion to human settlement project

Partnerships with private and public sector

P12 outlined the advisory board members have been playing a crucial role in promoting the department and advising on potential avenues to effectively advertise the programmes. P10 praised the department for initiating the Urban and Regional Planning Alumni Affinity Group Dinner, describing the space as enabling a platform for alumni networking and program promotion. Undergraduate students also attended, providing them with valuable networking opportunities with industry professionals.

These ongoing efforts are expected to significantly enhance the visibility and reputation of the department programmes within the planning industries. However, partnerships between the department and industry professionals are still needed through networking events, workshops, or conferences, providing students with opportunities for internships, mentorships, and job placements.

P2 outlined that since the transition from the Diploma program, in-service training has been lost, which was a critical element of the curriculum as it exposed students to 11 months of working in the industry under a mentor. P3 suggested the need for developing a new mentorship program linked with planning projects, this should leverage innovative and transformative approaches. This would ensure students are exposed to the planning profession and learn key aspects such as policy development, application submissions, and reviewing processes. P8 echoed this would achieve outstanding teaching, learning, and research outcomes, thereby bridging the gap between academic training and professional practice. Furthermore, key stakeholders could collaborate on joint events or initiatives that showcase the planning program and highlight its relevance to current planning challenges, furthering exposure and engagement (P8).

6 CONCLUSION

This study examined curriculum improvement as a strategy for program accreditation, using the Department of Urban and Regional Planning at the University of Johannesburg as a case study. Apart from the complex relationship between urban and regional planning theory and practice, addressing transformation issues and implementing the proposed strategies, the department has aimed to further enhance the quality and relevance of its programmes. Through an improvement plan, a proactive approach to addressing the challenges and opportunities to ensure the sustainability of the department programs. Key lessons learned reveal a focus on efforts on curriculum development, student support, research, and industry engagement, which have the potential to ensure graduates are well-prepared to meet the demands of the evolving urban and regional planning profession. The study recommends that support for transforming higher education curricula would assist graduates to become relevant to industry needs. A focus on digital maturity, which is one of the highly targeted skills within the Urban and Regional planning profession, must not be limited to the learning activities; it starts with planners being the agents of curriculum and pedagogy.

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reviewed paper

Redefining Livability through 15 Minute Neighbourhoods – An Approach to Enhance Quality of Life through Sustainable Mobility

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1 ABSTRACT

Rapid urbanization in India has strained infrastructure, mobility, and public spaces, reducing urban livability. By 2050, over 800 million people are expected to live in Indian cities (Bhagat, 2015), worsening these challenges due to poor planning, outdated design standards, and capacity constraints. Cities like Bengaluru, on their growth trajectory, face severe challenges such as congestion, flooding, inadequate pedestrian infrastructure due to urbanisation imapcting the every day experience of citizens. Traditional top-down master planning prioritizes large-scale infrastructure but often overlooks localized, people-centric needs. A decentralized, neighbourhood-focused approach is essential to create sustainable, inclusive communities where the residents move, eat, play, and feel included.

Using Nallurahalli, a mixed use neighbourhood in Bengaluru as a case study, this research applies a mixed-methods approach, including infrastructure benchmarking, user perception surveys, and mobility audits, to assess quality of life at a neighbourhood level. Findings highlight critical gaps in pedestrian infrastructure, last-mile connectivity, and public space accessibility, reinforcing the need for localized, neighbourhood-scale solutions – a gap effectively addressed through the 15-minute neighbourhood model.

This study highlights the potential of 15-minute neighbourhoods to enhance mobility, reduce private vehicle dependence, and promote environmental sustainability. It offers a replicable, bottom-up planning model tailored to Indian cities, providing actionable strategies for policymakers to implement 15-minute neighbourhoods.

Keywords: Walkability and Accessibility, Sustainable Mobility, Quality of life, Neighbourhood-level Planning, 15-Minute Neighbourhoods

2 INTRODUCTION

2.1 Reimagining Indian Cities – Need for Decentralised Planning

India's urban population is projected to grow by 416 million by 2050, nearly doubling its current size (UN DESA, 2018). Without strategic intervention, this rapid expansion will require strengthened urban planning frameworks to ensure sustainable growth, equitable infrastructure, and enhanced livability (ADB, 2012).

Masterplans play a crucial role in shaping urban development by guiding infrastructure investments, zoning regulations, and long-term city visions. Across India, 52% of statutory towns are expanding without master planning frameworks, leading to gaps in mobility, access to public spaces, and essential services (NIUA, 2021). Even where masterplans exist, their preparation often takes a long time, making it challenging to respond to the immediate needs of growing communities. For instance, Bengaluru, spanning 740 square kilometers with a population of 14 million, currently lacks a masterplan (World Population Review, 2024). Its previous plan expired in 2015, and the 2031 revision remains incomplete. Meanwhile, rapid urban growth has led to flooding, congestion, declining air quality, loss of green cover, and encroachment of public spaces, significantly impacting livability.

Given the scale and pace of urbanization of Indian Cities, there is a need to complement masterplans with decentralized, neighbourhood-level planning that prioritizes local accessibility, walkability, and public space enhancements. While masterplans focus on city-wide infrastructure such as transit corridors and major road networks, neighbourhood-level planning ensures that everyday urban experiences where people live, play, work, and interact are enhanced. This allows citizens to witness and benefit from observable, impactful changes such as walkable streets, improved public spaces, and access to high-quality amenities that promote public ownership and well-being (Yigitcanlar et al., 2015).

The 15-minute neighbourhood model becomes a method to ensure this – it enhances quality of life in neighbourhoods by ensuring the availability, accessibility, and quality of amenities reachable within a 15-minute walk from one's residence (Moreno et al., 2021). Through integrating neighbourhood planning within broader urban strategies, cities can create livable, resilient, and self-sufficient communities that enhance overall quality of life (Gehl 2010).

2.2 Research Scope and Approach

This study, part of a larger ongoing research initiative, examines the potential of 15-minute neighbourhoods to enhance quality of life in Bengaluru. It explores an implementation framework that includes benchmarking, needs assessment, and intervention strategies, offering a structured approach to operationalizing the concept.

Using place-based insights from Nallurahalli, a Bengaluru neighbourhood, the study demonstrates how 15-minute neighbourhood planning can provide hyperlocal solutions that can improve quality of life. While the concept of 15-minute neighbourhoods has been widely discussed, its practical implementation in highly developed, brownfield cities like Bengaluru remains underexplored.

Existing studies on 15-minute neighbourhoods have primarily focused on greenfield developments and well-planned urban expansions in cities like Paris (Moreno et al., 2021), Melbourne (Victoria State Government, 2015), and Portland. However, their application in densely populated, unplanned, or rapidly urbanizing cities in the Global South is still limited (Yigitcanlar et al., 2015). The challenges of retrofitting built environment, addressing diverse socio-economic conditions, and integrating new mobility solutions such as non-motorized transport (NMT) within existing infrastructure remain a significant challenge.

This study builds on existing research by positioning 15-minute neighbourhood planning as both a theoretical and actionable framework. By bridging the gap between policy vision and on-ground execution, this approach demonstrates how neighbourhood-level planning can be integrated into current planning paradigm.

3 RESEARCH METHODOLOGY

An implementation mechanism has been developed to systematically assess and transform neighbourhoods into vibrant 15-minute neighbourhoods. This process involves neighbourhood selection, baseline assessments, data analysis, and strategic recommendations. The Availability-Accessibility-Quality (AAQ) framework forms the foundation of this approach:

- Availability – Benchmarking of infrastructure and services based on planning standards (NBC, 2016; URDPFI, 2014).
- Accessibility – Evaluation through walkability, cyclability, and lux level surveys to assess ease of movement
- Quality – User perception surveys to gauge infrastructure usability, safety, and satisfaction

This mixed-methods approach has been applied and tested to gather quantitative and qualitative data from Nallurahalli neighbourhood, demonstrating its applicability in real-world urban settings.

Stage	Objective	Methods Used
Neighbourhood Selection	Identify areas with potential for 15-minute neighbourhood transformation	Administrative, transport, environmental, and socio-economic criteria
Baseline Assessment	Understand existing infrastructure and service distribution	GIS mapping, ground-truthing, open-source data validation
Availability Analysis	Determine the presence of essential amenities	Benchmarking against national and global standards on neighbourhood planning
Accessibility Analysis	Assess mobility and ease of movement within the neighbourhood	Walkability, cyclability, and lux level surveys
Quality Assessment	Evaluate user satisfaction and infrastructure usability	User perception surveys, community engagement
Data Analysis	Identify critical gaps and areas for improvement	Comparative analysis of findings
Strategic Recommendations	Develop targeted interventions for walkability, accessibility, and livability	Policy, planning, and project-based solutions

Table 1: Research Framework for 15-Minute Neighbourhood Implementation

3.1 Neighbourhood Selection

The 15-minute neighbourhood concept is built on walkability, with an optimal radius of 1–1.2 km. However, wards in Indian cities, including Bengaluru (3.5–4 km² on average), are significantly larger. To identify potential areas for compact, walkable neighbourhoods, the following criteria were applied:

- Administrative Factors: Consideration of ward boundaries, planning regulations, land use, and cultural/historical context.
- Transport Infrastructure: Proximity to public transit and mobility infrastructure.
- Environmental Factors: Natural boundaries like water bodies, forests to ensure ecological sensitivity.
- Socio-Economic Factors: Inclusion of income diversity, employment hubs, and informal settlements to ensure equitable access.

Nallurahalli, a 1.5 km² mixed-use neighbourhood in Bengaluru, was selected as the study area for its ongoing urban growth, development potential, and strong citizen engagement.

3.2 Availability-Accessibility-Quality Assessment Framework

After identifying and selecting potential neighbourhood, it was imperative to carry out baseline assessments of each before further planning and design. This study conceptualised the ‘Availability-Accessibility-Quality' framework which can be used to tangibly identify existing gaps in a neighbourhood.

3.2.1 Availability

First, using insights gathered from literature reviews, a list of amenities critical to day-to-day functioning was identified and benchmarked as the 'must haves’ of any neighbourhood (Refer Annex A). This list was built drawing insights from established standards such as National Building Code (NBC), and Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines for India. Furthermore, references to national guidelines like the Indian Road Congress, Model Building Bye-Laws 2016, and Harmonised Guidelines Space Standards for Universal Accessibility in India-2021, along with insights from international examples of neighbourhood planning and 15-minute communities, have enriched the indicators and requirements for developing a 15-minute neighbourhood.

Using this framework, A baseline study benchmarked critical infrastructure and mapped amenities in Nallurahalli using GIS, Google Earth, and ground-truthing to verify accessibility within a 15-minute walk from the neighbourhood’s central node.

3.2.2 Accessibility

Accessibility was assessed through multiple methods, including on-ground surveys using GPS tracking to capture walking and cycling routes, footpath conditions, cycle lanes, and pedestrian crossings. Light meters and observational audits evaluated street lighting, signage, and visibility. Photo documentation identified gaps in infrastructure, ensuring a comprehensive analysis of pedestrian and cyclist accessibility.

3.2.3 Quality

During this phase, qualitative information about neighbourhood amenities was collected through door-to-door surveys and online forms. Door-to-door surveys, conducted using mobile tools such as Google Forms and Survey CTO gathered detailed feedback from residents, with geo-tagged data. Simultaneously, online Google Forms distributed via WhatsApp, Resident Welfare Associations, and social media captured responses from a wider audience.

3.3 Neighbourhood Assessment Surveys

To implement the Availability-Accessibility-Quality framework, a series of neighbourhood assessment surveys were conducted to evaluate infrastructure, mobility, and user experience as illustrated in Figure 1. These surveys provided a comprehensive understanding of existing conditions and identified key areas for improvement.

- Validation Survey – Verified infrastructure presence using open-source data and field assessments.

- Infrastructure Assessment Survey – Evaluated the on ground condition and usability of parks, markets, and mobility hubs.
- Walkability Survey – Measured pedestrian safety, accessibility gaps, and network connectivity.
- Cyclability Survey – Assessed cycling conditions, revealing a lack of dedicated infrastructure.
- Lux Level Survey – Identified poorly lit areas impacting nighttime safety and walkability.
- User Perception Survey – Captured resident perspectives on accessibility, quality, and livability.

The study assessed 5 km of roads and 10 key infrastructure points across a 1.5 km² area, ensuring a detailed evaluation of neighbourhood. A systematic stratified sampling approach was used to select 104 respondents, ensuring adequate spatial coverage within the compact study area.The sample is designed to capture diverse socio-economic typologies by alternating respondents between adults and senior citizens of both genders.

To provide a comprehensive, well-rounded analysis, objective infrastructure assessments were combined with citizen perception surveys at key locations, including residential areas, transit hubs (Nallurahalli Metro Station), and public spaces (Nallurahalli Park, Nallurahalli lake, and Inner Circle Municipal Park). This mixed-method approach integrated quantitative infrastructure evaluations with qualitative user insights, offering a holistic understanding of accessibility, mobility, and neighbourhood amenities. Additionally, a city-wide online survey was conducted across Bengaluru to understand citizens' needs and aspirations regarding 15-minute neighbourhoods, gathering 1,640 responses. However, these findings are not included in this study as they do not specifically pertain to Nallurahalli.

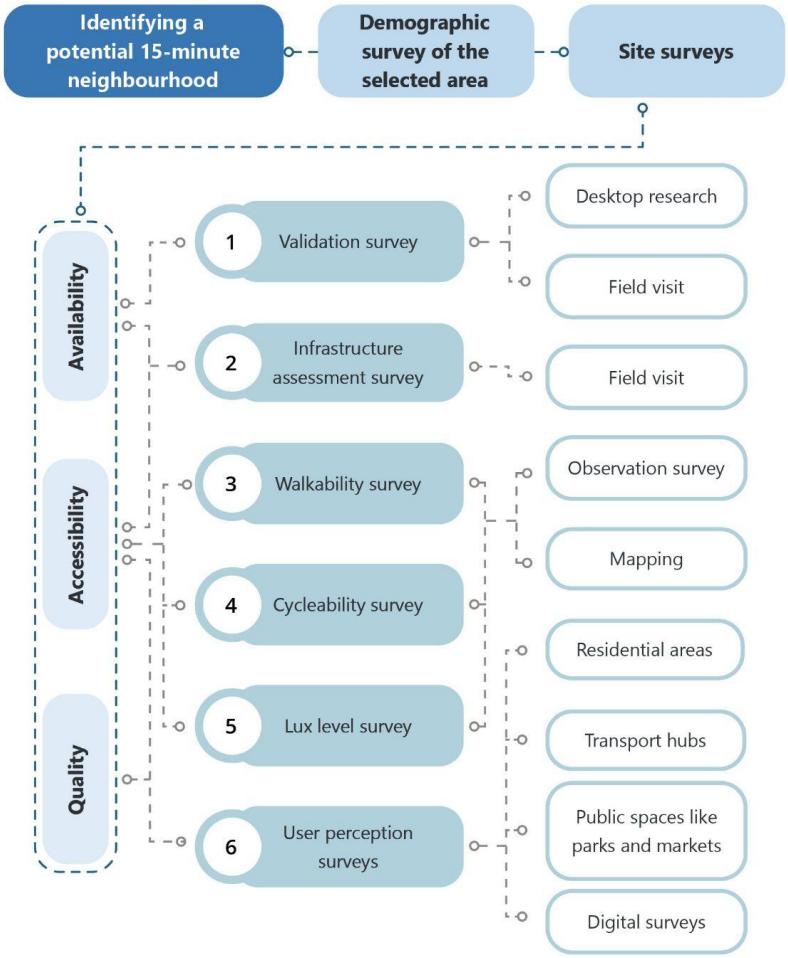

Fig. 1: Types of neighbourhood assessment surveys conducted in Nallurahalli. Source: Jana Urban Space Foundation (2024).

3.4 Indentifying and Analysing Gaps

After Neighbourhood-specific findings for each neighbourhood were obtained by administering the 6 types of neighbourhood assessment surveys following the Availability-Accessibility-Quality framework. Findings from each neighbourhood are collated and critically analysed against the standards identified as per the

Availability-Accessibility-Quality framework. This helped identify and analyse neighbourhood-specific gaps.

3.5 Devising Recommendations

After Neighbourhood-specific findings for each neighbourhood were obtained by administering the 6 types of neighbourhood

Based on neighbourhood-specific insights, three key intervention categories were identified:

- Policies – Advocating for decentralized planning, sustainable mobility, and inclusive development
- Plans – Developing neighbourhood-scale spatial planning models to promote compact, walkable neighbourhoods through active citizen participation
- Projects – Implementing targeted solutions such as improved footpaths, last-mile connectivity, and public space revitalization. While plans help define the physical limits of developmental activities in an area, projects serve as critical mechanisms that bring these plans to life.

4 FINDINGS

Based on the research methodology, gaps in mobility infrastructure, public spaces, and social infrastructure were identified and categorized under three themes: 'Move' (Mobility Infrastructure), 'Play' (Public Spaces), and 'Include' (Social Infrastructure). This structured approach ensures a comprehensive analysis of survey data. The findings presented are derived from a sample of 104 respondents in Nallurahalli and are expressed in percentages.

Category	Key Insights
"Move" (Mobility Infrastructure)	Inadequate pedestrian infrastructure, poor last-mile connectivity, and safety concerns hinder accessibility. Strengthening walkability, integrating public transport, and upgrading infrastructure are essential for improving mobility.
"Play" (Public Spaces)	Poor access, lack of wayfinding, and safety concerns limit the usability of public spaces. Enhancing lighting, signage, and footpath quality can increase their accessibility and usage.
"Include" (Social Infrastructure)	Limited availability and accessibility of essential services force residents to travel long distances for daily needs. Strengthening local markets, improving pedestrian infrastructure, and expanding access to healthcare and community spaces can improve liveability.

Table 2: Key findings at a glance

At the neighbourhood level, mobility emerged as the most pressing concern, with 96% of respondents prioritizing it over public spaces and social infrastructure. A notable takeaway was the strong community interest in participatory planning, with 50% preferring direct engagement through Resident Welfare Associations (RWAs) and ward meetings.

4.1 "Move" (Mobility Infrastructure)

Despite the presence of Nallurahalli Metro Station and Whitefield TTMC, reliance on private vehicles remains high, with 70% using them for daily commutes. Public transport adoption remains low (4%), with 86% rating their walking experience as "poor" due to lack of footpaths, unsafe crossings, and inadequate lighting.

- Last-mile connectivity remains a major issue, with 80% rating it "poor."
- Footpaths leading to transit hubs are largely inaccessible, limiting usage
- Lux levels at 17, falling below the 25-40 range recommended by IRC standards, affecting safety
- 49% cited waterlogging as a barrier to mobility
- 69% agreed that improving walkability would enhance their quality of life

4.2 "Play" (Public Spaces)

Public spaces remain underutilized and underappreciated – only 19% of residents actively use them, and 59% were unaware of their presence.

- Satisfaction with available public spaces is low, with only 21% expressing contentment.
- Nallurahalli Lake was the most frequented space, but 33% of users feel unsafe after 6 PM, citing poor lighting.

- Inner Circle Municipal Park sees 92% of users walking, yet only 11% rated footpaths as good.
- 80% of respondents found signage and wayfinding in public spaces inadequate.

4.3 "Include" (Social Infrastructure)

Accessibility to essential services remains a mixed picture. Basic amenities ranked as the third most important factor for a walkable neighbourhood, yet:

- 95% of residents walk for grocery shopping, but 12% travel over 5 km for larger shopping complexes.
- 53% spend under an hour accessing amenities, while 47% spend 2-5 hours.
- 15% travel outside Nallurahalli for entertainment and sports, with 30% traveling over 10 km.
- Despite proximity to hospitals, 65% still travel outside the neighbourhood for healthcare.
- 86% cited poor walking infrastructure as a major barrier to accessing social amenities.

Findings from this study indicate a strong infrastructural gap in locally available amenities and accessibility to them. As per many responses, basic amenities in the neighbourhood – including schools and anganwadis – are reported largely to be inaccessible to people with disabilities. Respondents were also asked whether any 'other' amenities, apart from the ones listed, were missing in their neighbourhood. The 'other' services and amenities listed were "playgrounds", "footpaths for safe walking", and "bus facilities".

Further, findings on 'Move' and 'Play' also align with this discussion on access to the social infrastructure within the neighbourhood. The poor walking experience remarked by 86% respondents, limited access to people with disabilities, and the absence of adequate transport options indicate that inclusive accessibility to amenities and social infrastructures within Nallurahalli, despite their sparse availability, is limited.

5 RECOMMENDATIONS FOR NALLURAHALLI

Recommendations derived from neighbourhood assessments and community engagement, are categorized under three themes: Move- Play- Include. The proposed interventions align with international best practices in urban planning, transport-oriented development, and place-making to ensure long-term impact.

5.1 "Move" (Mobility Infrastructure)

Nallurahalli's mobility landscape faces traffic congestion, poor last-mile connectivity, and limited alternatives to private vehicles. However, its proximity to key transit hubs like Nallurahalli Metro and Whitefield TTMC (bus station) presents a strong opportunity for transformation.

5.1.1 Quick-win projects include:

- Road and junction improvements to create walkable footpaths and dedicated cycling infrastructure.
- Enhancing safety with adequate streetlights, traffic calming measures, and safe pedestrian crossings.
- Improving bus infrastructure with well-designed bus stops offering shaded waiting space, wayfinding, and real-time transit information.

5.1.2 Policy Interventions:

- Feeder loops connecting inner neighbourhoods to metro and bus stations.
- Public Bike Sharing (PBS) zones to encourage cycling and designated parking near transit points
- Sustainable transport incentives such as subsidies for non-motorized mobility
- Mobility technology solutions like real-time transit apps for seamless multi-modal integration

5.2 "Play" (Public Spaces)

A well-designed public realm enhances social interaction and livability, yet Nallurahalli lacks high-quality, accessible public spaces. Enhancing urban design and activating underutilized areas can foster a sense of community and increase walkability.

5.2.1 Public space enhancement:

- Upgrading Nallurahalli Park with universal accessibility features, gender sensitive play areas
- Rejivenation of Nallurahalli Lake to establish a biodiversity-conscious, inclusive recreational space.

5.2.2 Policy and Community-Based Approaches:

- Installing navigational signage and information boards to improve access and awareness
- Encouraging local businesses, collectives, and corporate partnerships for public space maintenance
- Introducing temporary street closures, pop-up events, and placemaking projects to activate spaces.

5.3 "Include" – Social Infrastructure

Access to markets, community spaces, and essential services is critical to reducing reliance on private vehicles and promoting self-sufficiency. Nallurahalli currently lacks designated markets, organized vending spaces, and universally accessible community infrastructure.

5.3.1 Strengthening Local Economies and Community Infrastructure

- Establishing dedicated spaces for weekly markets to enhance access to local fresh produce
- Developing regulated, pedestrian-friendly vending spaces to support informal livelihoods.
- Building universally accessible schools and spaces to serve a diverse socio-economic demographic.
- Designing inclusive public spaces catering to women, children, elderly, and persons with disabilities.

The strategic transformation of Nallurahalli into a 15-minute neighbourhood requires integrated interventions in mobility, public spaces, and social infrastructure. A multi-pronged approach of combining quick wins, high-impact projects with long-term policy reforms will ensure sustained benefits for all residents. Community participation will be crucial in maintaining and scaling these interventions

6 NEIGHBOURHOOD LEVEL PLANNING AS TOOLS FOR CHANGE

Building on the recommendations for Nallurahalli, two lighthouse projects are currently under construction, driven by collaboration between private sector stakeholders, citizen collectives, and elected representatives. These projects focus on retrofitting pedestrian infrastructure to improve first- and last-mile connectivity and enhancing wayfinding through strategically placed information boards and signage.

However, to transform dense, million-plus cities like Bengaluru, Mumbai, and Delhi, a city-level programme is essential. Scaling up 15-minute neighbourhood planning requires enhanced institutional capacity, strengthened governance mechanisms, and a structured framework to guide implementation. Given the scale and complexity of Indian cities, a systematic, city-wide approach is necessary to ensure replicability and sustained impact.

6.1 The Need for a New Institutional Approach

While Local Area Plans (LAPs) are statutorily recognized in India, their implementation has been limited due to institutional ambiguity, regulatory obstacles, and fragmented governance structures (GRERA, 2022). Cities lack a dedicated institutional mechanism to operationalize neighbourhood-level planning, leading to delays, inconsistent execution, and weak community participation

Conversely, structured institutional setups have proven effective in driving urban transformation. For example, the Smart Cities Mission leveraged Special Purpose Vehicles (SPVs) to streamline decision-making, ensuring targeted project execution (MOHUA, 2019). A similar approach is needed for 15-minute neighbourhood planning, with a dedicated city-level programme, institutional framework, cross-sectoral coordination, and public engagement.

6.2 Pathways for Implementation in Other Urban Areas

Using findings from this study, this section proposes the 15-Minute Neighbourhood Programme as a scalable model – a possible implementation pathway to help develop 15-minute neighbourhoods in Bengaluru and other Indian cities. The following nine-step framework provides a structured roadmap for execution-

6.2.1 Roll-out

The city formally announces the 15-Minute Neighbourhood Programme, aligning it with existing city level master plans to ensure coherence. The masterplan serves as a strategic framework, integrating the programme into its broader vision while decentralised actions are implemented at neighbourhood levels. Local governments play a central role in coordination, decision-making, and obtaining necessary approvals to operationalise the programme.

6.2.2 Budgetary Allocations

A sustainable financial model is essential for funding capital, operational, and maintenance expenditures. The city must integrate the programme into existing urban development, mobility, smart cities, and public infrastructure budgets, leveraging state and union government funding.

6.2.3 Institutional Setup

The 15-minute neighbourhoods programme may be anchored by a steering committee formed by members of the urban local body, that acts as an apex body for the programme. This stage entails the formation of a 15-Minute Neighbourhoods Programme Cell within the urban local body that anchors the implementation of the programme in a city, and is entrusted with the budgetary allocations made in the preceding stage.

This cell must consist of urban planners and designers, architects, engineers, subject-matter experts, and community members. Additionally, ward committees and city mayor may be identified as local partners of the Cell that can steer implementation at the neighbourhood level. This Programme Cell would be responsible for carrying out policy analyses and providing inputs on the design of the programme itself, and its operationalisation. The other responsibilities of this Cell can include goal-setting, defining stakeholders' specific roles and conducting relevant research to identify potential 15-minute neighbourhoods in the city. The Cell must also actively work towards building capacities through training and knowledge dissemination of the programme, using guidelines for identifying and developing 15-minute neighbourhoods.

6.2.4 Neighbourhood Selection

The Programme Cell, along with relevant government stakeholders and partners from the ward committee, will select neighbourhoods identified as potential high-impact 15-minute neighbourhoods for development. The neighbourhoods must be selected based on administrative factors, transport infrastructure availability, environmental factors and socio-economic factors, as outlined in detail through this research.

6.2.5 Community Engagement

A neighbourhood-specific implementation body is formed under the Programme Cell to lead citizen consultations, participatory workshops, and data collection. This ensures planning reflects local aspirations and needs. Partnerships with Community-Based Organizations (CBOs) can further enhance community ownership and sustainability. This implementation body will also facilitate cultural planning, branding, and communication strategies to foster encourage more involvement.

6.2.6 Analysis

This phase entails a detailed analysis of the neighbourhood's infrastructure and amenities, using the Availability-Accessibility-Quality framework. This analysis must be based strictly on findings obtained through the detailed neighbourhood assessment surveys outlined in this research. First, a baseline study of the neighbourhood must outline the amenities available within a 15-minute walking distance from the neighbourhood. Then, data on access to the amenities identified within the neighbourhood must be obtained. This will help gather insights into the accessibility of these infrastructures, and whether or not one can access these on foot/using cycles. Parallely, inputs from citizens obtained through neighbourhood-level community engagements capturing their spatial perceptions and needs must also be incorporated to inform the analyses drawn. Additionally, these inputs can be used further for identifying neighbourhood-specific high-impact interventions that can enhance the residents' quality of life.

6.2.7 Design and Implementation

After critically analysing a neighbourhood for its availability, accessibility and quality of amenities, with inputs gained from public engagements, specific areas of intervention must be identified by the 15-Minute

Neighbourhood Cell. The Cell must also develop specific proposals for the selected neighbourhood that must follow the Policies, Plans, and Projects approach outlined in this research, to develop high-impact proposals that can be implemented within short, medium, and long term. Lastly, by deploying an additional loop of feedback through community engagements, the steering committee must open the proposal to public discussion, incorporating all major suggestions received from citizens.

6.2.8 Neighbourhood-level budgetary allocations

After identifying and finalising a proposal, a detailed and end-to-end cost estimate is required to be drawn by the 15-Minute Neighbourhood Cell for the implementation process. This budget will then be reviewed internally and will be critical in the allocation and disbursement of funds to the ward committee, and then to the concerned implementation body upon approval.

6.2.9 Impact Assessment and Maintenance

The 15-Minute Neighbourhood Programme Cell must conduct impact assessment studies for the implemented interventions at strategic intervals of time, based on predefined metrics. These metrics may include user-safety, climatic impacts, gendered perspectives, and impacts to public health, to name a few. The findings from this assessment must then be presented to the steering committee to review internally, and to the urban local body to advocate upscaling the 15-minute neighbourhood model to other neighbourhoods across the city.

Additionally, a strong maintenance plan and clear ownership structures must be established to ensure the long-term success and continuity of interventions. This includes engaging neighbourhood implementation group (refer step 5) in the upkeep and management of public spaces.

7 LIMITATIONS

While this study provides valuable insights into the applicability of 15-minute neighbourhoods in Bengaluru, certain limitations must be acknowledged. The sample size for Nallurahalli (104 respondents) may appear small in isolation; however, it is part of a broader study covering four neighbourhoods, with approximately 500 total survey responses (primary survey) and 1600 responses through a city level online survey. To ensure a comprehensive understanding, the research integrates multiple data sources, including objective surveys(walkability, cyclability, and lux-level surveys), infrastructure assessments, and targeted surveys at residential areas, key transit hubs and public spaces.

Additionally, while the study presents a structured pathway for implementing 15-minute neighbourhoods, scaling this approach across cities requires further exploration of institutional frameworks, governance mechanisms, and financial models. Further work is needed to establish long-term governance structures and policy pathways to integrate 15-minute neighbourhood planning into existing statutory planning frameworks.

8 CONCLUSION

The transformation of Nallurahalli into a sustainable 15-minute neighbourhood represents an ambitious yet achievable model for reimagining urban living in Indian cities. This research highlights the significance of decentralised, neighbourhood-level planning as a tool for addressing the complex challenges posed by rapid urbanisation. By focusing on hyperlocal solutions tailored to the specific needs and aspirations of residents, the 15-minute neighbourhood model not only enhances quality of life but also fosters inclusivity, equity, and environmental sustainability.

The research draws on the Availability-Accessibility-Quality framework to uncover critical gaps in Nallurahalli's mobility infrastructure, public spaces, and social amenities. Addressing these gaps through the proposed Policies-Plans-Projects framework provides a roadmap for enhancing walkability, fostering vibrant public spaces, and ensuring access to high-quality amenities. Immediate interventions, such as footpath enhancements and public space upgrades, offer visible improvements, while long-term projects like ecological restoration and inclusive infrastructure development build resilience and community ownership.

Findings from this study hold significant implications for urban planning, offering actionable insights for policymakers and other key stakeholders. By embedding principles of sustainable mobility and inclusive access into planning processes, the 15-minute neighbourhood model sets a precedent for tackling urban inequities and fostering environmental sustainability.

The value of this research lies in its potential to scale beyond Nallurahalli, providing a replicable model for other neighbourhoods in Bengaluru and across India. Its emphasis on collaboration between city governments, policymakers, development professionals, and citizens ensures that interventions are both context-specific and impactful. By positioning neighbourhoods as building blocks of urban transformation, this study offers a pathway to reimagine Indian cities as hubs of equity, sustainability, and improved quality of life.

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10 ANNEX A: BENCHMARKING OF "MUST HAVES" OF A 15-MINUTE NEIGHBOURHOOD

Indicator	Design Feature	Distance	Density
Move			
Access to NMT infrastructure	Footpaths	Minimum clear width for walking= 2mIn addition to dedicated walking area on the footpath, following zones must be provided for better walking experience: ● Minimum frontage zone width= 0.5m ● Minimum multi-utility zone (MUZ) width= 1.5m	Pedestrian density or pedestrian Level of Service (LOS) must be considered while deciding footpath widths
	Cycle infrastructure	Minimum clear width ● Cycle track (unidirectional)= 2m ● Cycle track (bidirectional)= 3m ● Cycle lane= 1.5m ● Segregated cycle lane (unidirectional)= 2m ● Segregated cycle lane (bidirectional)= 3m	Vehicle dimensions, clearance and volume (traffic) must be considered while deciding cycle track width
Access to public transport	Bus stops	Within 800m of neighbourhood Distance between bus stops: ● Arterial/sub-arterial roads= 500m	2-3 bus stops for 0.6 sqkm neighbourhood area
		● Collector/local roads= 300 – 400m	1 bus per 15,000 persons
	Metro stations	Within 800m of neighbourhood	Before metro rail can be sanctioned, it would be desirable for the city to have atleast 1 million ridership per day on organized public transport (any mode)
Access to intermediate public transport (IPT)	Auto-rickshaws/ e-rickshaws/ taxi stand	Within 400m of neighbourhood	Not available
Inclusive and accessible streets	Pedestrian crossings	At-grade crossings must be available at every 250m	Not available
	Landscape buffer	Width= 0.3 – 1.2m	Trees must be planted every 5-7m in the landscape buffer along footpaths
	Pedestrian waiting area	Street furniture must be placed at 100m intervals along roads with high volume of people	Not available
	Street lighting	Spacing of street lights along: ● Local/sub-local road: single sided, at 10m intervals	25-30 Lux level of lighting must be available on footpaths[5].
		● Collector road: staggered/opposite sides, at 15m interval	
		● Sub-arterial road: central, at 30m intervals	
		● Arterial road: central+ opposite, at 30m intervals	
	Wayfinding and signage	Warning signs should preferably be located: ● 1.2m ahead of pedestrian crossings	Not available
		● 50m ahead of intersections	
Indicator	Design Feature	Distance	Density
Play			
Access to open spaces	Parks	Within 300-800m	2-3 per 10,000 persons
	Playgrounds	Within local schools and educational institutions	2 per 10,000 persons
Inclusive and accessible public spaces	Public toilets	Every 500m in areas with high volume of people	Provision for male: 1 water closet (WC) per 100 to 400 persons1 urinal for 50 personsProvision for female:2 WCs per 100-200 persons[6]
	Drinking water fountain	Not available	Not available
Indicator	Design Feature	Distance	Density
Include			
Access to neighbourhood level markets	Local/ neighbourhood shopping complex	Within 1.5-2km of neighbourhood	1 per 15,000 persons
Access to social infrastructure	Convenience or grocery stores	Within 300-500m of neighbourhood	1 shop for every 110 persons

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Regime Complexities in the Political Economy of Cobalt Mining in the DRC

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1 ABSTRACT

The surge in global demand for cobalt, driven by the growth of lithium-ion battery markets, has ignited a mining boom in the Democratic Republic of the Congo (DRC). However, the extractive industries in the DRC are entangled in complex power dynamics, murky governance structures, and severe social and environmental degradation. This article employs the regime complex theory to dissect the intricate political economy of cobalt mining in the DRC. Our meta-synthesis of content analysis, integrating findings from diverse sources, exposes how the cobalt mining regime complex, characterised by intersecting international trade agreements, national mining codes, and informal artisanal mining networks, perpetuates inequality, fuels conflict and undermines sustainable development in the region. This research underlines the imperative for a nuanced understanding of the transnational governance arrangements that shape the political economy of cobalt mining.

Keywords: Democratic Republic of Congo, regime complex theory, cobalt mining, governance, sustainability

2 INTRODUCTION

As a key ingredient in lithium-ion batteries, cobalt will play a critical role in low-carbon transition and be pivotal in decarbonising the power and transport industries globally. The World Bank noted that the global consumption of cobalt is projected to reach 200 500 tonnes and 344 000 tonnes in 2025 and 2030, respectively, with an annual growth rate of 9.6% between 2017 and 2030 (World Bank, 2021). The demand for cobalt in lithium-ion-based batteries is estimated to increase 17−19 times from 2020 to 2050, requiring a drastic expansion of supply chains (Xu et al., 2020). The DRC supplies 70% of the cobalt mined globally (Calvão et al., 2021; Shengo et al., 2019; US Geological Survey, 2021), with 30% mined artisanally (Warneck, 2024). According to Alves Dias et al. (2018), approximately 55% (10 million tonnes) of global cobalt resources are in the DRC. As such, the country has a large opportunity to reduce poverty, contribute to low-carbon economies, and develop its economy by leveraging cobalt supplies. According to the International Monetary Fund (IMF, 2019), nearly a third of state revenue in the DRC comes from natural resource extraction. Table 1 shows the total cobalt production in the DRC from 2016 to 2020.

Year	DRC production	Global contribution from DRC
2016	64	58.2%
2017	90	57.1%
2018	73	71.4%
2019	100	69.4%
2020	95	67.9%

Table 1: DRC: Global cobalt contributions (thousand tons). Source: World Bank (2021)

In 2018, cobalt contributed to 35% of total mining exports and 10% of the country's gross domestic product (IMF, 2019. China dominates the refined cobalt sector, recording a market share of 67% in 2019, up from 53% in 2015, and owning 8 of the 14 largest cobalt miners in the DRC. The most refined cobalt supplied by China is specifically for cobalt chemical products (Organisation for Economic Co-operation and Development (OECD), 2019). However, artisanal and small-scale mining (ASM) own a significant share of the mineral production in the DRC, contributing 10% to 20% of the total supply. Despite their contribution, ASM miners only get meagre wages. In 2019, a lawsuit was filed in courts in the United States against many major automotive and technology companies, accusing them of aiding and abetting the exploitation of child miners in the DRC to source cobalt. This could negatively impact the country's comparative advantage in the projected supplies from 2025 (World Bank, 2021).

There is a need for the DRC to come up with a policy that protects the ASM to take advantage of the predictable window of opportunity in the global market. This should be drafted with care considering consumer concerns, promote economic opportunities for artisanal miners, provide legal security for miners'

work and increase access to legitimate supply chains. These issues, including poor working conditions in mining sites, protection of human rights, child labour, and corruption, need a closer look in the sector. Cobalt mining in the DRC has provided poverty reduction, community development, and regional stability, but it also poses risks such as accidents, environmental pollution, and violent conflict (Sovacool, 2019).

This paper employed the regime complex theory to dissect the intricate political economy of cobalt mining in the DRC. This research will shed light on the transnational governance arrangements shaping the cobalt mining sector in the DRC by examining the intersecting international trade agreements, national mining codes, and informal artisanal mining networks. This paper sought to contribute to a nuanced understanding of the complex power dynamics and governance structures that underpin the extractive industries in the DRC and to inform policy interventions that promote more equitable, sustainable, and responsible mining practices in the region.

The introduction provides an overview of the research context and objectives. The literature review examines the regime complex theory and its application to the study of global governance and extractive industries, as well as existing research on the political economy of cobalt mining in the DRC. The section on the cobalt mining regime complex in the DRC analyses the intersecting international trade agreements, national mining codes, and informal artisanal mining networks that govern the sector. The impacts of the cobalt mining regime complex on the economy, environment, and society in the DRC are then examined. Key findings are presented, followed by a discussion. Finally, the conclusion summarises the key findings and implications of the research and provides recommendations for improving the governance of the cobalt mining sector in the DRC.

3 LITERATURE REVIEW

3.1 Regime complex theory and governance in the cobalt mining sector in the DRC

As conceptualised by scholars such as Keohane and Victor, the regime complex theory explores the interconnected network of formal institutions, informal norms, and overlapping rules that govern specific policy domains. These regimes are often fragmented, resulting in legal inconsistencies and governance gaps, yet they also provide opportunities for powerful actors to manoeuvre strategically (Alter and Raustiala, 2018). The regime complexes are particularly relevant in extractive industries such as cobalt mining. The DRC exemplifies this complexity with its vast cobalt reserves. As the global leader in cobalt production, the DRC operates within a governance framework shaped by international agreements, corporate interests, and local norms. However, the overlapping nature of these structures often leads to fragmented decision-making and regulatory gaps, which can hinder effective resource management (Raustiala and Victor, 2004).

Power dynamics further complicate the governance of cobalt mining in the DRC. Major global powers such as the United States and China heavily influence the regime complex, shaping international rules and decisions that impact local governance (Jho and Kim, 2021). At the same time, the DRC government wields significant authority as the custodian of most global cobalt reserves, playing a crucial role in market supply (Alves Dias et al., 2018; World Bank, 2021). Nevertheless, the lack of coordinated governance mechanisms often exacerbates inequalities and creates uncertainty in policy implementation. Analysing the regime complex of the DRC's cobalt sector reveals challenges and opportunities, emphasising the need for collaborative governance approaches that balance international influence with local needs and sustainability goals.

3.2 Political economy of cobalt mining in the Democratic Republic of Congo

The interplay between global demand, local governance, and artisanal mining practices shapes the DRC. China's dominance in the cobalt value chain is evident, controlling 50% of the DRC's production and refining processes while also leading global electric vehicle production, an industry that heavily relies on cobalt (Gulley, 2023). The dependency raises concerns about market risks, environmental degradation, and ethical supply chains. Meanwhile, the artisanal mining sector remains central to the DRC's cobalt output, providing livelihoods but often operating under poor labour conditions and informal economies. Studies such as that by Sovacool (2020) argued that integrating artisanal mining into formal supply chains could enhance social sustainability and stabilise the sector, particularly as global markets push for a low-carbon transition.

Local governance and political instability further complicate the sector. Revising the Mining Code 2018 increased royalty rates and heightened investor risks due to governance challenges, corruption, and reputational concerns (Zeuner, 2018). Weak institutions and elite control over resources exacerbate inequalities, limiting community benefits. Nevertheless, the sector has contributed to poverty reduction and regional development. However, researchers like Anderson (2023) and Schleich (2024) underscored the need for policy reforms to address child labour, low wages, and human rights abuses. By fostering accountability and innovation, the DRC can leverage its cobalt reserves for sustainable development while addressing the pressing social and environmental issues tied to mining practices.

3.3 Reputational risks and governance challenges in artisanal cobalt mining in the DRC

In the DRC, ASM presents significant reputational risks for global supply chains due to its association with child labour, poor working conditions, and environmental degradation (Umpula and Dummett, 2024). Cobalt, a critical mineral for the global transition to green energy, has become a symbol of human rights abuses in the region. The lack of transparency and traceability in the cobalt supply chain has prompted many companies to exclude ASM cobalt from their value chains. This decision threatens the economic well-being of thousands of miners and communities reliant on this sector. According to Sovacool (2020), artisanal cobalt mining, despite its challenges, could be reformed to empower miners and drive socio-economic development if integrated into formalised systems. Efforts to address these issues, such as the 2019 decrees passed by the DRC government, Decree No. 19/15 and Decree No. 19/16, seek to end child labour and improve working conditions in the cobalt mining industry, involving collaborative efforts between the government, civil society, and small-scale producers (Umpula and Dummett, 2024).

The governance of cobalt mining in the DRC is deeply intertwined with national policies, international trade agreements, and the informal nature of artisanal mining networks. Informality, as Geenen (2012) explained, is exacerbated by conflict, poverty, and a weak state control, making formalisation efforts highly challenging. Economic and security considerations significantly shape decision-making in regions like the eastern DRC, where insecurity drives migration to artisanal mining sites (Maclin et al., 2017). The formalisation of ASM often places additional strain on miners, creating what Vogel et al. (2017) termed. the "miner's canary" effect, as livelihoods become increasingly precarious. However, researchers have highlighted that mutual benefit-sharing and negotiation between artisanal miners and state-sanctioned systems can enhance access to mineral wealth, underscoring the importance of inclusive reforms (Verbrugge et al., 2015). Schwartz et al. (2021) further emphasised the need for interventions to address health risks to children and communities associated with ASM, demonstrating that targeted policies can mitigate the sector's broader social and environmental impacts.

3.4 International trade agreements shaping the mining sector of the DRC

The DRC's mining sector is deeply intertwined with international trade agreements, shaping its governance, economic landscape, and resource management. These agreements influence the inclusion of Congolese artisanal cobalt in global supply chains, with considerations of bargaining power, resource dependency, and political stability at their core (Zeuner, 2018). The complex dynamics of corporate enforcement and overlapping property rights further exacerbate conflicts in the cobalt mining sector (Katz-Lavigne, 2020). In this section, the role of key trade agreements and their implications for the DRC are explored under specific themes.

The DRC is a signatory to significant trade agreements, including the World Trade Organization's Agreement on trade-related aspects of intellectual property rights (TRIPS), the African continental free trade area (AfCFTA), and the protocol on mining of the Southern African Development Community (SADC). These frameworks collectively aim to liberalise mineral trade, attract foreign investment, and foster regional cooperation. For example, the AfCFTA, established to create a single market for goods and services across Africa, holds transformative potential for the DRC's mining sector by boosting mineral exports and promoting economic growth (Abrego et al., 2019). However, while broader economic implications are widely documented, sector-specific impacts on mining remain underexplored in the literature. Similarly, the focus of the SADC on regional development initiatives, such as renewable energy adoption, could indirectly influence mining operations by addressing critical energy challenges in the region (Jadhav et al., 2017).

International legislation, such as the U.S. Dodd-Frank Act, has directly impacted the governance of the mining sector in the DRC. This law mandates companies to disclose the origins of minerals, including tin, tungsten, tantalum, and gold (3TG), to reduce the trade in conflict minerals (Byemba, 2020). Although well-intentioned, this regulation has inadvertently marginalised artisanal and small-scale miners, who often struggle to meet compliance requirements. Similarly, the Kimberley Process, designed to curb the trade of conflict diamonds, has improved the diamond mining sector but faces criticism for limited scope and inadequate implementation (Byemba, 2020; Mthembu-Salter, 2009). These measures underscore the challenges of balancing regulatory objectives with the realities faced by artisanal miners.

The TRIPS agreement has set minimum standards for intellectual property protection, impacting technology access in developing countries such as the DRC (Khor, 2002). Although TRIPS aimed to boost exports from developing nations, evidence suggests that it has predominantly benefited developed countries, particularly in the pharmaceutical sector (Lanoszka, 2003; Smith et al., 2009). It raises concerns about its applicability to the mining sector, where access to cutting-edge technologies is crucial for efficient and sustainable operations. China's involvement in the copper and cobalt mining of the DRC illustrates a dualistic approach combining developmentalist and extractivist strategies. While such engagements have supported infrastructure development and economic gains, they have also faced challenges tied to political instability and regime changes (Shen and Fu, 2024). These dynamics highlighted the need for a nuanced understanding of how trade agreements intersect with global partnerships in shaping the DRC's resource governance.

3.5 Impact of the DRC mining code revisions on governance and investment

In 2018, the DRC introduced significant revisions to its national mining code, seeking to address long-standing governance, transparency, and resource exploitation issues. The revision was seen as an attempt to rejuvenate the national mining sector while promoting sustainable development. However, as Zeuner (2018) highlighted, these changes triggered cautious investment decisions from mining companies, reflecting a growing concern about the balance between resource governance and economic exploitation. The increased premium risk introduced by the revised code underscores the tension between attracting foreign investment and ensuring equitable benefits for the Congolese population. While the code mandates that companies pay royalties and taxes and comply with environmental regulations, it has been criticised for its lack of transparency, limited state control, and insufficient social and environmental safeguards (Michel and Kime, 2021).

Despite the ambition of the 2018 revision, the code has yet to address many of its predecessor's weaknesses, leaving the DRC mining sector vulnerable to exploitation. Lisumbu (2020) argues that while the revised code was intended to stimulate national production alongside foreign private ventures, the increased tax burdens, such as the 10% royalty on strategic substances and a 50% super-profits tax, may undermine the country's competitiveness in the global mining market (Radley et al., 2017). As Radley (2018) observed, mining executives often view the taxes as manageable, expecting significant rewards from the country's vast resource wealth. However, the code's lack of effective enforcement mechanisms, particularly in treating ASM, could result in a missed opportunity for inclusive growth. Buraye (2017) pointed out that there are too few artisanal exploitation zones to accommodate many artisanal miners, exacerbating the sector's informality and perpetuating exploitation.

The World Bank's influence on mining regimes in Africa, including the DRC, further complicates the effectiveness of the mining code. Bush (2010) critiqued the World Bank's mining policies, arguing that they often undermine the development goals of African states by promoting policies that prioritise resource extraction over long-term socio-economic development. This challenge is evident in the DRC, where the mining code's focus on attracting foreign investment may not necessarily translate into tangible benefits for the Congolese people. Moreover, Renzi (2021) underscored the importance of enforcing environmental laws and mining codes in the DRC and neighbouring countries like South Sudan and Rwanda to create sustainable, high-quality environments. Effective enforcement is crucial to prevent environmental degradation, a persistent issue in the DRC's mining sector.

3.6 Social and environmental impacts of cobalt mining

Cobalt mining has led to widespread environmental degradation, with far-reaching consequences for ecosystems and communities. Deforestation, water pollution, and soil degradation are prominent concerns

tied to mining activities. For instance, cobalt extraction in the DRC has resulted in significant land cover changes, affecting water resources, trees, shrubs, grasses, and cultivated lands, ultimately threatening vulnerable populations (Brown et al., 2022). Mining operations contribute significantly to eutrophication and global warming, with activities such as medium-voltage electricity use and blasting identified as major contributors (Farjana et al., 2019). Additionally, the contamination of water bodies with toxic substances from mining poses serious risks to both environmental and human health, as noted by Sharma (2023). Alarmingly, 70% of global cobalt resources are situated in high-risk environments, exacerbating the potential for environmental damage (Lèbre et al., 2020). While the energy transition might offset some environmental impacts by 2050, as Meide et al. (2022) suggested, the immediate ecological harm remains concerning. Moreover, weak environmental oversight further amplifies the challenges, with mining practices releasing harmful contaminants into surrounding ecosystems and communities (Sovacool, 2020).

The social dimensions of cobalt mining are equally troubling, with issues such as child labour, forced labour, and human rights abuses dominating the sector. Artisanal mining in the DRC exposes vulnerable communities to toxic substances, resulting in severe health risks, particularly for children (Nkulu et al., 2018). The lack of transparency in the mining supply chain perpetuates corruption, undermines trust in government institutions, and fails to channel revenues into economic diversification or community development projects (Michel and Kime, 2021). The exploitation of labour, poor working conditions, and displacement of communities are common in cobalt mining regions. Schleich (2024) highlighted the destruction of land, homes, and farms, alongside physical and verbal abuse, non-liveable wages, and child labour, as grim realities for Congolese residents. Additionally, conflicts surrounding mining activities emerge both upstream and downstream in the supply chain, reflecting tensions in governance and resource management (Prause, 2020). Despite these challenges, Sovacool (2020) pointed out that cobalt mining, in certain situations, has also empowered communities, demonstrating its dual-edged impact.

The overlap of social and environmental challenges creates a compounded burden on affected communities. Environmental pollution from mining activities exacerbates health issues, while the absence of socio-economic investments leaves communities trapped in cycles of poverty and exploitation. Shen and Fu (2024) critiqued developmental and extractivist approaches in China's engagement with the DRC's mining sector, highlighting the socio-economic ramifications of the country's development trajectory. Meanwhile, Umpula and Dummett (2024) proposed a roadmap for addressing child labour and improving working conditions, emphasising the need for collaborative governance among the government, civil society, and small-scale producers.

4 METHODOLOGY

This study employed a qualitative methodology, using a desk review to explore the complexities of cobalt mining in the DRC's political economy. Data were sourced from various published materials, including books, peer-reviewed journal articles, and policy documents accessed through databases such as Google Scholar and Scopus. The approach ensured comprehensive coverage of relevant scholarly and institutional perspectives. Textual analysis was employed to interpret and examine the data, focusing on patterns, themes, and insights related to regime complexities. This method facilitated a nuanced understanding of the political and economic dimensions of cobalt mining governance..

5 FINDINGS

5.1 Fragmented governance in cobalt mining

The DRC's cobalt mining sector is governed by a regime complex characterised by overlapping formal and informal rules and fragmented decision-making processes. This complexity often results in governance gaps hindering resource management and legal inconsistencies. Despite this, the regime structure provides avenues for strategic manoeuvres by powerful global and local actors, further complicating regulatory oversight.

5.2 Global power dynamics and local challenges

Major global players such as the United States and China significantly influence the governance landscape of the DRC's cobalt sector. China, for instance, dominates the cobalt value chain, controlling production,

refining, and supplying electric vehicle manufacturing. Meanwhile, weak local governance, political instability, and elite resource control exacerbate inequalities and limit the benefits for local communities. In the DRC, the 2018 revision of the mining code, aimed at increasing state revenue, created tensions by raising investor risks while failing to address core governance challenges.

5.3 Artisanal and small-scale mining

ASM is vital in cobalt production but is plagued by poor labour conditions, child labour, and environmental degradation. While the sector provides livelihoods for many, its informal nature and lack of transparency pose reputational risks for global supply chains. Efforts to formalise ASM have faced significant challenges, often marginalising miners and creating economic insecurity.

5.4 Impact of international trade agreements

Trade agreements such as AfCFTA, SADC's mining protocols, and the US Section 1502 of the Dodd-Frank Act of 2010 shape the DRC's mining sector governance. While these frameworks aim to enhance economic growth and transparency, they often have unintended consequences, such as marginalising artisanal miners or creating compliance burdens. The DRC's integration into global supply chains remains constrained by the misalignment of these agreements with local realities.

5.5 Revised mining code and its implications

The 2018 mining code revisions introduced higher royalties and taxes on cobalt production, aiming to secure equitable national benefits. However, the changes increased investment risks and reduced the sector's competitiveness in global markets. Although the code includes environmental and social safeguards, it has been criticised for insufficient implementation and transparency, leaving the sector vulnerable to exploitation.

5.6 Opportunities for reform

Despite the challenges, the DRC's cobalt sector holds significant potential for sustainable development. Integrating artisanal mining into formal supply chains, improving transparency, and fostering collaborative governance could address the sector's social and environmental issues. International partnerships and targeted reforms can be pivotal in leveraging cobalt resources to promote economic growth and reduce inequalities.

6 DISCUSSION

The study revealed significant findings that aligned with existing literature on governance and the political economy of extractive industries. The research underscored the complexities of the regime complex theory, as articulated by Keohane and Victor (2011), highlighting the fragmented nature of governance structures in the DRC. This fragmentation leads to inconsistencies in regulatory frameworks, creating opportunities for powerful actors to exploit resources while undermining local communities. The findings suggested that the potential for sustainable development remains severely compromised without a cohesive governance strategy that integrates international agreements and local regulations.

Moreover, the study emphasised the role of artisanal mining in the DRC's cobalt sector, echoing Sovacool's (2020) assertions regarding the socio-economic implications of informal mining practices. Artisanal miners contribute significantly to cobalt production, yet face dire working conditions and limited economic benefits. The findings indicated that integrating these miners into formal supply chains could mitigate some challenges, promoting better wages and working conditions. It aligns with Anderson's (2023) and Schleich's (2024) calls for policy reforms that address human rights abuses and enhance accountability within the mining sector, suggesting that reforming artisanal mining practices could lead to broader community development.

The influence of international trade agreements on the DRC's mining landscape is another critical finding of this research. The study illustrated how agreements such as AfCFTA and the TRIPS framework shaped resource management and economic opportunities in the region. Zeuner (2018) highlighted similar themes, noting that while these agreements aim to liberalise trade and attract investment, they often overlook the

specific needs of artisanal miners. The findings suggested that a more nuanced approach to trade agreements is necessary to ensure they benefit local communities rather than exacerbate existing inequalities.

Finally, governance challenges related to child labour and poor working conditions in cobalt mining are underscored in this study, resonating with Umpula and Dummett's (2024) analysis of reputational risks associated with artisanal mining. The findings revealed that despite efforts by the DRC government to improve conditions through recent decrees, significant gaps remained in implementation and enforcement. It indicated a pressing need for collaborative efforts among stakeholders, including civil society and international organisations, to develop effective strategies for addressing these issues. These key findings highlighted the intricate interplay between local practices, international influences, and governance structures in shaping the future of cobalt mining in the DRC.

7 CONCLUSION

The cobalt mining regime complex in the DRC is characterised by a lack of transparency, accountability, and governance, which perpetuates negative social, environmental, and economic impacts. The fragmented governance structures exacerbate inequalities and hinder sustainable development as powerful actors exploit regulatory gaps. While crucial for local livelihoods, artisanal mining often operates under dire conditions, with miners receiving minimal economic benefits. Additionally, international trade agreements shape the mining landscape, influencing local practices and global supply chains. The findings underscored the urgent need for cohesive governance strategies that address human rights issues and promote equitable resource management. This study recommends that the DRC establish a unified regulatory framework integrating international agreements with local laws to enhance accountability and transparency in cobalt mining operations. It should involve collaboration between the DRC government, international organisations, and civil society.

Moreover, it should implement policies that support the formalisation of artisanal mining, ensuring that miners receive legal recognition and access to legitimate supply chains. It could improve working conditions and provide better economic opportunities for local communities. In addition, the country should strengthen enforcement of existing laws to eradicate child labour in the mining sector. It should include targeted interventions to support affected families through education and alternative livelihood programmes. The mining sector should encourage companies to adopt sustainable practices that minimise environmental degradation and support community development. It could involve investments in clean technologies and rehabilitating mined areas to restore ecosystems. Finally, there is a need to foster inclusive dialogue among all stakeholders – government, industry, local communities – as well as non-governmental organisations to ensure that the voices of those most affected by mining activities are heard in policy-making processes. Engagement can help build trust and facilitate more equitable resource management

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Retrofitting the Future: Sustainable Development Through Inclusive Community Initiatives in East Germany's Mitteldeutsches Revier Region

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1 ABSTRACT

This paper examines community-led innovation efforts in the Mitteldeutsches Revier, East Germany's coal-producing region undergoing a seismic transition. These initiatives are reshaping the local innovation system, in performing some of the functions of the traditional pillars of industry, government, and academia amid limited resources. The case studies we look at here rely on trial-and-error methods and local knowledge to act as transfer intermediaries between their communities and external actors. They retrofit old factories, repurpose historical landmarks, and redistribute funds from the coal industry to participatory planning, environmental rehabilitation, and other forward-looking projects. Multifaceted, inclusive collaborations involving different demographic groups, craftspeople, and scientists focus on talent retention, digitalization, and sustainability, addressing broader challenges linked to economic transition. But despite their creativity and resilience, these initiatives encounter persistent barriers such as inadequate infrastructure, unstable funding, participant disengagement or distrust, and overburdened leaders who struggle to meet their goals within institutional frameworks. Through interviews with leaders of selected initiatives, this study explores their obstacles, motivations, existing resources, and learning processes. It focuses on how they transform knowledge into actionable strategies and develop the capability to innovate despite persistent local deficiencies and bureaucracy. Beyond technical expertise, these organizations rely heavily on collaborative decision-making and social connectedness, which propel inclusivity and a shared sense of purpose. These elements, we argue, are essential for achieving sustainable local development in resource-constrained areas. Our analysis points especially to the importance of socialization, as we found the nurturing of strong networks, trust, and a collaborative spirit across stakeholder groups to be a core capability to absorb, apply, and transfer knowledge within a local innovation system.

Keywords: Innovation Systems, East Germany, Sustainability, Triple Bottom Line, Rural-Urban Divide

2 INTRODUCTION

Economic transitions pose grave challenges for cities and regions reliant on declining industries. Whether due to recessions, outsourcing, technological advances, regime shifts, or environmental imperatives to transform the energy grid, heavy industries' departure has been found to undermine communities' economies and social bonds (Beckfield et al., 2020). In Germany, this has contributed to a regional divide spurring commercial and population exoduses as well as political radicalization. At the same time, this scenario has created opportunities for civil-society organizations in East Germany to step in where support is absent or limited. These organizations often pursue sustainable objectives in their services, which are closely linked to their communities' needs.

The integrated version of the triple bottom line, which is gaining traction in academic circles, advocates for environmental, social, and economic sustainability to be given equal importance in business models, city planning, and policymaking (Elkington, 1994; Farny & Binder, 2021). The world's failure in taking such a holistic approach to sustainability thus far is evident in record-high carbon emissions, rising inequality, and environmental and political fallouts (van Zanten & van Tulder, 2021; United Nations, 2024). When economic development goals are reached, still based on monolithic measures such as Gross Domestic Product (GDP), environmental ones often take a hit. When progress is made in preservation and energy transition policies, the social part tends to be neglected; workers in traditional industries feel left behind and may misdirect their rage into electing parties that oppose sustainability efforts and threaten their continuity locally and internationally.

In the present study, we apply a case-study approach to inquire what we can learn from local intermediaries' mix of sustainability and social solidarity with cultural and economic aims, alongside their resource

limitations and barriers, in rural areas now transitioning from coal. Initiatives in the district of Burgenlandkreis, state of Saxony-Anhalt, are retrofitting old factories and historical landmarks into centres for innovative collaborations. In Meißen, Saxony, youth and industry professionals are working together towards youth competency development and talent retention, amid an aging population. Nordsachsen, also in Saxony, hosts socially sustainable environmental initiatives. Through semi-structured interviews with these entities and qualitative analysis, we tested assumptions derived from innovation-studies theories and arrived at some suprising results: Our data indicates that socialization conditions in tight-knit communities may still allow for knowledge transfers and product or service innovations, even if incrementally, where coordination and systematization are weak.

Based on our findings, we also propose that a high level of intrinsic motivation to serve and honour the needs of the community facilitates the adoption of an integrated approach to the triple bottom line of sustainability. Members of civil society in resource-constrained regions may be especially poised to do so, as they have had to learn how to creatively achieve more with less. As bridges between external and internal stakeholders in their districts, intermediaries may be uniquely positioned to channel different resources, knowledge, interests, and groups of participants into collective projects to address pressing issues for the local social fabric. This is underlined by the self-positioning of one of our interviewees, who leads a protestant diaconical service in Nordsachsen: "In the end (…) we are the glue of society. To a large extent, we ensure that our society doesn't fall apart. And that, at the very least, marginalized groups find some space to be heard and acknowledged."[1]

Such civil-society actors rely on experimentation and the resources at hand to redefine what a local innovation ecosystem could become, serving as a fourth pillar in a "quadruple-helix" model to compensate for the absence of the traditional "triple-helix" pillars of government, industry, and research, or link the community to external resources from those pillars (González-Martinez et al., 2021; Leydesdorff & Etzkowitz, 1998). Due to their competencies, motivations, personal values, and positions in social space, local intermediaries can see both the trees and the forest, so to speak. They can address sustainability both from a local perspective and more diverse, global viewpoints. To contextualize these projects, districts, and their region, Mitteldeutsches Revier, we now discuss the relevant historical and industrial background, before turning to our methodology and case studies.

3 BACKGROUND

3.1 The Tough Transition from Coal Mining and Heavy or Traditional Industries

Mining has been an integral part of East Germany's economy for centuries. It encompasses a deeply ingrained system of social ranks and identity, surviving in regionalartifacts, festivals, songs, and folklore, as well as in environmental decay and disadvantages to the working class still living off this traditional activity. While other minerals have seen their heyday come and go in Germany, coal is perhaps the most emblematic of the ongoing economic transition: Once the world's third-largest coal producer, Germany plans to phase out its coal-fired power generation by 2038. This deadline could be moved up as the country strives to quickly reduce its dependence on Russian fossil fuels amid climate change, the war in Ukraine, and rising prices in a declining economy and uncertain world order (Furnaro et al., 2021; Curry, 2022; Twidale, 2024; Fairless & Benoit, 2025).

Meanwhile, the Mitteldeutsches Revierand adjacent Lusatia regions are still known as Germany's hotspot for lignite (brown coal). Furnaro et al. (2021) report that productionreached an estimated430 million tons per year at its peak in the mid-1980s, making the area and its industrial ecosystem heavily dependent on one commodity.Then, after Reunification in 1990, two-thirds of coal-industry jobs, or 100,000, disappeared from East (Central) Germany. Population lows for both rural and urban areas in the region rapidly followed, as the industrial and business ecosystem collapsed.Nearby textile and chemical plants were abandoned and rural railways defunded. Without the Wall and with more opportunities in West Germany, many companies and inhabitants went there.

[1] Translated by Lucina Diehl from the original German interview, conducted with Janet Liebich on site at the Evangelisches Diakoniewerk Oschatz-Torgau, on November 13, 2024.

The effects of the accelerating industrial shift have been particularly harsh on a rural population that lacks the training to transition from traditional to technology-intensive services. Older professionals not yet at retirement age are often unable to compete in the job market with the younger generations which are in turn flocking, along with jobs, to urban areas. Besides heavy manufacturing, the obsolescence issue extends to crafts industries such as bakeries and wood- and metalwork, which must now learn to digitalize to reach customers. In recent years, government funding for rural regions has intensified and local educational offers have become more focused on in-demand competences, but the Mitteldeutsches Reviercontinues to struggle to secure investments, a skilled workforce, and the capacity for entrepreneurial innovation (Gramlich, 2019; Rammer, Gottschalk et al., 2020).

In fact, Germany as a country is found to be struggling to match other European Unionmembers' level of digitalization due to its resistance to new technologies and gaps in its telecommunications infrastructure, among other factors (Płóciennik, 2021).Also contributing to stagnation may be imbalanced infrastructural investments in general and a failure to tailor funding schemes for regional development, and their often steep bureaucratic requirements, to local communities' or intermediaries' needs and limitations. Whereas in the 20th century, theMitteldeutsches Revier had to dramatically adapt as towns were razed to clear way for the coal mines, this infrastructure is now gradually being replaced by windmills and human-made lakes with leisure areas.But outside bigger, more urbanized cities such as Berlin, Leipzig, Dresden, Chemnitz, and Halle, tourism and transport infrastructure, which often go hand in hand, remain underdeveloped in East Germany.Many of its smaller cities' once-buzzing commercial buildings and factories still lie empty, and this low activity translates into limited leisure and tourism options.A case in point is Zeitz,historically the biggest city in Burgenlandkreis and about 40 km from the Saxon city of Leipzig, which is about 20 times its size.Once a residence for bishops,monks, and dukes, the millennium-old Zeitz has seen its identity reshaped by the Industrial Revolution and now, again, by the Digital Revolution it must enter (Agents of Change in Old-Industrial Regions in Europe, n.d.).

Zeitzonce thrived on industries such as mechanical engineering, sugar production, and stroller manufacturing.Now, it has seen that base reduced to only a few major employers, namely the surviving coal operations of the Mitteldeutsche Braunkohlengesellschaft (MIBRAG), the Zetti confectionery, and the Südzucker sugar and bioethanol factory (Agents of Change in Old-Industrial Regions in Europe, n.d.). Despite government and grassroots efforts over the past 20 years to promote digitalization, organize large community events, and rehabilitate landmarks such as the Moritzburg Castle to attract business, tourists, and local culture enthusiasts, recovery for Zeitz and surroundings has been slow and painful (Zeitz Digital, n.d.; Agents of Change in Old-Industrial Regions in Europe, n.d.; Mitteldeutsche Zeitung, 2021).Zeitz has lost nearly half its 50,000 residents since 1989, with half the area's businesses having closed by 2001, after unemployment reached up to30%in some parts of the Mitteldeutsches Revier (Agents of Change in Old-Industrial Regions in Europe, n.d.).

Image 1: Old monastery retrofitted into the communal living, working, and cultural space Kloster Posa in Zeitz (Burgenlandkreis, Saxony-Anhalt). Taken by Ana Beatriz Ribeiro.

The State Chancellery of Saxony (2017) estimates this state to have lost 15% of its five million peoplein the two decades following the year 1990. Between 1930 and 1998, Leipzig itself, its biggest city, had lost 40%

of its 718,000 inhabitants. But along with Dresden, the state capital and one of its main touristic hubs, Leipzig has since entered the 500,000-1 million population range once again, qualifying as a "metropolitan area" (OECD, n.d.).Leipzig's population could grow by up to an estimated 13% and Dresden's by up to 10% by 2030, with Leipzig on the way to recouping its population peak by 2040 as Germany's fastest-growing city (State Chancellery of Saxony, 2017; City of Leipzig, 2025). This makes both cities more attractive to new industries – and thus further investments and renovations – than surrounding districts, whose populations keep declining.

For the Saxon district of Nordsachsen, projections point to an additional loss of as much as 7.5% of its present 200,000 residents by 2030 (State Chancellery of Saxony, 2017). Although its town of Schkeuditz houses one of DHL's global hubs and the Leipzig-Halle Airport, employing thousands of people, it is likely that due to its proximity to both Leipzig and Halle, at less than 30 km, most of its employees would rather live in those bigger cities. Meißen,next to Dresden, could lose a similar 7.2% out of its 250,000 residents, despite its eponymous city's reclaiming of its historic charm, built on the porcelain industry and a renovated cathedral and castle.

Without the diversified industries, research hubs, workforce, and institutional support densely populated urban areas enjoy, smaller, rural cities have been on the losing side of liberalization and its demands (Horbach & Rammer, 2022; Rammer, Kinne et al., 2020).High unemployment, low innovation, and weak infrastructure continue to drive people away or sow deep fear and discontent in German rural areas (Gramlich, 2019; Rammer, Gottschalk et al., 2020). It is telling that, with its populist, anti-globalization discourse, the far-right party "Alternative for Germany" (AfD) had won over more voters in the Mitteldeutsches Revier and Lusatia than anywhere else in the country by the 2021 Federal Elections (Voce & Clarke, 2021). The vote in Berlin was markedly more progressive and aligned with West-German metropolises; this mirrors regional, rural-urban divisions elsewhere in Europe and across the ocean in a United States undergoing similar industrial transitions.

Extreme right-wing parties have ridden to a meteoric rise on this tsunami of anger and scapegoating among those who believe democratic governments have failed them, taken advantage of by malicious political actors. However, as the subsequent sections will illustrate, intermediaries are rising up as progressive forces in rural East German communities to combat the illiberal influences that threaten plans for sustainability and inclusion.

3.2 The Rural-Urban Economic Divide and Social Counter efforts at the Grassroots Level

Germany's East-West, rural-urban divide has continued to manifest over the decades insocioeconomic figures. According to Gramlich (2019), East Germany's 18% unemployment rate in the early 2000swas twiceas high as West Germany's, and disposable income was 20% lower.Although East Germany narrowed these gaps over the next two decades, bringing unemployment below 10%, its per-capita productivity remained the lowest in the country. This applies to states of the former German Democratic Republic (GDR) – Thuringia, Saxony, Saxony-Anhalt, Brandenburg, and Mecklenburg-Western Pomerania – except for the Berlin metropolitan area, whose productivity surpassed that of the predominantly rural Schleswig-Holstein state in West Germany.

On a related note,Rammer, Gottschalk et al. (2020) found participation in research and development (R&D) activities among rural small and medium-sized enterprises (SMEs) in East Germany to be up to 9 percentage points lower than that of urban firms in the region. By comparison, they point to a much narrower gap in R&D,at 2 percentage points, between rural and urban firms in West Germany. This oftenleads toSMEs'low competitiveness and ability to bring product and process innovations to market vis-a-vis their urban or West German counterparts. Relying on a stronger innovation system and capabilities, bigger cities tend to be more resilient and able to eventually turn transitions and market demands into trade and renewal opportunities.

It follows that resources from academia, industry, and government, known as the traditional three pillars of innovation systems, are often concentrated in more populous, centrally-connected regions, leaving peripheral areas at a disadvantage (Ansari Vaghef, 2022; Leydesdorff & Etzkowitz, 1998). Such a disparity stresses the growing significance and integration of civil society, now recognized as a fourth pillar in innovation-systems theory (González-Martinez et al., 2021). In our research, we treat intermediaries as the fourth pillar in their respective local innovation systems due to their civil-society core: In the Mitteldeutscher Revier, they play a

catalytic role in supporting underserved communities and linking them to external resources. They even take onother, missing pillars' functions.This brings hope that revitalization efforts capitalizing on the region's existing strengths, alongside the drive for sustainability, will facilitate a rebirth for ruralMitteldeutsches Revier areas.

In line with this aim, some of our interviewees have taken on retrofitting infrastructure, such as an old monastery and a food factory, for cultural and educational offers and events (Kultur- und Bildungsstätte Kloster Posa, n.d.; Nudelfabrik Zeitz, n.d.). Another runs a MIBRAG-supported foundation to preserve local coal-related history, while inviting diverse local and international stakeholders to discuss sustainable transitions from coal (Recarbo Erlebnisregion, n.d.). At least one small entity, a digital-platform provider, has assumed a mediator role in a community forum helping bring far-right voters into more moderate positions (WeCreate, n.d.).Others develop locally innovative agricultural, environmental, or social outreach initiatives (Sächsisches Staatsministerium für Umwelt und Landwirtschaft, n.d.; Metropolregion Mitteldeutschland, n.d.; Sprungbrett e.V., n.d.).

As we will seek to demonstrate in the next sections, rural intermediaries could become established innovation facilitators locally if provided with the right forms of support to strengthen the region's collective capabilities and sustainability potential. Although these initiatives contend with many obstacles, and many are still works-in-progress, they reflect a deep determination to remake the region more sustainably and inclusively. In our research, we investigate such intermediaries' ability to turn from community cooperation spaces to innovation facilitators based on their existing capabilities, motivations, resources, and ways of knowledge transfer.We now turn to a discussion on how innovation-study theories shaped our assumptions and how we adjusted them based on our results from interviews with more than 30 service providers in the Mitteldeutsches Revier.The section includes an overview of our methodology and overall results informing our case-study selection and analysis.

4 CONCEPTUAL FRAMEWORK AND FINDINGS

Based on the extant literature on innovation and strategic management, we began our empirical research on the assumption that entities could only transition from cooperation spaces (coworking, networking events) to innovation facilitators (novel product and service development) once they had reached the exploitative stage of learning alongside robust socialization, systematization, and coordination capabilities (Kogut & Zander, 1992; Teece et al. 1997;Lichtenthaler, 2009;Gebauer et al., 2012; Ansari Vaghef, 2022).We found that most of our interviewees had not yet reached the exploitative stage, that in which knowledge, often externally acquired, is transmuted and applied into market-responsive, scalable innovations which can be transferred further as knowledge or technology (Lichtenthaler, 2009;Gebauer et al., 2012;Ansari Vaghef, 2022). However, manyinterviewees showed strong evidence of transformative learning, able to internally maintain and distribute knowledge, as well as reactivate it in response to identified opportunities for innovation. We nowargue that this is sufficient for them to transfer knowledge to the local community – without a profit- or market-driven core – in the form of training, consultancies, event planning and organization, structural renovations, makerspaces, and workshops and forums. They thus impart to recipients new or renewed forms of living, working, or interacting.

The organizations we identified for our sample are mostly led by private citizens who took the initiative, as individuals or like-minded groups, to address pressing issues for their communities, forming associations or small private operations. Our selection criteria for interviewees called for evidence of at least incremental innovations, meaning process or product improvements, or of knowledge transfers through active networks, consultancies, or cultural or job-related education in the districts of Nordsachsen, Meißen, or Burgenlandkreis. We used software-assisted qualitative content analysis (QCA) to categorize our sample and extract themes from our interviews, most conducted on site over 2023-24 (Schreier, 2012). About half the intermediaries we reached out to agreed to an interview. The distribution of theirorganizations' locations and types is seen in Table 1.

Table 1 displays a fairly even distribution among districts for our 33 interviews with leading representatives of intermediary organizations – those creating spaces for others to cooperate on potential innovations or offering innovative services or products themselves. About a third (8) took place with what we classified as "regional development organization," followed closely by "sustainable business or consultancy" (7). The former type, often non-profit, addresses aspects like tourism, economic diversification, or transport-network

development. Some are closely associated with local or regional government bodies, which strengthens their ability to connect beneficiaries to resources and knowledge from external pillars. The latter refers to private operations or non-profit associations involved in organic production, material recycling, or sustainable-tech development, or working as consultancies on innovative practices with a sustainability core. They often perform multiple roles, and could serve as both a civil-society and business pillar in creating innovations with close community input. These two categories of organizations were mostly concentrated in Burgenlandkreis and Nordsachsen (12).

Code System	Burgenlandkreis	Nordsachsen	Meißen	SUM
Type of organization				0
Coworking or networking event space	1	1	1	3
Sustainability promotion organization	1	2		3
Regional development organization	4	3	1	8
Continuing or vocational ed school	1	1	2	4
Educational association			2	2
Community improvement association	1	1		2
Sustainable business or consultancy	2	3	2	7
Cultural organization	3	1		4
SUM	13	12	8	33

Table 1: The types of organizations in the study's sample and their numbers per district. Generated with MAXQDA.

Six of the intermediaries we interviewed focus on education, four of them in Meißen. Four are institutions providing continuing or vocational education; two are non-profits whose primary aim is educational, although they are not official schools. From our interviews, we found some of the main concerns among intermediaries in this district to revolve around the training of craftspeople to become more competitive, digitalization for local SMEs, and youth talent retention. Although these intermediaries may not have explicitly expressed a concern with sustainability, the social dimension of the triple bottom line was evident for most under these categories.

We identified coworking spaces for each of the three districts, which speaks to a slowly growing trend in the region, tied to economic and social sustainability in their desire to offer affordable options to attract SMEs or keep them closer to home. About 9 percent (3) of the intermediaries we interviewed were found to be primarily dedicated to promoting sustainability, engaging in activities such as resource preservation or environmental rehabilitation. In Burgenlandkreis and Nordsachsen, the most locally embedded organizations were those spearheading culture or community improvements, playing an important role in preserving local identity and rebuilding social cohesion through community events and small renovation projects. In the absence of strong institutional support or innovation hubs, initiatives in culture or sustainability have emerged as potential local drivers of innovations as incremental as improved local theatre ticketing or as broad as regional organic farming.

The key catalyst to intermediaries' evolution into innovation facilitators we identified was socialization: that is, the capability to form, maintain, and link a dense social network within and outside the community (Gebauer et al., 2012). It emerged as the main combinative capability in our interviews, allowing for innovative activities and transfers even in the absence of robust systematization (standardizing procedures) and coordination (leading effective collaboration among stakeholders in decision-making). While cooperation, often face-to-face, has been essential to internal and external knowledge transfers, formalized communication and knowledge-storage procedures did not necessarily have to be in place in the case of the mainly small operations we interviewed.

But while socialization can function without the other two capabilities for them, the same is not true in reverse. Most of our interviewees saw themselves as both cooperation and innovation facilitators, speaking to the functions' mutual dependence in an environment where civil society has taken on innovation-pillar functions. Next, our case studies show the importance of community-rooted and intrinsic motivations, a commitment to sustainability, and robust social networks to establishing innovative initiatives despite significant obstacles.

5 CASE STUDIES

5.1 The Main Motivations Guiding Local Innovation Facilitation

In choosing our case studies for this paper, we sought to be representative of the diversity of offers for each of the districts, while accounting for sustainability dimensions and intermediares' potential to integrate the triple bottom line in their work. For Nordsachsen, we selected the "Peter Holstein Engineering Office" (Ingenieurbüro für ingenieur-wissenschaftliche Dienstleistungen),whose sustainable operation has developed an environmental sensor tested in the district (Metropolregion Mitteldeutschland, n.d.). For Meißen, we chose Sprungbrett e.V., a non-profit association that educates disadvantaged youth and rebuilds community cohesion (Sprungbrett e.V., n.d.). Finally, for Burgenlandkreis, our choice was Kloster Posa, premised upon cultural offers, alongside communal living and working and sustainable wine and crafts production (Kultur- und Bildungsstätte Kloster Posa, n.d.). All three interviewees shared motivations that put serving others above themselves, with profit-driven considerations playing a marginal role. All three also provided informed consent for their data to be used.

We conceptualized our interview guide and literature- and data-driven coding frame to analyze all interviews for motivations, obstacles, stages of learning, capabilities, and sustainable innovations in their operations. Table 2 presents their most-often mentioned personal motivations or skills in engaging in innovative activities. The numbers and colour intensities relate to how many times we detected each of the themes across the interviews.

Code System	Kloster Posa	Ingenieurbüro Peter Holstein	Sprungbrett e.V.	SUM
Motivation or pre-requisites for innovative work				0
Competence development	5	8	5	18
Community engagement or recognition	6	2	19	27
Sense of purpose or meaning	4	2	7	13
Instrinsic values or preferences	8	9	1	18
SUM	23	21	32	76

Table 2: The types of motivations or skills in the study's sample and number of mentions per case study. Generated with MAXQDA.

As can be inferred from Table 2, we assigned the theme "community engagement or recognition" to more than a third (27) of the 76 interview answers we classified under the "motivation" category. It appeared more frequently than any other types of motivation overall, although not evenly across the three interviews. While we found this to be the main motivation for Sprungbrett Deputy Board Chairman Martin Tritschler, it was not mentioned as often by our other two interviewees. The theme comprises a feeling of belonging, relatedness, engagement, or affiliation with the community served (Ryan & Deci, 2000;Kasser & Ahuvia, 2002;Seligman, 2010). For intermediaries, it is also tied to the notion that offers must be tailored directly to their local beneficiaries' levels and needs, based on deep knowledge of the community. It is perhaps best encapsulated by this answer by Tritschler, who indicated he valued practice-oriented over external academic input for the entity's youth-education, civic-participation, and structure-revitalization efforts: "You have to meet people where they are. It's no use if I say we're doing big things and no one comes. (…) If I set it too high, they can't do anything with it, they don't want to do it. But when it becomes concrete in their real lives, then something happens."[2]

Trischler has a background in intensive youth therapy and social work. Another interviewee, Peter Holstein, has been a university professor and inventor. Our third interviewee among the case studies, Lennart Sütterlin, is a graphic designer and board member at the Kloster Posa non-profit, where he manages the "musical printing workshop." The main motivation we identified for Holstein in running his small engineering operation, in which he and others work independently and remotely, concerned "intrinsic values or preferences." These encompass the ability to express one's authentic self, to accept oneself, or to derive pleasure or a sense of autonomy from the work (Ryff, 1989; Ryan & Deci, 2000; Keyes et al., 2002; Waterman, 2008; Seligman, 2010).This also came up as the main motivation for Sütterlin, who affirmed: "I don't want to sound arrogant, but I think that's our main point of view, that we do things the way we think [is] right and make offers the way we say would be good. (…) Like if I'm a good artist… I paint something

[2] Translated by Ana Beatriz Ribeiro from the original German interview, conducted in person with Martin Tritschler at the SEPT Competence Center in Leipzig on November 7, 2024.

because I think it's right [and not] to sell something. (…) I think that when we adapt to the demands of a market or a region or something like that, then we do it more out of our own motivation [by and large]."[3] But as Table 2 illustrates, he also pointed to the importance of competence development, for instance in navigating bureaucratic and legal matters. The theme applies to honing one's skills for productive pursuits or self-improvement (Ryan & Deci, 2000;Kasser & Ahuvia, 2002).

This motivation, and prerequisite to being able to facilitate innovations, was a close second for Holstein. A pure "sense of purpose or meaning" in performing an activity was the motivation least alluded to overall (Ryff, 1989; Keyes et al., 2002; Seligman, 2010). Pertaining both to competence development and intrinsic values or preferences, as well as to evidence of his having reached exploitative learning, Holstein told us in our interview:

I've always invented things in life… I've always really done my own things and tried to implement them (…) I've brought new devices onto the market [assembled from existing] components. (…) I can think of applications where in practice you would say, yes, that might be too difficult, you can't do that. And I've always tried to fill gaps like that, even earlier in industry. (…) I didn't just work as a service provider and as a fulfilment authority in industry, but at the same time I also held an A-professorship at the TU Ilmenau. (…) It is still a triangle of independence, serving a company and, at the university, student education…and that is actually an excellent climate for innovation.[4]

Given the local rural and economic-transition context and findings from sustainability literature, we readjusted our initial definition of "innovation" from tech- or R&D-intensive activities (Rammer, Gottschalk et al., 2020). For our purposes, "innovative" offers from intermediaries are those that address a service or product gap locally and at least two sustainability dimensions: social and environmental, social and economic, or environmental and economic (Schaltegger et al., 2012;Mignon & Kanda, 2018; Kundurpi at al., 2021; Cornish et al., 2024). This applies to novelties or improvements in tangible goods such as devices for resource management, as in Holstein's case; and intangible goods such as educational and cultural offers, as with Sprungbrett and Kloster Posa. In the following section, we take a closer look at each of our case studies from a sustainability perspective. We also examine how its dimensions relate to their motivations, obstacles, learning stages, and capabilities.

5.2 Sustainability in Product Development, Education, and Culture

All three of our case studies displayed at least moderate integration with the triple bottom line of sustainability (Elkington, 1994; Farny & Binder, 2021;van Zanten & van Tulder, 2021;Schaltegger et al., 2012).This means that intermediaries' activities classified as primarily environmentally sustainable, for instance emission reduction or greater resource efficiency or conservation, carry indirect economic or social benefits. Likewise, those primarily aimed at social sustainability – enhancing social well-being, cohesion, and inclusion via, for example, community events or job-creation programs – bring indirect environmental or economic benefits. At either end of the sustainability spectrum, we noted instances of high triple-bottom-line integration, in which the three dimensions have equal weight; and low integration, in which economic aims (greater cost efficiency, funding acquisition, or market competitiveness for the entity or its beneficiaries) take almost full precedence over the other two dimensions. Table 3 presents our analysis results on these points for our case studies.

Code System	Kloster Posa	Ingenieurbüro Peter Holstein	Sprungbrett e.V.	SUM
Level of TBL integration				0
3-dimensional (high integration)		1	2	3
Environmental (moderate integration)	1	2		3
Social (moderate integration)	4	2	12	18
Economic (low integration)		3		3
SUM	5	8	14	27

Table 3: Triple-bottom-line integration in the study's sample and number of mentions per case study. Generated with MAXQDA.

[3] Translated by Ana Beatriz Ribeiro from the original German interview, conducted with Lennart Sütterlin on site at Kloster Posa in Zeitz on November 17, 2023.
[4] Translated by Ana Beatriz Ribeiro from the original German interview, conducted with Peter Holstein via Zoom on October 29, 2024

Of the three interviewees, Holstein demonstrated the most evenly distributed engagement with sustainability dimensions (Table 3). His engineering office specializes in adapting and recombining existing technologies to, for instance, monitor water evaporation and thus improve public resource management amid local and global concerns over water scarcity. It serves as a new-industry pillar and intermediary between technical expertise and public administration, working with partners across government, academia, and industry to validate its products' applicability, demand, and market readiness. The water sensor Holstein invented, whose production is being scaled up, could raise the region's profile in sustainability offers, touching on all parts of the triple bottom line. To pilot the project in Nordsachsen over 2019-20, Holstein received about €127,000 under the regionally-targeted Unternehmen Revierprogramm of the Federal Ministry for Economic Affairs and Climate Action (BMWK), according to online data (Metropolregion Mitteldeutschland, n.d).But he indicates preferring to obtain smaller public grants bearing fewer bureaucratic hurdles, towards achieving incremental innovations.

Hence, Holstein's activities speak to both environmental and economic sustainability, although the obstacles he emphasizes are precisely related to government financing and bureaucracy, underscoring systemic issues he fears will continue to hinder innovation in Germany. He notes that public funding schemes tend to place high recruitment conditions for beneficiaries and favour younger, less-experienced founders while sidelining seasoned, independent innovators like himself, who possess the technical expertise for impactful advancements.

As for social sustainability, we observed it especially in answers attesting to Holstein's strong socialization and competences, which allow for exploitative learning despite weaker systematization and coordination:

It is very important for innovation that you don't think of it on your own [as it often emerges] from having cooperation networks in constellations that didn't exist before. (…) I have been working with a meteorologist for 40 years [and] we thought of many new things [together]due to good professional and personal relations. And if you keep that up, company-like structures emerge… engineering plus university offshoots plus other friendly colleagues in a network [which] drives innovation forward, even if it is not yet organized in direct product development. (…) It [is also] important that you go out there very actively in terms of your expertise [which benefits you] when you come into a new field – I have the advantage of having worked in several fields in my life. (…) You become more well-known and then slowly, for me mostly through conferences[, consultancies and teaching], you get the opportunity to meet many, many colleagues… that then becomes the personal network, which is also technically resilient for many, many years. (…) And these structures create really stable networks.[5]

We found Tritschler, the interviewee most highly motivated by community engagement, to be also the most attuned to social sustainability (tables 2, 3). These two aspects are integral to Sprungbrett, established in 1992 as a youth employment workshop linked to the Diaconal Work Riesa (Sprungbrett e.V., n.d.). Evidence that the association has reached transformative learning lies in Tritschler's understanding of the importance and practice of systematizing frameworks to maintain and reactivate knowledge, thus enabling innovative services. Ashe explained: "[Our] working groups are both external… and internal [to Sprungbrett such as in] assistant groups for the Board [in each of] five areas: public relations, organizational development, values, personnel, and finance, where employees get involved, and these groups try to drive things forward and create new things for the association."[6] Sprungbrett has come to combine vocational training with community- and civic-development projects through local partnerships, addressing issues of youth outmigration, recidivism, demographic shifts, and the destructive tendencies of right-wing populism – which capitalize on the enduring post-GDR fallout to win over supporters, as he also described. Such multifaceted offers can spill over into local economic and environmental sustainability, as youth gain new skills and, beyond boosting their own employability, come to see themselves as active parts of sustainable community development, which may be an incentive to stay local.

Sprunbrett's initiatives include the "Roll-In Bicycle Workshop," boosting youth-offender rehabilitation with skills training under socio-pedagogical supervision; a micro-grant program for residents to implement

[5] Translated by Ana Beatriz Ribeiro from the original German interview, conducted with Peter Holstein via Zoom on October 29, 2024.

[6] Translated by Ana Beatriz Ribeiro from the original German interview, conducted in person with Martin Tritschler at the SEPT Competence Center in Leipzig on November 7, 2024.

projects through participatory budgeting; and its "Week of Democracy," during which high schoolers receive hands-on experience in voting and project evaluation. The association's future vision centres on retrofitting Meißen's historic Göhlis Manor into a space for recreation, collaboration, learning, and dialogue for people of different ages, professions, and backgrounds. This may be especially vital given current pressing challenges (Table 4).

Code System	Kloster Posa	Ingenieurbüro Peter Holstein	Sprungbrett e.V.	SUM
Obstacles to service provision				0
Financial		5	2	7
Political or governmental	1	4	2	7
Socio-cultural	1	2	6	9
Infrastructural	8	1	1	10
Combinative capabilities				0
Systematization	1	2	5	8
Coordination		3	8	11
Socialization	11	10	12	33
SUM	22	27	36	85

Table 4: The main obstacles and capabilities identified and number of mentions per case study. Generated with MAXQDA.

The "obstacles" category in Table 4 emerged entirely from the interview data, rather than having a conceptual basis in innovation or management studies. The QCA method recommends a mix of both, to balance the achievement of theory-informed research goals with letting the data speak for itself (Schreier, 2012). Based on our QCA, "social-cultural" obstacles emerged as the most pressing for Sprungbrett: capable members being unable to rally together due to differences in approach; a lack of understanding by urban organizations or academics that attempt to help its rural beneficiaries; as well as a disconnect between different interest groups the association works with in the region. Tritschler emphasized the importance of developing more effective communication and adaptation methods leveraging his social skills to get through to different stakeholders, such as entrepreneurs, towards the community's integrated sustainable development. The inviting atmosphere at the Göhlis Manor could help "break the ice" between the different demographics Sprungbrett targets. Another helpful point would be the further development of coordination and systematization capabilities, which are not as strong as socialization for any of the interviewees. While socialization can lead to transfers, as we have argued, more coordination and systematization are needed to ensure communication and knowledge-retention methods are maintained and positive changes are scalable and outlast the presence of the leaders interviewed.

In fact, Sütterlin identified such internal infrastructural obstacles as the main ones preventing Kloster Posa, a retrofitted former monastery in Zeitz, from establishing itself as an innovation facilitator from its cooperative core. Despite acknowledging that he and his co-decision-makers have become good at publicizing and writing grants for the project, he lamented weak systematization and coordination for hindering internal knowledge sharing and external communications such as with the city administration. The association depends on the city both as its landlord and as co-developer of a concept that should eventually bring sustainable electricity and heating for Kloster Posa all year round, whereas its unstable gas heating keeps members away in winter now. Sütterlin also points out that it is hard to be strategic when the association's members still have to work other jobs to make ends meet and take care of basic issues to keep Kloster Posa functional, amid its flat hierarchies.

We argue that in its informality, Kloster Posa is still in the exploratory learning stage: While Sütterlin recognizes members' existing competences and the importance of obtaining knowledge – assimilated into managing their festivals and sustainable vineyard and crafts making workshops – he admits lacking a system to maintain or reactivate it. The latter functions would be essential for transformative learning and eventually knowledge transfers for strategic innovation (Ansari Vaghef, 2022; Gebauer et al., 2012). Besides mainly focusing on its socialization capability, the communal project prioritizes social over economic sustainability (tables 3 and 4),which is both part of its charm and a potential impediment to its further professionalization and longevity.

Nevertheless, Kloster Posa, launched in 2013 by private citizens from Meißen and Leipzig, has managed to turn a monastery into a celebrated cultural and artisanal centre unique in the region; and that, in itself, is an innovation (Kultur- und Bildungsstätte Kloster Posa, n.d.; Mitteldeutsche Zeitung, 2021). Amid his

pragmatic interview answers, Sütterlin took a moment to reflect on his pride over the non-profit's accomplishments thus far:

Image 2: Hand-cultivated vineyard at Kloster Posa in Zeitz, first run by monks in the 12th century and since rehabilitated, alongside the entity's modern crafts workshop. Taken by Ana Beatriz Ribeiro.

[Our overarching goal has been] to offer alternative cultural activities in rural areas and thus fill gaps [and] to create a positive example of the fact that social structures can be built here and that this can also have an impact on the city. (…) And now it is 10 years later. So something is happening in Zeitz, you can see that. People in various German cities, Leipzig in particular of course, have heard of Zeitz. There were quite a few who hadn't necessarily been here, but many had heard that something was going on… and we were definitely not the only ones, but Posa was one of the first places to make cultural innovations in the broadest sense [locally]. (…) There are a lot of other factors that have led to this, but I think you always need pioneers who go into the room and say, we are the first here to do something like this. Back then, I think – I wasn't here yet – there were individuals with whom you could network, but they didn't necessarily have a structure, so they weren't [a] club or… institution.[7]

Sütterlin's statement perfectly reflects the essence of civil-society intermediaries' role in the region: the ability to identify local gaps and existing opportunities and inhabit both the community and institutional realms, thus helping to formalize community members' interactions into a structure that could meaningfully contribute to the local innovation system. It is up to the other three, established pillars of innovation in Germany – industry, academia, and government – to provide support better tailored to these vital facilitators' needs, for raising their level of integration with the triple bottom line of sustainability and ensuring they thrive in the long term.

6 CONCLUSION

The shift from extractive industries to sustainable development and digitalization poses a significant challenge for smaller cities and rural regions that have historically relied on coal mining, heavy manufacturing, and other resource-intensive sectors. As these industries decline due to shifts in global markets, technological change, and environmental reforms, communities are often left grappling with economic stagnation, population loss, and underdeveloped support structures. This has come to lead to political radicalization which threatens the global sustainability agenda (United Nations, 2024).East Germany's Mitteldeutsches Revier exemplifies these points: As a region with a long history of mining, it faces profound economic restructuring and discontent amid the phase-out of lignite extraction. Unlike metropolitan centres with established innovation and R&D hubs, more rural regions such as the Mitteldeutsches Revier find themselves having to create alternative models for local development, reliant on civil society. The models we identified consider social and environmental goals more so than economic ones, as community-driven initiatives that prioritize multi-purpose, inclusive transformations.

[7] Translated by Ana Beatriz Ribeiro from the original German interview, conducted with Lennart Sütterlin on site at Kloster Posa in Zeitz on November 17, 2023.

The ongoing transition in the Mitteldeutsches Revier underscores both the vulnerabilities and resilience of post-industrial communities. This study has illustrated how three community-driven intermediaries in the region's districts are stepping in to fill gaps left by traditional innovation pillars. Through initiatives focused on education (Sprungbrett), cultural revival (Kloster Posa), and adaptive reuse of technology and infrastructure (Peter Holstein), these actors can offer a blueprint for balancing economic, social, and environmental sustainability. Their efforts, however, remain constrained by financial limitations, infrastructural deficiencies, and the need for stronger systemic support, alongside those of other small-scale intermediaries. As one of our interviewees from the theatre sector reported, emphasizing the importance and overburdening of the individual: "All of this is a crisis that I try to mitigate, where I go to a New Year's reception or summer party, and where I try to talk to people. And it only works through the person [i.e., her personal ability to rally support and raise funds]."[8]

Unlike top-down government interventions, such community-driven efforts are often rooted in local contexts, drawing on the knowledge, creativity, and agency of private citizens. They activate underutilized assets such as disused industrial sites, old factories, and historic residences, transforming them into versatile facilities that serve as cultural centres, coworking spaces, artisanal production sites, and vocational training areas. By engaging stakeholders from multiple sectors – including craftspeople, artists, entrepreneurs, and government authorities – these initiatives support capacity-building and participatory governance, which could help lead to shared economic growth. The strength of their socialization can have positive implications for a better integrated approach to sustainability, including socially conscious environmental rehabilitation in former coal extraction zones. At the same time, issues with receiving funding for viable, incremental innovations and necessities such as heating highlight the gaps in external support, such as from the government pillar, which could threaten the initiatives' very survival. If unable to cover the basics, how can they be expected to maintain innovations?

While the case studies we presented from the Mitteldeutsches Revier demonstrate remarkable adaptability, their sustainability, and that of other active intermediaries at the grassroots level, depends on broader changes in Germany. A multi-scalar approach – integrating bottom-up innovative solutions with top-down policies and targeted funds – could ensure that these efforts contribute meaningfully to a more enduring and fair economic transformation. By aligning funding, institutional, and social resources, East Germany's transitioning regions could avoid further pitfalls of stagnation and chart a path towards more inclusive, innovation-driven growth.

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Sheltering the Displaced: Lessons from Global Disasters and Conflicts

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1 ABSTRACT

Housing and shelter solutions play a crucial role in disaster recovery, yet many displaced communities face prolonged instability due to inadequate policies and poorly integrated temporary housing. This paper explores global approaches to post-disaster housing, analysing both short-term shelter solutions and long-term integration strategies. Using a mixed-methods approach, the study employs bibliometric analysis to identify research trends and gaps in disaster housing literature alongside a comprehensive literature review of past policies and interventions. Findings highlight the socio-economic and psychological impacts of displacement, the limitations of emergency shelters, and the challenges of transitioning temporary housing into permanent settlements. Case studies from major disasters, including Hurricane Katrina, the Haiti earthquake, and the Syrian refugee crisis, offer insights into both successful and problematic housing recovery efforts. The paper concludes with policy recommendations for governments and humanitarian organisations, emphasising the need for resilient, community-driven, and sustainable housing solutions. By synthesising existing research and lessons from past disasters, this study aims to contribute to ongoing discussions on improving post-disaster housing strategies.

Keywords: Disaster Recovery, Housing Solutions, Temporary Shelters, Post-Disaster Policy, Urban Resilience

2 INTRODUCTION

Housing serves as a fundamental pillar of human well-being, providing not only physical shelter but also a sense of security, belonging, and normalcy. In the aftermath of disasters, whether natural or conflict-induced, housing assumes an even more critical role, acting as the bedrock for restoring stability and rebuilding shattered communities. The destruction or damage of housing stock precipitates severe crises, often exacerbating pre-existing vulnerabilities and disproportionately impacting marginalised populations (Quarantelli, 1995). Displacement, a common consequence of such events, disrupts lives and severs crucial social and economic ties, thrusting individuals and families into precarious situations. These displaced populations face a multitude of interconnected challenges that hinder their ability to secure safe and stable shelter. Inadequate or damaged infrastructure, including water and sanitation systems, transportation networks, and communication lines, complicates access to essential resources and impedes reconstruction efforts. Limited financial resources, compounded by job losses and economic disruption, further constrain the ability of affected populations to rebuild their homes and livelihoods. Policy constraints, such as unclear land tenure arrangements, bureaucratic delays, and a lack of coordinated planning, can also impede recovery processes and prolong displacement. Addressing the complexity of post-disaster housing demands a nuanced and interdisciplinary approach, one that recognises the intricate interplay of social, economic, and environmental factors (Alexander, 2013). Effective solutions must consider not only the physical reconstruction of housing but also the restoration of social networks, economic livelihoods, and community infrastructure.

Despite increasing global awareness and concerted efforts to address post-disaster housing needs, significant gaps persist in the implementation of effective and sustainable long-term solutions. While emergency shelters provide crucial immediate relief, they are often designed for short-term use and lack the durability, habitability, and essential amenities required for prolonged habitation (Sphere Association, 2018). The transition from temporary shelters to permanent housing frequently proves problematic, with numerous obstacles hindering a smooth and timely process. These obstacles can include bureaucratic bottlenecks, funding shortfalls, land ownership disputes, and a lack of access to building materials and skilled labor. Consequently, many displaced individuals find themselves trapped in a state of prolonged instability, residing in inadequate temporary accommodations for extended periods, which can have detrimental effects on their physical and mental health, as well as their social and economic well-being (Kelman, 2015). Adding

another layer of complexity, the increasing frequency and intensity of natural disasters due to climate change underscore the urgent need for integrated and sustainable housing solutions (Burby, 2006). As climate-related risks escalate, housing must be designed and constructed to withstand more extreme weather events, incorporating resilience measures and adaptive strategies to minimise future damage and displacement. Furthermore, sustainable post-disaster housing must consider environmental impacts, promoting the use of eco-friendly materials and construction techniques and minimising the carbon footprint of reconstruction efforts. The convergence of these challenges highlights the critical importance of developing comprehensive and forward-thinking approaches to post-disaster housing that prioritise resilience, sustainability, and the long-term well-being of affected communities.

3 LITERATURE REVIEW

3.1 Urban Resilience & Disaster Risk Reduction (DRR)

Urban resilience encompasses the capacity of urban systems, including individuals, communities, institutions, and infrastructure, to withstand, adapt to, and recover from shocks and stresses, particularly disasters (Meerow, Newell, & Stults, 2016). It emphasises proactive strategies to anticipate, absorb, and bounce back from disruptive events, minimising damage and facilitating a swift return to normalcy (Cutter et al., 2008), involving not only physical infrastructure but also social, economic, and institutional dimensions (Pike et al., 2010). Disaster Risk Reduction (DRR) frameworks provide a structured approach to building urban resilience by focusing on proactive measures to minimise disaster risks (UNDRR, 2019). The Sendai Framework for Disaster Risk Reduction 2015-2030, a key international agreement, emphasises understanding disaster risk, strengthening disaster risk governance, investing in DRR for resilience, and enhancing preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction 2 (UNDRR, 2015). Effective DRR incorporates risk assessment, land-use planning, building codes and regulations, early warning systems, public awareness campaigns, and community participation (UNISDR, 2009).

3.2 Sustainable Recovery Models

Sustainable recovery models move beyond simply rebuilding infrastructure to emphasise reconstruction strategies that contribute to long-term community well-being and resilience (Johnson & Olshansky, 2016). These models recognise that recovery is not just a return to the pre-disaster state but an opportunity to build back better, creating more sustainable, equitable, and resilient communities (Berke et al., 2014). Key principles of sustainable recovery include environmental sustainability by minimising environmental impact through the use of locally sourced and sustainable materials, energy-efficient building designs, and waste reduction strategies (Vale & Campanella, 2005), economic feasibility by promoting economic recovery through job creation, business revitalisation, and access to financial resources (Chang-Tai & Hui, 2014), social inclusivity by ensuring that all members of the community, especially vulnerable groups, have access to housing, resources, and decision-making processes (Aldrich, 2012), community participation by engaging affected communities in the planning and implementation of reconstruction efforts to ensure that their needs and priorities are addressed (Davidson et al., 2007), and resilience building by incorporating measures to reduce future disaster risk, such as improved building codes, land-use planning, and community-based disaster preparedness programs (Kelman, 2015). Integrating displaced communities into host environments is a critical aspect of sustainable recovery, requiring attention to social cohesion, economic integration, and access to services (Muggah, 2012).

3.3 Key Trends in Disaster Housing Research (Bibliometric Analysis)

3.3.1 Emerging Themes & Research Gaps

Bibliometric analysis, a quantitative approach to analysing scholarly literature, has revealed several emerging themes in post-disaster housing research (Santos, 2020). These include a growing focus on climate resilience, investigating how housing can be designed and built to withstand the increasing impacts of climate change, such as extreme weather events and sea-level rise (IPCC, 2022), social equity, addressing the disproportionate impacts of disasters on vulnerable populations and ensuring equitable access to housing and resources during recovery (Fainstein, 2010), and adaptive housing models, exploring innovative housing

designs and construction techniques that can be adapted to different contexts and needs, including prefabricated and modular housing solutions (El-Anwar & Chen, 2016). Despite these advancements, significant research gaps remain, particularly in understanding the long-term social and economic impacts of displacement and developing effective strategies for policy implementation and long-term recovery planning, especially in resource-scarce settings (Aldrich, 2012).

3.3.2 Influence of Policy & Governance

Policy and governance play a crucial role in shaping post-disaster housing outcomes (Twigg, 2015). Effective housing recovery requires strong leadership, clear policies, efficient bureaucratic processes, and robust financial mechanisms (Johnson, 2007). Coordination among various levels of government, international agencies, non-governmental organisations, and community stakeholders is essential for successful housing reconstruction (Birkmann et al., 2010). However, bureaucratic inefficiencies, lack of transparency, extreme corruption, and funding constraints often hinder recovery efforts (Olshansky, 2005). Furthermore, land tenure issues whivh are particularly in informal settlements, can pose significant challenges where reconstruction is concerned (Moser & Norton, 2001).

3.4 Short-Term vs. Long-Term Housing Approaches

3.4.1 Emergency Shelters

Emergency shelters provide immediate, temporary housing in the aftermath of a disaster (Sphere Association, 2018). These shelters can include tents, prefabricated units, community centers, and temporary settlements. While emergency shelters provide crucial life-saving assistance, they often lack adequate living conditions, privacy, sanitation, and security (Saunders, 2015). Overcrowding, lack of access to basic services, and psychological stress can make emergency shelters unsuitable for long-term habitation (Boano, 2009). Furthermore, the prolonged use of temporary shelters can create dependency and hinder the transition to permanent housing solutions.

3.4.2 Permanent Solutions

Permanent housing solutions aim to integrate displaced populations into long-term resettlement programs and urban planning processes (Mulligan & Nadarajah, 2012). These solutions need to prioritise participatory design by involving affected communities in the design and construction of their homes to ensure that their needs and preferences are met (Aysan & Haigh, 2012), community-led reconstruction by empowering communities to lead the reconstruction process, fostering ownership and promoting long-term sustainability (Johnson, 2007), land tenure security by clarifying land ownership and providing secure tenure rights to residents to facilitate reconstruction and prevent future displacement (Durand-Lasserve et al., 2015), and access to basic services by ensuring access to essential services, such as water, sanitation, electricity, transportation, and healthcare, in permanent housing locations (UN-Habitat, 2016). The transition from temporary shelters to permanent housing is a complex process that requires careful planning, coordination, and financial resources. It is crucial to establish clear timelines, provide financial assistance to affected families, and address land tenure issues promptly to avoid prolonged displacement and facilitate a smooth transition to long-term housing solutions.

4 CASE STUDIES: LESSONS FROM PAST DISASTERS

4.1 Hurricane Katrina (USA, 2005)

Hurricane Katrina exposed significant weaknesses in disaster preparedness and response, particularly regarding housing. The Federal Emergency Management Agency (FEMA)'s provision of temporary housing, primarily through trailers, was plagued by logistical problems, health concerns, and a lack of accessibility for vulnerable populations such as the elderly and disabled (Comerio, 2006). Furthermore, bureaucratic hurdles and insurance complexities hindered rebuilding efforts, leaving many displaced residents in limbo for long periods (Gotham, 2010). However, Katrina also highlighted the crucial role of community-driven recovery initiatives. Organisations like the Make It Right Foundation, founded by Brad Pitt, and local community groups demonstrated the power of participatory planning and community-led reconstruction in creating more sustainable and resilient housing solutions (Elliott, 2011). These initiatives often incorporated green building

practices, addressed affordability issues, and prioritised the needs and preferences of affected communities, demonstrating the potential for long-term, positive change following a disaster.

4.2 Haiti Earthquake (2010)

The 2010 Haiti earthquake presented a complex humanitarian crisis, with hundreds of thousands displaced and in need of shelter. International aid and NGOs played a significant role in providing emergency shelter, primarily through tents and tarpaulins (Shelter Cluster, 2010). However, the sheer scale of the disaster and logistical challenges hampered these efforts, leading to overcrowding, inadequate sanitation, and vulnerability to further hazards such as flooding in temporary settlements (Buckley, 2012). A major obstacle to long-term housing solutions was the complex and often unclear land tenure system in Haiti. Disputes over land ownership and lack of secure tenure rights hindered reconstruction efforts and created challenges for integrating displaced populations into permanent housing (Smucker et al., 2015). The influx of aid also raised major concerns about coordination and effectiveness, with some critics arguing that a lack of local ownership and top-down approaches undermined long-term recovery prospects (Farmer, 2011).

4.3 Syrian Refugee Crisis

The Syrian refugee crisis, beginning in 2011, has resulted in a protracted displacement scenario, with millions seeking refuge in neighboring countries and beyond. Housing for Syrian refugees has taken various forms, including informal settlements, refugee camps, and integration into host communities (UNHCR, 2023). Informal settlements, often characterised by inadequate shelter and limited access to basic services, have become a common, yet precarious, housing option for many refugees (Human Rights Watch, 2016). Host country policies have significantly impacted the living conditions and integration prospects of Syrian refugees. Some countries have adopted relatively open policies, providing access to housing, education, and employment opportunities, while others have imposed stricter regulations, limiting refugees' access to resources and hindering their ability to rebuild their lives (Wickramasekara, 2017). The long-term nature of the crisis has highlighted the need for sustainable housing solutions that go beyond temporary shelter and facilitate the social and economic integration of refugees into host communities (Betts & Collier, 2017). The challenges of providing adequate and sustainable housing for refugees in protracted displacement situations underscore the need for international cooperation, long-term planning, and policies that promote inclusion and self-reliance.

5 METHODOLOGY

For this study, a mixed-methods approach was utilised, incorporating both a comprehensive literature review and a bibliometric analysis. This methodological framework enables a thorough examination of post-disaster housing solutions by integrating qualitative insights with quantitative data-driven analysis (Creswell & Plano Clark, 2011). This study aims to explore key trends, challenges, and best practices in post-disaster housing by addressing the following research questions:

- What are the key trends in post-disaster housing research?
- What are the challenges and best practices for transitioning from temporary to permanent housing?
- How can policy interventions improve housing recovery?

5.1 Literature Review

The literature review served to contextualise the historical and contemporary challenges of post-disaster housing. It explores systemic barriers, policy limitations, and socio-economic constraints that impact equitable access to adequate housing for displaced populations. By analysing key policy documents, academic articles, case studies of past disasters (e.g., Hurricane Katrina, Haiti Earthquake, Syrian Refugee Crisis), and reports from international organisations (e.g., UN-Habitat, UNHCR, Sphere Association), this review critically examines the successes and shortcomings of various post-disaster housing interventions. The literature review also provides insights into the socio-economic and psychological impacts of displacement, the limitations of emergency shelters, and the challenges of transitioning to permanent housing (Aldrich, 2012; Comerio, 1998; Davis, 1978; Felix et al., 2013, 2015; Johnson & Olshansky, 2016).

5.2 Bibliometric Analysis

A bibliometric analysis was conducted to map and analyse the knowledge structure of "post-disaster housing" using a quantitative approach. This method provides insights into key themes, influential authors, and emerging trends (Van Eck & Waltman, 2010). Relevant publications from 2000 to 2024 were extracted from Scopus using search terms like “post-disaster housing,” “temporary shelters,” and “disaster reconstruction.” VOSviewer was used to visualise co-authorship networks, citation relationships, and thematic clusters (Donthu et al., 2021). Document and author co-citation analyses identified influential works and collaboration patterns, highlighting global research distribution and thematic gaps in the field.

5.3 Case Study Selection

Three case studies were chosen for their diverse socio-economic and geographical contexts such as Hurricane Katrina (USA, 2005) for examining federal response failures and community-driven recovery. Haiti Earthquake (2010) for analysing the role of international aid and challenges in land tenure security and Syrian Refugee Crisis for investigation of housing solutions for displaced populations in protracted crisis scenarios.

6 RESULTS, ANALYSIS, AND DISCUSSION

6.1 Analysis of Annual Publications

Understanding publication trends over time is crucial for assessing research interest in a field. This study analysed bibliometric data from 2007 to 2025, revealing an initial slow progression in post-disaster housing research. From 2007 to 2011, publication rates increased slightly but declined between 2011 and 2017, followed by stagnant growth. A significant surge occurred from 2017 to 2021, rising from three to fifteen publications, driven by global disasters and conflicts. Events such as the Syrian refugee crisis (Aldrich & Meyer, 2015), hurricanes Harvey, Irma, and Maria (2017), the Sulawesi earthquake and tsunami (2019), and the Beirut port explosion (2020) exposed housing failures, shifting research toward sustainable, long-term solutions (Johnson & Olshansky, 2016). The COVID-19 pandemic (2020–2021) further reshaped priorities, emphasising public health integration in emergency housing.

Between 2021 and 2023, publication rates declined, possibly due to shifting academic interests. However, from 2023 to 2024, the number of publications doubled, reflecting renewed urgency following major global disasters and conflicts that worsened shelter displacement. Climate change-induced disasters, including wildfires, floods, and cyclones, have also fueled demand for climate-resilient housing solutions. Overall, the trend indicates growing scholarly attention to post-disaster housing, shaped by real-world crises and evolving research priorities.

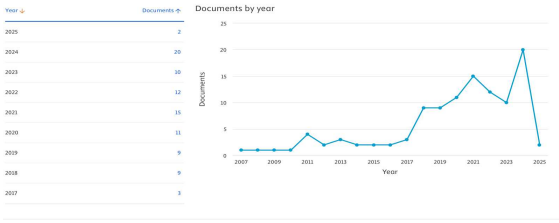

Fig 1: Graph depicting the publication trend of the topic area between 2007 and 2024.

6.2 Intellectual Knowledge Structure of the Field

The intellectual knowledge structure of the post-disaster housing field is revealed through an analysis of co-citation patterns, which illuminate the relationships between influential works and the evolution of key concepts. By examining how often documents are cited together, we can identify core literature that forms the foundation of the field, map thematic clusters representing distinct areas of inquiry, and trace the flow of ideas and influences between researchers. This analysis provides a valuable understanding of the intellectual underpinnings of post-disaster housing research, highlighting seminal contributions and emerging trends that shape the direction of future scholarship.

6.2.1 Conceptual Structure

The second dataset analysed co-occurring keywords in research publications from 2007 to 2025 to identify high-demand research areas. From 760 keywords exported from Scopus, different occurrence thresholds were tested. At a minimum of five occurrences, only 21 keywords met the threshold, with just two relevant to the research. Lowering the threshold to four which results in 28 keywords, and to three, which results in 42 keywords yielded similar results. Reducing it to two occurrences included 110 keywords but still only captured two relevant ones. Lastly, setting the minimum to one included all 760 keywords, forming 38 clusters with 7,469 links and a link strength of 7,750. Despite this broad scope, only three research keywords appeared exactly, one was split into two separate terms, and one was absent entirely. Table 1 lists the top 10 preferred keywords in this research area. The strong link between keywords and publication trends highlights the need for greater focus on housing solutions, whether through permanent post-disaster reconstruction or climate-resilient housing. Addressing these challenges contributes significantly to advancing sustainable housing research.

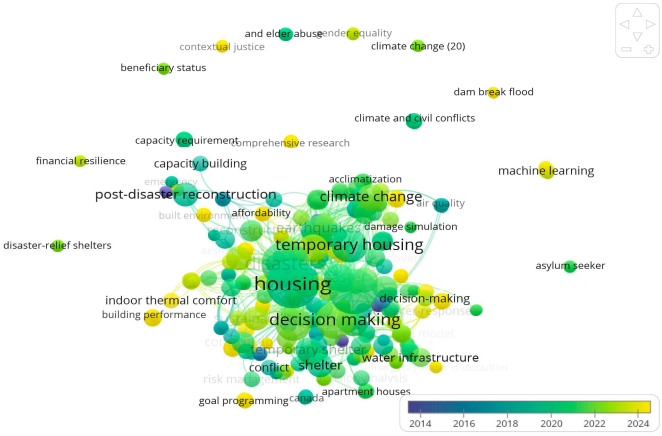

Figure 2: Visualised network map of research themes, overlay between 2014 and 2024 (10-year period) to understand the trajectory of research themes.

Keyword	Occurrences	Total link strength
Urban resilience	1	9
Site location for post-disaster temporary housing	1	11
Public policy	1	16
Post-disaster relocation model	1	17
Post-disaster	3	24
Temporary shelter	5	36
Disaster recovery	5	70
Climate change	6	106
Disaster management	19	301
Housing	22	331

Table 1: The top 10 Keywords in the research network

6.2.2 Intellectual Structure

To delve into the intellectual structure of post-disaster housing research, a co-citation analysis was employed. This method, as described by Small (1973), examines the frequency with which two documents are cited together, revealing intellectual connections and mapping the knowledge structure of the field. By analysing author and document coupling, the co-citation analysis aimed to identify influential works that have shaped the discourse, discern emerging research clusters representing key thematic trends, and understand the evolution of ideas within this interdisciplinary area of study. This approach allows for a deeper understanding of how foundational research informs current investigations and highlights potential areas for future scholarly inquiry.

Document Co-Citation Analysis

A document co-citation analysis mapped the intellectual landscape of post-disaster housing research, identifying key works that shaped the field. Using the Scopus database, 11,236 cited references were analysed, focusing on 554 references cited at least three times for the purpose of relevance. The co-citation network, visualised with VOSviewer, revealed thematic clusters, including temporary housing solutions (Felix et al., 2013, 2015), post-disaster recovery (Aldrich, 2012; Comerio, 1998; Davis, 1978), and community resilience (Amsden et al., 2010; Saldivar & Krasny, 2004). Work which is highly influential

emerged from the likes of Aldrich's Building Resilience (2012), which emphasises social capital where recovery is concerned, Davis's Shelter After Disaster (1978) which is a foundational study on shelter planning, and lastly, Comerio's Disaster Hits Home (1998), which helped shape urban housing policy. These frequently co-cited publications represent seminal contributions to the field. The analysis enhances understanding of post-disaster housing research trends, informing future studies and policy interventions for resilient housing solutions.

Author Co-citation Analysis

For this data set, the minimum number of citations of a cited reference was capped at 3. For a minimum number of citations of a cited reference being 2, of the 11236 cited references, 554 met the threshold, and for a minimum number of citations of a cited reference being 1, of the 11236 cited references, 11236 met the threshold. Neither of these minimums were not preferred as they made the data too large and too tedious to analyse, and therefore, a minimum of 3 is what the authors settled for. Author co-citation analysis was performed to examine the intellectual relationships between researchers contributing to the field of post-disaster housing. This approach identifies influential authors whose work is frequently cited together, revealing collaborative networks and shared intellectual influences. For this analysis, a minimum of three citations for a cited reference was set as the threshold, balancing the need to capture impactful contributions while maintaining a manageable dataset. From the initial 11,236 cited references, 554 met this criterion, forming the basis for the co-citation network. Analysing these co-citation patterns helps illuminate the key researchers shaping the discourse, the evolution of thought within the field, and the potential for interdisciplinary collaborations. This analysis complements the document co-citation analysis by focusing specifically on the researchers who have contributed significantly to the body of knowledge on post-disaster housing.

Figure 3: Visualised document co-citation network map of shelter displacement due to conflicts and disasters

6.2.3 Social Structure

In the last data set, the social structure of the field was developed by the authors. This approach was followed for the exploration of how authors collaborate and contribute to the body of knowledge from the perspective of the different networks and countries.

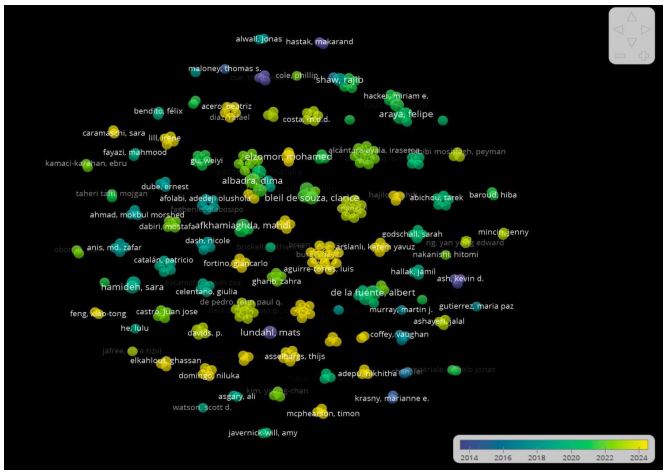

Figure 4: Visualisation of co-author network

Co-authorship Analysis

Scientific collaboration is essential for advancing knowledge, fostering specialisation, and enhancing skills. It enables diverse perspectives to drive progress while fulfilling institutional and national goals. This study analysed research networks using a minimum threshold of one document per author and zero citations, maximising the dataset to 284 authors. The total co-authorship link strength was calculated, identifying the most influential researchers. The co-authorship network visualisation reveals distinct clusters of researchers frequently collaborating on post-disaster housing studies. A key cluster centers around "Lundahl, Mats," while "Alwall, Jonas Hastak, Makarand" and "Ash, Kevin D." appear as significant contributors. The colour gradient from 2014 to 2024 illustrates the evolution of collaborations, with "Bendito, Félix" and "Aceron, Beatriz Diaz" forming recent connections, while earlier collaborations involve "Cole, Phillip Shaw." This visualisation offers a snapshot of the field's social structure, highlighting influential researchers and their collaborative networks.

Analysis of Country Collaboration

Within the global knowledge society, it is critical for there to be an understanding of the collaboration of countries to unpack where influential authors have emerged from and what their impact is globally. This analysis reveals key collaboration patterns, highlighting the top five research clusters. The largest collaboration, Cluster 6, involves the USA, Chile, Egypt, and South Korea, with 32 joint publications. Cluster 3 follows with 27 publications from the UK, Canada, Hong Kong, and Peru. Cluster 4 is in third place, featuring 18 publications between Iran, Australia, Spain, and Finland. In fourth place, Cluster 1 includes 14 publications across South Africa, Japan, the Philippines, New Zealand, Bangladesh, Denmark, Mexico, and Zimbabwe. Finally, Clusters 2 and 7 tie for fifth place, each with 10 publications. Cluster 2 involves India, Italy, and Saudi Arabia, while Cluster 7 includes the Netherlands and Sweden.

6.2.4 Global Network Knowledge

The analysis of data that has been done throughout this study yields results that are a clear indication that a significant amount of research has been carried out globally. This is backed up by the appearance of countries that represent most of the continents. Some of the countries have not experienced severe disaster and conflict but are greatly positioned to not be reactive in a situation where conflict or disaster strikes because of background knowledge of the possibility of being exposed due to unpredictability, especially where disasters are concerned, as they are one with nature.

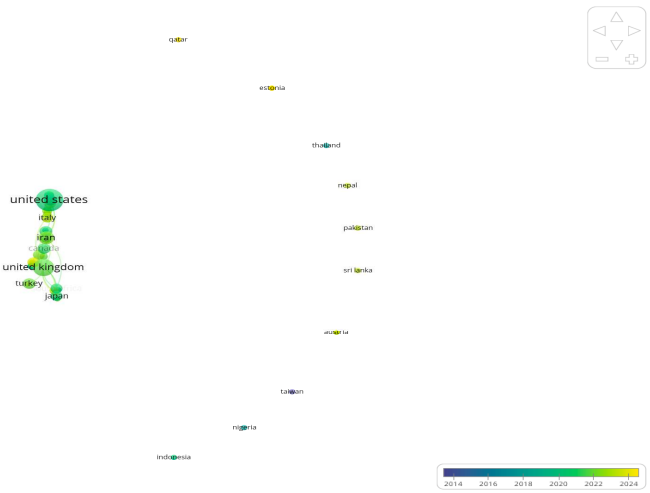

Figure 5: Visualisation of global collaboration (country collaboration network)

This global research engagement reflects a proactive approach, where countries invest in disaster preparedness and resilience-building, even in the absence of recent catastrophic events. The interconnectedness of academic networks has facilitated cross-border knowledge sharing, allowing nations with limited direct disaster experience to adopt best practices from regions frequently impacted by crises. Additionally, the growing focus on climate change and its role in intensifying natural disasters has driven global collaboration, as countries recognise that the effects of environmental shifts transcend borders. Co-citation analysis within this study highlights key research hubs such as the United States, Japan, and

European nations that frequently contribute to disaster housing literature while also revealing emerging contributors from regions like Southeast Asia and Africa. This expansive network of knowledge strengthens global capacity for disaster preparedness, policy formulation, and the development of adaptable housing strategies, ultimately fostering a more resilient international community.

International collaboration in post-disaster housing research is visualised through a network of collaborating countries, revealing a global effort to address housing challenges after disasters. Dominant collaborations are evident, particularly a strong cluster centered around the United States, United Kingdom, Turkey, Japan, Italy, Iran, and Canada, indicating a significant hub of research activity among these nations. Other countries, such as Estonia, Thailand, Nepal, Pakistan, Sri Lanka, Australia, Nigeria, and Indonesia, also participate in the network, highlighting the geographically diverse nature of collaborations in this field. The time overlay, ranging from 2014 to 2024, suggests the ongoing evolution of these partnerships and the potential emergence of new collaborative ties. This visualisation emphasises the importance of international cooperation in sharing knowledge and best practices to improve post-disaster housing solutions globally.

Country	Documents	Citations	Total link strength
United States	32	1239	12
United Kingdom	16	165	17
Australia	5	151	5
Saudi Arabia	2	84	5
Iran	8	68	10
Turkey	5	58	2
Netherlands	4	43	4
Chile	3	42	2
India	3	42	4
Switzerland	2	42	3
Canada	5	41	6
South Africa	4	40	8
Spain	4	40	1
Sweden	5	40	3
Indonesia	1	39	0
Japan	4	34	7
China	4	29	4
Finland	1	28	1
Portugal	1	28	1
Zimbabwe	1	25	1

Table 2: Top 20 Countries for Global Collaboration

Analysis of international research collaboration in post-disaster housing reveals a global network with varying levels of contribution. The United States dominates with 32 documents and 1239 citations, demonstrating its significant research output and influence. The United Kingdom also shows a strong presence with 16 documents and 165 citations. Australia, despite having only 5 documents, boasts a high citation count of 151, suggesting impactful research. Other contributing countries include Saudi Arabia (2 documents, 84 citations), Iran (8 documents, 68 citations), Turkey (5 documents, 58 citations), Netherlands (4 documents, 43 citations), Chile (3 documents, 42 citations), India (3 documents, 42 citations), Switzerland (2 documents, 42 citations), Canada (5 documents, 41 citations), South Africa (4 documents, 40 citations), Spain (4 documents, 40 citations), Sweden (5 documents, 40 citations), Indonesia (1 document, 39 citations), Japan (4 documents, 34 citations), China (4 documents, 29 citations), Finland (1 document, 28 citations), Portugal (1 document, 28 citations), and Zimbabwe (1 document, 25 citations). The "Total Link Strength" further emphasises the US and UK's central roles in international collaborations, with link strengths of 12 and 17, respectively, highlighting the collaborative nature of this research field.

Case Study Insights: Lessons from Major Disasters

The United States' response to Hurricane Katrina showed the value of community-driven recovery initiatives and significant flaws in federal strategies. Projects like the “Make It Right Foundation” demonstrated how community involvement can promote creativity and enhance environmentally friendly housing solutions. This case is a prime example of the bibliometric trend that highlights the value of community involvement in post-disaster policies, showing that such strategies not only improve recovery outcomes but also foster local trust.

Recovery efforts and the move to permanent housing were made much more difficult by the Haiti earthquake's aftermath, which revealed the intricacies of land tenure security. The uncoordinated global response made clear how important it is for aid organisations to better coordinate. This supports bibliometric

analysis trends and emphasises the necessity of well-defined policy frameworks. The importance of creating policies that support the integration and economic stability of displaced populations has been highlighted by the ongoing Syrian refugee crisis. Integration results were better in nations that allowed refugees more access to jobs and education. The relationship between inclusive policies and favourable housing outcomes confirms the bibliometric trend toward flexible policy frameworks, guaranteeing that housing solutions promote long-term integration rather than just short-term fixes.

7 CONCLUSION

This study has delved into the multifaceted challenges of post-disaster housing, employing a mixed-methods approach that integrated bibliometric analysis, a comprehensive literature review, document and author co-citation analysis, and an examination of international research collaborations. The bibliometric analysis illuminated key research trends, revealing a growing emphasis on resilience, sustainability, and community-driven approaches while also highlighting persistent gaps in policy implementation and the complexities of recovery which is long-term. The literature review provided a deeper understanding of the theoretical underpinnings of post-disaster housing, the inherent limitations of emergency shelters, and the enduring challenges associated with transitions to permanent housing solutions. Case studies, including Hurricane Katrina in the United States, the earthquake in Haiti, and the Syrian refugee crisis, underscored the importance of community involvement, land tenure security, and effective coordination among various stakeholders, from local governments to international aid organisations. Document and author co-citation analyses, along with visualisations of international collaboration networks, identified key researchers, influential works, and the global interconnectedness of research efforts. The visualisation of international collaborations including contributions from the United States of America, Canada, United Kingdom, Italy, Turkey, and other nations highlighted the need for cross-border knowledge sharing and resource mobilisation to enhance housing recovery efforts.

These findings collectively reinforce the urgent need for a paradigm shift in post-disaster housing, moving beyond reactive, short-term solutions toward proactive, integrated strategies that prioritise resilience, sustainability, and the long-term well-being of displaced populations. Effective post-disaster housing requires a holistic approach that addresses the physical rebuilding of homes and the restoration of social networks, economic livelihoods, and community infrastructure. Key strategies include community-centric approaches, where displaced populations actively participate in recovery efforts, ensuring that housing solutions align with their needs, secure land tenure, which is essential for long-term stability, particularly in fragile contexts like Haiti, and comprehensive refugee integration policies, providing access to housing, jobs, and essential services, as seen in responses to the Syrian refugee crisis. Additionally, coordinated efforts among stakeholders, including governments, non-profits, and international agencies are crucial for streamlining recovery processes and optimising resource allocation. Future research should explore innovative financing mechanisms, strengthen policy frameworks, and develop deeper insights into vulnerability and resilience. By synthesising existing knowledge, critically analysing past experiences, and fostering international collaboration, this study contributes to ongoing dialogues aimed at improving post-disaster housing strategies and reducing prolonged instability for displaced communities worldwide.

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Spatial Paradigms of Exclusion: Gated Communities and Post-Apartheid Inequality

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1 ABSTRACT

Land ownership continues to be a potent symbol of social stratification and inequality in South Africa as it continued to be used as a tool of segregation, even in the post-apartheid era. This paper explores the impact that gated communities have on spatial transformation in the new democratic era separating the haves and the have-nots. In South Africa, the advent of democracy brought with it a new spatial paradigm in the field of urban planning known as gated communities. This paper argues that gated communities are not founded on racial discrimination, but do restrict and monitor the movement of individuals who are not allowed within these communities. This spatial paradigm emerges based on the preferences of a specific socioeconomic group and is seen by this study as a segregation instrument manifesting as economic apartheid that strengthens pre-existing prejudices. This study adopted a qualitative method using an exploratory design approach to highlight the spatial disintegration phenomenon promoted by gated communities. This approach enabled the study to identify the shortcomings of spatial planning policies and their limitations in terms of integrated planning, sustainability and inclusivity of our cities. The findings suggest that there is a form of continuous disintegration of settlements within the city of Johannesburg through constructed spatiality that may be an intended form of segregation. The study concludes that the constructed spatiality within Johannesburg continues to promote segregation, revealing a persistent and potentially deliberate form of urban disintegration.

Keywords: spatial transformation, gated communities, sustainability, spatial segregation, apartheid economy

2 INTRODUCTION

South Africa has been in democracy for almost three decades and still faces urban challenges that are critical in shaping its cities. The country's landscape is constantly burdened by spatial shortcomings and broader societal pressures (Landman 2004). In a similar vein, the apartheid landscape structure was left unchanged despite many interventions by the democratic government since 1994, including global conditions of economic transition, urban expansion, technological shift and general insecurities that continue to challenge spatial planning efforts. Whether cities have changed for better or worse does not stop these processes from occurring, which necessitates the government to make urban areas more equitable, resilient, and productive (Duminy, Parnell, and Brown-Luthango 2020).

Among other critical shifts, urban growth caused by urbanisation, migration and natural population growth has led our cities to grow at an alarming rate and, as a result, there are demands to accommodate this surge. Service delivery, including housing, is given top priority. Urban growth came with many challenges such as urban insecurity and urban growth, including housing shortages, resulting in a backlog.

Gated communities came as a solution to mitigate the housing challenges. However, they have become more widespread across the globe since the 20th century (Blakely and Synder 1997) and became a key aspect of the development trajectory both in developed and developing countries (Jürgens and Landman 2006). Evidence indicates that gated communities gained momentum in the late 1990s. Today, gated communities in South Africa have become popular, especially in cities and their suburban areas (Webster, Glasze, and Frantz 2002). Landman (2012) believes it is caused by real-world processes that are linked to numerous heated discussions on sociopolitical issues among scholars since 1999.

Although gated communities provide a sense of belonging and safety (Landman and Du Plessis 2007), they equally promote consequences of segregation (economic, political or otherwise), resulting in a fragmented and uncoordinated spatial landscape. These consequences are a result of economic standing attributed since

the 19th century (Harrison and Todes 2013). City transformation, or how landscapes are unfolding, has caused wide interest, particularly in urban sustainability for future cities.

Planners see gated communities as problematic or not problematic. This phenomenon should not depend on what kind of references are used to define their consequences (Landman 2012). Although Blakely and Synder (1997) indicated that gated communities are not a new concept, they began with the emergence of cities to secure the urban landscape as a defence mechanism that came at a time of double-digit economic development in many rapidly urbanising countries (Webster, Glasze, and Frantz 2002; Landman 2004). Are they continuing to be viewed in the same light in this modern day?

The study sought to gain a broader understanding of the inconsistencies influencing how our cities morph. Torres-Gutiérrez et al. (2019) further allude that cities are the drivers of growth and the agglomeration of economies and other externalities characterised by urbanisation processes. It can be further deduced that cities are distribution centres for risks that are strengthened and supported by the market mechanism found in production factors (Ahmad 1996). Therefore, guided by institutional settings of shared goods and services, this rationale guides these gated developments (Palm, Södergren, and Bocken 2019; Palgan, Mont, and Sulkakoski 2021).

3 LITERATURE REVIEW

This section reviews the literature related to the key concept and theories of gated communities and spatial planning challenges. It outlines and discusses the origins of gated communities by tracing their growth through time in both developed and developing nations, including an overview of the past and present impacts of spatial legacy that are perpetuating fragmentation, exclusion and unjust cities, as well as the gaps, challenges and limitations of spatial planning policies in post-apartheid cities.

Gated communities emerged during a period of economic expansion in many rapidly urbanising nations, but received little attention until the late 1990s (Webster, Glasze, and Frantz 2002). This housing typology is a global phenomenon that originated in Florida where a privately owned road was gated to define the boundaries between private and public spaces (Landman and Badenhorst 2012). In the United States, the origins and effects of gated communities have been most noticeable since 1985, and they are termed edge cities, which provide many of the same services that were once found only in city centres (Blakely and Synder 1997).

Today, the proliferation of gated communities is estimated to be over 20 000 with more than three million units (Blakely and Synder 1997)). Although the literature suggests that this trend is also noticeable in countries such as England, Brazil, Argentina, Spain and Malaysia (Salah and Ayad 2018). It is crucial to explore the social, economic, cultural and institutional circumstances in which gated communities are forming in other parts of the world, as circumstantial evidence and research suggest that the global expansion in private communities has been impacted by the Unites States' experience (Webster, Glasze, and Frantz 2002). South Africa is no exception to global expansion, however, it is influenced by the past spatial legacy that is predominantly car-oriented (Jürgens and Gnad 2002).

The high rates of migration to cities during and after the first democratic elections in 1994 increased the strain on the country's already limited housing supply. Although this may be true, the growth of gated communities can be attributed to the increasing demand from various social divisions in pursuit of privacy and security, and as a response to rising levels of violence and fear of crime (Landman 2004; Franklin 2020). Crime and the associated dread of the unknown are reason enough for this kind of housing typology. However, shying away from the fact that it promotes biases of race and class in the country indicates the reluctance to share resources and the lack of integration in promoting sustainable cities.

Conceptual framework and definition of gated communities

There is no unique definition for the term gated communities. There are, however, specific elements that characterise them, such as physical barriers that restrict entry to its residents such as walls, boom gates, and closed-circuit television. Roitman (2010) indicates that these communities operate as a form of security measure to prevent external influences or unauthorised entry. Vesselinov (2008) concurs that the walls and gates of the earliest human settlements played a crucial role in protecting cities from intruders. However, in modern urban studies, gated communities are one of the most controversial issues such as being the cause of segregation and urban inequality.

Scholars view gated communities as a manifestation of past spatial legacy (Landman, 2002), while other scholars see them as a more exclusive and less inclusive type of settlement leading to a rise in privatism and a decrease in the local community's cohesiveness (Todes, Weakley, and Harrison 2018). To unpack these dichotomic views of the phenomenon, this study first explored the modelling concept of gated communities based on recurring literature trends as crime seems to be at the centre of scholarly debate and as the rationale of gated community proliferation.

Crime as the gated community concept. Gated communities are increasingly used to shape the city's landscape, with both positive and negative consequences (Webster, Glasze, and Frantz 2002). They are influenced by physical and social factors, such as safety and security, and can create a sense of community and belonging (Salah and Ayad 2018).

Production of space and the right to the city. The production of space and the right to the city is largely defined by a person's position in society and their position in the geographical landscape. This indicates the concept of creating space, which has three components for a space to be successful, namely physical, mental and social, such that users of the space ultimately influence its function to a large degree (Williams 2007). However, Lefebvre's concept of space emphasises that users become producers of the space or place where life transpires with a symbolic meaning. Molotch (1993) emphasises Foucault's theory that a place is also a means of power, control and dominance as far as economics and politics are concerned.

This is evident in gated communities; however, their influence is also shaped by culture, social relations, common interests and the use of space. These highlights a critical aspect in how "spaces or even places" are "created or create themselves" (Butterworth 2000). Urban spaces are highly conflicted and contested as far as power is concerned, leading to a rise in social inequality and conflicting urban ideas that are influencing social behaviours (Foucault and Miskowiec 1986). As previously mentioned, safety and security are often cited as compelling reasons to leave the inner city in pursuit of a better quality of life and to create a sense of community and belonging.

Foucault's theory on space production and power is prominent in gated communities and the concept of power is to assert control (Wiedmann and Salama 2019). Lefebvre's theory has planners question how modern urbanisation resulted in a rise in social inequality and conflicting urban areas that are influencing social behaviours (Kuymulu 2014). While Harrison et al. (2014) point to Lefebvre's notions that space is assumed to be in harmony with its surroundings (Purcell 2002). This affects the way people utilise and access space or place significantly by either restricting or allowing movement.

Accordingly, the right to the city concept, coined by Henri Lefebvre in the 20th century, aligns with the concept of excluding urban society in cities from participation (Williams 2006). Even today, these forms of exclusion come in different forms, such as urban renewal, gentrification, citizenship, and socioeconomic discourse, which to a large extent, limit movement (Fuchs 2019). These processes are all formed based on globalisation, competitiveness, good quality living environment, privatisation of public space, high security and amenities. These are all the aspirations of gated communities and ensure this is facilitated independently without government involvement (Johannes 2012). It is done in a way that benefits both users and consumers and depicts the right to access resources. One thing the gated community emphasises is to ensure that everyone's rights are not violated in accessing material well-being and fulfilment (Harvey 2008).

However, the new type of development known as gated communities does not seem to share these values. In large cities like the City of Johannesburg, gated communities have a huge impact on spatial transformation and their impact on the socioeconomic aspect of the city. In general, investing in people and the growth of the city is a key component of social development and inclusivity. This can largely contribute to the progression towards development in any country and can well represent social and economic inclusion (Purvis, Mao, and Robinson 2019). Thus the success of a society is inextricably tied to the well-being of each individual within the society, although the proliferation of gated communities has been widely noted.

Literature on gated communities, particularly on their preserving economic segregation, has not yet been widely explored. Despite various policy efforts, the apartheid spatial legacy still remains largely intact and more social ills develop due to how our cities grow (Strauss 2019). The apartheid rigidity is seemingly forcing the city to expand outwardly. These newly developed communities are expanding on the fringes of the cities, thus impacting how our landscape integrates and perpetuating segregation through class or income barriers. For these reasons, this study explored the impact of gated communities on spatial transformation,

and the disintegrating continuity perpetuating segregation through the apartheid economy as a new form of exclusion.

4 METHODS

In outlining the gaps concerning the phenomenon studied, the aim was to find meaningful responses toward transforming our cities in a sustainable manner in the City of Johannesburg (i.e., integrated cities). The study adopted a qualitative method to establish the contributing factors that led to the proliferation of gated communities in the northern part of Johannesburg – Waterfall City – to establish the socioeconomic profile of Polofields residents as well as to establish the factors that led the residents to purchase the properties in Waterfall City in the City of Johannesburg.

The qualitative method was the preferred approach for this study for dealing with unexpected phenomena that are subjective and cannot be quantified (Aspers and Corte 2019). This research approach was undertaken with the aim of better understanding the real-life situation that contributes to shaping the city to become user-friendly. Moreover, an exploratory and descriptive design approach was used to further explore the problem identified by the study to contribute to a similar real-life phenomenon.

The primary and secondary collecting methods were used to assist the study to realise its objectives. The importance of data collection is to keep the integrity and sincerity of the research to determine the true course of action to be taken without being biased (Paradis et al. 2016). This research understood both the strengths and weaknesses of the method chosen to answer the research questions in relation to time and cost. To help the study draw the analysis, recommendation and conclusion, semi-structured interviews and observations were used as the basis for primary data collection to establish the objectives of the study.

Overview of Waterfall City in Johannesburg

Johannesburg and Midrand make up a part of the Gauteng city region, which is considered the economic engine of South Africa. Despite this fact, Johannesburg inherited South Africa's geography and history's geographical distribution (Cheruiyot 2019). Statistics South Africa (2020) shows that around 15,5 million people account for 26 percent living in Gauteng, making it the most densely populated region and by far the smallest when compared to their neighbouring regions. The City of Johannesburg, on the other hand, is home to an estimated 4 434 827 million people with a population density of 1 963 people per square kilometre (Hofer et al. 2020). Midrand was established in 1981 and merged into Johannesburg Region 2 from late 1990 to 2006, and the regions in Johannesburg were later reduced to seven (Rogerson 2003). Midrand was amalgamated to form part of Region A (refer to Figure 1).

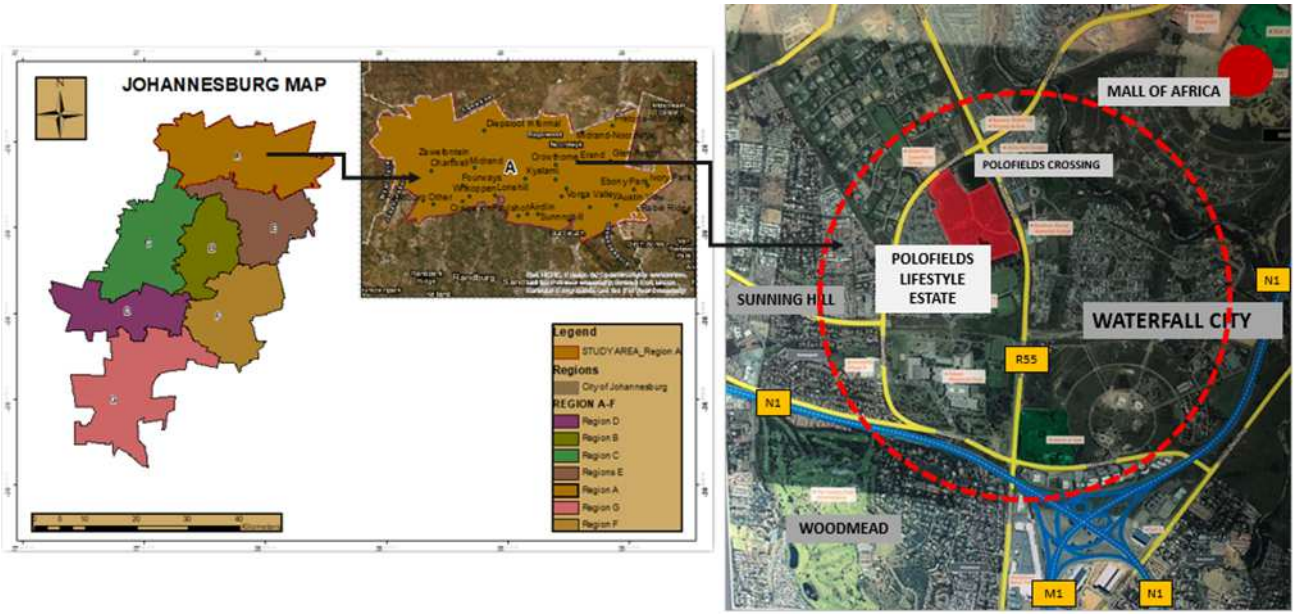

Figure 1: Johannesburg, Region A and Polofields Lifestyle Estate locality map (Source: Created from Google Maps by Author 2025).

The study randomly selected 20 participants from the gated community of Polofields, 10 of whom are residents as well as those employed within the gated communities (domestic workers, gardeners and restaurant workers), and five of whom were randomly selected from the management of Polofields

(homeowner association, real estate agent and developers). For the consideration of time, space and resources, this study aimed at a random selection of five municipal officials in order to assess how socioeconomic profile influences the residence preferences, behaviour and location of Polofields from a spatial planning viewpoint. The sample size was influenced by the aspect of the income principle, which Darin-Mattsson, Fors, and Kåreholt (2017) indicated as often linked to processes that create different social groups as it looks at the aspect of socioeconomic segregation. With this in mind, the researcher was sensitive to the views in reference to the belief systems, norms and values of the diverse nature of the population (Austin and Sutton 2014).

5 RESULTS

The research results are presented and analysed in this section through in-depth interviews with key respondents using semi-structured questions. Observations were made in and around Waterfall City and Polofields. Also, the literature and desktop evaluation of the research all contributed to the study's key findings and analysis, which the research data and literature focused on in answering the study's objectives.

Using semi-structured questionnaires, the study was able to gain a perspective from the professionals who had experience in spatial transformation and land use management processes. Thoughts and perspectives on the topic were analysed to find probable connections between the new proliferating paradigm of gated communities in the urban planning landscape and the new socioeconomic agenda manifesting as a new form of apartheid, namely economic apartheid.

The findings in this section helped to answer the objectives of the study, namely to (1) establish the contributing factors that led to the proliferation of gated communities in the northern part of Johannesburg, Waterfall City; (2) to establish the socioeconomic profile of Polofields residents; as well as (3) to establish the factors that led the residents of Polofields to purchase properties in Waterfall City in the City of Johannesburg.

The results indicated that although hundreds of the population live within gated communities, there are different types among them. What makes them distinct in their character and their physical aspects is the location lifestyle and amenities. Location is what generally attracts many to explore this type of residential environment, particularly in the north of Johannesburg – Waterfall City – for the reasons of the lifestyle and perception associated with it. As indicated by the data, many residents were quite satisfied living in gated communities because of the safety and security it offers as it gives them peace of mind.

Moreover, it has a return on their investment and also on their well-being. The results indicated that there is a correlation between the apartheid spatial planning system and the gated community, taking the role of strategic control of space and the engineering of spatial patterns. The difference is that apartheid emphasised how race influenced space in terms of distribution, as opposed to gated development where the qualifying criteria is class stratification classified by income brackets. This data was found in the apartment price variation per unit ranging between R2,2 million to R100 million. This analysis supports Foucault's theory, the capitalist's theory and Lefebvre's theory with regard to the production of space. This data suggest that gated communities tend to be characterised by a high degree of social segregation.

The extent to which various social and physical elements contributed to the proliferation of gated communities is seen by this study as the key influence. Thus, one's level of contentment in one's dwelling is affected by the nature of the surrounding community. For instance, the ability of gated community settings to foster a sense of community and belonging as well as safety and security is often stated as an attractive reason to move to such residential types. To establish these factors, professional perspectives on spatial transformation, exacerbated by gated communities, were outlined in the responses, and the description offered by scholars in the literature review was an important component of this, which was also shared by the respondents.

Results on gated community lifestyles and amenities offered as a contributing factor to their proliferation

Among safety and security is the sense of belonging and lifestyle offered by gated communities which is the major aspect leading to the growth of these types of developments. Some of the respondents shared that the physical and social aspects that gated communities offer are a key attraction to these types of residential development. To feel safe and have a sense of belonging within the walls, one of the respondents remarked:

In my view and from the sectional title view, gated communities offer one a sense of belonging and "neighbourliness". It offers safety, security and peace of mind. The amenities that are shared within the estate enhance that sense of community.

The meaning of neighbourliness according to one of the respondents:

Over and above crime issues in South Africa, people want to move to gated communities as a transition from chaotic city life, so they could get away from the noise and pollution of urban areas. People are now becoming increasingly concerned about physical and mental health which has become a more widely discussed topic of discussion.

The concept of a sense of belonging, neighbourliness and safety, as well as the drive for the new globalisation lifestyle, is a broadly investigated topic by existing literature on the reason for gated communities. This study collected data by observing the Polofields amenities and infrastructure in terms of ensuring the extent to which a sense of belonging (neighbourliness), safety and security are provided, as reasons these types of housing are in demand. Table 2 outlines the observed findings of the infrastructure provided by Polofields.

Observation of the infrastructure at the Polofields Lifestyle Estate		
Amenities facilitating social interaction	Pool area Kids play area Coffee shop Restaurant Convenient store Play area Gym Sports fields Garden	
Communion among those that share similar values	Schools Religious centre	
Taking part in neighbourhood events (organisation)	School events	
Recreational time shared	Residents have a limited number of user access	
Proximity to the shopping centre	500 m approximately 2 minutes	
Proximity to the mall	3.1 km approximately 7 minutes	
Roads	Adequately provided	
Transportation	Those residing inside the Polofields Lifestyle Estate	Vehicles
	Those residing outside the Polofields Estate	Taxis

Table 1: Infrastructure observed at the Polofields Lifestyle Estate. Source: Author (2025)

Smets (2005) indicates that countries such as the United States, where the government does not adequately provide amenities, cause a higher occurrence of gated communities. This by virtue creates opportunities for the ones who have the means and resources to produce safe and liveable spaces for themselves, while it creates the perception that income disparities typically increase social tensions and high crime rates in conventional communities. The satisfaction scale measurement that supports the link between access to amenities, safety, and neighbourliness. The resulting measure indicates that 90 percent of the population is extremely satisfied, accounting for only 10 percent of the residents that are measured as not satisfied, with zero percent of residents indicating any dissatisfaction.

Results of the establishment of the socioeconomic class of Waterfall City and Polofields Lifestyle Estate

The starting point of this discussion is based on the guidelines of the settlement with regard to its physical layouts. As discussed in the literature review, the ability of a community to produce opportunities is dependent not only on the number of people living there but also on the planning and construction processes that went into its development. The findings highlighted the disintegrating continuity of spatial transformation in this particular development, Waterfall City. The factors of providing a choice mode of public transportation were not visible in the data collected, particularly for those commuting to work. The following respondent profiled the kind of residents that typically reside in Waterfall City at large including Polofields:

Public infrastructure provision

Lack of transportation system that integrates with residential development. Gated communities like Polofields do not integrate with the public transportation infrastructure and contribute to significant implications for socioeconomic development. The lack of an integrated transport system and proper public transportation infrastructure creates a significant physical barrier for commuters, especially those without access to a vehicle. Figure 7 illustrates the reinforcement of fragmented spatiality through gated

developments that are typical in urban areas, resulting in marginalisation and social inequities. Additionally, gated communities promote exclusivity, which has the potential to add to social inequities and marginalise communities in low-income areas that are forced to serve these types of developments.

The lack of taxi or minibus infrastructure provision in the area indicates this socioeconomic disparity, where communities in low-income areas are the ones serving the gated communities without real spatial, economic, and social integration. The development still embraces the same apartheid spatial landscape, which continues to promote disintegrating development continuity and sprawl, until inclusionary housing is built to help cities become more compact and integrated. Therefore, transportation facilitates access and mobility, and planners need to conceptualise the movement of people more comprehensively by taking into account the strategic importance of public transportation, particularly in new developments.

Figure 2: Depiction of workers cycling to work (Source: Author 2025)

According to Raszkowski (2012), a key part of a city's socioeconomic transformation is looking at factors that might help all the development-related activities bear fruit in the form of sustainable socioeconomic growth, which is essential to enhancing the quality of life in the local community. The construction of facilities to facilitate this spatial transformation should be taken into consideration. Consequently, this also encompasses the infrastructure of public transit as a means of accessing places of employment. This is concurred by the observed active transportation system estimating that 60% of active transportation is by private vehicles, 25% by Taxis, followed by Gautrain which integrates with its Gautrain bus system at 12%, cycling is at 2% which mostly are residence who cycle to keep fit as well as the low-income workers, and lastly walking is at 1% who are mostly workers in the Waterfall City. The study suggests that there is a lack of effort towards spatial integration particularly to accommodate those living in low-income areas.

To establish the factors that led the residents of the Polofields Lifestyle Estate to purchase properties in Waterfall City in the City of Johannesburg. Polofields Lifestyle Estate is a gated community in Waterfall City, Johannesburg, where many people have decided to settle down because of the neighbourhood's reputation for peace and quiet. The estate is protected by a state-of-the-art security system, which includes digital pass systems, guards on duty around the clock, security patrols along the perimeter, fingerprint systems, and high-tech pan-and-tilt cameras at the guardhouse and on each street. Gated communities attract those who value safety, community, and neighbourliness.

People that have the means, such as celebrities and successful businesspeople, are the estate's primary clientele. Ninety percent of the estate residents are Black Africans, suggesting that economic rather than ethnic factors contribute to the segregation. The people who live in gated communities know all about the benefits of living there, including the privacy, security, and ease it provides. One of the respondents indicated that gated communities are good for the economy as a whole, a great place to live, and a promising way to reduce unemployment. However, the uneven distribution of people by occupation or income within residential neighbourhoods in a city or metropolitan region, known as socioeconomic segregation, leads to increased segregation.

Even though security is the case in most gated communities, including Polofields, the concept of creating space as discussed in the literature section (Foucault's theory) must have three components for a space to be successful: the physical, mental and social. More often, space corresponds to the user of such space. Hence this development was intentionally developed with these factors in mind. Furthermore, another important aspect is that creating space is often associated with power, control and dominance as far as economics and politics are concerned by those who produce it. By definition of these aspects, gated communities are influenced by power, control and dominance. This suggests that residents of gated communities are well-informed about what kind of spaces they are occupying, that is, spaces that offer safety and security, convenience and exclusivity. In view of this research, could this be just another capitalist strategy to get wealthier or another kind of economic revolution? The following is the view shared by the respondent: "People are buying or renting in gated communities for status reasons. Also to invest in these types of dwellings for capital appreciation". The respondent views it as an investment opportunity and an important part of the city's economy, seen as a potential solution to curb unemployment. In general, whether one sells or buys in South Africa, real estate investment is a capital-intensive and highly leveraged industry.

6 DISCUSSION

This section serves as a conclusion and summary of the key findings of the research, as well as a perspective on the study as a whole. It includes an examination of the obstacles and limits of the study and a set of suggestions for future studies based on the shortcomings. What led to the interest of this study was the observation of disintegrating continuity of urban settlements in Waterfall City in the City of Johannesburg, manifesting in the proliferation of gated communities and perpetuating segregation. This section discusses the overall results that address the research objectives.

The aim of the study was to establish the contributing factors that led to the proliferation of gated communities in Waterfall City in the northern part of Johannesburg. The results indicate that although there are hundreds of the population living within gated communities there are different types among them. What makes them distinct in their character and their physical aspect is the location, the lifestyle and the amenities. Location is what generally attracts many to explore this type of residential environment, particularly in Waterfall City in the north of Johannesburg, for the reasons of lifestyle and the created perception associated with them. As indicated by the data, many residents are quite satisfied living in gated communities because of the safety and security it offers as it gives them peace of mind and well-being, as well as the ability to give a good return on their investments.

Crime as a factor

The study investigated the extent to which the City of Johannesburg takes spatial integration into account when approving plans. The data indicate that gated communities in Waterfall City were not part of the city's spatial development framework, which indicates that the growth of urban enclosures and gated communities is influenced by a wide range of physical and social factors such as crime as a major aspect of gated community's proliferation. They are developed to fit the people's demands who are searching for safety and security, a high quality of life and a better lifestyle. It can be interpreted as a cry for help in response to the urban struggle suggested by the right-to-the-city concept coined by Henry Lefebvre in 1968.

The data found that there are many desirable aspects of a well-managed and governed neighbourhood that contribute to residents' sense of pride and belonging, whether it be a feeling of safety and security, a sense of community and identity, shared social values, a sense of economic stability, a preferred way of life or a high social status indicating major factors in determining the social makeup of gated communities. While the researcher's perception of gated communities was that they provided neighbourliness, encouraged by the nature of these types of developments. However, the result indicated that people are more interested in the safety aspects of gated communities as well as to isolate themselves.

This also gives an indication of why gated communities thrive in "close walls or high walls". This depiction indicates why amenities are such an important feature in these types of residential spaces as the motivation for neighbourliness. Although, this study argued that relationships are intentionally forged, whether one stays in a gated community or not, although encouraged by the environment. Through investigations, the study found that this depiction contradicts the scholarly knowledge that gated communities promote a sense of community. As a result of the demand for safety and security, the urban structure suffers as it does not align

with spatial planning policies in achieving the spatial integration mandate, as it alters public spaces and farm holdings and further creates cities within the city in an effort to pursue these demands.

7 CONCLUSION

One of the primary motivating factors for the growth of gated communities in South Africa is the need for its citizens to feel safe and secure within their own neighbourhoods. Technologies such as video cameras and permanent security guards are used to keeping residents safe in gated communities, but we must keep in mind that no matter how many safeguards are installed, criminal activity will persist. In this respect, the claimed safety of a gated community is speculative. Overall, residents of gated communities enjoy the benefits of safety and security which may not solve South Africa's economic and social issues. Despite this, people continue to invest in gated communities for reasons such as increasing their wealth and social standing. Making it obvious that this is a highly capital and debt-intensive move for the prestigious to classify the population, although this study found that gated communities are widening the gap between the already distinct socioeconomic group and strong perpetuators of segregation. It equally suggests that planners and stakeholders allow these disparities to persist, which significantly compromises policy progression and implementation, but at whose expense? In the view of this study, this can be achieved by having planners and stakeholders account by critically analysing the growth with respect to diversity and equality such as adopting a polycentric, transit-oriented approach to lessen the likelihood of the wounds of the past being relived. The prosperity of the economy as a whole depends on the ease with which people of varying financial means can have access to dignity that comes in the form of decent neighbourhoods. This study suggests that planners look intensely into policies that advocate for integration and the processes of implementation if we are to make an impact to transform our cities' landscapes.

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🏆 reviewed paper

Spatial Planning on Electricity – What smart meter data can tell us about spatial structures

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1 ABSTRACT

Spatial planning approaches such as densification, the 15-minute city, or net-zero initiatives increasingly promote and necessitate mixed-use land allocations. Traditionally, land use was segmented into distinct categories such as residential, industrial, commercial, or transportation. This zoning-based approach provided clear guidance on expected spatial functions and human activities within designated areas. However, as mixed-use developments become more prevalent, the conventional distinction between living, working, and other activities becomes increasingly blurred. Consequently, traditional zoning regulations use more and more mixed-use zoning to regulate spatial impacts. But the knowledge of spatial impact does not fit the need for coordination and regulation. The dynamics of urban life require planning instruments that go beyond static land-use maps and embrace real-time and usage-based data to inform spatial policies.

To address this challenge, planning authorities require an empirical foundation that captures real-world spatial usage and interactions. Conventional spatial data from federal or state topographic offices primarily describe physical land features but lack insights into actual usage patterns. This gap is increasingly critical as mixed-use developments grow in scale and complexity. The key challenge is no longer defining land use but understanding how space is utilized in real-time to inform better regulatory measures. Additionally, understanding peak hours of electricity consumption can provide indirect yet valuable insights into mobility patterns, working behaviors, and residential activity shifts.

Smart meter data offers a novel and dynamic source of information to bridge this gap. As Engelke (2017) states, "Not only more accurate and up-to-date geodata is available for planning, but also unprecedented knowledge about the actual use of space." By capturing detailed electricity consumption at the household level, smart meters provide indirect but valuable insights into human presence, activity patterns, and the intensity of land use. The mandatory rollout of smart meters presents an unprecedented opportunity to integrate high-resolution temporal data into spatial planning. The EU has decided in 2009 to implement smart meter in all member states, and e.g. Germany decided obligatory smart meters in all households by 2023. Switzerland intends to cover 80% of Swiss households by 2027.

Aggregated smart meter data at neighborhood or district levels allows planners to assess deviations between planned and actual land use, thus informing evidence-based policy adjustments and regulatory interventions. This integration has the potential to refine urban planning strategies, providing a data-driven approach to analyze urban vitality, the success of mixed-use developments, and urban energy efficiency.

Moreover, leveraging smart meter data can help policymakers refine zoning laws and introduce dynamic zoning approaches that adapt to real-time conditions. Instead of relying solely on traditional land-use maps, urban planners can create policies based on actual demand, energy efficiency, and mobility behaviors. For example, if a neighborhood exhibits a sharp increase in electricity consumption during typical work hours, it may indicate the presence of informal office spaces or remote work trends that challenge conventional zoning assumptions. By using smart meter data to validate and adjust planning regulations, cities can enhance the efficiency of land use, reduce urban sprawl, and support more sustainable forms of development.

This paper explores the potential of smart meter data for spatial planning, identifying its strengths, limitations, and future research needs. Using open data from the Swiss Lucerne region as a case study, the paper investigates how temporal spatial structures can be derived from electricity consumption data. The objective is not merely to analyze a specific case but to examine the broader applicability of such data in addressing spatial planning challenges. Furthermore, this research contributes to the debate on how digitalization and real-time data streams can enhance planning effectiveness, ensuring that cities remain adaptable and resilient in the face of growing urbanization and climate challenges.

Keywords: data science, smart city, spatial planning, smart meter data, energy

2 LITERATURE REVIEW ON SMART METER AND MOBILITY DATA

The spatiotemporal analysis of data enables the mapping, understanding, and optimization of complex dynamics of human behavior (represented by their energy consumption) and spatial patterns. Given the fact that there is rarely literature on the interaction between energy consumption and spatial patterns, but various studies on analyzing energy data, this paper examines these different methodological approaches and their implications for spatial planning.

Kragh-Furbo and Walker (2018) highlight how digital transformation in electricity metering generates fine-grained, high-resolution data, offering a deeper understanding of energy consumption patterns. This data not only enables more precise allocation of responsibilities in energy systems but also allows for new forms of governance and demand-side management strategies. The performative consequences of this transformation are particularly relevant for policymakers seeking to integrate data-driven insights into regulatory frameworks. Additionally, the ability to track energy usage at a granular level provides a means to optimize energy efficiency and support sustainable urban development.

In the domain of mobility research, Wang & Huang et al. (2019) demonstrate how spatiotemporal analysis of GPS-based taxi data helps identify urban traffic patterns. Their innovative visualization techniques, such as chord diagram plots, effectively represent origin-destination flows across multiple spatial scales. These findings underscore the interdependencies between mobility behavior and spatial structures, offering valuable input for sustainable urban planning. Moreover, by integrating mobility data with energy consumption data, planners can create a more comprehensive understanding of urban activity dynamics.

The methodological approaches to analyzing smart meter data are diverse. The Swiss Federal Office of Energy (SFOE, 2016) has developed classification and clustering algorithms that derive household characteristics based on consumption profiles. Machine learning techniques, enriched with additional data sources such as meteorological and demographic information, enable more precise energy advisory services and system efficiency improvements. Similarly, Wang & Henri et al. (2020) propose an activity-based modeling approach, leveraging smart meter data to recognize household activities and their temporal dynamics. These studies illustrate how electricity consumption data can extend beyond traditional energy management and contribute to broader urban planning applications. By employing advanced machine learning techniques, smart meter data can be further refined to predict future energy demands and urban mobility needs.

Peng et al. (2021) advance this field by developing a high-resolution predictive model based on potential flow theory. Their entropy-based indices quantify clustering intensity and meteorological dependencies, improving the accuracy of energy demand forecasting. This approach is particularly relevant for integrating smart meter data into spatial planning, as it provides predictive insights into future consumption trends and their spatial implications. The ability to anticipate future energy demands can aid in the planning of decentralized energy systems and localized energy production, fostering more resilient urban environments.

Alternative approaches in the analysis of urban mobility data provide complementary perspectives. Wang & Huang et al. (2019) apply interactive visualization techniques to large-scale trajectory datasets, enabling a granular understanding of traffic flows and their spatial distributions. Data-driven modeling strategies incorporate machine learning to classify and predict movement patterns, highlighting the synergies between energy consumption and mobility behaviors. Building on this, Wang & Lu et al. (2022) propose that generative intelligence models frameworks (AI) can enhance smart data analysis, e.g. in the field of mobility, by simulating emergent urban dynamics in response to infrastructure changes. These models generate probabilistic scenarios that allow planners to explore different land-use and transport policy outcomes, thus shifting the focus from static analysis toward an iterative, scenario-based planning methodology.

The reviewed literature demonstrates that smart meter data can serve as a crucial resource for uncovering spatial and temporal dynamics. The spatiotemporal analysis of smart meter and cab data shows how data-driven approaches can contribute to the optimization of urban systems. While smart meter data is mainly used for energy efficiency and forecasting, cab data offers unique insights into urban mobility patterns. Both approaches benefit from innovative methods such as machine learning, visualizations and interactive analysis tools. The integration of space and time in data analysis opens up new perspectives for the sustainable planning and management of urban infrastructures. In particular:

- Fine-grained energy consumption insights – Smart meter data enables detailed analysis of household activities and urban energy demands.
- Visualization as a planning tool – Innovative visual methods bridge the gap between complex data and practical applications for spatial planning.
- Integration with mobility data – Linking smart meter data with mobility patterns provides a more holistic perspective on urban dynamics, allowing for improved infrastructure planning and service provision.

By synthesizing these findings, this paper builds on existing methodologies to explore the applicability of smart meter data in spatial planning, with a particular focus on their impact on regulatory frameworks and future urban development strategies.

3 CASE STUDY

The insights gained from literature review will now be further examined in a case study. The selected case study region is the Swiss Lucerne Region, which offers a diverse range of spatial typologies – from rural areas to peri-urban agglomerations and the urban periphery of the core city of Lucerne. This diversity provides an ideal setting to analyze spatial dynamics and Smart City developments across different settlement structures. For this case study, an open data dataset containing smart meter data from the Swiss energy provider Centralschweizerische Kraftwerke is available (CKW 2024). These data will be systematically analyzed to assess spatial patterns, digital infrastructure, and governance strategies related to Smart City concepts. By leveraging these data-driven insights, the study aims to deepen the understanding of how digitalization and spatial planning interact across different territorial contexts within the Lucerne Region.

3.1 Case study region

3.1.1 Dataset Description

The used anonymized smart meter dataset consists of aggregated electricity consumption measurements from households across the CKW service area. To protect consumer privacy, the dataset includes only anonymized meter IDs and does not contain personally identifiable information. Additionally, large industrial consumers have been filtered out to ensure that the analysis focuses on residential and small commercial energy consumption patterns. The dataset includes the following key attributes:

Anonymized Meter ID: Unique identifier for each smart meter (text format).

Area Code: Postal code of the service area (categorical data).

Timestamp: UTC-based timestamp marking the beginning of a 15-minute measurement interval (ISO-8601 format).

Number of Meters: Count of smart meters aggregated per area (integer format).

Energy Consumption (kWh): Total measured electricity consumption in kilowatt-hours (continuous variable).

The data covers an observation period of one representative week in 2024 (calendar week 45), a period chosen to avoid anomalies caused by public holidays or school vacations. The temporal resolution of 15-minute intervals provides fine-grained insights into energy consumption trends, allowing for detailed spatiotemporal analysis.

3.1.2 Spatial Context of the Case Study

The case region includes the western part of Lucerne, the surrounding commuter catchment area, as well as peri-urban and rural areas to the west of Lucerne. These areas encompass municipalities classified as major centers and secondary centers of major centers according to the ARE municipality typology. Additionally, the case region includes municipalities situated along the A2 freeway, categorized as belts of major centers within the ARE typology, as well as agricultural municipalities, some of which are located within the UNESCO Entlebuch Biosphere Reserve. In total, it comprises 116 zip code areas within nearly 80 municipalities, three of which belong to the municipality of Lucerne itself.

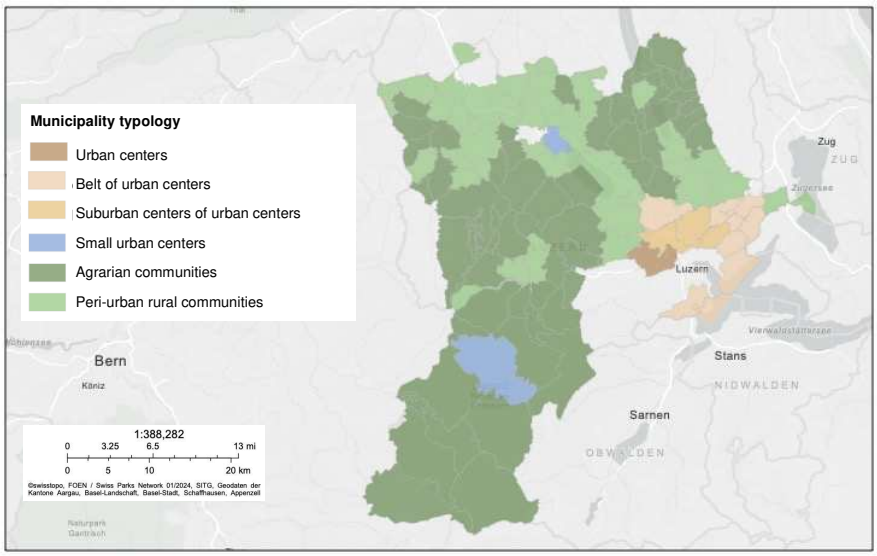

Fig. 1: Case study region with municipality categories of the zip code areas

To assess the suitability of smart meter data for spatial planning purposes, both temporal and spatio-temporal patterns in the data must be identified. The analysis begins with the examination of temporal patterns. For this purpose, selected municipalities are analyzed based on spatial categories, and behavioral patterns are derived from daily consumption trends observed on weekdays and weekends. In a subsequent step, spatio-temporal analyses are conducted.

To determine which community typologies – such as those related to commuter behavior – can be inferred from smart meter data, an average consumption pattern is first established across all days and all zip code areas within the study region. By comparing individual municipalities to this average daily consumption pattern, those exhibiting particularly distinct spatial consumption trends are identified. From this group, three municipalities displaying significant deviations from the average pattern are selected for further discussion.

The analysis initially focuses on temporal patterns. The following municipalities have been selected as representative examples of different spatial categories. The statistical methods used to identify these municipalities are not elaborated upon in this paper:

Willisau: Agricultural municipality with a predominantly rural character

Dagmersellen: Peri-urban rural municipality with direct freeway access to Lucerne via the A2

Root: Located within the commuting belt of major urban centers, adjacent to Lucerne

The locations of these three municipalities are depicted in Figure 2.

To bridge the transition from the case study region and dataset description to the analysis of temporal energy consumption patterns, it is essential to outline the methodological framework guiding this research. The study aims to examine how smart meter data can enhance spatial planning by revealing underlying patterns of human activity and land use. Building upon the literature review, which highlighted the potential of energy consumption data for spatial analysis, this research applies empirical methods to test these concepts in the specific context of the Lucerne region. The approach includes statistical evaluations of energy consumption trends, spatial clustering techniques to detect functional land-use variations, and comparative analyses across different municipal typologies. By structuring the investigation in this manner, the study seeks to answer key research questions: How do electricity consumption patterns correspond with land use functions? To what extent can these patterns refine existing planning paradigms? These inquiries will be explored through both temporal and spatio-temporal analyses in the following sections.

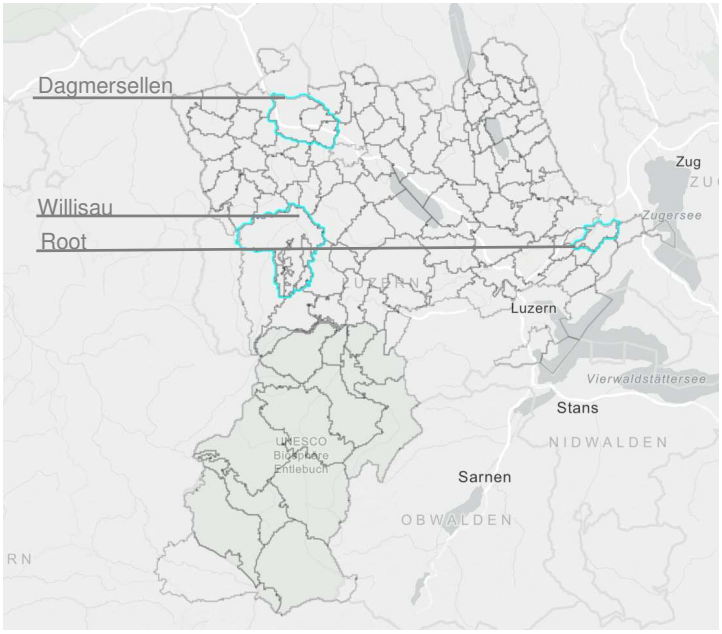

Fig. 2: Case study region and exemplary municipalities

3.2 Temporal representation of smart meter data

For improved readability, the daily electricity consumption patterns for Monday and Sunday are presented below, representing typical weekday and weekend consumption behaviors. Electricity consumption is displayed per capita and is derived from the average daily consumption patterns across all municipalities within the study region. The per capita electricity consumption is presented as an indexed value. It is important to note that the same calculation can also be applied per device instead of per capita. Since both approaches share the same total consumption value and the same proportional daily mean value, the relative deviations remain identical regardless of whether the consumption is indexed per capita or per device. Thus, the choice of unit does not affect the interpretation of consumption dynamics. The consumption patterns of the four exemplary municipalities are illustrated in Figure 3:

The daily consumption patterns observed in the analyzed municipalities reflect underlying spatial structures, population densities, and the functional characteristics of the settlements. These patterns provide critical insights for spatial planning, particularly concerning land-use diversity, mobility flows, and energy infrastructure.

Willisau, a predominantly rural municipality characterized by agricultural activities, exhibits a remarkably uniform consumption pattern throughout the week. There is little variation between Monday and Sunday, with only a slight increase in morning consumption, presumably linked to agricultural work. This stability indicates low commuting dynamics and a largely homogeneous pattern of land use. The spatial structure of Willisau is strongly shaped by its agricultural character, which is reflected in a low diversity of activities and a predominantly locally anchored population.

Dagmersellen, benefiting from direct highway access to the A2 leading to Lucerne, exhibits an even more pronounced commuter profile. On weekdays (Mondays), consumption peaks are particularly distinct in the morning and evening, while Sundays show a significant decline in consumption. The municipality's spatial function as a residential area for commuters is reinforced by its strong transport connectivity. Additionally, Dagmersellen demonstrates increased midday activity, suggesting the presence of work-related or service-oriented functions.

Root, located in the agglomeration of a major metropolitan center and adjacent to Lucerne, displays a particularly notable pattern. On weekdays (Mondays), electricity consumption remains high throughout the day but decreases in the evening. During weekends (Sundays), overall consumption is lower and more evenly distributed. This consumption behavior suggests that Root functions not merely as a residential municipality but also accommodates a significant number of workplaces or home-office activities.

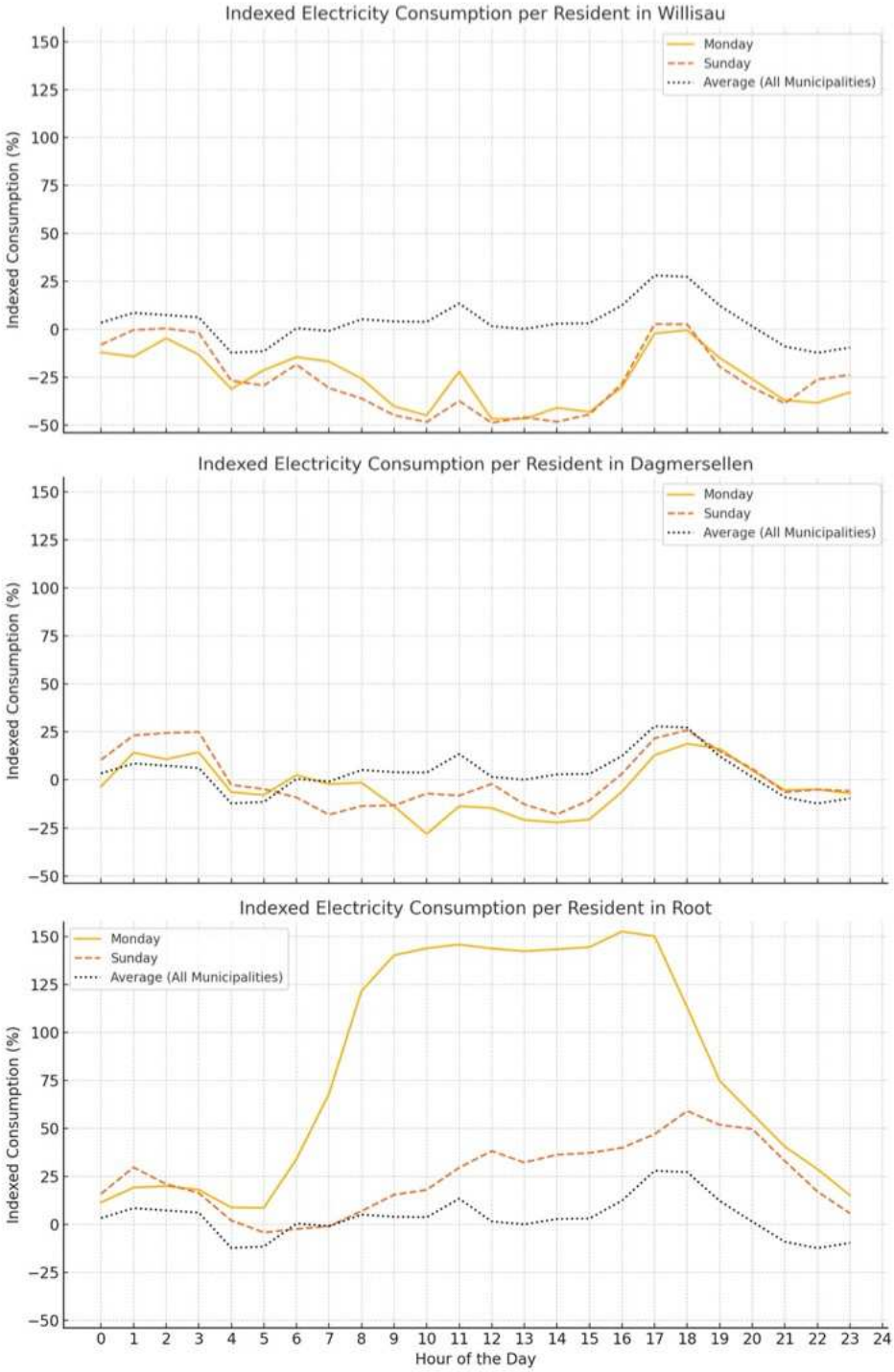

Fig. 3: Daily patterns of indexed energy consumption

Overall, the observed consumption patterns enable inferences about the spatial structures and the socio-economic functions of the municipalities. From a spatial planning perspective, these findings offer valuable indications for the development of tailored strategies in energy supply, mobility, and land-use planning. Such strategies should consider the specific characteristics of each municipality to enhance sustainability and efficiency in urban and regional development.

These findings directly address the gap outlined in Chapter 1. While traditional spatial planning has relied on zoning laws to regulate land use and by this behavior, the increasing prevalence of mixed-use developments necessitates a more dynamic approach that incorporates real-time data. Smart meter data contributes to this by offering empirical evidence of actual space utilization, enabling planners to identify discrepancies between intended and real-world usage. The integration of smart meter data into spatial planning thus facilitates the development of adaptive zoning strategies, enhances infrastructure planning, and ensures a

more efficient allocation of resources. By providing a more nuanced understanding of urban energy consumption, this approach strengthens the ability of planners to design sustainable and responsive urban environments. The next section will further examine how spatio-temporal analyses refine our understanding of urban energy use.

3.3 Spatio-temporal representation of smart meter data

In addition to analyzing temporal consumption patterns and identifying municipalities that deviate significantly from the average daily energy consumption pattern, the following spatial patterns are examined the spatio-temporal representation of smart meter data.

To achieve this, deviations from daily electricity consumption are visualized for all zip-code areas in a certain municipality. Specifically, quarter-hour intervals indicate whether consumption in a given interval deviates from the daily average in the respective postal code area. With one exception, deviations of plus or minus 25 percent are considered the average for each postal code area. This approach enables the identification of overarching spatial patterns within the study region, independent of individual municipalities. The analysis follows a key computational step of calculation of the nornmalized mean value per ZIP code per day. To establish a baseline ("zero point") for each ZIP code, the mean value for each day and postal code is determined. This enables the visualization of relative deviations, indicating increases or decreases in consumption relative to the daily mean for each ZIP code. The calculation is structured as follows, where 96 represents the total number of 15-minute intervals per day:

$$\text{Normalized mean value per ZIP code per day} = \frac{\sum \text{Normalized consumption per device per day per ZIP code}}{96}$$

For simplification, this paper presents consumption patterns at three distinct time points: Monday at 6 a.m., 11 a.m., and 5 p.m., which represent key moments in the weekday work rhythm. Due to the data format of the source data, the times are in UTC. So the local time in Switzerland at that period of the year is UTC +1 hour, so 7, am 12 noon, 18/ 6 pm. These are subsequently compared to the same time points on a weekend day (Sunday) to illustrate differences in consumption dynamics. In figure 4 on the spatio-temporal distribution on weekdays (Monday) as well as on figure 5 on weekends (Sunday).

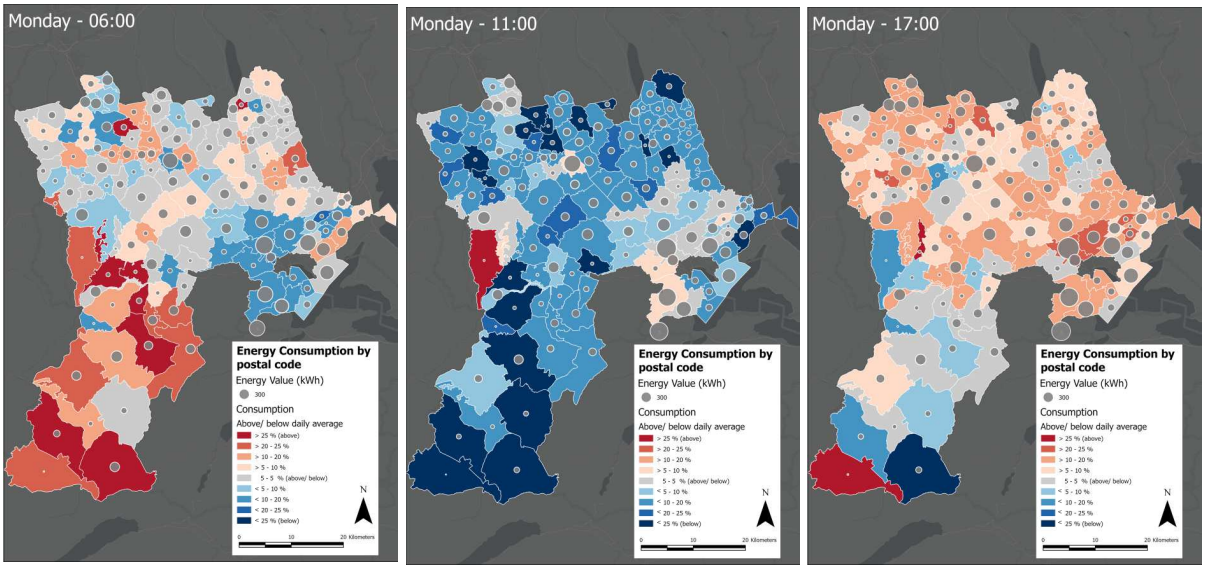

Fig. 4: Spatio-temporal distribution on weekdays (Monday)

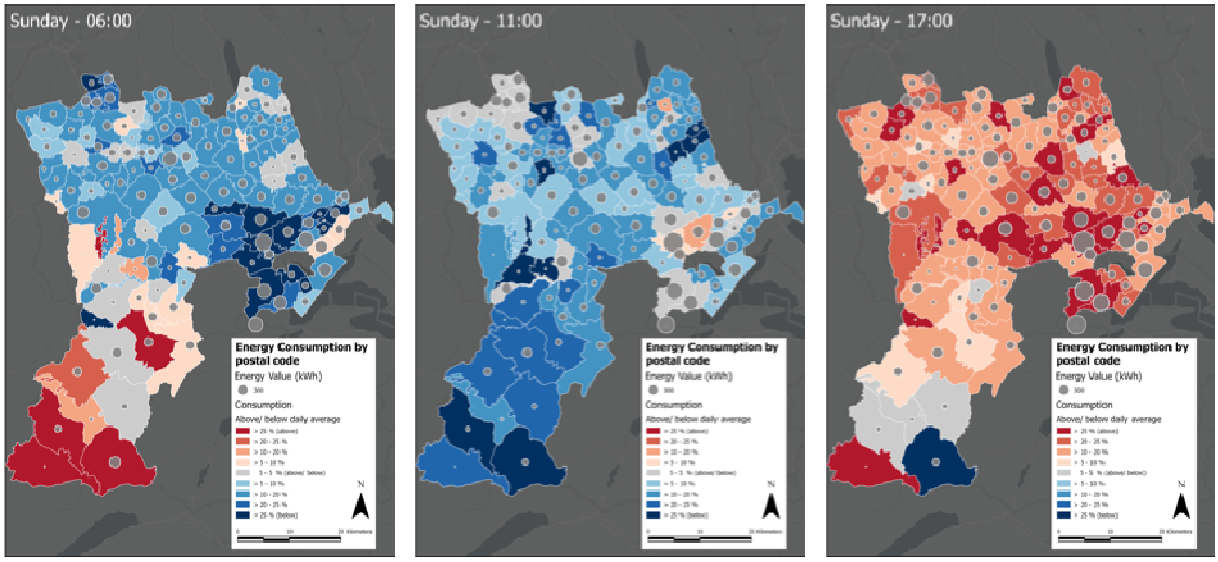

Fig. 5: Spatio-temporal distribution on weekends (Sunday)

A clear distinction emerges within the study region, which consists of two sub-areas. The northern part is strongly influenced by the municipality of Lucerne and comprises urban centers, suburban agglomeration, and other rural communities – effectively forming the commuter catchment area of Lucerne.

Monday, 6 a.m. – Electricity consumption in this northern sub-area is generally below the daily average. Notably, closer proximity to the urban core correlates with even lower consumption levels, whereas in more distant regions, certain postal code areas already exhibit above-average consumption at this early hour.

Monday, 11 a.m. – By late morning, consumption across most of this northern region remains below average, while the belt surrounding Lucerne shows comparatively higher electricity consumption.

Monday, 17:00/ 5 p.m. – By early evening, a general increase in consumption is observed across the entire region. The peri-urban belt around Lucerne shows the highest deviations from the daily average, indicating intensified household and workplace-related activities.

These emerging spatial patterns illustrate a clear daily cycle: the region "wakes up" in the morning, experiences a peak in commuting-related activity towards the urban center, sustains activity levels in the center throughout the day, and then undergoes a shift back towards suburban and peri-urban areas in the evening.

In contrast, the southern sub-area of the study region, characterized by predominantly agricultural communities, exhibits markedly different consumption patterns. These differences highlight the varying spatial functions of municipalities, which have implications for energy planning, mobility strategies, and land-use planning.

Sunday, 11 a.m. – Energy consumption remains low across the study region. In rural areas, patterns resemble those of weekdays, while urban and peri-urban areas show significantly lower demand, indicating a delayed start to activities.

Sunday, 11 a.m. – Overall energy demand remains below Monday levels, particularly in urban centers where commercial activity is reduced. Rural areas show steadier consumption, maintaining household and agricultural energy use.

Sunday, 17:00/ 5 p.m. – Energy use increases again, with a stronger residential focus compared to weekdays. Sunday's evening consumption surpasses Monday's in most areas, reflecting a shift toward leisure and home-based activities. The overall pattern highlights a slower start to the day and a more pronounced evening peak in residential zones.

The spatio-temporal representation of smart meter data refines the understanding of energy consumption by linking daily load curves to spatial distribution, complementing Chapter 2.1's focus on temporal trends. Unlike Chapter 2.1, which identifies peak consumption times, this section on spatio-temporal representation reveals how spatial discrepancies indicate varying land-use functions and mobility dynamics. In this paper, we picked the definitions of the classes to use as examples. For further investigation, both the time intervals

and the class widths must be statistically substantiated. As mentioned, the purpose of this study is to investigate the general suitability of smart meter data for spatial planning. And these insights show how smart meter data uncovers deviations between planned and actual land use, supporting data-driven adjustments in zoning and infrastructure planning.

4 CONCLUSION

This paper has demonstrated that smart meter data provides a valuable resource for spatial and transportation planning by enabling the mapping of spatial structures and identifying consumption patterns that align with or deviate from planned land use. Addressing the research gap, the study has shown how smart meter data extends beyond traditional zoning approaches by offering empirical insights into real-world energy usage in a region.

The literature review set the base of temporal and spatio-temporal data analysis in spatial planning, emphasizing that traditional spatial data sources are insufficient for capturing dynamic land use and mobility behaviors. Smart meter data fills this void by providing high-resolution temporal and spatial insights, which are particularly relevant in assessing the effectiveness of mixed-use planning strategies. The integration of energy consumption patterns with land-use data supports a more responsive and adaptive approach to zoning and infrastructure development.

The temporal analysis of smart meter data revealed daily consumption patterns that correspond to commuting behaviors and urban activity rhythms. It showed how commuter catchment areas exhibit higher energy demand earlier in the day, reflecting outbound mobility trends, while core urban areas experience increased consumption later as workers return home. These findings confirm that energy consumption serves as an indirect but effective indicator of human mobility and land-use functions, offering a complementary perspective to transport planning models.

The spatial-temporal analysis extended these insights by demonstrating how electricity consumption varies not only over time but also across different urban structures. It illustrated how energy use differs between urban, peri-urban, and rural areas, confirming that mixed-use zones exhibit distinct and fluctuating consumption patterns compared to purely residential or commercial areas. The observed spatial heterogeneity reinforces the necessity of integrating real-world data into planning frameworks, ensuring that zoning regulations and infrastructure investments align with actual usage patterns rather than static land-use designations.

Future research should focus on enhancing data aggregation methodologies in order to further improve the applicability of smart data data in spatial planning, such as smart meter data. The aggregation of household-level data at the street or neighborhood level would provide greater spatial granularity, enhancing its utility for land-use decision-making.

A key challenge remains the anonymization and representativeness of smart meter data. Ensuring that datasets maintain privacy while still delivering accurate spatial insights is crucial for their widespread adoption in planning processes. As finer spatial granularity is explored, it is essential to develop robust privacy-preserving techniques. This includes differential privacy and federated learning approaches that allow analysis without compromising individual data. Additionally, compliance with legal frameworks such as GDPR and national data protection laws must be ensured to balance analytical value with ethical considerations. Further investigation is required to validate the extent to which smart meter data accurately reflects mixed-use dynamics and whether additional contextual datasets, such as socioeconomic or mobility data, should be integrated to enhance analytical precision.

To improve the robustness of the findings, additional Smart City data sources should be integrated for validation. These could include mobility data from transport systems, socio-economic indicators, or sensor-based environmental data to cross-reference and contextualize energy consumption patterns. By incorporating these datasets, spatial planning decisions can be more accurately informed, and potential biases in smart meter data can be identified and addressed. Furthermore, a multi-source data validation approach would enhance the predictive capabilities of smart energy analysis, ensuring its relevance for diverse urban and rural contexts.

Beyond data aggregation, future research should also explore advanced aggregating, modeling and predictive analytics to enhance the utility of smart data in spatial planning. Generative AI models provide an

opportunity to aggregate and simulate urban dynamics based on smart data like mobility and energy data, offering scenario-driven approaches rather than static analyses. These models allow planners to explore different zoning, transport, and infrastructure interventions by generating adaptive predictions that account for policy shifts and behavioral changes. The integration of such AI-driven frameworks could significantly improve spatial planning decisions and long-term resilience strategies.

Ultimately, this study underscores the necessity of incorporating smart data into spatial planning to enable data-driven policy adaptations. In an era where urban environments are becoming increasingly dynamic, traditional land-use planning methods must evolve to reflect actual usage patterns rather than relying solely on predefined zoning categories. Particularly in mixed-use developments, where spatial functions overlap and evolve over time, static zoning frameworks are no longer sufficient. A more dynamic, data-driven approach can provide planners with continuous feedback on urban activity patterns, enabling more responsive governance and adaptive infrastructure investments. The future of spatial planning will not be defined solely by regulatory land-use frameworks, but increasingly by data-supported governance that guides human behavior and their spatially effective activities.

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reviewed paper

Spatialisation of Women Street Traders in Cities: Lessons of Newcastle

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1 ABSTRACT

Gender remains an underexplored dimension in urban development, with dominant "right to the city" frameworks often failing to account for gendered experiences. Women street traders play a vital role in urban economies by fostering job creation, enhancing economic activity, and strengthening social networks that contribute to urban vibrancy. Their presence in public spaces enriches social interactions and improves the overall urban environment. However, their spatial practices also expose significant barriers, including regulatory constraints, inadequate infrastructure, accessibility challenges, and insufficient essential services. The allocation of designated market spaces underscores the necessity of creating environments that cater to their unique needs while promoting inclusivity. Analyzing the spatial distribution of women street traders provides key insights into the extent to which cities are inclusive and accessible, aligning with the objectives of the Sustainable Development Goals (SDGs). This study examines the intersection of gender, urban planning, and spatial rights, highlighting the need for more gender-responsive and accessible urban spaces. Using qualitative methods – including interviews with women street traders and municipal officials, alongside observational data from various cities – the research argues that existing urban planning approaches frequently overlook women's specific needs, resulting in their marginalisation in public spaces. The paper concludes by offering policy recommendations and urban design strategies to create equitable and supportive environments for women street traders, contributing to the broader discourse on the "right to the city" and advocating for urban planning that accommodates diverse populations.

Keywords: street trade, Inclusivity, spatialisation, public space, women

2 INTRODUCTION AND BACKGROUND

The informal economy is a vital source of employment and income worldwide, particularly in developing regions, where it constitutes a significant portion of non-agricultural employment (ILO, 2018a). In Sub-Saharan Africa, around 72% of non-agricultural jobs fall within this sector, highlighting its economic significance. Women street traders play a crucial role in this economy, yet they face spatial and regulatory challenges that shape their access to urban spaces and economic opportunities (Roever & Skinner, 2016). In South Africa, the informal sector employed approximately 2.5 million people in 2019, contributing around 8% to the national GDP (Statistics South Africa, 2021). Despite their contributions, women traders frequently encounter constraints such as inadequate infrastructure, legal barriers, and competition that limit their ability to operate effectively.

The spatial dynamics of women street traders are central to achieving gender equality and inclusive urban development, as reflected in the Sustainable Development Goals (SDGs), particularly Goals 5 and 8, which promote gender equity and economic empowerment (UN, 2015). However, urban planning and policy often fail to accommodate the needs of women traders, restricting their ability to access prime trading locations and essential services (Brown et al., 2017). Addressing these challenges is crucial for ensuring sustainable and inclusive urban development that supports women's economic participation and their "right to the city" (Mitullah, 2003).

The concept of spatialisation provides a framework for analyzing how women traders engage with and adapt to urban environments. Spatialization refers to the way social and economic interactions are structured within space, shaping how individuals navigate and experience the urban landscape (Lefebvre, 1991). Women traders' spatial practices reflect broader gendered inequalities in access to resources, trading opportunities, and regulatory protections (McDowell, 1999). They often operate in contested spaces, where they must negotiate their presence amidst legal restrictions and competition (Baud, 2016). Understanding spatialization

not only reveals these challenges but also highlights how women traders contribute to the vibrancy of urban spaces, providing valuable insights for inclusive urban planning (UN-Habitat, 2016).

The paper will explore these themes through the lens of public space, drawing on literature that discusses the role of women in the informal economy, the "right to the city", and the legal frameworks governing street trade. It will present findings on trader locations, access to services, legal obstacles, and competition within markets, ultimately informing policies that foster inclusive and equitable urban spaces for women street traders. The study concludes with recommendations aimed at enhancing women's economic participation, addressing structural inequalities, and advocating for urban policies that recognize the diverse needs of informal traders.

3 LITERATURE REVIEW

3.1 A Spatial Review: Women In the Informal Economy

Research highlights the gendered dimensions of street trading, revealing the impact of social norms on women's experiences (McDowell, 1999). Women traders come from a variety of socio-economic backgrounds and have diverse responsibilities at home and in society, with differing levels of education, marital statuses, and ages. Despite their differences, they confront similar challenges at work, such as poverty, the necessity to support their families, and a lack of alternative job opportunities. Through selling a plate of food, clothes, vegetables, and other essential goods on the streets and providing services on the pavement, these individuals make a living, regardless of the economy's condition. While activities enhance livelihoods and urban vibrancy, women street traders operate in a legal gray area, risking eviction and loss of goods, hindering business profit and investments (Bromley, 2000; Roy, 2011). Discrimination and harassment in public spaces are order of the day, which further marginalises them (Amnesty International, 2022). Even though this is, statistics reveal that high rates of informal employment serve as a survival strategy for marginalised populations, with 92% of women in developing countries engaged in informal work (Bonnet & Chen, 2019; World Bank, 2023). It is important to recognise street trade in cities as a significant urban issue, as this acknowledgment can offer new insights into the changing norms of urban life. If anything, the above is proof that the informal sector carries the potential and ability to sustain livelihoods, provide employment, and alleviate poverty. A turn in perspective and government collaboration, local economic development, and social protection for women traders may be fostered. It is essential to advocate for the inclusion of marginalised groups in planning and decision-making processes to achieve sustainable development. Development plans should be designed to create regulations and policies that are relevant to those who engage in street trade.

3.2 The "Right to The City"

Cities have historically been designed by men, for men, reinforcing spatial and economic exclusion, particularly for Black women. In the South African context, urban spaces were initially structured to serve the elite, predominantly white populations, with infrastructure and resources distributed along racial and gendered lines (Parnell & Pieterse, 2014). Apartheid-era policies further marginalized Black women, restricting their access to urban opportunities (Miraftab, 2009). Even as industrialization enabled Black men to enter urban economies, planning frameworks continued to prioritize male-centric labour markets, overlooking the spatial needs of women (Turok, 2016). Consequently, Black women continue to grapple with urban environments that do not facilitate their full participation, reflecting persistent inequities in access, infrastructure, and spatial design.

Initially articulated by Lefebvre (1968), the "right to the city" serves as a framework for understanding urban social justice and inclusivity. It asserts that all urban inhabitants should participate in shaping and using urban spaces, emphasizing access to resources and decision-making (Harvey, 2008). Challenges in securing trading spaces arise from restrictive by-laws, competition, and limited access to essential services (Skinner, 2018; SERI & SALGA, 2018). For women, the "right to the city" is particularly significant, as their experiences are often influenced by gendered power dynamics and social inequalities (McDowell, 1999). Their access to urban spaces is frequently restricted by safety concerns and social norms (Matrix, 1985). In this context "the right to the city" entails not only the right to occupy urban spaces but also the right to influence spatial planning and design that meets the needs of women as well. This is especially relevant for women street traders, whose livelihoods rely on public space (Baud, 2016). The framework of the right to

alludes the need to recognise the needs of women's contributions to the urban economy and to include them in planning processes. It advocates for the creation of safe and supportive urban spaces for women's economic activities (UN-Habitat, 2016). Claiming of "right to the city," women street traders can challenge exclusionary practices and seek recognition for their essential role in shaping urban life (Roy, 2011).

3.3 Spatial Distribution and Access

Street trading serves as a crucial livelihood strategy for many urban residents, particularly marginalized groups such as women, migrants, and the unemployed (Huang et al., 2018). It provides a flexible and accessible source of income, especially for individuals with limited formal education or employment opportunities. Mitullah's (2004) study on African street trade highlights that the sector is predominantly female-dominated, with fewer men and underage children involved. Traders often travel from various parts of the city to the CBD, where consumer demand is concentrated. Due to high transportation costs, many choose to live within walking distance of their trading sites or operate close to their residential areas.

Access to central business districts is typically straightforward; however, legally securing trading sites and permits poses significant challenges for many street traders. Navigating street trading or trading by-laws can be perplexing, and obtaining permits from municipal authorities is often difficult, leaving numerous street traders vulnerable to evictions, harassment, and confiscation of goods (Ndaba & Reddy, 2024). Municipalities worldwide implement various strategies to regulate informal trading in public spaces, with permitting systems being particularly prevalent. Traders are generally required to acquire licenses to operate in designated areas, specifying locations, operating hours, and authorised merchandise. In South Africa, national legislation such as the Business Act provides a framework, but individual municipalities develop their own policies to balance the economic contributions of informal traders with effective public space management. Durban, a major city in KwaZulu-Natal, exemplifies these complexities; its substantial informal economy features numerous street traders. The city employs a licensing system for traders, yet accessing public spaces remains challenging. Globally, approaches range from strict permitting to more flexible policies. Highlighting participatory planning, collaboration with trader organisations, and integrating technology can enhance the inclusivity and sustainability of urban environments.

3.4 Arrangement and Services

While municipalities often designate specific areas for trading, other dynamics shape how traders, particularly women, arrange themselves in public spaces. Street traders strategically select their locations based on factors such as pedestrian traffic, proximity to essential amenities, competition, and visibility (Bromley et al., 2018). High-foot-traffic areas like transport hubs and commercial streets enhance their customer base, while access to water and sanitation is crucial for those selling food or perishables. Traders often cluster together to attract more customers; however, some may choose to locate away from competitors to secure niche markets (Brown et al., 2010). For women street traders, additional considerations significantly influence their spatial distribution; they prioritise safety and security, often seeking well-lit areas with visible policing and forming support networks (Cross, 2016). Cultural norms and societal expectations can restrict women's mobility, confining them to specific trading zones (Sutherland, 2015). The spatial distribution of street traders can reflect a complex interplay of economic, social, and cultural factors.

3.5 Competition

Competition in the informal sector, particularly in street trading, is influenced by various factors, including gender, resource access, and spatial dynamics. Women street traders encounter unique challenges within this landscape (Skinner, 2013). The dynamics of competition significantly affect trading practices and pricing strategies (Bromley, 2000). Traders often lower their prices to attract customers (Chant, 2006). Space also plays a vital role, as prime locations are frequently contested (Sampson et al., 2002), making it particularly difficult for women who may have limited access to resources and networks (Mitra, 2015). Furthermore, the presence of immigrant traders adds another layer of complexity to the competitive environment (Crush & Ramachandran, 2009). Tensions can emerge between local and immigrant traders, often exacerbated by xenophobic sentiments (Landau, 2012). These tensions may lead to disputes over space allocation, accusations of unfair pricing practices, and, in some cases, acts of violence. Thus, understanding the interplay of price, space, and the involvement of immigrant traders is crucial for analyzing the competitive challenges faced by women street traders on Terminus Street.

4 METHODOLOGY

This study examines the experiences and spatial navigation of women street traders along Terminus Street in Newcastle, KwaZulu-Natal, using a qualitative case study approach with a phenomenological lens. The research seeks to understand how these women navigate the urban environment, specifically focusing on their access to services, legal obstacles, and competition within market spaces. Data collection was conducted through a combination of methods to ensure a comprehensive understanding of the research context. Mapping street trader locations involved direct observation, and GIS visualisation was used to understand the spatial distribution of traders and operational spaces along Terminus Street. In-person semi-structured interviews were conducted with (n=18) women traders and took place at their trading locations, including roadside areas, containers, self-made shelters, and trading mortar houses. This was to allow for flexibility and in-depth exploration of the participants' experiences. Traders' questions revolved around the accessibility of services, resources, and public facilities in the area. They also expressed concerns about safety and security, as well as various challenges associated with public spaces in cities. Additionally, they sought to understand their relations with local authorities and to discuss interactions with other traders to uncover conflicts and competition. Field observations were conducted alongside the trader interviews to contextualise the interview data and capture the lived experiences of the traders within their operational environment. Online semi-structured interviews were conducted via TEAMS with (n=2) officials from the Department of Local Economic Development and the Department of Development Planning and Housing. These interviews lasted approximately 45 minutes to 1 hour. Legal obstacles were further investigated through the analysis of relevant municipal documents, complementing the interview data. Purposive sampling was used to select participants who could provide rich and diverse perspectives on the topic, including local authorities. Qualitative data from interviews and observations were analysed using thematic analysis to identify recurring patterns and themes related to the traders' experiences and spatial navigation.

Ethical considerations included obtaining consent from all participants before the interviews and confidentiality and anonymity were maintained throughout the research process. The study's narrow geographic focus on Terminus Street may limit the generalisability of the findings.

5 RESULTS AND DISCUSSIONS

Women street traders along Terminus Street in Newcastle, South Africa, navigate complex spatial, economic, and regulatory challenges within the informal economy. The study, based on interviews with municipal officials and eighteen women traders, reveals that women dominate this sector out of necessity rather than aspiration, often serving as primary breadwinners due to poverty and unemployment (Ngcobo et al., 2022; van Wyk & van Gaalen, 2021). This underscores the role of informal trade as a vital economic survival strategy for women who lack access to formal employment opportunities.

Fig. 1: Terminus Street Aerial View. Source: Author (2025)

This map shows the spatial distribution and visual representation of women operating as street traders. Further shows the dynamic existence of informal activities adjacent to formal, municipal-approved trading areas (storages and municipal shelters).

A key finding of this study is the influence of municipal permit systems on women traders' spatial access. Women primarily engage in fixed-location businesses, selling warm food "Iplayiti", which necessitates compliance with formal licensing processes. This contrasts with male traders, who often engage in mobile trade and frequently bypass permit requirements. However, despite adhering to regulations, women traders face inconsistencies in policy enforcement, including third-party permit rentals and inflated fees. These discrepancies highlight systemic regulatory shortcomings that contribute to the traders' economic vulnerability.

Strategic location choices play a crucial role in sustaining women's businesses. Women traders position themselves in high-traffic areas such as the Newcastle Taxi Rank and commercial centers to optimize visibility and customer access. Their choice of trading spaces is also influenced by proximity to essential services, yet access remains inconsistent. Many traders rely on informal and costly arrangements for services like sanitation and storage, revealing infrastructural deficiencies that exacerbate their economic insecurity.

The lack of gender considerations within Newcastle's urban planning framework further compounds these challenges. Poor infrastructure, inadequate sanitation, and minimal municipal intervention create an environment that undermines the sustainability of women's businesses. Additionally, competition from undocumented foreign traders intensifies market pressures, limiting economic opportunities for local women traders. Despite these obstacles, informal protection networks – comprising taxi drivers and the homeless – offer a degree of security, fostering a sense of street community and "ubuntu." This paradoxical reliance on informal safety mechanisms highlights the failure of formal urban governance to adequately support women traders. From a broader perspective, the study reinforces the significance of the informal economy in South Africa.

Applying a "Right to the City" framework to these findings emphasizes the need for inclusive urban policies that formally recognize and support informal traders. Enhancing infrastructure, security, and economic support would address systemic inequalities and promote the sustainable integration of women street traders into urban spaces. Municipal authorities must implement gender-responsive planning strategies that acknowledge the unique challenges women traders face, ensuring they have equitable access to resources and economic opportunities. By fostering a more inclusive urban economy, cities can contribute to reducing poverty and empowering women within the informal sector.

6 CONCLUSION AND LESSONS

The study emphasises the essential role of women street traders in Newcastle's informal economy, highlighting their reliance on this sector for financial survival. It identifies several challenges faced by these traders, including regulatory inconsistencies, inadequate infrastructure, and increasing economic insecurity, which collectively reveal systemic deficiencies in urban governance and planning. The exclusion of women traders from formal planning processes perpetuates inequalities, further limiting their access to crucial resources and economic opportunities.

Women engage in informal trade primarily out of necessity, underscoring the urgent need for economic inclusion. The inconsistencies in municipal regulations and enforcement create financial strain, hindering their ability to operate sustainably. Additionally, poor infrastructure, particularly insufficient sanitation and storage, poses significant risks to the safety and well-being of these traders. Informal protection networks play a critical role in providing security in the absence of formal municipal support. Furthermore, urban planning frameworks that neglect gender considerations contribute to systemic inequalities regarding access to public spaces.

To address these challenges, municipal authorities ought to develop gender-responsive urban policies that recognise and support informal traders as vital contributors to the economy. Necessary investments in sanitation, storage facilities, and designated trading spaces would enhance the sustainability of women traders. Establishing clear and consistent permit systems is essential to prevent financial exploitation and ensure equitable access to trading locations. Additionally, broadening financial assistance programs, skill development initiatives, and access to microfinance will better support women in the informal sector. For a

safer working environment, local authorities must implement formal safety measures that reduce reliance on informal protection networks. Lastly, it is crucial to actively include women traders in city planning discussions to ensure that their needs and challenges are adequately addressed in policy formulations.

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reviewed paper

SSSEIC – StreetScapes for a Social-Ecological Inclusive City: A Model for the Interdisciplinary Consideration of Streetscapes and Public Spaces

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1 ABSTRACT

The multiple crisis that today's metropolises and cities are facing, present an additional challenge when it comes to maintaining and improving the quality of urban public space in order to subsequently ensure living standards and quality of life. The conditions determining the state of public space represent an interwoven network of mutually dependent factors. Due to this complexity they cannot be treated by one discipline alone, rather, they require a strong inter- and transdisciplinary approach in order to ultimately produce future-fit urban spaces – ones that are ecological, social and inclusive (for human and not-human city-users).

In contrast to work on the building scale – where collaboration between architects and specialist planners (with or without BIM tools) is common practice – interdisciplinary exchange and coproduction at the urban and regional planning scale are not yet standard. Although, planning teams with experts from the fields of traffic or landscape design are also common there, and cooperative processes or participatory workshops are sometimes carried out, shifting the focus to the crucial street/block/neighbourhood scale brings new complexities and challenges, as well as a multitude of different actors and stakeholders. What is missing here are co-operative instruments and methods that, on the one hand, enable inter- and transdisciplinary urban planning and, on the other hand, bundle all the spatial qualities of public space in a holistic and systemic way. The disciplines relevant to such co-operation are many and varied, ranging from practitioners such as urban planners, architects, landscape architects, traffic planners, road engineers, etc., to researchers in the same disciplines, also including sociologists, material sciences, etc. Finally, the executive and administrative units must also be taken into account: the people responsible for the furnishing, cleaning, maintaining and preserving public spaces have extensive knowledge in their field, which is of fundamental relevance for any future-oriented planning.

This paper describes the design and development of the SSSEIC tool; a tool that encompasses two models in different spheres: on the one hand, aiming at a theoretical concept for capturing relevant qualities and, on the other hand, meaning a computer-based 3D model. The theoretical concept seeks to capture all the parameters that determine the quality of streetscapes, including, obviously, the parameters of the street space itself, but also those of the ground below and the adjacent buildings. To this end, interviews were conducted with experts from the fields of practice, research and administration, and a cooperative workshop was also held. The resulting concept represents a new type of holistic and systemic recording of qualities in the street space, including their interrelations and connections – and consequently it provides the basis for creating a 3D model that visualizes those qualities and parameters in an actual street space. The model should ultimately show/visualise/illustrate the impact and correlations of parameters and thus provide a possible planning basis for future inter- and transdisciplinary co-operation in the sense of a city information model (CIM).

Keywords: Streetscape, Public Space, CIM, Inter- and transdisciplinary, 3D Model

2 INTRODUCTION

Science and everyday life equally show and confirm the overall importance of urban streets. This tightly woven network spans the entire city and represents the largest share of unbuilt urban space; its surface area exceeds that of other public spaces such as parks or squares. While – over the last century – legislative and urban planning did consider streets purely as traffic spaces, it can no longer be denied that they indeed do represent much more than that: (not only) through their sidewalks they provide public space that can be easily accessed by anyone directly from their front door, the most immediate public space and the most important area for urban interaction, "a place where people can meet and move among, or simply observe,

each other relatively freely […] the site of interactive integration between minorities and majorities in a diversified society." (Psenner 2015, 583-584). They are also essential for a wide range of logistical infrastructures and processes. While waste collection, emergency services, and deliveries are in the direct field of vision, another supply network runs hidden below the street level and supplies the city with drinking water, sewage, electricity, gas and internet.

The main focus of public attention and research efforts is usually on main streets. Since they are part of important traffic routes or central shopping streets, overarching interests are proclaimed, which are also vehemently advocated by the respective stakeholders. By comparison, less attention is paid to secondary streets. However, this is a fundamental deficiency, since they make up the majority of urban street space. (Psenner/Tobisch 2023) This means that they are also essential to the city's ability to adapt to challenges such as climate change. By being prepared for rising overall temperatures and an increase in weather extremes like heat, draught and heavy rain, they can not only help to mitigate the impact on the immediate residents and street users, but also contribute to overarching issues such as reducing the urban heat island effect. (Hagen et al. 2014; Loibl et al. 202; Bügelmayer-Blaschek/Züger/Tötzer 2025) Purely on the basis of the number of secondary streets, it is clear, these streets are also where the majority of people live and therefore, where actual urban life takes place. (Tobisch/Psenner 2021) The way they are designed determines form, extend and intensity of urban life: are they purely a traffic area, or do they offer people the opportunity for a pleasant stay? Do they support socialising and participation? These usage options are enabled and promoted by certain qualities in the streetscape. The quality of life in cities is therefore directly affected by the quality of secondary streets.

2.1 SSSEIC – Developing a conceptual Framework for streets

A large number of regulations and associated processes that shape our cities to this day were mostly developed at the end of the 19th and beginning of the 20th century. The panacea of that time was to expand the city and functionally separate it. Today, however, there is a general consensus, that a city must be both mixed and compact in order to be sustainable and liveable. (Psenner 2012, Loeschenbrand/Tobisch/Psenner 2022, Peer/Psenner 2024)

The urban parterre (Stadtparterre) which consists of the streets, the ground floor zone of the adjacent buildings and the courtyards is the most relevant zone in the city to ensure an appropriate lifestyle for all its inhabitants and visitors. (Psenner 2023) The approach of this study is based on the Urban Parterre modelling (UPM) method, that provides a 3D modelled approach to viewing and evaluating the ground floor zone. (Psenner 2019 & 2020) Naturally, street space itself plays a unique role within the urban parterre, since, in addition to the overall plot arrangement, it demonstrates structural permanence – the framework of a city that endures for centuries – and serves as a location where public authorities and city administration can take immediate influence. (Kretz/Kueng 2016; Krusche/Roost 2010) Keeping the consideration of the neighbouring spaces and of course the interfaces between them (Zoller 2014), this study puts a special focus on street spaces themselves and examines them in detail.

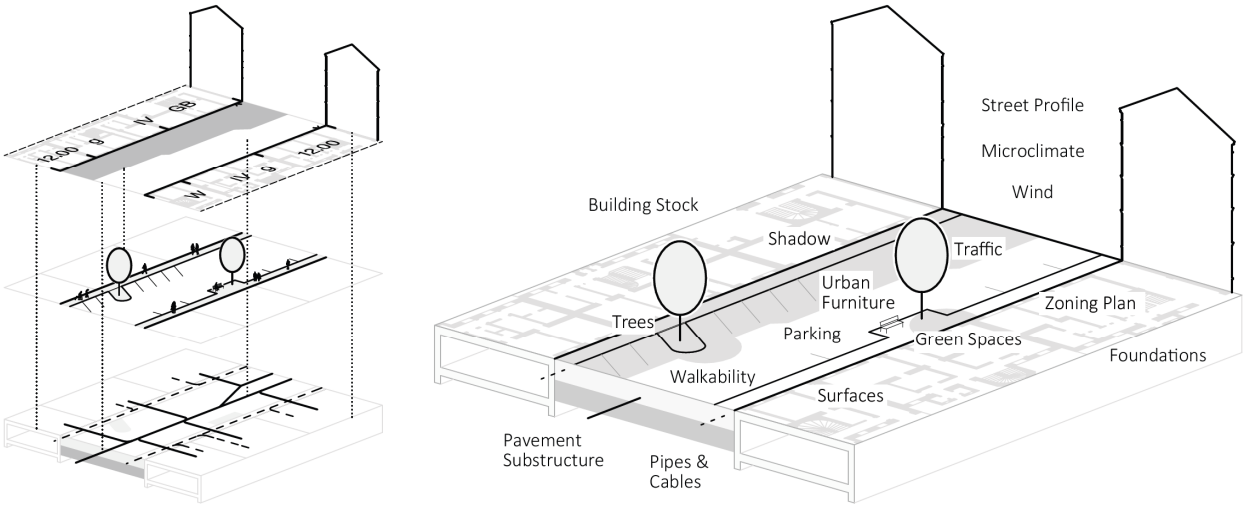

Fig. 1: The superimposition of layers with a variety of topics enables the holistic capturing and representation of street space. (Loeschenbrand, Tobisch, Psenner 2024)

To date, streets have been considered on the bases of their uses – either real life predominant uses or planned uses that never came to fruition. Categories like commercial street, main road and residential street are based on land use, and therefore on urban development parameters that must be considered outdated. (Loeschenbrand/Tobisch/Psenner 2023) SSSEIC (StreetScapes for a Social-Ecological Inclusive City) introduces a framework for a comprehensive understanding of streets, that includes a compilation of relevant criteria, that are spatial, urban development, traffic, climate-relevant and sociographic in nature (see fig. 1). This allows for a detailed, qualitative analysis of streets, while keeping the larger context and overarching aspects affecting the neighbourhood or the entire city in mind.

2.2 Interdisciplinary Work & CIM

Given the complexity of the space that is the street, it is clear that it cannot be addressed and planned by a single profession. The city of Vienna's municipal department MA18 (Magistratsabteilung 18) has made an effort to compile a list of all departments, agencies and services that currently engage with the street space in some capacity. (see fig. 2) It includes a total of 23 departments of the city, as well as the municipal district offices, the district representations, various coordination units, the chambers of commerce and labour, and federal authorities such as the police. (Schlager et al. 2018)

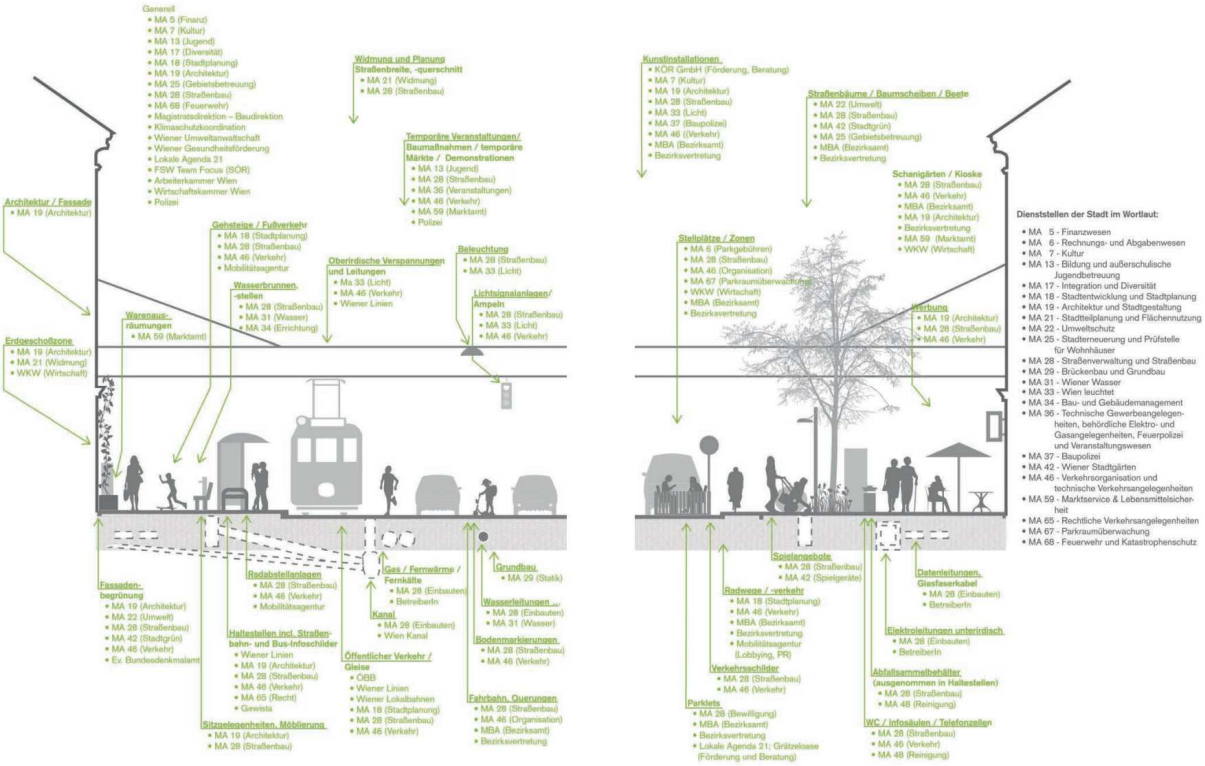

Fig. 2: "Who plans and manages public space in Vienna?" Illustration of all public authorities involved in public space, compiled by the City Administration (Schlager et al. 2018)

It is essential to recognize that these are only the involved parties from the public sector; there are many additional players, including planners from a variety of professions, and not least entrepreneurs, residents and passers-by. Considering the sheer number of the players, the question arises as to how the involvement of the individual parties in this public space is actually organised. Nowadays, there is little opportunity for multidisciplinary collaboration and co-creation since stakeholders are assigned a certain section of the street area and plan sequentially. Working groups are occasionally established to facilitate collaboration between different municipal departments, however they are usually limited to new urban development areas. Recently, participatory approaches that involve the public have also been increasingly implemented. (Brosenbauer et al. 2017) These are generally carried out by an external agency contracted by the city, inviting residents, business owners and street users to take part in the first steps of a transformation process by compiling their needs and preferences for the area in question in a guided process.[1] However, both of

[1] The participatory redesign process for the Gumpendorfer Strasse is a recent example in Vienna; the City of Vienna offers details on this and other public participation initiatives on its participation portal (mitgestalten.wien.gv.at).

those approaches only focus on a small group of the stakeholders that is only involved in a limited part of the entire process. The adequate tools for this kind of transdisciplinary work are also lacking: While Building Information Modelling (BIM) – that enables the direct collaboration between architects and specialist planners and even allows clients to participate in monitoring the process – is standard practise on an architectural scale, there is no shared standard at a larger scale, i.e. at the urban planning level.

Increasing transdisciplinarity and collaboration as well as an underlying database on which the 3D model is based (see 3.2) are reasons why the SSSEIC-tool is considered a City Information Model (CIM). Comparable to BIM, CIM operates on an urban scale and was introduced by Lachmi Khemlani in 2007. In recent years, the concept has become established in scientific urban discourse and has also increasingly found its way into urban design. Xu et al. describe CIM as 'a three-dimensional (3D) city model based on city information data with a multidisciplinary collaborative framework' (2021:1). Stojanovski (2013) sees CIM not only as a conceptual model, but also as an opportunity to reflect on urban theories, approaches and tools from different disciplines in an urban context.

A widely used approach, which was also central to early works, is the view of CIM as a merging and integration of BIM and GIS data. Xu et al (2014), for example, outlined early frameworks for CIM for dealing with BIM and GIS data sets. More recent CIM related papers illustrate technological developments using laser scans, point clouds, AI and VPL (La Russa et al., 2023), link CIM with smart cities, urban digital twins (Cureton/Harley, 2023), see CIM as a way to promote sustainable cities (Mohamed, 2023; Salles et al., 2023; Soltanifard et al., 2024) or identify ways to improve planning processes or to analyse environmental pollution and meteorological issues (Szeligova et al., 2024). A dynamic field of research in which different disciplines and approaches are adopting the CIM concept. Omrany et al. (2023) defined nine application areas for CIM: Natural disaster management; Urban building energy modelling (UBEM), Urban facility management, Urban infrastructure management, Land administration systems, Improvement of urban microclimates, From smart cities to digit twin of cities: the key role of CIM, Improvement of social engagement and Urban landscaping design. A clear definition of CIM did not exist a few years ago (Müller et al., 2016) and, according to the authors' current knowledge, does not exist today. Therefore, CIM can be regarded as umbrella term for intelligent city models.

The SSSEIC tool will introduce a new form of CIM that involves linking street space qualities with a three-dimensional city model at a micro-urban level. In addition to the complex core task of visualizing all the parameters influencing the street space, the aim is to identify synergies and correlations between individual qualities. Furthermore, the interaction between the street space qualities and the built environment should also be revealed. In other words, from a superior level, an understanding should be developed of which urban patterns and building typologies determine which qualities in the public street space.

In addition to the three-dimensional modelling of factors influencing actual urban street spaces, the project's further aim at a meta-level is to generate insights for consideration at the city-wide level.

2.3 Research Question and Methods

2.3.1 Research Question

Considering the complex nature of both the subject matter of the street itself and the processes surrounding its representation and planning in a transdisciplinary setting, the research question is divided into two parts:

(1) What are the relevant qualities in the street space from the perspective of stakeholders from different professional backgrounds, and what are the synergies and correlations between them?

(2) How can the complex space of the street with all of its characteristics be represented in a comprehensive theoretical concept, and how can this be converted into a CIM (computer-based 3D model with an underlying database) that can be used in collaborative processes?

2.3.2 Methods

The methods used to approach the research questions above can also be separated into two areas: the collection of qualities of streetscapes and the development of a theoretical concept for the holistic representation of the space. This will subsequently enable the creation of a comprehensive computer-based 3D model for analyses and collaborative design processes.

Interviews

For a comprehensive collection of qualities covering a wide variety of perspectives on streets, interviews with professionals from practise, research and administration with different disciplinary backgrounds were held. The questions were open-ended and process-oriented, revolving around the topics of historical development, adaptation of the status quo and novel methods (see table 1). The aim was to gain a comprehensive understanding of the elements and aspects of street space that are relevant to the respective profession and the associated general perception of street space. Tangible qualities and their possible incorporation into a computer-based 3D model were only enquired towards the end of the conversations to not limit the interviewees in terms of their expectations with regard to the feasibility object-orientated representability of qualities.

Interview Questions		
1. What are the inherent logics of the field in regards to street space and its planning? Historical, current and future aspects.	2. How are existing structures approached? What restrictions are there in terms of adaptability?	3. What are the interrelations of the respective field with other, city-wide systems?
4. What large-scale mishaps or planning errors have there been in the past, and do they still have an impact?	5. What standards are there in terms of planning? What approximations and assumptions can be used? What are the specifications?	6. What new approaches are there, and what are the corresponding planning paradigms? Are there positive/negative experiences?
7. What prerequisites are necessary and where is potential for conflict?	8. What conflicts of use in public space are relevant, how are they currently addressed?	9. What factors should be considered in terms of implementation and costs?
10. Life cycles of infrastructure: what are the renewal cycles and do they represent an opportunity for redevelopment?	11. Maintenance of infrastructure components and other street space elements. How is it performed, are is there anything to be considered?	12. Which of the aspects from your field do you think can be implemented in a 3D model? (spatial or quantifiable)
13. Literature, sources, tools... on the topic of the research project?	14. Additional information and tipps (for interview partners)	

Table 1: Interview Questions

In addition to the qualities that were explicitly mentioned by the interviewees, the qualities that were implied in the interview but not stated outright were also identified. The recommended projects and literature were also analysed for further aspects.

Workshop

A workshop was held in which the streetscape of 2040 was envisioned in a collaborative setting. While further qualities were also collected during the workshop, the focus was on the cooperation between the participants. Participants were asked to anonymously write down qualities from their field that they considered relevant in the street space in 2024 on individual cards. These were then shuffled in the middle of the table and drawn in turns. In this way, the participants received qualities that were not related to their own field of expertise. The qualities were then drawn on a prepared poster of an empty street space with adjacent buildings indicated, creating the impression that the street was part of an existing urban context. Together, the participants then considered positive (+), potentially conflicting (-) and neutral (o) aspects of these qualities.

This setting required the participants to reflect on qualities with which they were less familiar, while also considering different aspects of qualities and interrelations with other qualities. The step-by-step addition of elements by each participant resulted in a jointly negotiated vision of the street space. Throughout the workshop, the interactions and cooperation between the participants from different fields, as well as the synergies and correlations between the qualities, were observed and recorded.

Translation into a theoretical concept

Once the street space qualities had been collected, they were clustered according to different perspectives, for example according to the profession they concern, whether they can be represented in a computer-based 3D model or according to their physical location in the street space. In this way, different possibilities of structuring the qualities were tested in order to subsequently develop a holistic theoretical concept that is

able to represent all relevant qualities and their linkages. The aim is to enable the mapping and ultimately the collaborative planning of street space. The functionality and comprehensiveness of the concept was then evaluated in a further step by constructing a computer-based 3D model of segment of a research street.

3 RESULTS

3.1 Collection of Qualities – Interviews and Workshop

A total of 20 individual interviews were conducted with 22 individuals. They represented the fields of urban planning and urban development, zoning, architecture, landscape architecture, gender sensitive planning, sociology, traffic and mobility planning, urban climate, sustainability and environmental protection, urban soundscapes, street lighting, street construction, canalization, street cleaning and winter maintenance, waste collection, emergency services and land surveying. It is not possible to provide a precise distinction between the areas of practice, research and administration, as some interviewees work in both research and the private sector, and some departments in the public sector focus on either implementation or administration. However, it can be stated that 13 of the interviewees are employed by the municipality of Vienna in some capacity, while the remaining 9 people work in research and/or practice outside of the city administration.

The subsequent workshop was attended by a total of 11 people who worked in two groups. The groups were made up of 5 and 6 people respectively, with the aim of including as many different areas of expertise and different fields of work in each group as possible. This ensured that there were no redundancies in the professions and that the groups contained people from practice, administration and research in equal measure. Due to scheduling issues, the original plan to have the same individuals who had been interviewed collaborate during the workshops was only partially feasible. Six of the participants were present at both events, but as the five new participants were direct colleagues of the interviewees (and were sent by them as replacements) no entirely new areas of expertise were added at this stage.

In the workshop a total of 38 unique characteristics of streets were named by participants. A significant number of aspects were mentioned more than once, which demonstrates that there is considerable overlap in the professions in terms of relevant qualities. This was further confirmed in the discussions between the participants. There were significant differences in the tangibility, or immediacy with which these characteristics could be represented by physical objects. They ranged from aspects that could be represented by a single object (e.g. a bench), to those that encompass multiple objects (e.g. continuous shade), to those that could not be represented in an object-related way at all (e.g. diverse user groups). This suggests the need to define proxy parameters for certain concepts. For example, the presence of tangible aspects such as shade, planting and seating could be used as an approximation for a high quality of stay.

3.2 Development of the theoretical concept

The theoretical concept represents the translation and visualisation of the numerous individual qualities and parameters into one holistic vessel. In order to facilitate an understanding of the street, it is necessary to consider both the individual elements as well as their position within the system.

After a preliminary analysis, it was found that the parameters fell into three distinct clusters: Meta parameters that describe the context for the entire street. Modelling parameters that can be represented by objects in a computer-based 3D model and their respective attributes specified in the object properties. And evaluation parameters which have an effect on the qualities perceived but cannot be easily represented by specific objects or even be associated with a specific the street segment. In order to be able to take them into account, they are therefore represented in the underlying database of the model.

3.2.1 Meta Parameters

The first category of parameters provides the context for a finer grained analysis and can be recorded on a street segment basis. It includes aspects such as street orientation, proportions, linearity and gradient, the proximity to green spaces and the number of residents, but also legal aspects such as speed limits and access restrictions.

3.2.2 Modelling Parameters

The object-related modelling parameters can be divided into different spheres (see fig. 3): The street level, i.e. the surfaces of the street space and all its uses. The street furnishing, which includes all objects that are located in the public space above the street level. The underground, which includes all objects that are located below the street level. And the building level, which represents both the interfaces (i.e. the facades) and the spaces and uses of the buildings beyond. Ecology is treated as a separate sphere because its many interconnected aspects make it challenging to capture it within a single spatial category. Due to its relevance for the urban climate, it is also of significant importance to the future development of street space and is therefore given particular emphasis.

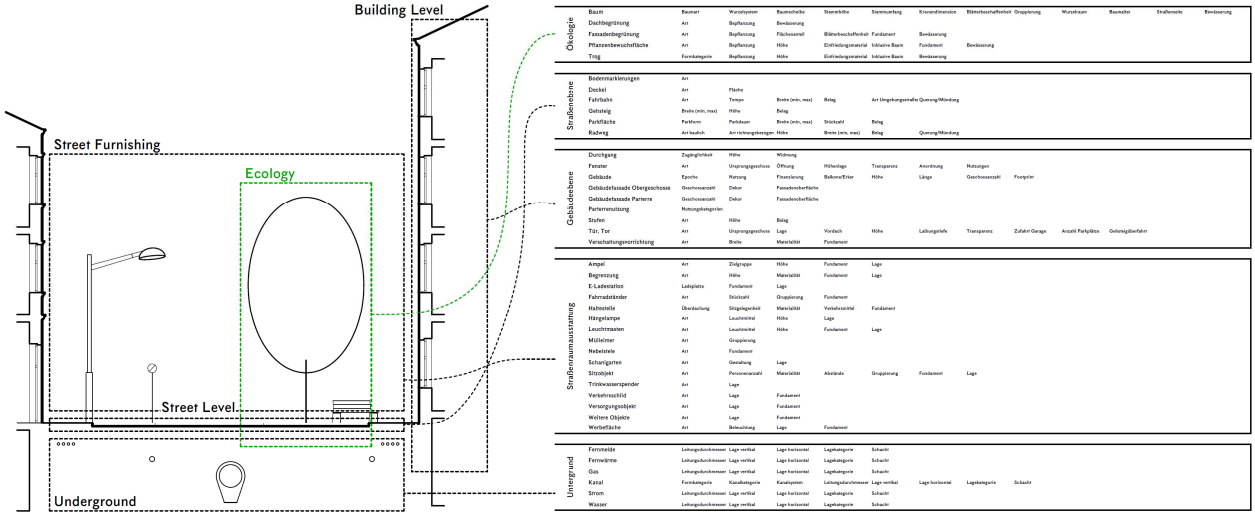

Fig. 3: Street spaces can be divided into different spheres of intervention in order to facilitate collaborative processes (Loeschenbrand, Tobisch, Psenner 2024)

The physical objects identified within the street space were described by modelling parameters in the categories of types, dimensions, and surface characteristics. Using a tree as an example, the parameters in the category of types include tree species, deep or shallow rooting, the tree pit and tree age; the dimensions include tree size, trunk height, trunk circumference and crown diameter; and the surface characteristics relate to the leaf character and size. Each of these parameters has been equipped with a list of up to 10 options (based on their occurrence in Vienna) e.g. the most common street tree species or the crown dimensions from 1m to >10m. This allows for a straightforward and, above all, standardised recording of the street space, which ensures subsequent evaluability.

While this concept was already capable of enabling the accuratele recording of the physical characteristics of street spaces in theory, the important semantic level was still missing from the theoretical concept. There was not yet an understanding of the relevant interrelations and utilizations of the parameters.

The interviews and workshop confirmed the previously held assumption that many real-life qualities are only achieved through a combination of elements. For example, in terms of the street climate, it is not only the presence, but the continuity of the tree shade that is relevant. Therefore, it cannot be assumed that recording individual trees is sufficient to fully capture this quality – a tree needs to be put in context with its neighbouring trees. Hence not only the distance to the nearest tree is taken into account, but also the number of trees in a group. Again, the statements of the experts interviewed were used to identify these cases. The category context was added and equally equipped with options.

3.2.3 Evaluation Parameters

Evaluation parameters are the least constrictive category; their parameters are characterized by the fact that the data must be considered in a much broader context and cannot be linked to specific objects or even the street segment. It includes aspects such as wind, microclimate, acoustics, traffic, public transport, air pollution, C02 values, life cycle analysis and social environment analysis. In most cases, the data can either be measured on site or recorded on the basis of evaluations or simulations. Although this data cannot be isolated at the fine-grained scale of the other parameter categories – due to the large number of interrelations

and exogenous influences – it is nevertheless of equal importance, especially with regard to the potential for adaptation of street spaces.

As a result of the interviews and the collaborative workshop, a total of 10 meta parameters, 20 evaluation parameters and 227 modelling parameters (relating to 42 distinct objects) were identified.

3.3 Proof of Concept – Creating a computer-based 3D model

In a next step the theoretical concept was implemented in a computer-based 3D model. The model was based on a segment of a street in the 16th district of Vienna, an area developed during the Gründerzeit. The block divisions, street widths and building structure are all characteristic of this area. This enabled the direct transfer and incorporation of the extensive knowledge of these structures from the UPM project, which focused exclusively on structures from this period.

The basis of the computer-based 3D model was created using publicly available, open government data (OGD)[2], using the terrain model (Geländemodell Dreiecksvermaschung) as a base, the roof model (Generalisiertes Dachmodell LOD2.1) for the 3D building shapes, the records of the cables and pipes (Zentrales Leitungskataster/Digitales Kanal Informationssystem) and the tree cadastre (Baumkataster). The 2D city plan (Mehrzweckkarte) was also used for the spatial distribution of street space. The city plan was also used to add more detailed information, such as the height of the kerb and the position of manhole covers.

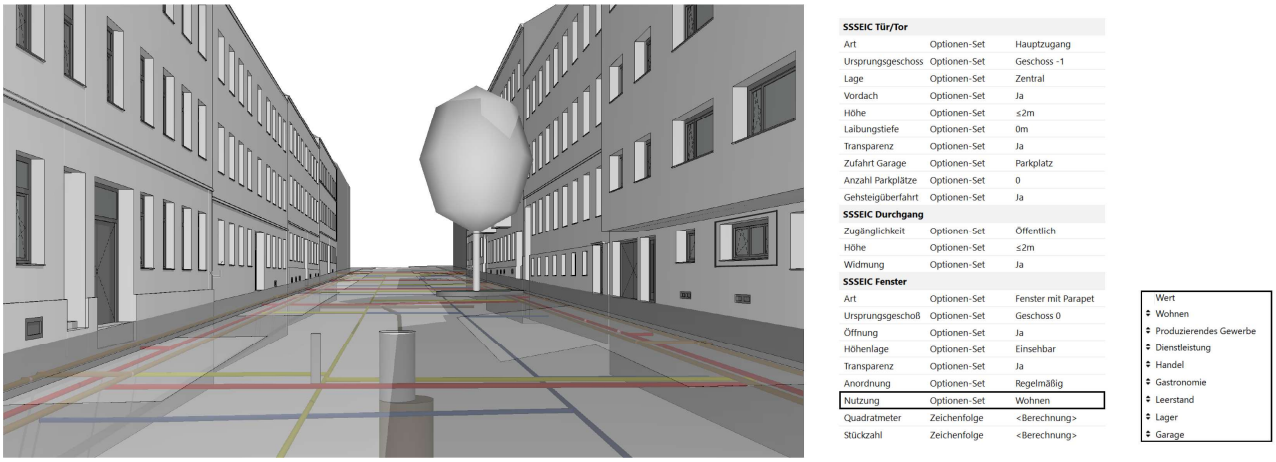

Fig. 4: View of the research street in the computer-based 3D model, featuring parameters and corresponding list of options using the example of a window (Loeschenbrand, Tobisch, Psenner 2024)

This very rough model (see fig. 4) was then enhanced with manually collected data. Analogue plans of all the buildings adjacent to the street, obtained from the Building Department (MA37) facilitated the three-dimensional construction of the facades and, on the ground floor, the spatial structures behind them. In addition, the public space was meticulously recorded on site, and street furniture such as lighting, street signs, waste bins and power distribution boxes were complemented. In accordance with the theoretical concept, all elements of the 3D model were equipped with their corresponding parameters and lists of options to be selected.

The computer-based 3D model represents a proof of concept, that allows the input of the relevant data for all parameters identified to date. Currently, only the parameters that could be collected and recorded by the authors have been entered for the research street. Further research and collaboration with interdisciplinary partners is needed to extend the model to include all the known parameters.

[2] Geländemodell Dreiecksvermaschung Wien (https://www.data.gv.at/katalog/en/dataset/bb86970f-3cef-4f9a-a79b-ff277ea925c8), Generalisiertes Dachmodell (LOD2.1) Wien (https://www.data.gv.at/katalog/dataset/86d88cae-ad97-4476-bae5-73488a12776d), Zentrales Leitungskataster (https://www.wien.gv.at/verkehr/strassen/leitungskataster/), Digitales Kanal Informationssystem (https://kanis.at/), Baumkataster bzw. Bäume Standorte Wien (https://www.data.gv.at/katalog/en/dataset/c91a4635-8b7d-43fe-9b27-d95dec8392a7) , Mehrzweckkarte Vektordaten Wien (https://www.data.gv.at/katalog/dataset/stadt-wien_mehrzweckkartevektordatenwien)

4 DISCUSSION

4.1 Scope and Limits

In order to test and improve the applicability of the theoretical concept and the computer-based 3D model, further research streets will be recorded and analysed. The current research street dating from the Gründerzeit has the typical proportions and associated architecture, the public space itself has been adapted to incorporate the motorisation in the second half of the 20th century, but has not been significantly updated since. This allows the potential of the tool to be explored in some areas, for example in terms of building-related parameters, but not fully exploited in other areas, such as street furniture. It is therefore planned to integrate further research streets from different periods. A street segment that features municipal housing from the era of Rotes Wien (Red Vienna) and one from a recent urban development project are currently being processed.

The issue of qualities that cannot be represented by only one object has only been partially solved so far. While qualities that apply to several objects of the same type are already captured in the context category of the model parameters, those that refer to objects of different types are not yet represented. An example of this is the quality of stay, while seating elements such as benches generally facilitate a longer stay, the associated behaviour only occurs if the environment is designed accordingly.[3] Consequently, the presence of shade in summer, visual connections or the arrangement of furniture to facilitate communication all play a role in whether people actually spend time at a certain location. A corresponding logical interlinking of the parameters is therefore necessary in order to be able to assess the situation. However, the programme used to create the computer-based 3D model does not allow the reciprocal linking of elements; the context must either be linked to one main element or recorded separately in all the elements involved, neither of which was considered an adequate solution. It is noteworthy, however, that there is a concentration of these context-based qualities in certain research areas, such as microclimate and soundscapes, but also in sociology and gender planning. These are also the fields that have traditionally been less well represented in urban design models.

The programme used – ArchiCAD – is a modelling programme commonly used in architecture. While it was sufficient for the proof of concept in one segment of a research street, it is not equipped to handle the amount of data that would be required to record several interconnected streets. For the analysis of a larger research area, a programme suitable for the scale of urban planning needs to be employed. To enable truly interdisciplinary collaboration, a single programme designed to meet the needs of a particular area is in any case not sufficient. A common platform into which all participants feed the data from their respective specialised programmes – as is already the case with BIM – is essential for a successful collaboration.

As the scope of the project only allowed for the integration of a limited number of relevant disciplines, it is considered necessary to extend the project to other fields. The theoretical concept has therefore been designed to be highly flexible, so that additional objects or parameters can easily be added.

While the theoretical concept was conceived for the analysis of street spaces, it is generally suitable to handle other complex spaces with minor adjustments to the occurring objects and parameters involved and their respective weightings; its application to squares would be a logical next step.

4.2 New syntax for streets

The theoretical concept lays the foundation for the creation of a new street syntax, where streets are recorded not according to their function, as is the case today, but according to their real-life qualities. An additional parameter weighting would enable an evaluation of the existing qualities. For a better overview, the parameters can be grouped in order to visualise shortcomings and potentials in certain areas. The already defined spheres of the modelling parameters would be suitable categories for this. Further categories will certainly be needed to map larger contexts – such as traffic or urban climate – which will then draw on the evaluation and meta parameters.

The workshop was used to prepare for the possibility of conducting a street space evaluation at a later date; the positive, potentially conflicting and neutral elements that were jointly identified are suitable to be further

[3] See the three different types of outdoor activity: While necessary activities have little preconditions to be performed, optional and social activities only occur with high frequency when the physical environment is favorable. (Gehl 1971)

developed into a rating system. Street segments can be rated within the various categories, and a coloured display could be employed to visualise how well the street performs in each category of the new street syntax. This will enable the targeted development of previously untapped potential.

Ultimately, this new syntax enables a city-wide consideration and evaluation of street space, and thus also gives the administration the opportunity to target areas where there is a substantial need for adaptation and, at the same time, significant potential. This facilitates the use of municipal resources in a way that delivers the most value.

5 CONCLUSION

The paper presents the initial results of an ongoing study that (for merely the first time) considers the street as a significant urban space that is NOT limited to public space itself, but rather is considered in its entirety. Therefore, all communicating elements of the urban parterre (Stadtparterre), consisting of the streets, the ground floor zone of the adjacent buildings and the courtyards, must be taken into account. Due to their importance as public space – directly accessible to everyone and the largest urban public sphere – the qualities of urban streets are crucial to the cities' ability to meet future challenges such as climate change and to maintain and improve the quality of life of their inhabitants and visitors.

Interviews with experts served as a basis for identifying qualities of street spaces. By integrating different approaches and expertise and by collaborating with practitioners, researchers and administrators, a comprehensive picture of the qualities of public space is created. Testing the interdisciplinary cooperation in a workshop setting revealed connections and interrelations between the different professional groups. This is also reflected in the resulting theoretical concept, which now offers a holistic and systemic framework that allows for the incorporation of a wide spectrum of qualities. At the same time, its flexible but fine-grained structure allows for a high level of detail, enabling a comprehensive assessment of streets.

The first proof of concept is currently evidend in the implementation and applicability of the theoretical concept to a three-dimensional model, which, supplemented by the extensive database, is to be considered a City Information Model (CIM).

Future work will focus on expanding and improving the concept and model, with an initial step of collecting and analysing additional research streets (and parts or sections of them). In a further step, additional disciplines shall be integrated to enable an even more comprehensive analysis. The final version of the SSSEIC tool is intended to serve as a basis for future inter- and transdisciplinary planning processes and promote a more inclusive, sustainable and integrated urban environment.

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Success and Failure of New Cities as Drivers of Urban Growth

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1 ABSTRACT

This paper builds on the findings of our REAL CORP 2024 paper: "Sustainable, Smart and Humane Cities: from utopia to reality. On the purpose and meaning of urban planning today: lessons from the New Cities". Based on publicly available data, we found some 80 new settlements, loosely defined as „New Cities" (NC), planned and/or under development. Most of them took place in fast urbanising Asia and Africa, fewer in South America, North America, Russia, and none in Europe, likely due to the smaller scale of its urban settlements and its own tradition of new towns.

Our analysis found five categories of NC depending on their key drivers: creating new seats of government (national and regional capital NC); stimulating and transforming national economies (productive NC); global corporate wealth seeking new lucrative investment opportunities (real estate NC); companies accommodating themselves (business NC) and satisfying ecological and social needs (green NC). International design consultancies seeking commissions of masterplans, combining ecocity and smart city design principles into increasingly futuristic images – are also an important part of NC drivers.

Studying the implementation progress of NC was more difficult. Although NC aimed at rapid development many of them did not progress quickly and some stalled altogether. Often kick-started by the public sector with investment in infrastructure, relaxed regulations and availability of cheap land, a first phase took place. However, subsequent development expected to be provided by private investment slowed down or stopped altogether, leading sometimes to ghost towns. Despite their often idealistic objectives, NC were accommodating the growing local middle class, excluding the low income population, and sometimes specific ethnic or religious groups. In some cases, smart technology was used for surveillance of inhabitants' activities.

After our initial review and analysis of the NC phenomenon, we aimed to understand the dynamic of these settlements better. We refrained from dwelling on the concept of "New City", as it amounts de facto to a very broad typology of urban settlements at diverse scales, mainly in developing countries, and in particular those with dynamic economies. Thus we focused on whether and how these NC-tagged settlements progressed over time.

We found that information in the public domain on emerging NC, embellished by starchitect generated images in pursuit of meeting client demands and attracting private investors was abundant, but their development tended to diverge from real-time progress. We opted to use information from Google Earth images to detect the current situation of the NCs on the ground. This method enabled us both to locate them in their physical context – not always an easy task – and to approximate the degree of compliance of NC realisations with their initial intention over time.

Keywords: urbanisation, population growth, new cities, urban growth, case studies

2 RESEARCH METHODOLOGY

We structured our analysis of the degree and pace at which the original NC proposals had developed into the following three approaches:

(1) synthesising the current situation of these NC according to the five categories of the typology we had developed in our previous paper: capital, productive, business, real estate and green NCs.

(2) analysing the spatial characteristics of these NC

(3)detecting the degree of compliance with the planning proposals of the analysed NC by comparing them with the images provided by Google Earth.

The data search focused on the following aspects:

- location, year of proposal, size, projected population and completion date

- masterplan and physical characteristics
- level of compliance with the original proposal
- evolution of NC, size and pace
- impact on natural environments
- non-physical, economic, environmental, social and cultural aspects.

The data sources were limited to publicly available information on the websites of public administration, consulting designers and developers, as well as the information provided by Google Earth corresponding mostly to the year 2024. It should be noted that in many cases the written information is neither dated nor updated, while several masterplans are mere computer-generated perspectives.

3 CURRENT SITUATION OF THE SELECTED NC

3.1 Capital NC

The Capital NC are usually initiated by governments, or more likely leaders of governments. From our sample of ten capitals – the reasons of both national and regional capitals to succeed or fail depend on who initiates them, the uncertainties of the global economy and the willingness of those designated to inhabit them to move there.

“Vanity projects” of presidents can succeed (Arkadag Turkmenistan), have their ups and downs (Ordos Kangbashi China) and tend to stall when they are disowned by their successors (Nusantara Indonesia, Amaravati India, Olaya-City of Peace Equatorial Guinea). Moreover, those remote from existing capitals tend to do ecological damage, such as intense jungle deforestation (Nusantara Indonesia, Olaya-City of Peace Equatorial Guinea).

Capitals planned as Economic Free Zones to boost the national economy (New Clark City Philippines, Dompak Ecocity Indonesia), even when supported by successive presidents, but left to foreign finance and developers to realise (Kilamba Kiaxi Angola, New Administrative Capital Egypt) tend to slow down. They also lack incentives for officials (Nasantara Indonesia), and the middle class to move there (Kilamba Kiaxi Angola), due to excessive property prices (New Administrative Capital Egypt) and lack of amenities (New Clark City Philippines), besides reluctance to leave behind urban life.

Capitals created by nationalistic, often anti-colonial motivation of autocratic leaders work, due to strong top down implementation (Naypyido Myanmar), or support by international corporations, albeit sometimes affected by fluctuations of the global economy (Putrajaya Malaysia).

Overall, not all these planned and/or enforced capitals seem to fulfil the expectations of their initiators. However, Putraya is in use, and Egypt’s New Administrative Capital, Arkadag and Kilamba New City are progressing.

3.2 Productive NC

Productive NC aim essentially at economic growth and diversification to attract international high-tech companies, sometimes along new universities, and also foreign direct investment. They are State-led and often given status of Special Economic Zones. The State is securing land assembly, initial infrastructure provision, while seeking cooperation from large scale international developers and investors. Many productive NC claim also smart and sustainable city status with focus on net zero energy and sometimes food self-sufficiency.

The deep port developments, mainly along the Chinese Belt and Road Initiative (BRI) are located in Asia and the Middle East. They are foremost industrial projects providing logistics for international goods transport and distribution. These ports are highly automated, thus usually without population projections or adjacent new settlements. Economic diversification aims to reduce fossil fuel dependency and to attract tourism with entertainment and leisure facilities.

The Deep Sea Ports on the Chinese Belt and Road Initiative seem to be planned as purely logistic productive ports without a new city to accommodate workers (Khazaen Economic City Oman, Patimban New City Indonesia). Nevertheless, other new port cities are including settlements with productive industrial parks (Lingang New City-Nanhuiat present- China, Colombo Port City Sri Lanka, King Abdullah Economic City

Saudi Arabia). All of them tend to displace the local rural population and gain extra land through sea reclamation.

Countries aiming at accelerating economic growth consider that Free Trade Zones will assist (Binhai Tianjin China, Enyimba Economic City Nigeria, Colombo Port City Sri Lanka, Duqm New City Oman, Dholera Smart City India, Nurkent Kazakhstan (BRI), Tatu City Kenya, Alaro City Nigeria. Yet, after initial start-off, their development tends to slow down as foreign direct investment (FDI) is not as forthcoming as expected (Enyimba Economic City Nigeria) or people do not choose to move there (Songdo South Korea) which can lead to real estate glut.

A lot is expected from high-tech industry to accelerate and develop economies, especially in developing countries (Songdo South Korea, Xiong'an China, King Abdullah Economic City Saudi Arabia, Enyimba Economic City Nigeria, Ordos Kangbashi Mongolia China, Technopolis Kenya, Dholera Smart City India, Kanza Technopolis Kenya, Ciberjaya Malaysia, Rublyovo-Arkhangelskoye Russia, Masdar City UAE, Kashiwa-No-Ha-Smart City Japan). This means a global chase to attract successful high-tech industries from the developed world which succeeds sometimes but at a loss of autonomy (Ciberjaya Malaysia). China created NC to accommodate high-tech industries during still rapid industrialisation, especially in its already most urbanised regions (Bibhai China, Xiong'ha China) to create synergy between mega-cities.

In more remote areas growth was envisaged from R&D alongside new university campuses (Ordos Kangbashi Mongolia China, King Abdullah Economic City Saudi Arabia, Ciberjaya Malaysia, Yachay-Knowledge City Ecuador). Investment in knowledge creation was also considered an important general driver of development (Chengdu Future City China).

Diversification was perceived as necessary, especially by the oil rich countries under pressure due to global policies to reduce global warming. Traditionally closed countries aimed to diversify by attracting international tourism by providing leisure and entertainment infrastructure as economic driver (Qiddiyah City Saudi Arabia, King Abdullah Economic City Saudi Arabia, Sultan Haitham City Oman).

A perceived selling point to attract foreign developers and investors was to give NC the credential of smart and sustainable city (Songdo South Korea, Qiddiyah City Saudi Arabia, Dholera Smart City India, Sultan Haitham City Oman, Rublyovo-Arkhangelskoye Russia, Kashiwa-No-Ha-Smart City Japan). This may add to their chance of development which depends on other incentives though, such as Free Economic Zones, accessible, location, favourable climate and relaxed regulation.

3.3 Real Estate NC

The real estate NC aim essentially at making money. They also have some declared purpose like catering for overspill from overcrowded large capitals (Diamniadio Lake new administrative city Senegal, Nkwashi satellite town of Lusaka Zambia, Jaber Ak Ahmad New City Kuwait, New Santa Cruz Bolivia), or for foreign leisure and tourism (Neom Saudi Arabia). Real Estate NC range from mega-fantasies (The Line Saudi Arabia) to contextless fictitious prototypes of "eco-NC" (e.g. designed and marketed by URB Dubai: The Parks South Africa, Net Zero City Al Nama Riyadh Saudi Arabia, Xzero Southern region of Kuwait, Nexgen Eastern Cairo Egypt).

The most realistic and successful Real Estate NC are relatively small new neighbourhoods for several thousand inhabitants, usually gated residential estates for higher income groups (Sharjah Sustainable City UAE, Dubal Sustainable City UEA, Rawabi Palestine) or for tourism (Yiti Sustainable City Oman). Another purpose of real estate NC is to become high tech innovative, sometimes smart or automated city experiments (Ho Chi Minh Innovative City – The Global City at present -Vietnam, Masdar UAE), again in need of FDI (foreign direct investment) and especially venture capital as they tend to be high risk undertakings and may end up as ghost cities (Masdar UAE, Nkwashi Satellite Town of Lusaka Zambia). Other high risk NC are pastiche cities (Tianducheng China which attempts to mimic Paris) and end up as ghost towns as well(Shenyang State Guest Mansions, China)

The much larger real estate NC require the initiation of the state or a political leader (Diamniadio Lake City Senegal, Neom Saudi Arabia) in cooperation with international developers, hoping to attract foreign investment, bank loans, other funds, as well as capital from individual plot purchasers). But even if such countries are contributing substantial initial public investment to such real estate NC, usually for land preparation and infrastructure, it does not guarantee other private investment and development slows down

considerably after the first phase or gets to a halt altogether (Shenyang State Guest Mansions China, Lavasa India). Nevertheless, there are also success stories of NC built to plan and completed (South Sabah Al Ahmad City Kuwait, Sabah Al Ahmad Sea City Kuwait).

3.4 Business NC

The three "new company towns" we found are single purpose settlements to satisfy the specific needs of their corporations. They tend to be small when they cater for administration, management and R&D (Toyota Woven City, Japan, Fujusawa Sustainable Smart Town, Panasonic) and larger when accommodating also workers to increase production (Net City China, Tencent). In Europe which, unlike the rapidly urbanising countries in the developing world, has been built up slowly with smaller cities and towns, such company complexes tend to remain pure workplaces without residents (e.g. Telefonica and Santander Financing City, near Madrid Spain).

3.5 Green NC

The "green" tag is used ambiguously by NC and covers a broad spectrum of settlements whose intention was to be close to nature but which had also a combination of other motivations. Some link sustainability and smartness by catering for the information age (The Orbit Innisfil Canada, Binhai EcoCity Tianjin China). Some seek a better balance between built up areas and open spaces when providing green new settlements as overspill of densely populated cities (Binhai EcoCity Tianjin China). Others add social housing to the green tag to help lower income people leave overcrowded cities (Ouedo Benin, Kinyinya Hill Pilot Project Kigali Rwanda). Others located in rural areas aim to retain population there trying to curb migration to the cities (Newtown Butanest Amhara region Ethiopia). Often though the green tag is used as a real estate selling point for NC in remote areas, including on reclaimed land (Forest City Malaysia). Large scale NC planned in remote locations were more prone to becoming ghost towns. This happened to Forest City in Southern Malaysia, despite its designation as duty free zone, planned as part of the Chinese Belt and Road Initiative and aimed at Chinese investment in second homes.

The "green" objectives to provide healthier affordable homes for low income groups or to assist populations to remain in their rural settings rather than to leave for overcrowded cities require strong governmental action and investment to succeed with their originally planned intentions. Ouedo built four storey blocks of affordable flats but lacked funding for greening these neighbourhoods and providing basic amenities such as schools, health centres, shops and job opportunities, and Green City Kinyinya improvement and development was slow, shifting towards more expensive housing in the hope to attract the middle class.

Large "green" overspill developments which are extensions of existing cities also require strong government commitment and forceful development companies to succeed. While the central district of Binhai Eco-City China got built only a few expected green settlements were built as scattered neighbourhoods for lack of private investment. Even The Orbit garden city in Innisfil (Canada), planned by the government to take advantage of a new railway station connecting the settlement to Toronto, was slow to take off.

4 SPATIAL CHARACTERISTICS OF NC

Project descriptions by developers and public sector authorities as well as data obtained from Google Earth images allowed the identification of the main spatial characteristics of the NCs analysed.

4.1 Design Criteria

Most of the NC proposals of spatial solutions are based on the principles of "the sustainable city" and "the smart city". A small number of cases are conceived according to traditional/functionalist planning (Ordos Kangbashi China, Tatu City Kenya, Nurkent Kazakhstan, Tianducheng China), New Urbanism (Lavasa India, Putrajaya Malaysia, Kilamba Kiaxi New City Angola), or Garden City rules (The Orbit Canada).

4.2 Geographic Characteristics

The geographic location of NC in relation to other cities varied considerably. We identified 9 different types.

Neighbourhoods/urban districts included within or expanding the existing urban fabric: Woven City (70 ha/2,000 pop) Susono Japan, Fujisawa SST (19 ha/3,000 pop) Fujisawa Japan, Net City (200 ha/80,000 pop) Shenzhen China.

Suburban or ex-urban districts: The Global City-Ho Chi Minh Innovative City (117 ha/42,000 pop) Vietnam, Sultan Haitham City (1,500 ha/100,000 pop) Muscat Oman, Tianducheng, (3,100 ha/100,000 pop) Hangzhou China, Dholera Smart City (92,000 ha/200,000 pop) Dholera India; Eko Atlantic City (1,000 ha/250,000 pop) Lagos Nigeria, Colombo Port City (269 ha/273,000 pop) Colombo Sri Lanka, Shenyang State Guest Mansions (no data, abandoned) Shenyang, China.

Districts included in metropolitan areas: Dubai Sustainable City (46 ha/2,700 pop) Dubai UAE; Sharjah Sustainable City (67 ha/7,000 pop) Dubai, Kashiwa-No-Ha Smart City (273 ha/26,000 pop), Tokyo Japan, Alaro City (2,000 ha/30,000 pop) Lagos Nigeria, Masdar (600 ha/50,000 pop) Abu Dhabi UAE, Ouèdo, (235 ha/60,000 pop) Cotonou/Porto Novo Benin, Jaber Al Ahmad New City (12.45 ha/80,000 pop) Kuwait, Cyberjaya (3,000 has/140,000 pop) Kuala Lumpur Malaysia, Songdo (610 ha/300,000 pop) Incheon South Korea.

New capitals: Olaya-City of Peace (8,150 ha/260,000 pop) 290 km Malabo Equatorial Guinea, Putrajaya (4,931 ha/350,000 pop) Kuala Lumpur Malaysia, Naypyidaw (705,400 ha/925,000 pop) 400 km Rangoon Myanmar, Nusantara (256,142 ha/1,900,000 pop) 1,400 km from Jakarta Indonesia, New Administrative Capital (NAC) (73,000 ha/6,500,000 pop) 45 km from Cairo Egypt, Dompak Eco City (925 ha/no pop data) 10 km from Tanjung Pinang Indonesia, Arkadag (1,000 ha/70,000 pop) 30 km from Ashgabat Turkmenistan, Kilamba Kiaxi (5,400 ha/500,000 pop) 20 km from Luanda Angola, New Clark City (9,450 ha/1,200,000 pop) 120 km from Manila Philippines, Amaravati (21,700 ha/3,500,000 pop) 280 km from Hyderabad India.

New towns near capital cities(less than 50 km): Chengdu Future City (469 Ha/no data pop),50 Km from Chengdu China, Trans-Ganga Hightech City (463 ha/no data pop) 10 km Kanpur India, Qiddiyah (33,400 ha/no pop data) 40 km Riyadh Saudi Arabia, Rawabi (630 ha/40,000 pop) 10 km from Ramallah, Palestine, Nkwashi (1,300 ha/60,000-100,000 pop) 36 km Lusaka Zambia, Tatu City (1,000 ha/80,000 pop) 20 km from Nairobi Kenya, Tianjin Eco-City (3,000 ha/350,000 pop) Tianjin, China, Nueva Santa Cruz (6,000 ha/370,000 pop) 20 km from Santa Cruz de la Sierra Bolivia, Yovo-Arkhangelskoye (460 ha/66,500 pop) 20 km Moscow Russia, Diamniadio Lake City (1,644 ha/350,000 pop) Dakar Senegal. 10

Isolated new towns: Khazaen (no data) 60 km from Muscat, Oman; Yiti Sustainable City (1,1000 ha/10,000 pop) 50 km from Muscat, Oman; Nurkent (6,895 ha/110,000 pop) 3,000 km to Beijing, China; Yachay (4,500 ha/120,000 pop),120 km from Lima, Ecuador; Lavasa (10,000 ha/200,000 pop) 70 km from Pune, India; Sabah Al Ahmad Sea City (800 ha/250,000 pop) 100 km from Kuwait; Duqm (15,000 ha/250,000 pop) 480 km from Muscat, Oman; Konza Technopolis (2,000 ha/250,000 pop) 64 km from Nairobi, Kenya; South Sabah Al-Ahmad City (6,150 ha/280,000 pop) 80 km from Kuwait; Lingang New City (7,000 ha/600,000-800,000 pop) 60 km from Shanghai, China; Ordos Kangbashi (35,000 ha/1,000,000 pop) 750 km from Beijing, China; Enyimba Economic City (9,803 ha/1,500,000 pop) 500 km from Lagos, Nigeria; King Abdullah Economic City (17,300 ha/2,000,000 pop) 1,100 km from Riad, Saudi Arabia; Xiong 'An (9,803 ha/5,000,000 pop) 105 km from Beijing, China. 15

Isolated mega-cities: Neom, including Trojena, Sindhala and Oxagon (2,650 km of coastline) and The Line (3,400 ha/9,000,000 pop) Saudi Arabia.

Experimental models: Kinyinya Hill Pilot Project (16 has/8,000 pop)Kigali Rwanda; Nestown Buranest (no data) Adiss Zemen Ethiopia.

In the pipeline: The Orbit (800 ha/150,000 pop) Innisfil Ontario Canada; XZero City(1.600 ha/100.000 pop) KWAIT, The Parks (1,700 ha/150,000 pop) South Africa, Alnama Smart City (1,000 ha/44,000 pop) Riyadh Saudi Arabia, Nexgen (580 ha/35,000 pop) Cairo's Eastern district Egypt.

4.3 Site Conditions

Most NC are located on flat land, even though there are cases in which their construction has substantially modified the environment, causing environmental alterations that contrast with the sustainability objectives they claim. Examples are:

Land reclamation from the sea: Net City, Forest City, Lingang New City, Songdo, Colombo City, Port Sabah Al Ahmad Sea City

Occupation of sensitive islands: Dompak Eco City

Destruction of vegetation cover: Nusantara, Olaya-City of Peace

Hill erosion: Rawabi.

4.4 Project Areas

The site sizes of NC are determined by the objectives of the NCs and vary according to whether they are neighbourhoods, urban districts or independent cities.

Small

less than 100 ha: Fujisawa SST; Kinyinya Hill Pilot Project, Jaber Al Ahmad New City, King Abdullah Economic City, Sharjah Sustainable City.

100 – 500 ha: Net City, Ouèdo, The Global City, Kashiwa-no-Ha Smart City, Trans Ganga Hightech City, Yovo-Arkhangelskoye, Chengdu Future City, Colombo City Port.

Medium

500 – 1,000 ha: The Orbit, Masdar, Rawabi, Dompak Eco City, Arkadag, Songdo, Tatu City, Eko Atlantic City.

1,000 – 2,000 ha: Shenyang State Guest Mansions, Nkwashi, Diamniadio Lake City, Forrest City, Yiti Sustainable City, Konza Technopolis.

2,000- 5,000 ha: Tianjin Eco-City, Tianducheng, South Sabah Al-Ahmad City, The Line, Putrajaya, Cyberjaya, Yachay.

Large

5,000 – 10,000 ha: Lavasa, Nueva Santa Cruz, Kilamba Kiaxi, New Clark City, Lingang New City, Nurkent, Khazaen, Olaya-City of Peace.

More than 10,000 ha: Naypyidaw, New Administrative Capital (NAC), Nusantara, Amaravati, Ordos Kangbashi, King Abdullah Economic City, Dholera, Duqm, Qiddiyah.

4.5 Planned Number of Population

Most NC stated the expected numbers of inhabitants, and sometimes of workplaces, except for the highly automated sea ports which were planned essentially as industrial-economic developments relying on existing neighbouring cities to accommodate their workforce. Often the development of NC involved displacement of existing populations without any replacement for them. The majority of NC are planned as medium size cities.

Small

Below 10,000 pop: Fujisawa SST, Woven City, Kinyinya Hill Pilot Project, Dubai Sustainable City, Sharjah Sustainable City, Yiti Sustainable City.

10,000 – 50,000 pop: Alaro City, Rawabi, Masdar, Kashiwa-No-Ha Smart City, The Global City.

Medium

50,000- 100,000 pop: Net City, Ouèdo, Tianducheng. Nkwashi, Jaber Al Ahmad New City, Arkadag, Tatu City, Yovo-Arkhangelskoye, Sultan Haitham City.

100,000 – 500,000 pop: The Orbit, Lavasa, Shenyang State Guest Mansions, Diamniadio Lake City, South Sabah Al-Ahmad City, New Santa Cruz, Putrajaya, Olaya-City of Peace, Kilamba Kiaxi, Ciberjaya, Songdo, Konza Technopolis, Dholera, Eko Atlantic City, Yatay, Colombo City Port, Duqm.

500,000 – 1,000,000 pop: Neom, Naypyidaw, Ordos Kangbashi, Lingang New City, Forest City.

Large

1,000,000 – 2,000,000 pop: Nusantara, King Abdullah Economic City, Enyimba Economic City.

Over 2,000,000 pop: The Line, New Administrative Capital (NAC), Amaravati, New Clark City, Xiong'An.

4.6 Gross Densities

From these population projections and the masterplan briefs and design it is possible to impute expected densities of NC. This estimate does not take account of real numbers of inhabitants which are not

surprisingly difficult to establish as it is not in the interest of NC developers to reveal real estate overproduction. Densities are key to assessing the level of sustainability of NC planning proposals.

Low, less than 100 people/ha

Woven City, Lavasa, Masdar, Tianducheng, Rawabi, Dubai Sustainable City, Nkwashi, South Sabah Al-Ahmad City, New Santa Cruz, Yiti Sustainable City, Putrajaya, Naypyidaw, New Administrative Capital (NAC), Olaya-City of Peace, Kilamba Kaxi, Nusantara, Amaravati, Arkadag, Cyberjaya, Lingang New City, Kashiwa-No-Ha Smart City, Tatu City, Dholera, Yachay, Nurkent, Duqm, Alaro, Sultan Haitham City.

Middle,100-200 people/ha

Diamniadio Lake City, New Clark City, King Abdullah Economic City, Konza Technopolis, Yovo-Arkhangelskoye, Enyimba Economic City.

High, more than 200 people/ha

Fujisawa Sustainable Smart, Net City, Tianjin Eco-City, Ouèdo, The Orbit, Kinyinya Hill Pilot Project, Shenyang State Guest Mansions, Jaber Al Ahmad New City, Forest City, Neom, The Line, The Global City, Sondo, Eko Atlantic City, Colombo City Port, Xiong´An.

NC name, NC Area	Population Planned numbers (year)	Population Actual size	NC category	Location, Nearest existing settlement
Mega-cities				
The Line 3400ha	9 million (2021)	Completion (2050) 300,000 (2030)	Real Estate 715km long skyscraper 2.4km by 2030	Saudi Arabia Red Sea to desert 1584km from Riyadh by road
New Administrative Capital 73,000ha	6.5 million (2015)		Capital national	Egypt 45km from Cairo
Amaravati 21,700ha	3.5 million (2014)	Completion (2029)	Capital regional	India Andhra Pradesh State 275km from Hyderabad
Diamniadio Lake City 16,500ha	3 million (2014)	Completion (2045) 280,000 (2014)	Real estate business park administration luxury housing	Senegal 30km from Dakar
Xiong'an 177,000ha	2-3 million (2017) 25 million share of triangle (2046)	Completion 2035) 1.2m existing (1950) 30,000 extra (2024)	Productive "City of the Century" high-tech	China Beijing Hebei Tianjin triangle 105km from Beijing
Binhai 119,900ha	2,998,600 (2019)	2.067m existing decrease (2020)	Productive Free Trade Zone	China Tianjin 170km from Beijing
King Abdullah Economic City 17,300ha	2 million (2005)	slow development	Productive port (inter)national advanced industry, tourism	Saudi Arabia On Red Sea Mecca Province 100km from Jeddah
Nusantara 256,142ha	1.9 million (2019)	153,000 in existing villages (2022)	Capital national government administration	Indonesia Balikpapan port city, Kalimantan, Borneo 400km from Jakarta
Enyimba Economic City 9803ha	1.5 million (2018)	Start (2023)	Productive Special Economic Zone	Nigeria Abia State 14km from Lagos
New Clark City 60ha Economic Zone 9450ha	1.2 million (2015)	Start (2016) Displacement 65,000 SEA games (2019)	Capital national	Philippines 120km from Manila
Neom 26,500ha	1 million (2017)		Real Estate Leisure, tourism	Saudi Arabia 1,426km from Riyadh
Ordos Kangbashi 8,700,000ha	1 million (2001)	30,000 (2009) 153,000 (2017) 2.15 million (2020)	Productive ex-coal mining town techno parks, universities	China Mongolia 716km from Beijing
Ho Chi Minh	1 million		Real Estate	Vietnam

Innovative City 117ha	(2022)		High-tech	District of Ho Chi Minh City
Naypyidaw 705,400ha	1 million (2000)	925,000 (2018)	Capital national	Myanmar 400km from Rangoon
Lingang New City 7400ha	600,000-800,000 (2003)		Productive new deep sea port	China Pudong 60km from Shanghai
Forest City 1400ha	700,000 (2014)	Completion (2035) 500 (2019) 9000 (2023)	Green high rise buildings on reclaimed lan	Malaysia Johor State 2km from Singapore
Qiddiyah City 33,400ha	500,000 (2019)	(2030) 1st phase 2023	Productive leisure and tourism sustainable city	Saudi Arabia 40km from Riyadh
Ecocity Dompak 925ha	500,000 (2006)	(2010) existing pop 2679 (2002)	Capital regional	Indonesia Riau Province 12 km from Tanjung Pinang (existing regional capital)
Kilamba New City 5400ha	500,000 (2008)		Capital regional	Angola Luanda Province 20km from Luanda
Shenyang State Guest Mansions 1700ha	500,000 (2010)		Real Estate State supported speculative development	China Shenghang 400km from Beijing
Medium Size Cities				
Nueva Santa Cruz 3000ha	370,000 (2022)		Real Estate Speculative design	Bolivia District of Santa Cruz
Binhai Eco-City, Tianjin 20.24ha	350,000 (2008) Competition HAO (2014)		Green on reclaimed land	China 35km from Tianjin
Putrajaya 4931ha	350,000 (1995)		Capital National administrative	Malaysia Sepang District 30km from Kuala Lumpur
Songdo 5336ha	300,000 (2000) (2003) 3m; (2015) 167,000	(2003) start (2015) 30,000 (2021) 80,000	Productive high-tech Smart and sustainable city Free Economic Zone	South Korea Incheon transport hub 30km from Seoul
Lavasa 100km2 10,000ha	300,000 (1999)	10,000 (2010) temporarily revoked (2012)	Real Estate developer led	India Maharashtra Pune District 188km from Mumbai
South Sabah-Al-Ahmad City 61,500ha	280,000 (2016)	Completion (2040)	Real Estate From public to private housing production	Kuwait 80km from Kuwait City
Colombo Port City 269ha	273,000 (2016)		Productive Special Economic Zone	Sri Lanka 3.5km from Colombo
Olaya-City of Peace 8150ha	260,000 (2017)		Capital national	Equatorial Guinea Djibloho Province 286km from Malabo capital (Bioko Island)
Sabah Al Ahmad Sea City 800ha	250,000 (1993) 460,279 (KEO est)	Completion (2040)	Real Estate Purely private speculative	Kuwait 151km from Kuwait City
Duqm New City 15,000ha	250,000 (2014)	2nd masterplan (2017)	Productive Special Economic Zone	Oman 547km from Muscat
Eko Atlantic City 1000ha	250,000 (2009)	(2009) start	Real Estate high income overspill	Nigeria Lagos 7.7km from Lagos centre
Technopolis 2000ha	250,000 (2008)	(2030) completion]1st phase (2013)	Productive high-tech	Kenya 60 km from Nairobi
Small towns				
Dholera Smart City 92,000ha	200,000 (2008)	(2024) completion	Productive smart city Special Innovation Region	India New Delhi Mumbai corridor 552km from Mumbai
Kanza Technopolis	180,000		Productive high-tech	Kenya 64km from Nairobi
Green City Kinyinya Hill 600ha	150,000 (2024)		Green Social housing planned but high income overspill	Rwanda district of capital Kigali
The Orbit 180ha	150,000 (2017)	completion (2050) 43,326 (2021)	Green new agro-tech and wilding	Canada Innisfil Ontario 106km from Toronto
The Parks 1700ha	150,000 (2022)		Real Estate Speculative design	South Africa (no location)

Ciberjaya 3000ha	140,000 (1997)		Productive IT global	Malaysia Sepang 25km from Kuala Lumpur
Yachay Knowledge City 4,489ha	120,000 (2014) 15,000 (2017)	Start (2015) 2000 (2022)	Productive Tech experimental university high tech SMEs	Ecuador Urcuqui 122km from Quito
Nurkent 6895ha	110,000 (2012)	Masterplan approved (2017)	Productive Economic Zone of Chinese Belt and Road Initiative	Kazakhstan Almaty region on old Silk Road 14.6km from Chinese city Khorgos
Sultan Haitham City 14,800ha	100,000 (2023)	completion (2045) 1st phase (2024)	Productive smart and sustainable city (model city) high income housing	Oman 45.7km from Muscat
Nkwashi Satellite Town 1300ha	60,00-100,000 (2013)		Real Estate Private speculative overproduction	Zambia 36km from Lusaka
Tianducheng 3100ha	100,000 (2007)	30,000 (2024)	Real Estate pastiche Paris	China 27km from Hangzhou
XZero City 1600ha	100,000 (2024)		Real Estate designer led	Kuwait (no location)
Ouedo 235ha	100,000 (2013)	3500 units built (2024)	Green social housing without green or amenities	Benin 35 km from Porto-Novo
Jaber Al Ahmad New City 1245ha	80,000 (2014) 18,287 (2015)	Masterplan SUF concept Low density (2007)	Real Estate Purely private speculative lacking investors	Kuwait 25km from Kuwait City
Net City (Tencent) 200ha	80,000 (2019)	completion (2027) 26,400 (2025)	Business IT company town, production, HQ, R&D	China Car free district Shenzhen
Tatu City 1000ha	80,000 (2008)	completion (2030) 1st phase (2012 start)	Productive Economic Zone	Kenya Ruiru Kiambu 21km from Nairobi
Arkadag 1000ha	70,000 (2018)	64,086 (2022) Inaugurated (2023)	Capital regional	Turkmenistan Ahal Province 30km from capital Ashgabat
Rublyovo-Arkhangelskoye city/district 460ha	66,500 (2019)	Competition (2918) Not implemented	Productive smart city, high tech	Russia Moscow Western suburb of Moscow
Masdar City 600ha	50,000 (2006)	1/4 built (2013) little inhabited (2020)	Real Estate high-tech	UAE 28km from Abu Dhabi
Al Namas 1000ha	44,000 (2022)	existing villages	Real Estate designer led	Saudi Arabia (no location)
Rawabi 6300ha	40,000 (2007)	1st phase 3000 (2012) built, not occupied no water 710 (2017) 5000 (2015 est)	Real Estate High income	Palestine 17 km from Ramallah
Nexgen Eastern District Cairo 580ha	35,000 (2023)		Real Estate designer led	Egypt (no location)
Alaro City 2000ha	30,000 (2019)	(2019 start)	Productive Free Customs Zone	Nigeria 89km from Lagos
Kashiwa-No-Ha-Smart City 273ha	26,000 (2005)	completion (2030) 1st phase completed (2024)	Productive smart sustainable city with renewable energy and high-tech incubator firms	Japan Tokyo metropolitan area 49km from Tokyo
Nestown Buranest 1600ha	20,000 (2012)	600-950 (2013) 8000 replica expected	Green social housing (model city) for reproduction, not achieved	Ethiopia Amhara rural region Addis Zemen 560km from Adis Ababa
Yiti Sustainable City 1100ha	10,000 (2022)	completion (2025)75% built (2024)	Real Estate tourism	Oman 37km from Muscat
Sharjah Sustainable City 67ha	5000 (2019)	Completed (2024)	Real Estate residential gated	UAE Sharjah 22.4km from Sharjah centre
Fujisawa Sustainable Smart City	3000 (2008)	Completed (2018)	Business Panasonic company	Japan Fujisawa

Panasonic company town 19ha			town R&D	48.2km from Tokyo
Dubai Sustainable City 46ha	2700 (2013)	Completed (2019)	Real Estate residential high income gated	UAE 29.3km from Dubai
Toyota Woven City, Japan 70ha	2000 (2021)	100 staff (2025)	Business Toyota HQ tech R&D (+ 50 visiting countries)	Japan Higashi, Fuji mountain 14km from Tokyo
NC without population data				
Khazaen Economic City 5200ha	Pop? (2019)		Productive port Free Zone	Oman 70km from Muscat
Trans-Ganga High-tech City	Pop? (2014) (1994?)	Plot sale auction not started	Productive industrial park for high-tech companies not happening	India 160km from Uttar Pradesh
Chengdu Future City 4600ha	Pop? (2019)	Latest info 2023	Productive university education based	China 50km from Chengdu
Patimban New City 350ha reclaimed land 334ha from existing owners	Pop? (2018) were displaced from 334ha	(2029) EIA social monitoring (2019-2023)	Productive new deep sea port and highway access	Indonesia Subang regency, West Java 145km from Jakarta

Table 1: NC Consolidated Data (rank ordered by population size).

5 COMPLIANCE OF BUILT NC WITH PLANNING PROPOSALS IN MASTERPLANS

The analysis of the spatial proposals contained in the masterplans of the new generation of NC enables us to detect significant aspects that, interrelated, help to describe the complex panorama of this singular planning practice.

5.1 Degree of Compliance and Pace of Development

Updated existing information, together with images of Google Earth – corresponding to the years 2023 and 2024 -were used to analyse the degree of compliance between effectively implemented NC and the initial urban planning proposals. The satellite photos provided relevant information to identify compliance of the built NC with the initial masterplans at two levels: urbanisation infrastructure (new street networks) and buildings (building blocks). The start date of the projects enabled us to detect the pace of the NC development. Finally, cross-referencing information on project design criteria, geographic location, assigned area, expected population, resulting gross density, percentage of effectively urbanised and built land formed the basis of our conclusions.

5.2 New Classification of NC, Based on Generic Simplification

Considering the enormous diversity of cases, a generic simplification was needed and led to the following classification:

Fully developed: Fujisawa SST (2008), Putrajaya (1995), Cyberjaya (1997), Songdo (2003), Tianducheng (2007) Dubai Sustainable City (2013)

Highly urbanised and built: Sabah Al Ahmad Sea City (1993), Ordos Kangbashi, (2001), Lingang New City (2003), Kashiwa-no-Ha Smart City (2005), Kilamba Kiaxi (2008), Shenyang State Guest Mansions (2010, abandoned), Jaber Al Ahmad New City (2014), South Sabah Al-Ahmad City (2016), Net City (2019), Sharjah Sustainable City (2019), Yiti Sustainable City (2022), Sultan Haitham City (2023)

Highly urbanised, partially built: Tianjin Eco-City (2008), Ouèdo (2013), New Administrative Capital (NAC) (2015), Nurkent (2017), Arkadag (2018)

Partially urbanised and built: Lavasa (1999), Masdar (2006), Rawabi (2007), Tatu City (2008), Eko Atlantic City (2009), Forest City (2016), Xiong'An (2017), Yovo-Arkhangelskoye (2019), Qiddiyah City (2019) Woven City (2021), The Global City (2022)

Scarcely urbanised and built: King Abdullah Economic City (2005), Dompak Ecocity (2006), Konza Technopolis (2008), Dholera Smart City (2008), Neston Buranest (2012), Nkwashi (2013), Yachay (2014), Diamniadio Lake City (2014), New Clark City (2015), Colombo City Port (2016), Olaya-City of Peace

(2017), Neom (2017), Duqm (2018), Nusantara (2019), Khazaen (2019), Nueva Santa Cruz (2022), Kinyinya Hill Pilot Project (2022)

Partially urbanised, not built: Amaravati (2014), Trans Ganga Hightech City (2014), Alaro City (2019), The Line (2021)

6 CONCLUSION

The analysis of the objectives, locational, spatial and design aspects of the selected New Cities (NC) confirms the elasticity of the concept of NC and its distinction from the term "new town" coined in the 1960s in Europe. Initially, the new towns referred to independent settlements, built from scratch according to the guidelines of a masterplan or, where appropriate, supported by small existing settlements to which planning imposed a significant urban expansion. Two criteria ensured their development over time: being sufficiently distant from the main urban centres to create both local population and economic activities, and the support of the public administration to ensure infrastructure investments. The generation of NC that emerged at the end of the twentieth century to respond to the demands of globalised societies is based on other aspects which dilute the original meaning of “new towns” to make room for a more flexible concept including other aspects associated with the concepts of “city”.

Versatility is a key feature of NC used during the last 20 years to name different types of developments. Genuine “new cities” built to fulfil specific objectives, as well as a wide range of urban neighbourhoods, suburban or metropolitan districts, pilot projects and model designs have adopted this denomination to distinguish themselves from traditional cities and their urban interventions. Another characteristic of NC is to confound the terms “sustainable city” and “smart city” when applied to the planning and design of NC, notwithstanding that sustainability and smartness have become claims of both conventional planning and the real estate industry. Adequate management – public or private – to ensure the permanent supply of the necessary investments – domestic or foreign – is possibly the factor which differentiates NC most from traditional city development. An added aspect associated exclusively with the material conditions of NC projects is the attraction or rejection by the expected population to move, purchase a home or take a job in these NC which had a considerable impact on the success or failure of many NCs. The combination of these factors fixes NC masterplans in the territory through infrastructure development and subsequent construction, and is defining their delay in time (unfulfilled stages) or their permanence in the pipeline, their failure (incomplete projects or ghost cities) but also the success of these proposals (fully completed or in progress).

Although there has been a significant increase in NC in recent decades – particularly in Asia, Africa and the Middle East, driven by rapid urbanisation, population growth, economic expansion and investment opportunities for foreign capital – there is no database that tracks these new urban developments on a global scale. The lack of a universal definition of NC makes it difficult both to classify them and to monitor and compare projects which would contribute significantly to knowing the factors that inhibit, delay or promote their development and thereby facilitate the tasks of managers, planners, designers and promoters.

What are the significant aspects of the NC experience?

Leaving aside the cases of new settlements conceived as autonomous units, strategically located in the territory with the aim of building permanent communities, most of the examples reviewed in this paper refer to urban interventions of different scales and purposes that aspire to differentiate themselves from the traditional city by providing new ways of life. What they have in common is a top-down approach devoid of public participation. Regarding their chances to succeed, it is worth noting that the most successful NC tend to be rather small settlements or neighbourhoods with a clear objective and secure financing.

The creation of NCs in the 21st century is an undeniable fact. The large number of cities built from scratch, of punctual interventions in existing urban fabrics and of suburban or metropolitan neighbourhoods and districts are evidence of the dynamic of this phenomenon. Even when it comes to proposals centred on the dual “sustainable” and “smart” concepts, albeit not always delivering their principles – the contribution of NC to the planning and design criteria of cities is undeniable.

7 REFERENCES

As mentioned in the introduction to this paper the data used for its elaboration come from a multitude of sources freely available on the Internet. The material used was retrieved mainly from three sources. Firstly, the information provided by the authors of the masterplans, such as date, location, surface area, objectives, number of dwellings, social facilities, spaces for productive activities, as well as the theoretical principles that guided their planning and design and the images of the expected urban future. Secondly, data published by developers: public administrations, non-governmental organisations or private investors selling their real estate products. Thirdly, open source and often short articles from various sources that helped to update the degree of spatial development of the selected case studies. There are too many to enumerate all of them here. Examples are:

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Territorial and Economic Evolution of Retail in Flanders: Post-Pandemic Suburbanisation and Dispersion?

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1 ABSTRACT

In this study, we study a short period (2009-2023) where detailed and (more or less) consistent data are available for publicly accessible functions.

“Locatus” database data for Flanders are made available from 2009 until the end of 2023. Initial analyses show that not all data are kept for the full period, so we need to make the right selection and correction first. In consultation with the members of the working group, a conversion table was made between the Locatus branches and the categories from the IHB decree

In the spatial analysis, we compare the datasets with the historical version of land use plans from 2009, 2013, 2016, 2019 and 2022. For the combination with other functions, we will use the building block typology from ‘Segmentation VI’ (Zaman, De Mulder & Pennincx, 2022) in addition to the land use map. Following area typologies are screened for their usefulness in function of this study: Urban centers, ribbon development, dispersed development, Urbanised, peripheral, rural, Land use plan categories, Mobility score (public transport, walking cycling) of retail locations.

Based on the findings and critical success factors, an analysis of planning permits (Socio-economic/ environmental permit for retail) will be carried out in the final phase.

The urban development policy stems from the observation that certain functions move from the core to the periphery. The current behaviour of network densification could be at the root of the sprawl of activities. The network dweller, or polycentric urbanite, (Grünfeld, 2010) uses a ‘pallet of places’ in everyday life. At every moment of the day and for every activity, the network dweller seeks maximum gain according to the goals of the moment. Self-interest and comfort is central. He is multi-connected and has complete freedom to shape his choices. Not surprisingly, this freedom is strongly linked to the mobility options available today. The reasons to go out somewhere, go shopping, or walk school,... are based less and less on proximity than on other characteristics such as where friends live, the quality of the offer, ‘something new’, on the way to school or work,... Even the choices of place of residence are less definitive than before. The polycentric urbanite lives in a network of connected cores and places. Since the Covid-19 pandemic, the widespread use of e-commerce comes on top of this: ordering and paying online, delivered a few days or even hours later, at home or at work. Within this context, we collectively want the centers of our cities and towns to remain vibrant, to have ‘something to do’. The general trends towards “pleasant”, “fast”, “on the way from A to B”, “digital”,.... often play to the disadvantage of the urban center, because it is easier (and cheaper) to offer this in places that are less complex and easier to control. Within this context, we collectively want the cores of our cities and towns to remain vibrant, to be dynamic and lived in; but there is little well-documented knowledge. While the impact of peripheral developments on the core has been widely depicted, there is little visibility on the opportunities to avoid the negative impact ‘ex ante’.

The behaviour of network urbanisation per se does not seem to be a sufficient explanation of the declining attractiveness of town centers and high streets. Rather, the polycentric urbanist uses in a non-traditional way the opportunities offered by the distribution of activities in the polycentric network, the nebulous city, Città Diffusa (Francesco Indovina), carpet metropolis (W-J Neutelings) the horizontal metropolis (Secchi & Viganò), or the Zwisschenstadt (Thomas Sieverts). To explain the distribution of publicly accessible functions outside the cores, we look more closely at the forces behind it.

Keywords: GIS-analysis, territorial analysis, Retail evolution, Inner city suburbanisation, post-pandemic

2 INTRODUCTION

In recent decades, retail in Flanders has undergone increasing spatial dispersion, following a development trajectory characterized by ribbon development and suburban expansion rather than consolidation in historically vibrant urban and town centers. In response, the Flemish government introduced the Decree on Integrated Retail and Commercial Establishment Policy in 2016, aiming to support local planning authorities in strengthening urban cores and counteract spatial fragmentation.

To assess the effectiveness of this policy, we examined the spatial evolution of retail (and other commercial and non-commercial publicly accessible functions) in Flanders between 2009 and 2023. Specifically, we have asked: To what extent has the 2016 Decree on Integrated Retail and Commercial Establishment Policy influenced spatial retail dynamics? To what extent does mobility influence the success or decline of retail? How has the COVID-19 pandemic accelerated pre-existing spatial trends?

We conducted a spatial analysis, comparing the detailed and consistent Locatus datasets with historical versions of the land-use accounting system (ruimteboekhouding) from 2009, 2013, 2016, 2019, and 2022. In addition, we incorporated functional classifications, such as the land-use map and the Segmentatie VI building block typology (Zaman, De Mulder & Pennincx, 2022). The following spatial typologies were assessed for their relevance to this research:

- Urban centers, ribbon developments, and dispersed buildings
- Urban, peri-urban, and rural zones
- Total land take
- Urban centers lacking a sufficient mix of essential services
- Service functions located within ribbon developments
- Mobility accessibility index (Mobiscore per hectare)

Beyond spatial patterns, mobility and (car) accessibility was considered a key factor influencing the vitality of retail. To assess its role, we conducted a qualitative study of ten mobility-related case studies, examining how specific interventions – such as pedestrianisation, parking policies, circulation plans, and bicycle infrastructure – influence commercial dynamics. Each case was analyzed through a mixed-methods approach, integrating quantitative data (e.g., retail floor space changes, business occupancy rates, and footfall) with qualitative insights from surveys and interviews with local business owners and visitors.

However, while mobility interventions are often framed within broader urban regeneration strategies, the spatial dispersion of retail cannot be explained solely by changing consumer preferences or urban mobility trends (e.g. polycentric urbanite (Grünfeld, 2010)). Drawing on concepts such as Città Diffusa (Indovina et al. 1990), the patchwork metropolis (Neutelings 1991; Pisano 2018), the horizontal metropolis (Secchi & Viganò 2010), and the Zwischenstadt (Sieverts 1998; 2003), we argue that "urban sprawl" reflects deeper structural and long-term drivers, including economic restructuring, infrastructure investments, and policy incentives. In this light, enhanced dynamics of dispersion, which we have witnessed since the COVID19-pandemic, merely constitute a new phase in the era of "secular suburbanisation".

3 SETTING THE SCENE: SECULAR SUBURBANISATION

3.1 The emergence of the Zwischenstadt

Urban sprawl and the decentralisation of retail are among the defining spatial transformations of the past decades in Flanders – and more broadly, in Western Europe. The concept of the Zwischenstadt, introduced by Thomas Sieverts (1998) provides a valuable framework for understanding these transformations, as it challenges the traditional dichotomous understanding of the city as a dense, functionally diverse environment, surrounded by a primarily agricultural, sparsely populated countryside. Rather, as Sieverts describes, the 20th century has seen the rise of the Zwischenstadt or "in-between city": an intermediate urban condition, characterized by dispersed density, functional mixing, a strong car-dependence. In contrast to classical suburbanisation, which implies a linear outward expansion from city centers, the Zwischenstadt concept captures a more complex reality. Here, urban functions have dispersed beyond historic cores, forming polycentric networks of economic activity, housing, and mobility flows. Flanders and the Ruhrgebiet are prime examples of this phenomenon, where retail, service-oriented businesses, and

recreational functions have increasingly located in ribbon developments, suburban nodes, and peripheral commercial clusters rather than traditional, recognizable town (or district) centers.

3.2 Three waves of suburbanisation

Rather than a single, uniform wave, suburbanisation has unfolded in successive waves, each shaped by distinct yet interrelated forces. Three main waves can be identified, broadly aligning with wider global trends (Sieverts 2003).

The first wave, occurring in the early to mid-20th century, was primarily driven by industrialisation and Fordist economic restructuring. As cities had already undergone massive metamorphoses, mass production expanded and cities became industrial powerhouses. Increased car ownership, rising incomes, and the widespread adoption of 'zoning policies' led to the emergence of early suburban housing developments. This led to a decrease in the relative importance of historic centers.

The second wave occurred in the 1970s, when many cities witnessed a decline in employment. Residents followed jobs to open spaces outside the city. The 'rural exodus' of the 1960s came to a halt, and for the first time since the onset of industrialisation, as Johann Jessen, Stefan Siedentop (2018) state, rural areas benefited from migration out of more densely populated regions. Jessen and Siedentrop analyzed this dynamic in West Germany and identified key explanatory factors: shifting location needs of businesses and subsequently private households; rising disposable income; increasing car availability; homeownership as a new residential ideal; skepticism toward the 'metropolitan reality', particularly among social elites; and fiscal and urban development policies encouraged decentralisation.

The third wave, from the 1990s onward was as marked by increased urban flight, particularly in Germany , with suburban belts absorbing a growing share of both population and economic activity. While employment in West-Germany increased by 5.5% between 1980 and 1997, this growth was concentrated in the outer metropolitan zones (+11%) and beyond (+9.9%), whereas core cities experienced a 3.1% job decline. This shift was not only due to the erosion of traditional industrial networks but also to a weakening position in emerging sectors, particularly the service industry. By 1998, suburban areas accounted for 56.17% of all jobs within agglomerations and housed 66.68% of the population, further reinforcing the decentralisation of both work and living spaces (Brake, Einacker & Mäding 2005).

3.3 Driving forces

Behind these waves lies a complex interplay of causal processes–differing between the three waves. Einacker and Mäding distinguish between (1) demographic and housing changes, (2) economic transformations and changes in leisure preferences, (3) changes in mobility patterns and policy, (4 &5) other federal (in the case of Germany), regional and local policies. Demographic changes, including household fragmentation and rising affluence, have increased housing demand, while homeownership aspirations and preferences for more spacious, green living environments have encouraged relocation from urban cores to suburban zones. Meanwhile, economic transformations, particularly the shift toward a service-based economy, have spurred the decentralisation of employment, making suburban areas more attractive for both businesses and residents. Increased car ownership and road infrastructure investments have further enabled suburban living, reinforced by tax incentives, housing subsidies, and urban planning policies.

The interplay between these factors has led to a self-reinforcing cycle of suburban expansion: as businesses relocate, residential demand in suburban areas grows, which in turn justifies further infrastructure development and policy support. The result of this is a long-term, multifactorial process of secular suburbanisation – a spatial evolution unfolding over decades, driven so extensively by structural factors, changing preferences, market forces, investments and policies that counteracting policy interventions have become largely ineffective.

The suburbanising consequences of specific policy decisions has been extensively documented. In Centro Oberhausen. Die verschobene Stadtmitte (2009), Walter Brune and Holger Pump-Uhlmann illustrate the unintended socio-economic consequences of large-scale commercial developments outside traditional city centers–intended as a catalyst for urban renewal and revitalisation–often drained economic activity out of the historic center instead. This exacerbated vacancy rates and congestion while shifting consumer footfall away from traditional retail districts. This pattern, they argue, is widespread across Europe, where urban planning has often reinforced rather than mitigated suburbanisation by adapting to new consumer and mobility trends.

This analysis aligns with Verhetsel and Beckers (2021), who describe the development of regional shopping centers in the 1990s as the third phase of retail decentralisation. Since the 1960s, retail has evolved "from local and small-scale to peripheral and large-scale". This shift began with the rise of supermarkets selling food products, followed by a second wave of peripheral retail parks in the 1970s and 1980s, offering non-food products such as furniture, carpets, DIY supplies, electronics, and garden equipment. Already at this stage, competition between traditional inner-city retail and peripheral retail strips intensified. By the 1990s, large suburban shopping malls were not only reshaping consumer behavior but also influencing urban planning itself – rather than resisting decentralisation, city centers began to adopt similar commercial concepts.

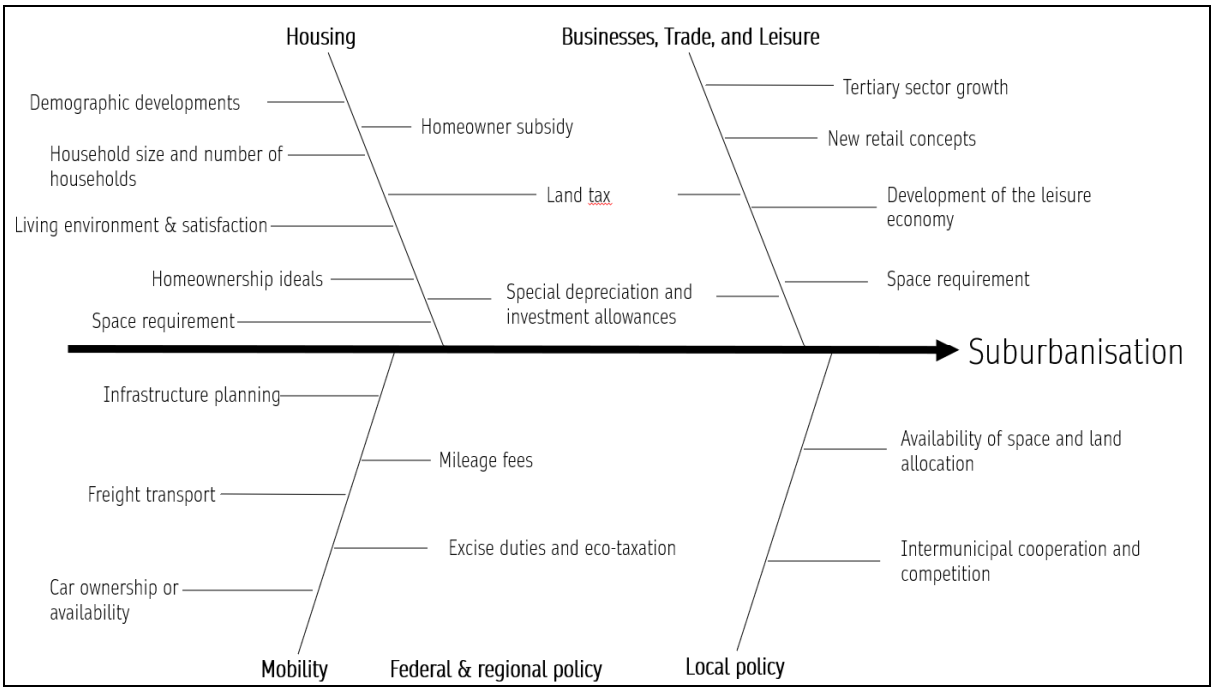


Figure 1: Driving forces and processes of suburbanisation (Einacker & Mäding 2005)

3.4 Suburbanising urban cores

As Hartenstein (2021) notes, urban planners did not merely react to suburban retail siphoning purchasing power and footfall away from city centers; they actively integrated suburban formats into the urban core. This led not to the immediate decline of inner-city retail but rather to its transformation: city centers increasingly mirrored the periphery, with large-scale retail concepts, a stronger focus on car accessibility, and a shift toward 'runshopping' over leisurely retail experiences.

Today, Verhetsel and Beckers identify three areas where this transformation is most visible: (1) regional and small-town centers, (2) secondary shopping streets in larger cities, and (3) dispersed retail locations. These areas, now resembling suburban retail environments, struggle to offer unique value to consumers. Lacking both the experience-driven appeal of traditional shopping and the convenience of suburban retail hubs, they are increasingly bypassed in favor of more accessible, comprehensive alternatives (Beckers & Verhetsel, 2021, p.71).

4 THE CASE OF FLANDERS: DID COVID19 CHANGE EVERYTHING?

While theoretical frameworks on suburbanisation and polycentric development offer essential insights into the underlying mechanisms shaping the Flemish retail landscape, the empirical evidence reveals a complex and uneven reality. In this chapter, we present the results of our spatial analysis, tracing the evolution of retail between 2009 and 2023. Three key dimensions emerge from our findings: the contraction of the retail landscape, the continued spatial dispersion of commercial functions, and the structuring role of mobility in shaping retail success and failure.

4.1 The Shrinking Retail Landscape

Over the past decade, the retail sector in Flanders has significantly contracted. Between 2009 and 2023, the total number of retail establishments declined by approximately 6,200 units, representing a decrease of 10%. More strikingly, in the already shrinking landscape, the number of vacant retail spaces has nearly doubled over the study period. In 2009, approximately 12% of retail units were unoccupied; by 2023, this figure had risen to 23%. This steady increase in vacancy rates suggests that closures are not being offset by the arrival of new retailers, leading to an increasingly fragmented retail fabric.

The contraction is particularly evident in specific retail segments, with businesses in the "plants, flowers, and gardening supplies" sector experiencing a decline of 28%, while the "other non-voluminous goods" category has seen an even sharper decline of 34%. Conversely, some segments, such as "health and beauty retail," have remained relatively stable, demonstrating that not all retail categories are equally affected.

Also, the reduction is not occurring evenly across the territory. Larger cities (+80.000 inhabitants) have been able to maintain their role as commercial hubs, but other urban centers have faced mounting pressures, with vacancy rates exceeding 25% in many smaller cities. At the same time, peripheral retail zones – typically large-format commercial clusters located near major transportation corridors – have shown relative resilience, maintaining a stable presence despite broader market shifts. In contrast, individual retail units located outside of structured shopping environments, particularly those in dispersed locations without clear agglomeration benefits, have been vulnerable to closure.

4.2 Growing floor space: food retail thrives

In contrast to the decline in the number of retail outlets, the total retail floor space in Flanders increased by 9% between 2009 and 2023. The floor space actually in use also grew more modestly, by 4%. This expansion was mainly realized between 2009 and 2013, after which total retail floor space stagnated. When vacant spaces are excluded, a slight reduction of -1.4% in retail floor space is observed from 2013 onwards.

The most notable exception to this trend is food retail, which has experienced a significant expansion of +22% over the same period. Unlike other retail categories, which have seen fluctuations in floor space usage, food retail has been on a steady rise, with an increase of 508,000 m² since 2009. This growth can be attributed to a highly competitive supermarket sector, characterized by an influx and of international chains and an ongoing so-called “supermarket war” (see for instance Cardinaels et al. 2023; Van Lier 2023; Fockedey 2025).

The number of supermarkets per 10,000 inhabitants in Belgium has grown by 50% in the past decade, reaching an average of 3 per 10,000 inhabitants. The most densely covered region, Mesen, now has one supermarket per 1,074 inhabitants. The rapid expansion of supermarket chains is largely driven by two factors: spatial planning and consumer behavior (De Smet 2023). In contrast to the Netherlands and France, where urban areas are denser, Belgium’s more dispersed population means that 6.72% of households still need to drive more than five minutes for groceries, compared to just 4.40% in the Netherlands. This reflects an opportunity for further expansion. Additionally, Belgian consumers tend to shop at multiple supermarkets, fostering the clustering of different chains in close proximity. The strategic positioning of supermarkets as "perfect neighbors" (Dumont 2015, Husslage 2021) can boost store's revenue by up to 20%.

However, while food retail continues to thrive, the supermarket sector is under increasing economic pressure. The fierce price competition, marked by discount wars and aggressive expansion strategies, has resulted in narrowing profit margins. Reports indicate that net profit margins in Belgian supermarkets have halved since 2018, dropping to 0.9% in 2024. This "race to the bottom" has led to bankruptcies (Makro), takeovers (Mestdagh), and financial struggles for multiple chains, highlighting the unsustainable nature of continued expansion in an already saturated market and a shrinking retail landscape.

4.3 A More Dispersed Spatial Pattern

Although the Flemish government introduced the Decree on Integrated Retail and Commercial Establishment Policy in 2016 with the aim of consolidating retail functions within designated commercial areas, our findings suggest that the process of retail decentralisation has continued unabated. The period between 2009 and 2023 was characterized by (a shrink of retail and) a steady outward shift of retail activity. Rather than concentrating in well-defined urban cores, commercial functions have increasingly spread across

the landscape, finding new footholds in suburban developments, peripheral retail clusters, and mixed-use peri-urban environments outside traditional shopping streets.

One key driver of dispersion seems to be that establishing a new location is often cheaper and more attractive than reusing vacant retail spaces in core areas. High vacancy rates in traditional commercial centers suggest that many businesses prefer moving to peripheral locations rather than adapting existing spaces. Additionally, a significant share of new establishments has emerged in areas that were not commercial zones in 2009 but have become so by 2022. These areas tend to be well-connected by car, reinforcing the role of car accessibility in business location decisions.

While urban sprawl in Flanders is a long-term trend, retail continues to expand into areas that were classified as open space in 2013. Our analysis shows that particularly small-scale commercial and service points have increasingly located in areas that were previously not part of the urban footprint but were nevertheless classified as buildable. The slow but steady expansion into these areas contributes to a more dispersed pattern, making it harder to reverse the trend of land consumption.

4.4 The Role of Mobility

A key consequence of retail dispersion is the expansion of service areas, with businesses attracting customers from greater distances. Data shows that travel distances for essential services like food retail have increased, with more people traveling over 5 km to reach a store. This trend is even stronger for businesses specialising in personal and voluminous goods, where service areas exceed 10 km. Car dependency remains a major factor, undermining sustainable urban planning efforts.

To assess mobility's role in retail evolution, we combined spatial analysis with case studies of mobility interventions across various urban contexts. Regression models confirmed car accessibility as a dominant structuring factor, correlating with service area size and retail floor space. We also analyzed multimodal accessibility indices (Mobiscore) and mobility policies to evaluate their impact on commercial dynamics.

The findings highlight that retail dispersion remains closely tied to car dependency. Over the past decade, service areas have expanded significantly, particularly for food retail and voluminous goods. Peripheral retail locations continue to attract a regional customer base, often exceeding expected retail floor space based on local population density. While urban cores still concentrate retail functions, suburban and peripheral clusters are growing faster.

A case study of 10 mobility interventions in Flanders revealed mixed results. In large urban centers, measures like pedestrianisation, cycling infrastructure, and circulation plans improved accessibility but had limited impact on consumer behavior, as car access remains crucial. Secondary urban centers and suburban shopping areas show even stronger reliance on automobiles, with mobility policies having minimal effect on footfall. In peripheral retail zones, car-based accessibility dominates, and policies primarily focus on optimising road infrastructure rather than promoting alternative transport modes.

These findings suggest that while mobility measures can enhance urban retail environments, they are insufficient to counteract broader structural trends driving retail expansion in suburban areas. The persistent reliance on car access underscores the need for integrated spatial and mobility planning, where accessibility policies align with land-use regulations and economic incentives. Without such coordination, mobility measures risk reinforcing retail dispersion rather than reversing it.

4.5 COVID-19 and its consequences

Since 2019, retail dynamics in Flanders have accelerated, with vacant retail space increasing by 45%, peaking in 2020-2021. Core retail areas saw a 6% decline in total floor space, while peripheral retail zones remained stable, indicating that commercial losses have primarily impacted urban centers.

So arguably, the COVID-19 pandemic played a critical role in amplifying ongoing trends. First, the rapid expansion of online shopping, combined with shifting consumer routines, accelerated the decline of physical retail in dense urban areas. Lockdowns and social distancing measures in 2020-2021 triggered an unprecedented surge in e-commerce, reinforcing behavioral changes that persisted even after restrictions were lifted. The convenience of digital platforms, coupled with the rise of hybrid work arrangements, further reduced footfall in traditional retail districts. As a result, many businesses closed, unable to justify the high fixed costs of a physical storefront in locations that no longer guaranteed the same level of customer flow.

Second, the resilience of peripheral retail areas suggests that the pandemic reinforced an existing spatial imbalance. While core districts lost floor space, suburban and outlying retail zones remained stable, benefiting from car accessibility and proximity to residential areas. The rise of hybrid shopping models, particularly the adoption of Buy Online, Pick Up In Store (BOPIS), has also favored retailers in suburban locations with ample parking and logistical advantages.

The hospitality sector presents a more complex pattern. Initially, restaurant and bar openings continued their growth trajectory post-lockdown, contributing to a perception of resilience. However, from 2022 onward, the number of hospitality venues has started to decline. While overall revenues in the sector increased by 13,2% in 2023, this expansion has not translated into sustained business growth. Rising costs, shifting spending patterns, and teleworking's impact on lunch and after-work dining likely contributed to this correction.

While the exact causal impact of COVID-19 on these developments remains difficult to quantify, the pandemic clearly acted as a catalyst for pre-existing retail and spatial trends. The contraction of urban retail, stability of peripheral zones, and hospitality sector volatility were already underway but became more pronounced after 2020. These shifts highlight the need for strategic planning that addresses decentralisation and evolving consumer behavior. The long-term implications remain uncertain, but the observed patterns suggest a continued need for strategic planning that takes into account the reinforced dynamics of decentralisation and changing consumer behavior.

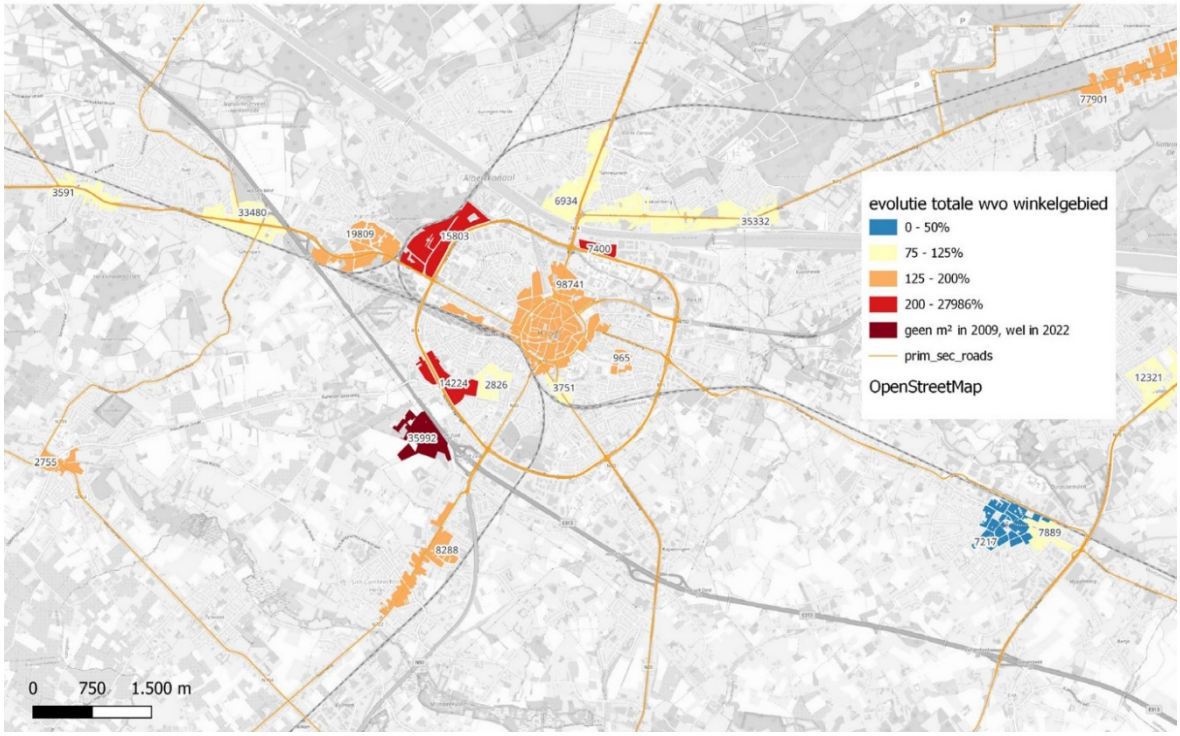


Figure 2: Evolution of Retail Floor Space in Shopping Areas 2009-2022 (Locatus, Adjusted) – Hasselt

5 CASES

5.1 Hasselt's Blue Boulevard

Hasselt is a mid-sized city Flemish city (+80,000 inhabitants) and the capital of the Belgian province of Limburg (900,000 inhabitants). The city has a commercial mix of retail, service industries, and education as economic drivers. Furthermore, it is known for its low-traffic historic city center (area inside the Green Boulevard (R70), see Figure 2), which enhances the pedestrian-friendly environment. In 2020, the city of Hasselt opened the residential and retail development Quartier Bleu just outside the historic city center– designed as "a vibrant waterfront district", combining 412 residential units, 22,500m² of retail floor space, and 3,000 m² of hospitality space. The aim of the project was, as stated by one deputy mayor, 'to attract shoppers and tourists, so they can enjoy not only the city center but also Quartier Bleu' (Donné, 2020). The opening of the underground, multi-storey car park Blauwe Boulevard (Blue Boulevard) was also part of the development. With three levels and 1,801 parking spaces, Parking Blauwe Boulevard was constructed as the

largest parking facility in Hasselt, designed to serve as a parking area for visitors to the entire city center. Favorable relative prices were intended to support this function of the Blauwe Boulevard. The hourly rate was set at €1.50, with a maximum daily rate of €10, far below the price of the four other parking garages in and around the city center, where the daytime rate is €2 per 45 minutes and €16 per day.

The impact on the city was apparent even before opening: AS Adventure, Media Market, C&A, H&M, JBC and Pronti all anounced they would leave the city center in favour of the Quartier Bleu, where they found larger retail units and 'could install innovative retail concepts.' The City did not fear increased vacancy rates, as (a few) newcomers had already announced their arrival in the newly available spaces in the city center. However, they had not accounted for the overall contraction of the retail sector.

Our data analysis revealed the following evolutions inside the city center (over the period 2009-2023):

Product category	2009	2013	2016	2019	2023	Difference (%)
Vacancy	58	105	121	128	169	+191.4%
Food	48	52	54	46	47	-2.1%
Personal Equipment	315	311	285	256	225	-28.6%
Plants, Flowers, and Agricultural Goods	4	3	3	3	4	0.0%
Transport Equipment	1	0	0	1	2	+100.0%
Other Voluminous Goods	8	5	6	4	7	-12.5%
Other Non-Voluminous Goods	105	101	83	66	76	-27.6%
Fuels	0	0	0	0	0	0.0%
Services	107	140	159	164	174	+62.6%
Hospitality	142	167	183	206	224	+57.7%
TOTAL OCCUPIED	**730**	**779**	**773**	**746**	**759**	**+4.0%**
TOTAL (VACANT + OCCUPIED)	**788**	**884**	**894**	**874**	**928**	**+17.8%**

Table 1: Evolution of Retail Units per Product Category, Hasselt City Center (2009-2023)

While the total number of outlets increased by 17.8%, the number of occupied retail points remained nearly stagnant, showing only a minor growth of 4.0%. At the same time, the number of vacant properties saw a dramatic rise of 191.4%. Certain product categories, such as food (-2.1%), personal equipment (-28.6%), other voluminous goods (-12.5%), and other non-voluminous goods (-27.6%), experienced a decline. Conversely, there was notable growth in transportation and transport equipment (+100%), services (+62.6%), and hospitality (+57.7%), particularly after 2021. Categories such as plants, flowers, and agricultural goods, as well as fuels, remained stable.

Product Category	2009	2013	2016	2019	2023	Difference (%)
Vacancy	5,594	12,386	16,807	20,329	32,099	+473.8%
Food	5,025	4,000	4,719	4,812	7,167	+42.6%
Personal Equipment	48,394	52,786	59,839	58,094	54,385	+12.4%
Plants, Flowers, and Agricultural Goods	200	165	269	269	409	+104.5%
Other Voluminous Goods	1,055	2,979	3,038	1,225	1,309	+24.1%
Other Non-Voluminous Goods	20,432	19,950	15,959	11,994	16,809	-17.7%
TOTAL OCCUPIED	**75,106**	**79,880**	**83,824**	**76,394**	**80,079**	**+6.6%**
TOTAL (VACANT + OCCUPIED)	**80,700**	**92,266**	**100,631**	**96,723**	**112,178**	**+39.0%**

Table 2: Evolution of Retail Floor Space per Product Category, Hasselt City Center (2009-2023)

The total retail floor area in Hasselt's city center expanded by 39.0%, with occupied space increasing by 6.6%. The number of vacant square meters grew even more significantly than the number of vacant properties, rising by 473.8%, indicating that larger retail spaces remained empty, particularly after 2017 and during the COVID-19 pandemic (2019-2021). In terms of retail floor space, food (+42.6%), personal equipment (+12.4%), plants, flowers, and agricultural goods (+104.5%), and other voluminous goods (+24.1%) saw increases, despite some experiencing a decline in the number of outlets, suggesting a trend toward larger retail units. Meanwhile, other non-voluminous goods showed a decrease in floor space (-17.7%), with fewer but larger outlets persisting.

Overall, the increase in retail units and floor space has led to an enhanced pressure on the city's retail structure. Most product groups have remained stable or grown slightly since 2020. Hospitality remains a key strength in Hasselt, growing steadily since 2013, and since 2020 supported by the new major hospitality strip at Quartier Bleu. However, despite the significant retail space expansion at Quartier Bleu, modest growth in most sectors has resulted in a significant vacancy increase since 2020–a trend which was probably strengthened by COVID 19 and its consequences (see 3.5). As passerby counts from 2021 and 2023 (Locatus) indicate increased foot traffic around Hasselt's major parking lots (Blauwe Boulevard and

Molenpoort) and slight declines in other shopping streets, the impact of the Quartier Bleu development cannot be ignored.

5.2 Core-periphery dynamics in the city of Ostend

The case of Ostend clearly illustrates core-periphery dynamics per product group for the period 2009-2022. Ostend is a very didactic example, because due to its hard borders north- (the North Sea) and eastside (the Bruges-Ostend canal) of the city, it has only one large peripheral retail cluster. So, in this case, the competitive dynamic between urban districts and single peripheral location remains unaffected by competition between multiple peripheral retail concentrations.

Figure 3: evolution food retail shopping areas 2009-2022 (%, Locatus) – Ostend

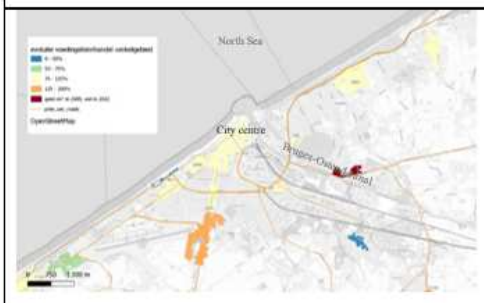


Figure 4: retail for personal goods shopping areas 2009-2022 (%, Locatus) - Ostend

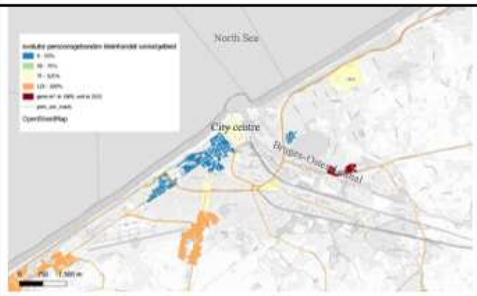


Figure 5: Voluminous goods, 2009-2022 (%, Locatus) - Ostend

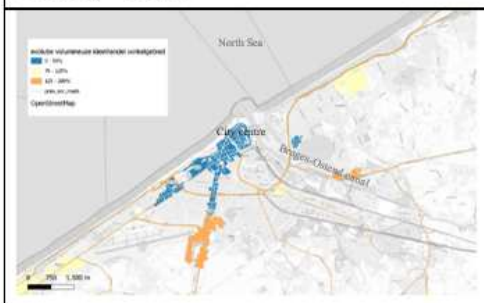
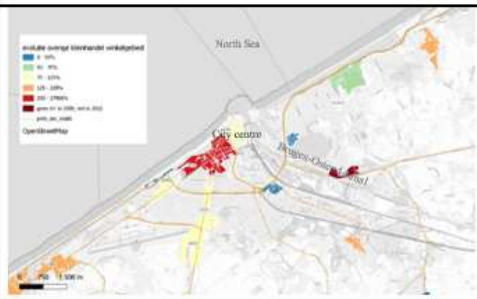


Figure 6: Other non-voluminous goods, 2009-2022 (%, Locatus) - Ostend



While food retail remains stable in urban areas, it has experienced significant growth in the periphery. In the city center, food retail covers 1,900m², whereas in the periphery, this figure reaches 8,700m². Personal care retail remains strong in the city center (18,368 m²), shrinks significantly in peri-urban shopping areas, and grows in the periphery (21,769 m²). Retail in voluminous goods has almost entirely disappeared from the city center and peri-urban shopping areas, while it has expanded to 32,118 m² in the peripheral cluster. The product category 'other non-voluminous goods' remains stable in the city center (5,208 m²) and the periphery (8,692 m²) but shows strong growth in peri-urban shopping areas (7,139 m²). In other larger cities, we saw similar patterns, with peripheral retail growing while the city center stagnates or contracts.

5.3 Shifting retail dynamics

The cases of Hasselt and Ostend both show a shift in retail dynamics between city centers, peri-urban areas and periphery. The city center remains relatively stable in both cases, despite challenges such as vacancy and changing shopping behavior. The differences lie mainly in the growth of the secondary peri-urban areas and periphery. In Hasselt, crowds are shifting to parking zones, while some shopping streets are becoming less popular. Ostend has a different dynamic: the core remains stable, but the periphery is growing strongly in food and personal retail, partly due to geographical features such as the coast and the canal.

6 CONCLUSION

Despite regional (Decree on Integrated Retail and Commercial Establishment Policy) and local (mobility interventions) policy efforts to strengthen urban cores, our findings indicate that core-reinforcement policies have had little to no impact on reversing retail decentralisation – in some cases, they may have even accelerated it. The case of Hasselt, where the Quartier Bleu development and associated mobility interventions ultimately drained retail activity from the city center rather than reinforcing it, closely mirrors

the Oberhausen experience in Germany. This highlights the structural limitations of policies aimed at revitalizing historic retail centers in the face of powerful suburbanizing forces. Notably, the rapid evolution of retail dynamics over a relatively short period (2009–2023) suggests that spatial transformations are accelerating, further challenging the effictiveness of existing interventions.

These trends can largely be explained by three interrelated mechanisms: (1) the long-term decentralisation of economic activity, which has progressively shifted commercial functions away from historic centers (cf. secular suburbanisation); (2) the cost, logistic and regulatory advantages of peripheral retail locations; and (3) shifting consumer mobility patterns, where car accessibility remains a key determinant of retail success (e.g. BOPIS). While policymakers advocate for a renewed strengthening of urban cores, contemporary retail concepts no longer prioritize such urban locations. Instead, businesses seek sites that maximize convenience, logistical efficiency, and consumer accessibility, thus reinforcing suburban expansion rather than reversing it.

For core-reinforcement strategies to be effective, they must fundamentally shift the cost-benefit calculus for businesses and consumers in favor of central locations. This requires not only incentives for urban retail but also targeted disincentives and restrictions on peripheral expansion. Given the structural drivers of suburbanization, addressing the challenges of suburban retail decentralisation requires a multifaceted approach, integrating spatial planning, economic incentives, and mobility strategies. Without coordinated action, urban core revitalisation efforts risk being undermined. Future research should explore policy interventions that proactively tilt the cost-benefit equation in favor of central retail locations ex ante.

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reviewed paper

The Arnstein Gap: Twenty Years On, What has Changed?

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1 ABSTRACT

At REAL CORP 2006 authors Bailey and Grossardt introduced the Arnstein Gap. Pioneering the use of Arnstein's Ladder of Citizen Participation (1969) as a direct gauge, they measured the perception of two key levels of public involvement – the experienced and the desired – using anonymous real-time polling in planning at professional forums and open public meetings in the U.S. Since beginning this protocol in 1999, Bailey and Grossardt had already amassed a database spanning numerous meetings from which they adduced four principles of public involvement. By aggregating these data and mapping the difference between the two measurements, they illustrate a predictable difference between experiences and expectations for specific groups, as well as between groups such as planners and citizens. Beacuse this difference is measured directly using Arnstein's ladder this is defined as the Arnstein Gap. In the following years, including at subsequent REAL CORP conference (2007) as well as in various journals (e.g. Bailey and Grossardt 2010, Bailey et al 2011, Bailey and Grossardt 2015), the authors continued building the Arnstein database and conducting measurements in a number of US states as well as internationally in countries ranging from Japan, Singapore and New Zealand, to Romania, and Costa Rica and Colombia. Since 2005 other researchers have adopted this framework and applied it during their work, adding to the knowledge base (e.g. Wood 2015, Weymouth and Hartz-Karp 2019, Weymouth et al. 2020).

This article summarizes this work across the temporaral perspective of twenty years and a strongly international geographical range, spanning more than twenty-five countries where such measurements have been conducted. This review in combination with extensive raw stakeholder data obtained by the authors at numerous planning forums, shows that the key Arnstein Gap measurement remains remarkably consistent across time, and that although there are variations in the baseline perceptions of public involvement, depending on local planning experiences, methods, and outcomes and leading to variations in the documented magnitude of the Arnstein Gap from almost four rungs at maximum (Romania, Colombia) to less than two rungs at minumum (Vienna), the desired level of "partnership or level six on the Ladder, is remarkably consistent. These easily-obtainable data present significant implications for planning professionals in both the theory and practice of urban planning. For example, professional assumptions about citizen expectations and perceptions of public involvement may not be shared by the citizens, and that effective planning in the face of a large documented Arnstein Gap (> 3 rungs) presents different challenges and requires a different set of methodologies and practices than in cases where the measured Gap is smaller.

Keywords: Methodology, Planning, Citizen Participation, International, Arnstein Gap

2 THE ARNSTEIN LADDER

Sherry Arnstein's seminal paper "A Ladder of Citizen Participation" published in the Journal of the American Institute of Planners (Arnstein 1969) is one of – if not the single – most influential article(s) in the field of planning. Arnstein characterized proportions of expert to citizen control over planning using an eight-step ladder as a heuristic, with each rung from Level 1 to Level 8 corresponding to increasing proportions of citizen control with corresponding reduced proportions of expert control. She applied descriptive terms to describe each Level on the Ladder, from "Manipulation" through "Therapy" and "Consultation" all the way to "Citizen control." This formulation is widely regarded as simple and efficient in terms of characterizing binary decision control proportions (e,g Contreras 2019).

2.1 Limitations of Ladder

Arnstein (1969:217) was cognizant of the limitations of this heuristic. "The justification for using such simplistic abstractions is that in most cases the have•nots really do perceive the powerful as a monolithic 'system,' and powerholders actually do view the have-nots as a sea of 'those people,' with little

comprehension of the class and caste differences among them." The authors have almost never encountered any public confusion about the terminology used by Arnstein at open public meetings, however, in scholarly circles there has been more debate about both the intelligibility of the scale and the value-laden descriptors. For instance, Fung (2006:67) argues that Arnstein's Ladder "improperly fuses an empirical scale that describes the level of influence individuals have over some collective decision with normative approval." If so, this means different things to different people and it is not clear where such normative approval is centered.

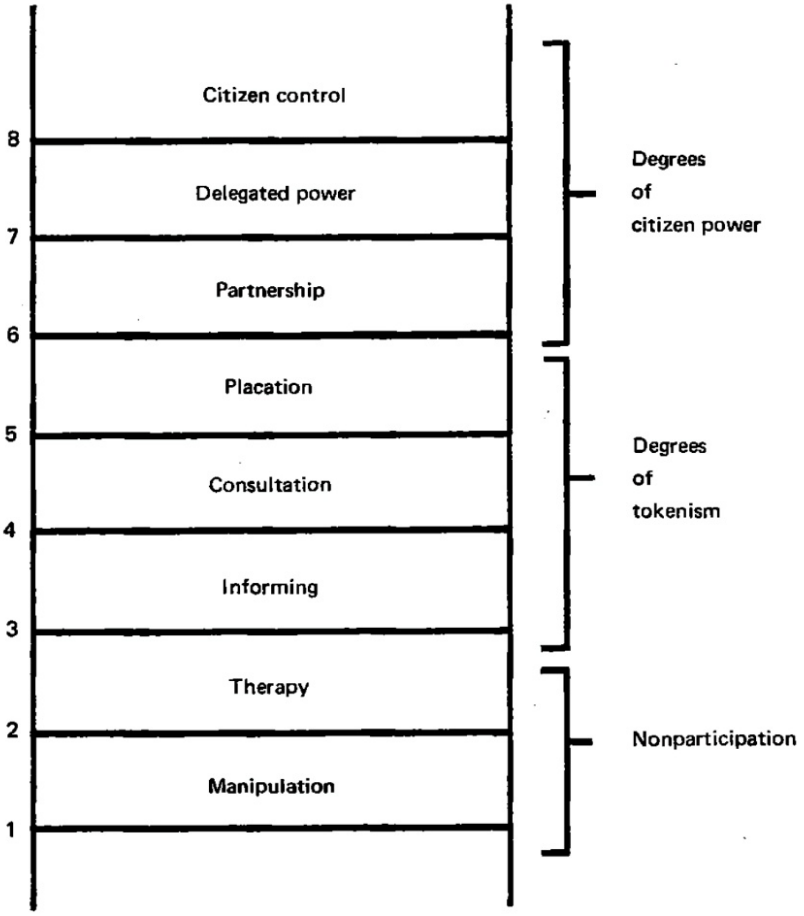

Figure 1. The Arnstein Ladder (Arnstein 1969).

2.2 Impact of Arnstein's Ladder

During the subsequent fifty-plus year period the professional impact of her work has become increasingly evident in the profession and beyond, via planning syllabi, training workshops, repeated scholarly efforts to enhance and extend the concept (Connor 1988, Karner et al. 2019), and the use of the Ladder by researchers in cognate fields to characterize public involvement (Flinders and Dommett 2013, Nandigama 2020). By February 2025, Google Scholar listed 35,444 citations for her paper. This scholarly impact places Arnstein in elevated company among social scientists broadly writ; David Harvey's 1974 classic "Population, Resources and the Ideology of Science" registered 849; Alan Sokal's 1996 parody "Towards a Transformative Hermeneutics of Quantum Gravity" 2,219 cites. Arnstein's citation impact is greater than even books by renowned authors such as Being Digital (Negroponte 1995) at 12,582 and Manufacturing Consent (Herman and Chomsky 1988) at 13,577. For perspective, Constitution of Society (Giddens 1984) registered 72,849 cites and A Theory of Justice (Rawls 1971) shows 121,450.

2.3 Origin of the Arnstein Ladder database

In the late 1990s, authors Keiron Bailey and Ted Grossardt encountered Arnstein's work, with its intuitive graphic and its highly communicable heuristic of a simple ladder representing degrees of power sharing in planning between experts and citizens. The authors were surprised despite numerous claims regarding its applicability (e.g. Cunningham 1972, Kroutil and Eng 1989, Maier 2001 and many more) and efforts to adapt (e.g. White and Langenheim 2022), that no direct use of Arnstein's formulation as a measurement

appeared to have been made by researchers. Over the next five years, the authors used Arnstein's Ladder initially to measure public perceptions of the existing levels of public involvement in various transportation and urban planning projects. This was achieved by showing participants the Ladder, asking them directly at open public meetings at what Level they believed public involvement was conducted and using electronic polling to record their valuations anonymously and in real tme. We then showed the participants their own aggregated data and compared this with data from previous meetings. It became evident from the tenor of the citizens' contributions and post-meeting discussions that this initial measurement only captured a portion of what was important to project sponsors and engineers tasked with creating this infrastructure.

2.3.1 Establishing common ground

Being confronted with various unsupported and often-contradictory assertions about what citizens wanted from public involvement, ranging from "there is a need for planners to advocate for citizen control of the planning process in all contexts" (Silverman et al. 2020:4) to Mayor Cabaldon, quoted by Ehrenhalt (2018) "Public meetings take up huge amounts of time and rarely produce anything of genuine value,"and every position in-between, as well as what planners should do to deliver the putative level, the authors seized upon the obvious; why not keep the Ladder graphic in front of the audience for another few moments, and ask them what they felt would be an ideal level of public involvement? The first few occasions presented a surprise; an almost-complete unanimity in the view that Level 6, "partnership," was ideal. This result was repeated across different projects and different States with what seemed remarkable consistency. The difference between the bar charts of the two polls, the perceived and aspirational Ladder levels, was consistent in sign if not always in magnitude. This pattern became sufficiently established that by 2005 the authors could predict confidently what citizens would poll for the aspirational level. Repetition of this poll at professional forums yielded further insight, in that there were some groups whose perceived Level was higher than the citizens' mean, characterized as "professional conceit" (Bailey et al. 2011).

3 THE ARNSTEIN GAP

Similarly to Arnstein's own goal of creating a simple and accessible indicator, it occurred to the authors that beyond characterizing the magnitude of the difference between participants' current experiences and their desires, this difference could itself serve to mobilize better participatory planning in a measurable way; i.e. closing, or at least reducing, the measured gap within the realistic context of the project at hand becomes a goal of the public involvement process. Reflecting on the increasing number of these data sets, the authors formulated the thesis regarding the difference; the Arnstein Gap.

In 2006 the authors introduced the Arnstein Gap at the CORP Geomultimedia conference (Bailey and Grossardt 2006). Over the subsequent two decades the authors have worked on a number of planning and infrastructure projects in the US as well as attending numerous professional conferences and hosting workshops in the fields of planning, transportation and environmental management in more than twenty-five countries. The authors have amassed the largest Arnstein Ladder database in publication, with numerous articles detailing Arnstein Gap measurements in projects from nuclear plant visioning (Grossardt et al. 2010); context-sensitive bridge design (Grossardt et al. 2007); transit-oriented development (Bailey and Grossardt 2007); integrated transportation and land-use planning (Bailey et al 2011); environmental justice work (Bailey et al. 2012); and many more.

In search of what Connelly et al. (2021:5) term "good translation" between academe and professional planning domains, this article reviews almost twenty years of research to detail national and international consistencies in Arnstein Ladder levels, to examine what has changed since the original presentation in 2006 and what durable lessons may be learned, as well as point to future research in planning.

3.1 Internationally Consistent Features of the Arnstein Gap

3.1.1 Desired Arnstein Ladder Levels

The desired Arnstein Ladder levels remain remarkably consistent, with more than 96 percent of all respondents selecting Level Six across more than eight thousand responses in twenty-four different countries since 2005. This is consistent across international contexts. For example, the chart below shows the results of Arnstein Ladder polling conducted in Hachioji, Japan in 2019 and Auckland, New Zealand in 2023.

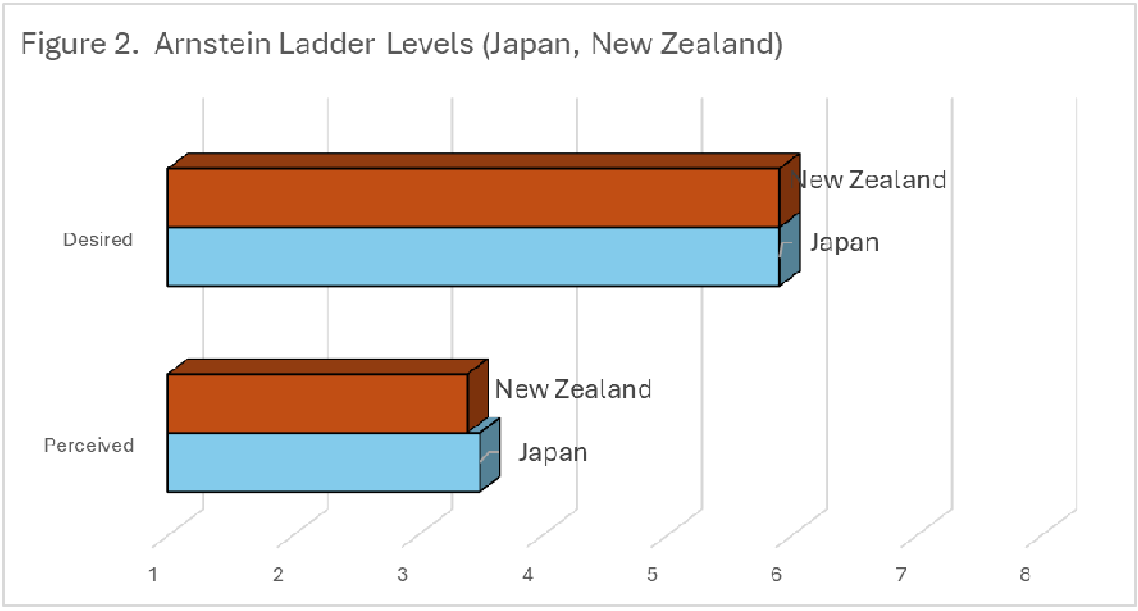

Figure 2. Arnstein Gaps in Japan and New Zealand

These results are consistent with previous forums in Argentina, Australia, Brazil, Bulgaria, Canada, Colombia, Costa Rica, Hong Kong, Netherlands, Peru, Portugal, Romania, Singapore, Spain, Taiwan, and United Kingdom. While sample sizes have varied, these levels can be predicted with sufficient confidence globally that, for example, one seminar participant in New Zealand (2023) remarked "Thank you for sending over the result as you expected and explained in the lecture. It feels like magic even with such a small sample and large margin of error."

3.2 Highest Perceived Levels and Smallest recorded Arnstein Gap

The polling conducted by the authors at CORP in Vienna in 2007 remains the only set obtained from Austria and includes approximately sixty respondents from two forums. The mode response was Level Four with few at Level Three or lower. The mode response for desired level was Level Six although there were some at Level Five. Nevertheless, this set generated interesting discussion because this represents both the highest perceived Ladder level we have measured in any of these open polls and the smallest Arnstein Gap, of just over two Levels.

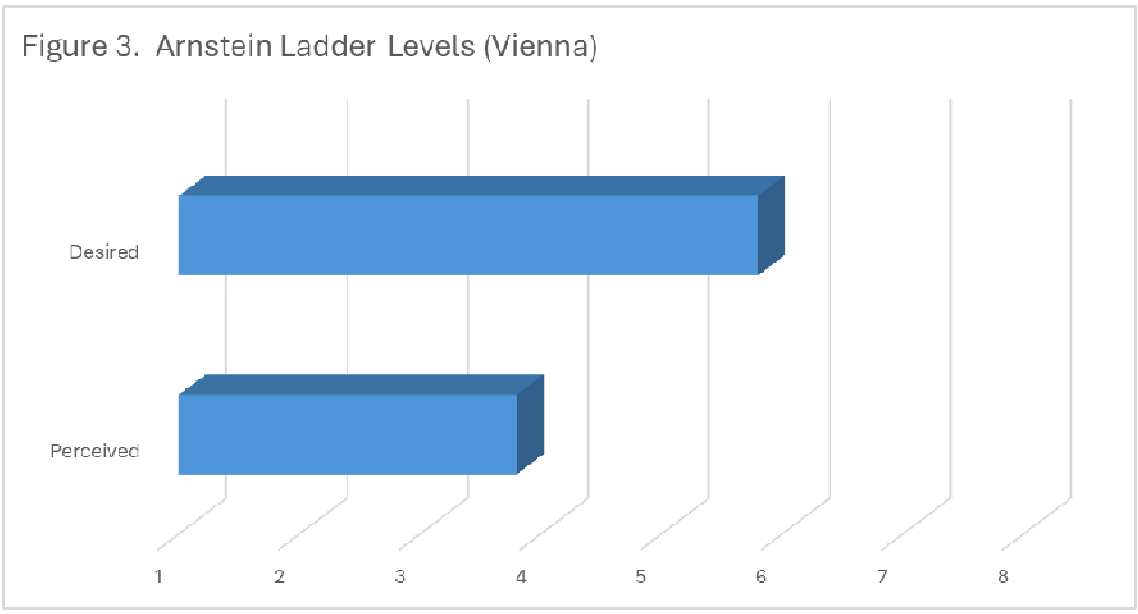

Figure 3. Arnstein Gap in Vienna

Although it would be a reach to link this small sample data set directly to the title of "World's Most Livable City" bestowed on Vienna repeatedly by the Economist Intelligence Unit (EIU 2023), the potential

connections between smaller Arnstein Gaps and higher citizen perceptions of urban functionality and environmental quality merit closer investigation.

3.3 Highest and Lowest Perceived Levels

Most forums have generated results with mean perceived levels between 2.8 and 3.4. Results of less than 2.8 are unusual. At the forums in Bucharest (Academy of Economic Sciences) and Bogota (Universidad de los Andes), both numbering approximately fifty attendees of whom some were students and faculty and some were professionals and planning officers, the means were 2.2. The mode response was Level Two and there were few of Level Four or above. When shown the international data sets and asked for reasons for their valuations, respondents noted authoritarian regimes and in the case of Bucharest, a crisis of perceived civic capacity rooted in either direct experience of, or family communication about, the Ceausescu era and the legacy (Ianos et al. 2017). In Bogota there was a measure of agreement that the results were consequent to the approach of a specific Mayor. It is worth noting that institutional provisions and high-level mandates for participation do not appear to bear any relationship to the observed Arnstein Ladder levels. The 1991 Colombian Constitution enshrines participatory rights to an uncommon degree globally and citizens are demonstrably prepared to exercise these rights (Shenk 2022).

The lowest perceived Arnstein Level from a professional group was the set obtained from the U.S Department of the Interior in 2011, where the professionals' perception of the Level of public involvement was lower than the citizens and from where the Gap to the normal desired Level Six was relatively large. A discussion was held using other Arnstein data sets to facilitate understanding, and the participants explained that all field managers had spent several years in regional offices before rotating to DC headquarters, and that the context of their work on highly-contentious land management issues, undertaken in partnership and sometimes conflict with sovereign native nations, mitigated against unrealistic beliefs or wish fulfilment regarding the quality of citizen involvement.

3.3.1 Lowest recorded Perceived Levels in project meeting

The lowest Ladder levels at any individual forum were obtained at Paducah, Kentucky, during the authors work on the Paducah nuclear plant's end-state visioning process. There were few participants, less than ten, but everyone polled Level One (Blandford et al. 2011). This discovery prompted a methodological re-evaluation for the public involvement process, with knowledge gaps being addressed by a game-show event prior to scenario evaluations being conducted. The profound overall lack of confidence cannot be solved by a set of planning meetings, no matter how well-designed and conducted, but every action has the potential to increase attendance and thereby increase the quantity of stakeholder-sourced data. In this case a snowball effect was observed with increasing attendance at later meetings as well as high satisfaction scores from those who attended. Similar effects have been observed in other projects conducted by the authors.

3.4 Challenges in measuring Ladder levels

Outside of the authors' work, others have applied the concept (AbouAssi et al. 2013). Weymouth and Hartz-Karp (2019) conducted a detailed investigation in urban planning projects in Western Australia. Wood (2014) attempted to conduct such polling during a Kansas City streetcar project. He discovered that "While both parties expressed an early eagerness to contribute to this project and to find ways to improve the city's public participation strategies, complications soon arose. The Streetcar project staff requested that I rephrase the questions relating to past transit proposals to more explicitly imply that the city had always taken public participation as seriously as it did in 2014, a notion I knew from my research to be patently untrue. Later, city officials were shown a copy of the original survey, and they asked me to change the wording of Arnstein's Ladder so as to not "give participants the idea that their government could ever be less than democratic," or in other words, to remove the lower half of the Ladder from the survey. I objected to both of these requests on ethical grounds, and was told that without approval from the city government, I would not be permitted to conduct a survey during one of their public meetings. Consequently, the overall direction and research questions of this thesis had to be adjusted, and a new survey approach had to be undertaken. I found these attempts at censorship troubling but also informative, especially considering the original intent of this thesis was to examine the ways city planners can influence public opinion."

The authors have not experienced exactly what Wood describes but we have certainly encountered reluctance from project management and sponsors to conduct such polling a priori. In our case after early

results were published, working with civil engineers resulted in more rapid agreement to poll because the value of published data and the data-driven methodological connection between Arnstein Gap measurements and selection of public involvement methods to reduce the chances of project failure and/or mass rebellion became clear to project sponsors and managers (Grossardt et al. 2008).

4 THE T- AND C-WORDS IN PLANNING

The word "trust" is often used in planning research and workshops to characterize a desirable process quality and even sometimes as a direct goal of public involvement (Laurian 2009). The artificial presumption – even appropriation – of intimacy by functionaries in a publicly-funded process is problematic for many reasons. The authors fundamentally disagree with such terminology. Planners are not friends of, or in an emotionally-reciprocal relationship with, the citizens and stakeholders whose public meetings they run and whose monies pay for the projects. Planners can conduct effective public meetings with inclusion, respect, and a measure of agreement on outcomes as well as agreement to disagree on valuations.

"Consensus" is another often-used (Innes 2004) and problematic term (Woltjer 2000, Kaza 2006). What does this mean, and to whom? Who should be silenced or excluded in pursuit of such definition?

Reducing the Arnstein Gap is not a matter of building "trust" or achieving "consensus." It is a matter of delivering good quality public involvement, increasing stakeholder confidence in time and resource investment, and thereby facilitating the universally-aspirational partnership between citizens and professionals that delivers useful planning products such as safer, more efficient, more environmentally sound urban systems and spaces. Yet the Arnstein Gap remains the same, and there is work to do.

4.1 Beyond "trust"; reducing the Arnstein Gap

Arnstein (1969:224) addresses the complexities of Level Eight, citizen control, thus: "Among the arguments against community control are: it supports separatism; it creates balkanization of public services; it is more costly and less efficient; it enables minority group 'hustlers' to be just as opportunistic and disdainful of the have-nots as their white predecessors; it is incompatible with merit systems and professionalism; and ironically enough, it can turn out to be a new Mickey Mouse game for the have-nots by allowing them to gain control but not allowing them sufficient dollar resources to succeed."

Citizens may recognize these ideological and practical difficulties and, as the data show, strongly and consistently prefer Level Six i.e. Partnership (Grossardt and Bailey 2018). The authors' extensive results are supported by the small number of other studies that have performed similar direct Arnstein Ladder measurement, e.g. despite survey difficulties, Wood (2014:82) found that 74 of the 87 respondents in a Kansas City streetcar project selected "partnership" as the desired level, and Weymouth and Hartz-Karp (2019:6) found that "The WA [Western Australia] city-region's community assessment of the current level of participation with their government very closely resembled the findings by Bailey et al. in the US."

But if Level Six is so universally desired by citizens and professionals, as all the data suggest, what is preventing this confluence of interests? Arnstein (1969:222), in her own exemplification of Level Six of her Ladder, proposed: "In most cases where power has come to be shared it was taken by the citizens, not given by the city." While this phrasing may convey the revolutionary tenor of the late 1960s, the authors are sympathetic to this view based on what they have observed during polling at hundreds of meetings and how fear of citizen control – a goal neither planned nor desired during these processes – has sometimes contaminated experts' willingness to listen and include citizen valuations.

If Level Eight, citizen control, is a goal specified by almost nobody, and if as Wang and Chan (2020:1) observe; "the Arnstein gap can seldom be filled in cases where there are divergent interests and differentiated power"; then the thorny question of how participatory planning processes acknowledge and handle inevitable power differentials without seeking or moving for citizen control is central to improving the quality of participation from the near-universal lower Levels to the universally-desired Level Six, Partnership.

5 CONCLUSION: THE ARNSTEIN GAP, TWENTY YEARS ON

Evidently, the Arnstein Gap did not appear at the moment the authors characterized it. Arnstein's original article was motivated in the first instance by her own considerable skepticism of the efficacy of public involvement she observed and experienced in the 1960s, with her narrative capturing differences between

professional and citizen expectations and practices. Reflecting on Arnstein's Ladder thirty-eight years after its publication, Mees and Dodson (2007:35) observed "Meaningful public participation in urban planning remains an elusive goal despite decades of rhetorical commitment by decision-makers." The authors' near-two decades of Arnstein Ladder data collection since then reinforces this point. What Krek (2005) termed "rational ignorance" of citizens i.e. intelligent individuals logically electing nonparticipation because of perceived input/output process investment imbalances and lack of process utility, remains a daily practice all over the world. This is despite enormous celebration during the last fifteen years of the potential of social media, online participation platforms and other technologically-driven data-collection methods that promise to revolutionize participation, always with the chimera of more fidelity under the umbrella promotion of rather vague democratic ideals.

The Arnstein Ladder database prompts useful deductions regarding planning desiderata and practice; for instance, these data show that complete redistibution of decision-making power (Level Eight) is neither desired nor – therefore – useful in delivering improved planning processes (Tritter and McCallum 2006), but these data also show that the perceived Levels are invariably substantially lower than participants desire. Moreover, because these data show that both professionals and citizens aspire to the same Level Six, Partnership, (Bailey et al. 2011), there is no irreoncilable difference between experts and citizens' desires. Closing the Arnstein Gap is desirable for almost all stakeholders. This suggests the apparently-daunting complexities of immutable power dynamics may be addressed effectively using a methodological approach.

What is needed to reduce the persistent and pervasive Arnstein Gap is closer methodological attention to what Weymouth and Hartz-Karp (2019) term "participatory interventions" in planning processes. By applying this logic during an ongoing regional process, they were able to document a reduction in the measured Arnstein Gap to approximately two Levels or less. They concluded: "These results indicated that the Arnstein gap applied in Australia and America, across regional areas and over time, and that participatory interventions could potentially narrow the gap." (Weymouth and Hartz-Karp 2019:7). To that end, stakeholder-driven performance frameworks for public involvement that set transparent, measurable goals for participation, address the needs of different stakeholders, and within which specific participation methods can be identified, utilized, and sequenced, can maximize overall performance (Bertelsmann Foundation 2010, Bailey and Grossardt 2015, Grossardt et. al 2019).

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reviewed paper

The City as Resilient Organism: the Sustainability Route of Social Innovations and Adaptive Structures for Quality of Life and Social Justice

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1 ABSTRACT

This paper invites you on a sociological journey, conceptualizing cities as resilient organisms and exploring how social innovation and adaptive structures can improve quality of life and promote social justice. Based on the metaphor of the "resilient organism", cities are seen as complex, dynamic systems that must constantly adapt to new challenges. But what makes cities resilient and sustainable? How can they improve the quality of life of their residents and promote social justice? In the light of sociological theories by Luhmann, Lefebvre and Latour, a multi-layered picture of urban resilience emerges. It, the sustainable urban reslience, appears as an emergent property that arises from the interplay of social, ecological, economic and technical factors. Particular attention is paid to social innovations and adaptive structures as the key to renewal and adaptability. Resilience is not a value-neutral concept, but is closely linked to issues of power, participation and justice. The example of medium-sized cities is used to illustrate how a manageable size, strong networks and civic engagement can strengthen resilience. The journey culminates in a plea for resilience research and practice that incorporates sociological perspectives and breaks new ground including interdisciplinary work. The conclusion is that resilience must be measured by whether it enables all city dwellers to lead a good life. It requires adaptive, heterarchic governance, experiments, unusual alliances and a vision of the city as a learning, constantly renewing organism.

Keywords: Sustainability and Justice, Adaptive Structures, Social Innovation, Medium-Sized Cities, Urban Resilience

2 DYNAMIC CITIES AS RESILIENT ORGANIZATIONS

Cities, settlement areas in general, are challenged by climatic, demographic and socio-economic changes and migratory movements. Utopian and dystopian prospects alternate – especially at a time of social upheaval and geopolitical rearrangements. Three things are obvious. Firstly, current developments are serious and are setting powerful forces of transformation in motion – at both global and regional level. Secondly, settlement areas must adapt to changes, and cities even play a central role in the transformation process. Thirdly, the adaptations can be shaped; although not everything can be planned, urban developments are possible that depend on the cities' capacities and abilities to adapt and align the development paths in corridors in the long term. From a sociological perspective, settlement areas – villages, cities and megacities – are dynamic systems that adapt to circumstances and have a lasting impact on living conditions. They can be understood as a "resilient organism".

This is an invitation to a sociological perspective on the understanding of cities and sustainability. The narrative approach invites us to think about cities not only rationally, but also creatively and emotionally. The article begins with the consideration that cities, and in particular the "sustainable city" need a broader concept and therefore draws on the metaphor of "organism" to make the complexity more accessible. Despite being aware of the sometimes misleading conclusions of such a metaphor, a "city" is seen as a "resilient organism" to make a connection to something that everyone intuitively understands – the human body or a living organism. The whole system depends on and exists in many elements (smaller systems). Such imagery not only helps to visualize the complexity of urban systems, but also makes their dynamics, vulnerability and adaptability more tangible. In systems there exist chains-of-causality, i.e. small peaces can break down the general functionality.

In the meantime, initiatives and networks have been established that explicitly address the resilience of cities. The "Resilient Cities Network", for example, has existed since 2013 and formulates urban resilience as "The capacity of individuals, communities, institutions, businesses and systems within a city to survive, adapt and grow no matter what kinds of chronic stresses and acute shocks the experience." (resilientcitiesnetwork, 2025)Resilience is about capacity, capacity building. On the one hand, the connotation of urban resilience is often emphasized in terms of the ability of cities to survive crises and disasters – resilience as a stress test

(e.g. blackout tests). On the other hand, urban resilience is predominantly reduced to ecological, environmental, engineering aspects and challenges – resilience as a technical, infrastructural, structural function.

As a comprehensive concept, urban resilience can be understood as the subject of sociology. In the perspective of urban and spatial sociology (Dell 2023, Friedrichs 1995, Häußermann et al. 2004, Löw 2008) it is deeply embedded in the urban social fabric of cities. The concept of the "city as a resilient organism" emphasizes the interplay of human and non-human actors by applying sociological theories and drawing specifically on the systems theory of Niklas Luhmann (1984), the urban sociology of Henri Lefebvres (1991, 2016) and the actor-network theory of Bruno Latour (2007). The concept of the city as a resilient organism understands the city as an open, dynamic system in which control processes create "states of equilibrium"and as a space of emergent dynamics in which the availability and distribution of opportunities to access resources largely determine how sustainably resilient the city is. Thus, quality of life and social justice become central signposts for how resilient cities are in the long term, in which they manage transformations through permanent renewal and adaptation. Social innovations such as participatory governance and co-living initiatives enable communities to jointly develop solutions to urban challenges. Adaptive structures such as multifunctional buildings and green infrastructure enable cities to respond dynamically to ecological, economic and social changes.

The thesis is also introduced that medium-sized cities in particular serve as laboratories for urban innovation due to their balance between complexity and manageability. Cities of this size in particular are characterized by increased adaptability and a moderate and resilience-promoting ratio of resource availability, regional or local cohesion and manageable structures. They are better able to manage dynamics and implement transformation requirements more quickly and sustainably. So, the argument.

3 URBAN RESILIENCE FROM A SOCIOLOGICAL PERSPECTIVE

Resilience originally means "resistant", "robust" or "adaptable". The term is used in various contexts, for example in ecology to describe the ability of ecosystems to return to a state of equilibrium after disturbances, or the same in engineering, i.e. the ability of technical or infrastructural systems not to fail completely in the event of crises or failures, but to maintain essential system services or quickly restore full functionality. The social sciences understand resilience more broadly as the ability of individuals, communities and systems to cope with adversity, adapt and emerge stronger. A key aspect of the concept of resilience is that it encompasses learning and development skills inherent to the system. Resilience means coping, regeneration, learning and the ability to transform in the sense of long-term regulation and re-stabilization of the system or society.

In the urban context, resilience refers to the capacity of cities to absorb shocks, adapt to changing conditions and transform and thrive in the face of crises (Meerow et al., 2016). Resilience can be understood as a multidimensional concept, with social, ecological, technical and economic aspects. Social resilience in cities refers to the importance of community networks, social capital, participation and equity for the resilience and adaptive capacity of cities. (Aldrich & Meyer, 2014). Ecological resilience refers to the ability of urban ecosystems to maintain essential functions and services in the face of disruption, for example through biodiversity, green infrastructure and sustainable resource use (McPhearson et al., 2016). Economic resilience can be translated into the capacity of urban economies to withstand shocks, recover and transform, for example through diversification, innovation and adaptability (Brinkmann et al., 2017).

Resilience overlaps with related concepts such as sustainability, vulnerability and adaptability (Folke, 2006). Sustainability aims to meet current needs without compromising the ability of future generations to meet theirs (WCED, 1987). While sustainability describes a desirable target state, resilience emphasizes the ability to achieve and maintain this in the face of disruption. Vulnerability refers to the susceptibility of systems to damage from external stressors based on their exposure, sensitivity and coping capacity (IPCC, 2007). Resilience and vulnerability are complementary concepts, with resilient systems being considered less vulnerable. Adaptive capacity refers to the ability of systems to adapt to changing environmental conditions in order to mitigate potential damage and take advantage of new opportunities (Engle, 2011). Adaptability is a central component of resilience. Despite conceptual overlaps, resilience is characterized by its focus on dynamics, uncertainty and transformation. Resilience emphasizes not only resistance and recovery, but also

the ability to emerge from crises stronger and transformed (Keck & Sakdapolrak, 2013). This requires a shift away from understanding urban systems as stable equilibria towards a view of complex adaptive systems on the "edge of chaos" (Folke, 2006).

3.1 Resilience from a systems theory perspective

From a systems theory perspective, cities can be understood as complex, functionally differentiated social systems (Luhmann, 1984). Like biological organisms, they consist of interdependent subsystems such as the economy, politics, law, science and education, each of which fulfills specific functions for the system as a whole. The resilience of the urban system depends on the ability to organize the interactions between the subsystems and to process externally induced irritations. Luhmann (1984) argues that complex systems cope with uncertainty and contingency by reducing complexity. They make selective decisions based on system-internal distinctions and expectation structures. Resilient cities are therefore characterized by flexible, adaptable decision-making structures that allow disruptions to be used as an opportunity for systemic learning processes and transformation. From a systemic perspective, this requires a high degree of "variety" (Ashby, 1956), i.e. a diversity of possible courses of action and functional equivalents. It can be assumed that governance structures that distribute decision-making power and have redundant functions are better suited to this because they react more flexibly to disruptions than hierarchical, centralized systems. Such polycentric or heterarchic governance structures require cross-system communication and cooperation between the subsystems in order to pool resources and enable collective learning processes.

From a systems theory perspective, the development of resilient cities requires a co-evolution of social and physical structures. Technical and structural infrastructures are to be understood as artifacts of decisions that enable certain options for action and exclude others(Luhmann, 1984). In this sense, adaptive infrastructures such as multifunctional buildings and digital platforms are to be understood as "enablings constraints" (Juarrero, 1998) that structure urban complexity and open up spaces of possibility for innovation and resilience.

3.2 Resilience as a dimension of urban space

The French philosopher and sociologist Henri Lefebvre developed an influential theory of the social production of space (Lefebvre, 1991). According to this theory, (urban) space is not a container, but a social construct that is produced and shaped by the space-structuring actions of social actors. Lefebvre distinguishes between three dimensions of spatial production. Firstly, spatial practices, the physical-material production and reproduction of space, for example through urban planning and architecture. Secondly, the representations of space, i.e. the "thought", abstract spatial concepts and discourses as they prevail in science, planning and politics. Thirdly, spaces of representation, i.e. lived space, which is constituted by symbols and meanings and opens up possibilities for resistance, appropriation and alternatives. Lefebvre argues that capitalist modernity is characterized by a dominance of abstract concepts of space that colonize concrete, lived space. Cities are planned as homogeneous, functionally zoned and exchange-value-oriented spaces, which leads to alienation, segregation and exclusion (Lefebvre, 2016). In contrast, Lefebvre formulates the "right to the city" as a claim to participation and appropriation, i.e. the right of all city dwellers to participate in the design of urban space and to use it according to their needs. Lefebvre's spatial theory offers important insights for understanding resilient cities. Accordingly, resilience cannot be reduced to technical and organizational measures, but requires emancipatory urban development "from below".

As Kendra et al. (2008) show in their study on cooperation and improvisation in crises, the local expertise and creativity of residents are often decisive in responding to disruptions in a situational manner. Examples such as the "informal urban development" in Orangi Town (Karachi) through local self-organization (Hasan, 1995) or the participatory reconstruction strategies in New Orleans after Hurricane Katrina (Irazábal & Neville 2007) illustrate the transformative power of bottom-up initiated resilience strategies. At the same time, Lefebvre's critique points to the need for a "right to a resilient city" that gives all residents access to resources and opportunities to participate in the sustainable and equitable design of urban space. In this context, Harvey (2006) speaks of "spatial justice", which can be seen as the basis for the development of resilient cities. This brings power structures and social inequalities into focus, which can stand in the way of inclusive resilience. Following Vale (2014) and the example of the gentrification of "resilient" neighborhoods in Boston after natural disasters, resilience strategies often go hand in hand with the

displacement of low-income population groups; similar findings of Letelier & Irazábal (2018) for the city of Talca, Chile, after the 2010 earthquake.

Lefebvre's perspective emphasizes the importance of participatory approaches geared towards social justice in the development of resilient cities. Inclusive governance structures that include marginalized groups as actors and not just as beneficiaries of urban resilience are crucial. Examples such as the "community resilience" strategy in Medellin with a focus on co-production of public services (Castro & Echeverri, 2011) or the establishment of polycentric "urban living labs" as experimental spaces for sustainable urban development (Voytenko et al., 2016) suggest possible paths to emancipatory resilience.

3.3 Cities as socio-technical networks

The actor-network theory (ANT) of the French sociologist of science Bruno Latour offers an approach to understanding urban systems that accentuates society as a network of human and non-human actors ("actants") that mutually influence and stabilize each other (Latour, 2007). Cities thus appear as complex socio-technical "assemblages" (Farias & Bender, 2010) of infrastructures, artifacts, forms of knowledge, routines and power relations. Latour's perspective draws attention to the active role of technical objects and infrastructures in structuring urban spaces and practices. For example, Hommels (2005) on the development of the Parisian metro network shows how technical persistences make social relationships permanent and influence urban resilience. New technologies such as autonomous vehicles or digital "smart city" infrastructures are therefore not simply tools, but co-actors of resilience that open up and limit the scope for action. Latour (2001) argues that the stability of networks is based on their ability to create and translate connections between heterogeneous elements. Applied to resilience, this means that cities must be able to mobilize and coordinate a variety of actors and resources in order to cope with disruptions. This requires a "diplomacy" (Latour, 2007) between different forms of knowledge, interests and logics of action. As an example, participatory adaptation strategies to climate change in Barcelona (Camps-Calvet et al., 2016) can be mentioned here, which require participatory approaches – e.g. development groups, hybrid forums, etc. – that involve citizens, scientists, urban planners and local businesses. In this way, diverse knowledge is integrated and socially robust solutions are developed. The resilience of the city here is based on the ability to build networks that combine social and ecological aspects and create a collective capacity to act.

In Latour's view, resilience is not a property, but a precarious process of networking and stabilization that has to be re-established again and again (Latour, 2007). In order to be resilient, cities must continuously work on their networks, create border objects between different social worlds and mediate conflicts. This requires a high degree of reflexivity and the ability to learn in order to recognize weaknesses and enable innovation. Resilient cities can be described as "distributed preparedness networks" (Collier & Lakoff, 2008); they are organized decentrally and learn to deal with uncertainty through continuous experimentation during operation. This requires open spaces for cooperation and improvisation, urban future labs, innovation workshops or similar; "enablers" in which citizens, researchers, students, entrepreneurs and local politicians work together on specific challenges.

Latour's theory underlines the importance of socio-technical networks for the resilience of cities. Hybrid strategies that integrate technical and social innovations and involve a wide range of actors are crucial. Digital platforms for the coordination of resources and activities in crises illustrate possible approaches; e.g. the "Ushahidi" application opened in Kenya in 2008 (Gutiérrez 2018; Boersma et al 2014), or applications for participatory mapping of disaster management. Yet, Latour's perspective points to the need to open up the black box of technical systems and critically reflect on political implications (Latour, 2007). As technological disasters in Fukushima or Beirut show, socio-technical networks can also amplify risks if interactions and cascading effects are not sufficiently taken into account (Molyneaux et al., 2019; Hatoum et al., 2022).

3.4 Core elements of urban resilience from a sociological perspective

The sociological perspectives presented converge in a view of cities as complex adaptive systems whose resilience is based on the interplay of social, technical and ecological factors. In contrast to engineering approaches, which understand resilience primarily as the ability to absorb shocks and maintain functions (Hollnagel et al., 2006), sociological perspectives emphasize the importance of adaptability, learning and transformation. Accordingly, resilience requires a high degree of diversity and connectivity in urban systems

in order to be able to react flexibly to disruptions and open up new development paths. The ability to integrate heterogeneous actors and forms of knowledge and to create a collective capacity to act is crucial. This requires participatory governance structures that enable all city dwellers to participate in the design of resilient cities, particularly in order to realize humane living conditions and social justice in the long term. Resilience is therefore not a value-neutral concept, but is closely linked to issues of balancing interests (Loidl, 2013), power and justice. Resilience strategies are not neutral in terms of their social effects; they can exacerbate social inequalities if they ignore the needs and perspectives of marginalized groups. Vulnerable groups that are less able to formulate their interests are at a structural and long-term disadvantage when it comes to shaping processes and their ability to resist. Emancipatory resilience therefore requires critical reflection on the political implications and the active shaping of inclusive urban development processes geared towards social justice. Finally, sociological perspectives point to the central importance of socio-technical networks and infrastructures for urban resilience. Technical systems are not simply neutral tools, but co-constitute urban spaces and practices. Resilient cities are characterized by adaptive, adaptive infrastructures that open up spaces for experimentation and innovation. At the same time, it is important to critically reflect on the political implications and unintended consequences of technical systems.

In summary, sociological theories offer important impulses for a holistic, normatively sound concept of urban resilience. They complement engineering and scientific perspectives with the social and political dimension and open up new ways of designing sustainable, just and future-proof cities. On this basis, a sociologically informed theory of urban resilience can be formulated that comprises the following core elements:

- Resilience as a multidimensional, relational concept that integrates social, ecological, economic and technical aspects.
- Resilience as an emergent property of complex adaptive systems based on diversity, redundancy, modularity and connectivity.
- Resilience as a process of learning, adaptation and transformation that requires proactive action and anticipation.
- Resilience as a normative concept that raises questions of power, justice and inclusion and requires emancipatory urban development.
- Resilience as a result of co-production by human and non-human actors in socio-technical networks and infrastructures.
- Resilience as a context-specific, locally situated phenomenon that requires participatory, bottom-up approaches and the integration of different forms of knowledge.

4 SOCIAL INNOVATIONS AND ADAPTIVE STRUCTURES IN URBAN DEVELOPMENT

Social innovations and adaptive structures conceived as potential for renewal and adaptation play a key role in the resilience and sustainability of cities, particularly in terms of quality of life and social justice.

4.1 Cities as socio-technical networks

Social innovations are defined differently, depending on the disciplinary approach and level of analysis (Howaldt & Schwarz, 2010). A common definition comes from Zapf (1989), who distinguishes seven groups of social innovation and understands them as new ways of achieving goals through organizational forms, new regulations, new services, new social technologies, new lifestyles, political innovations, new inventions by or with the participation of those affected, new patterns of satisfying needs. These new ways change the direction of social change, solve problems better than previous practices, and are worth imitating and institutionalizing (Zapf, 1989). Social innovations are characterized by three core features (Gillwald, 2000; Howaldt & Jacobsen, 2010). These are, firstly, novelty: social innovations are new, unprecedented practices that deviate from established routines and thought patterns. They can include technical, organizational, institutional or cultural innovations. The second core characteristic of this concept is intentionality: in contrast to emergent social changes, social innovations are consciously and purposefully initiated by individual or collective actors in order to solve specific problems or fulfill needs. The third core characteristic is improvement: social innovations promise an improvement on the status quo by offering

more effective, efficient or sustainable solutions to social challenges. They aim to improve the quality of life and the common good.

Social innovations can be found in all areas of society, from the world of work and the education system to consumption and lifestyles (Rückert-John, 2013). They are becoming increasingly important in the context of urban development, as cities act as a focal point for social problems and a laboratory for new solutions (Gerometta et al., 2005). Social innovations are embedded in their era. Parks, libraries, baths and kindergartens were just as much social innovations of their time as today's concepts of car-free neighborhoods, community gardens or solidarity agriculture (Reinhardt, 2020). A distinction can be made between "top-down" and "bottom-up" innovations in terms of their origin (Mortensen & Bloch, 2020). While the former are initiated by politics, administration or science, for example in the form of model projects or real-world laboratories (Reinermann & Behr, 2017), the latter are the result of the initiative of citizens, companies or civil society organizations (Seyfang & Smith, 2007). Social innovations often develop in niches and open spaces far removed from the mainstream, where they are shielded from established rules and constraints (Geels, 2019).

For the diffusion and institutionalization of social innovations, it is important to recognize and strategically use windows of opportunity (Westley, 2013). Crises, political upheavals or technological breakthroughs can open "windows of opportunity" to test and anchor innovative practices on a broader scale (Olsson et al., 2006). This requires change agents and institutional entrepreneurs who are adept at mobilizing resources, forging alliances and challenging the dominant system (Westley et al., 2013). Learning processes and capacity building are also crucial in order to build skills for the development and implementation of social innovations (Moulaert et al., 2005). Through networks, intermediaries and support structures, experiences can be exchanged, synergies exploited and a joint capacity for action established (Moore & Westley, 2011). Social innovations often require the co-production of knowledge and solutions by various actors from science, politics, business and civil society (Voorberg et al., 2015).

4.2 Adaptive structures

Adaptive structures are a central concept in resilience research that describes the ability of systems to react flexibly to changes and disruptions (Folke, 2006). In contrast to conventional structures geared towards stability and control, they are characterized by openness, diversity and the ability to learn (Meadows, 2008). The aim is to design systems in such a way that they can absorb unexpected events and shocks, adapt and, if necessary, transform themselves (Walker et al., 2006). Adaptive structures typically have the following characteristics (Carpenter et al., 2001; Folke et al., 2010):

- Diversity and redundancy: A variety of elements, functions and feedback mechanisms avoid one-sided dependencies and enable alternative development paths. Redundant structures increase reliability and buffer capacity.
- Modularity: Instead of hierarchical management and centralized control, adaptive structures rely on loosely coupled, decentralized units that can act autonomously and recombine as required. This avoids cascade effects and increases adaptability.
- Connectivity and networking: Adaptive structures are based on networking and cooperation between different actors, levels and sectors. By sharing information, resources and experience, synergies are utilized and collective learning processes are initiated.
- Self-organization and distributed governance: Instead of top-down planning and central coordination, adaptive structures rely on self-organization and polycentric governance. Local actors are empowered to make situational decisions and develop context-specific solutions without jeopardizing overall coherence.
- Experimenting and learning: Adaptive structures see uncertainty and surprises as an opportunity for innovation and further development. Pilot projects, monitoring and reflective learning loops generate new knowledge and identify successful practices that can be adaptively adopted on a larger scale.

Adaptive structures are used in various areas of urban development, from infrastructure planning to risk management and governance arrangements (Deppisch, 2016). The concept of the "adaptive city" aims to design urban systems in such a way that they can deal with complex, dynamic changes such as climate

change, digitalization or internationalization (Schipper et al., 2022). This requires "safe-to-fail" structures that allow scope for action and learning processes without jeopardizing the functionality of the overall system (Ahern, 2011). One example is multifunctional, flexible infrastructure that can be adapted to changing usage requirements. The flooded areas of the "Benthemplein Water Square" in Rotterdam, for example, serve as retention basins during heavy rainfall, while they are used as sports and recreational areas during normal operation (Spaans & Waterhout, 2017). The modular design also allows for gradual expansion and conversion. Adaptive structures also play a central role in climate adaptation. By combining various "nature-based solutions" such as green roofs, façade greening and urban trees, heat reduction and water retention can be flexibly adapted to local conditions (Kabisch et al., 2017). At the same time, redundancy increases resilience and achieves positive side effects for biodiversity, air quality and health.

In the area of governance, adaptive structures rely on network-based, collaborative approaches that integrate different actors and forms of knowledge (Duit & Galaz, 2008). Round tables, mediation processes and deliberative forums are used as discussion forums to emphasize common ground in problem definitions, future scenarios are developed and options for action are weighed up (Linnenluecke, 2017). By collectivizing the corridors of goals, expectations and actions, they can prevent the fragmentation of interests. Examples include climate alliances in cities, which bring together administration, business, science and civil society to develop integrated climate protection and adaptation strategies (Bulkeley & Kern, 2019).

Adaptive structures require a rethink in urban planning and development. Instead of deterministic master plans and rigid regulations, we need frameworks that allow for flexibility and experimentation (Campbell, 2016). Temporary zoning, trial permits and placemaking approaches can open up spaces for innovative uses and social practices without making long-term commitments (Bishop & Williams, 2012). Continuous evaluation and adjustment is crucial in order to learn from experience and consolidate successful approaches.

4.3 Reframing social innovations and adaptive structures as social capital

Robert Putnam (1993, 2000) defines social capital as the networks, norms and social trust that promote coordination and cooperation for mutual benefit. He emphasizes that social capital has value both for the individuals involved and for society as a whole by facilitating collective action and the provision of public goods. Social innovation and adaptive structures share a common "denominator" and can be related to Putnam's social capital theory to emphasize the importance of the social urban fabric for sustainability and resilience. What are the common potentials in Putnam´s perspective?

- Participation and civic engagement: Putnam sees the active participation of citizens in activities oriented towards the common good as an essential source of social capital. Social innovations and adaptive structures promote precisely this type of engagement by creating opportunities for participation and empowering people to help shape their living environment.
- Networks and cooperation: Then, social networks based on reciprocity and trust are a key component of social capital. Social innovations and adaptive structures are often built on or generate such networks, for example in the form of neighborhood initiatives, sharing platforms or cross-sector partnerships.
- Local anchoring and context sensitivity: It emphasizes the importance of "local" social capital, which is created in manageable communities and relies on direct reciprocity and face-to-face interactions. Social innovations and adaptive structures build on this local social capital by developing context-specific solutions that are adapted to local needs and potential.
- Learning processes and trust: Social capital is not a fixed stock, but a dynamic phenomenon that grows through repeated interactions and shared experiences. Social innovations and adaptive structures enable such iterative learning processes in which trust is built, knowledge is shared and skills are developed.

The concepts differ in the following arguments. Putnam primarily emphasizes the positive, community-building effects of social capital, whereas the discussion of social innovations and adaptive structures also addresses possible negative effects and ambivalences, such as fragmentation, exclusion or instrumentalization. In addition, Putnam's focus is strongly on the local level and the role of traditional associations such as clubs or churches, while social innovations and adaptive structures often operate in a network-like manner, across levels and in new institutional settings. Nevertheless, Putnam's social capital

theory provides a valuable conceptual framework to first understand the importance of social relationships, networks and trust for cooperative problem-solving processes that strengthen a city's resilience potential in terms of sustainability, innovation and adaptability. Quality of life and social justice can then be read as an expression of this very social capital. Social innovations and adaptive structures can be understood as strategies to mobilize and strengthen local social capital and thus promote the resilience and sustainability of cities. Conversely, the discussion on social innovations and adaptive structures can help to further develop Putnam's concept and transfer it to new fields of application.

4.4 Potentials and limits for urban resilience and sustainability

Social innovations and adaptive structures offer promising approaches for resilient and sustainable urban development. Through their participatory and emancipatory character, social innovations promote the commitment and problem-solving ability of citizens – they connect people to their living environment, they activate residents to appropriate their living environment. They enable context-sensitive solutions anchored in the real world that respond to specific local needs and potential and strengthen social cohesion (Mehmood, 2016; Moulaert & Nussbaumer, 2015). Social innovations are often resource-light and cost-effective, as they utilize untapped potential, networks and creativity (Jaeger-Erben et al., 2017). They follow a logic of "empowerment" and open up experimental spaces for sustainable practices and lifestyles that can provide transformative impetus (Göpel, 2016; Pellicer-Sifres et al., 2018; Seyfang & Haxeltine, 2012).

Adaptive structures, in turn, make it possible to deal flexibly with uncertainties and risks, such as those posed by climate change or the energy transition (Wardekker et al., 2021). They promote inclusive urban development geared towards the common good through decentralized, networked forms of organization that create opportunities for participation and mobilize local knowledge (Frantzeskaki & Rok, 2018; Goldstein et al., 2015). In addition, adaptive structures act as "incubators" for social and technical innovations by opening up niches and spaces for new ideas and practices (von Wirth et al., 2019). Through integrated, cross-sectoral approaches, they help to combine the resilience and sustainability of different urban subsystems and exploit synergies (Li et al., 2020; McPhearson et al., 2016; Pisano, 2020).

Social innovations and adaptive structures sometimes also come up against limits and challenges. Social innovations often remain localized and, without supportive frameworks and resources, fail to reach a critical mass to fundamentally change dominant institutions and power structures (Avelino et al., 2019). Adaptive structures, in turn, require a high degree of coordination, communication and trust between the actors involved and entail the risk of free-rider behavior, conflicts and fragmentation if they are not embedded in overarching strategies (Duit, 2016; Loorbach et al., 2017; Ostrom, 2010).

What is needed is a reflexive, integrative governance of urban resilience that enables and promotes social innovations and adaptive structures, while at the same time providing critical support. Urban policy is required to provide conducive contexts and resources, for example through experimentation clauses, co-financing and capacity building (Bauknecht et al., 2020; Sbeih et al., 2020; Sørensen & Torfing, 2019). At the same time, social innovations and adaptive measures must be embedded in long-term urban development strategies that set normative guidelines and take equity aspects into account (Hölscher et al., 2019; Mieg & Töpfer, 2013; Sharifia & Yamagata, 2022). Last but not least, the implementation of both approaches requires a rethink in politics, administration and planning towards "adaptive governance" that relies on flexibility, cooperation and polycentrism (Chaffin et al., 2014; Pahl-Wostl et al., 2013).

5 THE ROLE OF CITY SIZE FOR URBAN RESILIENCE? – ARGUMENTS

Does size make a difference? This article is just a brief argument. It begins with the consideration that very small settlement areas such as rural villages (few resources, little capital) as well as very large settlement areas such as "mega-cities" (complexity, spatial heterogeneity) have a harder time than medium-sized cities in the governance and design of urban resilience, in the implementation of social innovations and sustainable developments. Of course, the very concept of "medium-sized" is definitionally elastic.

Cities with 50,000 to 500,000 inhabitants are usually considered medium-sized. What is considered "urban" changes over time. A significant proportion of the world's urban population lives in cities of this size: in Europe, it is around 44% (Eurostat, 2022), and the UN (2018) predicts that the population in medium-sized cities will grow by 32% by 2030, faster than in megacities (+ 25%). They are said to play a crucial role in resilient and sustainable urban development, acting as links between rural areas and metropolitan regions and

offering specific potential, but also challenges (ESPON, 2019). One of the strengths of medium-sized cities is their pronounced social cohesion. Their manageable size fosters close social networks, community building and a high level of civic engagement (Keck & Sakdapolrak, 2013). This promotes resilience in the face of crises because mutual support and collective action can be drawn on. At the same time, the proximity and accessibility of medium-sized cities make it easier for citizens to actively participate in political decisions and design processes, and neighborhood networks and civic engagement would develop more strongly.

Medium-sized cities are also characterized by their adaptability and flexibility. Thanks to their less complex administrative structures, they can test and implement innovative solutions more quickly. They are the more "real"experimental fields and laboratories for social and technical innovations that can be transferred to other cities if successful (Bulkeley & Kern, 2019). This is shown by the example of Heidelberg, for example, which was able to implement ambitious measures such as a climate protection fund or mobility management as part of the "100% Climate Protection Master Plan" (Schüle et al., 2018). It is argued here that it is not so much the size of the city that makes a difference, but the "neighborhood".

Another advantage of medium-sized cities would be their sustainability potential. Compact settlement structures reduce land consumption and transport costs and encourage the switch to environmentally friendly forms of mobility such as walking and cycling (Reckien et al., 2015). Cities such as Münster and Copenhagen achieve cycling shares of over 30% (Harms & Kansen, 2018). The proximity to agricultural areas and ecosystems close to the city facilitates the establishment of regional economic and material cycles, of "circular economy principles", as the example of the Italian city of Faenza shows (Caputo et al., 2021). Multifunctional green structures and concepts such as the "sponge city" can increase resilience to climate risks, for which the Chinese city of Changde can serve as a model (Li et al., 2020). Medium-sized cities also have economic advantages. As specialized business and knowledge locations, they can tap into innovation and value creation potential based on regional expertise and networks (Giffinger et al., 2016). By focusing on sectors in future-oriented fields, promoting start-ups and the creative industries and connecting to supra-regional clusters, they can build economic resilience, as demonstrated by the Danish city of Sonderburg with its specialization in CO_2-neutral energy systems (Thellufsen et al., 2020).

These potentials are not automatically given, but require strategic action and supportive framework conditions. For example, integrated, participatory urban development concepts need to combine ecological, social and economic concerns (Mieg & Töpfer, 2013). By establishing regional innovation systems and strategic partnerships, such as those envisaged by the Science Park Concept Steyr (Fraunhofer IAO, 2022), endogenous resources can be mobilized and external impetus harnessed. Supra-local policies are also needed that specifically promote medium-sized cities and give them room to maneuver (ESPON, 2019). Medium-sized cities are not a homogeneous category, but are characterized by a high degree of diversity. Their specific strengths and weaknesses depend on their historical character, economic base and institutional capacities (Bell & Jayne, 2009). Context-sensitive, locally adapted strategies are therefore necessary. Case studies from Freiburg, Kigali and Portland show how different the paths to resilient, sustainable urban development can be. Freiburg has been consistently promoting renewable energy, energy efficiency and sustainable mobility for decades and has been able to significantly reduce its CO2 emissions as a result (Fastenrath & Braun, 2016). Participatory governance and the involvement of citizens in projects such as energy cooperatives or the "Freiburg 2030" working group are crucial (Hager & Hamagami, 2020). Kigali, on the other hand, is pursuing a consistent policy of green urbanization that focuses on compact settlement structures, the preservation of green spaces and a zero-waste concept despite limited resources (Macknick, 2016; Kabera et al., 2019). The population is actively involved through community activities and neighborhood assemblies. Portland demonstrates the potential of polycentric, compact urban development. By limiting the settlement area, promoting local mobility and strong civic participation cultures, it is possible to combine sustainability and quality of life (Hagerman, 2007; Song et al., 2021). These are a few examples to show that there are neither blueprints nor guarantees for resilient, sustainable urban development. Even medium-sized cities are constantly challenged to adapt to changing conditions, learn from experience and try out new solutions (Wardekker et al., 2021). However, their manageable size, adaptability and social resources offer good conditions for this.

6 CONCLUSION

The conceptualization of cities as resilient organisms opens up valuable perspectives for sustainable urban development that focuses on quality of life and social justice. The combination of sociological theories by Luhmann, Lefebvre and Latour makes it clear that urban resilience a multidimensional, relational phenomenon that emerges from the complex interplay of social, ecological, economic and technical factors. Resilience proves to be a normative concept that requires participatory, inclusive governance structures emancipatory urban development "from below". Social innovations and adaptive structures are identified as key starting points for strengthening cities' ability to adapt and transform while at the same time promoting engagement and opportunities for participation. It is crucial to build up social capital in the sense of networks, trust and cooperation in order toenable joint solutions to problems. The example of medium-sized cities illustrates that a manageable size, close social relationships and flat hierarchies provide good conditions for urban resilience, whereby context-sensitive strategies are required that build on the specific potentials and challenges.Overall, the article argues for greater consideration of sociological perspectives in urban resilience research and practice. They draw attention to the social embedding and political dimension of urban resilience and provide important impetus for a socially just, participatory transformation of cities in the interests of sustainability and quality of life. Resilience is not an end in itself, but must be measured by the extent to which it enables a good life for all city dwellers and leaves no one behind. This requires bold experiments, unconventional alliances and a new view of the city as a learning, constantly renewing organism.

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reviewed paper

The Contribution of Urban Climate Models for the Adaptation to Heat Stress – Lessons Learned from three Transdisciplinary Case Studie

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1 ABSTRACT

Climate change poses significant multiple challenges to urban areas, affecting public health, infrastructure, and essential services through rising temperatures, increasing dry seasons, heavy rain events, and shifting precipitation patterns. In response, cities must develop climate adaptation strategies and implement adaptation measures to create climate resilient infrastructures, adopting green urban planning, and fostering community engagement. One of the most pressing concerns is the intensifying impact of extreme heat, particularly during summer months, which is aggravated by both climate change and human activities. In urban environments, where the landuse is characterized by extensive impervious artificial surfaces and heat-retaining structures like buildings and roads, extreme heat events contribute to the Urban Heat Island (UHI) effect. In order to meet these challenges, city planners need useful tools that allow the modeling of different city development scenarios and the related effects on the environment. Against this background, the paper presents and discusses the practical use, main results and lessons learned from transdiciplinary case studies using three different urban climate models in three German cities. The “PALM-4U” model was employed to analyze heat stress in Geesthacht's city center, while the “FITNAH 3D” model by GEO-NET was applied to the entire urban area of Boizenburg/Elbe, including surrounding green and water spaces. Additionally, the "ENVI-met" model was used to simulate the effects of greening strategies on microclimates at four heat-stressed sites in Lüneburg.

Although all models have the focus on the temperature field and the thermal well-being of the citizens, the model approaches – including the needed model input – differ from model to model. These different model applications – conducted in close transdiciplinary collaboration with local key stakeholders – and the specific results, highlight the differences of model outcomes. This paper gives an overview of the main model characteristics. Furthermore, it discusses the typical information gained from such modeling approaches in the context of open questions related to the transfer of model results into administrative processes. Hence, our research can help urban planners, architects, and policymakers seeking to design and retrofit urban environments to improve thermal comfort and sustainability.

Keywords: urban climate models, heat stress, climate change adaptation, case studies, transdiciplinarity

2 INTRODUCTION

Climate change caused by human activities has far-reaching impacts. Extreme weather events, such as heatwaves, forest fires, floods and droughts are occurring more frequently and with increasing intensity in Europe as well (IPCC 2022). During these events, increasing heat stress, which is also becoming far more noticeable in Europe and Germany, is one of the societally most important impacts of climate change. In a direct comparison, for example, Europe is warming more rapidly than the global average (Copernicus Climate Change Service 2024). Temperature distributions are also shifting throughout Germany towards higher values because of climate change, increasing the occurrence probability of extreme heat (Deutschländer & Mächel 2017).

In general, the impacts of increasing heat vary, depending on how vulnerable and affected the regions, urban districts and people are (IPCC 2014). The GERICS-Klimaausblicke (climate oulooks) show for example for 401 German areas on the district level how the temperature and heat periods may change in the future (Pfeifer et al. 2021). Regardless of the location, older people, children, groups with low socio-economic status and individuals with health problems tend to be more vulnerable to the impacts of climate change than the general population (GERICS 2020). The health of individuals with certain illnesses (e.g. cardiovascular and respiratory diseases or diabetes) is also more affected by heat, which is often associated with a higher

risk of heat-related death (European Climate and Health Observatory 2022; EEA 2018). Pregnant women are likewise more susceptible to heat stress. Overheating and dehydration can lead to premature labor (WHO Europe 2021). Of great importance is that the combination of an increasing number of individuals over the age of sixty-five and the higher summer temperatures has led to an increase in the overall exposure of older people to heatwaves since 1980 (European Climate and Health Observatory 2021).

Altogether, the negative impacts of heat on human well-being and health are clearly documented (GERICS 2020; Hanefeld et al. 2019; Muthers et al. 2017), whereby very warm nights can lead to the body's inability to regenerate properly, thereby increasing the general risk of illness. Heat has not only been proven to lead to decreased labor productivity overall, but also to additional and sometimes serious economic consequences, resulting in associated costs that develop subtley and slowly, so they often remain unnoticed. In summary, heat events are responsible for approximately 99% of at least 30,000 extreme weather-related deaths in Germany since the year 2000 (Trenczek et al. 2022a; Trenczek et al. 2022b).

The impacts of increasing heat in the city vary widely, depending on the proportion of sealed areas, building development, and the the degree of cold air venilation. In addition to its direct health impacts, heat stress can lead to damages of different parts of the critical infrastructure, such as roads, the power supply, or the IT infrastructure, causing significant economic repercussions (Groth et al. 2023). But not only extreme events have to be considered. The gradually changes are similar problematic, because their effects are not immediately apparent.

Addressing the UHI effect requires a comprehensive understanding of how factors such as the building type, the spatial distribution of buildings, the location and functionality of ventilation corridors, and the extent of urban greenery influence local microclimates and heat dynamics. Related questions can be answered with urban climate models. They support urban planners when searching for the balance between functionality as well as sustainable development and minimal heat-related stressors, especially with regard to the effects of climate change. As the individual models are designed for different use cases, it should be clear to the processors in advance which model is best to be used.

It is also important to note in this context that an individual's perception of warmth is not only determined by the air temperature. Rather, the complex interactions of meteorological (air temperature and humidity, wind speed, radiation influences) and non-meteorological factors (perspiration rate, work energy turnover, clothing) are responsible for thermal well-being. Various indices have been developed to estimate thermal sensitivity, like the "Universal Thermal Climate Index (UTCI)" (Błażejczyk et al. 2013), the "Physiologically Equivalent Temperature (PET)" (Höppe & Mayer 1987) or the "Predicted Mean Vote (PMV)" (Fanger 1972) (table 1). In this paper we focus for each case on results for the PET – an index based on the Munich Energy-balance Model for Individuals (MEMI) –, which provides a one-dimensional biometeorological measure that quantifies the perception of thermal comfort or discomfort (Höppe 2019). The PET is expressed in °C and is not to be confused with the de facto air temperature.

Thermal Perception	Degree of Physical Stress	UTCI (°C)	PET (°C)	PMV
Very cold	Extreme Cold Stress	< -40	< 4	< 3,5
	Very Strong Cold Stress	-40 to -27		
Cold	Strong Cold Stress	-27 to -13	4 to 8	-3,5 to -2,5
Cool	Moderate Cold Stress	-13 to 0	8 to 13	-2,5 to -1,5
Slightly Cool	Slight Cold Stress	0 to 9	13 to 18	-1,5 to -0,5
Pleasant	No Thermal Stress	9 to 26	18 to 23	-0,5 to 0,5
Slightly warn	Slight Heat Stress		23 to 29	0,5 to 1,5
Warm	Moderate Heat Stress	26 to 32	29 to 35	1,5 to 2,5
Hot	Strong Heat Stress	32 to 38	35 to 41	2,5 to 3,5
	Very Strong Heat Stress	38 to 46		
Very Hot	Extreme Heat Stress	> 46	> 41	>3,5

Table 1: Comparison of classification methods for describing thermal perception.

Against this background, the paper presents and discusses the practical application, main results and lessons learned using different urban climate models. The study is based on practical examples, whereby the focus of

the model application is in general not on the exact numerical values but on the differences between scenarios or land use characteristics. For these reasons, and for cost aspects, it is not a common practice to compare results of different city climate models in one model site. It is therefore difficult to find such direct comparisons with the same scale in literature. For our study we use the following model approaches:

The "PALM-4U" model was employed to analyze heat stress in the central part of the city of Geesthacht (chapter 3), while the "FITNAH 3D" – used in a contract work by the company GEO-NET – was applied to the entire urban area of Boizenburg/Elbe, including surrounding green and water spaces (chapter 4). Additionally, the "ENVI-met" model was used to simulate the effects of greening measures on microclimates at four heat-stressed sites in Lüneburg (chapter 5). Based on these specific case studies, a brief model comparison will be carried out (chapter 6), followed by a summarizing conclusion (chapter 7).

3 THE GEESTHACHT CASE STUDY

3.1 General aspects – the PALM-4U modeling approach

The high-resolution urban climate model PALM-4U (Parallelized Large-eddy Simulation Model for Urban Applications) developed at Leibnitz University in Hanover (Maronga et al. 2019; Steuri et al. 2019) was utilized to simulate the current thermal comfort and heat load in the city of Geesthacht (33.000 inhabitants) in Northern Germany (Bender et al. 2024). PALM-4U is the enhanced version of the basic PALM model (Raasch & Schröder 2001), which has already been used frequently for urban climate analyses (Knoop et al. 2014; Letzel et al. 2012; Park & Baik 2012).

The Palm-4U model can be used to simulate entire cities as well as individual urban neighborhoods down to a resolution of one to two meters. Examples of weather situations are specified as external drivers for the calculations. The model requires geo-based information on terrain, building structures, vegetation, sealed surfaces and water surfaces as additional input variables (Heldens et al. 2020). As a result, the model provides spatial information on temperature, humidity and wind (speed and direction) as well as for biometeorological parameters. These parameters always relate to humans and provide information on human well-being and physiological heat stress (Fröhlich & Matzarakis 2019; Kuttler 2009).

For the urban climate modeling carried out here, the PALM-4U Version 21.10-rc1 was used with the following input data (sources specified):

- Aerial images (visible): resolution 0.2 m (Geesthacht City Administration).
- Aerial images (infrared) (County of Herzogtum Lauenburg).
- Surface model as raster data with a grid width of 1 m (digital terrain model: DGM1) (Geesthacht City Administration).
- Digital landscape model (DLM) to describe the landscape topography and relief of the earth's surface in vector format or digital surface model (DOM) with a grid width of 1 m (Geesthacht City Administration). The height accuracy for solid surfaces without vegetation is ≤ 0.3 m.
- Land use data as a shapefile or feature class (green areas, trees, traffic areas), based on data from Corine Land Cover (CLC) as well as from the Geesthacht City Administration.
- Building information from the official property cadastral information system (ALKIS): for example, information on the geometry, location, and shape of land parcels and buildings, type of use, terrain shape (Geesthacht City Administration).
- Digital 3D building models; “Level of Detail – refering to the level of complexity in a 3D-generated model” (LOD2): standardized roof shapes, building floor plans based on the official property map; the height accuracy is predominantly 1 m, information on the building function (County of Herzogtum Lauenburg).
- OpenStreetMap (OSM) data in 1 m resolution as input variables for determining sealing and location of bridges and water areas (rivers, canals and ponds). This information is from the year 2020.

The thermal comfort was modeled at a resolution of 5 m x 5 m. A total of 1,000 x 800 x 320 grid points in the x, y and z directions are included in the model calculation. They describe a region with an area of 20 km² and a height of 1,600 m. The assumed meteorological boundary condition is an autochthonous weather

situation – characterized by unobstructed solar radiation with little cloud cover and very light winds. Under these conditions local climatic characteristics of a landscape can develop particularly well and the urban heat island – the thermal load – is most pronounced currently. For initializing the calculation, a spatial constant temperature profile of a summer day (here June 20th, 2015) with an initial temperature of 23.4°C (296.5 K) at the surface for the start time of 21:00 CET (Central European Time) is specified. The PALM-4U model region includes the central part of the city of Geesthacht. Figure 1 provides an overview of the input variables used for the subsequent urban climate modeling. The map notably reveals the urban areas with office buildings and the surrounding areas characterized by agriculture and forests. In large portions of the city, the image is heterogeneous, with some green areas and large areas with little vegetation (assumed here to be bare ground).

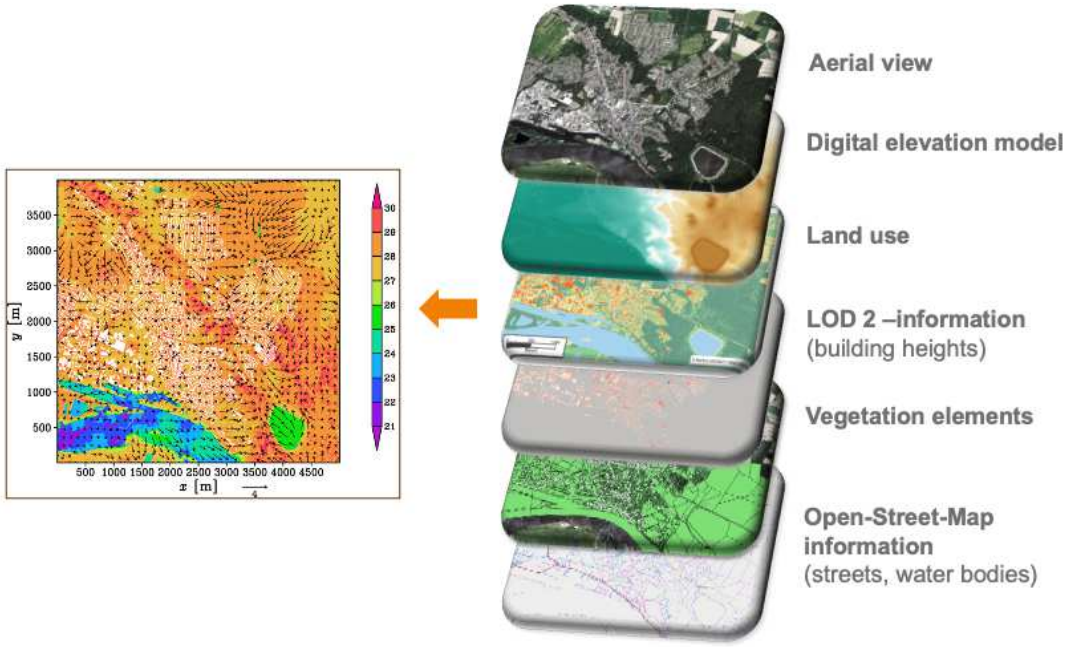

Fig. 1: Input data overview for the "City of Geesthacht" modeling area (scale: 1:30,000).

3.2 Map of the heat stress (PET-values) for the city of Geesthacht

The PALM-simulations show the daily course of the heat load, here displayed by the PET values, that correlates strongly with the short-wave solar radiation. Highest heat loads occur not only inside the city center over sealed surfaces without shading, but also in the surrounding open spaces. At nighttime (shown at 04:00 h) the PET value distribution shows that no thermal stress is to be expected. Rather, PET values below 18°C are found in the peripheral areas of the city, near the river Elbe, in the surrondings of the reservoir and in some parts of the city, which corresponds to "slight cold stress" according to the specific PET classification (figure 2). With increasing warming during the day there is a significant increase of the thermal stress, too, whereas the highest stress occurs at 16:00 h. At that time "moderate heat stress" only occurs around the Elbe and above the reservoir. Within the urban region, the PET values rise above 42°C in many areas, which corresponds to "extreme heat stress". As with the air temperature at 2 m height, the urban forest is also the separating element here, with PET values between 39°C and 45°C. The lowest PET values (between 36°C and 39°C = "strong heat stress") can be observed south of the Elbe, in smaller wooded areas on the eastern edge of the city, above the open spaces north of Narzissenweg, in the north-eastern outskirts and in the Börmweg area.

To summarize, the assessment based on the PET values shows that no thermal stress occurs at night in the whole urban area. In contrast, during the day, the heat stress is increasing to an extreme level in most parts of the developed parts of the city. Even though heat stress occurs at a lower level in the surrounding, it is still heavily pronounced there as well. Moderate conditions can be found near the water bodies and in shaded areas. With respect to increasing temperatures in the future, city administration should face this challenge in upcoming city planning processes.

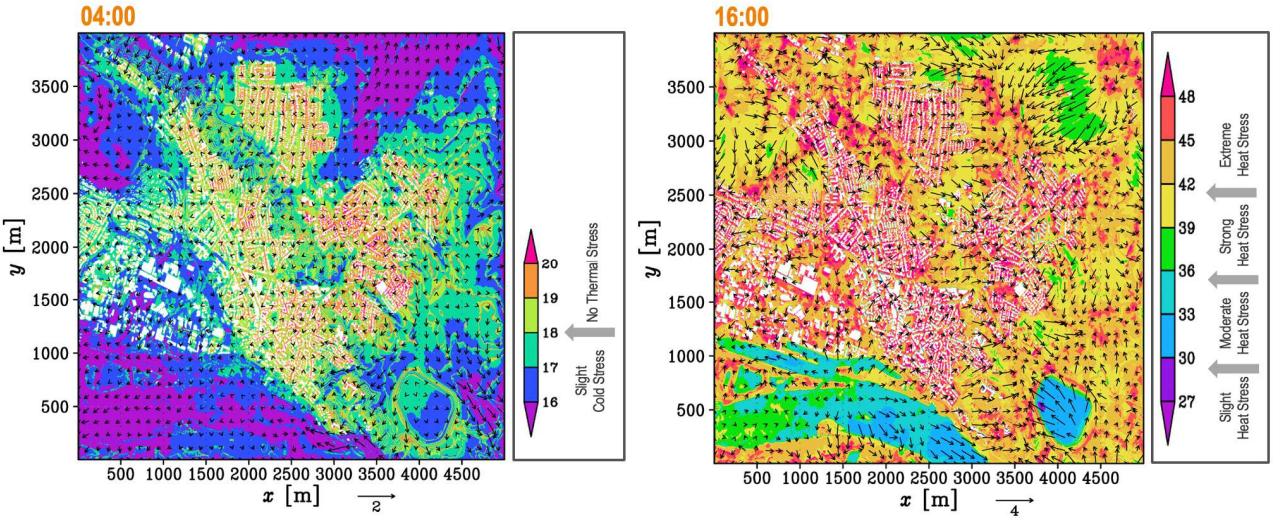

Fig. 2: Physiological Equivalent Temperature and wind speed at a height of 10 m, at 04:00 (left) and 16:00 (right); "City of Geesthacht" model.

4 THE BOIZENBURG/ELBE CASE STUDY

4.1 General aspects – the FITNAH 3D modeling approach

A model frequently used in Germany for urban climate assessments is FITNAH 3D from the company GEO-Net (Gross 1993; GEO-Net 2013). An area-wide model analysis was conducted for the city Boizenburg/Elbe (7,500 inhabitants) with a spatial resolution of 5 m x 5 m (GEO-Net 2021). For the detailed modeling, the following input data was needed: aerial images or topographic maps, DGM, DOM (LOD 0 or LOD 1), land use data. Building geometries, provided by the city of Boizenburg/Elbe in the form of a 3D model, were integrated into the analysis. The detailed information of structural heights (buildings and green structure) enables a realistic representation of flow barrier impacts on the air exchange together with the influence of urban morphology on the local microclimate. Typically, assessments with FITNAH 3D encompass both nighttime conditions – with the focus on cold air production and associated flows – and daytime bioclimatic loads, providing a comprehensive assessment of the microclimatic characteristics across the urban area (figure 3).

The model area of Boizenburg/Elbe covers approximately 121 km². The peripheral areas are dominated by open and green spaces (total area of 47.4 km²), which makes these parts very important for the cold air production at night and the cooling of the city. The climate analysis was based on the meteorological framework of an autochthonous summer day, which serves as a representative condition for the model calculations. Autochthonous weather patterns occur in Boizenburg on 5 to 7 days per month during summer (June, July, August). These conditions are characterized by clear skies and minimal synoptic wind influence, allowing the local climatic features of the town and its surrounding region to be distinctly observed. A hallmark of such high-pressure weather conditions is the formation of surface winds, driven by temperature gradients between cooler open spaces and warmer built-up areas. An autochthonous summer day typically results in the highest thermal loads due to intense solar radiation and limited air exchange, therefore this modell situation can be seen as a worst-case scenario. It is important to note that this climate analysis provides a snapshot of the urban area's microclimatic conditions under specific meteorological scenarios.

4.2 Map of the heat stress (PET-values) for the city of Boizenburg/Elbe

In general, for commissioned expert opinions mostly the PET index is calculated for the time with the maximum air temperature (normally 16:00 to 17:00 h) or for the maximum intensity of solar radiation (normally 13:00 to 14:00 h). In our case, the map with the PET index at 14:00 h is used. Compared to the nighttime air temperature with a maximum difference of 5 K, the PET exhibits a greater range across the study area (18 K) at daytime. The lowest PET values are observed over wooded areas, ranging from approximately 26°C to 28°C. In these areas, individuals at a height of 1.1 meters above ground level are situated beneath the tree canopy, which provides protection from direct solar radiation. As a result, forests and parks with dense tree coverage can serve as vital refuges, offering only moderate heat stress.

Comparable PET values are achieved locally within urbanized areas beneath individual trees, such as those in the church and town hall square. These locations, which otherwise experience extreme heat loads exceeding 41°C PET due to the absence of shading, benefit significantly from the presence of tree cover (Groth et al. 2022). Relatively low heat loads, with PET values between 28°C and 32°C (slight to "moderate heat stress"), are observed over larger water bodies, including the harbor at the river Boize and in the surroundings of the Elbe River. All these areas benefit from the cooling effect of the water, experiencing lower thermal loads compared to areas further away from these watercources. By contrast, maximum PET values exceeding 42°C ("extreme heat stress") are recorded over open meadows and farmland in the surrounding regions. Highly sealed commercial areas in the eastern part of the city experience similar extreme heat stress. The absence of shading, combined with unimpeded solar radiation and limited evaporative cooling from sealed surfaces, contribute to these elevated thermal loads. A similar level of heat stress is widespread in the historic city center. While shading provided by trees and buildings locally reduces the heat load by 10 K, the prevalence of highly sealed and unshaded open spaces dominates the microclimate. Adjacent buildings reflect incoming solar radiation, further amplifying the heat load. Additionally, the dense spatial arrangement of buildings can reduce wind speeds, compounding the thermal stress.

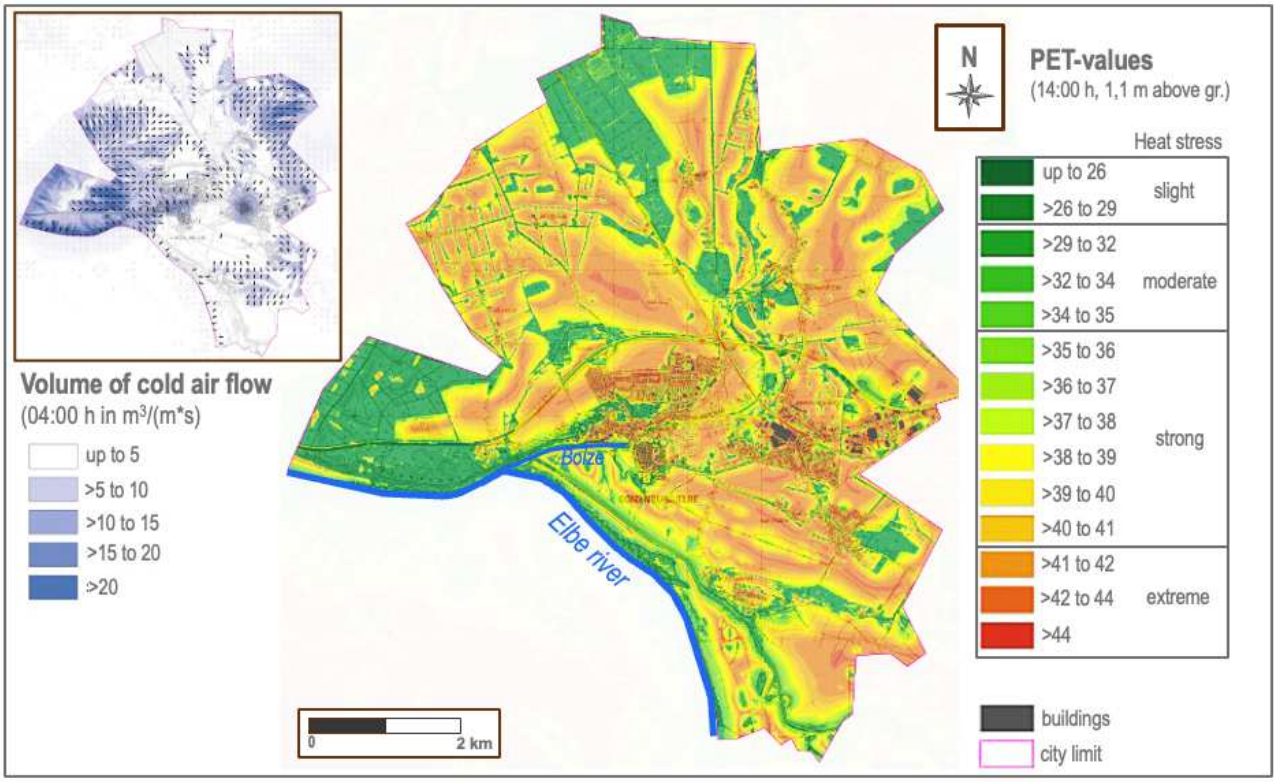

Fig. 3: Distribution of PET (14:00 h) in the "Boizenburg/Elbe"-model and a overview of the cold air flow (04:00 h).

To summarize, the settlement areas in the central part of the map experience relatively high thermal loads. Although these areas are characterized by loosely arranged single-family homes with a relatively high proportion of green spaces, some zones still face extreme heat stress due to the lack of shading. Individual trees in these areas, which were not explicitly considered in the modeling, provide cooling only locally and have limited influence on the overall heat load. The surrounding areas, mainly in the west and in the northeast, are important for the cold air production, but their impact is not big enough for the small city, so adaptation actions inside the residental areas are still necessary to lower the daytime heat stress.

5 THE LÜNEBURG CASE STUDY

5.1 General aspects – the ENVI-met modeling approach

The third microclimate model is ENVI-met (Bruse & Fleer 1998), a three-dimensional, geo-referenced, non-hydrostatic microclimate model, that can be used to calculate and simulate climatic parameters with high spatial (0.5 to 10 m) and temporal solutions up to 10 seconds. This model accounts for the intricate exchange

of long-wave and short-wave radiation between surfaces, vegetation, and the atmosphere in urban environments. It is frequently used to assess the effectiveness of mitigation and adaptation strategies, e.g. by comparing the impacts of different potential measure packages. It calculates the microclimatical dynamics during a diurnal cycle using fundamental laws of thermodynamics and fluid dynamics.

After the analysis of the urban climate for the whole city of Lüneburg (80,000 inhabitants) with FITNAH (GEO-Net 2019) the question, how can greening reduce the microclimatic stress at different sites in the city center, was posed. To address this question, a project exploring potential adaptation strategies to the impacts of climate change in Lüneburg was launched in collaboration with the project "Zukunftsstadt Lüneburg 2030+ (City of the future Lüneburg 2030+)".[1] Four prominent locations were selected for the modelling, to be simulated in three different scenarios each. Whereas the baseline scenario (s-quo) on a hot summer day with approximately 30°C – representing the current state of these sites – is characterized by minimal greenery, high degrees of surface sealing, and low albedo due to artificial materials, two potential greening scenarios should analyze the effects of urban green. The moderate greening (s-mod) seeks to strike a balance between preserving site usability and enhancing thermal comfort. Measures include partial surface unsealing and the incorporation of large plants for shading, while maintaining most of the existing site infrastructure. The maximum greening scenario (s-max) represents a more intensive application of greening measures, involving major structural modifications including vertical and roof greening that substantially alter the appearance of the sites. While disregarding legal and social constraints, this scenario aims to illustrate the maximum possible cooling effects of urban greening interventions. The steps represented by s-mod and s-max serve as benchmarks for future greening strategies, offering an evidence-based framework to estimate the expected cooling effects at the studied locations.

Analyzed key parameters include potential air temperature, mean radiant temperature, and PET – as the indicator for thermal comfort. The selected four locations represent a diverse range of site sizes, structural characteristics, and greening potentials, spanning enclosed small courtyards (375 m2) to partially open urban squares (6,750 m2). All of these locations hold direct relevance to inner-city development in Lüneburg.

5.2 Map of heat stress (PET-values) for the Marienplatz

The second largest location (4,875 m2) – the Marienplatz – serves as an example to show the procedure of a scenario analysis done in this project. Two times were used for the comparison of the heat stress (calculated as absolute PET values): 13:00 h and 17:00 h (figure 4). These parameters were visualized for all locations in bird's-eye-view maps, customized to the relevant area. A black arrow indicates the orientation of north, while a red arrow shows the angle of solar incidence. It is important to note that only values within the modeled site are interpretable. The microclimate of Marienplatz in its current state (status quo) is predominantly characterized by direct sunlight and relatively high PET values. The existing groups of trees play a critical role in shading the square, particularly during the afternoon hours. In the shadow-free majority of the square the mode shows an extreme heat stress, with PET values of around 56°C at 13:00 h (A1), rising to over 57°C at 17:00 h (B1). By contrast, areas shaded by tree groups exhibit significantly lower PET values, ranging from 38°C to 48°C. This clear contrast highlights the critical role of shading in reducing thermal discomfort. However, across the entire site – even in shaded areas – the PET values remain within the highest physiological stress category, corresponding to extreme heat stress. The direct effects of further shading by more trees are shown by the differences of the PET values for the comparison of s-quo vs. s-mod (A2 and B2) and s-quo vs. s-max (A3 and B3). The implementation of both greening strategies demonstrates a substantial reduction in PET across many areas. In the s-mod scenario, the areas with reduced PET are more limited, but the PET values still decrease by up to 17 K. In the s-max scenario, significantly larger areas show a reduction of the PET-values at 13:00 h and 17:00 h, respectively. The maximum cooling effect relative to the baseline (s-quo) is approximately 20 K at 13:00 h and nearly 25 K at 17:00 h. The cooling effect is mostly pronounced under tree canopies, although it does not occur above water surfaces, due to the heat buffer effect of water bodies. Consequently, the physiological heat load is reduced by one PET-level when the s-max scenario is applied, offering theoretically a meaningful improvement in thermal comfort. However, the practical application must be critically scrutinized.

[1] https://www.lueneburg2030.de/stadtklima/index.html

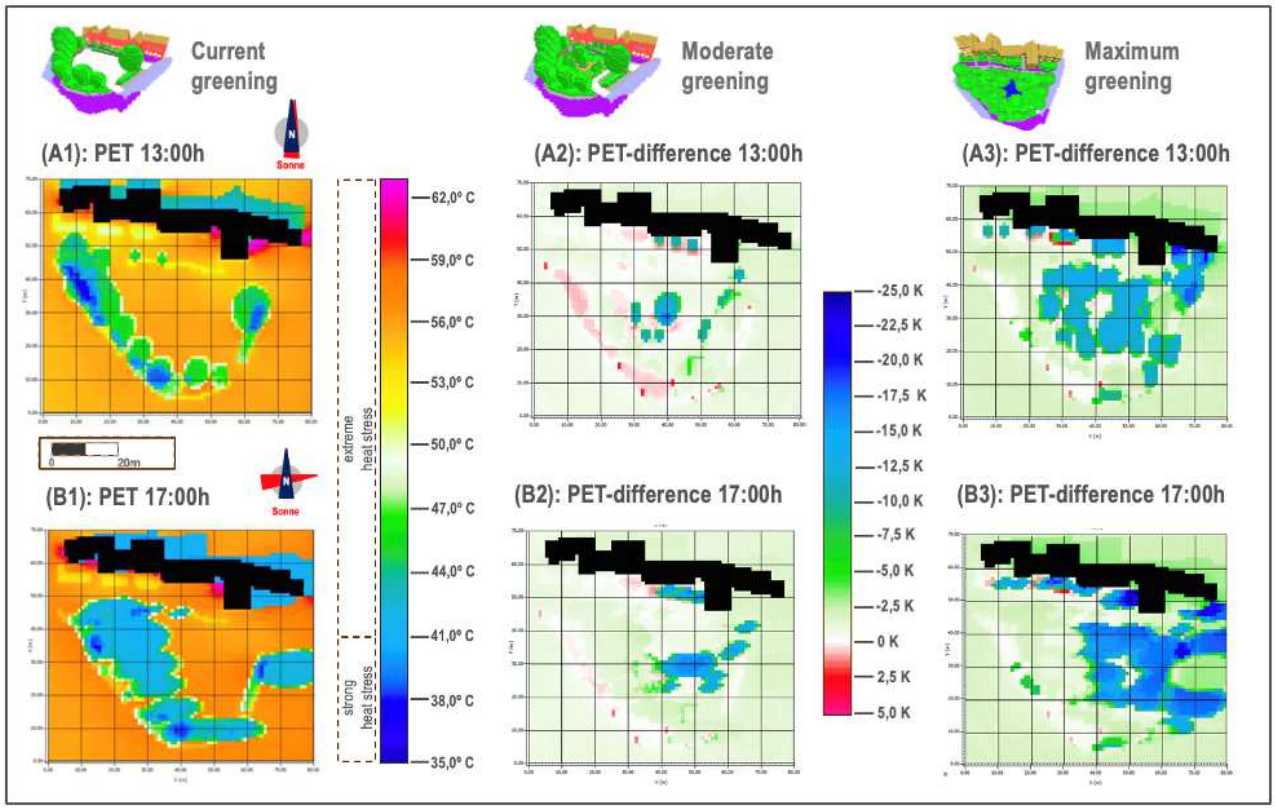

Fig 4: Distribution of PET (13:00 h (A1). and 17:00h (B1)) in the "Marienplatz"-model and the results of the comparison s-quo vs. s-mod (13:00 h (A2), 17:00 h (B2)) and s-quo vs. s-max (13:00 h (A3), 17:00 h (B3)). Buildings are shown in black.

The comparison of the three greening scenarios points out that PET values can be effectively reduced with the introduction of more vegetation. However, to fully evaluate the impact of these concepts, PET values must be analyzed in conjunction with the area of their effect. In general, the combination of greenery and water featueres, significantly reduces the thermal load. The quality of shade is particularly enhanced in areas featuring dense, multi-layered vegetation. Whereas the widespread shading of grassy areas is critical to ensuring their usability throughout the day. Therefore, an optimal design should incorporate strategically placed individual trees or groups of trees that provide a mix of extensive and partial shade. Additionally, larger clusters of trees with intensively planted understory vegetation could act as "cooling islands". The contribution of water features to thermal mitigation should not be underestimated. Integrating water elements into the design and creating an inner-city green oasis would further enhance the microclimate and improve thermal comfort. However, it should not be forgotten that the square is also intended for other uses in addition to its role as a "cooling island". These must be reconciled as well, whereby previous prioritization of the desired types of use should set the framework for the redesign.

6 MODEL COMPARISION

The three selected examples provide a good insight into the different modeling philosophies and the associated issues. While at first glance all urban climate models can be used to simulate heat stress in the city, a second look shows that the issues are much more complex in practice. Table 2 provides a brief overview of the three models.

For example, the PALM-4U model aims to enable city administrations to create a digital model of their own municipality almost independently (or with support). This type of condition should make it possible to update the current status at regular intervals and to model planning scenarios with associated impacts. Up to now, however, this has required a lengthy familiarisation period (assuming existing scientific knowledge) and access to high-performance computing. As the computing and processing times required are still very high, its use in practice is only a viable option for well-positioned local authorities, especially in view of shrinking financial and personnel resources.

Model	Possible use cases	Possible resolution & Model area size	Input data	Remarks
PALM-4U	• a) • b) • c) • d)	• 1 m to 50 m. • Individual projects to city-wide analyses.	• Data with high level of detail and high spatial coverage of individual actual urban structures.	• Open source, but high computing costs. • Access to mainframe computer required. This access is supplied by various providers.
FITNAH-3D	• a) • b) • d)	• Minimum up to 5 m. • Single projects to supra-regional analysis.	• Data of terrain height, land use, buidling information and the large-scale weather. • Non-resolvable small-scale information is collected in sum parameters.	• No free and open-source software.
ENVI-met	• a) • c) • d)	• Recommended: 1 m to 4 m. • Individual projects, to whole cities with max. 5 x 5 km (with 10 m grids).	• Data consists of surface roughness, diurnal cycle of air temperature, specific and relative humidity, information of vegetation, buidlings and soil types.	• Open source in simplified trial version.

a) Thermal comfort (Analysis of the heat load in urban areas), b) Cold air balance (Analysis of cold air production and functionality of cold air pathways), c) Wind comfort (Analysis of the effects of wind on buildings and the human perception of comfort), d) Pollutant dispersion (Analysis of pollutant dispersion from traffic and domestic fire emissions).

Table 2: The three city climate models at a glance (based on Pavlik et al. 2022; own modification).

Using the FITNAH-3D model is an approach including a commercial service provider, whereby the focus of the considerations is primarily on maintaining and improving the transport of cold air in and within the city. As practice has shown, questions of varying complexity can be answered, and options for action can also be developed, for example for the redesign of neighbourhoods. As every change in land use represents a new scenario to be analyzed – and payed for – the available budget limits the repeated use of the model.

The modelling approach with ENVI-met occupies a compromise from the operator's point of view. The model can be operated independently (with a certain familiarisation period) or by a commercial service provider. The focus of the application area is on the local level, such as the modeling of a city district, a street or a square. The fact that the calculations can be carried out relatively quickly on a standard computer means that it can be used easily to compare a higher number of different planning scenarios. However, it should be noted that the focus is only on local changes. Changes that take place in other parts of the city, but which can have an influence on the local urban climate (such as the development of fresh air corridors), can only be considered indirectly in the model layout.

Finally, it should be noted that the direct interpretation of the model results and the associated implications for the daily business can hardly be found in any final project report. For this reason, a basic prerequisite – regardless of the model results – is expert knowledge of what the maps and numbers mean or what can be derived directly from them. Even if some final reports provide recommendations, these still need to be translated into practical measures and understanding, to make the modeling results useful and applicable.

7 CONCLUSION

Climate change presents significant challenges to urban areas, with extreme heat, particularly during the summer months, being one of the most pressing impacts. Addressing the thermal comfort and heat stress in municipalities requires a comprehensive understanding of how factors such as ventilation corridors, urban greenery, building design, and spatial layouts have a combined impact on local microclimates and heat dynamics. Urban climate models are designed to tackle these challenges. They can also help to raise the awareness of specific challenges by visualizing current and future hot spots in city districts. This approach is

particularly suitable for demonstrating the theoretical effectiveness of adaptation measures to increase the thermal well-being in a district. The focus is not on the exact extent of temperature reduction through individual measures, but rather on identifying potential challenges and possible solutions, and to raise awareness to pave the way for integrating adaptation into future city planning activities.

However, since the individual models are designed to address specific issues, they require different personnel and IT resources. Hence, it is essential for urban planners to identify in advance which model is most suitable for their needs and provides usable information for practical adaptation that is also fit for being seemlessly integrated in the city's existing data enquiry structure.

In general, urban development decision-makers should prioritize integrating microclimatic modeling as a fundamental component of planning measures. This approach could minimize, or ideally prevent, misinvestments in ineffective or counterproductive interventions. The model results can build a base to facilitate the efficient design of inner-city greening strategies and promote sustainable solutions for the municipality to tackle increasing heat-stress. They can also form an important building block for urban adaptation efforts to broader social goals and challenges beyond climate resilience.

Furthermore, it has to be considered, that adaptation in cities can be as diverse as projected climate change impacts. Each city has its own vulnerable sectors, places and infrastructure elements depending on the climatic, environmental and socio-economic frame. The keys for successful adaptation are scientifically based regional climate information and a holistic system understanding. Other important components for adaptation are an existing pressure to act, city needs, available knowledge, and accessible city specific information.

Therefore, adaptation is more than creating hot spot maps or developing adaptation strategies. For successful adaptation, communication is key. Therefore, only through the co-development and co-design with local decision-makers and local experts (such as urban planners, water and energy suppliers, etc.), the inclusion of local knowledge can be ensured. Communication is also the best tool to improve integrative system understanding, since the various expertise from all necessary areas can be incorporated. This not only benefits the success of the project but is also expected to increase the acceptance due to its local and individual character.

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reviewed paper

The Exploration of Smart Port Concept to Improve Efficiency and Productivity of the Port: Case study Port Elizabeth

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1 ABSTRACT

The aspect of transitioning traditional port operations into a smart port is more than just not merely a technological improvement; it is considered as a contingency plan that addresses the various challenges faced by South African ports in a rapidly evolving global trade environment. This research paper stresses that the adoption of smart port concepts is essential for enhancing operational efficiency, reducing congestion, and fostering economic growth. The concept of integrating advanced technologies that encompass automation, the Internet of Things (IoT), and data analytics,allows the Port of Port Elizabeth to overcome the current challenges associated with the old infrastructure and inefficient methods.

This study argues that even though smart port concept is a vehicle for the port that drives productivity and sustainability at the port of Port Elizabeth, there are concerns regarding job losses due to a lack of skilled labour force and this can be addressed through upskilling of the workforce. The successful transition of this port into a smart port model requires not only focusing on the technological investment but also considering the policy frameworks that prioritize human capital development to successfully implement automation. There has been a tremendous increase in global growth port competition and changing maritime dynamics, and this research paper intends to evaluate the potential benefits as well as the challenges of adopting the concept of smart port at the Port of Port Elizabeth. The ultimate goal is to contribute to the broader discourse on the strategic ways in which South African ports can provide for future development, as well as the requirement for inclusive socioeconomic and sustainability.

The Port of Port Elizabeth is facing critical challenges, including outdated infrastructure, poor maintenance practices, and logistical bottlenecks, which have resulted in inefficiencies, long turnaround times, and reduced competitiveness in global trade. These issues threaten the port's ability to support South Africa's economic growth. This study was motivated by the urgent need to modernize the port's operations and explores the adoption of smart port concepts as a solution. The paper argues that transitioning to smart technologies, such as automation and data-driven decision-making, is essential to address these challenges, improve productivity, and position the port as a key player in the global maritime industry.

Keywords: Smart port, Port development framework plan, Efficiency, Productivity, Intelligent infrastructure

2 INTRODUCTION

South African seaports are regarded as the main components facilitating trade to ensure economic growth across the world. A seaport is regarded as a maritime facility that is predominantly well-equipped with operational equipment and considerable space necessary for loading and unloading shipments or cargo (Sarkar & Shankar, 2021). Modern ports do not operate as early ports, which were primarily simple harbors for exporting goods to other countries. Mlambo(2021) delineates that the demand for international trade has increased tremendously and propelled modern ports to venture into technologically advanced infrastructure, which requires multimodal intersections for the transportation of goods from various ports that encompass integrated transportation networks such as railway, road, air, and seawater.

The study is based on the port of Port Elizabeth, which is one of the nine state-owned ports in South Africa facing issues of underperformance due to dilapidated infrastructure and a lack of equipment to accommodate more vessels (Transnet National Port Authority, 2019). The research dissertation takes into consideration the in-depth analysis of restructuring the dilapidated infrastructure for the port of Port Elizabeth and explores the possibility of adopting the smart concept to ensure improved efficiency and productivity in the port system.

Mcetywa (2021) outlines that the current existing dilapidated port infrastructure, such as rail and road transport, needs constant renovation, the research further outlines the current port performance and the expected performance after the implementation of the smart port concept. To alleviate port inefficiency and unproductivity in the port system, it is essential to understand the integrated approaches that can be used to improve port performance. Through this research, gaps in port efficiency in the local ports and the international ports can be identified.

The study aimed to assess the impact of smart port concepts on restructuring the dilapidating infrastructure to improve port efficiency and productivity. The literature review has outlined the international ports that have successfully implemented smart port concepts and the local ports in developing countries that are moving towards smart port concepts. A vast majority of the studies are of the view that port efficacy is equivalent to port productivity; in cases where the port is deemed ineffective, customers lose confidence and tend to cease any business with South Africa. The concept of a smart port ensures that there is connectivity between the port and the surrounding infrastructure, and this will ensure the easy flow of traffic throughout the whole connectivity system network (Grimett,2022). The improved port efficiency and productivity will allow South African ports to better compete with well-performing world ports, which further attracts more business opportunities in the port system while propelling the growth of the South African economy.

3 RESEARCH BACKGROUND

The world's economic growth is increasing at an exponential rate through global trade, and that has been reshaped by The world's economic growth is increasing at an exponential rate through global trade, and that has been reshaped by transportation connectivity networks and the port system (Notteboom, 2013). Seaports are the main link that ensures the smooth operation of logistic supply and international trade between two different countries. The ports are predominantly provided with infrastructure and necessary facilities that optimize the cargo to be handled, stored, and moved inland through the use of an integrated system that encompasses trucks or railways (Isaacs, 2020). Isaacs (2020) further outlines that ports require deep entrance channels and berths so that larger vessels can be docked in the port.World trade propels the growth of seaborne trade. South Africa is one of the African countries that is dominant in the maritime sector, considering the wide variety of oceans and the international trade patterns across the global system (Othman et al., 2022). The country is strategically situated on one of the busiest international routes, and its geographical location caters to more opportunities for increased levels of trade as well as a thriving maritime industry (Dube, 2020). The maritime transport industry is increasingly growing, more specifically considering containers and dry bulk services, which are the main commodities that contribute greatly to the South African economy. Molavi (2020) alluded to the fact that the main fundamental challenges that are hindering the progress of ports consist of traffic congestion, which causes major delays in the transshipment of cargo within the port limits.

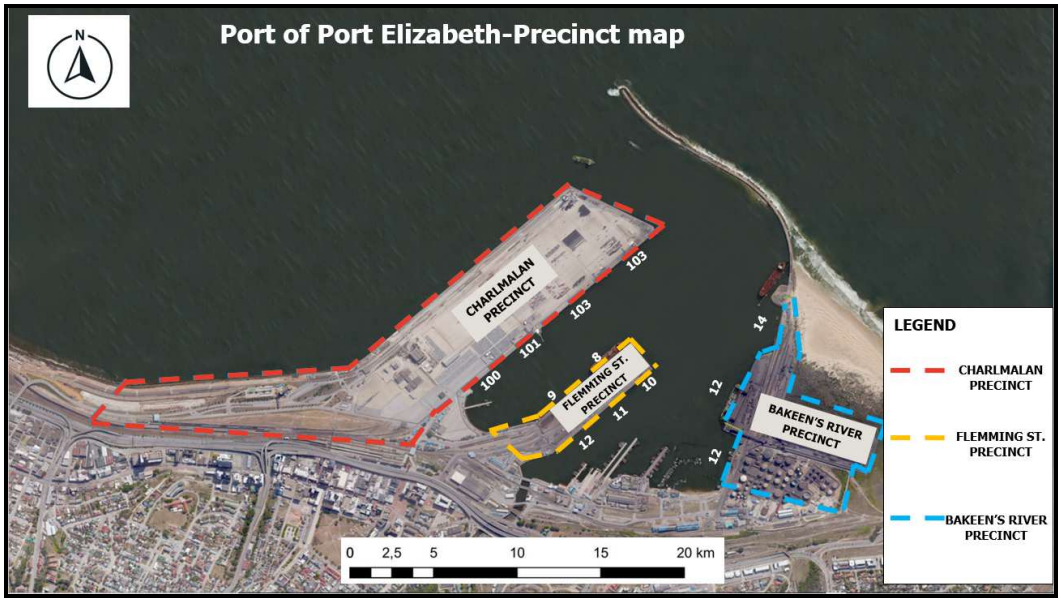

Figure 1: Port of Port Elizabeth precinct map

The port of Port Elizabeth was first established in 1933 and rapidly became one of the main ports facilitating trade. It is located in the central region of South Africa (Isaacs, 2020). The port of Port Elizabeth is regarded as one of the three specialized container-handling facilities along the South African coastline. The port of Port Elizabeth is connected to the city and the coastline of Port Elizabeth to serve the surrounding business hubs. port mainly specializes in automotive, vehicle, container, and agricultural products, offering valuable services such as storage facilities, packing and unpacking of containers, and logistics management (Transnet National Port Authority, 2019). Port Elizabeth is one of the nine operating ports in South Africa that is located within the jurisdiction of Nelson Mandela Metropolitan Municipality and largely supported by the economic zones. The figure below outlines the precincts where different commodities are accommodated in the port of Port Elizabeth.

The Port of Port Elizabeth is regarded as an established port in the central region that predominantly handles containers, manganese ore, vehicles, liquid bulk, general dry bulk, as well as break-bulk cargo (Transnet National Port Authority, 2019). This is one of the South African ports that experiences a catastrophe of traffic congestion, which causes unproductivity and inefficiency. The exploration of smart ports comes as an integrated solution that predominantly reduces truck congestion within the port system. The smart port concept encumbers the cargo delays in the road network to the interlinked business hub from the ports (Mazibuko, 2020). The adoption of the smart concept is essential to addressing these challenges of poor performance because, if they are not addressed, they result in underlying transportation costs and inefficiencies that gradually grow at an exponential rate.

4 RESEARCH PROBLEM

South African seaports are currently faced with a catastrophe of underperformance and a lack of efficiency and effectiveness to compete with other international ports such as the port of Barcelona and the port of Rotterdam. The lack of integration in the port system, when there is a decline in port productivity and efficiency, automatically implies a decline in economic growth in the country (Mcetywa, 2021).

The main problem leading to this research is understanding how the smart port concept can address the issues of inefficiency and unproductivity in the port of Port Elizabeth. According to recent statistics, the Port of Port Elizabeth has faced significant challenges that hinder its operational effectiveness. For instance, the port's container throughput has decreased by approximately 15% over the past five years, reflecting inefficiencies in cargo handling and logistics (South African Revenue Service, 2024). Additionally, the average turnaround time for vessels at this port is reported to be around 48 hours, which is considerably longer than the global average of 24-30 hours seen in more efficient ports (World Trade Organization, 2023) The concept of smart port has been adopted in international ports and is working successfully to improve efficiency and productivity. These inefficiencies not only affect the port's operational capacity but also have broader economic implications.

South African ports are no exception in this regard, as they are also under immense pressure to optimize port performance. It is imperative to outline that there is also a lack of thorough and comprehensive research studies conducted over the years to improve efficiency and productivity in this port. In tackling the prevailing issues in the port system, Port Elizabeth needs to explore the aspect of adopting the smart concept, which will address the underlying issues of unproductivity.

4.1 Research Objective

The main research objective of the study is to assess the impact of the smart port concept on restructuring South African ports that are faced with port inefficiencies and unproductivity.

4.2 Research Question

What is the main impact of the smart port concept to restructure South African ports that are faced with port inefficiency and unproductivity?

5 UNPACKING THE SMART PORT CONCEPT

The concept of the smart port is that the port relies heavily on modern technology, which acts as a service in the transportation sector of the port system (Frazzon et al., 2019). This encompasses any service, including processing, collecting, and analysing any relevant information that has been provided (Sari & Pamadi, 2019).

The concept of smart port is based on the full automation of infrastructure, which is mainly connected to the Internet of Things (Yang et al., 2018). Smart ports are regarded as a new generation where ports are designed to be more efficient and innovative as compared to traditional ports. The international ports have mainly adopted advanced technologies, which encompass artificial intelligence, IoT, big data, and automation, to improve port operations and the port economy. According to Grimett (2022), smart ports are integrated in terms of design to ensure connectivity in the logistics sector and industrial environments.

Advanced technology is essential in improving the flow of goods and the information between the cargo and the terminal operators in the port system. They also have an open innovation mindset, which allows them to continuously improve their operations through the use of new technologies and ideas (Liao et al., 2023). "The smart port concept entails the use of technologies to transform the different public services at ports into interactive systems with the purpose of meeting the needs of port users with a greater level of efficiency, transparency, and value" (Ozturk et al., 2018). The smart port can only be successful when there is alignment between collaboration, digital strategy, and port strategy.

The smart port concept is a phenomenon that predominantly integrates and ensures productivity in port operations by promoting port competitiveness and efficiency (Jović et al., 2019). The essence of the smart port concept is that it propels the integration of the city and the port in a restrictive municipality (Othman et al., 2022). In addition, the concept of smart port is a fundamental overview that predominantly outlines that there is a need for technological port development that is cost-effective while promoting the economy of the country. The smart port utilizes technology to enhance innovation by accessing current existing resources to improve port operations (Belmoukari et al., 2023).

6 PORT PRODUCTIVITY AND EFFICIENCY

The concepts of port productivity and port efficiency are two elements that are inexplicably linked, even though they are different. According to Motau (2015), the concept of port productivity is regarded as the combination of results pertaining to the available resource utilization as inputs to be transformed into outputs, while efficiency can be defined as the relative productivity necessary to achieve a desired output over a period of time or space. The concepts of productivity and efficiency in the port are therefore the two important concepts that mainly measure port performance, expressing different ranges of parameters and variables, to be further unpacked in this dissertation.

According to Booi (2022), the concept of port efficiency is essential in attracting investments in the port system while at the same time enhancing the port's competitiveness. The utilization of technology plays a fundamental role in the port system to achieve the volumes that are needed to meet the required financial targets (Dlamuka, 2022). Booi (2022), citing Wang et al. (2014), defines productivity as occurring when port assets increase through increasing utilization or operating efficiency. Equipment productivity can be increased by increasing the number of hours that are utilized on a specific day.

7 SIGNIFICANCE OF THE PORT

Ports are critical infrastructure facilities for maritime trade and logistics, serving as key transportation hubs for cargo and people. According to Bichou (2021), from a public policy standpoint, seaports are regarded as the economic engines for the markets and regions they serve. Bichou (2021) further outlines that ports are predominantly viewed as the main catalyst for generating socio-economic benefits, which encompass tax income, the creation of job opportunities, the generation of business, the inter-sector multiplier effect, and the spatial dimension for the agglomeration of different business entities. According to Trujillo (2008), seaports play fundamental roles in a country's trade and logistics efficiency. As controllable aspects of global supply chains, they require particular attention. The efficiency of port operations significantly reduces transport and trade costs, while port delays and inefficiencies lead to excessive costs in logistics and supply chains (Cullinane & Wang, 2006).

In South Africa, ports predominantly act as the gateway in terms of facilitating the functions of the country's trade and logistic activities (Bichou, 2021). The majority of trade in the country is conveyed by the seaports, which consequently ensures the reliance on ports. Furthermore, the reliance on seaports is emphasized by the country's economic trade based on its geographical location, which is heavily characterized by long distances to trade markets and extensive hinterlands and transit corridors. The aspect of maritime seaports does not only contribute to the urban economy; it also encompasses certain interdependent urban spaces (Li et al.,

2023) The primary integration of different modes of transport within the ports and the city predominantly ensures the easy movement of goods from port to port through either rail or road transportation.

8 RESEARCH METHODOLOGY

The researcher has opted for a qualitative research approach to unpack that research problem from the perspective of a third party. According to Brannen (2017), qualitative research is regarded as an approach that aims to understand the research problem from the perspective of the participants. The concept of the qualitative research approach is based on human behaviours, which also encompass the opinions, beliefs, emotions, and relationships of the affected individuals (Onwuegbuzie et al.,2012). The data was collected through the administration of survey questionnaires via email to the respondents.

The response rate was 100%, based on a sample size of 24 employees who had a broad understanding of the port operation. Questions were formulated, and they were made simple, concise, and specific to the research objective while ensuring there were no ambiguities in the research study. Port jargon was simplified to ensure people who are not familiar with the port operation understand this jargon. The potential participants were approached by the researcher at the port and were issued an approval letter from the organization detailing the essence of the study.

Participants were given time to complete the questionnaire at their own comfort and pace, and the researcher followed up after five (5) days to collect the completed questionnaires. If not completed, a second chance was given, and a follow-up was done. The main advantages of using a survey questionnaire that is of sound construction include convenience, encouraged anonymity, and varied data from closed-ended and open-ended questions (Griffee, 2012). The thematic analysis allows the researcher to determine precisely the relationships between concepts and compare them with the replicated data (Braun &Clarke, 2006). The aspect of applying thematic analysis ensures that there is a link between the various concepts and opinions of the study and compares these with the data that has been gathered in different situations at different times during the project. This is a method that is predominantly widely used in the aspect of analyzing experiences and the opinions of the participants, as well as behaviours.

9 RESULTS, INTERPRETATION, AND DISCUSSION

The essence of the research objectives is based on bridging the gap between the best-performing international ports and the underperforming ports in South Africa through the exploration of smart ports to improve port performance. The study has shown that the port of Port Elizabeth is faced with issues of inefficiency due to a lack of equipment and skilled workers, which has led to poor port performance.The overall aim of this study was to assess the impact of the smart port concept on improving port productivity and efficiency in the port system. The questionnaires that were applied in this study analysed carefully to ensure that the data gathered was presented clearly with the use of tables and graphs, where possible. Data was collected from the study questionnaires, which were completed by a total of 24 employees who participated. Concerning the readiness of the port to adopt the smart port concept, the response rate was positive for 79% of the employees who stated that the port is ready to adopt the smart port concept to improve port efficiency and productivity. The data was analysed to outline the causes of port inefficiencies and unproductivity and the possible interventions that can be applied to alleviate such challenges.

9.1 Challenges of adopting the smart port concept at the Port of Port Elizabeth

The adoption of smart port technologies at the Port of Port Elizabeth presents several challenges that need to be addressed for successful implementation.The research has portrayed that there are many challenges associated with the adoption of the smart port concept, including the lack of maintenance of infrastructure in the port and the consistent breakdown of equipment, which causes more delays. The main challenge is the outdated infrastructure, congestion from trucks entering the port, as well as long turnaround times and marine delays.The port's facilities are unable to accommodate larger vessels or handle increasing cargo volumes efficiently. Expanding and modernizing infrastructure requires significant investment and poses environmental risks, such as disrupting marine ecosystems and surrounding communities. The port currently uses a manual booking system for trucks entering the port, which causes more traffic in the port while overloading the road system. One of the main fundamental issues that causes port inefficiencies is the poor implementation of capital projects and the poor terminal oversight.

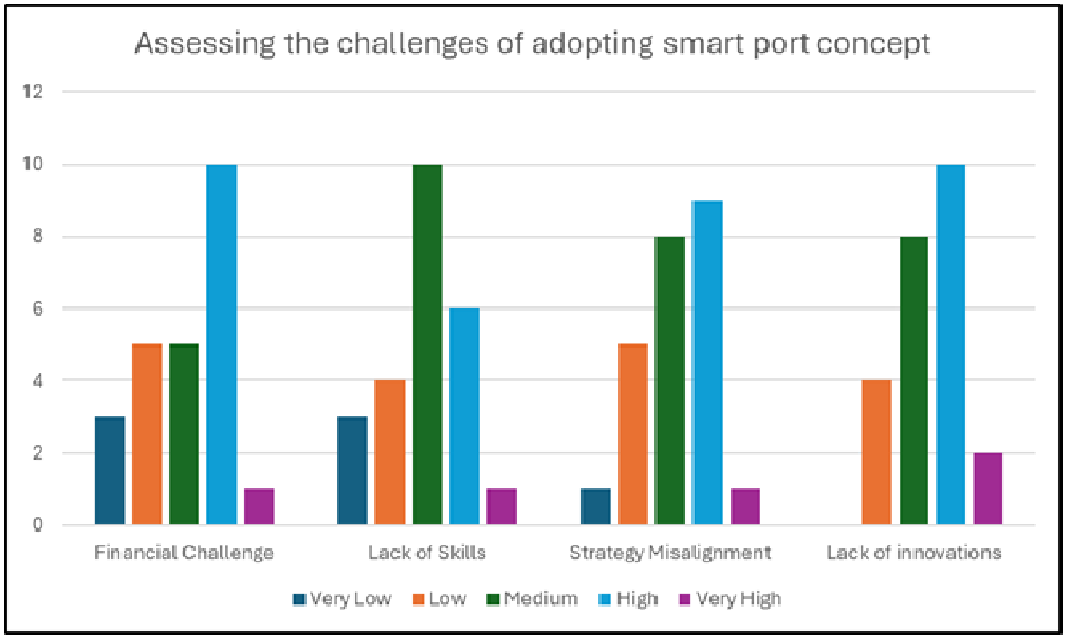

Figure 2: Challenges of adopting smart port concepts

The Port of Port Elizabeth is currently facing issues of breakdowns that cause considerable delays in operations. The geographic location of the port is integrated with the city, which, while essential for the integration of city planning and the port, has an adverse effect on port efficiency because any disruption in the city causes more delays in port operations.The concept of implementing smart port technologies requires substantial funding from investors, which is challenging for a port with limited resources such as the Port of Port Elizabeth. Inefficiencies in current operations increase operating costs while reducing productivity. The lack of financial capacity to invest in automation systems, and IoT devices limits the port's ability to modernize into a smart port.

The transitioning of an ordinary port to a smart port requires advanced digital systems for the real-time data tracking of cargo, predictive analytics, and automated operations. However, the Port of Port Elizabeth still lacks these systems which makes it difficult to optimize logistics and remain competitive globally. The research participants' recommendations on how the city can resolve the smart governance challenges they encounter in the process of being smart were given by the respondents.

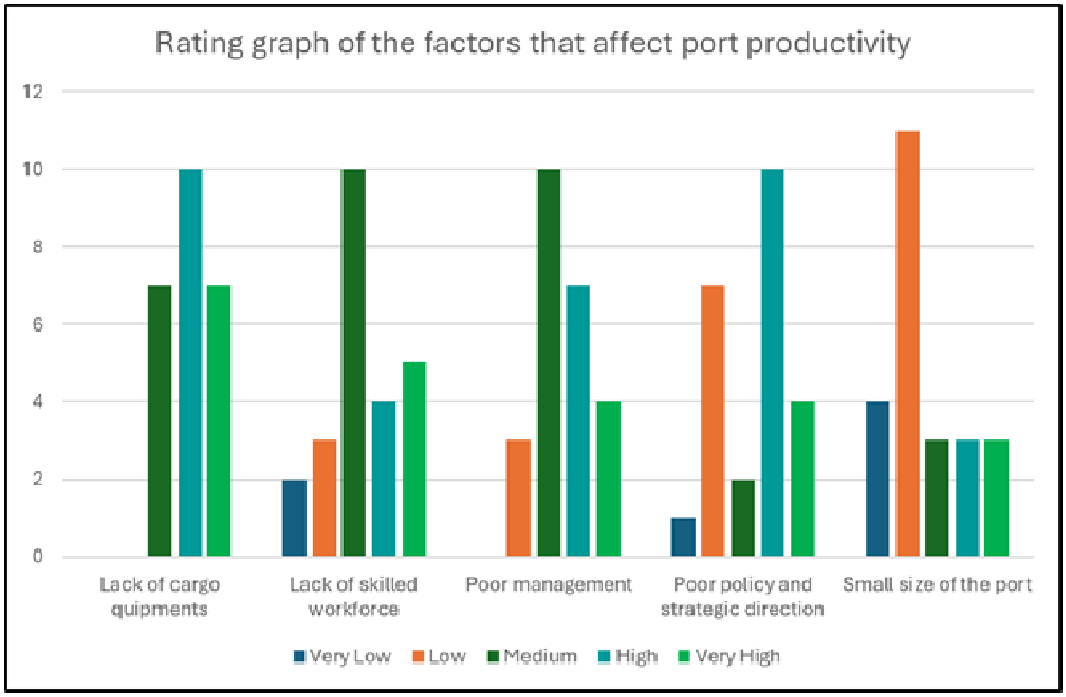

Figure 3: Rating of the factors that affect port productivity

9.2 Integrated approaches to improve the performance of the port through the smart port concept

The implementation of smart port systems is essential in monitoring the condition of the infrastructural elements, which consist of quays, cranes, and rail systems, through the use of Internet of Things (IoT) devices. In this manner, it becomes easier to analyze big data and port operators by predicting maintenance needs and scheduling repairs or replacements before infrastructure reaches a critical state of disrepair. The strategic approach is based on the implementation of a port system to alleviate the current inefficiencies and unproductivity by exploring the smart port concept. The aspect of smart port systems is essential in monitoring the condition of the infrastructural elements, which consist of quays, cranes, and rail systems, through the use of Internet of Things (IoT) devices. This plays a fundamental role in analyzing big data while at the same time predicting maintenance needs and scheduling repairs or replacements before infrastructure reaches a critical state of disrepair. The port serves as a vital hub for South Africa's automotive and agricultural sectors, emphasizing the necessity for improved infrastructure to accommodate increasing trade demands.

9.3 Strategic initiatives to reconfigure the dilapidating infrastructure to improve efficiency and productivity

The main integrated approach to improving port performance through the smart port concept is the assessment of current port infrastructure and equipment, which is one of the ways to identify and reduce inefficiencies. The acquisition of marine fleets (e.g., tugboats) is another means to address frequent marine-related breakdowns. The research study has highlighted the importance of adopting the smart port concept not only for the port of Port Elizabeth but for the whole port system. The proposed concept has been highlighted as an effective solution to address the deteriorating infrastructure in the port, which has immensely affected port performance and increased inefficiencies that have led to poor port productivity and high transport costs. The port has a strategy to reduce dwell time by increasing rail capacity and reconfiguring the port to implement technology-related interventions. Some of the strategic initiatives in the port system consist of the truck booking system and automated truck work permits. The smart booking system ensures that there is no traffic congestion in the port system, and trucks will be allocated a scheduled time to avoid any port congestion. The port is working towards the implementation of the smart port concept with the current projects that are in the pipeline.

9.4 The strategic approach of Smart port South Africa`s economic growth

The notion of smart port technology offers a unique opportunity to solve unemployment in Port Elizabeth by developing new skill development routes and novel employment initiatives. The implementation of Smart port technology represents an integrated strategy for workforce development by recognizing that the 4IR necessitates a significantly altered labor force. The Port of Port Elizabeth requires skill development efforts for present personnel, which include the creation of focused maritime technology certification programs. This will ensure the collaboration between educational institutions and port industries, and implementation of quick upskilling initiatives for the employees who are currently working.

The transition to smart ports represents more than a technological upgrade it is a comprehensive workforce transformation strategy. Proper adoption of the smart port concept at the port will ensure there is reduced unemployment due to the fact that people will be well-informed about how to use the well-advanced equipment that will enhance workforce employability, and this will modernize local workforce capabilities.

10 INTERNATIONAL APPROACH OF SMART PORTS AT THE PORT OF ROTTERDAM

The Port of Rotterdam (POR) is regarded as one of the largest ports in Europe, ranked in the top 20 in 2017 in the world port rankings (Isaacs, 2020). The Port of Rotterdam has made significant investments in handling equipment for effective operations and has revolutionized the idea of a new transportation system. The Port of Rotterdam has the benefit of being able to handle larger ships without any problems. The port consists of well-organized infrastructure, deregulation of transportation services, and logistical trends that make up the smart port idea feasible. One logistics mega center that has adopted the smart port concept is the Port of Rotterdam.

10.1 The strategies and initiatives for the Port of Rotterdam

The adoption of the smart port concept will mainly entail reduced traffic congestion within the port limits for both road and rail transport, which will promote connectivity within the port (Mswephu, 2020). South African ports are experiencing the catastrophe of traffic congestion; hence, the adoption of smart ports comes as an integrated solution that predominantly reduces truck congestion within the port limits. In addition, the smart port concept alleviates the cargo delays in the road network to the interlinked business hub from the ports. The adoption of the smart concept is essential to addressing these challenges of poor performance, which, if not addressed, result in underlying transportation costs and inefficiencies that gradually grow at an exponential rate.

The essence of digital transformation in the world can be proven to be evident at the port of Rotterdam through the transition from physical operation to digital port. Digital The port consists of a digital twin that mainly intends to track the movements of the ships,the upgrade of infrastructure, changesinweather, and geographic data to enhance the port efficiency and overall operations (Merk, O., &Notteboom,2013).

The port uses various technologies that encompass the IoTto collect and process dynamic data such as the flow ships, and visibility. This data is used in the aspect of predicting the port infrastructuremanatiance to optimize the logistics.The port predominantly capitalizes on fostering collaboration between companiesdeliveredto companies such as tech providers, cargo owners, and financial institutions to develop innovative and sustainable services. Karas (2020) further states that the terminal operators have a real insight into the specific handling of their loads in the terminal. According to Yau (2020), the use of modern devices ensures that customers urgently receive the relevant information regarding the cargo on the train, its destination, and the expected time for it to arrive for unloading. This further encompasses the work progress related to the load at the terminal.

10.2 Strategic Overview of the Port of Barcelona

The Port of Barcelona is one of the ports that has committed to adopting the concept of smart port that involves the gradual movement towards the aspect of efficient suitability with the main aim of continuous services to improve productivity (Henríquez et al., 2022). The Port of Barcelona is a leading port when it comes to the integration of the city with the port, which has been propelled by smart policies at an international level.The port also utilizes electronic documental interchange (EDI) among the different stakeholders at the port (Yau et al., 2020). The vision of a smart port concept is predominantly based on reliance by the port on the digital system to ensure improved technology while reducing the costs of port operation and the consumption of resources while ensuring that the environment is not adversely affected by the operation.

Nowadays, the cruise tourism sector around the world has progressively shown massive growth and high demand in the market. The Port of Barcelona is a major destination for cruise tourism due to its well-equipped cruise terminals that are in operation (Henríquez et al., 2022). The strategic positioning of the Port of Barcelona makes it among the most advantageous ports in Europe, owing to its closeness to numerous popular tourist destinations in the western Mediterranean. The port consists of cruise liners, the port is anticipated to remain a key port that accommodates cruise ships. The port is a major attraction for tourists thanks to the presence of high-quality architecture coupled with history, food, and good accessibility to the city as compared to the surrounding regions (Yau et al., 2020).

10.3 Integration of InternationalPort with South African Port

The port of Rotterdam is one of the best-performing ports in Europe because of its advanced technological equipment. These systems are essential in that they provide the relevant information in real-time, ensuring that there is no unrealistic communication that would cause any delay in the transportation of goods through the sea operation. The smart port concept consists of well-structured infrastructure and the liberalization of transport services and logistic trends. The Port of Rotterdam is classified as a main logistics hub that has implemented the smart port concept. The port of Port Elizabeth can learn a lot from this port and invest in equipment that will eliminate downtime or delays. However, in order to explore technologically advanced equipment, there is a need to have maintenance plans in place. This further encompasses the financial viability of procuring the equipment that is required for smart technology.

The Port of Barcelona is one of the international ports that possesses the qualities ofthe smart port concept based on the utilization of technology to demonstrate an environmental commitment to become a sustainable port, and orientating port activities to the needs of both customers and the port authorities. The Port of Port Elizabeth has the responsibility to uphold through focusing on several elements to align with the strategies of the Port of Barcelona. The port of Port Elizabeth is on the verge of implementing the smart port initiatives which include the expansion of automotives and the development of the waterfront. The port of Port Elizabeth can achieve this by integrating the port with the city to promote ecological transition and accommodate urban life. This involves designing public spaces that improve understanding of port activities and facilitate mobility between neighboring districts.The development of the waterfront not only supports the tourism sector in the port but also grows the economy of the city and the province and the hotels that are in close proximity will immensely benefit. They possess all the qualities that the Port of Port Elizabeth wants to accomplish in order to be a well-developed port in the provision of the tourism sector.

11 CONCLUSION

In conclusion, the essence of the study was based on exploring the smart port concept to improve port performance, taking into consideration international ports that have fully adopted the concept. The study has shown the underlying challenges and the strategic approaches that can be used to counteract those challenges by improving port efficiency and productivity. The adoption of the smart port concept will ensure that the South African port system experiences the aesthetic of port planning, taking into account that the ports will become more competitive with lower transportation costs while ensuring the reliability of transportation through integrated planning. The adoption of the smart port concept is expected to drastically reduce truck congestion within the port area. This means that transportation issues will be resolved in the surrounding areas as well because both rail and road will be integrated. If these challenges are not addressed in an orderly manner, the South African port system will continue to face challenges of inefficiency and unproductivity. Eventually, investors will not be keen on doing business with South Africa due to a lack of trust, and that will affect the economy of the country in the long run.

The concept of the smart port model will influence the employees at Transnet to adapt to the change in technology and embrace the planning integration of different land uses that promote the viability of the transportation system. Intelligent infrastructure will be introduced across the port system, which will ensure improved port performance. This will encourage investors to have more confidence to trade with South Africa because of its good performance and reduced transportation costs in the port system. There will be an integrated logistics chain, and the port system will be an integrated gateway for trade. The aspect of leveraging technology and modernizing infrastructure, South African ports can improve their competitiveness in the global market while supporting economic growth.

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reviewed paper

Towards Resilient Energy Systems: The Role of BIM and GIS Integration in Southern Africa

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1 ABSTRACT

Driven by emerging technologies, the integration of Building Information Modelling (BIM) and Geographic Information Systems (GIS) is an expanding field supporting the digital transformation of energy infrastructure. However, a significant gap exists in digital transformation research in Southern Africa compared to developed countries, exacerbated by governance challenges in developing regions. This paper reviews the state-of-the-art in BIM and GIS integration research to enhance the resilience and adaptability of green infrastructure planning. Using bibliometric analysis, the study examines publications related to green infrastructure, BIM-GIS integration, and climate change. The findings highlight emerging research areas, including sensor data, microgrids, green infrastructure, digital twins, digital transformation, and cybersecurity. Despite these advances, developing countries face critical challenges, such as the need for support systems, affordable digital twin technologies tailored to local contexts, and capacity building for decision-makers and experts. Key lessons reveal that BIM-GIS integration solutions must accommodate diverse equipment types and operating conditions. The findings provide valuable insights for policymakers, urban planners, and stakeholders to create resilient, equitable, and sustainable urban environments that address the unique challenges of Southern African cities.

Keywords: Building Information Modelling, Geographic Information Systems, digital transformation, green infrastructure, literature review

2 INTRODUCTION

Driven by emerging technologies, the integration of Building Information Modelling (BIM) and Geographic Information Systems (GIS) is an expanding field supporting the digital transformation of energy infrastructure. Globally, the adoption of digital technologies to assist climate change strategies has become the cornerstone of effective green infrastructure planning (Wang et al., 2013; Rafiee et al., 2014; Bansal, 2010). Over time, developing countries have grappled with underlying inefficiencies related to technology adoption, a topic extensively studied (Yau et al., 2014; Irizarry & Karan, 2012). BIM is a digital representation of a facility's physical and functional characters. It is based on technology incorporating information in three dimensions. In contrast, GIS is developed to manage and analyze spatial data, which is based on geomatics technologies. The integration system of BIM and GIS enables the effective management of information in various stages of a project's life cycle, namely planning, design, construction, operation, and maintenance (Amirebrahimi et al., 2015; Hijazi et al., 2011). BIM-GIS integration has been hailed as a solution, leveraging technology to address shortcomings in green infrastructure planning. Aligning national priorities and project objectives is paramount for meeting the Sustainable development gaoal mandates. With unified BIM and GIS technologies, it can occur seamlessly, reducing waste and enhancing designs. Scholars have outlined that the adoption and utilisation of BIM-GIS applications hold promise in alleviating collaboration challenges within the green energy sector while streamlining processes and improving efficiency in the planning lifecycle.

Global development organisations can streamline workflows, enhance communication, and unlock efficiencies throughout the project lifecycle by leveraging digital technologies such as Building Information Modelling (BIM), Geographic Information Systems (GIS), and cloud-based collaboration platforms. However, the journey towards digital transitioning in the green energy sector of developing countries is not without its challenges (De Laat et al., 2011; Virmani et al., 1997). Limited digital infrastructure, skill gaps,

and institutional barriers often hinder the widespread adoption of digital technologies and workflows (Horrocks, 2008; Xiao et al., 2007). Moreover, cultural factors, stakeholder resistance, and data privacy and security concerns further complicate the landscape. Despite these challenges, the imperative for digital transformation remains clear. The benefits extend beyond mere efficiency gains to encompass broader socioeconomic impacts, including job creation, economic growth, and improved quality of life for communities. By embracing digital workflows and fostering collaboration between public and private stakeholders, organisations in the built environment of developing countries can unlock new avenues for innovation, resilience, and inclusive development (Stanton-Chapman et al., 2011; Liu et al., 2014). This chapter seeks to explore the role of organisational digital workflows in driving digital transitioning within the built environment of developing countries. Through case studies, best practices, and insights from industry leaders and experts, we aim to elucidate the opportunities, challenges, and strategies for harnessing the power of digital technologies to catalyze sustainable development and build more resilient and equitable societies.

Nevertheless, the literature suggests that achieving widespread BIM-GIS adoption and usage requires a paradigm shift and establishing common standards and operational protocols, among other considerations (Eadie et al., 2015; Ahuja et al., 2020). Ensuring the active engagement of key stakeholders during the planing, design and development phases is crucial. Scholars have advocated for proactive involvement particularly significant during the early stages of implementation (Becker et al., 2009; Boguslawski et al., 2011). This proactive action can greatly enhance the flow of information across the design, operations and maintenance phases (Olowa et al., 2022). However, in many African countries, several obstacles hinder the widespread adoption of BIM-GIS integration in green infrastructure projects. Scholars have noted a lack of involvement by government agencies and resistance from project owners; Inadequate participation by planning professionals, failure of architects to share complete models with engineers, and the reluctance to share project data (Stadler, 2007; Gröger, 2012; Valentini, 2014). Similay, the lack of education and training can make it difficult for built environment professionals to implement BIM effectively (Taylor & Bernstein, 2009; Peters, 2010).

Tan et al., (2019) mentioned that one of the most serious challenges to BIM-GIS implementation in green infrastructure projects is the adaptation to new technology and processes. Stakeholders, especially those in a developing market, have to deal with the difficulty in effectively reengineering the existing process, which significantly constrains BIM-GIS implementation. Stakeholders have to spend extra time and effort ensuring the digital objects in a BIM model have the required level of development. Thus, the extra workload will result in negative attitudes toward BIM implementation. The implementation of BIM unavoidably changes project delivery and potentially an organisation's structure. Stakeholders in the construction industry are known to be resistant to change. They are used to traditional paper-based methods and unwilling to adopt new technologies (Kolbe, 2009; Wang, 2012). Persuading these reluctant parties to use BIM can be extremely difficult. External motivation has been identified as an important factor affecting new technology implementation (Yau et al., 2014). However, stakeholders in the South African industry generally do not have enough motivation to intergrate BIM and GIS, and the incentive mechanism for BIM implementation in South Africa has not been well established. Such insufficient external impetus will inhibit positive attitudes towards BIM. The limited study of BIM-GIS integration, conducted within the context of South Africa could lead to a low level of adaptability and hinder actual implementation. To address this gap, this study reviews the state-of-the-art BIM and GIS integration research to enhance the resilience and adaptability of green infrastructure planning

3 METHODOLOGY

The continuing lag in technology adoption within the green energy practice is emerging as a growing concern amongst developing countries. This digital divide among professionals poses a considerable obstacle to fostering resilient infrastructure and inclusive growth. The review of the literature was undertaken using PRISMA protocols and bibliometric analysis. Literature from Scopus database was collected for the bibliometric analysis. All studies relating to the research were eligible for review with no specification on publication years. The database search in WoS was conducted and classified using the following keywords. The database search and the subsequent analysis were both carried out on a global scale.

- “Green infrastructure” and “Building information modeling”

- "Green infrastructure" and "Geographic information system"
- "Green infrastructure" and "climate change"

The inclusion criteria were all articles published in the field of quality of service in public transport (table 1).

Inclusion criteria	**Exclusion criteria**
All articles with topics in green infrastructure in climate change research	Studies outside green infrastructure scope
All articles with topics relating to BIM-GIS integration in climate change research	Unpublished thesis and dissertations; Non-peer-reviewed papers
All articles with topics relating to BIM-GIS integration in green infrastructure planning	Newspapers, conference papers
Language: English	Non-English language
Countries: All	

Table 1: Inclusion and exclusion criteria for the data collection extracted from the database.

The search in the literature was directed by screening titles and abstracts for each article to confirm eligibility. The protocol for the inclusion and exclusion process is presented in Fig. 1 as guided by the PRISMA protocols. The approach was adopted to eliminate bias when conducting a literature review. Therefore enhancing the validity of the study's findings of the study.

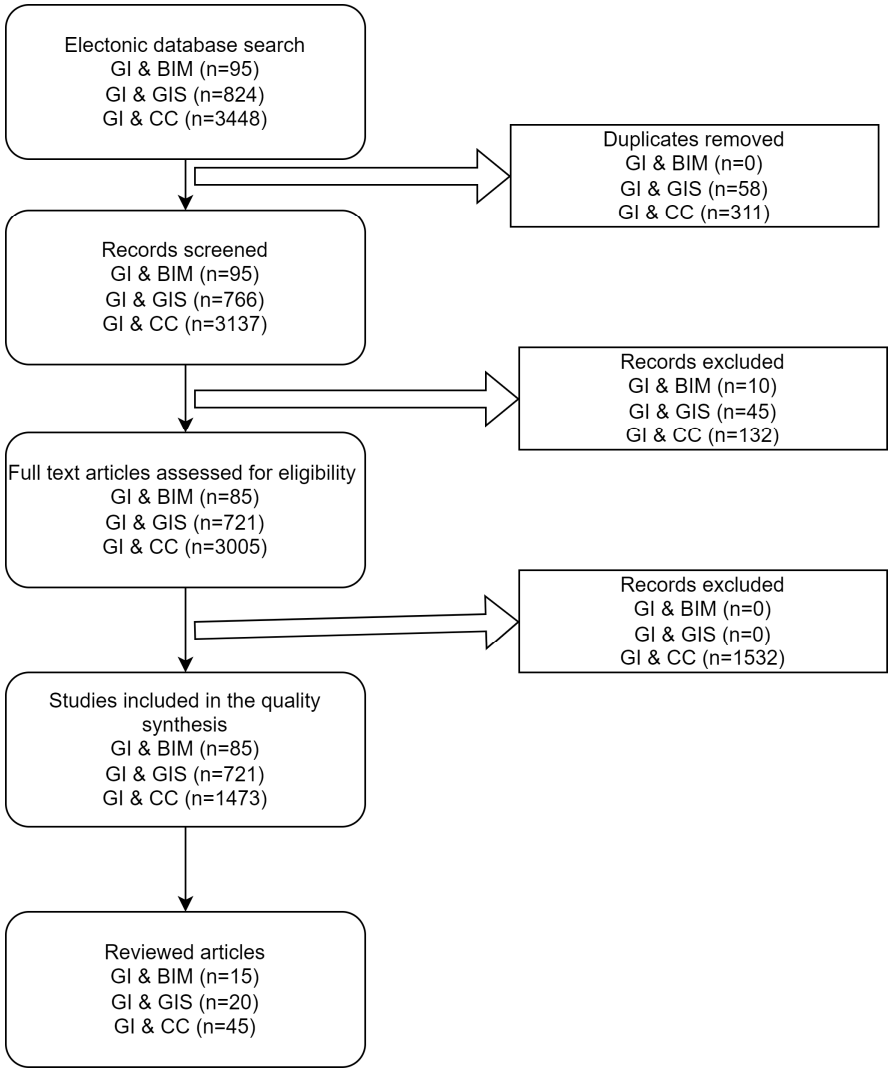

Figure 1: Summary of search procedure

4 FINDINGS AND DISCUSSION

Figure 2 presents the development of research on BIM-GIS integration within green infrastructure planning as part of efforts to address climate change challenges between 1996 and 2025. Up to 2008, research was limited, inconsistent, and highly fluctuating. An increase in research is noted from 2012 to 2020 and remained constant in 2025. Findings corroborate the trend observed in the existing literature on digital maturity and a lack of detailed analyses of barriers encountered in achieving successful BIM-GIS integration (Musonda et al., 2025). The sudden increase in research from 2020 could be because research on the subject had become a "recent vintage". This illustrates that while research on the subject is not new, it is simply now being valued and given more consideration than before.

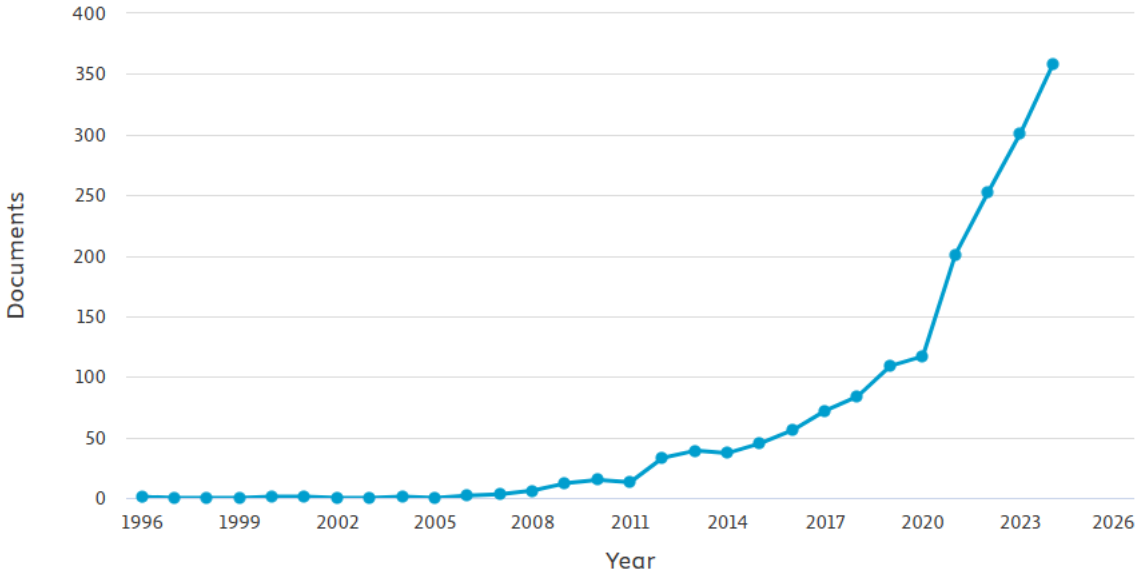

Figure 2: Research publication trend between 1996 to 2025

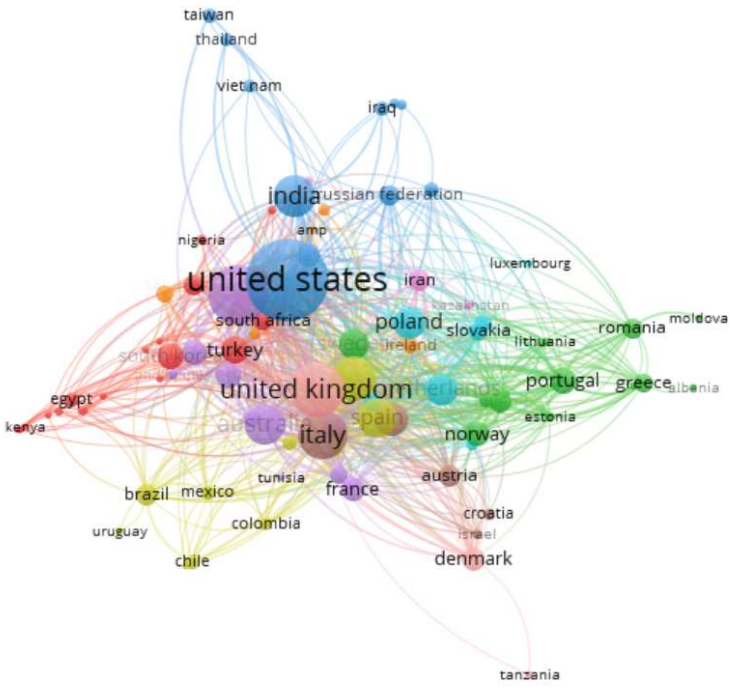

Figure 3: Institutional collaboration

4.1 Co-occurrence network analysis of institutions

Co-authorship between institutions publishing research on BIM-GIS integration within green infrastructure planning is shown in Figure 2. 73 countries met the threshold with a minimum of 5 documents. The United

States (232 documents, 268 total ink strength), the United Kingdom (509 documents, 250 total ink strength), China (265 documents, 201 total ink strength), and Germany (158 documents, 193 total ink strength), were the dominant countries. In Africa, South Africa (30 documents, 44 total ink strength), Egypt (18 documents, 17 total ink strength), and Kenya (4 documents, 8 total ink strength) are producing research on the subject. The low publications in Africa could be because of low BIM-GIS adoption. The relatively low research performance is also reflected in research on digital maturity in Africa.

4.2 Emerging Research

Figure 3 reveals the existing, current and emerging research trends in GIS-BIM integration research in green infrastructure from 2019 to 2021. The timelines are divided into 4 clusters (yellow, navy blue, green, and turquois blue). The navy blue cluster indicates the trend topics in research GIS-BIM integration research in green infrastructure from 2019 to 2019.5. A turquois blue cluster presents trend topics from 2019.5 to 2020. In addition, 2020 to 2020.5 is presented by a green cluster, while 2020.5 to 2021 is presented by a yellow cluster.

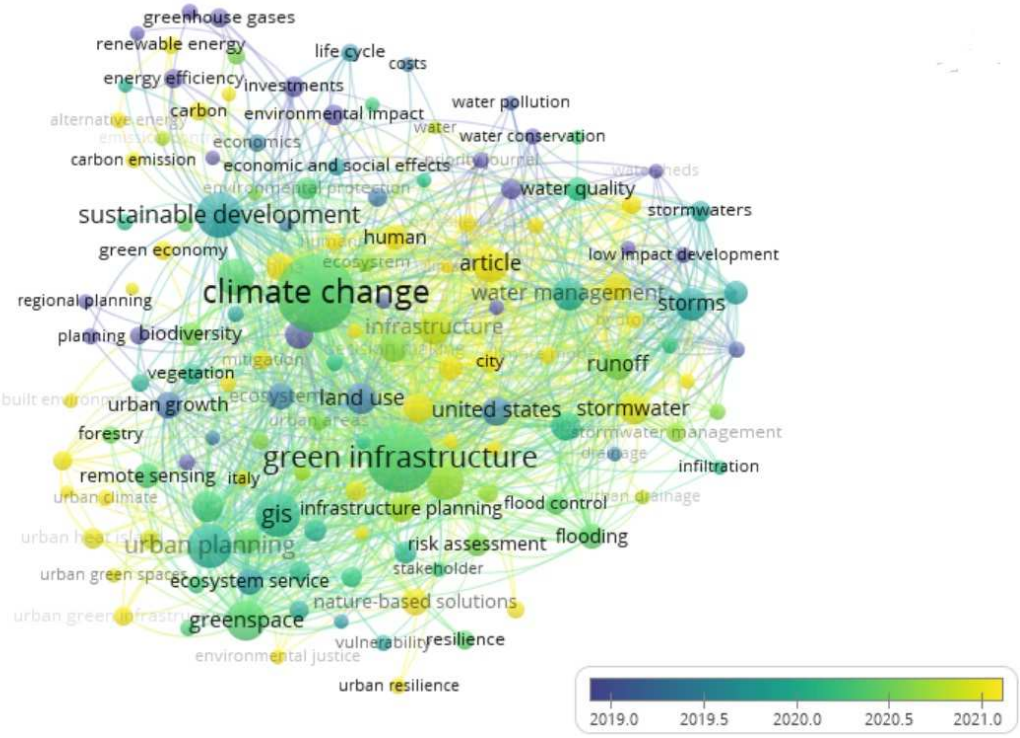

Figure 4: Emerging research areas

The significance of information and technology management is on the rise, especially with the advent of smart cities. The integration of BIM and GIS at data level normally involves the introduction of new standards, revision of old standards, or the conversion/translation of data format. The introduction of a new standard or model has the potential to fundamentally transform and revolutionize the integration problem by eliminating barriers between different domains (Wang et al., 2013; Rafiee et al., 2014; Bansal, 2010). However, emerging standards and models typically address integration from a specific perspective such as typology of green infrastructure, rather than providing a comprehensive, all encompassing solution. No single standard can fully cover all aspects of a region due to the inherent complexity and diversity of urban environments.

One of the primary reasons for this limitation is that developing a new standard or model is a resource-intensive process, requiring significant time, expertise, and financial investment. Additionally, information loss whether intentional or unintentional remains an unavoidable challenge, particularly in large-scale, ambitious models that attempt to encompass all elements of a region. As standards and models evolve, gaps may emerge due to discrepancies in data compatibility, institutional constraints, or the sheer difficulty of integrating diverse datasets. A review of existing frameworks suggests that targeted, domain-specific projects tend to achieve greater success (Yau et al., 2014; Irizarry & Karan, 2012). These focused initiatives demonstrate higher efficiency in minimizing information loss, maintaining flexibility, and optimizing labor

costs. By concentrating on well-defined objectives rather than attempting to create an all-inclusive model, such projects are more adaptable to evolving technological and contextual requirements. Ultimately, while new standards and models play a crucial role in addressing integration challenges, their effectiveness depends on strategic implementation, incremental development, and careful consideration of domain-specific needs. Striking a balance between comprehensiveness and practicality is key to ensuring sustainable and scalable solutions for integration in complex environments.

A critical pathway to digitalising the energy sector is through the adoption of GIS and BIM at process level. BIM and GIS have different contents and data structures, and BIM normally has much more information than GIS. In order to develop a seamless integration system, a reference ontology as part of semantic web technologies can be used to store and represent the differences. The ultimate goal of semantic web is to "allow data to be shared effectively by wider communities, and to be processed automatically by tools as well as manually. Similar to the ongoing work on "Climate change" and "green infrastructure" are the most central and dominant topics, indicating a strong research focus on sustainability and resilience strategies. This reveals implementing GIS-BIM integration necessitates a systematic, incremental development process in collaboration with users, occurring both on-site and off-site.

In the past decade, BIM-GIS technology has made significant progress, leading to its widespread acceptance. The rapid growth can be attributed to the manifold benefits across the project lifecycle, encompassing planning, design, operation, and maintenance (Ramaji et al., 2020). The Internet of Things (IoT) integration has been instrumental in modernizing green infrastructure planning, facilitating data integration, and real-time data exchange (Zhang et al., 2022). By incorporating artificial intelligence (AI) and machine learning algorithms, processes can be optimised, leading to the implementation of more effective information-based management strategies (Arisekola & Madson, 2023).

The last cluster of integration methods is at application level. At this level, both source data and object data are not changed, and no service or ontology is developed. The integration methods at application level solve the problem from one particular angle, and normally cannot be adopted by other methods. Furthermore, the integration of emerging technologies not only enhances operational efficiency but also facilitates predictive maintenance and performance optimisation. IoT sensors continuously monitor various aspects of building performance, such as energy consumption or production, and equipment health. This real-time data is then fed into models, enabling stakeholders to simulate different scenarios, predict potential issues, and proactively address them before they escalate. Moreover, the convergence of with IoT, and AI offers opportunities for enhanced collaboration and decision-making throughout the building lifecycle (Žigiene et al., 2019; Nabizadeh & Hossein, 2021). By centralizing project information and streamlining stakeholder communication, project teams can work more cohesively, reducing errors and delays. Additionally, AI-driven analytics enable data-driven insights, empowering stakeholders to make informed design, construction, and operation decisions.

The presence of "GIS," "remote sensing," and "infrastructure planning" suggests the growing use of spatial data and technology in sustainable urban development. By continuously updating BIM models with real-time data from IoT sensors, facility managers can monitor green energy facility performance, identify inefficiencies, and implement corrective actions to improve operational effectiveness and occupant comfort. Combining BIM with GIS has yielded substantial achievements in automation, error diagnosis, energy optimisation, facility management, and sustainable development (Biswas et al., 2024). Additionally, The interlinkage with "risk assessment" and "flood control" shows the application of geospatial technologies in climate adaptation. The synergistic benefits of implementation include increased productivity, efficiency, and the integration of cost and schedule management for construction projects (Nawari, 2019; Zhang et al., 2023). Moreover, BIM-GIS integration finds applications in green energy evaluation, clash detection, optimisation, and enhancing communication and productivity (Liu et al., 2016; Abdal Noor & Yi, 2018).

Santos et al. (2017) underscore the role of BIM-GIS based project management tools in enhancing project learning outcomes, bridging the gap between theory and real-world challenges. espite these advancements, the energy sector faces challenges in establishing common understandings of BIM-GIS concepts and consistent methodologies. As seen with the interlinkage between "risk assessment" and "flood control" shows the application of geospatial technologies in climate adaptation. Hooper (2015) suggests that while technology facilitates collaboration through proprietary BIM-GIS tools, there's still a need to enhance

industry-wide stewardship of digital information throughout green infrastructure project phases. Overall, the benefits of BIM-GIS integration are vast, but there remains a gap in knowledge dissemination and standardised methodologies.

5 LESSONS LEARNT AND IMPLICATIONS FOR PLANNING

The finding from the review has several implications with regard to the new knowledge generation for academic purposes and policy formulation and implementation in the local, provincial, and national spheres. The rise of "GIS" and "BIM" implies that spatial technologies are becoming fundamental tools for climate adaptation and urban planning. The transition to BIM-GIS integration adoption has the potential to improve real-time information management on green infrastructure projects. BIM-GIS integration uses data collected from sensors, simulations, and other sources to digitally represent the physical system. A close reflection on emerging research trends reveals in developed countries, digital maturity with regard to BIM-GIS integration is at an advanced level. Additionally, the diverse range of topics, from economic effects to environmental justice, highlights the interdisciplinary nature of climate adaptation research.

While in the global South, few countries have made strides to utilize BIM and GIS in green infrastructure projects. In Africa, knowledge gaps exist due to few local case studies are available that have successfully implemented GIS-BIM integration in green infrastructure projects. Additionally, Musonda et al., 2025 have outlined that most planners have not participated in at least one project where GIS-BIM integration was adopted in Southern Africa. This reveals low awareness and adoption of emerging technologies. Addressing these barriers is essential for facilitating the successful implementation of GIS-BIM integration and promoting their widespread adoption in the energy sector.

The focus on "urban resilience" and "nature-based solutions" suggests that cities increasingly incorporate green infrastructure to enhance climate adaptability. These efforts require governments and relevant stakeholders in developing countries to play a crucial role in supporting and investing in GIS-BIM integration initiatives. By providing funding, infrastructure, and regulatory frameworks conducive to green implementation, policymakers can help drive the built environment's digital transitioning and unlock this technology's potential benefits for economic growth and development.

6 CONCLUSION

The integration of BIM and GIS is essential for advancing digital workflows in urban planning, infrastructure management, and smart city development. This paper reviews the state-of-the-art in BIM and GIS integration research to enhance the resilience and adaptability of green infrastructure planning. Three levels of BIM-GIS integration methods were revealed in this study, namely at data, process, application level. As a compromise, semi-automatic methods have shown potential in balancing integration efficiency with cost-effectiveness. Additionally, application-focused methods provide effective solutions but often lack generalizability. However, achieving seamless interoperability requires overcoming technical, semantic, and institutional barriers. While new standards and ontologies offer long-term solutions, practical integration today relies on adaptable, application-driven, and semi-automated methods. The key to successful integration lies in fostering openness and collaboration across disciplines, ensuring that stakeholders from both domains work together to develop shared frameworks and best practices. Moving forward, initiatives that promote cross-domain cooperation, supported by advancements in ICT and smart city technologies, will be crucial in realizing the full potential of BIM-GIS integration.

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reviewed paper

Translating the Planning Lexicon: a Systematic Review towards Localised Planning Glossaries in South Africa

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1 ABSTRACT

Planning theory has evolved towards a Post-collaborative agenda of non-tokenistic participation and reverence for perspectives from the Global South. Yet, practical implementation is complex and often falls short of participatory ideals in highly diverse and unequal contexts, such as South Africa, where formal land use management systems confront traditional leadership and customary practices in impoverished rural areas. To gain a deeper understanding and identify potential good practice examples, this paper engages with the international planning lexicons that shape participatory discourse, specifically examining whether, and to what degree, scholarly outputs, practical plans, and related documents evidence a shift towards more Post-collaborative and co-productive practices. A systematic literature review of academic and grey sources from 2000 to 2024 is conducted. From 664 potential publications, a final sample of 101 (15.22%) sources is reviewed and subjected to bibliographic and qualitative analyses to extract key themes. As an exploratory study, preliminary findings indicate that publications from the Global North continue to dominate. Scholarship maintains support for planning frameworks that more effectively engage with local conditions and incorporate indigenous knowledge, but limited practical guidance is provided. The tone of official planning documents, including their glossaries and explanatory definitions, continues to target a professional and well-educated audience through technical planning language. A small number provide direct linguistic translations, but most fail to support further understanding with contextualised discussions or examples. Locally informed planning glossaries, as participatory tools, may thus be relatively novel. Notwithstanding limited good practice examples, there is significant potential for South Africa to develop context-specific planning glossaries that enhance communication between planners and communities. To this end, this paper draws conclusions and makes related recommendations, including an example for a more localised South African planning glossary.

Keywords: Planning Glossary, South Africa, Public participation, Systematic review, Planning Lexicon

2 INTRODUCTION

Debate has surrounded the discipline of urban planning and its normative and procedural principles for decades, as theories and practices of planning have responded to significant epistemological and ontological shifts towards a more mainstream focus on equity and justice (Williams, 2020). Section 3 below explores these shifts to inform a guiding theoretical framework. The theoretical framework, with its discussion on Post-collaborative planning and the Global South, provides a segue to Section 4 to explore the historical and contemporary structural characteristics of rural South Africa, highlighting conflicting challenges in land use management (LUM) and the need for more localised approaches. This is followed by a brief exposition of the methodology enacted to complete the systematic literature review, before bibliographic and thematic results are presented in section 6. A final discussion triangulating Sections 3 and 4 with the results of the systematic review is provided. The paper concludes with Section 7, deliberating on the way forward, including an example of a more localised South African planning glossary entry.

3 THEORETICAL FRAMEWORK

This paper employs a simplified ontology of three planning movements, the Rational Comprehensive Planning Model (RCPM), Communicative and Collaborative Planning and Post-collaborative Planning, as a catchall for several later interpretations. The positivist RCPM saw the planner as technical expert and objective decision-maker relying on quantitative methods (Innes, 1998) to promote a Rostowian development pathway towards modernity (Schrijver, 2011; Lategan, 2017). With post-positivism came the realisation that singular expert knowledge and modernisation neglected those affected by planning and development decisions by disregarding diversity, power imbalances or inequality in plan-making and

execution. Collaborative and Communicative Planning, as interrelated movements, developed in response to recognise the value of consensus-building grounded in participation and deliberation (Lategan, 2017). Communicative theorists promote collective decision-making (Fischler, 2000) with Innes (1995) noting "planning is more than anything an interactive, communicative activity" and Taylor (1998) proposing that “planning can best be viewed as a process of practical deliberation involving dialogue, debate, and negotiation". Such claims echo Jurgen Habermas’s views on communicative action and democratic governance exhibiting limited self-interest within an ideal state of deliberation characterised by rational argumentation towards the common good (Purcell, 2009). Communicative and Collaborative theorists rely heavily on participation in the practice and research of planning (Frediani and Cociña, 2019). Participation remains an issue of lively debate fuelled by critiques against Communicative and Collaborative Planning and the outcomes of participatory approaches. Traditional Collaborative Planning failed to align and renegotiate power imbalances or to respond to extreme inequality (Frediani and Cociña, 2019) with the notion of spontaneous or independent consensus-building labelled unrealistic and simplistic (Fischler, 2000). The limitations of participation were already noted in the 1960s when Sherry Arnstein (1969) presented her simplified ladder of participation highlighting how degrees of participation may be enacted and legitimised as tokenistic processes of compliance. Even participatory processes motivated by intentions to learn and adapt, may produce outcomes stemming from peer pressure, coercion, self-interest or lowest denominator resolutions (Innes and Booher, 2015). Participation outcomes often disappoint professionals and leave the public unfulfilled, antagonistic or polarised (Innes and Booher, 2000). Critiques against participation further refute the likelihood or value of neutral dialog, proposing that provocative and a-political language may deliver the most effective results (Purcell, 2009). Such critiques nurtured Agonistic Planning to transcend a mere recognition of pluralism, diversity and inclusion towards the mobilisation of antagonistic distortion and the disruption of power relations to foster effective communication and extract value from exchanges laden with productive tension (ibid). Conflict thus becomes a constructive constituent of social relations and a source of innovation (Frediani and Cociña, 2019). Radical Planning emphasises productive conflict by channelling blatantly oppositional forces (Aylett, 2010; Monno and Khakee, 2012; Lategan, 2017) to support insurgency and local actions that may remake the city from below (Miraftab, 2009).

A new wave of planning theory directed from, and on, the Global South is also gaining a foothold (Frediani and Cociña, 2019). The Southern turn focuses on contexts that were long disregarded as underdeveloped and subjected to blunt theories and practices imported from the Global North. Southern theory-making questions Northern dominance and development ideals by challenging existing intellectual traditions under post-colonialism (Watson, 2009a; Lategan and Cilliers, 2017). Southern theory thus calls for the participation and validation of the marginalised and the expression of indigenous knowledge, local ingenuity and livelihood strategies to inform representative planning methods that embrace difference. In realising such approaches, the co-production concept denotes a symbiotic relationship in which expert knowledge joins local input informed by alternative systems of knowing to deliver transcendent development practices that may bridge binaries between the formal and informal, modern and traditional, the professional and the citizen (Lategan and Cilliers, 2017). The consideration of such approaches to participation in planning are particularly highlighted in Global South contexts of severe diversity and inequality. South Africa, with its twelve official languages and the title of most unequal country globally (Lategan et al., 2025), expressed in severe wealth disparities, racial tension and a strong rural-urban divide, presents fertile ground for further exploration in this regard.

4 THE CASE OF RURAL SOUTH AFRICA

South Africa’s socio-economic, cultural and physical landscape reflects its tumultuous past. The country is heading toward a 70% urbanisation rate (Lategan et al., 2025), but this still implies that a remaining 19 million people reside in rural areas, many of which are trademarked by crippling poverty and subpar service delivery following the devestation of colonialism and apartheid. Apartheid relied on the racial classification of urban and rural populations to reorder the regional and urban geography (Oldfield, 2004). The system demarcated ten rural Bantustans, or homelands, that were symptomatically underdeveloped and deprived with limited mining or agricultural promise and presented substantial isolation from economic urban nodes. Homelands were designated based on diverse ethnic and tribal affiliations (Van Wyk, 2015), but despite claims of support for autonomy and cultural sensitivity, these rural hinterlands homogenised diverse peoples that did not necessarily identify with one another owing to rich multi-ethnic, multi-lingual and regional

variations (Lategan, 2017). Still, certain groups maintained a sense of tradition. In Mpondoland, Transkei, Beinart (2012) notes that residents largely spoke their own language and displayed a certainty and self-assurance about their traditionalist beliefs. The majority were committed to customary land holding and continued to construct their traditional dwellings in impoverished, but subjectively bucolic, settings. Following many contradictions in apartheid's outcomes, the homeland system could not reconfigure African society completely. The homelands contributed to resistance and the preservation of African traditional authority by offering a platform for the reassertion of chieftaincies actively supported by the apartheid state to help suppress descent (ibid). The approach drew on colonial precedents to transform traditional leaders into malleable pawns of the administration, which bred mistrust and opposition (Koenane, 2018). This contradicted the historic reverence for accountable traditional leadership, which generally supported freedom of speech and consensus towards collective well-being (ibid). The position continues to carry great significance. As the custodians of land, traditional leaders are often regarded as direct links to the ancestors with the right to allocate land and decide its use, including the location of a homestead, crop planting, grazing or protecting sacred sites (Nel, 2016). Customary communal tenure arrangements were upheld under apartheid in the homelands, significantly supported by local chiefs. Such arrangements were increasingly bound by legislation in democratic South Africa that empowered traditional authorities with more control (Beinart, 2012). The drive to centralise this power has been criticised for discounting the participatory aspects inherent in customary decision-making processes and for compromising democracy and citizenship rights in rural South Africa (Ubink and Duda, 2021).

Control constituted a main point of contention from traditional leaders against formal LUM processes seen to usurp their authority (Reddy et al., 2006; Nel, 2016). The issue reached its peak during deliberations prior to the promulgation of the 2013 Spatial Planning and Land Use Management Act (SPLUMA). Before SPLUMA, LUM was not implemented in areas under the jurisdiction of traditional authorities, but the Act called for "wall-to-wall" schemes that would cover the entire municipal area (Reddy et al., 2006), thus including previously excluded territories like informal settlements and former homelands specifically (Van Wyk, 2015). SPLUMA mandates LUM via zoning schemes (Reddy et al., 2006). However, zoning also remains a contested construct in the South African context (Nel, 2016). Zoning, a concept of German origin that has transversed the globe, is criticised for its unsustainable and exclusionary outcomes (Reddy et al., 2006) in promoting monofunctionality and an oversimplification of land use using inflexible technical restrictions and categorisations that separate space and people (ibid). Yet, SPLUMA also allows for scheme amendments resulting from stakeholder input.

Opportunities for participation are enshrined in South Africa's development agenda to encourage contributions to technical planning schema for LUM, but also for strategic planning as part of five-yearly Integrated Development Plans and their constituent Spatial Development Frameworks (Nel, 2016; Lategan, 2017). Notwithstanding, legislative support for engagement, Van Wyk (2015) states: "Little guidance is available on the precise ambit of "participation" and …exactly where participation starts and ends. Moreover, the will to implement (appropriate and adequate) measures to ensure participation has proven to be sorely lacking in practice". The impacts of neoliberalism have often left participation restricted to formal "invited" engagements that are only rhetorically significant as checkboxes in policymaking and plan enactment, relegating citizens to spectators in decision-making (Watson, 2009a) and undermining deliberative democracy and Post-collaborative trends in engagement. When participation is attempted, it is often guided by a specialised legal-technical discourse that may require prior knowledge from stakeholders to facilitate meaningful engagement. Those without the necessary social or cultural capital are often excluded or dominated (Brandsen et al., 2018). Traditional leaders are not necessarily equipped with the technical acumen and expertise required to assess the suitability of land for specific uses, often resulting in poorly located settlements that expose residents to environmental hazards. Consistent with SPLUMA, targeted assistance is required in these rural contexts to facilitate informed decision-making and legal development practices (SALGA, 2019). However, planners have demonstrated limited capacity to engage with stakeholders presenting restricted knowledge of technical planning lexicons or to engage fully with the distinctive and culturally diverse contexts that now require LUM. There is also a potential disjuncture between such formal, Northern-derived systems of modernisation and the neo-traditionalist customs that inform life in much of rural, and peri-urban, South Africa, including traditional building practices,

agricultural activities, rites of passage, ritualistic animal sacrifice, traditional medicine and witchcraft (Beinart, 2012) that jar with modern interpretations of development.

From perspectives gained following sections 3 and 4, this paper emphasises the parameters that influence communication with marginalised communities, like the rural in South Africa, in matters of LUM. If, and the degree to which, international scholarly outputs, practical plans and related documents evidence a move from positivist approaches to more Post-collaborative practices is thus of interest. In keeping, the folowing section details the methods followed in completing a systematic literature review of such sources to deepen understanding and identify case studies of good practice to inform more locally responsive LUM instruments in South Africa. The language and tone employed in communicating planning terminology is of specific interest in the facilitation of participatory and co-productive approaches to LUM.

5 METHODS

This paper employs a three-phase, five-stage systematic literature review: identifying the research problem; developing a protocol (Table 1); searching the literature; extracting data; and reporting findings (Lategan et al., 2025).

↓ Identifying appropriate literatures ↓
The review incorporated both grey and academic literature to ensure broad coverage. Grey literature provided access to policies, plans, and cases, whilst academic sources offered theoretical insights and could help identify case studies.
↓ Deliberate on appropriate databases and basic parameters ↓
For grey literature, Google was identified, whilst, Google Scholar was selected as database for academic literature (Xiao and Watson, 2019). Open access sources were prioritised, with the institutional library of the Cape Peninsula University of Technology providing access to multiple subscriptions not available on Google Scholar. The review covered the period 2000 to 2024.
↓ Deliberate on appropriate keywords ↓
Keywords and search strings reflected simplicity, exhaustiveness, and precision (Wanden-Berghe and Sanz-Valero, 2012). Search strings for Google included: Urban planning glossary; Urban planning lexicon; and Urban planning vocabulary. These were also employed for Google Scholar, with the addition of: Urban planning AND indigenous knowledge; and translating urban planning terms AND community participation.
↓ Deliberate on appropriate codes ↓
Coding was completed following a deductive and then an inductive approach. Deductive codes were derived from the research question and aims and logically related terminology. Inductive codes were identified during the first phase of coding as new concepts and relevance emerged in the literature. Once a full code tree had been drafted, all sources were reviewed again applying the full list of codes (Hübscher, 2021).
↓ Deliberate stopping rule ↓
Initial sample identification was deemed complete after the end of the tenth search page of each database was reached (Xiao and Watson, 2019).
↓ Identify reference management software ↓
Endnote was chosen as the bibliometric platform. Folders were created for each database and further organised by search query. Additional folders were used for sources removed after screenings for relevance based on inclusion criteria (Okoli and Schabram, 2015).
↓ Search the literature ↓
Databases were searched following the steps detailed above and the protocol established.
↓ Screen for inclusion ↓
The final sample was produced following the application of inclusion criteria based on English language; Full text available; Title; Abstract and Conclusion; and Full text review.
↓ Extract data ↓
↓ Review full text ↓
An intensive review of the sample content followed.
↓ Extract bibliographic data ↓
As a first step of review, bibliographic data were extracted from the final sample to identify frequencies; world regions of origin and citation numbers (see Table 2).
↓ Code the literature ↓
Deductive and inductive coding using Atlas.ti followed. See “Deliberate on appropriate codes” above.
↓ Analyse and synthesise data ↓
↓ Apply descriptive statistics ↓
Bibliographic data were analysed with descriptive statistics. See Table 2 for results.
↓ Thematic and content analysis ↓
Codes were utilised to identify themes. Content analysis of themes was supported by memos to note commentary, connections, similarities, differences, and points of interest in the literature.

Table 1: Systematic review protocol employed.

Certain limitations in the protocol should be noted. Whilst diverse keywords and search strings were used to ensure a comprehensive literature sample, sources with alternative terminologies, non-English languages, or inaccessible formats were excluded. Only PDF formats were considered for Google sources, and publication quality was not a criterion for inclusion. Additionally, the potential influence of reviewer subjectivity and bias in selection and interpretation is acknowledged. A discussion of results follows.

6 RESULTS

6.1 Bibliographic Results

As per section 4, Table 2 below captures frequencies and basic descriptive statistics that characterise the final sample identified for review.

Database	Initial sample size	Final sample size	Global North	Global South	Global North and Global South	Citations
Google Scholar	484	45 (9.3%)	36 (80%)	7 (15.56%)	2 (4.44%)	67 808
Google	180	56 (31.1)	52 (92.86%)	4 (7.14%)	0	N/A
Total	664	101 (15.22%)	88 (87.13%)	11 (10.89%)	2 (1.98%)	N/A

Table 2: Frequencies and descriptive statistics linked to the review sample

As captured in Table 2, a combined total of 664 sources were identified in the initial scoping, with the majority (72.89%) coming from Google Scholar given the additional terms searched, and 27.11% emanating from Google. After the application of inclusion criteria, a sample of 101 (15.22%) sources remained for full review. It must be noted that 87.13% of sources in the final sample emanated from the Global North, 10.89% originated in the Global South and only 1.98% were the result of Global North-Global South collaboration. Sources in the Google Scholar sample were cited 67 808 times by February 2025. Of note, Arnstein (1969) accounted for 35 444 (52.27%) citations, underscoring the seminal nature of her contributions and the lasting alure of research on public participation. The following section discusses the thematic results delivered following the coding process.

6.2 Thematic Results

As expected, several sources identified on Google Scholar reflect on planning theory. Communicative and Collaborative Planning features prominently (Healey, 2006; Healey, 2003) echoed in Arnstein‘s (1969) simplified participation ladder, which is cited by Cornwall (2002); Sandercock (2004); Innes and Booher (2004); Cowen (2005); Rowe and Frewer (2005); and Fung (2006). Fainstein (2009) connects communicative planning with spatial justice, relating it to movements like new urbanism. Sandercock (2004) emphasises diversity and multi-culturalism, frequently cited in literature informing a Southern turn in planning theory (Friedmann, 2005; Healey, 2006; Watson; 2009a; Silva, 2015; Porter, 2016; Watson, 2016). Watson‘s (2009b) concept of “conflicting rationalities” is informed by the application of Northern theories in the Global South without local adaptation. Silva (2015) provides a historical account of planning in sub-Saharan Africa, countering generalisations and the uncritical adoption of foreign theories. Roy (2005) argues for the integration of informality into planning epistemology, drawing on Global South examples to advance justice. Zurba et al. (2022) review co-production literature and apply co-production based on a Canadian Inuit group’s indigenous knowledge. The shift towards Southern planning and diverse alternatives aligns with the decolonisation agenda, that sees Porter (2016) question indigenous inclusion in Northern-derived planning, linking this to dispossession and arguing for planning as a cultural process rather than a neutral technical exercise.

Indigenous knowledge features prominently in the review sample. Mapara (2009) reflects on Zimbabwe’s indigenous systems, emphasising traditional land management and a symbiotic human-nature relationship. Briggs and Sharp (2004) critique the limited inclusion of indigenous knowledge in development, warning of selective incorporation reinforcing Northern ideals and power imbalances. In disaster risk reduction, Mercer et al. (2010) highlight the holistic value of indigenous knowledge, proposing its integration with Northern systems through participatory learning to reduce community vulnerability. Briggs (2005) examines challenges in using indigenous knowledge in development, noting empirical biases, binary frictions with Northern science, power dynamics, romanticisation, and de-contextualisation. Corburn (2003), using New York City cases, outlines four ways local knowledge enhances (environmental) planning: expanding epistemological contributions; advancing procedural democracy; improving cost-effective policy solutions; and exposing inequitable risk divisions. The role of indigenous knowledge in pedagogy is underscored by Battiste (2005) in a Canadian First Nations context, while Semali and Kincheloe (2002) critique its marginalisation in Northern-led education and its potential to deliver more just outcomes.

A focus on context to accommodate diverse places and people is another common thread. Herbert and Murray (2015) highlight the value of ethnographic research in human geography, stressing researcher

positionality, ethics, and participant relationships. Innes and Booher (2004) critique public participation failures in the United States, advocating for inclusive, adaptive, and co-productive processes. Bratteteig and Wagner (2012) examine power imbalances in participatory design, shaping outcomes through unequal knowledge, resources, and authority. Fung (2006) and Fung (2015) provide guidelines on participant selection, distinguishing between self-selected, purposefully chosen, random, or targeted groups of lay or professional stakeholders. Magigi and Drescher (2010) shift to the Global South, discussing conflicts between customary land tenure and formal legal frameworks in Tanzania. Whereas Andrea and Coelho (2007) explore participation in post-democratic transitions, emphasising social mobilisation, agency, and the need to empower participatory institutions.

Introducing new concepts, or defining and finetuning existing interpretations for use by multiple stakeholders, is a main contribution in the literature on planning glossaries, lexicons and vocabulary form Google Scholar. Rowe and Frewer (2005) argue that the imprecise definitions and understanding of critical terms in public participation hinders research and impacts the development of efficient participatory practices. The authors thus define key concepts like public communication, public consultation, and public participation and derive four communication (e.g., public meetings); six consultation (e.g., consultative workshops); and four participation (e.g., co-production) mechanisms to improve effectiveness. Peel and Lloyd (2007) attempt to contextualise approaches to encourage civic engagement and public participation in Scotland's territorial land-use planning, proposing that a new national planning vocabulary be considered to facilitate inclusive, participatory and democratic processes. Dühr et al. (2007) examine the Europeanisation of policymaking and the new planning terminology that accompanies cross-border development. The authors note that some terms carry different meanings across context and boundary, leading to ambiguity and contestation, whilst others are new inventions. Schmid et al. (2018) lament that traditional urban studies have been moulded by Northern concepts that fail to adequately account for diversity and local variation due to oversimplification or misinterpretation. To address informal urbanisation, multi-layered urban growth and difference, the authors develop nine new concepts of urbanisation, of which four, popular urbanisation (self-organised by residents); plotting urbanism (subdivision and private development); multi-layered patchwork urbanisation (overlaps of old and new); and the incorporation of urban differences (contextual uniqueness) are discussed. Bhan (2019) focuses on urban planning terms rooted in an Indian context. Following a critique of Northern dominance in planning, a discussion of the specific concepts that describe different stages of informal urbanisation are presented to challenge the narrative of chaos and illegality. These are 'squat' (claiming space); "repair" (improving space); and "consolidate" (gaining recognition and legitimacy). Shared characteristics are discussed and the expansion of a vocabulary of Southern urban practice argued. Fernández et al. (2021) contend that the conceptual apparatus supporting engagement, with related issues of power and dominance, are embedded in a "Northern" language and that observing urban development practices in the Global South is important in the construction of Southern planning vocabularies. The authors identify three new terms. The first, "perverse incentive planning" based on experience from Colombia and the domination of legal and procedural mandates. The second, "ingraining" to capture bottom-up approaches to the conservation of pre-existing structures in Argentina. The last, "occupying" to represent land and housing occupation practices in Brazil. D'Arc (2001) studies cases in Brazil and Mexico to question the degree to which the specialised technical language used by experts, derived from international conventions, allows, or rather stifles, meaningful dialog with marginalised communities who often rely on lay language and everyday experience in their communications and may already place limited faith in the outcomes of participation. The lack of a shared vocabulary that bridges the linguistic divide by incorporating local terms and knowledge is thus recognised.

Certain authors take a more direct route by providing translations of critical concepts. Allain and Baudelle (2006) pen a comparative multi-lingual dictionary of twenty terms, mostly related to land use, for British, Belgian, German and French project partners to advance a shared comprehension by also discussing each concept in the terms and contextual understanding of each country and highlighting semantic differences. Gawryluk et al. (2020) provide a professional resource as a glossary of technical terms used commonly in planning, architecture and related disciplines in English, Polish, Spanish and Lithuanian, but without any substantiating discussions or examples. For Hong Kong, Chiaradia (2020) presents an urban design glossary that defines and translates terms from English to Mandarin. The Los Angeles County Department of Regional Planning (2023) presents an English to Spanish term translation, but no definitions. In a Swiss case,

Sinatra and Kaufmann (2023) deliver a glossary of spatial planning terms in English and German, with all definitions maintained in English. Røsnes (2006) examines complexities in translating planning terminologies across different national systems into a shared language, specifically English, based on eleven Baltic countries with distinct languages and planning frameworks. A nuanced understanding of the national setting, potential interconnecting structures and civil rights issues related to each context are identified as core considerations in the delivery of meaningful cross-national translations of planning terms.

Several sources provide glossaries accompanying official planning documents like Comprehensive, General, Community and Master Plans (City of Los Altos, 2002; California Planning Round Table, 2003; Blaby District Council, 2005; City of Barre, 2010; City of Beverly Hills, 2010; City of San Diego, 2015; Queens Town Lakes District Council, 2015; Breckland Council. 2016; National Capital Planning Commission, 2016; County of Monmouth, 2016; City of Alexandria. 2017; Fairfax County, 2017; City of Kaua'I, 2018; City of Mississauga, 2021; City of Carson, 2022; Southwark Council, 2022; Palo Alto, 2023; Town of Truckee. 2023; City of Bellevue, 2024; Ealing Council, 2024). The majority are intended for use by professionals, but also public stakeholders wanting to engage with LUM issues. The language employed in almost all definitions and related substantiating discourse adopts a formal and technical tone, especially where quantitative requirements or legal issues are discussed. The vast majority originiate in Northern America, followed by the United Kingdom.

Dedicated dictionaries were also encountered. Davidson and Dolnick (2004) deliver 4,200 terms utilised by planners across the United States to eliminate ambiguity and ensure effective professional communication. The dictionary provides contextual commentary complimented by schema and photographs. Cowen (2005) defines language and concepts pertinent to urbanism, urban design, planning, architecture, regeneration, and environmental studies also supported by illustrations. Though not labelled a dictionary per se, Brooks (2022) presents a resource for understanding various urban planning and development terminologies accompanied by references to relevant literature sources. From Germany, Willinger and Schopp (2021) define key terms, methodologies, instruments, and tools relevant to urban development. Additionally, featuring supplementary essays on topics like justice, narratives, processes, and transformation. The publication establishes a shared vocabulary to bridge gaps between new and experienced professionals, experts, and laypeople, as well as theory and practice. There are also glossaries published by institutions like the World Bank (2021) and United Nations (2017) to define developmental concepts and clarify the organisation's interpretations. Other publications provide planning definitions for the sake of educational and informative purposes, but continue to rely on relatively technical wording (Committee, 2008; Kumar, 2017; Locality, 2021). Of note is the City of Dallas's (2022) "Paul the Alpaca teaches us about Urban Planning in Dallas", an illustrated guide for children that provides definitions in appropriately simple language assisted by activities. Several sources are more diversly specialised. The Mayor's Institute on City Design (2017), the Urban Design Institute of Australia (2023) and Plater-Zyberc and Company (2014) define urban design terms. TEEB (2010), TNFD (2023) and AWARD (2018) provide glossaries of biodiversity and environmental planning terms, with the last including spatial planning and South African references.

7 DISCUSSION AND WAY FORWARD

7.1 Northern theoretical support for a localised approach meets limited expression in the South

A key theme in the literature is the call for planning frameworks that reflect local conditions rather than replicating Northern models (Briggs and Sharp, 2004; Friedmann, 2005; Roy; 2005; Healey, 2006; Andrea and Coelho, 2007; Watson, 2009a; Porter, 2016; Silva, 2015; Watson, 2016; Fernández et al., 2021). This aligns with discussions on the Southern turn in post-colonial planning, mirroring power, justice, and participation as core tenets of Communicative, Collaborative and Post-collaborative planning. The Northern dominated sample, however, provides limited practical examples of how these theoretical constructs have entered planning practice, specifically in the Global South. Calls for a localised approach find a strong foothold in the South African context where colonial and apartheid legacies continue to shape socio-spatial constructs and dictate the rules of engagement between authorities and the local population. SPLUMA seeks to redress past inequalities, particularly in rural areas, but integrating customary land management into municipal planning remains contentious. Traditional leaders often resist zoning and formal mechanisms, fearing a loss of authority (Nel; 2016; Ubink and Duda, 2021). These conflicts highlight continuous tensions between Northern-derived land management concepts and informal or customary practices that reflect ways

of life in rural communities, in contradiction to the theoretical discourse. While it is imperative to acknowledge and respect traditional hierarchies, such as those within South Africa's traditional leadership structures, it is equally critical to ensure that marginalised and underrepresented groups have a voice. Planners must critically reflect on their roles as experts, with ethical responsibilities, to foster democratic processes that engage community leaders and to provide participatory platforms capable of incorporating diverse perspectives to inform co-productive planning practices.

7.2 The integration of indigenous knowledge systems in the Global South is complex and abstract

The literature underscores the value of indigenous knowledge in planning, but discussions remain largely theoretical. With 87.13% of all sources emanating from the Global North, and few case studies beyond North America, limited evidence is provided for practical guidance on how the complex gauntlet of engagement with indigenous knowledge and its incorporation is to be achieved.in the Global South. No South African cases were encountered. While South African rural communities retain strong ties to indigenous governance, traditional leadership remains contested. Some regard traditional authority as preserving cultural identity, whilst others argue that traditional leadership has been co-opted by the state to perpetuate colonial mechanisms of local control. This adds another dimension to the power dynamics to be considered in representative participation, as some leaders with limited support from their constituencies, may act as restrictive gatekeepers or autocrats. The lack of technical expertise in matters of land use planning, often exacerbating vulnerabilities, becomes a critical consideration to facilitate meaningful discourse towards more sustainable local land use practices that incorporate indigenous knowledge systems. In this, the tools and communication methods used in planning, as maps, documents, and terminology, become critical resources. The drafting of these tools must reflect, and on their part, foster, local input.

7.3 Northern language continues to dominate, and localised glossaries are novel

Effective participation, as emphasised in Communicative and Collaborative Planning, requires accessible language to move beyond tokenism (Arnstein, 1969; d'Arc, 2001; Rowe and Frewer, 2005). Technical jargon can alienate marginalised communities, limiting engagement in meaningfully decision-making (d'Arc, 2001; Rowe and Frewer, 2005). The sample includes several documents providing direct translations of key planning terms. Demonstrating the dominance of literature from, and on, the Global North, almost all examples provide translations from English to major European languages (Allain and Baudelle, 2006; Gawryluk et al., 2020; Sinatra and Kaufmann, 2023), mostly failing to deliver truly simplified explanations or any relation to local context. Fernández et al. (2021) advocate for Southern planning vocabularies reflecting local urban experiences. The dictionaries cited (Davidson and Dolnick, 2004; Cowen, 2005; Willinger Brooks, 2022) primarily target professionals. Examples of practical planning documents, for e.g., comprehensive plans, land use schemes, bylaws, regulations, guidelines or glossaries that explicitly employ a Southern vocabulary, meaning either translations to minority languages, simplified definitions, or examples and illustrations relating to a marginalised or Southern geographical context, are conspicuously absent in the sample. Whilst the direct translation of planning concepts, as demonstrated in the sample, provides a basic foundation for shared understanding, definitions and examples must also be contextually relevant and representative. Using the widely recognised term, "zoning", Table 3 illustrates how a localised planning glossary entry could be developed for an isiXhosa community in South Africa.

Term	Zoning
Technical definition	Means a defined category of land use which is shown on the zoning map of a land use scheme.
Term translation	Setyenziso mhlaba (noun); Ukusetyenziswa komhlaba (verb).
Technical definition translation	Kuthetha udidi oluchaziweyo lokusetyenziswa komhlaba oluboniswe kwimephu yezoning yeskimu solawulo lomhlaba.
Localised definition	Means that only certain buildings and activities can be built or take place on a piece of land. Normally, this would mean that land is used for a homestead, for farming such as a kraal or planting, for a place of worship, and other purposes. A map shows which buildings and activities are allowed in accordance with a land use scheme document. Zoning may be changed with permission from the local municipality.
Localised definition translation	Ithetha ukuba kuphela izakhiwo kunye nemisebenzi ethile enokuvunyelwa ukwakhiwa okanye ukwenzeka kumhlaba othile. Ngokwesiqhelo, oku kuthetha ukuba umhlaba usetyenziselwa ikhaya, ukufama njengekhraali okanye ukulima, indawo yokunqula, kunye nezinye izinto. Imaphu ibonisa ukuba zeziphi izakhiwo nemisebenzi evumelekileyo ngokwemigaqo yeskimu sokusetyenziswa komhlaba. I-Zoning ingatshintshwa ngemvume kumasipala wale ndawo.

Table 3:Example of a localised planning glossary entry in South Africa

Table 3 provides a preliminary attempt and should not be regarded as a final product. Interdisciplinary engagement with anthropologists, sociologists, and linguists together with community stakeholders is recommended to deliver more targeted and representative glossaries. The approach should not regard the rural as homogenous based on shared language but should ideally differentiate geographically and culturally within such groupings in pursuit of truly localised definitions and examples. Individual LUM schemes are not advocated here, but rather supplementary glossaries attached to existing schemes to better explain the technical terms employed. Accordingly, truly locally informed glossaries may move beyond semantics to unlock new terminologies and opportunities for future engagement.

Findings also suggest that more concerted research is required to uncover potential case studies on, and from, the Global South. Future research should expand to more databases, like Web of Science; consider expanded search terms targeting specific countries and regions; include multiple multi-lingual researchers; employ snowball sampling in discovery; and include ethnographic fieldwork to gain practical insights. The outcomes of such undertakings may provide novel substantive and procedural contributions to shape planning theory and practice in the Global South, with significant lessons for the Global North in dealing with increasingly oppositional diversity and difference in participation (Lategan and Cilliers, 2017).

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TwinCity3D – Neue Möglichkeiten zur Planung der Stadtentwicklung für Klein- und Mittelstädte

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1 ABSTRACT

Um die Herausforderungen in den Bereichen Mobilität, Stadtentwicklung, Umweltüberwachung und Klimawandel zu bewältigen, brauchen Städte und Gemeinden eine Vielzahl an räumlichen (Geo-) Informationen. Dafür müssen Daten gesammelt, bearbeitet und ausgewertet werden, damit Planer daraus Maßnahmen ableiten und politische Entscheidungen besser und transparenter getroffen werden können. Oft wird in diesem Zusammenhang der Wunsch nach einem sogenannten Urbanen Digitalen Zwilling (UDZ) laut – also einem digitalen Abbild der Stadt. Allerdings stoßen vor allem kleine und mittlere Städte schnell an ihre Grenzen, wenn es darum geht, ein solches digitales Modell ihres Gebiets zu erstellen.Am Beispiel Landsberg am Lech wurde im Rahmen des mFUND-Forschungsprojektes “TwinCity3D” ein “Digitaler Zwilling” für Stadtplanungsaufgaben wie obenerarbeitet. Mit Hilfe einer neuen Technologie zur kostengünstige Geodatenerfassung aus der Luft wurden eine Vielzahl an raum-zeitlichen Geoinformationen erfasst und mittels KI-Verfahren ausgewertet. Zur Datenanalyse werden KI-basierte Algorithmen entwickelt, um das Potenzial dieser “bigdata”-Datenquellen vollumfänglich nutzen zu können. Mutitemporale und multispektrale Luftbildbilddaten bieten ein Informationspotenzial, das bisher Klein- und Mittelstädten nicht zur Verfügung stand. Planerische Fragestellungen wie „Wie viel Fläche nimmt der oberirdisch ruhende Verkehr ein?“, „Wo befinden sich Hitzeinseln innerhalb des Stadtgebietes?“ bis hin zu „Wie hoch ist das Grünvolumen im Stadtgebiet und wie verändert sich dieses?“ lassen sich zukünftig durch den Einsatz der entwickelten Analysemethoden flächendeckend auswerten. Am Beispiel der Förderung umweltfreundlicher Mobilität wird das Potenzial dieser neuen Technologien in diesem Beitrag präsentiert.Im Zuge einer nachhaltigen Stadtentwicklung stellt der Ausbau von Fahrradwegen eine zentrale Maßnahme zur Förderung umweltfreundlicher Mobilität dar. Dieser Ausbau führt jedoch zu Nutzungskonflikten im städtischen Raum: Einerseits könnten Parkplätze reduziert werden, andererseits droht der Verlust von Grünflächen wie Grünstreifen und Alleen. Angesichts der fortschreitenden Klimaerwärmung ist der Erhalt und Ausbau des Baumbestands jedoch essenziell, da Bäume zur Abkühlung des zunehmend überhitzten Straßenraums beitragen und das Mikroklima verbessern. Die Herausforderung besteht darin, eine Balance zwischen nachhaltiger Mobilität und urbaner Klimaanpassung zu finden. Innovative, integrative Planungskonzepte sind gefragt, die sowohl den Radverkehr fördern als auch den Erhalt von Stadtgrün sicherstellen.Eine 3D-Visualisierung der Analysen im digitalen Zwilling verbessert die Kommunikation zwischen Verwaltung und Mitgliedern des Stadtrates, erhöhtin der Folge die Transparenz im Rahmen der Vorbereitung von politischen Entscheidungen, so dass letztendlich die gesamte Stadtbevölkerung profitieren kann.

Keywords: KI-Algorithmen, Klein- und Mittelstädte, Luftbildauswertung, Digitaler Zwilling, Datenplattform

2 GEODATENERFASSUNG

Der Ausbau von Radverkehrsinfrastruktur nimmt einen zentralen Stellenwert ein, wenn es um die Erreichung der Klimaziele geht. In gewachsenen baulichen Strukturen mitteleuropäischer Städte sind dazu umfangreiche Maßnahmen zur Umgestaltung des Straßenraums erforderlich. Während Großstädte aktuell daraufsetzen, einzelne Fahrspuren für den motorisierten Verkehr zu sperren und diese Flächen dem Radverkehr zuzuschlagen, lässt sich dieser Ansatz in Klein- und Mittelstädten, bei denen der Straßenraum nur eine Fahrspur je Richtung bietet, nicht umsetzen. Wenn neue Flächen für Radwege geschaffen werden sollen, entstehen oft Nutzungskonflikte. Für eine umfassende Analyse müssen daher nicht nur die Verkehrsflächen und ihre effiziente Nutzung betrachtet werden, sondern auch, wie diese Flächen mit bestehenden Grün- und Freiräumen zusammenhängen. Da die verfügbare Fläche begrenzt ist und verschiedene Nutzungen miteinander in Konkurrenz stehen, müssen Entscheidungen sorgfältig abgewogen werden.Dabei stellen sich

Fragen wie: Sollen Grünflächen verkleinert werden, um Platz für Radwege zu schaffen? Oder können die entlang der Straßen vorhandenen Parkplätze in Radwege umgewandelt werden, um den Straßenraum neu zu gestalten? Und wie beeinflussen die geänderten Flächennutzungen das städtische Klime in Zeiten der Klimaerwärmung? Auf diese Fragen müssen Antworten gefunden werden.

Den meisten Städten fehlen geeigneteGeodaten, um diese Zusammenhänge genau zu analysieren und daraus nachhaltige Maßnahmen für die Stadtentwicklung abzuleiten. Genau hier setzt das Forschungsprojekt an: das Stadtgebiet wurde drei mal (2020, 2021 und 2023) mit einem speziellen Multisensorkamerasystem (MSKS) erfasst, das an ein Ultraleichtflugzeug montiert wurde. Das Flugzeug fliegt dabei in nur etwa 300 Metern Höhe und erstellt mit verschiedenen Kamerasystemen hochaufgelöste Luftbilder. Das MSKS besteht aus fünf RGB-Kameras, einer Thermalkamera und einer Multispektralkamera. Da alle Kameras gleichzeitig Daten aufnehmen sind, können aus einem einzigen Flug verschiedene Luftbildprodukte erstellt werden (Abbildung 1; RealityMaps, 2024).Anhand einer mehrfachen Befliegung des Stadtgebietes sollten zeitliche Aspekte und Entwicklungen analysiert werden. Mit der Erfassung von Luftbildern ist es jedoch noch nicht getan: damit die Geodaten hinsichtlich der genannten Fragestellungen effizient ausgewertet werden können, sind spezielle Verfahren der objektbasierten Bildanalyse mittels KI-Algorithmen erforderlich.

Abb. 1: Aus einem Bildflug können mehrere Luftbildprodukte erzeugt werden: RGB-True-Orthofoto (links oben), Oberflächenmodell (rechts oben), Multispektralaufnahme (links unten), Thermalaufnahme (rechts unten) (RealityMaps, 2024)

3 GEODATENANALYSE

Die Luftbilddaten wurden in mehreren getrennten Schritten ausgewertet. Zuerst wurden die Grünflächen in der Stadt erfasst und klassifiziert, damit später ihr Verhältnis zum Straßenraum beurteilt werden kann. Danach wurde untersucht, wie viel Platz der ruhende Verkehr (d.h. parkende Autos) einnimmt und wie diese Flächen im Stadtgebiet zwischen Straßen-, Grün- und Nebenflächen verteilt sind. Im dritten Schritt wurde die Hitzeverteilung in der Stadt analysiert, indem die Thermaldaten in die Bewertung einbezogen wurden.

3.1 Analyse des städtischen Baumbestands

Grünflächen in der Stadt spielen eine wichtige Rolle für das Mikroklima. Sie helfen zum Beispiel, Regenwasser zu speichern und so das Schwammstadtprinzip umzusetzen. Um die Stadt widerstandsfähiger

gegen Klimaveränderungen zu machen, sind Entwicklungspläne für das Stadtgrün und ein regelmäßiges Monitoring von Grünflächen notwendig. Ein Baumkataster, das alle Bäume im öffentlichen Raum erfasst, gehört zu den Pflichtaufgaben jeder Stadt, um die Verkehrssicherheit zu gewährleisten. Bäume auf privaten Grundstücken werden dabei nicht berücksichtigt. Für eineAnalyse des Stadtklimas werden jedoch Informationen über den gesamten Baumbestand im Stadtgebiet benötigt. Deshalb wurde ein Algorithmus zur automatischen Erkennung von Bäumen entwickelt, der speziell auf sehr hochauflösende Luftbilder (5 – 10 cm) trainiert wurde. Dieser KI-Algorithmus erkennt nicht nur den Standort von Bäumen, die größer als 2 Meter sind, sondern misst auch den Durchmesser der Baumkrone und unterscheidet zwischen Laub- und Nadelbäumen.Gegenüber dem städtischen Baumkataster, innerhalb dessen 7.024 Bäume regelmäßig kontrolliert und kartiert werden, wurden durch die Verwendung des KI-Algorithmus 41.883 Bäume automatisch erkannt und in Höhenklassen zugeordnet. Die Klassifikationsgenauigkeit lagdabei bei > 94 %. Wenn in Zukunft auch Multispektralaufnahmen in die Analyse einbezogen werden, könnten zusätzlich Erkenntnisse über die Artenverteilung und den Gesundheitszustand der Pflanzen gewonnen werden.

3.2 Flächeninanspruchnahme durch geparkteFahrzeuge

Der sparsame Umgang mit der Ressource „Fläche“ stellt einen zentralen Punkt in der Arbeit von Stadtplanerndar. Insbesondere wenn Nutzungsarten konkurrieren und Flächen beansprucht werden, muss eine wohlüberlegte Abwägung stattfinden. Soll beispielsweise der Radverkehr ausgebaut werden, so werden hierfür Verkehrs- oder Grünflächen benötigt. Denkbar wäre zum Beispiel Fahrradwege auf Kosten von Parkflächen am Straßenrand anzulegen. Dabei stellen sich Fragen: wie wirkt sich das auf die Parksituation im Stadtgebiet aus? welche Flächenbelegen geparkte Kraftfahrzeuge, also der ruhende motorisierte Verkehr?Belastbare Daten dürften nur den wenigsten Städten bekannt sein.

Deshalb wurde ein KI-Algorithmus entwicklet, mithilfe dessen Fahrzeuge automatisiert und in hoher Genauigkeit aus den Luftbildern erkannt werden. Dabei werden die Klassen „Car“, „Pickup Truck“, „Minivan/ SUV“, „Caravan Trailer“, „Bus“, „Truck“, sowie „Agricultural/Construction“ unterschieden. Im Vergleich zum Referenzdatensatz erreichte das Trainingsmodell dabei über die Fahrzeugklassen eine Gesamtgenauigkeit von 98,39%. Die erkannten Fahrzeuge wurden im Rahmen einer GIS-Analyse statistisch bezüglich des Flächenverbrauchs und der Flächenaufteilung ausgewertet. Innerhalb desdicht besiedelten, etwa 1.800 hagroßen, Stadtgebietes werden knapp 182 ha (10,1%) als innerstädtische Verkehrsflächen geführt. Insgesamt wurden drei Luftbilddatensätze von 2020-2022 untersucht. Zwei Befliegungen in 2020 und 2022 wurden an jeweils einem Mittwoch durchgeführt. Dabei wurden insgesamt 15.862-16.792 Fahrzeuge (davon 13.987-14.511 in der Klasse „Car“ bzw. „Pkw“) erkannt, die eine Gesamtfläche von 17,5-18,2 ha in Anspruch nahmen. Somit nehmen allein parkende Fahrzeuge eine Fläche von 9,6-10,0 % der Verkehrsflächen in Anspruch, was in etwa1,0 % des Stadtgebietes entspricht. Bei der an einem Sonntag durchgeführten Befliegung in 2021, wurden im gleichen Gebiet 10.315 Fahrzeuge (davon 8.807 „Pkw“) erkannt, die eine Fläche von 13,1 ha in Anspruch nahmen. An diesem Sonntag nahmen die Fahrzeuge nur 7,2 % der Verkehrsflächen in Anspruch, was bezogen auf das Stadtgebiet 0,7 % sind. Im nächsten Schritt wurden die Fahrzeuge herausgefiltet, die sich zum Zeitpunkt der Befliegungin Bewegung auf der Fahrbahn befanden. Beim Datensatz von 2020 wurden dabei 8 % (1.277 Fahrzeuge) herausgefiltert, beim Datensatz von 2021 dagegen 14 % (1.412 Fahrzeuge) und beim Datensatz von 2022 wurden 17 % (2.854 Fahrzeuge). Die resultierenden Werte für die Flächeninanspruchnahme reduzieren sich auf 8,5 % der Straßenverkehrsflächen in 2020, auf 6,4 % der Straßenverkehrsflächen in 2021 und auf 9,0 % der Straßenverkehrsflächen in 2022.

In einem weiteren Schritt wurde der „ruhende Verkehr auf Fahrbahnflächen“ und der „ruhende Verkehr auf Nebenflächen“ differenziert. Die Auswertung der Luftbilder ermöglicht hierbei nun eine flächenhafte Auswertung für das Stadtgebiet. Ergebnis der GIS-Analyse war dabei, dass innerhalb der Stadt Landsberg am Lech ca. 2,8 ha(jeweils in den Daten von 2020, 2021 und 2022) des Straßenraums durch den oberirdisch ruhenden Verkehr, d.h. zum Parken beansprucht werden. Dies entspricht einem Anteil von 18,4 % (2020), 24,3 % (2021) bzw. 17,4 % (2022) der Gesamtflächeninanspruchnahme des oberirdisch ruhenden Verkehrs über das dicht besiedelte Stadtgebiet.

Die statistische Größe des „oberirdisch ruhenden Verkehrs auf der Fahrbahn“ ist vor allem für die Verkehrsplanung und Stadtentwicklung interessant, weil Längsparker ein Potential zur Umverteilung des zur Verfügung stehenden Straßenraums für die Radverkehrsinfrastruktur darstellen. Die

Flächeninanspruchnahme durch längsgeparkte Fahrzeuge auf der Fahrbahn stellt einen interessanten Wert dar, der bisher lediglich in einzelnen Straßenzügen erhoben werden konnte. Alternativ könnten zur Gewinnung von Radwegen beispielsweise Grünstreifen umgewandelt werden, was sich allerdings ungünstig auf das städtische Klima auswirken könnte.

Durch die Auswertung der erkannten Fahrzeuge in Nutzungsklassen, können auch interessante weitere Erkenntnisse über deren Verteilung im städtischen Raum gewonnen werden. Zum Beispiel wurde in den letzten Jahren eine zunehmende Zahl an Wohnmobilen festgestellt, die an einzelnen Hotspots im Straßenraum abgestellt werden. Über die drei Jahre variierte die Zahl auf der Fahrbahn abgestellter und erkannter Wohnmobile von 58 (in 2020) über 36 (in 2021) zu 54 Fahrzeugen (in 2022). Gesamtstädtisch betrachtet, stellt die Anzahl dieser Fahrzeuge aktuell kein Problem dar.

3.3 Erkennen von Hitzeinseln im Stadtgebiet

Thermalaufnahmen, die an heißen Sommertagen erfasst werden, können zur Erkennung von Hitzeinseln im Stadtgebiet genutztwerden. Jeder Bildpunkt der Thermalaufnahme repräsentiert dabei die Oberflächentemperatur an der aufgenommenen Stelle. Während der Befliegungstage wurden zudem Temperatursensoren an vereinzelten Dachflächen ausgebracht, die als Referenzwerte genutzt wurden. Mit räumlichen Analysen werden komplexe Zusammenhänge sichtbar. Eine statistische Clusteranalyse macht räumliche Muster in der Hitzeverteilung in der Stadt sichtbar. Ähnliches kann anhand der Verteilung des Baumbestands untersucht werden. Ein Vergleich der beiden Clusteranalysen zeigt, wie der Baumbestand zur Kühlung des Stadtgebietes beiträgt. Stadtteile mit wenigen Grünstrukturen heizen sich dagegen deutlich stärker auf (Abbildung 2, Industriegebiet links oben).

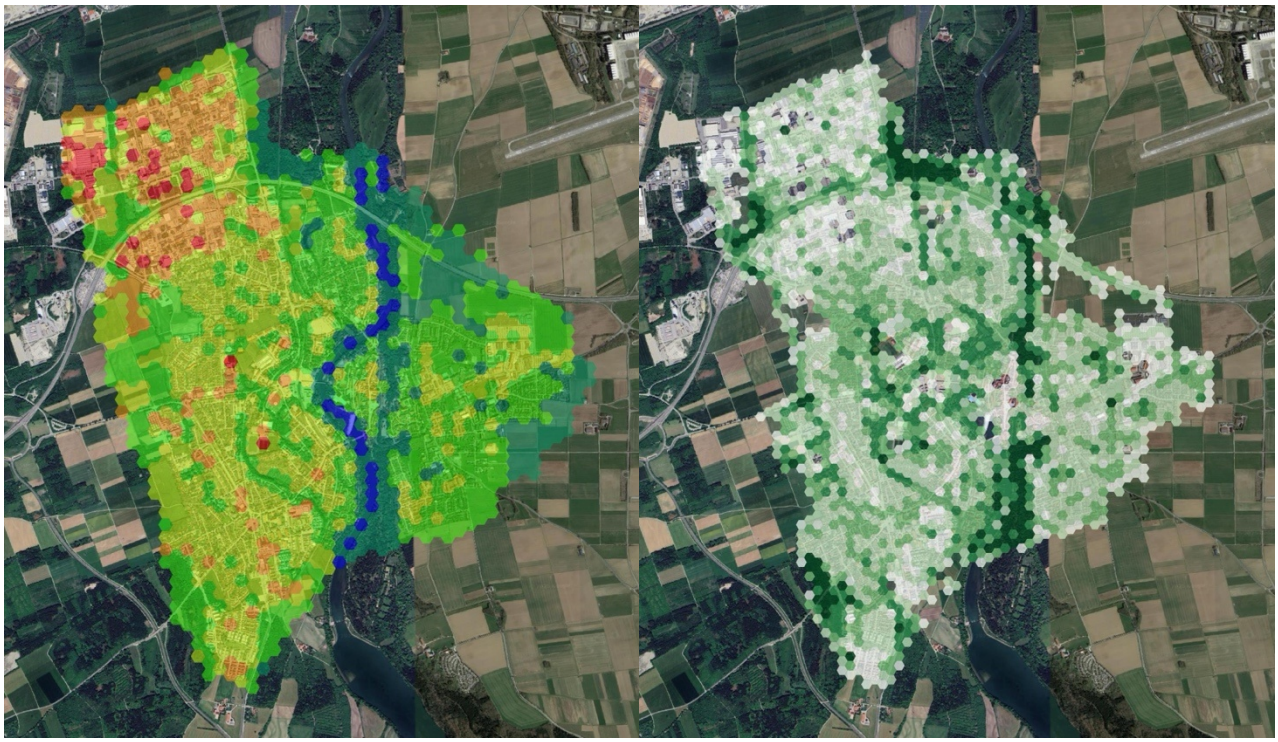

Abb. 2: Temperaturunterschiede innerhalb des Stadtgebietes an einem warmen Sommertag (links), Density-Analyse der erkannten Grünstrukturen über das Stadtgebiet (rechts) (3D RealityMaps 2024)

Auch Straßenverkehrsflächen wurden im Hinblick auf deren thermale Wirkung analysiert. Die Auswertung des Thermalbildes liefert hierzu Informationen, welche Straßenzüge sich an einem warmen Sommertag wie stark aufheizen. Neben der versiegelten Straßenverkehrsfläche selbst, tragen auch die oberirdisch abgestellten Fahrzeuge zur Aufheizung der Umgebung bei. Die kombinierte Auswertung der Thermalinformation der Straßenverkehrsflächen und denGrünstrukturen macht die Abhängigkeiten deutlich: Straßenbegleitgrün in Form von Alleebäumen trägt zur deutlichen Kühlung der Straßenverkehrsflächen bei. Straßenzüge und Straßenverkehrsflächen ohne, beziehungsweise mit wenig begleitenden, Grünstrukturen heizen sich dagegen deutlich stärker auf (Abbildung 2,3).Aus Sicht des Stadtklimas ist es wichtig, bestehende Grünflächen zu erhalten, da sie sich positiv auf die Umgebung auswirken. Eingriffe in diese

Grünflächen oder deren Entfernung sollten so weitwie möglich vermieden werden.Thermaldaten, die die Temperaturen in der gesamten Stadt zeigen, können dabei helfen, Flächen zu erkennen, die entsiegelt werden könnten – also Bereiche, wo Asphalt oder Beton entfernt werden kann, um neue Grünflächen zu schaffen und das Stadtklima zu verbessern.

Beim Ausbau der Radverkehrsinfrastruktur zeigen die ausgewerteten Daten, dass Parkplätze entlang der Straßen reduziert werden könnten, um Platz für Radwege zu schaffen. Diese flächendeckende Analyse bildet die Grundlage für eine stadtweite Strategie, die zu einer neuen Aufteilung des Straßenraums in den betroffenen Straßen führen kann.

Abb. 3: Erkannter oberirdischer Verkehr und dessen Verteilung auf die Straßenverkehrsflächen als Heatmap (links), Auswertung von Thermalinformationen der Straßenverkehrsflächen (rechts). Grün: kühl – rot: heiß (3D RealityMaps 2024)

4 DIGITALER ZWILLING

Die TwinCity3D-Plattform ist die Basis des räumlichen digitalen Zwilling von Landsberg am Lech. Hier werden alle Geodaten zusammengeführt. Basis ist ein aus den Luftbildern berechnetesnaturgetreues 3D-Stadtmodell mit seinem niedrigen Abstraktionsgrad, es ermöglicht ein besseres Verständnis der räumlichen Zusammenhänge im Stadtgebiet. Gleichzeitig dient die Plattform als Visualisierungsebene für unterschiedlichste Geodaten und die Analyseergebnisse. In der Planungsebene wird schließlich ein Blick in die Zukunft geworfen: Bauplanungen werden als 3D-Objekte in das städtische Umfeld eingesetzt und können so besser beurteilt werden. Der Digitale Zwilling dient als praktisches Planungswerkzeug, das Mitarbeitende der Stadtverwaltung künftig selbstständig im Arbeitsalltag nutzen sollen.

4.1 Ein virtuelles 3D Stadtmodell als Basis für den digitalen Zwilling

Die aktuellesteLuftbildbefliegung und das daraus berechnete 3D-Mesh-Modell bildet die Grundlage der TwinCity3D-Plattform. Es dient als Orientierungshilfe und ist so detailliert, dass sich auch Menschen ohne Fachwissenleicht darin zurechtfinden können.Da das Modell mit Geokoordinaten und einer Datenbank mit zusätzlichen Informationen verbunden ist, lassen sich alle wichtige Orte und Daten im virtuellen 3D-Stadtmodell genau dort anzeigen, wo sie sich in der realen Stadt befinden. Die TwinCity3D-Anwendunghat einenSplitscreen-Modus, in dem einfach zwischen dem 3DMesh-Modell und dem abstrakten CityGML-Modell hin- und hergeschaltet werden kann (Abbildung 4).

Das CityGML-Modell liegt im Level-of-Detail-2 (LOD2) vor, d.h. es handelt sich um ein Blockmodell mit Standarddachformen (KOLBE 2008:3) und wird vom Bayerischen Landesamt für Digitalisierung, Breitband und Vermessung (LDBV) im Rahmen der OpenData-Strategie zur Verfügung gestellt. Verschiedene Datenebenen können, nach Themen organisiert, einzeln angeschaltet werden. Der mittels KI erfasste Baumbestand kann in der Planungsansicht in einer vereinfachten Darstellung in Form von abstrahierten Bäumen mit korrekter Höhe und Kronendurchmesser visualisiert werden. Die Datenbank kann nach

verschiedenen Informationen abgefragt werden, wie zum Beispiel nach Baumhöhen, Laub- und Nadelbäumen oder nach Zuständigkeit gemäß Amtsstruktur (Abbildung 5).

Abb. 4: Benutzeroberfläche der TwinCity3D-Plattform im Splitscreen-Modus (RealityMaps 2024)

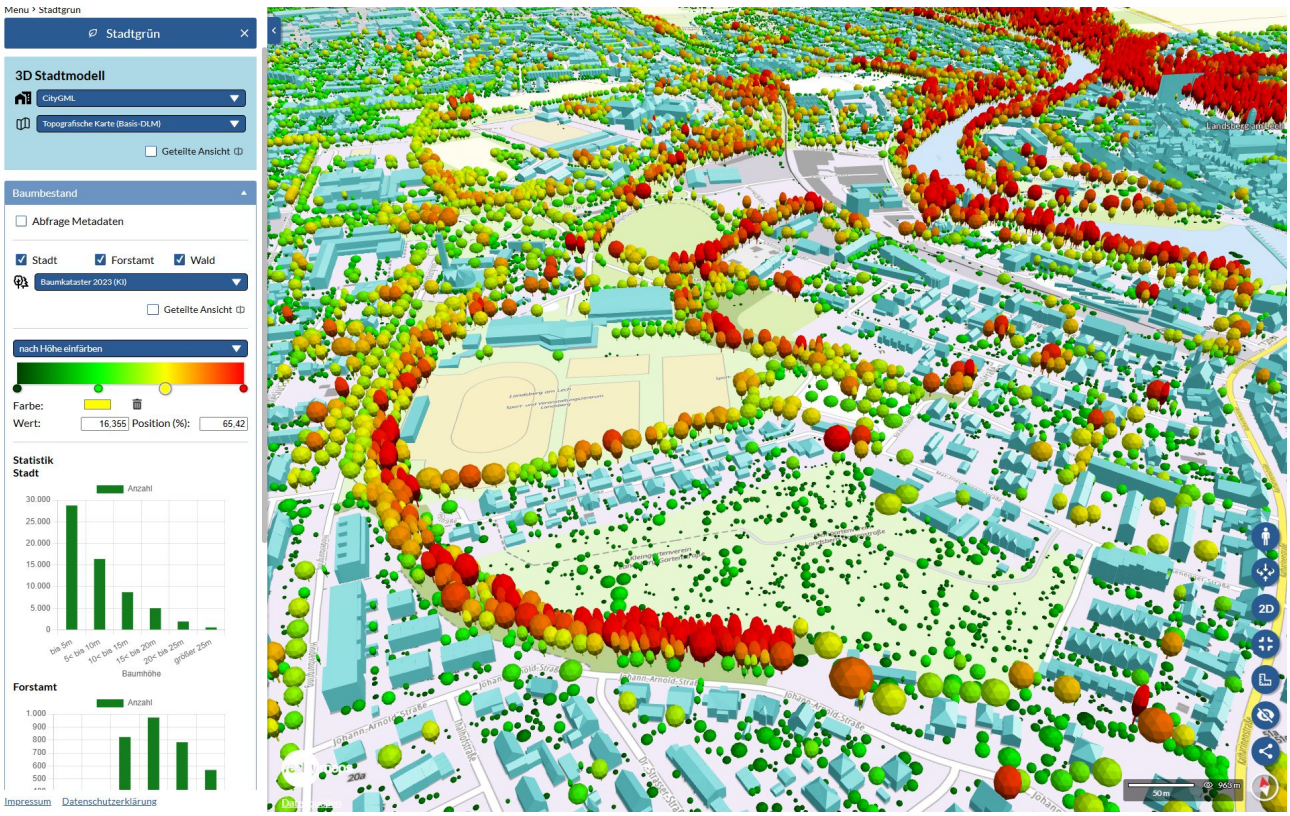

Abb. 5: Anzeige desmittels KI erfassten Baumbestands mit farblicher Unterscheidung von Höhenklassen

Ergebnisse von GIS-Analysen können als 2D-Kartenebenen überblendet werden. Aktuell sind erste Heatmaps mit Thermalinformationen, Baumdichten oder Infos zum oberirdisch ruhenden Verkehr verfügbar.

Durch die halbtransparente Überblendung im virtuellen 3D-Meshmodell werden Zusammenhänge zwischen verschiedenen Phänomenen im räumlichen Kontext sicht- und begreifbar.

Wiederholte Luftbildbefliegungen helfen zeitliche Veränderungen sichtbar zu machen und den Erfolg von planerischen Maßnahmen zu überprüfen. Der digitale Zwilling wird so zu einem Monitoring-Tool, mit dem gewollte und ungewollte Veränderungen schnell erkanntwerden können. Der Vergleich von Luftbildern aus verschiedenen Jahren hilft zum Beispiel die Entwicklung des Stadtgrüns zu überwachen. Eine wiederholte Analyse der Grünstrukturen über mehrere Jahre lässt qualitative und quantitative Vergleiche zu. Die nachfolgende Abbildungsreihe zeigt die Orthofotos von Luftbilddaten aus 2020 und 2023 im Vergleich. Das Ergebnisbild der Differenzanalyse (rechts) zeigt die Veränderungen in einem Spektrum von blau (Zuwachs) über gelb bis rot (Verluste). Im unten geszeigten Bildausschnitt wurden mehrere Bäume und Büsche im Zuge einer Umgestaltung des Gartens gefällt. Auch ein Alleebaum wurde wegen Krankheitsbefall gefällt (Abbildung 6). Anhand einer Differenzanalyse wird es erstmalig möglich auch kleinste Veränderungen im gesamten Stadtgebiet automatisiert zu erkennen.

Abb. 6: Durch die vergleichende Auswertung von multitemporalen Luftbildern können zwischenzeitliche Veränderungen beobachtet und festgehalten werden: hier ein Ausschnitt von 2020, 2023 und das Ergebnis der Differenzanalyse).

4.2 Planungsebene

Das 3D-Mesh-Modell und das CityGML-Modell sind zwei verschiedene Arten, eine Stadt darzustellen. Beide haben ihre eigenen Vor- und Nachteile und werden je nach Bedarf eingesetzt.Das Mesh-Modell zeigt die Stadt sehr detailliert und realitätsnah. Es eignet sich besonders gut, wenn es um eine hohe visuelle Qualität und die schnelle, genaue Erkennung von Gebäuden und Orten geht.Das CityGML-Modell ist abstrakt und weniger detailliert. Dafür eignet es sich besser für Planungen und Simulationen, bei denen abstrakte Darstellungen ausreichen. Ein Beispiel dafür ist die Schattensimulation in der TwinCity3D-Plattform: Hier kann durch die Eingabe von Datum und Uhrzeit visualisiert werden, wie Schatten im Stadtgebiet fallen und welche Auswirkungen diese haben.

Die TwinCity3D-Plattform bietet eine Importfunktion, um 3D-Modelle von Bauplanungen in verschiedenen Formaten wie zum Beispiel XPlan einzulesen und im virtuellen 3D-Stadtgebiet visualsierenzu können. Durch den Beschluss des IT-Planungsrates wurde festgelegt, dass alle Bebauungspläne künftig im Datenstandard XPlanung (XPlanGML) erstellt werden müssen. Das sorgt dafür, dass die Pläne einheitlich aufgebaut sind und leichter ausgetauscht werden können. Die TwinCity3D-Plattform kann XPlanGML-Dateien einlesen. Bebauungspläne legen als rechtliche Vorgaben fest, wo und wie gebaut werden darf. Damit man besser verstehen kann, wie sich diese Vorgaben räumlich auswirken, wird das Import-Tool der TwinCity3D-Plattform die Inhalte der Bebauungspläne in 3D umwandeln. So werden Baugrenzen, Baulinien, die erlaubte Höhe von Gebäuden oder die Anzahl der Stockwerke direkt im Digitalen Zwilling sichtbar.

3D-Modelle, wie sie von Architekten und Bauplanern erstellt werden, können ebenfalls importiert werden. Da es sich hierbei um extern erstellte CAD-Konstruktionen handelt, wird eine Checkliste vorbereitet, wie diese Dateien vorbereitet werden müssen, dass ein Import und eine korrekte Darstellung in TwinCity3D möglich ist. Wenn die 3D-Modelle ohne Geokoordinaten vorliegen, dann kann das 3D-Modell vom Nutzer interaktiv im Stadtmodell positioniert werden. Für erste Überlegungen zu Bauvorhaben wird weiterhin ein dreidimensionales Konstruktionstool in der TwinCity3D-Plattform bereitgestellt. Anhand eines Polygons kann das 3D-Meshmodell beschnitten und geplättet werden um wie im physischen Modellbau – eine

Bodenplattezu erzeugt,auf der verschiedene einfache Baukörper platziert und dimensioniert werden können. Der Vorteil dieses Planungswerkzeuges liegt auf der Hand: Bei Überlegungen zur städtebaulichen Entwicklung könneneinfach und schnell verschiedene Szenarien im realen Umfeld simuliert werden.

Abb. 7: Import eines Bebauungsplans im XPlan-GML-Format in der Planungsebene (RealityMaps 2024)

Abb. 8: Der Digitalen Zwillings als immersiveVR-Anwendung

Das 3D-Modell kann mit Hilfe der TwinCity3D-Plattform auch als Virtual-Reality-Anwendung (VR) erkundet werden. Dabei erleben Nutzer die Stadt in einer virtuellen Umgebung, die einen realistischen Spaziergang ermöglicht. Durch die detailgetreue 3D-Darstellung wird es einfacher, die digitalen Inhalte mit der echten Stadt zu verbinden. Im Vergleich zu statischen 2D-Plänen oder einzelnen gerenderten Ansichten bietet die TwinCity3D-Plattform mehr Flexibilität: Der Standort kann frei gewählt und verschiedene Planungsoptionen können interaktiv diskutiert werden. Dies greift das Konzept der „Echtzeitplanung“ (ZEILE 2010) auf und entwickelt es weiter. So wird die Bewertung neuer Bauvorhaben hinsichtlich Größe,

Wirkung und Integration transparenter und verbessert insgesamt die Kommunikation im Planungsprozess (STREICH 1996).

5 FAZIT UND AUSBLICK

Mit dem mFUND-Forschungsprojekt „TwinCity3D“ sind eine Vielzahl neuer Erkenntnisse für die Stadt Landsberg am Lech erarbeitet worden, die in den Anwendungsbereichen Stadtplanung, Klimaschutzund Klimaanpassungsplanung Verwendung finden. Das neue Sytem zur Erfassung von Geodaten aus der Luft eröffnet völlig neue Möglichkeiten für die Analyse städtischer Strukturen. So kann das städtische Baumkataster um Daten zu Grünflächen auf nicht-städtischem Gelände ergänzt werden, was eine Gesamtbilanz des Grünvolumens und eine CO_2-Berechnung ermöglicht. Auch der Platzbedarf des ruhenden Verkehrs kann für die gesamte Stadt erfasst und in GIS-Analysen statistisch ausgewertet werden.Mithilfe einer umfassenden Analyse der Zusammenhänge zwischen Verkehrsflächen, Grünstrukturen und Wärmeentwicklung lassen sich fundierte Planungsgrundlagen für eine nachhaltige Stadtentwicklung schaffen. Regelmäßige Befliegungen machen die Plattform zu einem effizienten Monitoring-Tool für langfristige Stadtplanungsprozesse.Zudem sollen die entwickelten Methoden es kleineren Städten ohne umfassendeSmart City-Strategie ermöglichen, kostengünstige Geodaten für die Stadtentwicklung einzusetzen.Die in die TwinCity3D-Plattform integrierte Planungsebene macht es einfacher, städtische Planungen anschaulich darzustellen und verständlich zu erklären. Für eine nachhaltige Stadtentwicklung und Mobilitätsplanung ist es entscheidend, Geodaten zu erfassen, auszuwerten und aufzubereiten – in Zukunft wird das wohl eine Pflichtaufgabe in der Stadtplanung sein.Nur mit einer soliden Datenbasis können Planungen und politische Entscheidungen nachvollziehbar und transparent gestaltet werden. Objektive Fakten helfen dabei, persönliche Meinungen oder Gefühle zu ergänzen. Das führt zu mehr Verständnis bei Bürgerinnen und Bürgern sowie im Stadtrat und stärkt das Vertrauen in Planungen und politische Entscheidungen.

6 DANKSAGUNG/FÖRDERHINWEIS

Der vorliegende Beitrag entstand im Zuge des darin vorgestellten Forschungsvorhabens „TwinCity3D – Entwicklung einer geodatenbasierten “TwinCity3D”-Plattform und KI-Analysetools zur Unterstützung einer umweltfreundlichen Stadt- und Verkehrsplanung”, welches im Rahmen der Innovationsinitiative mFUND des BMDV gefördert wird. Die Autoren bedanken sich beim mFUND und dem BMDV für die Förderung und beim TÜV Rheinland für die inhaltliche und organisatorische Unterstützung.

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🏆 reviewed paper

Überholabstände Kfz-Rad: Ergebnisse aus Realexperimenten und Planungsempfehlungen

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1 ABSTRACT

Die Einhaltung ausreichender Überholabstände von Kraftfahrzeugen (Kfz) gegenüber Radfahrenden ist ein zentraler Bestandteil der Verkehrssicherheit und ein entscheidender Faktor für die Förderung des Radverkehrs. In dieser Studie wurden die Überholabstände zwischen Kfz und Radfahrenden in zehn Modellkommunen in Baden-Württemberg analysiert, um die Wirksamkeit verschiedener Maßnahmen zur Verbesserung der Überholsicherheit zu bewerten. Mithilfe des OpenBikeSensors (OBS) wurden Vorher-Nachher-Daten erfasst, um die Auswirkungen von Infrastrukturänderungen, Tempolimits, Piktogrammketten und Überholbuchten zu untersuchen.

Die Ergebnisse zeigen, dass Maßnahmen wie die Verbreiterung von Schutzstreifen oder Radfahrstreifen und die gezielte Gestaltung von Überholbuchten die mittleren Überholabstände vergrößern können und die Häufigkeit gefährlich enger Überholmanöver (<100 cm) reduzieren können. Besonders die Einführung klar definierter Überholbereiche führte zu positiven Effekten. Gleichzeitig verdeutlichten die uneinheitlichen Ergebnisse bei Maßnahmen wie Tempolimits oder Piktogrammketten die starke Abhängigkeit von lokalen Faktoren wie der Straßenbreite, Verkehrsführung und Verkehrskultur.

Die Studie macht deutlich, dass gesetzlich vorgeschriebene Mindestüberholabstände auf engen innerstädtischen Straßen durch bauliche Maßnahmen allein häufig nicht erreicht werden können. Ein integrierter Ansatz, der Infrastrukturmaßnahmen mit Öffentlichkeitsarbeit und einer konsequenten Ahndung von Verstößen kombiniert, ist unerlässlich, um die Sicherheit von Radfahrenden nachhaltig zu verbessern.

Die vorgestellten Ergebnisse liefern praxisorientierte Handlungsempfehlungen für Städte und Planerinnen und Planer, die sichere und attraktive Radverkehrsinfrastrukturen schaffen möchten. Die Erkenntnisse tragen zur Förderung des Radverkehrs als umweltfreundliches Verkehrsmittel bei und leisten einen wichtigen Beitrag zur Verkehrswende.

Keywords: Überholabstände, Verkehrssicherheit, Verkehrsplanung, objektive und subjektive Sicherheit, Modellversuche

2 EINLEITUNG

Die Einhaltung ausreichender Überholabstände von Kfz gegenüber Radfahrenden ist ein zentraler Aspekt der Verkehrssicherheit (Sinus Markt und Sozialforschung 2023) und ein entscheidender Faktor für die Förderung des Radverkehrs. Insbesondere im städtischen Kontext, wo enge Straßenverhältnisse und hohe Verkehrsdichten den Alltag prägen, stellt die Sicherheit von Radfahrenden eine große Herausforderung dar. Der Überholabstand spielt dabei nicht nur eine Rolle für die objektive Verkehrssicherheit – die auf statistischen Unfallanalysen basiert –, sondern auch für die subjektive Sicherheit, also das individuelle Sicherheitsgefühl der Radfahrenden (Mellinger 2022, Useche et al. 2019). Beide Aspekte beeinflussen maßgeblich die Bereitschaft, das Fahrrad als Verkehrsmittel im Alltag zu nutzen und so zur Verkehrswende beizutragen.

Die Problemstellung lässt sich in zwei zentrale Dimensionen gliedern: Einerseits zeigen Unfallstatistiken, dass bei Fahrradunfällen in über 70 % der Fälle ein oder mehrere PKW involviert sind (Destatis 2023). Besonders kritisch sind sogenannte „Dooring"-Unfälle, bei denen Radfahrende durch das plötzliche Öffnen von Autotüren gefährdet werden (Brockmann 2020, GDV, 2019). Andererseits verdeutlichen Untersuchungen, dass subjektiv wahrgenommene Bedrohungssituationen – etwa durch enge Überholvorgänge – eine zentrale Rolle für das Sicherheitsgefühl spielen. Verschiedene Studien zeigen, dass Radfahrende enge Überholvorgänge als dominierenden Stressauslöser wahrnehmen, insbesondere im Mischverkehr oder bei der Nutzung von Schutzstreifen (Merk et al., 2021, Hauenstein et al. 2023).

Obwohl die StVO-Novelle 2020 innerorts einen Mindestüberholabstand von 1,5 Metern und außerorts von 2,0 Metern vorschreibt, werden diese Abstände in der Praxis häufig nicht eingehalten (Merk et al. 2022, Röder et al. 2020, Richter et al. 2019). Zudem mangelt es an einem Bewusstsein für die Bedeutung dieser Abstände bei vielen Verkehrsteilnehmenden (Sinus Markt und Sozialforschung 2023). Solche Defizite gefährden nicht nur die objektive Sicherheit, sondern erschweren auch eine breite gesellschaftliche Akzeptanz des Fahrrads als vollwertiges Verkehrsmittel.

Ziel dieses Papers ist es, die Überholabstände zwischen Kfz und Radfahrenden zu analysieren, die relevanten Einflussfaktoren zu identifizieren und daraus Empfehlungen für die Gestaltung von Straßeninfrastrukturen und Maßnahmen zur Verhaltensänderung abzuleiten. Dabei wird ein besonderes Augenmerk auf die Verbindung von objektiver und subjektiver Sicherheit gelegt, um die Wirkung von Überholvorgängen ganzheitlich zu betrachten. Neben der Analyse bestehender Forschungsergebnisse und Daten aus Realexperimenten sollen praxisnahe Lösungen vorgestellt werden, die Kommunen dabei unterstützen, den Radverkehr sicherer und attraktiver zu gestalten.

Dieses Thema ist von zentraler Bedeutung für die Förderung einer nachhaltigen Mobilität, da sichere Überholabstände nicht nur das Sicherheitsgefühl der Radfahrenden stärken, sondern auch zu einem besseren Miteinander im Straßenverkehr beitragen können. Die Erkenntnisse dieses Papers sollen somit eine Grundlage für die Planung und Umsetzung wirksamer Maßnahmen bieten, die sowohl die Verkehrssicherheit erhöhen als auch die Integration des Fahrrads in den urbanen Verkehrsraum verbessern.

3 METHODIK

Im Rahmen des Forschungsprojekts gÜ-Rad wurden in Zusammenarbeit mit zehn Mitgliedskommunen der Arbeitsgemeinschaft Fahrradfreundlicher Kommunen (AGFK) in Baden-Württemberg neuralgische Straßenzüge identifiziert. Diese Straßenabschnitte galten aufgrund ihrer Bedeutung für den Radverkehr und der Einstufung durch kommunale Radverkehrsbeauftragte sowie Bürgerinnen und Bürger als besonders kritisch. Die Auswahl dieser Abschnitte diente als Grundlage für Vorher-Nachher-Messungen, die auf die Analyse von Überholabständen zwischen Kfz und Radfahrenden abzielten.

Im Jahr 2022 wurden zunächst Vorher-Daten erhoben. Hierbei wurden freiwillige Radfahrende in jeder der beteiligten Kommunen über einen Zeitraum von drei Wochen mit dem OBS ausgestattet. Der OBS ist ein Ultraschallsensor, der die Überholabstände von vorbeifahrenden Fahrzeugen misst. Um die Überholvorgänge korrekt zuzuordnen, mussten die Teilnehmenden diese mittels Knopfdruck bestätigen. Die so erfassten Daten wurden im Anschluss analysiert und visuell aufbereitet. Dies ermöglichte eine präzise Identifikation von Straßensegmenten, an denen es zu engen oder kritischen Überholszenarien kam.

Basierend auf diesen Erkenntnissen wurden in einem interdisziplinären Konsortium aus AGFK-Vertretern, Expertinnen und Experten aus der Wissenschaft und kommunalen Radverkehrsbeauftragten Maßnahmen für Verkehrsversuche entwickelt. Ziel dieser Maßnahmen war es, die Überholabstände zu vergrößern und so die Sicherheit und das subjektive Sicherheitsgefühl der Radfahrenden zu erhöhen. Die entwickelten Maßnahmen wurden anschließend im Jahr 2023 in den entsprechenden Straßenabschnitten umgesetzt. Dazu zählten temporäre Veränderungen der Straßeninfrastruktur wie Markierungen, Beschilderungen oder andere verkehrslenkende Maßnahmen. Tabelle 1 zeigt die einzelnen Modellversuche in den verschiedenen Kommunen.

Um die Wirkung der umgesetzten Maßnahmen zu evaluieren, wurden im Herbst 2023 die Nachher-Daten erhoben. Die gleichen Radfahrenden, die bereits an der Vorher-Erhebung teilgenommen hatten, wurden erneut mit dem OBS ausgestattet. Wie zuvor zeichneten sie die Überholabstände auf und dokumentierten kritische Überholszenarien. Im Anschluss an den Erhebungszeitraum wurden die Nachher-Daten analysiert und mit den Vorher-Daten verglichen. Dies ermöglichte eine fundierte Bewertung der Wirkung der durchgeführten Verkehrsversuche und lieferte wichtige Erkenntnisse über die Wirksamkeit der Maßnahmen zur Verbesserung der Überholabstände zwischen Kfz und Radfahrenden.

4 ERGEBNISSE

Die im Rahmen des Projekts gÜ-Rad durchgeführten Realexperimente lieferten detaillierte Erkenntnisse zu den Überholabständen zwischen Kfz und Radfahrenden. Insgesamt wurden Messungen in 10 Modellkommunen durchgeführt, wobei unterschiedliche infrastrukturelle und verkehrsorganisatorische

Maßnahmen untersucht wurden. Dabei wurden sowohl Vorher-Daten ohne spezifische Infrastrukturänderungen als auch Nachher-Daten nach der Implementierung der Maßnahmen erhoben.

Zunächst wurde die Vergleichbarkeit der Kommunen untereinander untersucht. Dafür wurden Abschnitte ausgewählt, die gleiche infrastrukturelle Merkmale aufweisen, wie eine Kombination aus spezifischer Straßenbreite und entweder Mischverkehr oder Radverkehrsinfrastruktur. Besonders auffällig ist, dass trotz gleicher infrastruktureller Bedingungen der Median in allen Kommunen stark streut. Dies deutet darauf hin, dass weitere Faktoren, wie beispielsweise die lokale Verkehrskultur, erheblichen Einfluss auf die Ergebnisse haben. Beispielhaft wird in Abbildung 1 die Verteilung für Straßen mit einer Breite von 7 Metern in fünf Modellkommunen dargestellt. Für andere Kommunen wurden auf dieser Breite keine Daten erhoben (Baden-Baden, Mengen, Offenburg, Singen, Ulm). Die deutliche Streuung der Werte unterstreicht, dass neben der Infrastruktur auch externe Einflussfaktoren wie Verhaltensmuster und lokale Rahmenbedingungen berücksichtigt werden müssen.

Kommune	**Straße**	**Maßnahme**	**Umsetzungs-zeitraum**
Aalen	Heinrich-Rieger-Straße	Schutzstreifen 1,50 m beidseitig mit Rotmarkierungen an Gefahrenstellen	Juni 2023
Aalen	Eduard-Pfeiffer-Straße	Schutzstreifen 1,50 m Ost nach West	Juni 2023
Aalen	Carl-Zeiss-Straße	Schutzstreifen 1,50 m Ost nach West	Juni 2023
Aalen	Robert-Bosch-Straße	Radfahrstreifen 1,85 m Ost nach West	Juni 2023
Backnang	Sulzbacher Straße	Markierung eines Sicherheitstrennstreifen zum ruhenden Verkehr Markierung einer Überleitung vom Schutzstreifen in den Mischverkehr vorbei am ruhenden Verkehr	Juni/August 2023
Backnang	Gartenstraße	Verbreiterung des Schutzstreifens auf 1,60 m.	September 2023
Backnang	Annonay-Straße	Markierung von Piktogrammen auf der Fahrbahn	Juli/August 2023
Backnang	Aspacher Straße	Markierung eines Sicherheitstrennstreifens im Mischverkehr zum ruhenden Verkehr	September 2023
Baden-Baden	Alte Landstraße	Tempolimit 50 km/h	Juli 2023
Baden-Baden	Lange Straße	Verbreiterung des Schutzstreifens auf 1,60 m + Rotmarkierungen	Juli 2023
Heilbronn	Heidelberger Straße	Schutzstreifen/Radfahrstreifen mit 1,70 m bis 1,85 m Breite, beidseitig von Nord nach Süd	Juli 2023
Mengen	Flachsstraße	Öffentlichkeitsarbeit – Aufstellen von Bannern am rechten Straßenrand	Oktober 2023
Offenburg	Kehler Straße	Markierung einer Piktogrammkette und eines durchgehender Schutzstreifens	Februar 2024
Offenburg	Zeller Straße	Umwandlung des östlichen Abschnitts in eine Fahrradstraße	Oktober 2023
Offenburg	Rammers-weier Straße	Tempo 30 km/h-Abschnitt verlängern und VZ 277.1	Oktober 2023
Offenburg	Weingarten-straße	Öffentlichkeitsarbeit in Form von Abstandsschildern	November 2023
Schorndorf	Feuersees-traße	Mischverkehr + Verbot des Überholens von einspurigen Fahrzeugen: Aufstellen des VZ 277.1	Oktober 2023
Singen	Hohen-krähenstraße	Einteilung der Straße in drei Abschnitte, Test folgender Maßnahmen: Markierung eines Schutzstreifens mit 1,50 m Breite Führung im Mischverkehr mit Piktogrammkette Markierung eines Schutzstreifens mit 1,85 m Breite	Juni 2023
Stuttgart	Waldburg-straße	Verbreiterung der Schutzstreifen + zwei Überholbuchten	August/Sep-tember 2023
Stuttgart	Schickhardt-straße	Markierung von Sharrows in Fahrtrichtung Nord	September 2023
Ulm	Mähringer Weg	Rote Markierungen parallel zu den bestehenden Schutzstreifen zur Erhöhung der Aufmerksamkeit	März 2024
Ulm	Söflinger Straße	Überholverbot von einspurigen Fahrzeugen: Aufstellen des VZ 277.1 versuchsweise	März 2024

Tabelle 1: Übersicht der Modellversuche in den zehn Modellkommunen

4.1 Verbreiterung der Radverkehrsinfrastrukturen

In mehreren Kommunen, wurde die Breite von Schutz- oder Radfahrstreifen vergrößert, beispielsweise von 1,5 m auf 1,85 m. Die Ergebnisse zeigen eine leichte Erhöhung der mittleren Überholabstände. Auf der Waldburg Straße in Stuttgart stieg der mittlere Überholabstand von 135 cm auf 146 cm. Gleichzeitig sank der Anteil der Überholvorgänge mit sehr engen Abständen (< 100 cm), was darauf hindeutet, dass die Verbreiterung der Infrastruktur nur begrenzt Einfluss auf die kritischsten Situationen hatte. Es konnte allerdings nicht in allen Kommunen eine Verbesserung des Überholabstandes herbeigeführt werden. In Tabelle 2 sind die Vorher-Nachher Daten der einzelnen Verkehrsversuche dargestellt.

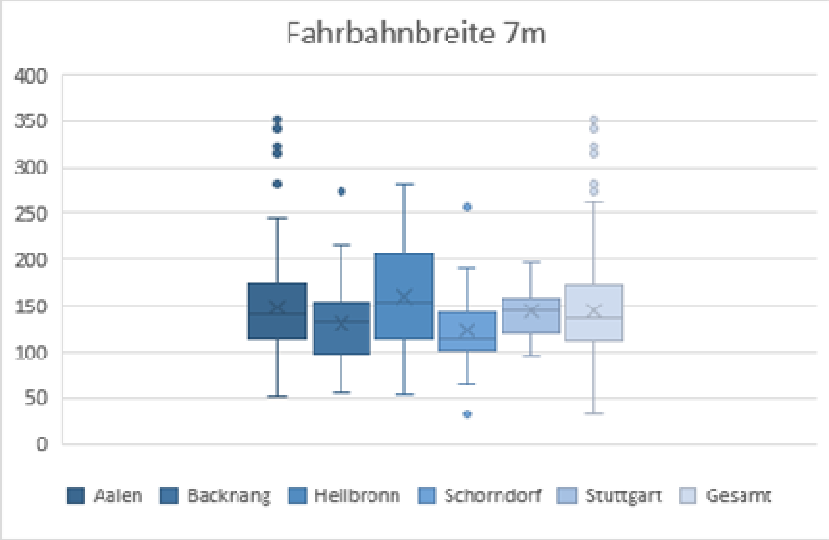

Abbildung 1: Verteilung Median in den verschiedenen Modellkommunen im Jahr 2022/23 (eigene Darstellung)

Kommune Straße	Realexperiment	Mittelwert Überhol-abstand (Vorher - Nachher)	Überholvorg. unter 150 cm in % (Vorher -Nachher)	Überholvorg. unter 100 cm in % (Vorher -Nachher)	Überholdichte Ü/100 m Befahrung (Vorher -Nachher)
Backnang Sulzbacher Straße Süd	Schutzstreifen um Sicherheitstrennstreifen erweitert	129 – 161	78-0	56-0	0,16 – 0,06
Baden-Baden Lang Straße N	Schutzstreifen von 1,2auf 1,6 m verbreitert	148 – 153	52 – 39	14 – 10	1,06 – 1,11
Baden-Baden Lange Straße S	Schutzstreifen von 1,2auf 1,6 m verbreitert	154 – 141	50 – 56	11 – 19	2,71 – 0,12
Stuttgart Waldburgstraße	Schutzstreifen von 1,5 auf 1,85 m verbreitert Fahrbahn von 4,5 auf 4,15 m schmaler	135 -146	58 -56	13 – 9	0,24 – 0,31
Heilbronn Heidelberger-straße Nord	Schutzstreifen von 1,5 auf 1,85 verbreitert und Mittellinie beseitigt	152 – 157	52 -44	11 – 11	0,37 – 0,27
Heilbronn Heidelberger-straße Süd	Schutzstreifen von 1,5 auf 1,85 verbreitert und Mittellinie beseitigt	158 – 160	46 -42	15 – 12	0,24 – 0,15

Tabelle 2: Übersicht Maßnahmen mit Verbreiterung der Radfahrinfrastruktur

Kommune Straße	Realexperiment	Mittelwert Überholabstand (Vorher - Nachher)	Überholvorg. unter 150cm in % (Vorher -Nachher)	Überholvorg. unter 100cm in % (Vorher -Nachher)	Überholdichte Ü/100m Befahrung (Vorher -Nachher)
Backnang Annonay Straße Süd	Mischverkehr in Schutzstreifen umgewandelt	129 – 132	75-71	20-14	0,39 – 0,13
Singen Hohenkrähen-straße	Mischerverkehr in Schutzstreifen 1,5m umgewandelt	137-127	72 -83	15 – 14	1,35 – 1,1
Singen Hohenkrähenstraße	Mischverkehr in Schutzstreifen 1,85m umgewandelt	139 -130	68 – 80	17- 15	1,0 -0,8
Aalen Robert-Bosch Straße Ost	Mischverkehr auf Radfahrstreifen 1,85m umgewandelt	162 – 158	35 – 43	24 – 0	0,63 – 0,21
Aalen Robert-Bosch Straße West	Mischverkehr auf Radfahrstreifen 1,85m umgewandelt	162 – 144	40 – 66	24 – 7	0,58 – 0,79
Aalen Heinrich-Rieger Straße Nord	einseitigen Schutzstreifen in beidseitigen Schutzstreifen umgewandelt	155 – 149	43 – 57	14 – 6	0,2 – 0,33
Aalen Heinrich-Rieger Straße Süd	einseitigen Schutzstreifen in beidseitigen Schutzstreifen umgewandelt	147 – 148	56 – 51	16 – 18	0,51 – 0,18

Tabelle 3: Übersicht Maßnahmen Implementierung Schutzstreifen und Piktogrammkette

4.2 Markierung von Schutzstreifen und Piktogrammketten

Die Umwandlung von Mischverkehrsbereichen in Schutzstreifen sowie die Markierung von Piktogrammketten hatte uneinheitliche Auswirkungen. In der Hohenkrähenstraße in Singen, auf der ein Schutzstreifen von 1,5 m markiert wurde, verringerten sich die mittleren Überholabstände von 137 cm auf 127 cm. Gleichzeitig nahm der Anteil der regelkonformen Überholvorgänge (> 150 cm) von 28 % auf 17 % ab. Im Gegensatz dazu zeigte die Einführung einer Piktogrammkette in Stuttgart eine leichte Verbesserung der Überholabstände, der Anteil der Überholvorgänge mit sehr engen Abständen blieb jedoch weitgehend

4.3 Einfluss von Tempolimits

In Baden-Baden wurde auf der Alten Landstraße die zulässige Höchstgeschwindigkeit von 100 km/h auf 50 km/h reduziert. Die Daten zur Temporeduzierung zeigen allerdings ein uneinheitliches Bild. In Fahrtrichtung Nord, aus dem Ort hinausführend, hat die Temporeduzierung den gewünschten Effekt erzielt: Die Überholabstände haben sich im Mittel um 20 cm vergrößert (2022: 141 cm, 2023: 161 cm). In Fahrtrichtung Süd hingegen, von der B3 kommend in Richtung Steinbach, ist der mittlere Überholabstand gesunken. Hier wurde 2023 im Durchschnitt minimal enger überholt als 2022 (2022: 164 cm, 2023: 156 cm). Dieses Ergebnis zeigt, dass die Auswirkungen von Temporeduzierungen von weiteren Faktoren wie Verkehrsführung, Streckencharakteristik oder Verkehrsdichte abhängig sein könnten.

4.4 Bewertung der Wirksamkeit der Maßnahmen

In Stuttgart wurden verschiedene Maßnahmen auf einem ca. 800 m langen Abschnitt auf der Waldburgstraße untersucht. Die Verbreiterung eines Schutzstreifens von 1,5 m auf 1,85 m sollte eine Fahrbahnverengung bewirken und das Überholen faktisch unmöglich machen. Bergaufwärtsführend wurden sogenannt Überholbuchten eingeführt. Hierzu wurden auf der zum Radverkehr gegenüberliegenden Fahrbahnseite das Parken entfernt, in Fahrtrichtung wurden auf einer Länge von jeweils etwa 100 m zwei 1,85 m breite Radfahrstreifen markiert, um ein sicheres Überholen mit ausreichendem Abstand zu ermöglichen. Die gewünschten Effekte traten teilweise ein: Während auf dem verbreiterten Schutzstreifen von 1,85 m weiterhin mit ähnlicher Überholdichte wie zuvor überholt wurde, vergrößerten sich die Überholabstände auf den Radfahrstreifen leicht. Bei Überholbuchten zeigte sich ein besonders positiver Effekt: Der mittlere Überholabstand stieg von 126 cm im Jahr 2022 auf 152 cm im Jahr 2023 und die Überholdichte hat sich in diesen Bereichen verdreifacht. Zudem sank der Anteil der Überholvorgänge mit sehr engen Abständen (< 100 cm) von 19 % auf 2 %. Diese Ergebnisse deuten darauf hin, dass die gezielte Gestaltung von Überholbereichen nicht nur die Abstände vergrößert, sondern auch die Sicherheit des Radverkehrs erheblich verbessern kann, indem die Zahl gefährlicher Überholmanöver mit zu geringen Abständen deutlich reduziert wird.

Maßnahme	Mittelwert Überholabstand	Überholvorg. unter 150cm in %	Überholvorg. unter 100cm in %	Überholdichte Ü/100m Befahrung
Verbreiterung Radinfrastruktur	Tendenziell Zunahme Überholabstand (4 von 6 Bsp.)	Uneinheitliche Entwicklung regelkonformer Überholabstand	Uneinheitliche Entwicklung sehr enge Überhol-abstände	Tendenziell seltener überholen (4 von 6 Bsp.)
Markierung Schutzstreifen statt Mischverkehr	Engere Überholabstände (5 von 7 Bsp.)	Einhaltung regelkonforme Überholabstand geht zurück (5 von 7 Bsp.)	Seltener sehr enges Überholen (5 von 7 Bsp.)	seltener überholen (5 von 7 Bsp.)
Markierung Piktogramm-kette im Mischverkehr	Uneinheitliche Entwicklung Überholabstand	Uneinheitliche Entwicklung regelkonformer Überholabstand	Uneinheitliche Entwicklung sehr enge Überhol-abstände	seltener überholen (4 von 4 Bsp.)
Änderung zulässige Höchstgeschwin-digkeit	Uneinheitliche Entwicklung Überholabstand	Uneinheitliche Einhaltung regelkonformer Überholabstand	Uneinheitliche Entwicklung sehr enge Überhol-abstände	Uneinheitliche Entwicklung Überholdichte
Bereich zum Überholen und nicht Überholen	Intendierte Entwicklung	Intendierte Entwicklung	Intendierte Entwicklung	Intendierte Entwicklung

Tabelle 4: Übersicht Interpretation der Maßnahmen

5 DISKUSSION

Die Ergebnisse verdeutlichen, dass nicht alle Maßnahmen zur Verbesserung der Überholsicherheit von Radfahrenden gleichermaßen effektiv sind und teilweise unerwartete oder uneinheitliche Effekte zeigen. Insbesondere die Verbreiterung der Radinfrastruktur und die Markierung von Schutzstreifen anstelle von Mischverkehrsflächen weisen auf Zielkonflikte hin: Während die mittleren Überholabstände und das sehr enge Überholen teilweise verbessert werden, bleibt die Einhaltung des regelkonformen Mindestabstands oft unzureichend. Dies unterstreicht die Notwendigkeit, Maßnahmen differenziert zu bewerten und ihre Wirkung auf verschiedene Aspekte des Überholverhaltens systematisch zu untersuchen. Zudem zeigen die uneinheitlichen Ergebnisse bei der Markierung von Piktogrammketten und der Änderung der zulässigen Höchstgeschwindigkeit, dass kontextabhängige Faktoren, wie Verkehrsdichte oder Straßengestaltung, eine entscheidende Rolle spielen können. Besonders hervorzuheben ist jedoch die klare Wirksamkeit von Maßnahmen zur Definition von Bereichen zum Überholen und Nicht-Überholen, die konsistent positive Ergebnisse in allen untersuchten Parametern zeigen. Diese Beobachtungen deuten darauf hin, dass gezielte und klar kommunizierte Regelungen besonders wirksam sind und bei der Planung zukünftiger Infrastrukturmaßnahmen verstärkt berücksichtigt werden sollten.

6 FAZIT UND AUSBLICK

Die Förderung sicherer Überholvorgänge zwischen Kraftfahrzeugen und Fahrrädern ist ein zentraler Beitrag zur Verbesserung der Verkehrssicherheit und hin zu einem attraktiveren Radverkehr. Die Ergebnisse der Modellkommunen zeigen, dass zahlreiche Faktoren – wie die Gestaltung der Verkehrsinfrastruktur, Verkehrsaufkommen oder Verkehrskultur – das Verhalten der Verkehrsteilnehmenden beeinflussen. Monokausale Zusammenhänge zwischen Infrastrukturmaßnahmen und Überholverhalten lassen sich daher nur bedingt feststellen, was die Komplexität der kommunalen Planungspraxis verdeutlicht.

Die begrenzten Erfolge vieler Realexperimente unterstreichen die Herausforderung, gesetzlich vorgeschriebene Überholabstände auf engen innerstädtischen Straßen allein durch bauliche Maßnahmen sicherzustellen. Dennoch besteht die Möglichkeit, durch systematische Forschung und innovative Ansätze – wie breitere Schutzstreifen, technische Lösungen zur Anzeige von Überholabständen oder integrierte Konzepte, die Infrastruktur, Öffentlichkeitsarbeit und Ahndung kombinieren – neue Impulse zur Verbesserung der Überholsicherheit zu setzen.

Ein erheblicher Forschungsbedarf bleibt bestehen, insbesondere hinsichtlich der Wechselwirkungen von Überholabständen, Überholdichte und infrastrukturellen Rahmenbedingungen. Begleitende Wirkungskontrollen und der Austausch von Erfahrungen zwischen Kommunen sind essenziell, um Maßnahmen effektiv zu evaluieren und den allgemeinen Wissensstand zu erweitern. Langfristig kann so die Grundlage für sichere und verträgliche Überholvorgänge geschaffen werden.

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reviewed paper

Unpacking the Drivers of Gentrification: A Systematic Review of Selected African Countries

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1 ABSTRACT

Gentrification is a globally urban phenomenon that has relatively been researched. However, the drivers of gentrification remain a subject of ongoing enquiry. Consequently, this literature review examines the core drivers of gentrification within Africa, offering a comprehensive synthesis of key findings across disciplines to deepen our understanding of this complex process. The investigation employs bibliometric analysis and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol to examine the literature on the drivers of gentrification in African cities. Using VOSviewer version 1.6.20 software, the study analyses trends, citations and authorship patterns to identify dominant themes and scholarly networks. Drawing from a comprehensive dataset of articles published in the Scopus database, the paper clearly highlights the drivers of gentrification scholarship in the region through an analysis of relevant keywords, co-occurrences, and co-citation patterns. Findings reveal economic, socio-cultural shift, political and institutional factors emerge as critical drivers in directing gentrification trajectories. By synthesizing fragmented insights from existing literature, this review addresses key research gaps, particularly the lack of integrated analyses bridging economic, social and political dimensions of gentrification. In addition to advancing theoretical understanding, this review offers practical insights for urban policy. It emphasizes the need for context-sensitive urban planning strategies, inclusive housing policies, and institutional mechanisms that prioritize social equity and minimize displacement risks. This review contributes to the broader discourse of urban change and inequality, providing both scholarly clarity and actionable recommendations for fostering more equitable and sustainable urban development in gentrifying cities.

Keywords: Gentrification, Urban transformation, Global Capital, Housing policies, Systematic Review

2 INTRODUCTION

Gentrification, a process involving the transformation of urban spaces through economic and demographic shifts, has become a salient topic of inquiry in the global South. While much of the scholarship on gentrification originates from the global North, the African setting presents unique socio-economic, political, and spatial dynamics that warrant dedicated examination. Africa, characterized by rapid urbanization, persistent inequality, and diverse cultural landscapes, offers a rich yet underexplored field for understanding the drivers and implications of gentrification (Frenzel et al., 2022; Ntakana et al., 2023). Urban centers across the continent are undergoing significant transformations influenced by global capital flows, local governance policies, and the aspirations of a growing middle class. These changes often result in the displacement of marginalised communities, reshaping the socio-spatial fabric of cities. For instance, proactive upzoning policies aimed at economic development frequently exacerbate displacement pressures on low-income residents (Denoon-Stevens & Nel, 2020). Similarly, the commodification of cultural and historical urban spaces through tourism and digital technologies has intensified gentrification processes in cities such as Cape Town and Johannesburg (Frenzel et al., 2022). These trends illustrate the intersection of global market forces and local urban governance in driving urban transformation. Despite these developments, the discourse on gentrification in Africa remains fragmented. The majority of studies focus on isolated case studies, lacking a systematic synthesis that consolidates diverse insights into a cohesive narrative. Furthermore, existing research often neglects the broader socio-political and economic conditions unique to African urban settings. Critical questions remain unanswered: How do informal settlement dynamics influence gentrification? What role do international aid and development agencies play in shaping urban spaces? How can governance frameworks better address the displacement of vulnerable communities?

This gap in the literature highlights the need for a comprehensive review of the drivers of gentrification across African cities. While scholars, including Ntakana et al. (2023) advocate for inclusive urban space production models, practical implementation remains limited, particularly in addressing the socio-economic disparities exacerbated by gentrification. Similarly, Breetzke et al. (2018) highlight the disproportionate impacts of urban transformation on historically disadvantaged groups, yet policies to mitigate these effects remain underdeveloped. This research addresses these gaps by synthesizing existing studies to provide a systematic understanding of the drivers of gentrification in Africa. Through integrating insights from diverse sources, it aims to identify region-specific factors influencing gentrification and propose pathways for more equitable urban development. This effort not only contributes to the academic discourse but also offers practical guidance for urban planners navigating the challenges of urban transformation.

This paper provides a systematic review of the key drivers of gentrification in African cities, synthesizing fragmented insights from existing literature to bridge economic, social and political dimensions of urban transformation. It begins by outlining the methodological framwork, which includes bibliometric analysis and the PRISMA protocol, before presenting an overview of publication trends, co-citation networks, and thematic clusters emerging in gentrification research. The paper then explores the dominant drivers of gentrification – economic shifts, socio-cultural changes, political and institutional influences – highlighting their interplay in different urban contexts. Through an in-depth discussion of keyword co-occurences and case studies from cities such as Johannesburg, Cape Town, Accra, and Lagos, the paper critically examines how gentrification unfolds across diverse African landscapes. The findings underscore the need for inclusive urban policies, equitable housing strategies, and governance frameworks that mitigate displacement risks. By integrating bibliometric insights with broader theoretical debates, this review contributes to the discourse on urban change and offers practical recommendations for fostering socially just and sustainable urban development in Africa.

3 METHODS

This study employed Scopus as its primary data source because of its comprehensive coverage and high reliability within the academic community. Scopus offers a broad spectrum of scholarly outputs, indexing approximately 25,000 journals from over 5000 international publishers. This extensive database facilitates a robust analysis of scholarly trends, particularly for research pushed from 1996 onward (Magadán Díaz & Rivas García, 2022). While other databases, such as Web of Science (WOS), were considered for this study, Scopus was ultimately chosen because it provided more accurate and comprehensive results. Unlike WOS, which leans more towards scientific disciplines, Scopus offers a broader range of coverages, making it better suited for the study's objectives.

A bibliometric analysis and systematic review were conducted using Preferred Reporting Items for Systematic Reviews and Meta Analysis (PRISMA) protocol to trace the evolution of research on the causes of gentrification, particularly in African cities. This methodological approach provided a rigorous framework for assessing the impact of key studies and sources, identifying dominant themes, and understanding the development of gentrification scholarship within the global and African contexts.

3.1 Bibliometric Analysis

The bibliometric dataset was retrieved on January 25, 2025, using the Scopus database with the keyword search "Causes AND of AND Gentrification[1]", which inititially yielded 5,853 documents. After removing 10 duplicates, 5,843 documents remained. Titles, abstracts, and keywords were screened and refined, leading to the exclusion of 26 documents that did not meet the inclusion criteria. To narrow the focus to Africa, the keyword "Africa" was added, limiting the study to English-language documents. This resulted in 1,082 documents and after removing 10 duplicates, 1,072 documents remained. A detailed review revealed that gentrification studies were concentrated in 15 African countries: South Africa, Ghana, Nigeria, Uganda, Zimbabwe, Zambia, Tanzania, Rwanda, Morocco, Ethopia, Egypt, Cameroon, Burkina Faso, Benin and Algeria. These countries are likely studied more frequently due to better data availability, academic interest,

[1] While this paper identifies the drivers of gentrification, it is important to note that the bibliometric review used the search terms "Causes AND of AND Gentrification" instead of " Drivers of Gentrification" because it yileded better results. In this study, the terms drivers and causes of gentrification are used interchangeably and hold the same meaning.

urbanisation patterns, and socio-economic development trends. Following further screening, 1,023 documents were excluded for not meeting eligibility criteria, leaving 49 documents for final analysis.

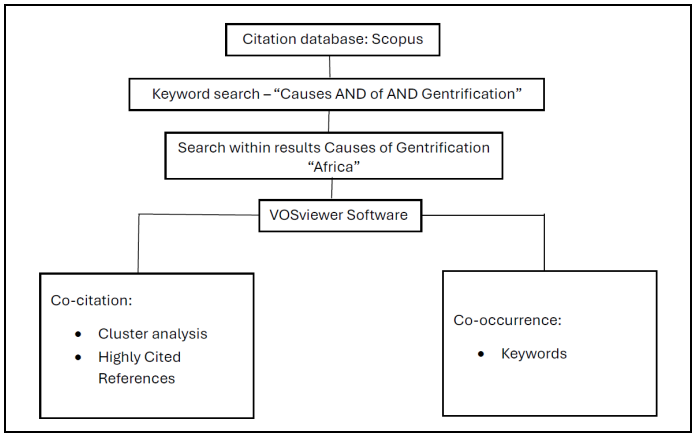

Fig. 1: Bibliometric review used for this study.

The retrieved data were saved and exported as a CSV file in Excel, illustrating publication trends and citation patterns over time. For further analysis and visualisation, the data were converted into plain text format and imported into Vosviewer, a tool that enabled an in-depth exploration of the dataset. Vosviewer was used to map citation networks and author collaborations, helping to identify dominant themes and emerging trends in the literature (see Fig. 1). This systematic bibliometric approach provided valuable insights into the development of gentrification studies in Africa within the broader global academic discourse.

3.2 PRISMA Framework for Systematic review

To ensure rigor and transparancy, this study followed the PRISMA protocol, consisting of a 27-item checklist and a four-phase flow diagram (see Fig. 2), which offered a systematic framework for accurately selecting the sample database and critically assessing systematic reviews (Maier et al., 2020). The PRISMA methodology was applied to identify, screen, and assess relevant studies on the causes of gentrification in Africa. The initial Scopus search using the keywords "Causes AND of AND Gentrification" and "Africa" yielded 5,853 documents. After removing duplicates, 5,843 records were screened based on titles, abstracts, and keywords. Studies that did not align with the research objectives were excluded, refining the dataset to 5,817 documents. Notably, no prior bibliometric studies specifically examining gentrification in Africa were identified.

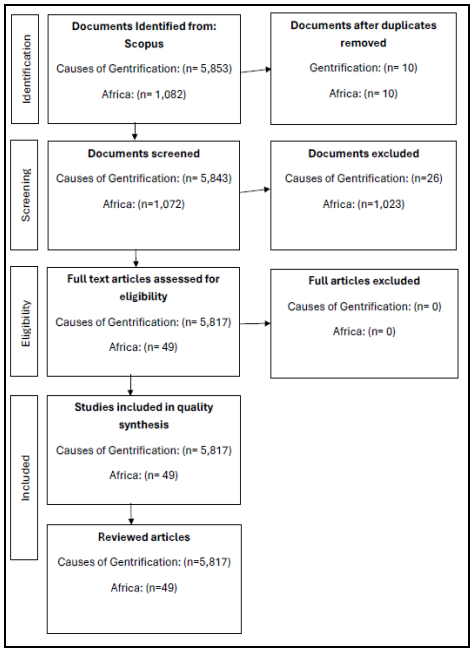

Fig. 2: The PRISMA flow diagram used to identify, screen and include papers for the bibliometric review.

A final eligibility assessment was conducted to ensure that selected studies directly addressed gentrification in African cities. After applying strict inclusion and exclusion criteria, 49 documents were retained for the systematic review. The PRISMA approach ensured that only the most relevant, high-quality studies were included, contributing to a structured synthesis of existing knowledge on the drivers of gentrification. This methodology provides a solid foundation for further research and policy discussions on the impact of urban transformation processes in Africa.

4 RESULTS AND DISCUSSION

4.1 Distribution of Gentrification Drivers Research in Africa

Fig. 3 illustrates the annual publication and citations on gentrification drivers in Africa from 2011 to 2025. The first significant work in this area, by Cumming in 2011, explored spatial resilience and how factors such as location and connectivity influence the resilience of complex systems, using diverse case studies to highlight the importance of spatial variation in addressing ecological and social issues (Cumming, 2011). Between 2011 and 2015, publications were minimal, with only three recorded, and citations peaked in 2011 (206 citations) but dropped sharply afterward. This suggests limited engagement with the topic, reflecting the underexplored nature of gentrification drivers in Africa during this period, aligning with Loretta Lees' 2011 call to broaden gentrification studies beyond the Global North's perspectives (Lees, 2012, cited in Ah Goo, 2018).

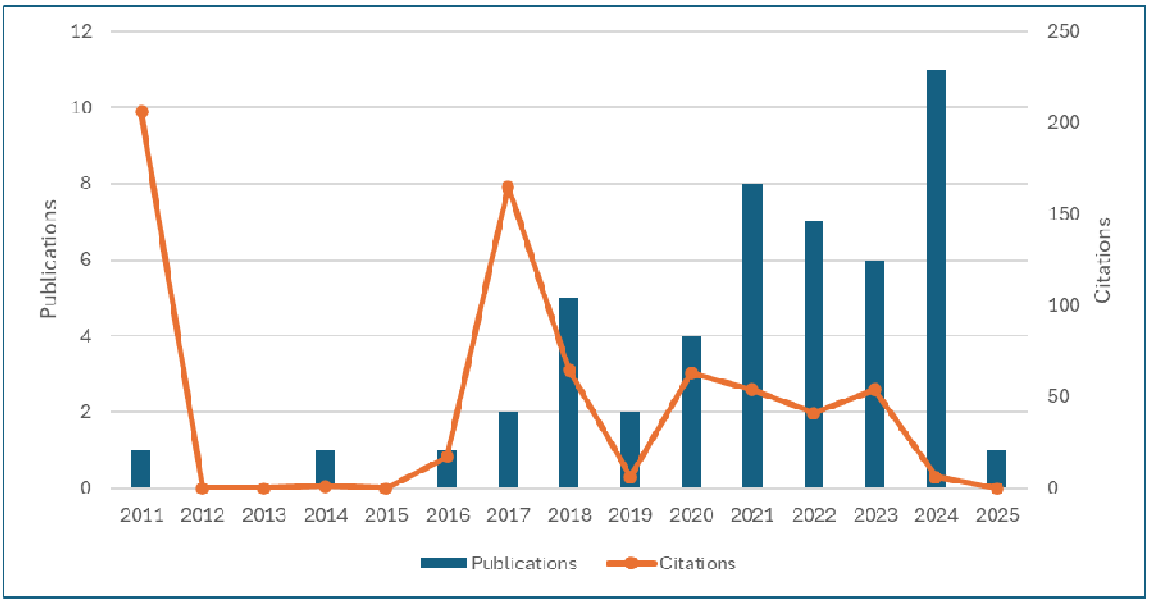

Fig. 3: The annual number of publications and citations on drivers of Gentrification in Africa from 2011 to 2025.

Between 2016 and 2021, there was a significant increase in both publications and citations, with a peak of eight publications in 2021. This growth was likely driven by increasing scholarly interest in urbanisation and socio-spatial transformations in African cities, linked to rising urbanisation and economic development on the continent (Lees et al., 2008). Gentrification in the Global South became associated with industrialization, modernization, and suburbanization (Lees, 2014). From 2022 to 2025, publication numbers fluctuated, with a decrease in 2023 (six publications) followed by a sharp increase in 2024 (11 publications). However, 2025 saw only one publication, possibly due to incomplete data or declining interest, while citations decreased significantly after 2021, possibly reflecting the academic lifecycle and factors such as funding, shifting academic priorities, and evolving research methodologies.

4.2 Keyword co-occurrence analysis

We conducted a co-occurrence analysis of author keywords related to studies on gentrification drivers in Africa, using bibliographic data from 49 publications indexed in the Scopus database (see Fig. 4). Four distinct thematic clusters emerged, represented by red, green, blue, and yellow. Each cluster highlights key themes, offering insights into urban transformation and gentrification in the region. The red cluster is characterized by keywords such as adaptive management, climate change, environmental justice, equality

and equity. The green cluster, closely linked to the red, focuses on democracy, development, displacement, gentrification and metropolitan transformation. Empirical studies illustrate how these themes have played out in African cities. In Johannesburg's inner city, Ah Goo (2018) examines how post-apartheid migration patterns contributed to urban overcrowding, rising crime, and the out-migration of the white middle class. In response government-led regenerative initiatives, such as City Improvement Districts (CIDs) and the Johannesburg Development Agency (JDA), sought to revitalize the area through property-led urban renewal. However, programs like the Better Buildings Programme (BBP), which aimed to restore deteriorated structures, often resulted in the displacement of low-income residents. Similarly, in Kumasi, Ghana, urban transformation displaced low-income residents to the city's outskirts. Rather than being restored or repurposed, traditional buildings were demolished, erasing architectural heritage and reshaping the social fabric (Khambule et al., 2023). Sutton (2020, p.89) describes gentrification as a visible expression of economic inequality, where rising costs – whether for housing or everyday goods – push out marginalised communities, deepening social exclusion and limiting access to essential urban spaces. Environmental justice concerns also interact with gentrification. Reckien et al. (2017) argue that anti-sprawl policies, while aimed at controlling urban expansion, often exacerbate housing affordability issues, displacing low-income populations in a process known as environmental gentrification. These dynamics reveal how gentrification in African cities is shaped not only by economic and social factors but also by environmental and governance-related processes.

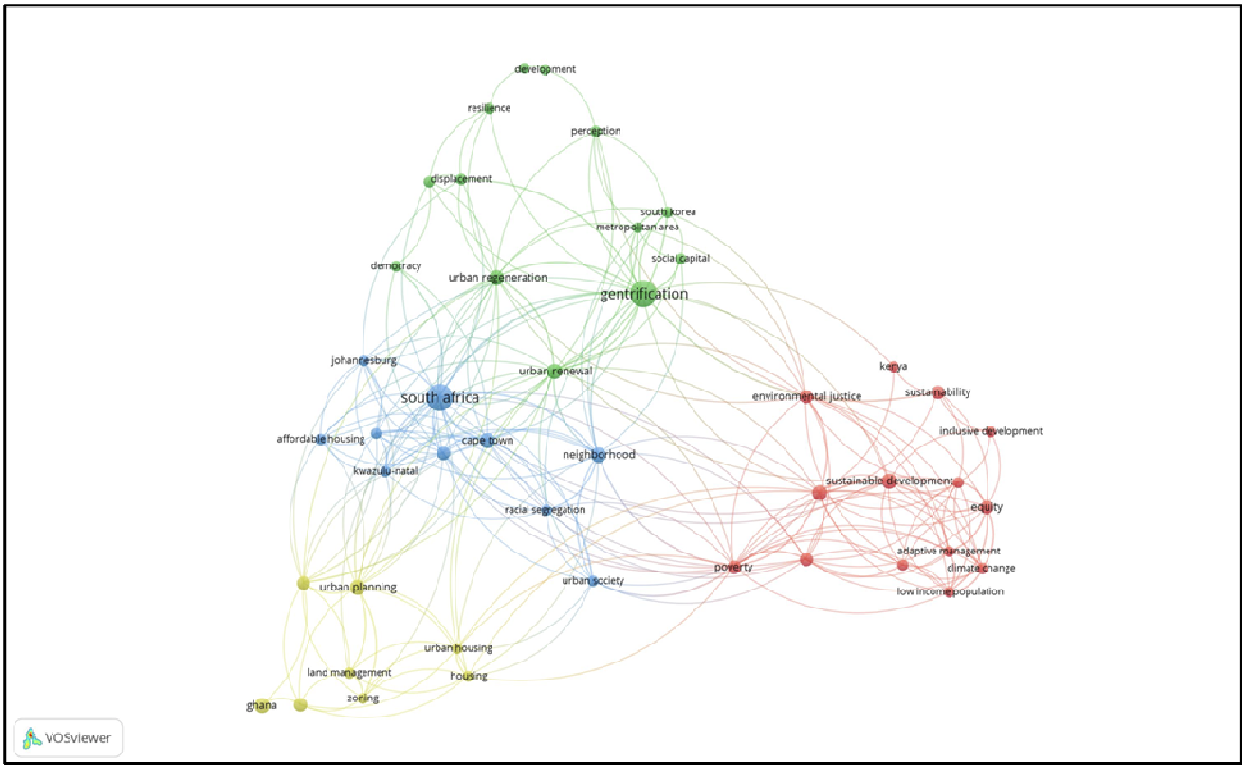

Fig. 4: Co-occuring keywords on drivers of gentrification in Africa on the Scopus.

The third, blue cluster, is primarily centered on the following keywords: affordable housing, Cape Town, Johannesburg, KwaZulu-Natal, and neighbourhood dynamics. Gentrification in Cape Town's Bo-Kaap area has been driven by increasing demand, limited development and escalating property costs, all of which place pressure on long-term residents. Despite efforts by the community to resist large-scale change, grassroots improvements are slowly reshaping the neighbourhood (Michell & Le Roux, 2023). In a similar manner, Neluheni & Boshoff (2022) analyse the transformation of a once-abandoned industrial district into the Maboneng Precinct, a mixed-use area that began its regeneration in 2008. The process was led by private developers, while the middle class played a pivotal role in fostering a 'creative class economy,' which was expected to drive economic growth and urban revitalization. Connected to the blue cluster is the yellow cluster. The yellow cluster's prominent keywords are Ghana, urban planning, zoning, land management and housing – are intrinsically connected. In Appolonia, a rural community in Ghana, the commodification of land in a rapidly urbanizing context has disrupted social ties and access rights, leading to increased economic and social inequalities. Gentrification has intensified dispossession, as urban pressures reshape land use in a

previously rural community, deepening the divide between long-time and newer residents (Ablo & Bertelsen, 2022). Geyer (2024) further examines the impact of government-led initiatives, such as upzoning in two case studies: in Eveline Street, Namibia, the formalization of business rights and municipal support drove investment, transforming residential properties into commercial spaces. Similarly, in the Eastern Cape, public-led industrial development, including industrial estates and the Coega Special Economic Zone, incentives private investment through affordable land, infrastructure, and tax rebates, fostering industrial grow and job creation.

4.3 Co-citation of gentrification research

The scope of drivers of gentrification research in Africa appear through four distinct focal areas. The primary focus, in red, is followed by additional focal points in green, blue, and lime. To ensure accurate classification of each cluster, a detailed review and analysis of the original papers within each group were conducted. The primary cluster (red) includes research subfields focused on spatial planning, urban policy, government regulations, inclusive and equitable development, sustainable urban development and urban tissue. The secondary cluster (green) represents subfields associated with climate change, environment and urbanisation, adaptation and mitigation policies and urban development processes. The blue cluster represents research focused on zoning guidelines, redevelopment plans, urban planning and transformation. Lastly, the lime cluster land conversion, conservation and development, subdivision and biodiversity.

Author	Documents	Citations	Total link strength
Reckien, D	2	195	0
Tyrrell, P	2	6	0
Takyi, S	2	9	0
Ntakana, K	2	2	0

Table. 1: Co-citation of authors

In the analysis of the co-citation of authors (Table 1), we found that certain authors showed no links to one another. This lack of connections suggests that their work is independent, with no clear overlap or intersection in their research topics within the existing literature (Mas-Tur et al., 2021). This could point to a gap in the connection between these fields or indicate the development of distinct, separate areas of research. The authors in each cluster play an important role in shaping the research trajectory of their respective subfields. For example, Reckien, D (195 citations) in the green cluster, Tyrrell, P (with 6 citations) in the lime cluster, Takyi, S (with 9 citations) in the blue cluster and Ntakana, K (with 2 citations) in the red cluster. Tyrrell et al., (2021)examines how land transformation in southern Kenya, driven by high land prices, reduces biodiversity and regional sustainability, while highlighting the challenges of maintaining conservation areas due to land speculation. Ntakana (2024) explores the need for inclusive urban real estate development in South Africa, presenting innovative strategies to promote equity, accessibility, and sustainability in urban environments, based on a study of built environment professionals and statistical analysis. Anaafo et al., (2021)[2] explores how the COVID-19 pandemic has highlighted the link between urban planning and public health, proposing an agenda for transforming urban planning in Ghana to create more just, healthier, and inclusive cities. Reckien et al., (2017) examines how climate change events, such as heatwaves, flooding and landslides, amplify urban inequality, with socioeconomic status and gender as key factors, and offers solutions to address equity concerns in urban climate adaptation and mitigation efforts.

4.4 Institutions publishing on drivers of gentrification

Identifying the most active institutions in a field can provide valuable insights into the origins of influential research, reveal potential biases or gaps in the existing literature, and inform strategic decisions regarding future funding allocations and collaborative partnerships. Table 2 presents the institutions that have contributed the most to gentrification research in Africa between 2011 and 2025. A minimum requirement of two documents per organization was established and out of a total of 137 organisations, four met this threshold. None of the four items in the network were connected to each other (see Table 2), suggesting that the institutions publishing on gentrification drivers in Africa could be working independently rather than collaborating. Institutions could also be focusing on different aspects of gentrification, leading to a lack of overlap in citations and co-authorship networks.

[2] Please note that Takyi, S is a co-author of Anaafo et al. (2021), which is why Takyi, S appears in the co-citation instead of Anaafo et al.

Organisation	Documents	Citations	Total link strength
Chungnam National University, Daejeon, South Korea	2	18	0
Department of Estate Management, Kumasi Technical University, Kumasi, Ghana	2	23	0
Department of Wildland Resources, Utah State University, Logan, Ut, United States	2	6	0
University of Johannesburg, South Africa	2	0	0

Table. 2: Most productive institutions publishing on drivers of gentrification in Africa.

The Department of Estate Management at Kumasi Technical University, Ghana ranks first, having produced two documents with 23 citations. Chungnam National University in Daejeon, South Korea, ranks second, with two documents and 18 citations. The Department of Wildland Resources at Utah State University, United States has published two documents with six citations, while the University of Johannesburg, South Africa produced 2 documents with no citations. The ranking order remains unchanged, as none of the four institutions exhibit any co-authorship network.

4.5 Full text analysis

Gentrification in African cities is influenced by a range of socio-economic, political, and cultural factors that vary across regions. Asante and Helbrecht, (2018) highlight the role of urban redevelopment policies in Ghana, particularly in Accra, where housing renewal projects have been instrumental in driving gentrification. Their study stresses that while these initiatives aim to modernize urban infrastructure, they often result in the displacement of low-income communities, highlighting the tension between development and equity. Similarly, Afolayan (2024) explores gentrification dynamics in Lagos, Nigeria, focusing on the intersection of property market liberalization and urban renewal. The research reveals that the influx of private capital into real estate markets has led to significant spatial transformations, with wealthier populations occupying formerly low-income neighbourhoods. This trend has exacerbated socio-economic inequalities, highlighting the need for regulatory frameworks to balance private interests with social goals. In East Africa, Tyrrell et al. (2021) examine the impacts of infrastructure development on urban transformation in Nairobi. They note that projects such as new highway constructions and commuter rail systems have catalysed gentrification, particularly in neighbourhoods previously occupied by lower-income groups. While these developments improve connectivity and economic opportunities, they often marginalize vulnerable populations who are priced out of upgraded areas.

From a cultural perspective, Tyrrell et al. (2021) analyse the role of heritage preservation in gentrification processes in Mombasa. They observe that efforts to restore and commercialize historical sites have attracted tourism and investment but have also led to the displacement of local communities. This dual impact shows the need for inclusive strategies that integrate cultural preservation with social equity. Across these studies, a recurring theme is the tension between development objectives and social equity. The literature highlights the need for inclusive planning approaches that consider the socio-economic impacts of gentrification on vulnerable communities. Through synthesizing these diverse perspectives, this review provides a comprehensive understanding of the drivers of gentrification in Africa and highlights the importance of equity-focused urban policies.

5 EMERGING TRENDS AND FURTHER RESEARCH

Fig. 5 provides an overview of research findings on the evolving drivers of gentrification, highlighting existing patterns, current dynamics, and emerging trends between 2018 and 2021. The timeline is divided into four distinct clusters, each represented by a different colour: navy blue, turquoise blue, green and yellow. The navy-blue cluster reflects the dominant themes in gentrification research from 2018 to 2019, while the turquoise-blue cluster represents the key themes emerging between 2019 to 2020. The green cluster captures the prevailing themes from 2020 to 2021, and the yellow cluster signifies the research focus from 2021 to 2023. Between 2018 and 2019, research primarily centered on themes such as urbanisation, housing, neighbourhood dynamics, urban population growth, and affordable housing. The period from 2019 to 2020 saw a shift in focus towards studies based in South Africa, particularly in KwaZulu-Natal and the Western Cape, with urban renewal and sustainable development emerging as key concerns. Between 2020 and 2021, research expanded to include Kenya while also addressing themes of gentrification, urban regeneration, and Cape Town.

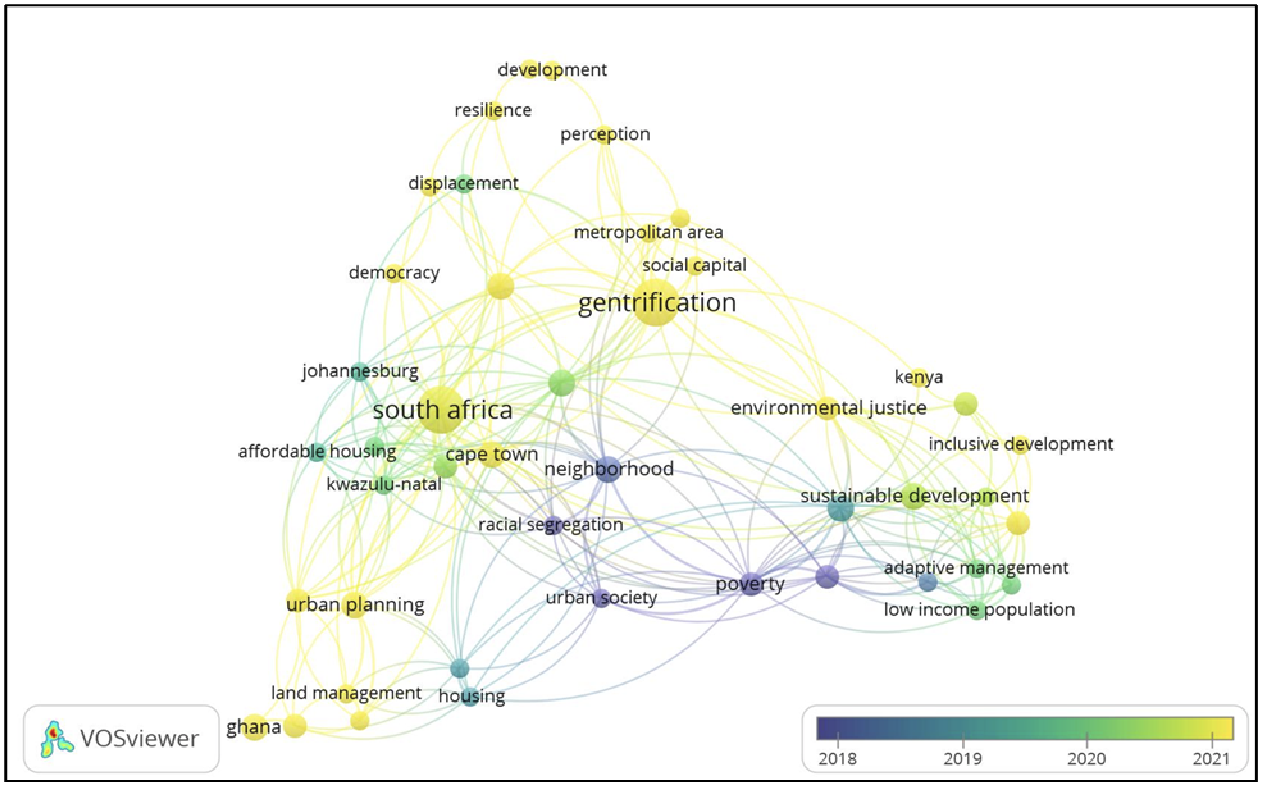

Fig. 5: Emerging trends in research on drivers of gentrification in Africa.

Research on the drivers of gentrification in Africa has expanded beyond traditional urbanisation narratives to focus on localized socio-spatial transformations. Early studies (2018-2019) mainly examined urbanisation, housing affability, and neighborhood dynamics, while later research (2019-2020) emphasized urban renewal, sustainable development, and spatial restructuring particularly in South Africa's KwaZulu-Natal and Western Cape. By 2020-2021, studies extended to Kenya, highlighting the role of urban regeneration and state-led interventions in shaping gentrification. The main emerging trend is the intersection of gentrification with environmental justice and climate change. Policies aimed at controlling urban growth, such as anti-sprawl measures and green infrastructure projects, have contributed to "environmental gentrification," displacing marginalised communities in the name of sustainability (Reckien et al., 2017). Governance and state policies also play an important role in shaping urban development, as seen in Ghana and Namibia, where land commodification and municipal development programs have reinforced economic inequalities (Geyer, 2024; Kambule et al., 2023; Ablo & Bertelsen, 2022). Privatization and the influence of the private sector have also emerged as significant drivers of gentrification. Johannesburg's Maboneng precinct illustrates how development driven by developers and the increase of "creative economy" have transformed urban spaces, while Cape Town's Bo-Kaap reflects the pressures of tourism-driven demand on long-standing communities (Neluheni & Boshoff, 2022; Michell & Le Roux, 2023). These cases highlight the increasing role of market forces in reshaping African cities.

While gentrification has been widely studied in the Global North, there is limited research on how it unfolds in the Global South (Ah Goo, 2018). Notwithstanding these insights, there are gaps in understanding drivers of gentrification across different regions in Africa, where unique socio-political and economic forces shape urban transformation. The findings from this study, based on research in the Scopus database, indicate that much of the existing literature focuses on South Africa, Ghana, Kenya, Zimbabwe, and Namibia, with limited studies on other rapidly urbanizing areas. Comparative studies across diverse urban contexts could offer a broader perspective on drivers of gentrification and processes. Additionally, more attention is needed on how gentrification intersects with informal settlements and rural-to-urban migration. Future research should prioritize longitudinal studies that track long-term socio-economic and spatial impacts of gentrification, as well as community-centered approaches that foreground the experiences of affected populations. The role of digital technologies and "smart city" initiatives in driving urban transformation is also an emerging area that requires further exploration. As the study of drivers of gentrification in Africa continues to evolve, it must adopt a more holistic, multi-scalar, and socially conscious approach, ensuring

that urban change is understood not just as economic restructuring but as a deeply social and political process with lasting implications for urban communities.

6 CONCLUSION

Gentrification in Africa is a multifaceted process shaped by economic, political, and socio-cultural forces that intersect in complex ways. This study has revealed that while global cpaital flows, state-led urban policies, and middle-class aspirations drive urban transformation, these forces often operate in tension with social equity and inclusion. The displacement of marginalised communities, the commodification of cultural heritage, and the expansion of private-sector-led development are persistent themes across African cities, highlighting the uneven consequences of urban change (Frenzel et al., 2022; Ntakana et al., 2023). Moreover, the findings underscore the fragmented nature of gentrification research on the continent, with limited comparitive studies and a predominant focus on a few countries such as South Africa, Ghana, and Kenya. This lack of regional diversity in scholarship limits our ability to generalise findings and calls for a more expansive approach to studing gentrification beyond major urban centers.

Addressing the challenges posed by gentrification requires governance frameworks that are responsive to the socio-spatial dynamics of African cities. The study highlights the need for policies that balance urban development with social justice, ensuring that revitalisation efforts do not come at the cost of displacement and exclusion (Breetzke et al., 2018). Inclusive urban planning, participatory decision-making, and equitable housing strategies must be at the core of future interventions. Furthermore, as gentrification increasingly intersects with environmental sustainability initiatives, critical attention is needed to ensure that “green” urban policies do not disproportionatrly disadvantage low-income populations (Reckien et al., 2017). By synthesizing existing literature, this study not only advances theoretical discussions on gentrification in Africa but also provides a foundation for future research that is context-sensitive, comparative, and policy-oriented. Ultimately, fostering socially just urban transformation requires rethinking gentrification as not merely an economic phenomenon but as a deeply political and contested process with lasting implications for urban communities.

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Urban Planning and the Politics of Spatial Integration in South Africa: the Fleurhof Mixed-Income Housing Experiences

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1 ABSTRACT

How can mixed-income housing developments contribute to spatial integration, in societies with protracted histories of racialise planning and related socioeconomic and spatial injustices? This is the question that this paper endeavours to grapple with. While a plethora of housing-related legislation and strategies have punted "spatial integration", "spatial harmonisation" and "inclusive planning" as being central to the reconstitution of South Africa's socio-spatial milieu; the spectres of colonial/apartheid planning have proved to be difficult to exorcise. Using the Fleurhof mixed-income development as a case study; the paper asserts that there is a huge disconnect between the legislative and strategic planning vision on one hand and the realities on the ground. Put differently, South Africa's planning effort remains fundamentally informed by the 'politics of radical difference', i.e. differences in race, class, religion, nationality, and other related markers that are used every day to justify spatial fragmentation. Thus, in fleshing out the counters of these politics of every day that define planning; the case study research design was adopted, and a qualitative approach was employed to gain in-depth insights into the lived experiences of residents, the socio-economic dynamics within the development, and the broader governance and policy challenges influencing spatial integration in Fleurhof. Data was collected through a combination of qualitative research methods, including interviews, participant observation, and document analysis. The results show that the development of Fleurhof mixed-income housing has been largely influenced by political dynamics, which have in the main, frustrated the legislative vision of spatial integration. Residents' experiences within Fleurhof reflect a complex interplay of social interactions, economic disparities, and institutional dynamics in planning. Furthermore, research reveals that effective community engagement and participatory decision-making processes are crucial for ensuring the success and sustainability of mixed-income housing initiatives. In conclusion, there is a need for a comprehensive approach to development planning that prioritises spatial, and social justice, particularly in cities characterised by deep inequalities.

Keywords: mixed-income housing, spatial integration, urban planning, Fleurhof, Johannesburg

2 INTRODUCTION

The legacy of apartheid urban planning in South Africa remains deeply embedded in the country's spatial structure, despite 30 years of democracy and progressive policy intervention. Apartheid-era planning was deliberately designed to segregate communities along racial and economic lines (Strauss, 2019; Kibido, 2022; Marutlulle, 2022), creating urban environments that continue to reflect stark inequalities in access to housing, infrastructure, and economic opportunities (Schensul and Heller, 2011; Hänel, 2019; Sanderson, 2024). To address these historical injustices, post-apartheid South Africa has made efforts to make spatial integration the centre of its urban agenda; however, despite a profusion of housing-related strategies advocating for spatial harmonisation, integration and inclusivity, colonial and apartheid planning traces run very deep within the country's spatial landscape (Berrisford, 2011). Mixed-income housing developments have emerged as a possible strategy for achieving spatial integration by means of socioeconomic integration within the community (Lukhele, 2014; Geyer Jr, 2024). In its ideal sense, mixed-income housing endeavours to demolish the conventional barriers of separation by enabling citizens of diverse economic strata the chance to live together in an open urban arena. Whether such housing effectively causes integration or not remains contentious. Structural inequalities, socio-political tensions, and class-based divisions continue to seep into the lived experiences of residents of such developments. Secondly, the disparity between policy

rhetoric and real-world implementation raises important questions about the effectiveness of mixed-income housing as a tool of urban transformation.

In this paper, an in-depth analysis of structural inequalities, socio-political tensions, class-based divisions, and the gap between policy rhetoric and real-world implementation was conducted using Fleurhof mixed-income housing development. Fleurhof was selected as a case study as it is one of the newly integrated housing development projects that the City of Johannesburg has commissioned as a strategy to address these inequalities that the city continuously faces even in post-apartheid South Africa (Baloyi, 2020). Fleurhof is located in the southwest of Johannesburg, between Soweto and Florida within the City of Johannesburg's Region C. It was introduced as an inclusive mixed housing development that will offer housing to individuals of different income levels (Hofer et al., 2021). Yet this paper uncovers that this development has been shaped by the political and economic imperatives as much as by its spatial planning agenda. The residents' experience in Fleurhof shows the interconnected dynamics of governance, social interaction, and economic stratification that work to undermine the very ends of integration that the project seeks to enhance. This paper used a qualitative case study approach to assess the huge disconnect between the legislative and strategic planning vision and the realities on the ground. It argues that whilst mixed-income housing has been used to contribute to spatial transformation in other areas, in South Africa, the enduring "politics of radical difference" that is marred by race, class, and other social divides continues to shape urban development in ways that perpetuate exclusion rather than combat it. Ultimately, this paper argues that successful spatial integration in South Africa will require more than just policy rhetoric. It will require the government and planners alike to reconsider the planning practices based on community participation, equitable governance, and long-term investment in social infrastructure. Drawing from Fleurhof's experiences this paper aims to contribute to debates on the use of mixed housing developments as a strategy to achieve spatial justice through integration in divided societies like South Africa. The paper starts by looking at the theoretical context which supports spatial justice and integration efforts, setting the stage for the introduction of Fleurhof mixed-income development as the study area. It then delves into the research methodology, outlining the approaches used to gather and analyse data, before concluding with a discussion of the study's key findings.

3 THEORETICAL FRAMEWORK FOR SPATIAL INTEGRATION

South Africa's spatial integration efforts can easily be explained by urban planning theories and legislative frameworks that aim at addressing the country's spatial historical injustices. The country's urban landscape is still dominated by decades of racially motivated spatial engineering that continues to segregate people along racial and socio-economic lines (Spinks, 2001; Hamann, 2015; Lowton, 2021; Monama, Mokoele and Mokgotho, 2022). After the country gained its democracy in 1994, there has been an intensive implementation of policies and legislation that aims to restructure cities and promote equitable access to resources and opportunities (Maharaj and Ramballi, 1998; Turok and Parnell, 2009; Phosho et al., 2021). However, even with all of these efforts, the reality on the ground shows a disconnect in the policies and legislation implemented and practice as evidenced by the continued marginalisation of the urban poor and the economic divide that still characterises many South African cities. This section looks into the key theoretical framework that supports the spatial integration efforts by examining how these mixed housing developments are situated within the frameworks as strategies to address the historical injustices, whilst some limitations and contradictions emerge in practice. The paper looked at the theoretical perspective on spatial justice and spatial integration, and mixed-income housing as a tool for integration to provide a foundation for understanding the complexities of spatial transformation.

Spatial justice, as articulated by scholars such as Peter Marcuse and Edward Soja, underscores the inseparability of spatial and social injustices (Marcuse, 2009; Soja, 2013). Soja notes that spatial justice concerns 'greater control over how the spaces in which we live are socially produced' (Soja, 2010). He further states that spatial justice 'seeks to promote more progressive and participatory forms of democratic politics and social activism, and to provide new ideas about how to mobilise and maintain cohesive collations and regional confederations of grassroots social activist'. In South Africa, the National Development Plan 2030 emphasises spatial justice as one of its overarching principles for spatial development and states that 'all spatial development should conform to the principle and should explicitly indicate how they will meet the requirements of this principle' (Republic of South Africa, 2012). While the

inclusion of spatial justice as a development principle is appreciated and supported by many people, it has raised questions as to what exactly spatial justice means for South Africa, what this is intended to achieve, and what the requirements would be to achieve it. The concept of spatial justice in South Africa is not merely about redistributive equity but also about transforming the spatial structures that sustain systemic injustices.

To understand spatial integration, one must first understand the concept of segregation, which has historically shaped urban landscapes, particularly in societies with deep-rooted racial and economic inequalities like South Africa. Segregation can be defined as a reflection of social causes (e.g. prejudice, discrimination, a sense of superiority) with physical manifestations (i.e. denial of access to space, spatial concentration) and social consequences (e.g. social dislocations) (Ruiz-Tagle, 2013). Spatial integration is a result of efforts by governments/states to dismantle the spatial divisions that segregation creates. In the context of this study, spatial integration refers to the process of creating urban environments where people from different socioeconomic, racial, and cultural backgrounds can live in close proximity, share public spaces, and access equal opportunities. It is about breaking down the physical and social obstacles that separated people in South Africa's past, predominantly those generated by apartheid planning which insisted on segregation along racial lines (Murray, Shepherd and Hall, 2007). This is an important component of the democratic government's efforts to mitigate the long-term effect of apartheid spatial planning. This study argues that while mixed-income communities like Fleurhof can make spatial integration possible, the actualisation of this potential depends on bridging deeper socio-economic divisions and actualizing the gains from integration for all the residents.

4 STUDY AREA

Fleurhof is a privately owned housing scheme that was developed in partnership with the City of Johannesburg municipality for integrated residential properties. It is located on the Southwest of Johannesburg's Region C in between the township of Soweto and the suburb of Florida as shown in the figure below. It is one of the largest mixed-income housing developments in Johannesburg. The development is situated in the centre of one of the CoJ's main urban concentration zones. The development's construction got underway in 2011. With 10 411 residential units spread across 4.4 km2, it can accommodate an estimated 83,000 people (Calgro M3, 2014). The development is a mixed-income human settlement development that includes various housing typologies and tenures, which are targeted at specific economic markets that comprise fully subsidised BNG housing, social housing, open-market rental housing, and open-market bonded housing (Khan, 2014: 16). The project started in 2011 with the fully subsidised BNG housing as the first phase, and the other types of housing happening after two years. Hence, the project was known for some time as a subsidised BNG housing development.

Fig. 1: Fleurhof Locality (Source: Google Maps)

5 METHODOLOGY

This study employed a case study research design using a qualitative research approach to explore the extent to which mixed-income housing developments contribute to spatial integration in post-apartheid South Africa. The Fleurhof mixed-income housing development was selected as the primary case study due to its strategic role in Johannesburg's spatial transformation agenda. Data was collected through semi-structured interviews, direct observations, and document analysis, allowing for a comprehensive examination of the interplay between policy, planning practices, and lived experiences within the development. A total of thirty interviews were conducted with municipal planning officials, residents of Fleurhof and developers. In addition to interviews, direct observations were conducted to assess physical integration, infrastructure provision, and social interactions in communal spaces. Particular attention was paid to the design and use of public spaces, patterns of mobility, and the spatial distribution of amenities to understand the development's effectiveness in fostering integration. Furthermore, document analysis was undertaken through a desktop review of key policy documents, spatial planning frameworks, municipal reports, and housing legislation. Documents such as Breaking New Ground (BNG), the Integrated Urban Development Framework (IUDF), and local spatial development plans were analysed to contextualize the Fleurhof development within broader urban planning and spatial justice discourses. Thematic text analysis was applied to qualitative data from interviews and policy documents to identify recurring patterns related to spatial justice, governance, and socio-economic dynamics within mixed-income developments.

6 FINDINGS AND DISCUSSIONS

This section of the paper presents two critical aspects that the paper aims to uncover in the Fleurhof mixed-housing development: the lived experiences of residents and the disconnect between policy intentions and on-the-ground realities. The first part explores social and economic interactions between members of different income groups, whether or not the development has been successful in promoting social cohesion, or whether underlying racial, economic, and cultural divisions continue to shape daily life. From the point of view of the residents, the study mapped both good practices regarding integration and the long-standing barriers which inhibit social mixing within the community. Then the second part focuses on planning and governance themes, looking at the disjuncture between the spatial integration policy goals and the consequent implementation challenges faced in Fleurhof. It explored how political requirements, institutional constraints, and administrative inefficiencies influenced consequences, normally missing the mark on creating the ideal integrated community. Through the analysis of these interrelated issues, this section attempted to answer the question "How can mixed-income housing developments contribute to spatial integration, in societies with protracted histories of racialise planning and related socioeconomic and spatial injustices "?

6.1 Resident Experiences: Social and Economic Interactions

The findings reveal that there are many social and economic benefits of mixed-income housing: economic desegregation; access to improved infrastructure and services; better calibre of housing; a safe community and an increase in local amenities; poverty alleviation; low and medium-income earners gain access to functional social networks and good role models (high-income earners) for better behaviour and lifestyle changes; everyone benefits by being exposed to a variety of people and lifestyles and by developing an appreciation for their differences (Levy et al., 2013; Gina, 2022). The findings from Fleurhof reveal a complex dynamic interplay of social relations among residents from different income groups, with alternating phases of integration and profound division.

The results show there is more social cohesion between the communities that live in Fleurhof. Bernard (1999) described the social cohesion concept as a "quasi-concept, that is, one of those hybrid mental constructions that politics proposes to us more and more often to simultaneously detect possible consensuses on a reading of reality, and to forge them". Madonsela (2017) describes it as the cornerstone of social relationships, which depend critically on the social systems that determine people's behaviour. Taking into account the two definitions of social cohesion, it is clear that mixed-income housing developments like Fleurhof play a crucial role in fostering integration by creating shared spaces and economic interdependencies that bring diverse groups together. As a key driver of social cohesion, shared public spaces between residents of varying economic means, such as parks, community centres, and shopping areas, have

allowed for informal social interactions across class lines to occur (Mehan, 2024). These areas have fostered a sense of belonging and collective identity within the community. These spaces are neutral spaces where residents of different socioeconomic backgrounds interact with each other through the course of their daily lives, generating spontaneous contact that might otherwise not be made in a classically segregated urban setting. The provision of these neutral spaces in this development has created spaces for informal conversation and economic exchange, thus helping break down social barriers and foster an inclusive neighbourhood climate.

Fleurhof has also fostered economic inclusion and upward mobility by providing lower-income residents with access to enhanced infrastructure, employment, and public services. For low-income residents, the proximity to middle-class families has a tendency to attract higher-quality amenities, improved transportation networks, and additional private-sector investment in the community (Rosenthal and Ross, 2015). This is a phenomenon referred to at times as the "neighbourhood effect", which suggests that mixed-income neighbourhoods have the potential for positive spillover effects, where the presence of middle-income households creates demands for improved service and infrastructure (Settersten Jr, 2001). The result in Fleurhof is that the low-income group in the area are exposed to improved schools, health facilities, and commercial centres which would otherwise be lacking in predominantly low-income areas.

There is also a noticeable increased access to public transportation. This is mainly because the middle-income commuters' presence has led to increased investment in effective transportation systems and thus the low-income citizens' also get easier access to working areas in the rest of the city's districts. Such improved connectivity is playing a prominent role in preventing the poverty trap through the reduced cost of commuting and closer proximity to work centres. In addition to infrastructural benefits, private investment in this neighbourhood has brought economic growth and employment opportunities. During the construction of Fleurhof, many people in the surrounding neighbourhoods got employed, and even though the employment was short-term, many jobs were created. After the completion of the project, some businesses opened shops in the area because of the new diverse customer base. These businesses end up employing the residents which plays a crucial role in intermixing the middle- and low-income population which in turn results in economic networking, whereby informal referrals for employment and business alliances arise out of daily interactions.

Despite the intention of creating spatial integration, Fleurhof continues to experience profound social and economic challenges that deter the full development of an integrative society (Hofer et al., 2021; Gina, 2022). The most evident problem remains racial homogeneity in development, as whites continue to be rare in the area. While Fleurhof has been designed as a mixed-income, integrated community, the lack of racial diversity suggests that time-honoured traditions of segregation continue to shape housing choices. White families, particularly middle- and better-off families, are reluctant to move into the neighbourhood due to long-standing attitudes regarding safety, property value, and social homogeneity. This shortage also highlights broader patterns of racialized settlement and delimits the extent to which Fleurhof is possible as an instance of real integration along class lines.

Affordability is also an essential issue raised by some of the residents, particularly for low-income residents who struggle to bear the economic costs of maintaining a secure home in the area. While the development has subsidized types of housing, dwelling in Fleurhof is quite costly for most low-income households. Essentials such as electricity, water, and transport have proved to be a burden, especially for those working in informal or irregular conditions. Furthermore, the disparities in income levels between different groups within the community are creating social tensions since lower-income residents may be kept out of certain areas or economic opportunities that middle-class households can more readily access. The affordability issue is whether Fleurhof will remain a true mixed-income community in the future or whether fiscal pressures will push out the most vulnerable residents in the long run.

The higher cost of living in the country has also put at risk the sustainability of social and economic diversity in Fleurhof. While inflation, rates on property, as well as service fees, increase, poorer families are finding it more challenging to stay in their homes, potentially leading to displacement. This is particularly concerning given that mixed-income housing is meant to provide for long-term stability among poorer residents while providing for social integration. Unless economic burdens are reduced, Fleurhof can experience a type of "economic filtering" such that only residents who can bear rising expenses stick around, ultimately

undermining the developmental purpose for which it was originally planned. In the absence of certain affordability tactics such as subsidies, rent capping, or legislation protecting low-income households from displacement by cost, Fleurhof may reflect the same kind of inequality that it was originally designed to relieve. These ongoing problems highlight the challenges of achieving true spatial and social integration in South Africa's urban space. While the development has managed to bring together inhabitants from different income levels, structural differences still exist, dictating who can afford to live there and who cannot. For Fleurhof to be a continued inclusive, integrated community, policies must address affordability but also systematically encourage added racial and economic diversity. Without these, the vision of mixed-income housing as a vehicle for spatial justice can be maintained as an ideal, but not a reality that will endure.

Overall, while challenges remain, the findings suggest that social cohesion is emerging in Fleurhof through shared spaces, economic interdependencies, and collective community initiatives. These aspects demonstrate that mixed-income developments have the potential to foster meaningful integration, provided that opportunities for organic interaction and mutual engagement are actively nurtured. Fleurhof's experience highlights that, despite historical divisions, everyday encounters and shared interests can contribute to the gradual development of a socially cohesive community.

6.2 Planning and Governance Issues: Disjuncture Between Policy and Reality

The Fleurhof mixed-income housing project was designed as a spatial integration model, in accordance with national policies like the National Development Plan 2030 (NDP), Breaking New Ground (BNG) Strategy, and Spatial Planning and Land Use Management Act (SPLUMA). All these policies demand inclusive, integrated human settlements that break from apartheid-era spatial imbalances (Adebayo, 2021). However, what is on the ground still represents a broad gap between policy intentions and realization. While Fleurhof has achieved some level of class integration, the absence of any white residents reflects the limits of racial integration in the sense that deeper societal and economic forces continue to shape residential patterns in cities. Another noticeable key planning failure is the lack of provision of effective public transport links between Fleurhof and major centres of employment. Most of the residents, particularly the low-income group, still heavily rely on informal transport services such as minibus taxis, which are unreliable and expensive (Hoferet al., 2021. Poorly coordinated, affordable public transport works to reinforce economic segregation by limiting access to job opportunities, thereby inhibiting lower-income residents from the full benefit of living in a mixed-income community.

A critical factor shaping Fleurhof's development is the overwhelming dominance of private developers whose interests do not necessarily represent the government's broader spatial justice agenda. While private investment has accelerated construction and the delivery of infrastructure, it has also created affordability problems. The majority of the housing units, including those labelled "affordable," remain unaffordable to lower-income families, consolidating the risk of displacement. The balance between government priorities such as the delivery of long-term affordability and spatial justice and private sector interests in profitable development is an unresolved issue that affects the realization of Fleurhof's integration goals. Perhaps the greatest problem in the long-term viability of Fleurhof is a lack of meaningful measures of accountability guaranteeing that developers and government departments adhere to promises of spatial integration. Regulations and policies are set in place for the sake of inclusive urban development, but these are not being enforced effectively. As an example, middle-income housing is generally preferred by developers because of wider profit margins and promises of having enough low-income housing may fall short at times. Inadequate stringent control means that the most vulnerable are being excluded from the benefits of mixed-income living.

The rigidity of existing policies, which cannot keep up with emerging socio-economic challenges, is another challenge. While policies such as SPLUMA and BNG advance spatial justice, they do not normally account for rising living expenses, gentrification pressures, and economic shifts affecting affordability. Some of the poorer residents risk being priced out due to increasing property values and rising living costs in a mixed-income complex. Failing to implement adaptive policies to mitigate such problems threatens the long-term viability of Fleurhof as a mixed neighbourhood.

The Fleurhof case shows once again the stubborn challenge of moving spatial integration policy from paper to practice. Even as Fleurhof's development is a good step towards removing entrenched spatial inequalities, governance weaknesses and tensions between public and private interests erode the initiative. These will

have to be surmounted through more effective accountability frameworks, responsive policy, and insistence on ensuring that mixed-income housing developments benefit all residents, particularly those who have long been disadvantaged.

7 CONCLUSION

The Fleurhof mixed-income housing development is both a promise and a challenge of spatial integration in post-apartheid South Africa. While some social cohesion through shared public facilities, schools, and economic interactions has been fostered in the development, deep-seated divisions limit full integration. Affordability, public transport shortcomings and bureaucracy inefficiencies have served to undermine its success. Private sectoral interest dominance and poorly established accountability institutions also threaten future sustainability. This study highlights that genuine spatial integration is more than a mixed-income housing development, it requires inclusive governance, sensitive policies, and forward-looking action to close socioeconomic gaps. In the absence of these interventions, spatial justice will remain an unattainable ideal and not an achievable phenomenon in South African cities.

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reviewed paper

Urban Sprawl in Riyadh: Assessing the Impacts of Horizontal Expansion on Sustainability and Quality of Life

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1 ABSTRACT

Riyadh City's urban expansion has led to car dependency, traffic congestion, and social fragmentation. This study proposesan increase of density, and areconfiguration of the city's urban fabric through the integration of high-rise developments along the main streets and central areas, modifying urban sections and proposing finer urban fabric. This attempt, guided by New Urbanism principles,aims to produce walkable, mixed-use, and transit-oriented communities. The paper specifiesstrategies to limit urban sprawl by adoptingsustainable development, zoning and urban formtransformations, and by encouraging walkable areas coupled with quality architecture and urban design. Recommendations are proposed to curb urban sprawl and promotesustainable urban development in Riyadh,primarily through higher densities via vertical growth, and effective connectivityby reforming urban morphology.

Keywords: sustainability, population, cities, planning, urban sprawl

2 INTRODUCTION

2.1 Urban sprawl

Urban sprawl describes a low-density, sporadic, and leapfrogging urban development pattern across the cityscape, consuming rural or peripheral areas. This type of growth is characterized by low population density, scattered growth, single-use zoning, and large areas of undeveloped land. This sprawl is rapid and typically accompanied by an increased reliance on private automobiles for transportation (Polidoro et al., 2012).

Urban sprawl, also characterized by the separation of land uses and poor street connectivity, causes longer travel times and higher gas consumption. This is often linked with traffic congestion, given that the development is more dispersed and of low density. Sprawl consumes land, causing the destruction of natural habitats and agricultural land and placing a burden on water resources in an already arid region. Negative consequences of sprawl include the fragmentation of communities into relatively unconnected areas with limited social cohesion and unequal access to services and facilities. Aggravated by the hot summer, longer distances make walking and cycling difficult. Urban sprawl has also resulted in the failure of small businesses because there is no customer base within neighbourhoods to support them, while at the same time there is insufficient pedestrian traffic to make car dependency unnecessary. (Abdelfattah &Nasreldin, 2019; Ewing, 2002; Ewing & Hamidi, 2015).

2.2 Urban Sprawl and Riyad City

Riyadh City has been evolving since the construction of Al-Murabba Palace, which led to its expansion beyond its walls in the 1930s, to the modern architecture in Al-Malaz area from the 1950s, to the super grid structure of Doxiadis' master plan in the late 1960s, and to the oil boom that saw the city expand rapidly beyond the Doxiadis plan in the 1970s.In recent years, the city has embraced ideas of subcenters and transit-oriented strategies. Today, Riyadh City demonstrates both the positives and the negatives of rapid urbanization in the 21st century (Alhathloul& Mughal, 2004). Nonetheless, Riyadh City is suffering from the effects of the very rapid and uncontrolled urban growth, which has caused many problems in the social, economic, and environmental domains.

2.3 Study Goal and Significance

This research seeks to investigate the problem of urban sprawl in the city of Riyadh by reviewing relevant literature about the city to verify if the problem exists, to understand its influence on the quality of life, and

to outline previously proposed solutions for the issue. The importance of analyzing this phenomenon is critical, as outlined in numerous research works.

Socially, sprawl has resulted in fragmented communities, reduced social interactions among residents, and long commute times, which have impacted people's overall well-being and led to uneven access to public services and facilities. Economically, sprawl has created significant financial challenges because of the extensive expansion of infrastructure, which increases personal transportation costs for residents, in addition to the inefficient land use that contributes to economic inequalities. Environmentally, sprawl has led to the loss of habitats and agricultural land, to increased vehicle use that has elevated air pollution levels, and placed a burden a burden on water resources in an already arid region (Alkhayyal, 2017; Sarkar, 2016a).

In terms of health, urban sprawl, a car-dependent development, has numerous adverse effects. These effects include increased air pollution and respiratory issues, higher rates of motor vehicle crashes and pedestrian injuries, reduced physical activity leading to obesity and other diseases, threatened water quality and quantity, and creating urban heat islands. Sprawl also impacts mental health and social capital, contributing to stress and social isolation (Frumkin, 2002).

3 LITERATURE REVIEW

Urban planners frequently cite a range of population densities of 10,000–15,000 people/km² to ensure compact development and to limit the expansion into agricultural areas. They advocate for supporting walkable neighbourhoods, public transit, and mixed-use development, reducing car dependency, lowering greenhouse gas emissions and energy consumption, preserving green spaces, reducing habitat fragmentation, and encouraging vibrant communities with good access to amenities, jobs, and services (Litman, 2016; Nadeem et al., 2021).

In 2008, a study investigated the rate of growth and changes in land use in Riyadh's urban area between 1972 and 2005, and found that the growth rate had slowed, and gaps within the city had been filled, indicating a shift towards sustainable urban development (Aina et al., 2008). However, subsequent studies on sprawl presented rather different results. The latter studies claimed that the city is expanding more and more toward its edges and that there is a need for appropriate planning frameworks to moderate the sprawl development.

A study examined land use and land cover changes in Riyadh City between 1990 and 2009 and reported that the city had expanded outward outwards to the periphery, having increased by 90% (Sarkar, 2016b). A later study observed a decrease in the rate of sprawl. This study assessed the expansion and land cover changes in Riyadh City and reported that urbanization has expanded by 37% between the years 2000 and 2013 but also noted that there still is a need to promote sustainable urban development (Atif & Mahboob, 2017).A study on the air quality of Riyadh City indicated that the air in Riyadh City does not meet the international environmental standards and that emission reduction should be considered in the future strategies to enhance air quality and public health (Modaihsh et al., 2016)

In another research study conducted by Alsheheri et al., the link between temperature, vegetation, and urban development areas was explored. The study revealed that there is an inverse relationship between temperature and vegetation levels while there is a correlation between temperature and urban built-up areas (Alshehri et al., 2023), suggesting less horizontal urban development. Using LANDSAT imagery from 1987 to 2017 for the city of Riyadh, a study by Altuwaijri et al. predicted urban growth for 2047 and reported an expected expansion of the urban area of Riyadh City to increase by nearly38% (Altuwaijri et al., 2019).

The sprawl of Riyadh City is evident, being rapid and uncontrolled outward growth. This development pattern has substantially transformed the Saudi capital's landscape; the city has undergone huge horizontal expansion, with new neighbourhoods and developments stretching far beyond the original urban core. This expansive development has resulted in a less population density, in greater reliance on cars, and in the consumption of previously undeveloped land on the city's periphery. The phenomenon has profound implications for Riyadh's infrastructure, environmental sustainability, and overall urban planning strategies.

Riyadh's layout is a product of Doxiadis' master plan, which has a grid system of 2x2 kilometres defining neighbourhoods of 4 km², flanked by main arterial roads and freeways. Figure 1 shows Riyadh City's future plan, and figure 2 depicts four internal collectors subdivide each neighbourhood into four sections.

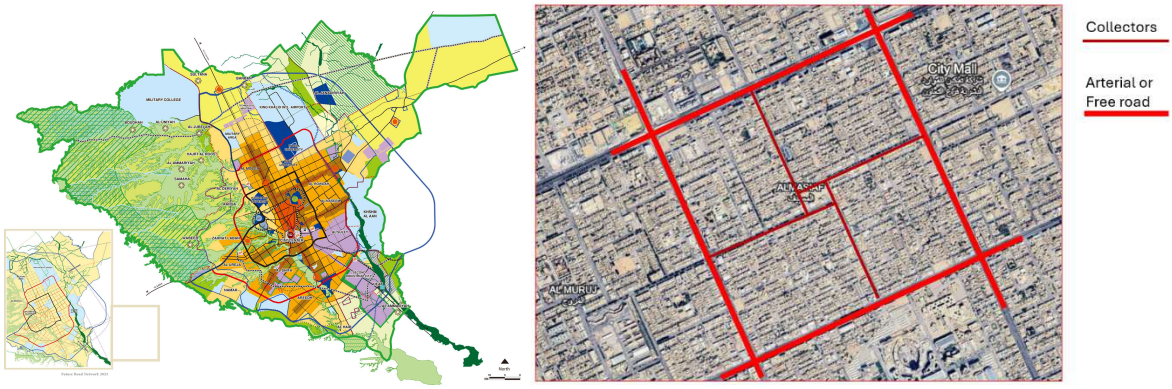

Figure 1, Riyadh Plan. Source: ADA, 2013: p. 4. Figure 2, Neighbourhood plan. Source: Google Earth.

With this street hierarchy, connectivity is limited to arterials, which cause congestion at the arterial and freeway intersections. Each of the 1-km collectors has U-turns only at their ends, resulting in more driving time even within the neighbourhood itself. At lower road hierarchy levels, urban blocks were analyzed and were found to have fine urban fabric. Local streets are found to be scaled in a good way relative to the heights of buildings, resulting in good urban enclosures.

4 THEORETICAL FRAMEWORK

4.1 Key Concepts

The key concepts are: first, sprawl, characterized by low density, scattered growth, single-use zoning, car dependency, and encroachment on agricultural and natural land. Second, sustainable urban development aimed at creating liveable, efficient, and environmentally friendly cities. It encompasses compact high-density development, mixed-use zoning, transit-oriented design, walkable communities, and curbing urban horizontal expansion, as shown in figure 3.

Figure 3: Urban sprawl as a problem and sustainable urban development

4.2 Theoretical Foundation

Smart Growth Theory and New Urbanism Theory are selected to work as the theoretical foundation for an effective urban development model to reduce urban sprawl in the city of Riyadh. Smart Growth is an urban planning approach aimed at creating compact, transit-oriented, and walkable communities which reduce travel distances and promote sustainable living. It promotes mixed land use, diverse housing options, and the preservation of open spaces, intending to enhance the quality of life, reduce urban sprawl, and protect the environment. Smart Growth is reported to deal with challenges like congestion, pollution, and the demand for housing and infrastructure. Previous literature upheld that well-designed communities could lead to more

sustainable and equitable living environments, emphasizing the importance of resident involvement in shaping urban growth (Daniels, 2001; Shrivastava & Sharma, 2012).

New Urbanism Theory offers a robust and rational alternative to conventional development, fostering community with good urban design measures (Ellis, 2002). However, the implementation of New Urbanism Theory has faced challenges such as regulatory barriers, market preferences, affordability concerns, and the failure to fully realize its ideas (Grant, 2015), figure 4.

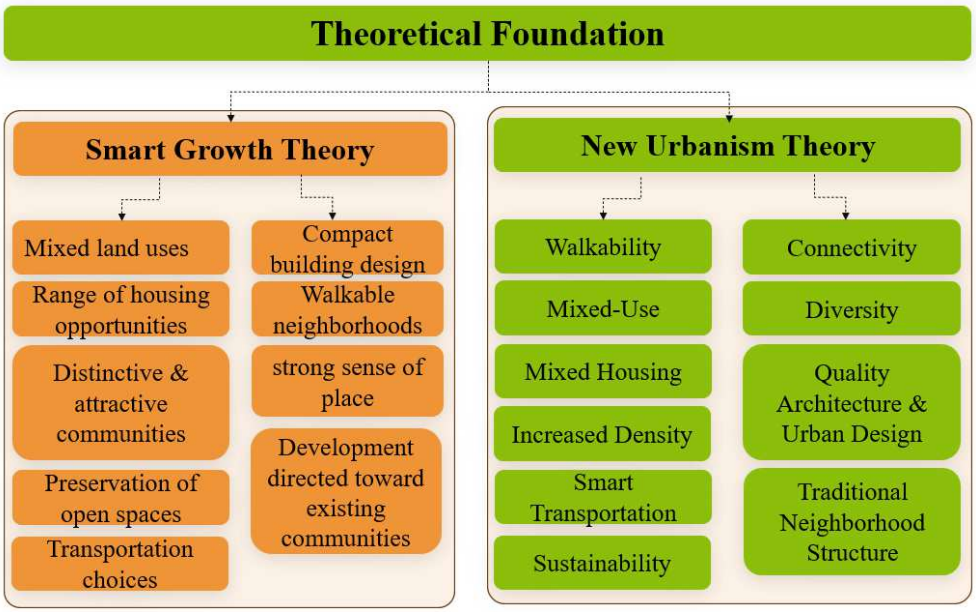

Figure 4. Theoretical foundation: Smart Growth Theory and New Urbanism Theory

4.3 The model

From the two theories, a total of 14 measures were identified and classified into three groups: morphological, social, and life quality. Morphologically, finer street patterns and smaller urban blocks are recommended to enhance connectivity. This entails promoting even traditional urban layout with minimum street hierarchy. This will also support the notion of going back to traditional neighbourhood design. Mixed land use is recommended to encourage walking and reduce car trips. Mixed housing is recommended as well, consequently, different social groups can interact, and affordable smaller houses can be offered across the city. Compact urban fabric and increased population density will result in higher demand, within walking distances, on small local businesses, because small businesses generally would go out of business due to fewer clients in low-density neighbourhoods.

Socially, the sense of place is the emotional and psychological connection people have with a particular location, often influenced by its unique characteristics, history, and cultural significance, fostering identity, belonging, and meaningful experiences for inhabitants and visitors (Carmona et al., 2003). Diversity is a global concept that promotes allowing everyone to use public places equally regardless of their different backgrounds. Different sizes and prices of housing units will allow for affordable houses for all and an opportunity to mix all categories of the community together, having easy access to their needs. Additionally, transportation choice is a critical factor in creating good quality of life; considering designing for multi-modal transportation including private cars, public transit, cycling, and walking, will create vibrant urban spaces with better and healthier choices. Existing communities can be enriched with urban design and planning measures to bring about sustainability and better quality of life. The quality of life, sustainability, walkability, high quality of architecture and urban design, and preservation of public spaces are positive urban policies and design measures that can be applied to the city of Riyadh; its existing urban context and its future developments, figure 5.

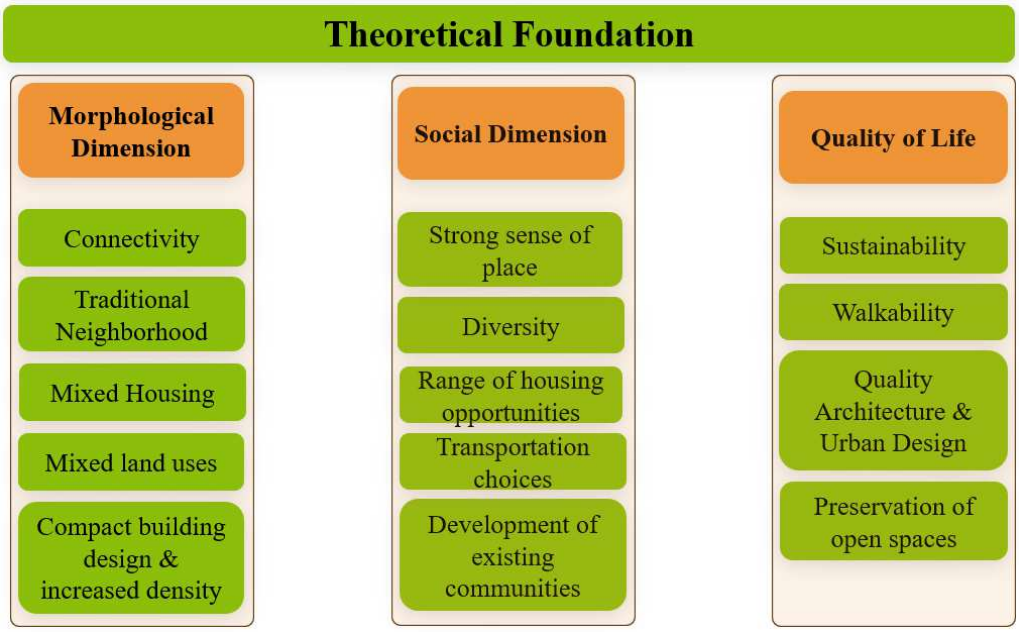

Figure 5. Theoretical foundation: derived model

5 RESEARCH METHODOLOGY

The methodology is arranged in sequential stages in a qualitative attempt to suggest avenues of exploration and guide analysis of the urban sprawl phenomenon in Riyadh. The study begins with a review of the literature related to urban sprawl generally, and its specific manifestation in Riyadh City particularly. The review was structured to first verify the phenomenon's presence in the city. Consequently, the study delved into exploring the dimensions and perspectives of the urban sprawl phenomenon from various points of view in a general manner (Garvey & Jones, 2021).

Next, the study was oriented towards the phenomenon of urban sprawl in Riyadh City and the various consequences of the phenomenon on the quality of life in the city. Then two urban planning and design models were explored: Smart Growth Theory and New Urbanism Theory. Both models' measures were identified. The study then went into the discussion section where the applications of these measures were visualized as possible solutions to the problem of urban sprawl in the city. The research concluded by outlining potential solutions and then suggesting recommendations for policy makers, urban planners and designers.

6 DISCUSSION OF POTENTIAL SOLUTIONS

An increase in density is needed.This research suggests increased density by allowing buildings taller than 30 floorsalong arterial and freeways, supported by car parking podiums, and stepping down to 5 floors toward the center of the neighborhoods, figure 6.

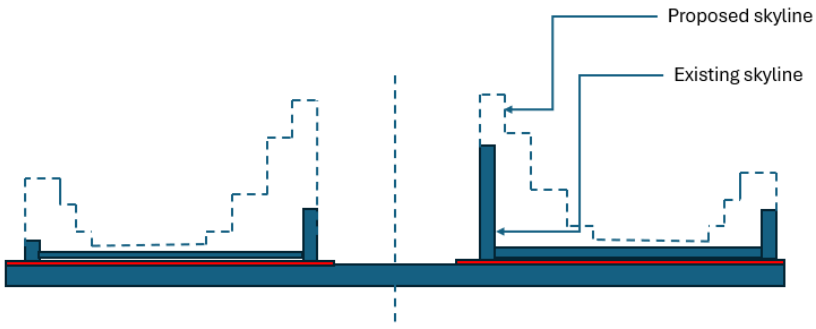

Figure 6: proposed increased density for a typical arterial road in Riyad; graded urban sect.

Improved connectivity and finer urban fabric are needed. Doubling the arterial roads in both directions of the grid can reduce the urban unit to a quarter of its size, reduce the hierarchy of streets, and operate the underutilized collectors as arterial roads. Underground walkable roads can join the one-kilometer sections together. This change is major, and extensive future research is needed to explore its details, figure 7.

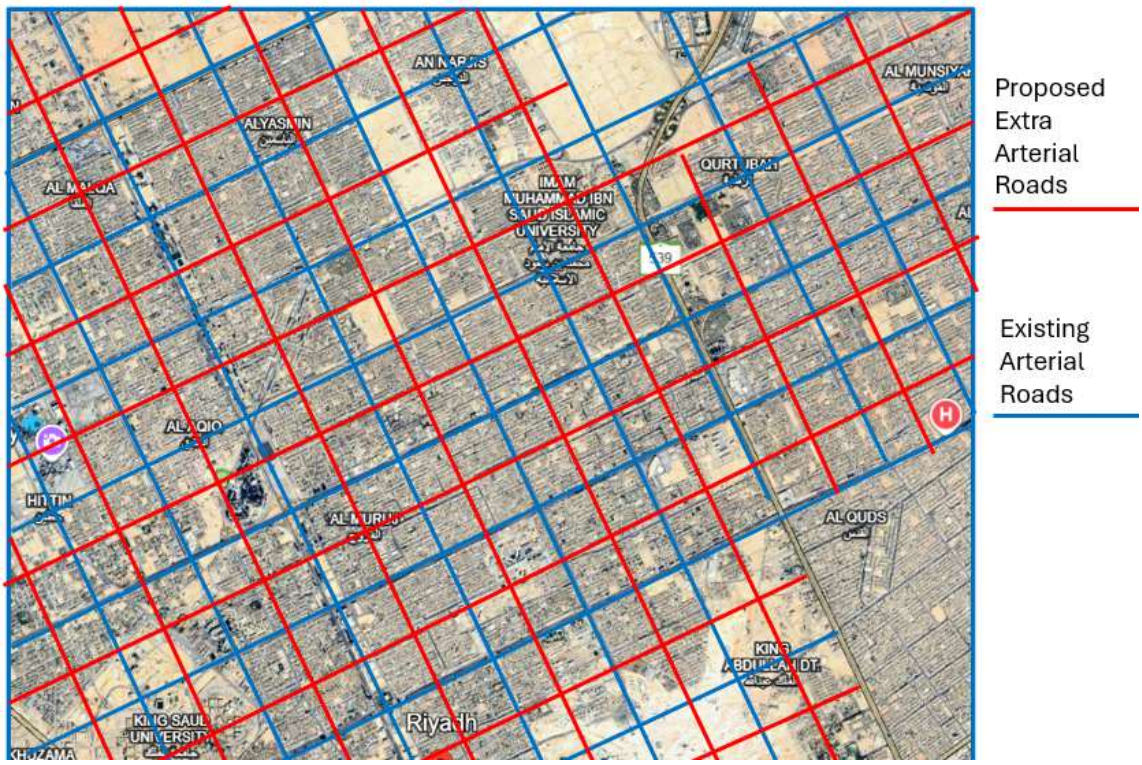

Figure 7: proposed extra arterial roads resulting in finer urban fabric, less congestion and more connectivity. Map source, Google Earth.

Although the urban fabric inside neighborhoods is relatively fine, introducing more local streets to create a smaller grid system is advised as shown in figure 8.

Figure 8: proposed extra roads resulting in finer urban fabric and more connectivity. Map source, Google Earth.

Regarding morphology, the traditional neighbourhood layout, promoted by the New Urbanism Theory, is already applied in Riyadh city plan to a reasonable extent. Nevertheless, there is a need to revise the school distribution in the city, to bring the locations of schools within 500-700 m walking distance. Moreover, and especially in further urban extensions, smaller urban block is suggested to enhance urban connectivity. For mixing land uses, the existing regulation allows for local commercial at the collectors. Based on the

recommendations above, collectors will be arterials, commercial activities should be zoned as mixed with residential. Additionally, there is a need for mixed housing; this can be achieved through new regulations and incentives to encourage and direct developers to diversify the sizes and prices of housing units. Moreover, regarding compact building design, Riyadh City is compact horizontally and can become denser only through allowing more building heights.

The key generators for the sense of place can be focusing on buildings symbolizing the Kingdom history and their surrounding public spaces which can be designed to convey sensorial values and inspire attachment to the country and people's identity. The one square kilometre section can be redesigned for transit and bicycle lanes in addition to pedestrian walkways. This experience can be enriched by cafes and restaurants flanking a multi-modal avenue. Successful existing communities, especially those with good urban spaces and street layouts, can be preserved, and modified for enhancement. With the kingdom's plan to plant one billion trees across the country, Riyadh City has a better chance to mitigate dust storms, hot summers and dry weather. Integrating the trees into green urban corridors will surely enhance the city's quality of life.

7 CONCLUSION

Smaller-scale urban patterns, high level of connectivity, multimodal transportation, mixed use, measures for enhanced architecture and urban design, good street furniture design, diverse types and sizes of housing, shorter car trips, and higher population densities will enhance sustainable development of Riyadh, neighbourhoods' walkability, and quality of life. By reconfiguring urban morphology to promote compact, connected, and sustainable neighbourhoods, Riyadh City can address the challenges posed by urban sprawl, such as traffic congestion, air pollution, and social disconnectedness. The proposed strategies, including increased density, improved connectivity, and mixed-use developments, aim to create a more liveable and environmentally friendly urban environment.

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reviewed paper

Urban Transformation Agenda in South Africa: A Spotlight on Designing Theoretically and Evidence-Based Urban Development Strategies

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1 ABSTRACT

Urban transformation in South Africa presents both significant challenges and opportunities, shaped by the nation's unique historical, social, and economic context. By critically examining current urban policies and practices, this research identifies gaps between theoretical frameworks and practical applications in South Africa's urban planning and governance. It also highlights the need for strategies that not only address the spatial and socio-economic inequalities inherited from the apartheid era but also promote sustainable and inclusive urban growth. Through a comprehensive review of literature, policy analysis, and case studies, the study offers insights into how urban transformation can be more effectively managed in South Africa. It emphasizes the importance of integrating empirical evidence with robust theoretical models to develop strategies that are both contextually relevant and practically implementable. The findings aim to inform policymakers, urban planners, and stakeholders on how to create resilient, equitable, and sustainable urban environments that respond to the complex realities of South African cities

Keywords: Urban Transformation, Agenda, South Africa, SDGs, Urban development

2 INTRODUCTION

Global initiatives such as the New Urban Agenda (UN-Habitat 2016a) and the 2030 United Nations Sustainable Development Goals (SDGs) acknowledge the crucial role of urban transformation in promoting sustainability and resilience in cities (Hölscher and Frantzeskaki, 2021). Approximately 56% of the world's populationcurrently reside in cities and the number is estimated to double by 2050 (World Bank Group, 2025), unequivocally demonstrating the urgent need for action. Thus urban transformation is and has frequently been promoted as a solution to the numerous issues that metropolitan areas face (Crane et al. 2021; Williams, 2021) The significance of urban transformation requires a comprehensive understanding of its meaning. Ostensibly, urban transformation can be defined as a process of significant change to a city's or an urban area's physical, social, economic, and environmental landscape (Apostolopoulou, 2021;Işık, M. E. and Erdem, N. 2024). Urban transformation also increases competitiveness, innovation and development in cities resulting in improved quality of life for urban dwellers (Sarkisyanand Varlamova, 2024). Using the Ibero-American Exposition of 1929 and the Universal Seville Exposition of 1992 as case studies, Simó et al. (2024)reported that urban transformation in these case studies had a major impact on their city's development and the incorporation of former exposition sites into contemporary urban life. Additionally, in one study Alves and Pereira da Silva, (2024) evaluate the implications of urban transformations within the municipalities of Cuiabá and Várzea Grande from 2006 to 2021, findings reveal a positive impact on infrastructure improvement, rising standard of living, and creation of green spaces. Similarly, urban transformation promotes a sense of belonging and improves community engagement through the development of recreational areas (Morano et al. 2023; Alves and Pereira da Silva, 2024).

However, critics contend that urban transformation reinforces the apartheid legacy experienced in African cities. Çetin et al. , (2025) highlight a different picture of Turkey's urban transformation, which led to uneven distribution of population densities. These areas in Turkey lackadequate access to services and facilities as a result of urban transformation projects. Furthermore, Kazmi et al. (2025) point out that one of the aftermaths of urban transformation is uncontrollable development which changes the urban landscape and identity. Thus they need to evaluate the theoretical frameworks and practical applicationsof urban transformation in cities.

3 RESEARCH METHODOLOGY

A systematic literature review conducted in this study adopted the Preferred Reporting Items for Systematic Review and MetaAnalysis (PRISMA) protocols (Figure 1). PRISMA involves the quantitative approach to analyze the literature offering clarity, transparency, quality, and limiting bias (Sohrabi et al. 2020; O'Dea et al. 2021). Data collection was conducted through various databases mainly Google Scholar, Web of Science (WoS), and Scopus for a broader and deeper analysis. The search focused on urban transformation dynamics in cities. This was followed by inclusion and exclusion criteria; Only publications within the scope of the study were included for the analysis and review. The exclusion criteria involved discarding all publications that do not use the English language.

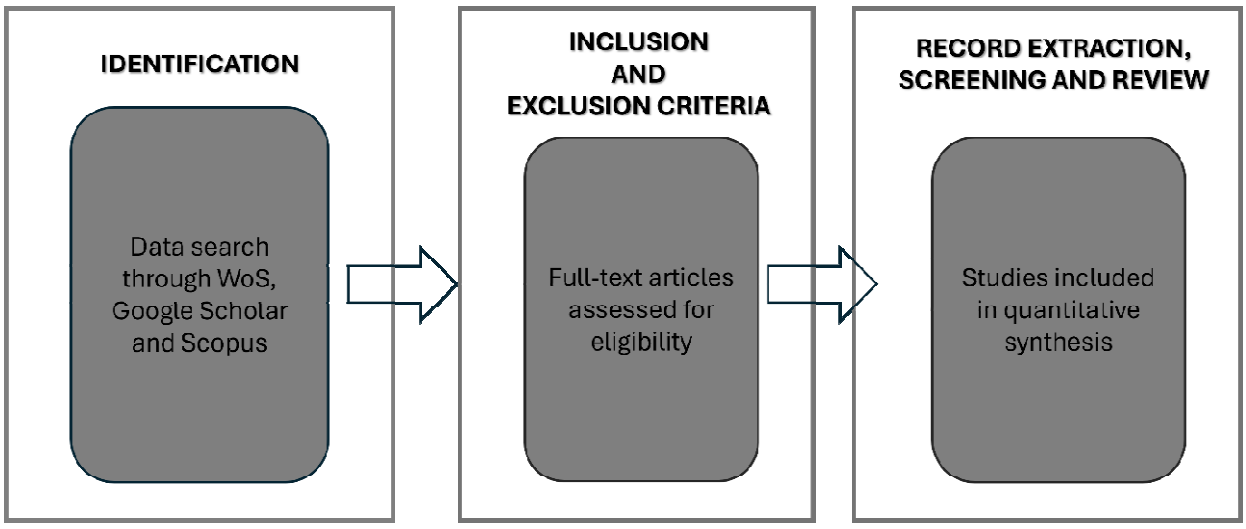

Figure 1: Systematic literature review approach

The last stage involved record extraction, screening and review. This stage involvesthe extraction of key insights from selected studies to identify patterns, challenges, and best practices in urban transformation. Additionally, policy reviews included policy and legislative frameworks, government reports, and strategic plans guiding urban transformation. Data was then analyzedusing thematic analysis and MATLAB. Key themes from the literature and case studies, including technological advancements, social repercussions, and economic factors, were identified through the application of thematic analysis. Urban development policies, infrastructural investments, and socioeconomic consequences in various cities were examined using a comparative perspective. To draw attention to persistent issues and trends, MATLAB was used for visualization. Although MATLAB is often used for numerical computation and algorithm creation, it can also be used for data analysis and visualization. MATLAB (short for Matrix Laboratory) is a programming tool often used across different fields like engineering, physics, economics, and other sciences for its robust toolboxes and integrated functionality for intricate mathematical and statistical calculations (Moler and Little, 2020; Gatzke, 2021).

4 FINDINGS AND DISCUSSIONS

4.1 Publication years and trends

Urban transformation has become much more prominent in the literature around early 2015 (Figure 2). Using various case studies, Mitrasinovic (2015) identified the role of urban transformation and approachesutilized to reinvent the cities, highlighting the need for inclusive and participatory urban planning in the future that extends beyond the physical aspects of the environment. Consequently, there is a noticeable dip in 2017-2019, associated with numerous factors, including the focus shift of research into other approaches tothe city's revitalization. However, In 2019, due to rapid urbanization, there was a surge of interest driven by increasing challenges in cities that require urban transformation due to rapid urbanization. In 2021, there was a marked resurgence in research growth, driven by increasing climate change and a call for an urban transformation to mitigate the challenges (Hölscher and Frantzeskaki, 2021; Henrique and Tschakert, 2021; Grainger-Brown et al. 2022; Cobbinahand Finn, 2023).

An important aspect of urban transformation is to analyze the changing focus and trends in the literature (Figure 2). Understanding the main issues and focal points in the field of urban transformation is greatly aided by the prevalence of particular keywords in the research.

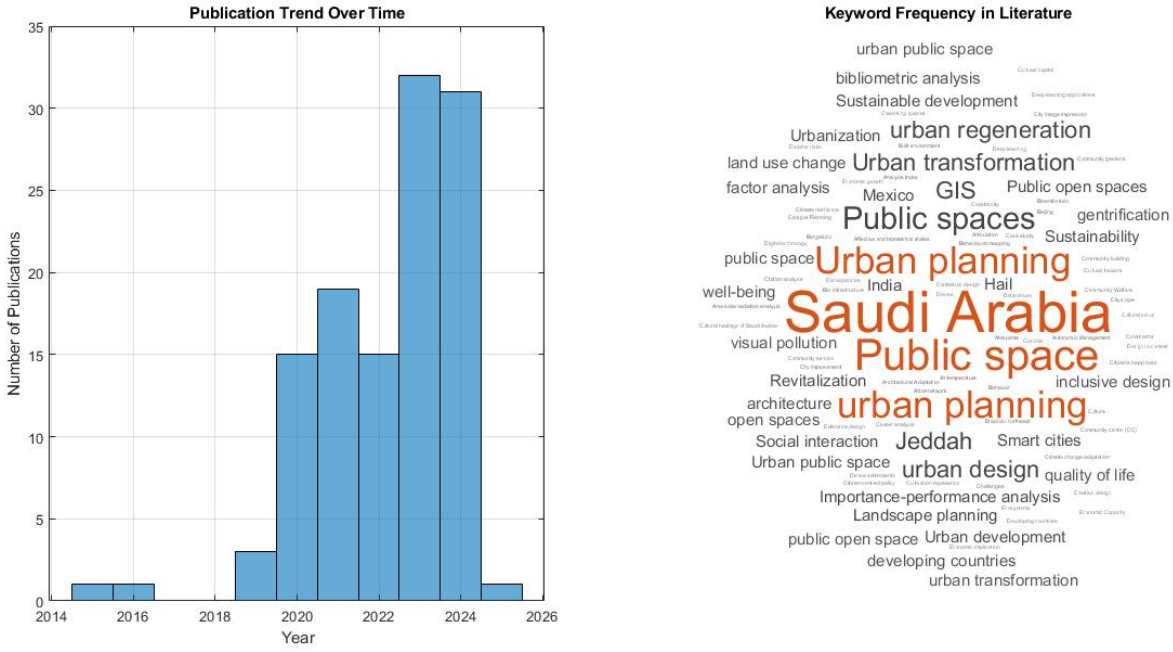

Figure 2: Publication years and trends overtime

In addition, Figure 3 illustrates the research areas that researchers were most interested in at various points in time, thisis determined by looking at the most frequent keywords during this time (Figure 3).

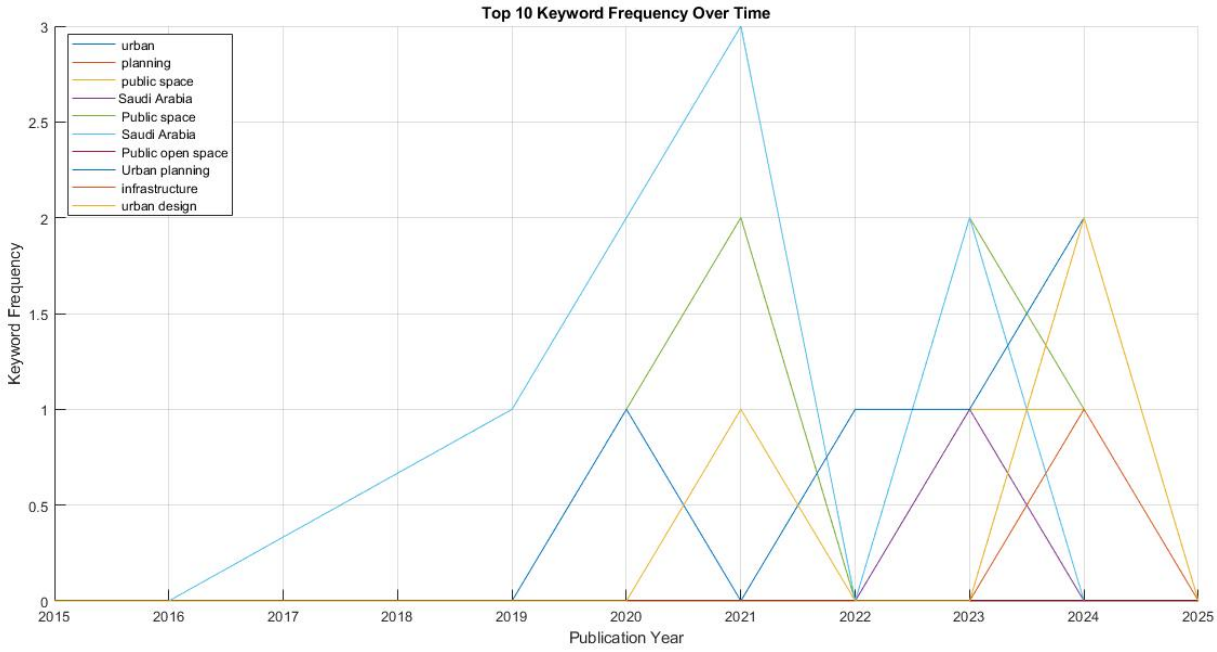

Figure 3: Keywords Frequency over time

The most frequent keywords are; Saudi Arabia, public spaces, urban planning, infrastructure, urban regeneration and urban design. Keywords like urban planning further emphasize the role of urban planning in shaping cities. Urban planning's suitability as a tool to support sustainable development is called into doubt by Saudi Arabia's urbanization pattern. However, the detrimental effects of urbanization on sustainable development are lessened when planning is done at several geographic scales (Addas and Alserayhi, 2020Almulhim and Cobbinah, 2023; Vazquez, 2024). In Mauritius, urban planning proved to be an

inefficient tool in addressing the transportation needs of the public rather than more focused on pushing the economic agenda on transport infrastructure, in contrast to policy improvements that are in line with public requirements (Thondoo, 2020) reflecting African experiences. Equally important are green spaces and public spaces in cities. Using street photos and information from Baidu Maps to direct urban development,Liu (2024) highlights the impact of safety, aesthetics,and green areas and the utilization of data-driven approaches to citizen involvement. The studies state that urban transformation it is not just a process of changing the socioeconomiclandscapes of cities, it is equally important to investigate how the process is implemented and what are strategies employed to address the current challenges.

4.2 Drivers of Urban Transformation in South Africa

The effectiveness of urban transformation in shaping South African cities can be better examined through case studies that highlight its key drivers behind implementation and implications. In South Africa, urban transformation is often propelled by socioeconomic and physical dynamics, apartheid legacy, policy and technological advancements.

JOHANNESBURG'S INNER CITY REVITALIZATION

The city center (CBD) of Johannesburg has changed significantly, especially in the past 20 years (Figure 4). The public and private sectors are working together to transform abandoned buildings into retail establishments, office buildings, and loft apartments.

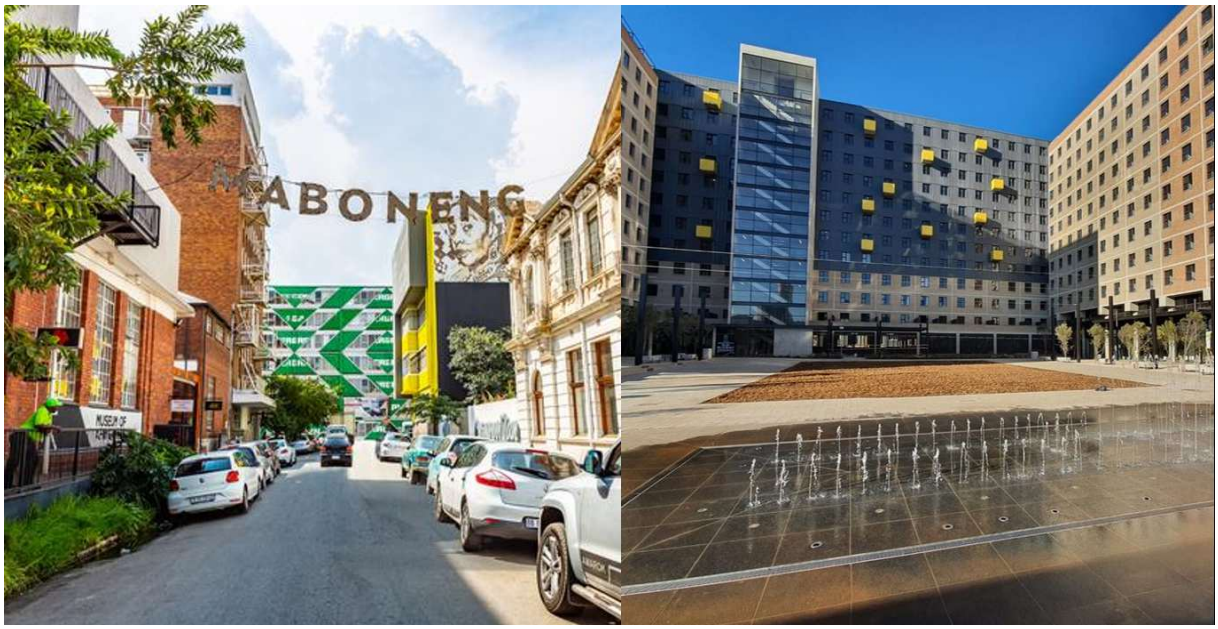

Figure 4: Maboneng, Johannesburg (Solterbeck, 2024)

The construction of important landmarks like the Maboneng Precinct (Figure 4), a bustling neighbourhood full of eateries, art galleries, and creative companies, is another example of revitalization (Parker and Khanyile, 2024). However, Maboneng's building and neighbourhood improvements benefitted the recently arrived "creative class", whereas Jeppestown's supply of cheap dwellings decreased.

CAPE TOWN V&A WATERFRONT

One of the most prominent instances of urban change is the Victoria & Alfred (V&A) Waterfront in Cape Town (Figure 5). It was once an industrial harbor region but has since been transformed. The transformation involves a significant development of mixed-use business and tourism centers featuring retail centers, eateries, lodging facilities, and residential areas (Demhardt, 2023; Sarhan, et al. 2020; Kelly, 2021). This change is a component of a larger movement to revitalize cities to draw in investment and tourists (Swart et al. 2024).

5 THEORETICAL PERSPECTIVES AND REALITIES OF URBAN TRANSFORMATION

Urban transformation in cities can be viewed through different theoretical lenses. Key theories include the modernization theory, developed in scholarly sociology following the 1950s, impacted by several American,

British, and European theorists, such as Ernest Gellner and Talcott Parsons. The theory views urban development as a non-linear process that can be associated with industrialization (Damianos,2022) and following the path of developed countries (Thahaand Galib, 2022). In contrast, theories such as "right to the city" by Lefebvre in 1967 advocate for citizen participation in the urban development and transformation process because the city inherently is a capitalist space, exacerbating social inequalities (Roulier, 2022; Friendly, 2024; Karchagin, 2024). Meanwhile, smart city theory and urbanism drive the integration of data-driven decision-making and technological advancements in city transformation (Krivý, 2016; Verrestand Pfeffer,2019). Although these ideas provide different perspectives, they all concur that urban development is profoundly political and social rather than merely technological.

Figure 5: V&A Waterfront project in Cape Town, South Africa (Business Tech, 2024)

While the case of Maboneng and Cape Town showcasesthe successful implementation of urban transformation, it has also caused low-income residents to be uprooted, which resulted in the loss of their social and economic support systems (Letlape and Gumbo, 2019; Mudzunga, 2022). Consequently, Low-income neighbourhoods are often left out of these advancements, which exacerbates socioeconomic and geographic disparities. Additionally, participatory initiatives such as policy frameworks like South Africa's Breaking New Ground (BNG) housing policy have attempted to address the inequalities, however, Private developers often gain more from revitalization initiatives like Maboneng and Cape Town examples. Though they provide strong frameworks for rethinking cities, urban transformation theories are difficult, contentious, and highly political to implement in practice and policy. Therefore, this advocates for inclusive urban development and sensitive to a variety of lived experiences, whether this is accomplished through smart technologies, rights-based design, locally grounded methods, or modern infrastructure.

6 IMPLICATIONS FOR POLICY AND PRACTICE

The shortcomings of South African urban transformation initiatives highlight the significance of community-focused, sustainable, and inclusive development approaches. Despite the Cape Town and Johannesburg urban transformation initiatives, it has exacerbatedsocial inequalities by creating environments that are not conducive to the urban poor (Marutlulle, 2021). Long-term planning, financial responsibility, and environmental sustainability must be given top priority in future initiatives, and local communities must be actively included in the process. In addition to consultation, this entails true empowerment and ownership in the planning, execution, and oversight of these projects. More successful and equitable urban transitions in

South Africa can result from learning from past failures like the Johannesburg and Cape Town experiences. This should also include tackling some important concerns, such as poor community participation, opaque finance management, and a lack of consideration for environmental impact. Additionally, to guarantee that these initiatives continue to be sensitive to the changing needs of the communities they serve, the urban transformation process needs to be data-driven.

7 CONCLUSION AND FURTHER RESEARCH

A significant gap in the literature surrounding urban transformation in South Africa is the lack of data-driven approaches and concrete guidelines for evaluating and enhancing the effectiveness of these processes. While theoretical frameworks exist, practical, measurable tools and methodologies are needed to assess the impact of interventions, track progress, and inform decision-making. This includes developing robust indicators for social, economic, and environmental outcomes, as well as establishing clear benchmarks for success. Addressing this gap through rigorous research and the development of evidence-based guidelines is critical for ensuring that future urban transformation projects are not only well-intentioned but also demonstrably successful in achieving their stated goals and creating positive, lasting change for communities.

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reviewed paper

Urbanisation and Mixed-Income Residential Development in South African Townships: A Case Study of Olievenhoutbosch

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1 ABSTRACT

The legacy of the poor apartheid planning system still prevails in South African cities, with people of colour mostly being placed on the outskirts of the cities in townships where there is a lack of economic opportunities. Despite the policies that have been implemented in post-Apartheid South Africa to address inequalities and social, environmental, political, and economic challenges, there is still much that needs to be done to achieve a South Africa that is inclusive. Currently, citizens can democratically choose to reside wherever they want, but the ability to afford always determines where one will reside. To promote inclusivity, mixed-income residential development approaches have been applied both locally and internationally to ensure that access to resources and services is shared equally among people of different economic classes. This paper examined the impact of rapid and high levels of urbanisation on mixed-income residential development in South African townships, focusing on the township of Olievenhoutbosch. It also investigated how urbanisation rates have impacted access to and availability of mixed housing. The paper reviewed literature on the impact of urbanisation on the development of mixed communities in the context of South African townships. Data was collected through in-depth interviews with twenty-six residents of Olievenhoutbosch township in Johannesburg. The results highlight inadequate housing units to accommodate everyone thus leading to the invasion of new government-assisted housing projects before their completion and the illegal occupation of land that is not suitable for residential developments mainly attributed to high rates of urbanisation. Thus, to address the housing shortages, homeowners have resulted in building structurally inadequate backyard rooms for rentals to increase accessibility and availability, This study recommends that policymakers and urban planners prioritise the implementation of sustainable mixed-income residential developmental strategies. This will help to address the housing backlog, promote inclusivity, and integrate economically disadvantaged communities into urban centres while ensuring proper planning and infrastructure development.

Keywords: Olievenhoutbosch, Inclusivity, Mixed-income housing, Urbanisation, Planning

2 INTRODUCTION

According to Zhang (2016), despite the positive impact of urbanisation on global economic performances and advancing countries to high-income status, it also has its share of challenges such as housing shortages that need urgent attention, especially in cities of developing countries. Developing countries that are experiencing high urbanisation rates of more than 60% are likely to achieve 50% of the Sustainable Development Goals (SDG) (Chen et al., 2022). This comes in handy for developed countries since they often experience more than 70% of the urbanisation rate, enabling them to combat the repercussions that come with urbanisation. Developing countries are still struggling to achieve SDG 11 where cities and human settlements are inclusive, safe, resilient and sustainable even though the right to adequate housing is considered a basic human right in most countries. Despite the urban strategies that have been employed, most cities, especially in developing countries, still face challenges with integrating migrants into the urban economy (Migration and Its Impact on Cities, 2017).

By the year 2021, South African cities were able to accommodate almost 67.85% of the country's total population (Stats SA, 2023). The majority of the cities in Africa are urbanising at a fast rate but are facing policy challenges in addressing the good management of urbanisation, and failure to do so poses socio-

economic and environmental threads to the communities (Abrahams et al,.2018). Despite Africa being the least urbanised continent, South African cities such as Johannesburg in the Gauteng Province and Cape Town in the Western Cape Province are catching up.

The apartheid policies of the National Party government from 1948 to 1994 have immensely negatively affected urbanisation. The policies intended to create spatial inequalities, separating people due to their skin colour, with people of colour being placed at the periphery of the city centres, far from benefiting from economic opportunities. The restriction of people of colour in certain areas has led to the development of slums and townships on the outskirts of the city, where the cost of living is relatively lower (Bakker et al., 2020). Even though the post-Apartheid policies allowed people of colour to reside wherever they wished, the capability to afford always determines where one will reside. Most of the people of colour are found on the outskirts of the cities in townships and informal settlements, where the cost of living is relatively lower compared to the inner city. This calls for urgent attention, since in a world that is rapidly changing and urbanising, the provision of adequate housing becomes the biggest priority (Khan & Thring, 2003).

The township of Olievenhoutbosch is found in the province of Gauteng which is regarded as the economic hub of South Africa (Chakwizira et al., 2018); hence, it has attracted both international and local migrants. The township faces challenges in achieving a safe mixed-income residential area and adequate housing and shelter for all, despite the effort that has been made by the South African government to provide housing to those in need. The township has been awarded several housing projects that have been completed and aimed at assisting low-income and poor people. The recent low-income housing projects have been illegally occupied by the residents of Olievenhoutbosch and some from Alexandra, Atteridgeville, and Mamelodi, while the buildings were still under construction in 2020. The rightful owners are still residing in informal settlements (Ndlazi, 2021). The fights between the people who have illegally occupied the houses, the rightful owners and the Department of Tshwane Housing make it hard to achieve the integrated housing development that the township aims to achieve. There have also been several evictions of informal houses that were built on private land (Mokhoali, 2022).

3 CONCEPTUAL AND THEORETICAL FRAMEWORK

The incessant demand for urban housing can directly be linked to high urbanisation rates (Akinyemi et al., 2020). Despite the need for housing in cities, competent legislative regulation and good urban planning and design are required to achieve sustainable mixed-income housing communities (European Strategy and Policy Analysis System, 2019). Planning is an evolving process leading to alterations and removals of land use restrictions to accommodate the need for housing and the development of residential communities (Jenkins et al., 2006). Despite all the alterations that have been made to land rights, there is a lack of collaboration that keeps on persisting between the housing developers and the local authorities, with difficulties in obtaining clearance for housing planning authorisation (Yakob et al., 2013).

The mixed-income housing policies and projects that have been implemented are not only aimed at providing shelter to the needy and making housing affordable but also at bringing integration between the people who come from different economic backgrounds to combat the socio-economic challenges that were created by the poor apartheid planning that created segregation (Funde, 2023).

The well-developed mixed-income residential developments include Cosmo City mixed-income housing and the Fleurhof integrated residential. Cosmo City is the first fully integrated, sustainable human settlement to be successful in South Africa. It was founded by the Gauteng Department of Housing and the City of Johannesburg in 1998 but became successful in 2012 (South African Housing and Infrastructure Fund, 2020). Fleurhof is located between the township of Soweto and the suburb of Florida in the south of Johannesburg. It is similar to the Cosmo City mixed-income housing development as it has also incorporated different housing typologies and tenures, such as fully subsidised Breaking New Ground (BNG) housing, social housing, open-market rentals, and bonded housing (Mnisi & Karam, 2020).

Unlike the above two discussed case studies of the development of mixed communities in Cosmo City and Fleurhof, which have been designed at an initial stage to accommodate people who come from different economic backgrounds, the township of Olievenhoutbosch was earlier designed for low-income people. The recent development of middle- and high-income households within the dominating low-income households of Olievenhoutbosch is what gives it a sense of a mixed-income community. Currently, Olievenhoutbosch

presents a variety of land uses, housing typologies, and people from different economic classes co-existing in the area. The fully subsidised housing that has been provided by the government for the low-income class comes in different formats, from single-stand and semi-detached houses, which are mostly found in Extension 36 of the township, to row dwellings, enabling the residents to have more options and break the homogeneous setting that is mostly created by government-assisted houses (Department of Planning, Monitoring, and Evaluation, 2016).

Most of the policies and legislations that have been put in place, even though they did not solely intend to create mixed-income residential developments, advocated for the provision of adequate housing. The Constitution of the Republic of South Africa Act 108 of 1996 has highlighted that access to adequate housing is a basic right. The state is tasked with the responsibility of coming up with legislation and strategies that will ensure that everyone has access to housing (Republic of South Africa, 1996). Housing Act of 107 of 1997 has also highlighted that the government should intend on building affordable, sustainable housing that ensures access to the socio-economic benefits that the city has to offer. The legislation also aims to eradicate the development of informal settlements and eliminate descriptions that can be influenced by one's gender (Act, 1997).

The Breaking New Ground: National Housing Code (2009) aimed to establish the underlying policy principles, guidelines, norms, and standards that align with the existing programmes that address housing issues. It is aligned with the comprehensive plan for the development of sustainable human settlements (Department of Human Settlement, 2009). Fully subsidised (RDP) housing was introduced by the African National Congress (ANC) in 1994 and aimed to address the historical inequalities caused by the Apartheid planning system to achieve economic progress. The programme does not only construct new buildings but also redevelop the abandoned existing buildings (Nokulunga et al., 2018).

South Africa implemented several housing policies and legislation in the post-apartheid period that aimed to address the poor apartheid spatial planning, however, mixed-income housing development plans have not generally received support from private property investors in townships such as Oliven. Most of the successful housing projects are those of low-income housing (Todes & Robinson, 2020).

4 STUDY AREA

The township of Olievenhoutbosch is located in Region 4, which is the southwestern part of the city of Tshwane. It was founded in the 1990s but was made part of the city of Tshwane in 2000 (South African History Online, 2020). Despite the new developments of middle- and high-income households, the township is dominated by low-income houses (Department of Human Settlement, 2016). During the early years of the development of the township, the area was used as a transit area, which has led people from other places to move to the township due to easy access to public transport. The following is a map of Olievenhoutbosch township.

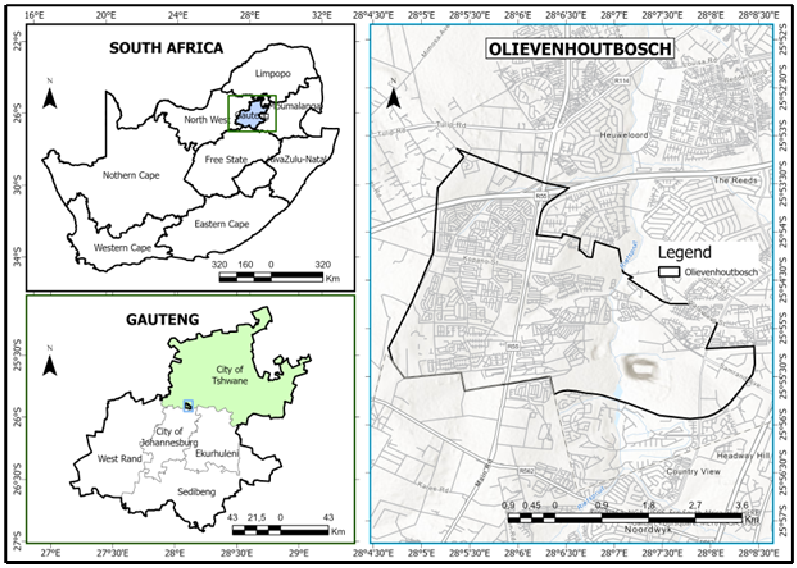

Figure 1: Locational map of Olievenhoutbosch township (Source: Authors, 2025).

The township of Olievenhoutbosch is found close to the borders of the City of Johannesburg, enabling easy commuting of the residents between the City of Johannesburg and the City of Tshwane.

Region 4, where the township of Olievenhoutbosch is located, has an estimated population of 379 349, with 70 863 people residing in Olievenhoutbosch in 2011 (Statistics South Africa, 2012). However, since there have been no updated general census data on the population of Olievenhoutbosch since 2011, the population seems to be increasing, and that is seen through the constant demand for access to housing and the high rise of backrooms and informal settlements.

5 METHODOLOGY

This study applied the qualitative research approach to examine the impact of rapid urbanization on mixed-income residential development in South African townships, with a focus on Olievenhoutbosch. The qualitative methodology allows the researchers to collect in-depth data as it incorporates the thoughts, opinions, experiences, and body language of the participants through its data collection methods. Qualitative research methods include interviews and direct observations. It allows physical and direct interaction between the participants and the researcher (Rahman, 2020). The research also applied the case study design, which focuses on a single case of the impact of urbanisation on the mixed-income housing developments in the township of Olievenhoutbosch.

The study adopted purposive sampling to select two (2) participants from each of the twelve (12) official extensions of the township of Olievenhoutbosch, as well as an official from the City of Tshwane human settlement department and the community councillor who is aware or involved in the development of housing in the township, was invited to participate in the study. For data collection, the researcher conducted field observation and interviews.

Despite the limited number of papers addressing the impact of urbanisation and the development of households for different economic classes in the township of Olievenhoutbosch, the need for adequate urbanisation management strategies and the need for housing in the township is seen through the growing number of backyard rooms for rentals, the illegal occupation of government housing projects, and private land that was not designated for residential developments.

6 FINDINGS

6.1 Housing projects

Currently, thirteen government-assisted housing projects have been implemented in the following extensions: 13, 15, 19, 20, 21, 22, 23, 24, 25, 26, 27, 36, and 37. Some of the projects are similar in structure and were developed almost at the same time, and it is hard to distinguish since the boundaries of the extensions are not visible at times. The development of government-assisted houses has also incorporated different housing typologies, from stand-alone to semi-detached, that are mostly found in Extension 36 (Absa) and flats.

There is currently no available land for future residential developments in the township of Olievenhoutbosch. However, the government plans to engage with the private owners of land close to the area to develop social housing. Future developments in Olievenhoutbosch can be done on the north side of the township along N14. The city is currently hesitant to develop or build in the area due to the steep landscape of the area. It will be difficult and costly to develop service infrastructure such as water and sewage. The land is also sensitive; special material is required to build the houses.

6.2 Housing Diversity in Olievenhoutbosch

Below is a picture of the 919-flat housing project in Olievenhoutbosch Extension 36 which was illegally occupied by the residents in the year 2020, while the people who were approved to have the houses are still in need.

Figure 2: Illegally occupied housing project of 919 flats in Ext 36 in Olievenhoutbosch (Source: Authors,2023).

Picture A shows flats that were completely done, had streetlights, parking, water, and electricity, and were legally occupied by their rightful owners. Picture B shows flats that were illegally occupied by residents and were not yet completed.

Figure 3: Middle-income rental flats in the low-cost households of Olievenhoutbosch Extension (Source: Author,2023).

The township of Olievenhoutbosch present different housing typology. The above picture are rental apartments of middle-income earners and are found in the heart of low-income households in Olievenhoutbosch Extension 36 (Absa). It breaks the traditional feeling of residing in a township since it is placed close to the shopping centre and petrol station (approximately less than a 5-minute walk).

6.3 Social Mix in Olievenhoutbosch

The failure of Oliven to develop a mixed-income residential development that is sustainable is seen through the lack of social mix strategies that have been implemented in the area to achieve inclusivity and to break the stereotypes that might have existed between people from low-, middle-, and high-income households. There are no programmes that have been put in place to promote interaction between people of different classes.

7 STRATEGIES THAT CAN BE IMPLEMENTED IN OLIEVENHOUTBOSCH

7.1 Developing Rural Areas.

Despite urbanisation being a product and contributing immensely to the economic development of cities, a high number of people coming into the city strains accessibility to housing and other service deliveries from the government (Dufhues et al., 2021). The goal is to make urban migration a choice, not a necessity. The government can promote economic opportunities through specialised legislation and policies to reduce rural-

urban migration and give people a choice to migrate to cities by choice, not only because more opportunities are being presented in cities than in rural areas.

7.2 Developing programmes that promote social mix.

The use of social mix programmes has been applied in town planning for a while to achieve inclusive cities (Sarkissian, 1976). It is seen as an objective of good planning as well as a solution to bring a sense of modern life to the ageing social housing neighbourhood. The township of Olievenhoutbosch can use what they already have, such as parks and sports activities, to promote interaction.

7.3 Supporting other programmes that ensure access to housing.

7.3.1 Issuing serviced stands

To combat the issues of slums and the continuing housing backlog, the Gauteng province has implemented programmes that provide serviced stands rather than building houses. The community members who need houses are given a choice: wait for the houses to be built for them or be provided with the stands. The City of Johannesburg has already implemented a strategy of this kind. The township of Olievenhoutbosch can also adopt this strategy of providing serviced stands instead of building houses. This will help the municipality save money. The strategy can be developed in such a way that it restricts the building of backyard rooms and shacks for rentals. This will help with reducing informality.

7.3.2 Rental buildings by Government

Despite the effort that has been made by the City of Tshwane with the development of social houses that include rental and purchasing and are supported by FLISP within Region 4, where Olievenhoutbosch is found, such similar projects are not in existence in the area. The development of rental buildings by the government within the township will not only increase accessibility to housing but also bring diversity to a mixed-income community and give people a choice of place to stay. The generated money from the rental buildings can be used to provide free houses for people in the low-income class who require adequate shelter.

7.3.3 Supporting the Gauteng Partnership Fund to address the backyard rooms.

The majority of the backyard rooms in Oliven are shacks that were built close to each other, lacked sustainability aspects, and could be a risky fire if they were to start since the electricity cables were also exposed on the ground. Programmes such as the Gauteng Partnership Fund (GPN) can be useful in assisting individuals who would like to build backyard rooms for income but do not have financial means. It has programmes such as Kasi 4 Real, which enhances the township economy through the funding of rental room projects. Promotion of such programmes in Olievenhoutbosch will increase accessibility and availability of housing and ensure that the water, sewerage, and electricity needs of the new developments can be accommodated by the existing service infrastructure.

8 CONCLUSION

The overall aim of this study was to examine the impact of urbanisation on mixed-income residential development in South African townships, focusing on the township of Olievenhoutbosch. Despite the efforts made by the government to provide housing, the township of Olievenhoutbosch still faces a housing backlog. There has been illegal occupation of the recent housing projects, while the deserving residents of the houses remain in the informal settlements and backyard rooms. Unlike other implemented mixed-income communities in South Africa, Olievenhoutbosch was not initially developed to be a mixed-income community; the development of the new middle- and high-income households is what gives it a sense of inclusivity. The fights between the residents who have illegally occupied the provided social houses, the rightful owners, and the Department of Housing jeopardise the safety in the area and make it difficult to achieve an inclusive and sustainable mixed-income development in the township. The area has also seen a high number of residents hijacking private land that was not zoned for residential development and creating slums.

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reviewed paper

Utilisation of Digital Marketing Platforms for Customer Engagement in Sustainability in the Net Zero Energy Transition in the German Building Sector

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1 ABSTRACT

Achieving a net zero energy future in the German building sector is an extraordinary societal endeavour that requires – besides the adoption of sustainable practices – intensified consumer engagement. However, shifting from consumer awareness to consumer commitment needs a deeper understanding of the social drivers. Until recently, scientific research focused on technical and economic aspects of energy transition, while the contribution of social science in this field is still in a fledgling state (Komendantova, 2021). Consumer engagement is suggested a promising route to follow to integrate social science approaches into this research stream. In achieving enhanced consumer commitment, digital marketing platforms are seen as a powerful tool, as they allow for better consumer targeting, measurability and monitoring as well as establishing a long-term relationship with them. This study validates the applicability of digital marketing platforms for consumer engagement and investigates the impact of perceived consumer value on engagement behaviours in sustainability in the net zero energy transition of the German building sector. To achieve this, the study pursued a qualitative research approach applying a process of planning, designing, preparing, collecting and sharing data (Yin, 2003). Using purposive sampling and snowballing techniques, seven respondents with experience in marketing and business development in construction and architectural firms were interviewed. The qualitative analysis resulted in categories and the establishment of a coding framework via the Maxqda software. The results show that awareness and research in the context of sustainable buildings are the most important stages of the consumer experience influenced by digital marketing platforms. The research suggests a model of digital consumer experience strategy that emphasises simplicity, reachability, transparency, and personalization. In addition, the research found that mainly utilitarian values, environmental values, safety and self-expression are values ranking top of mind of consumers or citizens that influence engagement behavior when acquiring sustainable buildings with social values not to be neglected. This research should enable construction companies to develop relevant and effective propositions for their consumer engagement strategies.

Keywords: net zero energy transition, engagement behaviour, Digital marketing, consumer engagement , Planning

2 INTRODUCTION

Consumer engagement is seen as a critical part of achieving the net zero energy transition in the building sector. Consumers‘ participation and commitment, leading to the adoption of high energy performance solutions throughout the building lifecycle, will shape the success of the net zero energy transition. Consumer engagement refers to the set of different voluntary behaviours towards a specific product (service) (van Doorn et al., 2010). It fosters a broader societal shift towards active involvement of peers and communities.

In Germany, supported by the goverment’s target of being “nearly CO_2-neutral” by 2050, there are massive contributions to be expected in the building sector not only from renewable energy applications but also from energy efficiency solutions, which are being promoted to gain consumer interest and acceptance.

Digital marketing platforms are a powerful tool for fostering a sense of shared commitment and social involvement through educating and engaging audiences in sustainable efforts (Dadabaeva and Jamoliddinov, 2024). They also allow targeted communication and facilitate interactivity among audiences. In addition, these channels provide competence of data analysis and montoring to better understand consumer preferences.

This research aims to study the utilization of digital marketing platforms for consumer engagement in sustainability in the net zero energy transition in the German building sector.

It addresses the most recent suggestion by Durmus (2024, p.23) for future research: "forthcoming endeavors could delve deeper into the evolving landscape of digital marketing strategies, explore innovative approaches to enhance consumer engagement ....ensuring our understanding of sustainable marketing continually adapts to the ever-changing energy and environmental landscape".

This study is divided into five further sections. In section 3, there are the background of sustainability and its importance for the German building sector; digital marketing platform in sustainability and its impact on consumer engagement. Furthermore, it initiated about the sustainable engagement behaviours of consumers in the net zero energy transition of the German building sector. In the section 4, the authors explain the research method to design the analysis, data collection technique and data analysis procedure. Section 5 presents the findings of the qualitative research. In the section 6, the main discussion takes place and, finally, the conclusion is provided in session 7.

3 LITERATURE REVIEW

3.1 Sustainability and its importance for the German building sector

Sustainability

Sustainable development aims to strike a balance between the needs of different generations (World Commission on Environment and Development, 1987). Its concept on the triple bottom line embraces economic, social and environmental sustainability (Catlin, Luchs and Phipps, 2017; Elkington, 1998). Driven by civilisation, buildings have become extremely necessary to maintain the standards of human life. Whilst the construction industry is crucial to the economy and the social aspects of life by designing, constructing and enhancing the living environment (Mjakuškina, Kavosa and Lapiņa, 2019), the built environment sector is the largest greenhouse gase emitter accounting for 37 per cent of the global emissions (Dyson, 2023).

The German building sector toward sustainable development

The building sector in Germany has contributed a significant share to the construction market due to rapid urbanisation and population growth caused by immigrants (Technavio, 2024). This leads to a large consumption of utilities and resources which are responsible for greenhouse gas emissions. As a result, this sector has become the third largest greenhouse gas emitter with 111 million tonnes of CO_2 in 2022 (Nasr, 2024). To ensure its long-term development, the German government has set itself the target of being "nearly CO_2-neutral" by 2050. It has promoted regulations and legal frameworks that support green development, high productivity and digitalisation in the market (Technavio, 2024). The shift towards decarbonisation is associated with a number of relevant companies in the building sector making significant efforts to position themselves as ecological and environmentally friendly.

3.2 Sustainable marketing, digital marketing, digital marketing platforms and its impact on consumer engagement in the field of sustainability

Marketing and digital marketing in sustainability

Triggered by concerns about climate change, technology innovations and supporting policies, sustainable marketing has become a powerful tool to promote positive impacts of companies on ecology, society and economy. According to Rastogi, Agarwal and Gopal (2024, p. 1), "sustainable marketing involves developing and promoting products and services in such a manner that the resources are utilized optimally, providing maximum satisfaction to the consumer and the company, along with ensuring a better life for both current and upcoming generations". According to Bhuvaneswari (2021, p. 1), "digital marketing is the promotion of products or services using online channels, electronic devices, and digital technologies". In practice, however, sustainable marketing faces a major challenge related to lacking consumer awareness that leads to misunderstanding and mistrust towards promotion of sustainability (Durmus, 2024). Thanks to the evolution of the wireless transformation era, digital marketing has become an influential tool for promoting sustainability applications (Dadabaeva and Jamoliddinov, 2024).

Digital marketing platforms and its impact on consumer engagement in the field of sustainability

Digital marketing platforms refer to social media, blogs, webinars and online forums to engage consumers on sustainability issues (Durmus, 2024). According to Cevher (2024), websites, email marketing and search engines represent digital channels. These platforms have a positive correlation with consumer engagement (Arjang, Utami and Redjeki, 2024). They have a significant impact at each stage of the consumer experience consisting of awareness, research, purchase and after-sales stages (Cevher, 2024). It requires companies to adopt digital experience strategies that focus on customer engagement and determining how digital elements integrate into customer experience journey. The digital customer experience strategy (DX) maturity spectrum provides a digital consumer experience strategy that navigates consumer engagement across the digital channels with the following key elments (Anon., 2024). Channel flexibility refers to the ability to move between channels; the consistency of content and tracking and the tracking and retention of consumer's interactions; reachability focuses on the availability and accessibility of the consumer's preferred digital channels; fast and real-time support is included in the service and purchase convenience; personalisation means establishing individual experiences; simplicity is relevant to user-friendly features and design (Anon., 2024); in addition, transparency exerts a key influence in digital platforms to build trust, especially with ecologically minded consumers (Dadabaeva and Jamoliddinov, 2024). By integrating these important factors into their digital strategies, companies can demonstrate their truthful accountability through comprehensive sustainable reporting and information.

3.3 Consumers' sustainable engagement behaviours in the net zero energy transition in the German building sector

The shift in societal, especially, household attitudes towards energy use is crucial to energy transition (Smaliukienė and Monni, 2019). By gaining consumers' acceptance of green alternatives and innovations, the clean energy transition is accelerated through the application of innovations and green solutions. The building sector is in the third phase of its transition to net zero energy, with increasing applications towards energy efficiency, low-carbon electrification and low-carbon fuels (Markard and Rosenbloom, 2022). It is important for the solution providers to understand the concept of consumer engagement and the drivers of consumer behaviour, so that they can offer effective engagement strategies.

Consumer engagement refers to a set of different voluntary behaviours towards a specific product (service) (van Doorn et al., 2010). These behaviors encompass seeking information, proactive managing, sharing feedback, helping and advocating (Bănică, Patrício and Miguéis, 2024). Indeed, Bănică, Patrício and Miguéis (2024) shared their view that seeking information enables a better understanding of products and services; proactive managing focuses on monitoring and optimizing their use; sharing information belongs to social dissemination to improve solutions; helping means supporting to deal with product-related issues; and advocating refers to providing recommendations.

Value perceptions have a major influence on purchase behaviours and lead people to choose one brand over another (Sweeney and Soutar, 2001). Durmus (2024) highlighted that personal values, social norms and environmental perspectives lead to consumer behaviours in the area of sustainability. According to Smaliukienė and Monni (2019, p. 21), "economic benefit is a very important stimulus for behavioural changes". This is reflected and extended in the concept of utilitarian value, which belongs to the consumer's consumption demands such as quality, usefulness and price value (Chen et al., 2019). In addition, social value is another driver of engagement behaviours, that refers to social network returns (Wang et al., 2021). Furthermore, it is confirmed that environmental value is related to consumers' environmental concerns, which can be satisfied by green solutions (Komendantova, 2021). Bănică, Patrício and Miguéis (2024) confirmed that utilitarian value has a significant impact on seeking information, proactive managing, helping and advocating while social value is aligned with sharing, helping and advocating; environmental value has an indirect impact on seeking information, proactive managing and advocating. In this context, it seemed interesting to the researchers to observe the relation between materialist values and post-materialist values, i.e. self-expression, quality of life or environmental attitudes, as discussed by Inglehart (1981) and its impact on consumer behavior in the building sector of Germany.

3.4 Initial conceptualization and research table

The figure one shows a graphical representation of the four research questions followed by the research methodology chosen comprising detailed research objectives, research questions and interview questions.

The research aims to validate the applicability of digital marketing platforms for consumer engagement in sustainability of the net zero energy transition in the German building sector. It also investigates the drivers that influence engagement behaviours in the net zero energy transition in the German building sector. By pursuing a qualitative approach, the upcoming results are expected to fulfil these study objectives. The study includes four research questions: (1) To what extent do diverse digital platforms influence consumer engagement in sustainability in the German building sector? (2) How can digital platforms be strategically used for consumer engagement in sustainability in the German building sector? (3) To what extent does the materialist value orientations of individuals influence their prioritization of environmental protection versus security and economic factors? (4) How do consumer values influence engagement behaviours in the German building sector?

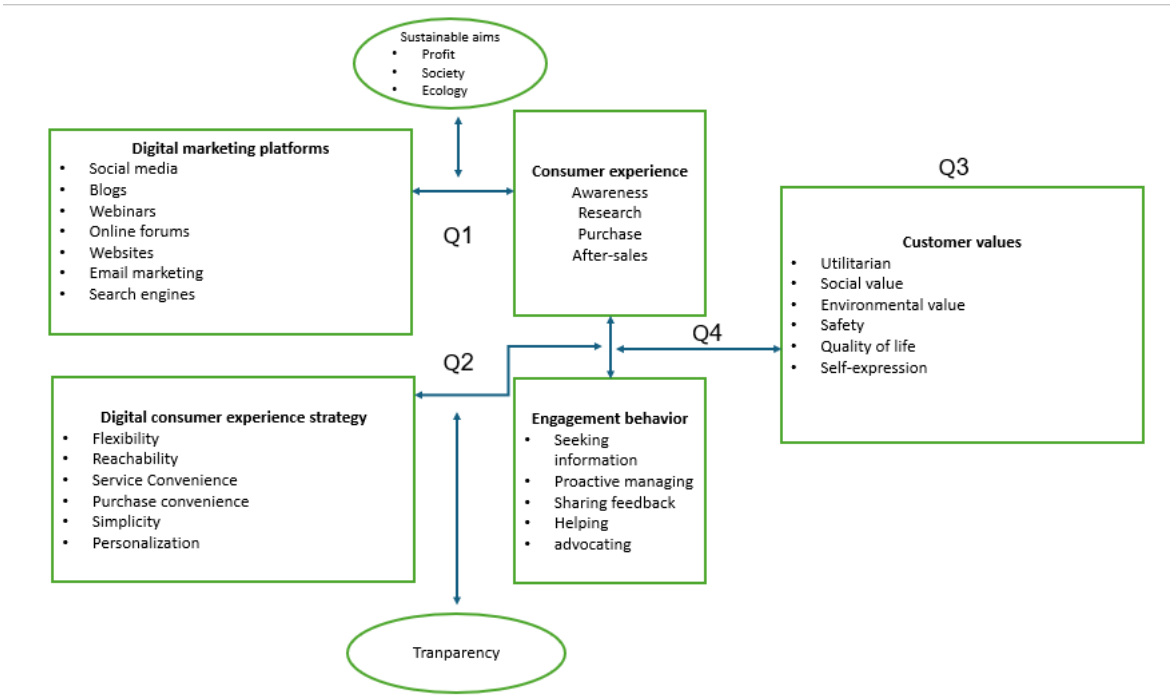

Figure 1: Initial Conceptualization developed by the authors based on Durmus (2024), Bănică, Patrício and Miguéis (2024), Komendantova (2021), Dadabaeva and Jamoliddinov (2024), Anon., (2024), Inglehart (1995)

4 RESEARCH METHODOLOGY

This study aims to fill the gap in the literature with empirical evidence and concepts to identify the relationship between different digital marketing platforms and consumer engagement in the net zero energy transition in the German building sector.

4.1 Research approach, design and data collection

This exploratory research paper uses the case study method to answer “why” and “how” questions. It allows for analysis in a real-life context with direct observations. Qualitative research was chosen due to the limited existing literature on the topic. There are six interdependent stages of the qualitative research process including planning, designing, preparing, collecting and sharing (Yin, 2003). Based on the literature review, the four questions were identified. The interview questions were asked in semi-structured interviews facilitating open-ended questions for eliciting independent and diverse perspectives of respondents.

4.2 Sample selection

The study uses purposive sampling and snowballing technique. The main sampling criterion was experience in marketing and business development in the German building sector. There were three female and four male who participated in the interviews. The seven interviews were conducted in English. All interviews lasted between 20 and 60 minutes. The interviews were recorded and transcribed for analysis.

4.3 Data analysis procedure

The processes of the applied qualitative research included interviews, observation and documentation. The qualitative analysis is based on categorization and the establishment of a coding framework. Coding is generated from keywords, research questions and relationships. The study used the MAXQDA software to code and categorise data. Initial codes were established from keywords according to the research questions and arranged subsequently into thematic categories.

After the interviews had been conducted, the transcribed documents were used for the analysis. The final steps are the research findings and documentation. Direct quotes from participants are provided for validity purposes.

4.4 Ethical considerations

Prior to the interviewing, all respondents were informed of the research objectives in the invitation letter and at the beginning of the interviews. All recorded data were used for analytic reasons only and were deleted once transcription had been completed. The identities of the interviewees were kept anonymous.

5 FINDINGS

5.1 Digital maketing platforms

The respondents were asked as to which digital marketing platforms they used in their business.

Websites and social media are the most often used platforms by all respondents as R3 illustrates: “The website provides detailed information about our project, service, and the company’s commitment to sustainability”. While all respondents confirmed their use of Linkedin, Instagram is used by R3, R4, R6, R7; Facebook is used by R4, R7 and Youtube by R7. Exemplarily, R3 refered to online forums: “online forums provide communication channels for the consumer and share experience and maybe ask questions about our products that we complete with the sustainable process.” Webinars are also organised to provide in-depth information so that consumers get a better understanding about the companies’ solutions (R3, R7). However, R1 reported his concern about webinars: “I think it slowed down again. It was quite popular during the Covid times, but I think after that they somehow disappeared”. R1 and R4 use blogs on their webpages. R1 and R6 take advantages of search engines. R1 and R7 confirmed their application of email marketing in terms of newsletters. R4 articulates their use depending on the market interest: “In Germany you will probably have consumers that get upset about newsletters and find that it’s a very difficult and very aggressive marketing tool. But in the US it’s different and they have a very high acceptance. So, we decided to only reach out for mainly our clients that are connected to our US office”.

Summarizing, it is evident that the respondents differentiate as to the purposes of different digital marketing platforms.

5.2 Consumer experience

The respondents were asked as to how important these digital platforms are for engaging consumers in the consumer journey stages of awareness, research, purchase and after-sales.

Awareness

All respondents drew attention to the high importance of digital platforms for the consumers’ awareness. In this vein, R1 emphasized: “Definitely, awareness is highest on the agenda; they enable us to raise awareness of the company, our ambition, products, solutions”.

Also, R6 confirmed R1: “So, for my specific value that I offer to the market, I would say it's really the level of awareness that I can effect on social media platforms”.

Research

Research is influenced by digital platforms (R1,R2, R3, R6) as well. R6 gave a practical example: “Sure, research, yes, if people now start looking into agriculture – photovoltaic, for example, they should find my company affiliated with the topic; and then, they could get in touch”. R2 explained in more detail: “For research, they're also very useful; this also depends on the kind of user; for example, of course, researchers itself need to be targeted via peer-reviewed papers”.

Purchase

While R1, R2, R4, R5, R6 do not pay attention to the role of digital marketing platforms in the purchase stage, R3 acknowledges its slight impact: “In the purchasing stage, the website and online forum contribute to impacts on the decision making process by providing specific information about our product and sustainable architecture awards”.

After-sales

R1 and R3 mentioned the impact of these digital platforms on after-sales. R1 outlined: “Our consumers are also getting younger and younger, and the young generation, they use the digital platforms to really actively search for information. So, this is definitely, I would say, a growing trend that we see, also as to research and after-sales”.

5.3 Sustainability aim

The respondents were asked whether environmental and social sustainability objectives are included in companies’ digital platform strategy alongside profit objectives.

Unanimity was witnessed on both dimensions of sustainability. This is reasoned by sustainability being regarded a core value of companies (R1, R3, R4, R5, R6). R4 indicated this: “Our main aim is to talk about sustainability like how we think, how we take responsibility, we should be and act as an industry”. Environmental objectives are embraced rather than social objectives in the building sector (R2, R4, R5) as R5 explains: “Definitely, the ecological impact is getting more important because more people are searching environmental-friendly products” and continued that it has been influenced of regulatory forces of the government. Accordingly, R2 gives an examle: “For example, we will reach this amount of CO_2 emission savings. So, ecological aims are priority number one for us; and to prove everything, or to give numbers for the clients and users; and, regarding sustainability aims, it's always connected to economic aims also in the long-term”.

In contrast, R4 ads the importance of social objectives in their business: “It’s interesting because we are in our urban planning projects, we do always discuss this also in our urban planning projects, this social part is addressed. We support sometimes landscape architects that are trying to influence the situation of having natural environments to be close or inside of cityscapes”.

5.4 Digital consumer experience strategy

This category examines the answers of the respondents on the critical areas of digital consumer experience strategy in the DX model.

Simplicity is the key factor in the digital consumer journey (R1, R2, R3, R4, R5, R7) as R1’s view exemplarily reflects: “We conducted tests with users, we found so many insights, and we felt that also people today are so fast. If it's not nice or if it's too complicated to use, they will not use it”. Consistently, R3 explains how this applies to the building sector: “In sustainable design, which is providing complex information, everything is so complicated to be understood. So, that's why simplicity is very important to explain complex concepts”.

Respondents confirmed the impact of the reachability factor (R1, R2, R3, R6, R7) stated by R3: “With reachability, information and services are available to the consumer anytime and anywhere”.

In addition, personalisation was emphasized by R1, R5, R6, R7 as articulated by R1: “If I am a consultant or an architect for a building, I want to see content which is related to my field of work which is offered and somehow linked to my activity”.

On the other hand, purchase and service convenience are viewed as lower impactful factors (R1, R3, R4, R6) because consumers prefer here direct contacts through personal meetings and direct communications rather than on digital platforms.

Transparency, however, plays a significant role to engage with consumers (R1, R2, R3, R4, R5, R6, R7). In this context, R3 stresses: “It builds just by providing clear information about a company operations such as production process and environment of methods. It enables consumers to practise their participation and to give feedback and make responsible purchasing decisions”.

5.5 Consumer values

This category discussed the prioritization of consumer values in the net zero energy transition in the German building sector.

All respondents agreed that a utilitarian value was top of the consumers' priority. R2 highlighted this preference: "Consumers put a lot of cost on their shoulder to reach sustainability" confirmed by R7: "At least, it makes sense for consumers to see that it pays off after some amount of time; they really are afraid of taking a loan for now".

Furthermore, R1, R2, R3, R5, R6, R7 highlighted the value of security. R1 stated that "the security is the basis".

Self-expression also plays an important role among consumer values (R1, R2, R3, R6, R7). R3 gives a practical example: "We have worked with big brands that produce sustainable products. So, their buildings should be built in the sustainable way with the sustainable materials". R1's view exemplarily reflects: "In digital marketing, it's a lot about self-expression. I feel always. So, the more people are active in the digital space, the more they are willing also to express themselves. Uh so, this will bring the engagement high up."

Environment and quality of life is mentioned by R1, R2, R3, R6. R3 explained that "the consumers need to put their trust and safety in quality units and also bring spatial values in quality of life".

R2, R6, R7 state that social value has a certain priority but lower than the utilitarian one. Additionally, R1 introduced ethics as an important value because the European market is much concerned about this value in all processes and components that belong to the value chain.

5.6 Engagement behaviour

This category discussed in more detail how utilitarian, social and environmental values influence engagement behaviours in sustainability in the German building sector.

Utilitarian value plays a key role on seeking information (R1, R3, R6, R7), helping (R5) and proactivemanaging (R3). R3 stated that the "utilitarian aspect ensures that the product or service met consumer needs and expectations directly influencing information seeking".

Environmental value has an impact on sharing (R2), seeking information (R5, R7), and advocating (R1, R7). However, these respondents confirmed that this value does not play a major role such as utilitarian value, but it should not be totally neglected. By providing local context in creating awareness of sustainablity, its impact was high on these engagement behaviours (R1, R2, R3, R4, R5, R6, R7).

Social value was emphasised in sharing feedback (R7, R2, R6) and in helping as shown by R6's statement: "Sharing feedback and helping, I would say these are the two mostly related to social values. Of course, it's also helpful to improve and to change things". This is confirmed by R3 stating: "Sharing feedback and helping are very important on social media, because this builds reputation, trust and promote your competency".

6 DISCUSSION

Regarding the first research question focused on identifying the key factors influencing consumer engagement through digital marketing channels, it was found that awareness and research are the most important stages influenced by digital marketing platforms (R1, R2, R3, R4, R5, R6, R7). This is confirming the literature that social media platforms stand as unparalleled arenas for engagement, these platforms have the positive relationship with consumer engagement (Arjang, Utami and Redjeki, 2024). As earlier discussed in the literature review, the platforms enable companies' to present their sustainability efforts and engagement with their audiences (Dadabaeva and Jamoliddinov, 2024). Sustainable values are highlighted through the platforms to educate consumers (R1, R2, R3, R6). After analysing the responses, the authors found that purchase and after-sales receive little attention on the digital platforms, as most services and products in buildings are provided as tailored-made through direct physical sales and after-sales services (R2, R4, R5, R6, R7). The authors found that websites and social media are the most used platforms by all respondents.

Research question 2 identified key factors applied in the digital platform strategy for consumer engagement in sustainability in the German building sector could be found.

It is suggested that flexibility, reachability, personalisation, simplicity service and purchase convenience are key areas of digital consumer experience (Anon., 2024). In addition, transparency is a key influence in digital platforms to build trust, especially with ecologically minded consumers (Dadabaeva and Jamoliddinov, 2024). After analysing the data, the authors conclude that simplicity (R1, R2, R3, R4, R5, R7), reachability (R1, R2, R3, R6, R7), transparency (R1, R2, R3, R4, R5, R6, R7) and personalisation (R1, R5, R6, R7) are key areas that considerably influence the digital consumer journey. They enable complex technical concepts in the building sector to be made clear and easy to be understood in order to build trust and close consumer relationship (R1, R2, R3, R7). Besides, due to regulation and consumer demands, environmental objectives are embraced rather than social objectives in the building sector (R2, R4, R5).

The third research question investigated which materialist value orientations of individuals influence their prioritization of environmental protection versus security and economic factors. The results showed that, safety and economic factors and a lower ranking of ecological values were suggested by literature (Komendantova, 2021). Confirmed by the findings, safety and utilitarian values seem to be a conditio sine qua non (R1, R2, R3, R5, R6, R7). R5 also mentioned that "security in terms of fulfilling the regulation, it is more important than environmental aspect". According to fundamental life conditions and legal reasons, safety and utilitarian are above ecological values (R2, R5). Whilst utilitarian values were prioritized, respondents in the building sector placed a strong emphasis on self-expression (R1, R2, R3, R6, R7). R3 explained that buildings play a crucial role in presenting and symbolising the owners. Interestingly, R1 suggested ethics to be a significant factor because there are serious concerns about the ethics claimed in all processes and components of the products in Europe. Ethical perceptions of consumers have a positive impact on cultivating a sense of loyalty and emotional attachment to companies (Iqbal, 2024).

Referring to research question 4, the relationship between utilitarian, social and environmental values on engagement behaviours was investigated. According to Bănică, Patrício and Miguéis (2024), utilitarian values have a significant impact on seeking information, proactive managing, helping and advocating while social value is aligned with sharing, helping and advocating; environmental values seem to have an indirect impact on seeking information, proactive managing and advocating. According to the data analysis, the authors experienced that utilitarian values play a key role in seeking information (R1, R3, R6, R7), helping (R5) and proactive managing (R3). Environmental value has an impact on sharing (R2), seeking information (R5, R7), and advocating (R1, R7). Social value was emphasised in sharing feedback (R7, R2, R6) and in helping (R6). Commenting on the relationship between materialist, utilitarian and post-materialist values, the findings imply an integration and balanced consideration of these diverse values: whilst utilitarian values were strongly confirmed and prioritized in Germany, self-expression, environmental values and quality of life and, to a lower extent, social values were also regarded highly relevant. The following figure two summarizes the findings.

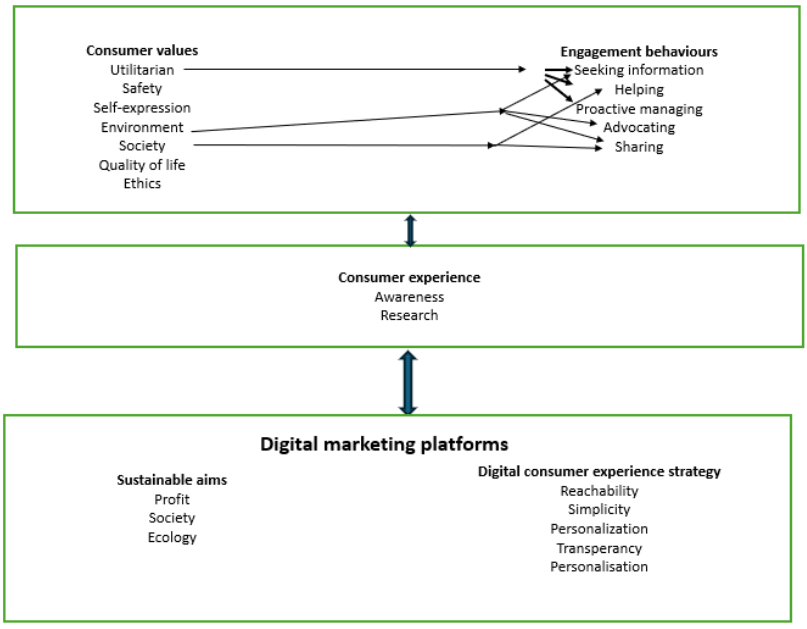

Figure 2 Final model

7 CONCLUSION

In this study, the authors examined the application of digital marketing platforms for consumer engagement in sustainability in the net zero energy transition in the German building sector. The study provided further insight into the relationship between these platforms, consumer experience and consumer engagement behaviour. According to the exploratory empirical findings, awareness and research are the most important stages of the consumer experience, that are influenced by digital marketing platforms. In terms of digital marketing platform strategies, this paper proposes the concept of sustainable marketing and the model of digital consumer experience with the emphasis on simplicity, reachability, transparency and personalisation. This provides companies with more strategic support for their digital marketing strategies to achieve consumer engagement.

In addition, the study examined how consumer values influence engagement behaviours in sustainability in the net zero energy transition in the German building sector. The results showed that utilitarian, safety and self-expression values are ranked as the top priorities. Hence companies should pay serious attention to these core values and apply easy-to-be-understood communication to meet these values. Besides, environment, social values, quality of life and ethics are consumer values that contribute to engagement behaviors. This study also indentified that seeking information, sharing and helping are the most influential engagement behaviours in digital marketing channels. By understanding the key values that drive consumer behaviour, businesses and policymakers would customize their digital marketing strategies to foster awareness, commitment and participation in sustainable practices. These efforts can enhance adoptions of green solutions, facilitating a boarder shift towards accelerating the transition to a net zero energy future in the construction sector.

Limitations and future research

The study has serveral limitations. The first limitation is that the factors that stimulate the interaction between digital marketing platforms and consumer engagement are only from the perspective of companies. Hence, future research could be conducted from the perspective of consumers. Further research could also investigate the impact of security, self-expression, quality of life and ethics on engagement behaviour not having been assessed in this study. A future quantitative study is suggested to investigate the nature of relationships between the concepts under study, the weight of the factors, possible moderating and/or mediating effects and a cause-effect analysis with engagement behaviours as the dependent variable.

Furthermore, future research could extend the scope of social science approaches as indicated by the suggestions of the following researchers. Specifically, "there is a lack of studies regarding stakeholders' involvement in Net-zero projects" (Terenzi, Locatelli, Winch, 2024). Beyond the perspectives of consumers/citizens and businesses, mid-level actors such as – local authorities, service providers, trusted local actors, educational settings, businesses, local employers, community infrastructure, social housing providers etc – play a crucial role in driving societal change towards net zero policies (Bickersrtaff, et al., 2024). These actors facilitate the transition process between top-down and bottom-up policies (Bickersrtaff, et al., 2024). Futhermore, Sovacool, Iskandarova and Geels (2023) emphasize the significance of relevant social groups including designers, engineers, system builders, national and local politicians, industry associations, unions, universities, research institutes, community groups, environmental not-for-profit organisations in net zero industrial projects. Consequently, a future study could examine the roles of these ecosystem stakeholders in adopting consumer engagement strategies supported by digital marketing within the building setor in Germany.

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reviewed paper

Visual Analytics for Urban Heat Risk Assessment: A Scenario-Driven Dashboard for Exploring Microclimate Development

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1 ABSTRACT

Given the ongoing dynamics of climate change and its adverse impacts, improving communication about climate exposure and risk in urban areas has become more critical than ever. To advance these efforts, we present an innovative digital platform that enables stakeholders to intuitively visualize, analyze, and respond to complex microclimate developments effectively. Specifically, we present a web-based, scenario-driven visual analytics dashboard designed to visualize and explore complex spatio-temporal microclimate dynamics in an engaging and accessible way. The dashboard integrates several key features, including detailed spatial and temporal heat mapping, heat hazard identification, and the evaluation of potential mitigation strategies, such as nature-based solutions and urban shading interventions. The user interface offers multiple linked views, including geographic maps, aggregated visualizations (e.g., histograms), and views showing temporal changes (e.g., line charts). These visualizations are interconnected and highly responsive, whereby actions in one view immediately affect the others.

A number of public demonstrations were conducted with a diverse group of stakeholders (e.g., policy-makers, urban planners, government representatives, scientific and industry partners, students) to assess the effectiveness of our dashboard in identifying priority areas that require immediate intervention. These sessions aimed to evaluate how well the dashboard supports users in recognizing high-risk zones and understanding the dynamics of heat exposure within urban environments. These demonstrations provided valuable insights into the dashboard's ability to guide users through complex datasets, while enhancing the communication of heat risks and supporting the consideration of targeted strategies to mitigate the impacts of extreme heat in urban environments.

Keywords: microclimate development, climate risk assessment, climate simulation, visual analytics, decision support system

2 INTRODUCTION

2.1 Background

With the increasing frequency and severity of extreme heat events, the urgency to comprehensively assess and identify vulnerable areas within urban environments has become more critical than ever (IPCC 2022). This vulnerability is largely driven by rapid urbanization, which leads to high population density in cities and resulting pressure on urban infrastructure (Garschagen and Romero-Lankao 2015, Sterzel et al. 2020). Additionally, Stolte et al. (2024) highlight that urban vulnerability is equally shaped by other dimensions, such as exposure to natural hazards, sensitivity of the population, and adaptive capacity. These phenomena are further exacerbated by environmental changes driven by climate change, such as rising temperatures, heatwaves, and heavy precipitation events (Jurgilevich et al. 2021). With current climate change trends expected to accelerate in the coming decades, urban areas around the world will only continue to face an increasing number of challenges (IPCC 2022).

In this context, effective communication of risk and exposure is essential for understanding and addressing the impact of extreme heat on urban areas and their communities. However, many stakeholder groups, though motivated to tackle heat-related challenges, lack intuitive and accessible tools to visualize, explore, and understand the spatial and temporal dynamics of heat exposure. This gap greatly hinders their ability to implement targeted and informed interventions based on local contexts. This is because traditional methods of communicating heat exposure and risk often rely on overly technical and static cartographic representations or coarsely aggregated city- or country-wide risk indicators (Cariolet et al. 2019, Fuhrmann et al. 2024, Stolte et al. 2024). These approaches tend to obscure the fine-grained nuances of local vulnerabilities. Consequently, policymakers frequently struggle to translate such technical data into

actionable strategies that address specific local contexts. Traditional methods also lack the capacity to facilitate quick, widespread understanding or the practical identification of priority areas requiring immediate attention, ultimately limiting their ability to support timely and effective decision-making.

2.2 Overview

We present an innovative digital platform that enables stakeholders to intuitively visualize, analyze, and effectively plan their response to complex urban heat dynamics. Specifically, we present a web-based, scenario-driven Visual Analytics (VA) dashboard designed to visually and interactively explore complex spatio-temporal microclimate dynamics in an engaging, user-friendly, and accessible way. The VA dashboard integrates several key features, including detailed spatial and temporal heat mapping, interactive identification of heat hazard hotspots, and tools for assessing the effectiveness of mitigation strategies, such as nature-based solutions and urban shading interventions.

We also discuss the public demonstration phase, during which the VA dashboard was showcased to various stakeholders, demonstrating its practicality and relevance in supporting real-world decision-making processes. Feedback from this phase highlighted the dashboard's capacity to enhance spatial and contextual identification of high risk zones, support evidence-based planning, and promote collaborative discussions among stakeholders.

3 METHODOLOGY

3.1 Data sources and simulation setup

The VA dashboard relies on pre-computed simulation data generated by an environmental numerical model, designed to provide a comprehensive analysis of heat flow dynamics and interactions. Specifically, we employed the Ladybug plugin and its respective library of tools, which are seamlessly integrated into the Rhinoceros 3D/Grasshopper modeling environment (Roudsari et al. 2013, Vuckovic et al. 2019). The plugin is built on validated energy and daylighting engines, including EnergyPlus, Radiance, and Daysim, ensuring high reliability of modeling output. We considered two distinct scenarios in our study: the base case (i.e., the current state) and an intervention scenario that incorporates cost-effective urban strategies, such as urban shading and nature-based solutions, particularly urban trees, see Figure 1 (Vuckovic et al. 2023). The placement of these interventions was informed by the initial assessment of the base case and the related identification of hotspots within the study area (see Figure 2). Specifically, our analysis highlighted the need to address heat stress in the open plaza and several urban street canyons within the target area.

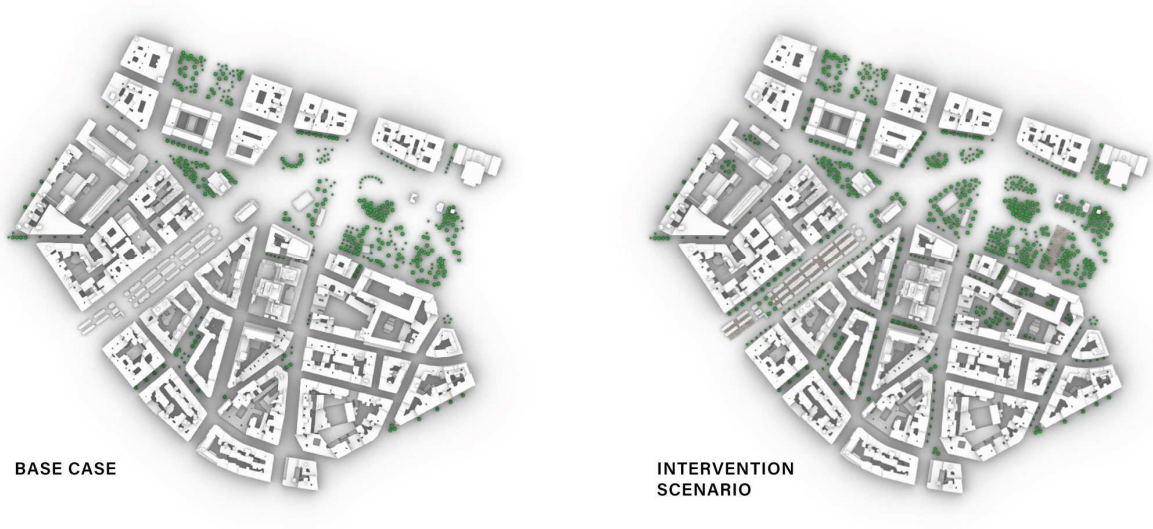

Fig. 1: Two distinct scenarios considered for a highly frequented central urban location in Vienna, Austria: (left) the current state; (right) cost-effective urban interventions – urban shading and urban trees.

The input weather conditions are representative of a typical meteorological year for the city of Vienna (Vuckovic and Schmidt 2020). However, unlike many studies that rely on generic weather trends and conditions derived from airport data, the freely available weather files offered by the U.S. Department of Energy's (DOE) Building Technologies Office (BTO) are, in the case of Vienna, also available for highly

dense urban morphologies (EPW map 2025). This ensures a more precise representation of localized microclimatic conditions. The input morphology information was based on Open Government Data provided by the Vienna City Surveying Department (MA41 Geodata 2025). The data is provided as georeferenced building polygons with respective height information. Using a specific set of rule-based algortihms available in the Rhinoceros 3D/Grasshopper modeling environment, these building polygons are extruded based on the height information, transforming them into a detailed 3D model. The position of existing trees was based on tree cadastre dataset for the city of Vienna, acquired from the official Open Government Data catalogue (OGD 2025). The data are represented as georeferenced data points, enriched with additional semantic information (i.e., unique tree ID number, tree species, planting year, etc.).

The respective thermal simulations were conducted for Karlsplatz, a highly frequented central urban location in Vienna, Austria (see Figure 1 and 2). We simulated a one-week period that represents conditions of an extreme hot summer week. The results are averaged over this period to create a reference day, which helps reduce the impact of slight diurnal variations throughout the week. Our study was based on the Universal Thermal Climate Index (UTCI), an internationally recognized metric that quantifies the human physiological response to the thermal environment (Jendritzky et al. 2012). The UTCI not only provides a scientifically robust assessment but also makes the results more understandable and accessible to a wide range of stakeholder groups, as it is expressed in degrees Celsius (°C).

We also extracted temporal daily heat profiles for several predefined locations within the target area (Figure 2). This was done exclusively for the base case to investigate the actual mechanisms of heat exchange in each setting and to establish a baseline for comparison with future interventions. Specifically, we sampled profiles from unobstructed, open spaces in the main plaza (Karlsplatz), a shaded spot under trees, and two locations within urban canyons (i.e., streets) of different geometrical characteristics – a narrow canyon (low width-to-height ratio) and a wide one (high width-to-height ratio). The square locations help assess the impact of solar radiation on location-specific heating regimes, while the tree-covered spot explores the thermal benefits of nature-based solutions for heat reduction. The different morphological characteristics of the urban canyons provide insights into the effects of shadowing from surrounding buildings.

Fig. 2: Two microclimate simulations carried out for a highly frequented central urban location in Vienna, Austria: (left) the current state; (right) the urban interventions. The predefined locations, from which the temporal daily heat profiles are extracted, are marked within the target area.

3.2 Technical foundation

Built on the flexible Tableau framework, the VA dashboard leverages Tableau's ability to seamlessly integrate, visualize, and link large, complex datasets in a highly responsive, user-friendly manner (Tableau 2025). Specifically, Tableau can seamlessly integrate various data types and formats into a unified data

ecosystem, enabling streamlined access and the creation of custom metrics across multiple data sources. This capability simplifies complex data workflows, allowing users to merge, analyze, and visualize diverse datasets within a single, cohesive platform. Furthermore, Tableau provides a diverse selection of built-in visual representations, including charts, diagrams, maps, and tabular formats. These visualizations are designed to accommodate both geospatial and non-geospatial data, effectively displaying comparisons, relationships, distributions, and compositions. This versatility ensures that users can choose the most appropriate visualization type to communicate insights clearly and effectively, whether analyzing spatial trends, illustrating data correlations, or presenting aggregated metrics. Once all individual visual representations are created, they are arranged on a dashboard canvas, where users can define various filters and interactivity rules. This enables the creation of a dynamic and responsive dashboard, offering great flexibility in configuring these elements to ensure the dashboard can cater to a wide range of analysis needs and user preferences.

3.3 Dashboard anatomy and user interaction

The user interface represents an integrated single-page dashboard featuring multiple linked visualization modules, such as geographic maps, aggregated visualizations (i.e., histograms), and views showing temporal changes (i.e., line charts, strip plots), see Figure 3. Geographic maps enable users to visualize spatial developments and trends, providing a clear understanding of spatial patterns. Histograms offer an overview of the distributions of individual values within the dataset, making it easy to identify frequency patterns and outliers. Line charts facilitate the analysis of temporal evolutions of a parameter, allowing users to track changes and trends over time. In our application, we also employed strip plots to visually represent specific hours during which UTCI values correspond to different heat stress categories, such as strong, moderate, or no thermal stress. These categories are depicted as color-coded dots aligned along a timeline, providing a clear and intuitive overview of hourly distribution of heat stress categories. The single-page layout enables easy navigation and a clear overview by presenting all visualization modules at a glance, removing the need for scrolling and enabling effortless comparison across different data dimensions. We incorporated multiple histogram views that distinctly represent the baseline and scenario case, enabling users to perform a comparative analysis between the existing conditions and intervention outcomes. We also provided users with layer control on the geographic map, enabling them to explore different layers (e.g., base case and intervention scenario) by toggling off the unwanted visualizations for a better overview of desired states. We also added supporting labels that not only display the respective parameter and its values, but also highlight the ranges corresponding to no thermal stress, moderate stress, or high thermal stress.

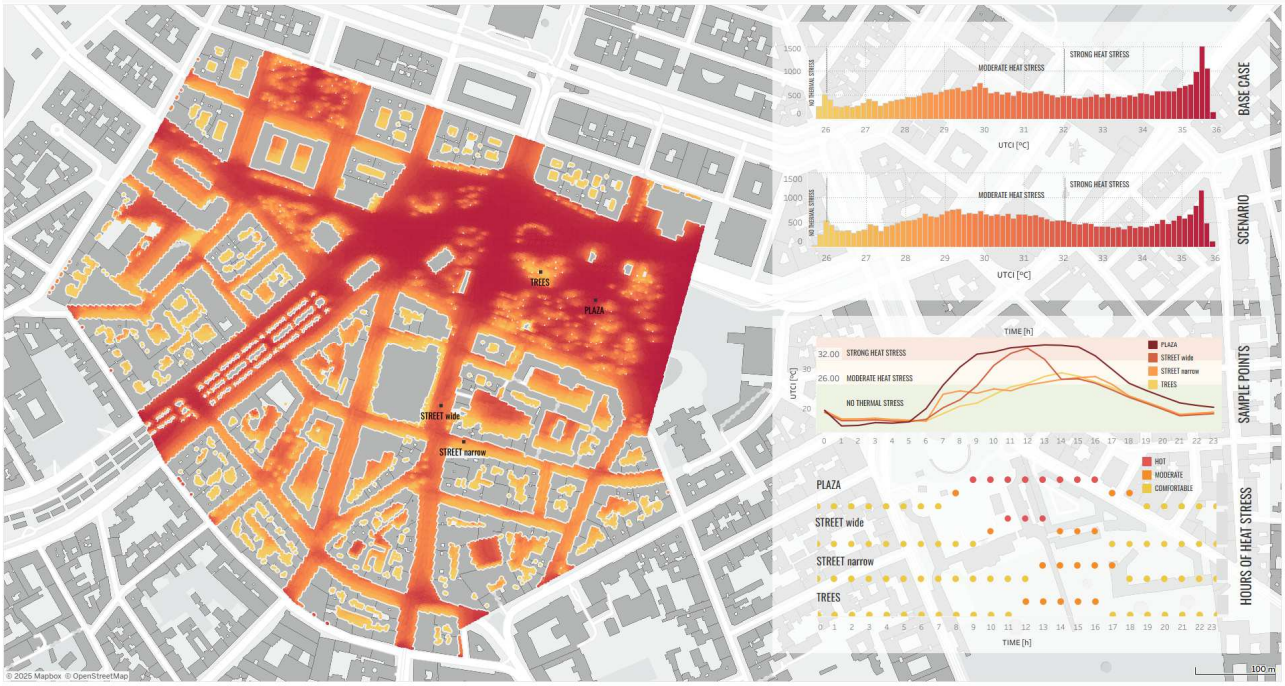

Fig. 3: The user interface of a web-based, scenario-driven visual analytics dashboard designed to visualize and explore complex spatio-temporal microclimate dynamics in an engaging and accessible way.

The visualization modules are interconnected and highly responsive, whereby actions in one view immediately affect the others. Users can dynamically explore data through techniques such as selection (rectangle and lasso selection) and filtering, allowing them to focus on a specific subset of data in one view while simultaneously visualizing the corresponding data points across other views, ensuring consistency and relevance throughout the interface (see Figure 4). The dynamic opacity adjustments available on the geographic map help preserve the contextual relationships within the entire dataset when specific data points are selected, ensuring a clear connection between the selected and surrounding data (see Figure 5). Additionally, consistent color encoding across the dashboard assigns unique hues to distinct values, enabling clear differentiation and intuitive interpretation of the data. This approach eliminates the need for additional contextual elements, such as legends, reducing visual clutter and enhancing the overall user experience. For example, in the histogram view, the applied binning technique aggregates data into predefined UTCI value ranges, visualizing frequency by counting the number of data points that fall within each range. Each bin is then color-coded with unique hues that are directly linked to the numeric UTCI labels underneath, providing a seamless connection between the visual and numerical data (see Figure 3). Lastly, we implemented a tooltip functionality to enhance interactivity and provide additional contextual information. By hovering over specific elements within the visualizations, users can instantly access detailed value information on data points, such as the UTCI value, but also how many data points are considered within an active selection.

4 PUBLIC DEMONSTRATIONS

4.1 Structure and format of the public demonstrations

As a research organization, we are dedicated to the continuous improvement of our technologies by actively reflecting on their usability and functionality, informed by feedback from external audiences. To this end, we conducted several public demonstrations with a diverse group of stakeholders, including policymakers, urban planners, government representatives, scientific and industry partners, and students. These sessions were held at our research institution's premises during various public events over the past year.

Specifically, during these demonstrations, we showcased an exploratory workflow designed to highlight the dashboard's ability to guide users through complex geospatial datasets, enhance communication of heat risks, and support the conceptualization of targeted strategies to mitigate the impacts of extreme heat in urban environments. The workflow focused on assessing how effectively the dashboard helps users identify high-risk zones, prioritize areas for immediate intervention, and understand the dynamics of heat exposure in urban settings. The high-level evaluation relied on observational data, capturing the audience's reactions, while participants were also encouraged to ask questions to assess their level of understanding, fostering an interactive and insightful experience for all.

4.2 Explorative workflow

We began with a brief introductory segment where we provided an overview of the numerical simulation setup, the planning strategies considered, and the methods used to assess the resulting outcomes. Following this, we proceeded with the interactive demonstration, starting with an explanation of the interface design and the purpose of the data visualization modules. We then went deeper into the geospatial map visualization, demonstrating the spatial heat distribution of both the base case and the intervention scenario by toggling the respective layers on and off. This was meant to provide a general overview of the spatial thermal situation within the target area, but also an overview of the spatial thermal benefits resulting from the considered interventions, such as urban trees and shading. However, we found it necessary to manually direct the user's attention to specific areas where the benefits were occurring, as the untrained viewers had difficulty memorizing the spatial distributions from the previous layer (i.e., the base case) and perceiving the respective deviations in the active layer (i.e., the intervention scenario).

The full potential of our dashboard was realized when we employed the histogram view and its interactive features. By selecting values that corresponded to strong heat stress (i.e., a range between 32 and 38 °C), the map view responded in real time, instantly isolating the areas experiencing these conditions (Figure 4). This interaction evoked a highly positive response from the audience, as it provided an intuitive and immediate way to visually identify vulnerable localities within the target area that are prone to summertime overheating and strong heat stress. We then explored how these conditions of high heat risk varied across different cases by toggling the map layers on and off yet again. However, this now became much easier to perceive, as only

a smaller portion of the data points were visible in both layers, making the resutling deviations more apparent even to the untrained eye.

Following, we demonstrated the interconnected functionality of the visualizations by selecting areas of strong heat stress directly on the map, corresponding to areas where interventions were applied in the intervention scenario (Figure 5). This interaction triggered an instantaneous update in the histogram view, enabling the audience to analyse the impact of these mitigation strategies through a side-by-side comparison of two histograms, one representing the base case and the other the intervention scenario. This interaction helped the audience clearly understand how such measures could reduce heat stress, supported by the visible shift in value distribution in the histograms between the two cases, along with the noticeable reduction in data points representing strong heat stress in the intervention scenario.

Finally, we examined the heat regimes of preselected locations within the target area. We began by explaining the temporal evolution of each diurnal cycle within open plaza, under the trees, and from the two urban canyons, using a line chart. To make this chart even more comprehensive, we introduced color bands that corresponded to value ranges representing different levels of heat stress (Figure 6). The line chart is linked to strip plots showing the amount of hours of heat stress. By selecting the strong heat stress band from the line chart, we could immediately visualize the hours during which these conditions occurred in strip plots below. These strip plots also facilitated a comparative assessment across different locations, highlighting the significant differences in heat stress hours. For instance, during the investigated diurnal cycle, the open plaza experienced 8 hours of strong heat stress, the wide canyon had 3 hours, while the other two locations saw no strong heat stress at all. These insights allowed us to demonstrate the potential of different urban configurations in either naturally mitigating (e.g., radiation shielding by the surrounding geometry) or being vulnerable to urban overheating (e.g., a full exposure to the incoming solar radiation).

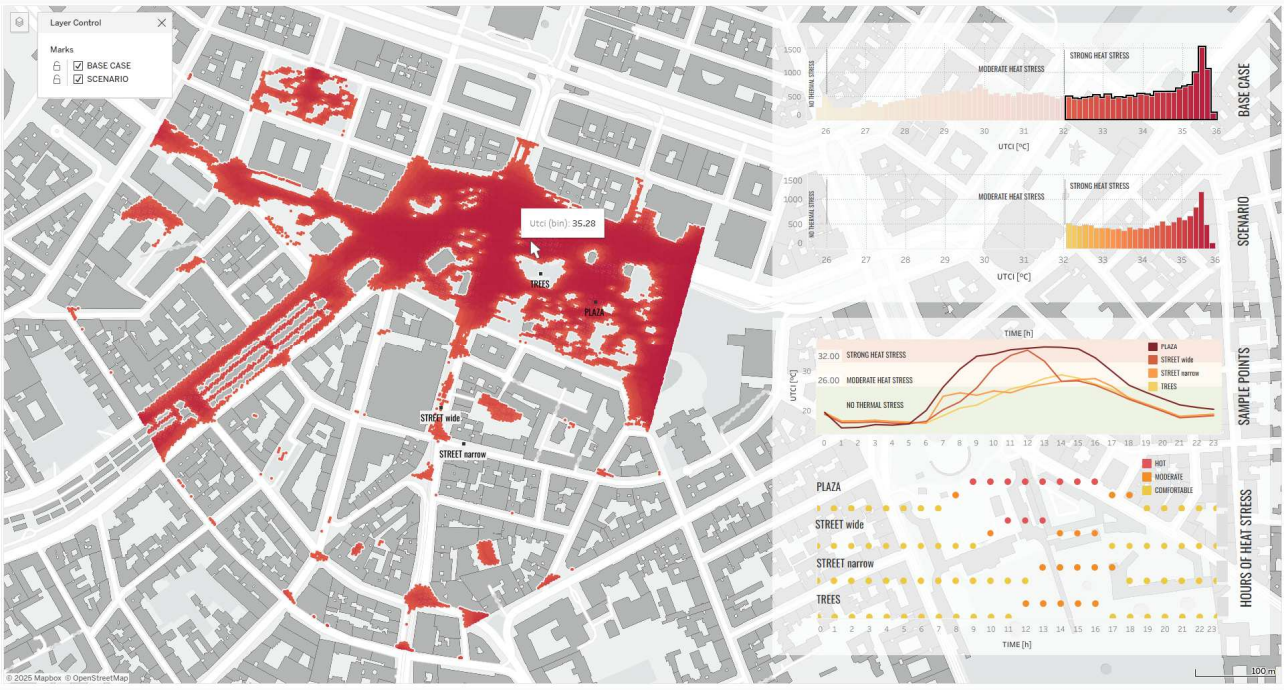

Fig. 4: Real-time geospatial mapping of urban areas experiencing strong heat stress (32 – 38 °C), with dynamic filtering isolating affected zones enabled by the histogram view and its associated user interactions.

Fig. 5: Demonstration of the interconnected visualizations, where selecting areas of strong heat stress on the map triggered instantaneous updates in the histogram view, allowing a side-by-side comparison of the base case and intervention scenario.

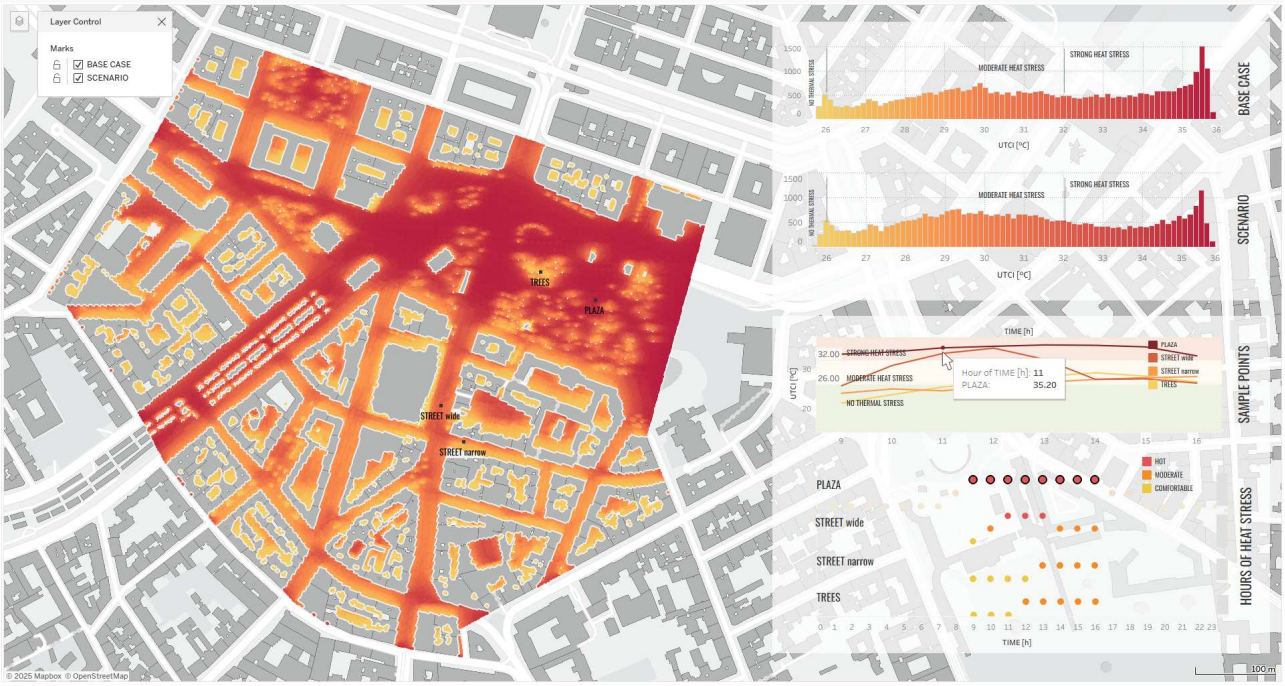

Fig. 6: Interactive selection of the strong heat stress band from the line chart, visualizing the corresponding hours of same conditions in strip plots below. The strip plots enabled a comparative assessment across multiple locations, revealing significant differences in total amount of heat stress hours.

5 CONCLUSION

In this paper, we introduced an innovative web-based, scenario-driven Visual Analytics (VA) dashboard designed to support stakeholders in visualizing, analyzing, and responding to the complexities of urban heat dynamics. We emphasized the dashboard's core features, showcasing its interactive capabilities, interlinked responses, and real-time updates across multiple visualization modules. Additionally, we discussed feedback from a public demonstration phase, which highlighted the platform's practical application and its significant value in real-world decision-making. Overall, the VA dashboard proves to be a powerful tool for urban planners and decision-makers, enabling more effective, data-driven responses to urban heat challenges and promoting a collaborative approach to climate adaptation.

6 ACKNOWLEDGEMENT

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🏆 reviewed paper

Von Funktionalität zu Integration: Energiespeicher im urbanen Raum neu gedacht

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1 ABSTRACT

Die Energiewende erfordert neben dem Ausbau erneuerbarer Energieerzeugungsanlagen auch eine deutliche Erweiterung der Energiespeicherkapazitäten, um die Volatilität von Wind- und Solarenergie auszugleichen. Trotz der wichtigen Rolle von Energiespeichern im Energiesystem bleibt deren räumliche Integration bislang weitgehend unbeachtet. Der Beitrag untersucht die Raumwirksamkeit dieser neuen technischen Infrastrukturen und zeigt theoretische sowie praktische Ansätze zur besseren Integration von Energiespeichern in den baulichen und landschaftlichen Kontext auf.

Als eines vonverschiedenenWerkzeugen, wie z.B. frühzeitige Bürgerbeteiligungen oder die Schaffung finanzieller Anreize, stellt die städtebauliche Integration der Speicheranlagen ein potenzielles Werkzeug zur Erhöhung gesellschaftlicher Akzeptanz dar. Dadurch könnten Widerstände in der Bevölkerung und damit verbundene Verzögerungen im Ausbau reduziertwerden. Der Beitragstelltfünf theoretische Ansätze zur Integration vor: von einer rein Monofunktionalität bis hin zu Ansätzen, die Design, Information, Multifunktionalität und lokale Identität miteinander verbinden. Im Rahmen des vom BMWK geförderten Projekts NEKOM wurden erste Entwürfe für Klein- und Mittelstädte im Rheinischen Revier entwickelt, die auf den lokalen Gegebenheiten und Bedürfnissen basieren.

Die dargestellten Entwürfe zeigen, wie Speicheranlagen zukünftig als städtebaulicher Mehrwertverstanden werden können. Ziel ist es, technische und gesellschaftliche Anforderungen zu vereinen, um übertragbare Konzepte für die zukünftige Praxis zu schaffen. Ein Leitfaden für kommunale Akteure soll dabei helfen, die Akzeptanz durch innovative Integrationsstrategien zu fördern und den Speicherausbau voranzutreiben.

Keywords: Städtebauliche Integration, Smart Grid, Energiespeicher, Akzeptanz, Technische Infrastrukturen

2 EINFÜHRUNG

Die Transition unseres Energiesystems in Richtung erneuerbarer Energiequellen stellt eine der essentiellen Säulen globaler Bemühungen dar, Treibhausgasemissionen zu reduzieren.Eine nachhaltige Energieversorgung verringertdie Abhängigkeit von endlichen fossilen Ressourcen. Neben dem stetigen Ausbau erneuerbarer Erzeugungsanlagen stellt die Zunahme an Energiespeicherkapazitäten eine elementare Gelingbedingung der Energiewende dar(BMWK 2024; VICTORIA et al. 2019; IPCC 2011).

Die Dargebotsabhängigkeit der Wind- und Solarenergie bringt im Vergleich zur konventionellen Energieerzeugung einen variablen zeitlichen Versatzzwischen Energiebereitstellung und -verbrauch mit sich. Um diesen Versatz auszugleichen, gibt esim Wesentlichen zwei Lösungsansätze: Nachfragesteuerung und Speicherintegration(WENDORFF 2022). Dieser Beitrag setzt die temporäre Speicherung der Energieüberangebote in Form von Elektrizität, Gas oder Wärme in den Fokus. Der Bedarf und Ausbau an Energiespeichern wächst dabei besonders in den letzten Jahren massiv an und stellt auch die Basis zukunftsfähiger intelligenter Stromnetze dar. Im Vergleich zum Jahr 2020 (17 GW) soll sich die global installierte Speicherleistung bis zum Jahr 2030 (358 GW) mehr als verzwanzigfachen (BLOOMBERGNEF 2021). Während die technische Integration der Speicher in die Energienetze seit Jahren im Fokus der Forschung steht, bleiben die signifikanten räumlichen Auswirkungen dieser neuen technischen Infrastrukturen bisher weitestgehend unbetrachtet. Energiespeicher werden dabei nicht nur wenig wahrnehmbar in peripheren Räumen installiert, sondern auch als präsent sichtbare Infrastrukturen in direkter Nähe zur Erzeugung und Verbrauch in urbanensowie suburbanen Siedlungsbereichen ausgebaut. Während gesamtgesellschaftlich eine hohe Zustimmung zur Transition des Energiesystems ausgemacht werden kann(AGENTUR FÜR ERNEUERBARE ENERGIEN E.V. 2023), materialisieren sich Defizite der lokalen Akzeptanz in Form von Protesten bis hin zu Vandalismus gegenüber den neuen raumrelevanten Komponenten der Energiewende. Die Vernachlässigung der lokalen Bedürfnisse bei geplanten Projektender

Energiewende kann Planungen erheblich verzögern oder gänzlich zum Scheitern bringen(ALTHAUS 2012). Zur gesellschaftlich getragenen und akzeptierten räumlichen Integration des Bausteins Energiespeicher sind neueIntegrationsansätze gefordert, um auch die Raumrelevanz der Speicheranlagen adäquat berücksichtigen zu können.

Im Rahmen dieses Beitrags werden zunächst Wirkungsweise, Relevanz sowie Raumwirksamkeit von Energiespeichern näher vorgestellt. Anschließend werden theoretische Integrationsansätze von Energiespeichern und intendierte Auswirkungen auf die lokale Akzeptanz präsentiert. Darauf aufbauend werden im fünften Kapitel konkrete Entwürfe für ausgewählte Klein- und Mittelstädte im Rheinischen Revier vorgestellt und erläutert. Der Beitrag endet mit einem Ausblick zur Schaffung übertragbarer Ansätze der Speicherintegration zur Steigerung gesellschaftlicher Akzeptanz.

Die hier vorgestellten Ansätze und Ergebnisse stellen erste Zwischenergebnisse des vom Bundesministeriums für Wirtschaft und Klimaschutzes (BMWK) geförderten Forschungsprojekts NEKOM – Nachhaltige Speicher- und Energieverteilungssysteme in kleineren und mittleren Kommunen unter Berücksichtigung gesellschaftlicher Akzeptanz der Energiewende dar. Die dargestellten theoretischen Ansätze leiten sich aus einer umfangreichen Literaturrecherche zur städtebaulichen Integration technischer Infrastrukturen und deren Anwendung auf Energiespeicher ab. Als Grundlage der konkreten Entwürfe wurde eine Interviewstudie mit den im NEKOM-Projekt beteiligten Kommunen durchgeführt. Im Rahmen eines interdisziplinären Lehrprojekts erarbeiteten Masterstudierende der Architektur und Stadtplanung an der RWTH Aachen im Wintersemester 2024/25 innovative Ansätze zur Speicherintegration, welche im weiteren Verlauf dieses Beitrags näher vorgestellt werden.

3 ENERGIESPEICHER ALS BAUSTEIN DER ENERGIEWENDE

In diesem Kapitelwird zunächst die Bedeutung von Speichern im Energiesystemdargestellt. Darauf aufbauend werden unterschiedliche Speichermedien und -typen vorgestellt sowie auf Standortfragen und Herausforderungen in der Platzierung der neuen technischen Anlagen näher eingegangen.

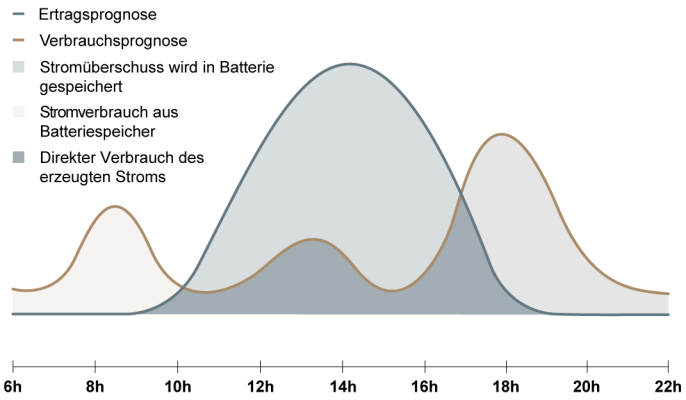

Abbildung 1:Schematische Darstellung Anwendungsfall Stromspeicher. Eigene Darstellung

3.1 Funktion und Bedeutung im Energiesystem

Energiespeicher stellen neben den erneuerbaren Energien einen immer wichtigeren Baustein in der Umsetzung der Energiewende dar. Die Energieproduktion aus Wind- und Solarenergie ist volatil, also abhängig von Wetterbedingungen und unterliegt tageszeitlichensowie saisonalen Schwankungen.Auf diese Weise entsteht ein zeitlicher Versatz zwischen Energiebereitstellung und -verbrauch. Zur Überbrückung dieses Versatzes stellt die Speicherintegration einen Ansatz dar, die Energieversorgung aus regenerativen Quellen auch zu Zeiten geringer Produktion zu gewährleisten.Abbildung 1 zeigt die exemplarische Auf- und Entladung eines Batteriespeichers aus Solaranlagen. Energiespeicher können, nebender Erhöhung des Eigenverbrauchs, noch weitere Funktionen im Energiesystem einnehmen, wie unter anderem die Netzstabilisierung, den Einsatz imNetzengpassmanagement sowie die Gewährleistung einer unterbrechungsfreien Stromversorgung bei kritischen Infrastrukturen wie Krankenhäusern oder als Systemdienstleistung (STADLER & ECKERT 2017; STERNER et al. 2017c). Neben den vor allem im Eigenheimbereich bereits vielfach genutzten Stromspeichern werden zukünftig Wärme- und

Wasserstoffspeicher sowie Batteriegroßspeicheranlagen eine essentielle Rolle im Energienetz einnehmen und zur Systemintegration erneuerbarer Energien beitragen(BMWK 2024).

3.2 Technologische Grundlagen und Typen von Energiespeichern

Es bestehen verschiedene Ansätze zur Klassifizierung von Energiespeichern. Ein oft verwendeter Ansatz nimmt die Einteilung anhand der gespeicherten Energieform vor. Dabei lassen sich vier Formen unterteilen: elektrische, chemische, mechanische und thermische Energie, welche in weitere Untergruppen aufgeteilt werden können (STERNER & BAUER 2017).

Elektrische Speicher in Form von Kondensatoren und Spulen ermöglichen eine direkte Speicherung elektrischer Energie ohne Wandlungsverluste, sind jedoch aufgrund ihrer geringen Energiedichten und hohen Kosten meist Nischenanwendungen(STERNER et al. 2017b; STADLER 2017). Bei chemischen Speichern wird Energie in Form von gasförmigen, flüssigen oder festen Medien gespeichert.Chemische Energiespeicher spielen eine entscheidende Rolle in der Energiewende, insbesondere als Langzeitspeicher sowie für die Bereitstellung von Brenn- und Kraftstoffen in den Sektoren Mobilität und Wärme (STERNER & BAUER 2017; STERNER et al. 2017a) . Überschussstrom aus erneuerbaren Energien kann zukünftig mithilfe von Power-to-Gas zur Herstellung von Wasserstoff und synthetischem Methan genutzt werden, welches dann in Gasspeichern (STERNER & BAUER 2017) gespeichert werden.

Elektrochemische Speicher wie Akkumulatoren und Batterien stellen eine Untergruppe der chemischen Speicher dar und dienen oftmals als Kurzzeitspeicher in Form von Heimspeichern oder Quartierslösungen. Die Anlagen werden in Form von Containerlösungen im Außenbereich oder in Gebäuden platziert. Wärme- und Kältespeicher zählen zu den thermischen Speichern, diese nutzen thermodynamische Prinzipienum Energie zu speichern (STERNER & BAUER 2017; STADLER & HAUER 2017). Hierbei werden unter anderem große Erdwärmebecken oder großen Tanks/Behälter eingesetzt. Mechanische Speicher in Form von unter anderem Pumpspeichern nutzen die Grundlagen der Physik, um Energien zu speichern(STADLER et al. 2017).

Im weiteren Verlauf des Beitrags wird der Fokus primär auf elektrochemische sowie thermische Speicher gelegt.

3.3 Energiespeicher im Raum

Durch den Ausbau von erneuerbaren Energien wie Windparks und Freiflächenphotovoltaikanlagen verändern sich die Standorte der Stromproduktion von zentralen Großkraftwerken hin zu dezentralen Anlagen, wodurch die Energieproduktion näher an die Verbrauchseinheiten rückt. Durch die oben aufgeführte Volatilität nimmt nicht nur die Anzahl der Erzeugungsanlagen zu, auch wird die Zahl der benötigten Speicher signifikant ansteigen müssen. Dabei werden die Anlagen, analog zu den Erzeugungsanlagen, immer präsenter und wahrnehmbarer im Raum verortet werden. Energiespeicher als neue technische Infrastrukturen treten dem Konkurrenzkampf um die begrenzte und begehrte Ressource Raum bei. Durch die Größe der Anlagen kommt ihnen in vielen Fällen eine signifikante Raumrelevanz zu. Die Bundesstiftung Baukultur hält fest: „Infrastrukturen prägen Landschaften und Städte bisweilen für Jahrhunderte.“(BUNDESSTIFTUNG BAUKULTUR 2024: 26). Verortung sowie Integration der Speicher in den baulichen Bestand und die Landschaft stellen damit eine wichtige und wegweisende Zukunftsaufgabe aus stadt- und raumplanerischer Perspektive dar. Vergleichbar zum Ausbau der Erzeugungsanlagen ist auch beim konkreten Ausbau der Speicheranlagen mit partieller Ablehnung seitens der lokalen Bevölkerung zu rechnen. Die Berücksichtigung lokaler Gegebenheiten und Interessen könnte Ansätze liefern, die gesellschaftliche Akzeptanz zum Ausbau neuer technischer Anlagen zu erhöhen. Im Folgenden werden zunächst theoretische Ansätze aufgezeigt, wie Energiespeicher mit Raumbezug zur Erhöhung der lokalen Akzeptanz beitragen könnten. Anschließend werden diese Ansätze anhand konkreter Entwürfe kombiniert und visualisiert.

4 THEORETISCHE INTEGRATIONSANSÄTZE FÜR ENERGIESPEICHER: VON DER FUNKTIONALITÄT ZUR RAUMGESTALTUNG

Neuebauliche Anlagen können aus städtebaulicher Perspektive, je nach Intention und vorhandenen Ressourcen, auf verschiedene Art und Weise in den Bestand integriert werden.REICHER(2017) unterscheidet beispielsweise die Prinzipien der Über-, Unter- und Einordnung neuer Bauwerke in den

Bestand. Basierend auf den Integrationsansätzen von REICHER(2017), BESIER(2016) und CUCUZZELLA & GOUBRAN(2019)leitet WENDORFF(2024) Integrations- und Gestaltungsansätze für technische Infrastrukturen im urbanen Raum ab. Aufbauend auf diesen Ansätzenund anhand von good-practice-Beispielen wurden spezifische Integrationsansätze für Energiespeicher abgeleitet, schematisch dargestellt in Abbildung 2.

Wie alle anderen Stadtbausteine auch, lassen sich Energiespeicher auf vielfältigen Wegen in die gebaute Umwelt integrieren. Übergeordnet lässt sich zwischen der technischen und der städtebaulichen Integration unterscheiden. Die technische Integration von Energiespeichern zeichnet sich durch einen fast ausschließlichen Fokus auf techno-ökonomische Effizienz in der gestalterischen Umsetzung der Anlagen aus. Die Anlagen weisen damit in der Regel keinen Bezug zum Bestand auf. Städtebauliche Integrationsansätze versuchen dahingegen durch dasbewusste Einfügen und Anpassen der neuen technischen Infrastrukturen in den Bestand zusätzliche Mehrwerte für dielokale Bevölkerung zu realisieren. Die beiden genannten Integrationsansätze lassen sich noch einmal hinsichtlich ihres Nutzungsansatzes sowie ihres Gestaltungsansatzes unterteilen. Der Nutzungsansatz adressiert die Funktionen der Anlagen im Raum. Der Gestaltungsansatz beeinflusst insbesondere die Wahrnehmbarkeit der Energiespeicher. Das Spektrum der gestalterischen Einbettung reicht von einer möglichstdezenten Integration bis hinzu einer stark raumprägenden Integration.Abbildung 2 ist die schematische Einteilung im Überblick zu entnehmen. Im Folgenden werden die theoretischen Nutzungsansätze zur besseren Verständlichkeit kompaktskizziert. In der Praxis können Anlagenkonzepte oft mehreren Ansätzen zugeordnet werden. Der Übergang zwischen den einzelnen Ansätzen ist fließend.

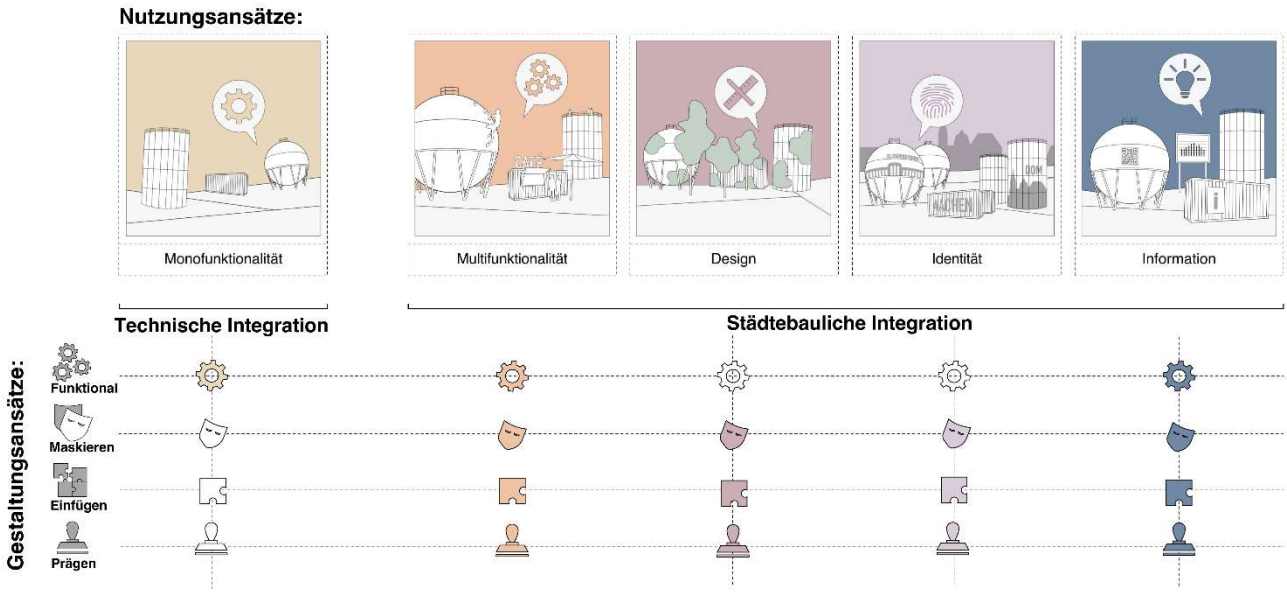

Abbildung 2: Integrationsansätze. Eigene Abbildung

4.1 Monofunktionalität

DermonofunktionaleNutzungsansatz zeichnet sich durch eine techno-ökonomische Perspektive auf die Gestaltung sowie Verortung vonEnergiespeichern aus. Die technologischen Aspekte stehen fast ausschließlich im Vordergrund, um eine maximale Effizienz bei der Energiespeicherung realisieren zu können. Die gestalterischen Belange sowie der Landschaftsbezug bleiben weitestgehend unbeachtet. Monofunktionale Integrationsansätze stellen aktuell den Status quo bezüglich des Ausbaus von Speicheranlagen dar. Für das Beispiel eines Batteriespeichers auf Quartiersebene sind dem Ansatz der Monocodierung beispielsweise die in der Regel in gräulichen Farben gehaltenen Container zuzuordnen, welche die einzelnen Speichereinheiten beherbergen.Abbildung 3 zeigt einen monofunktionalen Stromspeicher auf Quartiersebene.

Abbildung 3: Monocodierter Quartierspeicher. Foto: Sarah Hermens

4.2 Multifunktionalität

Der Nutzungsansatz der Multifunktionalität koppelt den Anwendungsfall der Energiespeicherung mit jeweils einer oder mehreren weiteren Funktionen. Die Anlagengestaltung orientiert sich in der Regel an der zusätzlichen Funktionalität. In Heidelberg wurde beispielsweise ein Wärmespeicher zur Flexibilisierung des lokalen Energiesystems installiert, in welchem die bei der Stromerzeugung entstandene Wärme gespeichert und an kalten Tagen wieder abgegeben wird. Neben dem prämierten Architekturkonzept ist auch eine Multifunktionalität vorgesehen. Auf dem Speicher entsteht bis 2026 eine Gastronomie mit einer Aussichtsterrasse. Zudem ist der Wärmespeicher als eines von mehreren Bestandteilen in den entstehenden angrenzenden Energie- und Bewegungspark eingebettet (STADTWERKE HEIDELBERG GMBH 2022).

4.3 Information

Beim Nutzungsansatz der Information werden Speicheranlagen durch ein informatives Angebot ergänzt und derengesellschaftliche Mehrwerte erklärt. Die Wissensvermittlung kann auf unterschiedliche Art und Weise erfolgen, beispielsweise in Form von detailliertenLeistungsanzeigen, Infotafeln oder auch über die niedrigschwellige Vermittlung von Informationen wie Größenverhältnissen. InAbhängigkeit der Ausgestaltung kann das Informationsangebot auch im Vorbeifahren bzw. -gehen wahrgenommen werden. Mit den Angeboten soll das Verständnis für den Nutzen und die Notwendigkeit der Infrastrukturen vergrößert werden. Außerdem istdie Herstellung eines persönlicheren Bezugs zu den Anlagen erwünscht. Insbesondere Leistungsanzeigen, die den Anwohnern diepositive Auswirkung der Energieerzeugung für ihren Wohnort zeigen, könnten eine Möglichkeit der Akzeptanzsteigerung bieten.Bei regenerativen Erzeugungsanlagen, wie etwa Freiflächensolaranlagen, werden Informationsangebote bereits häufig verwendet und in der Öffentlichkeitsarbeit empfohlen (MINISTERIUM FÜR UMWELT, KLIMA UND ENERGIEWIRTSCHAFT BADEN-WÜRTTEMBERG 2019).

4.4 Design

Der Nutzungsansatz des Designs zeichnet sich durch einen Fokus auf die Gestaltung der Energiespeicher aus. Die Erfüllung der gestalterischen Belange kann zum Beispiel durch eine Bemalung der Anlagen ohne eine Beeinträchtigung der Funktionalität und Effizienz erfolgen. Bei Ansätzen,welche eine besondere Formgebung der Anlagenvorsehen, ist es jedoch möglich, dass sich die Effizienz oder die Rentabilität der Anlagen verschlechtert. Durch eine möglichst ansprechende und auffällige oder eine bewusst maskierende Gestaltung der Anlagen wird der Ansatz in der Regel bei Standorten mit einer guten Sichtbarkeit angewendet. Die Anlagen sollen dabei, je nach Ansatz, bewusst wahrgenommen werden oder in den Hintergrund treten. Ein Beispiel für eine auffällige Gestaltung stellt eine Community-Battery in Melbourne, Australien, dar. In diesem Ansatz wurde der Energiespeicher von einem lokalen Künstler durch Anregung der lokalen Bevölkerung gestaltet.

4.5 Identität

Der Nutzungsansatz der Identität nimmt lokalspezifische Besonderheiten in die Ausgestaltung der Anlagen auf. Auf diese Weise sollendie Anlagen als organischer Bestandteil des Raumes verstanden werden und zur Stärkung der Regionalidentifikation beitragen. Durchdie Wahrnehmung von beispielsweise Energieerzeugungsanlagen als Teil der Landschaft besteht die Möglichkeit, den Widerstand gegen dieAnlagen zu reduzieren(SCHWEIGER et al. 2018).Die Integration von lokalen Aspekten kann zum einem

konservativ-phobisch erfolgen. Das bedeutet, dass bestehende Narrativeder Region aufgenommen und fortgeschrieben werden. Es kann an die Historie eines Ortes erinnert werden oder typischeIdentifikationsfarben der Region in der Anlagengestaltung verwendet werden. Alternativ kann die Integration progressiv-obsessivgeschehen. Das heißt, dass beispielsweise Energieerzeugungsanlagen für den Beginn neuer regionaler Erzählungen genutzt werden können.Dies kann zum Beispiel durch die Nutzung von Eigennamen für die Energieerzeugungsanlagen erfolgen (SCHWEIGER et al. 2018).

Abbildung 4: Gestalteter Batteriespeicher in Melbourne. Foto: Sarah Hermens

Abbildung 5: Überblick Rheinisches Revier. Eigene Abbildung auf Datengrundlage von OpenStreetMap

5 INTEGRATIONSENTWÜRFE FÜR DAS RHEINISCHE REVIER

Das im Westen Deutschlands, zwischen den Städten Köln, Mönchengladbach und Aachen, gelegene Rheinische Braunkohlerevier (vgl.Abb. 5) ist seit Jahrzehnten eng mit dem Abbau sowie der Verstromung und Veredlungvon Braunkohle verbunden. Im Rheinischen Revier leben ca. 2,4 Millionen Einwohnerinnen und Einwohner auf ca. 5.000 km² und in 65 Kommunen (ZUKUNFTSAGENTUR RHEINISCHES REVIER 2020). Einst als Möglichmacher des industriellen Aufschwungs endet der Kohleabbau in Deutschland zum Jahr 2030. Die Energiewirtschaft sowie die energieintensive Industrie stellen eine wichtige Säule des Wohlstandes der Region dar. Das Rheinische Revier als Europas größtes Braunkohleabbaugebiet steht damit vor enormen und teilweise sehr individuellen Transformationen. Auch nach der anstehenden Transition soll das Rheinische Revier als Energieregion fungieren. Neben dem enormen Ausbau regenerativer Erzeugungskapazitäten sieht das Wirtschafts- und Strukturprogramm des Reviers den Aufbau einer Vielzahl von Energiespeicheranlagen als essentielle Säule zur Meisterung der Energiewende der Region vor (ZUKUNFTSAGENTUR RHEINISCHES REVIER 2021).

Im Rahmen des oben genannten Forschungsprojekts NEKOMerarbeitet die RWTH Aachen University in Kooperation mit der Universität Duisburg-Essenfür die drei Kommunen, die Stadt Heinsberg, die Stadt Bedburg sowie die Gemeinde Roetgenund deren Netzbetreiber,Konzepte zur technischen Auslegung, Verortung sowie der städtebaulichen Integration von Energiespeichern. In den folgenden Absätzen werden divergierende studentische Ansätze vorgestellt, welche verschiedene Möglichkeiten aufzeigen, Energiespeicher als mehrwertstiftenden und akzeptierten Stadtbaustein zu verstehen und zu nutzen.Die entstandenen Entwürfe stellen an die lokalen Gegebenheiten angepasste Mischformen aus den im vorherigen Kapitel vorgestellten Nutzungs- und Gestaltungsansätzen dar.

5.1 Energiespeicher als Mehrwert

Technischen Anlagen aus stadtplanerischer Sicht weitere Nutzungen hinzuzufügen kann sich positiv auf deren gesellschaftliche Akzeptanz auswirken (WENDORFF 2024). Dieses Phänomen lässt sich nach Auffassung der befragten Expertinnen und Experten auch auf Speicheranlagen übertragen, indem die rare Ressource Fläche neben der Beheimatung technischer Anlagen weitere Nutzungsmöglichkeiten für die lokale Bevölkerung schafft und sich mehrwertstiftend in den Bestand integriert. Die entwickelten und nachfolgend aufgezeigtenEntwürfe können übergeordnet dem im vorherigen Kapitel vorgestellten Nutzungsansatz der Multifunktionalität zugeordnet werden. Bezüglich des Gestaltungsansatzes reicht dieWarhnehmbarkeit von einer möglichst zurückhaltenden über eine einfügende bis zu einer prägenden Wirkung. Im Folgenden werden drei studentische Entwürfe eines mehrwertstiftenden Integrationsansatz exemplarisch vorgestellt und die theoretischen Konzepte greifbarer gemacht.

5.1.1 Abenteuerspielplatz Schafhausen

Für das Neubaugebiet Schafhausen in der Stadt Heinsberg wurde ein Quartiersspeicher geplant, welcher den Überschussstrom aus den Solaranlagen des Wohngebiets tagsüber aufnehmen und abends und nachts wieder an die Wohneinheiten abgeben soll. Der elektrische Speicher im Containerformat wird dabei verstärkt, zu großen Teilen mit Erde bedeckt und mit seiner besonderen Topographie in den angrenzenden Abenteuerspielplatz integriert. Die aufgeschüttete Erhöhung schafft neue Spielmöglichkeiten, verortet z.B. Rutschen und ermöglicht Aus- und Überblicksgelegenheiten. Die dicke Erdschicht sowie deren Bepflanzung fungieren als Isolierschicht. An der vom Spielplatz abgewandten Seite bleibt die Zugänglichkeit der Speicheranlage zur Wartung und Reparatur erhalten. Abbildung 6visualisiert den Integrationsansatz. Der Entwurf zeigt beispielhaft, wie Energiespeicher als unauffälliger Bestandteil in Neubaugebieten zum einen die Energieselbstversorgung des Gebiets erhöhen und gleichzeitig die Aufenthaltsqualität durch neue Nutzungen verbessern können. Die Speicheranlagen werden ohne Vorwissen von der Bevölkerung nicht als technische Anlagen wahrgenommen.

Abbildung 6: Stromspeicher Abenteuerspielplatz Schafhausen. Quelle: Rieke Ahlvers & Sophie Bußmann 2025

5.1.2 Marktplatz Heinsberg

Ein weiterer Ansatz, in der Stadt Heinsberg Energiespeicher mehrwertstiftend und flächensparend zu integrieren, wurde für den Marktplatz entwickelt. Hierzu wurden eine Reihe neuer Stadtmöbel konzipiert,

welche die Möglichkeit Überschussstrom aus benachbarten Solaranlagen lokal zu speichern mit der Erhöhung der Aufenthaltsqualität kombiniert. Die modular gestalteten Infrastrukturen fügen sich in den Bestand nahtlos ein undverbinden Energiespeicherung beispielsweise mit der Schaffung neuer Sitzgelegenheiten, Begrünungsoptionen oder Buchschränken. Anders als der Speicher im vorherigen Beispiel, sind die vorgeschlagenen Ansätze für den Markt deutlich wahrnehmbarer. Durch die Aufnahme lokaler Gestaltungsansätze und Ergänzung bestehender Nutzungen vor Ort, z.B. Gastronomie fügen sich die neuen Infrastrukturen jedoch harmonisch in das bestehende Stadtbild und die bereits vorhandenen Nutzungen ein (vgl. Abb. 7).

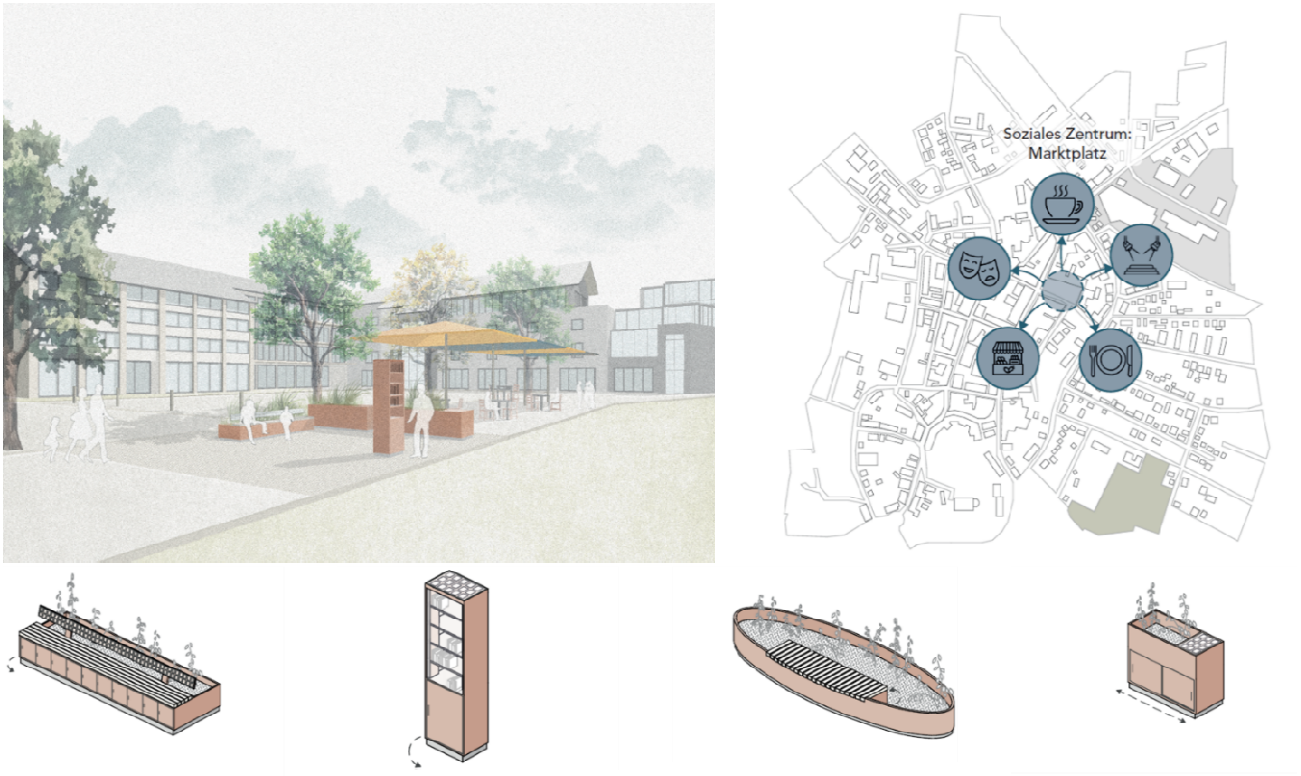

Abbildung 7: Modulare Stromspeicher für den Heinsberger Marktplatz. Quelle: Konrad Leven & Philipp Oehme 2025

5.1.3 Naherholungsgebiet Oberbruch

Der letzte Entwurf zur mehrwertstiftenden Integration von Energiespeichern nutzt am Beispiel eines Wärmespeichers die neue Infrastruktur, um den sie umgebenden Raum neu zu prägen. Als saisonaler Wärmespeicher sieht der Entwurf für Heinsberg Oberbruch die Nutzung industrieller Abwärme und Überschussstroms zur Erwärmung eines Erdbeckenspeichers vor. In den kälteren Monaten gibt der Speicher die Wärme an die benachbarten Wohngebiete wieder ab. Durch eine Isolierschicht, vergleichbar zu den Ansätzen von z.B.VAN HELDEN et al. (2021), wird der Wärmespeicher von einem weiteren Wasserreservoir getrennt. Das so entstehende Gewässer soll der lokalen Bevölkerung als Naherholungsgebiet dienen. Umgeben wird der entstehende See von einer Uferpromenade, Schwimmstegen und einem Fahrradweg. Der geplante Wärmespeicher fungiert somit nicht nur als nachhaltige Energiequelle, sondern prägt den Charakter des Gebiets von Grund auf neu und steigert dessen Attraktivität durch neue Freizeitaktivitäten (vgl. Abb. 8).

5.2 Lokale Identitäten stärken

Während die im vorherigen Unterkapitel vorgestellten Ansätze versuchen gesellschaftliche Akzeptanz für Speicher über die Schaffung neuer Nutzungen zu realisieren, adressieren die folgenden Entwürfe die lokale Identität. Durch etwa die Verwendung regionaler Baustoffe oder Bautechniken und die Referenzierung lokaler Narrative sollen die Anlagen als organischer Bestandteil der Stadtlandschaft wahrgenommen werden. Damit lassen die hier vorgestellten Entwürfe sich primär dem Nutzungsansatz Identität (vgl. Abb. 2) zuordnen. Bezüglich der angewandten Gestaltungsansätze lässt sich zwischen einem einfügenden und einem prägenden Ansatz unterscheiden.

Abbildung 8: Naherholungsgebiet Oberbruch. Quelle: Rieke Ahlvers & Sophie Bußmann 2025

5.2.1 Rathausplatz Roetgen

Für das bestehende Nahwärmenetz zwischen Rathaus, Schwimmbar und Grundschule sieht der Entwurf die Integration eines Wärmespeichers für das Zentrum Roetgens vor. Anstatt den Wärmespeicher zu verstecken,wird dieser präsent auf dem Verwaltungsvorplatz platziert. Um nicht als Fremdkörper wahrgenommen zu werden nimmt der Speicher lokaleGestaltungselemente des Bestands auf. Der für den Sockel verwendete Naturstein nimmt die klassische Bauweise der Region auf. Der Schriftzug „Tor zur Eifel“ referenziert auf die lokale Identität Roetgens. Der Entwurf verbindet den Bedarf neuer technischer Infrastrukturen mit der Berücksichtigung lokaler Architektur und versteht die neuen technischen Infrastrukturen als Stadtbausteine, die sich analog zu anderen Bauwerken in das bestehende Stadtbild integrieren sollen (vgl. Abb. 9).

Abbildung 9: Rathausplatz Roetgen. Quelle: Mirjam Niels & Jill Werchosch 2025

5.3 Umspannwerk Heinsberg

Das Umspannwerk in Heinsberg stellt einen Knotenpunkt der lokalen Energieverteilung dar. Großskalige Energiespeicheranlagen in direkter Nähe zu Umspannwerken können u.a. dazu beitragen die Stabilität des Energienetzes zu gewährleisten und benötigte Ausbaukapazitäten zu verringern. Überschussstrom der benachbarten Wind- und Solarparks wird bei begrenzten Netzkapazitäten eingelagert und zu Zeiten erhöhten Bedarfs abgegeben. Die Stromspeicher des in Abb. 10 gezeigten Entwurfswurden entlang der südlichen Einfallstraße Heinsbergs platziert. Während die Verortung und Materialität der Anlagenprimär der technischen Integration zugeschrieben werden können, versucht der Ansatz durch die optische Gestaltung der Speicher die Geschichte Heinsbergs erlebbar zu machen. Durch Abbildungen lokaler Wahrzeichen kann

die historische Entwicklung der Stadt Heinsberg im Vorbeifahren und –gehen nachvollzogen werden. Prägnante Darstellungen von Bauwerken unterschiedlicher Epochen zeigen Heinsbergs Entwicklung von ersten Römersiedlungen bis heute. Ein Fokus der gezeigten Geschichte wird auf die Bedeutung von Energie für die Region gelegt. Folgend auf den Bergbau wird die Transition in Richtung erneuerbarer Energien erfahr- und nahbar. Durch die Referenzierung lokaler Entwicklungen und Identitäten sollen die neuen technischen Infrastrukturen als integraler Bestandteil der Region wahrgenommen und die lokale Akzeptanz erhöht werden.

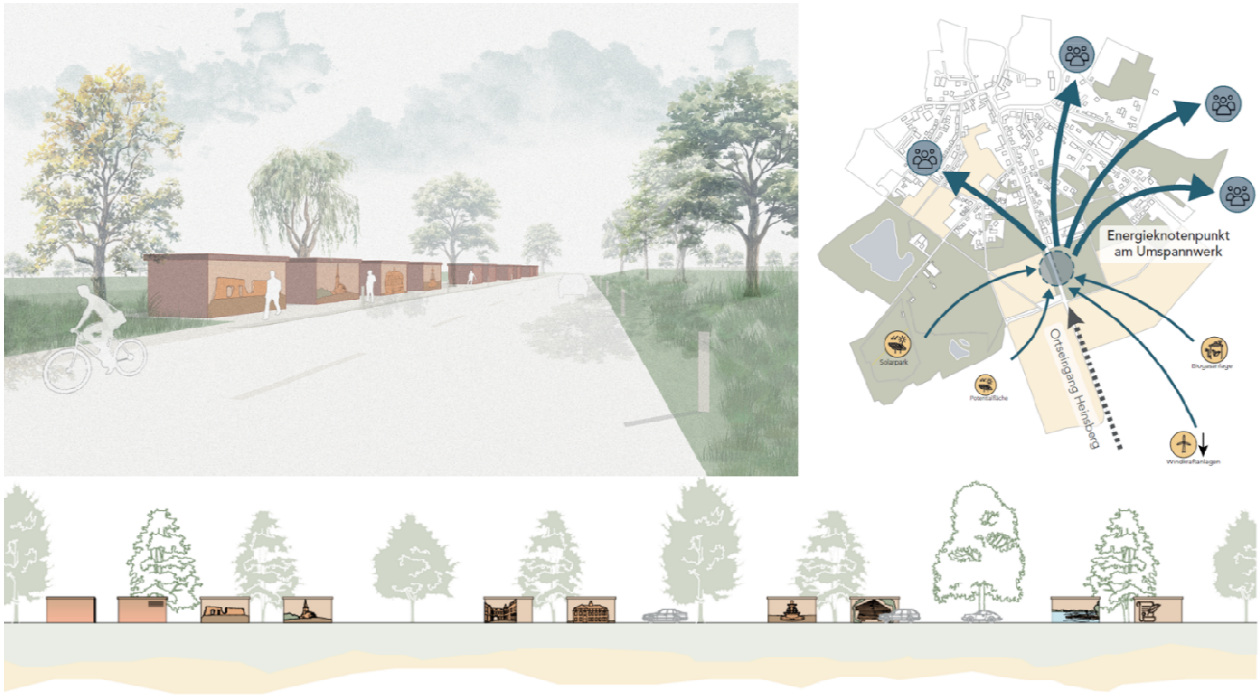

Abbildung 10: Umspannwerk Heinsberg. Quelle: Konrad Leven & Philipp Oehme 2025

6 FAZIT UND AUSBLICK

Energiespeicher werden zukünftig mehr und wahrnehmbarer im Raum verortet. Neben der technischen und ökonomischen Machbarkeit gilt es auch einen gesellschaftlichen Konsens zum Ausbau von Energiespeichern zu finden, um widerstandsbedingteVerzögerungen zu vermeiden. Veränderungen des Stadt- und Landschaftsbildes bergen ein hohes Potenzial für gesellschaftlichen Widerstand, analog zu den Erzeugungsanlagen. Als Resultat lokaler Ablehnung sind Verzögerungen im Bau sowie Kostensteigerungen zu erwarten. Als Teil verschiedener Bausteine wie z.B. frühzeitige Bürgerbeteiligungen und Informationen sowie finanzielle Anreize, stellt die städtebauliche Integration der Speicheranlagen ein potenzielles Werkzeug zur Erhöhung gesellschaftlicher Akzeptanz dar. Die hier präsentierten Entwürfe stellen erste Ansätze dar, um Energiespeicher nicht nur als technische Infrastruktur, sondern als mehrwertstiftenden Stadtbaustein zu verstehen.

Die dargestellten Integrationsansätze gilt es in einem nächsten Schritt des Forschungsprojekts NEKOM im Rahmen einer repräsentativen Umfrage auf Akzeptanzkriterien zu untersuchen. Auf diese Weise sollen jene Aspekte weiter herausarbeiten werden, die das Potenzial besitzen, die lokale Akzeptanz nachhaltig zu erhöhen. Aufbauend auf den Ergebnissen der Akzeptanzanalyse sollen die technische und ökonomische Machbarkeit von städtebaulich integrierten Speicheranlagen weiter untersucht werden, um abschließend umsetzbare Konzeptezu identifizieren. Ziel des Projekts ist die Entwicklung eines niederschwelligen Leitfadens für kommunale Akteure zum technisch sinnvollen und gesellschaftlich akzeptierten Speicherausbau.

Wir plädieren dafür, die materiellen Auswirkungen der Energiewende als Chancen der Gestaltung des urbanen und ländlichen Raums zu betrachten und betonen die Bedeutung des Ausgleichs von Ausbauzielen für erneuerbare Energien mit lokalen Anforderungen und Ästhetik.

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Vulnerabilitäts-Schnellanalyse für die praxisnahe Anwendung in Städten – das VESPA-Tool

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1 ABSTRACT

Städte sehen sich zunehmend mit den Auswirkungen des Klimawandels und anderer globaler Krisen konfrontiert, die ihre bebaute Umwelt, ihre Infrastruktursysteme und die allgemeine Lebensqualität ihrer Bevölkerung erheblich bedrohen. Während Großstädte oft über die Ressourcen und Expertenwissen verfügen, um diese Herausforderungen zu bewältigen, und sich aktiv an Initiativen wie EU-finanzierten Forschungsprojekten beteiligen, können mittlere und kleinere Städte häufig mit diesen Entwicklungen nicht Schritt halten. Sie stehen vor zahlreichen Herausforderungen bei der Gestaltung und Umsetzung von Veränderungen und Maßnahmen, die für den Aufbau von Resilienz erforderlich sind. Oft fehlt ihnen sogar die grundlegende Kenntnis darüber, in welchen Bereichen sie am vulnerabelsten für externe Einflüsse sind. Diese Vulnerabilitäten zu identifizieren und kennen ist jedoch eine entscheidende Voraussetzung dafür, transformative Veränderungen hin zu widerstandsfähigeren Strukturen voranzutreiben.

Daher entwickelte ein Konsortium rund um AIT, TU Wien und PlanSinn im Projekt VESPA, das vom österreichischen Klima- und Energiefonds finanziert wurde, einen Prototypen für eine Vulnerabilitäts-Schnellanalyse, der Städten und Gemeinden eine evidenzbasierte Grundlage zur Bewertung von Risiken und Herausforderungen bietet. Diese Vulnerabilitätsanalyse ist als webbasiertes Tool für die praktische Anwendung implementiert und ermöglicht es österreichischen Städten, individuelle Vulnerabilitätsprofile zu erstellen und zu analysieren. In diesem Beitrag stellen wir die Schlüsselelemente des VESPA-Tools und erste Erfahrungen mit der Anwendung in Teststädten vor und geben einen Ausblick auf mögliche Weiterentwicklungen.

Keywords: Web-Applikation, Partizipative Stadtplanung, Vulnerabilitätsanalyse, Co-Creation, Resilienz

2 VULNERABILITÄT ALS WICHTIGER SCHRITT ZUR URBANEN RESILIENZ

Österreichs Städte sind sich zunehmend der Auswirkungen des Klimawandels sowie weiterer krisenhafter Entwicklungen bewusst (Giffinger et al. 2021) und sehen insbesondere eine Gefährdung ihrer baulichen, blauen und grünen Infrastruktursysteme sowie der Lebensqualität der Bevölkerung. Eine frühzeitige und vorausschauende Anpassung an veränderte Rahmenbedingungen und zukünftige Entwicklungen ist daher essenziell. Ein zentrales Element des Anpassungsprozesses ist die umfassende Kenntnis des Status quo und der bestehenden Vulnerabilitäten, um das lokale Vulnerabilitätsrisiko klar abschätzen und effektive Maßnahmen für robustere Infrastrukturen und verbesserte adaptive Kapazitäten setzen zu können (Füssel und Klein, 2006; IPCC, 2022)

Längerfristige Transformationsprozesse in Richtung Resilienz können nur dann erfolgreich verlaufen, wenn bestehende Systeme hinreichend robust, anpassungsfähig und lernfähig sind. Das gemeinsame Lernen und Identifizieren von vorhandenen Vulnerabilitäten stellt einen entscheidenden Schritt dar, um Betroffenheit zu erzeugen, gezielte Anpassungsstrategien nach Dringlichkeit und Dimension zu sortieren und resilienzorientierte Steuerungsansätze zu etablieren. Durch eine vorausschauende, systematische Anpassung bestimmter Entwicklungsbereiche können Vulnerabilitätsrisiken reduziert werden.

Es gibt jedoch weder hinsichtlich Vulnerabilität noch hinsichtlich Resilienz ein Patentrezept, wie Städte und Regionen am besten damit umgehen können. Die Betroffenheit von Städten und Regionen variiert in Abhängigkeit von regional unterschiedlichen klimatischen und wirtschaftlichen Auswirkungen sowie den divergierenden Anpassungskapazitäten der jeweiligen Städte. Daher ist eine differenzierte Betrachtung erforderlich, die auf einer fundierten Analyse der bisherigen Vulnerabilitätserfahrungen basiert und sozioökonomische, naturräumliche sowie geografische Rahmenbedingungen berücksichtigt. Zudem sind eine Verbesserung der Informationsgrundlagen und eine Stärkung der Entscheidungsprozesse notwendig.

Zur Erfassung, Beschreibung und Analyse der Widerstandsfähigkeit von Systemen gegenüber Bedrohungen von außen entwickelte das Projektkonsortium auf Grundlage einer systemischen Herangehensweise das begriffliche Konzept der „Vulnerabilität". Dabei wird dieser Begriff nicht nur zur Analyse der Funktionsweise bestimmter Ökosysteme bei der Bestimmung von Risiken verwendet, sondern Bezug zu einem breiten „Spektrum von sozialen, wirtschaftlichen, institutionellen und ökologischen Gefährdungen sowie deren Wechselwirkungen" genommen (Greiving, 2018). Häufig wird dieses Konzept in der wissenschaftlichen Auseinandersetzung mit den Folgen des Klimawandels angewendet, wobei diese Risikoabschätzung nach Füssel und Klein (2006) vier wesentliche Zwecke verfolgt: Neben dem Verständnis für klimaempfindliche Systeme und der Spezifizierung von Zielen zur Bremsung des Klimawandels sollen politische und wissenschaftliche Bemühungen priorisiert und Anpassungsstrategien zur Risikominimierung entwickelt werden, was eine fundierte Informationsbasis voraussetzt (S.324). Im Zentrum vieler wissenschaftlicher Auseinandersetzungen steht die Frage nach den Determinanten der Widerstandsfähigkeit oder der Verletzlichkeit von Systemen gegenüber mannigfaltigen Gefahren und Bedrohungen: Bereits in frühen theoretischen Arbeiten, die sich mit diesem Konzept der befassten, wird Vulnerabilität als Funktion von Sensibilität, Anpassungsfähigkeit und Exponiertheit gesehen (Brooks, 2003; Polsky et al., 2007).

Nach dem 5. IPCC Assessment Report ist Vulnerabilität neben den konkreten Gefährdungen („hazards") und der Exponiertheit („exposure") eine der drei Komponenten, die das Risiko gegenüber den Folgen des Klimawandels bestimmt. Somit wird in diesem Zugang Vulnerabilität als die spezifische Neigung oder Disposition für eine nachteilige Beeinträchtigung verstanden, die durch Sensibilität, ("sensitivity"), Empfindlichkeit („susceptibility") oder mangelnde Anpassungsfähigkeit („lack of capacity to cope and adapt") eines Systems entscheidend beeinflusst wird (IPCC, 2014). Um die Widerstandsfähigkeit oder die Verletzlichkeit von einzelnen Städten und Regionen abschätzen zu können, braucht es daher nicht nur ein grundlegendes Verständnis für Gefahrenpotenziale und Vulnerabilitäten, sondern auch eine evidenzbasierte Abschätzung der spezifischen Risikoneigung. Mehrere Studien versuchen daher, die unterschiedliche Betroffenheit von klimawandelbedingten Naturkatastrophen und Extremwetterereignissen anhand bestimmter relevanter lokaler Gegebenheiten abschätzen (Alfieri et al., 2015; Tapia et al., 2017). Diese Aufgabe stellt jedenfalls eine Herausforderung hinsichtlich möglicher Analysewerkzeuge und einheitlicher Indikatoren dar. Erkenntnisse aus Projekten zu Smart City Indikatoren (Giffinger und Kramar, 2022;Demel, 2021), und Resilienz in Stadtregionen(Giffinger et al., 2021) zeigen, dass (1) jede Stadt ihre spezifischen Vulnerabilitäts- und Anpassungsmerkmale auf Grundlage stadtspezifischer Stärken und Schwächen identifizieren muss, (2) Indikatorenkonzepte an die sachlichen Anforderungen bestimmter Entwicklungsbereiche (z. B. Mobilität, Energieversorgung) angepasst sein sollten, um städtische Profile präzise abzubilden, und (3) allgemeine Indikatorensysteme für größere Gruppen von Städten durch stadtspezifische Indikatoren ergänzt werden müssen, um deren spezifischen Gegebenheiten gerecht zu werden.

Mit diesem Vorwissen zielte das Projekt VESPA (https://smartcities.at/projects/vespa/), das vom österreichischen Klima- und Energiefonds finanziert wurde, darauf ab, eine Vulnerabilitäts-Schnellanalyse für Städte zu erstellen. In einem Konsortium bestehend aus AIT Austrian Institute of Technology GmbH, Technischer Universität Wien und PlanSinn Planung & Kommunikation GmbH wurde ein Prototyp dafür entwickelt, der Städten und Gemeinden eine evidenzbasierte Grundlage zur Bewertung ihrer Vulnerabilität bietet.

3 METHODISCHE GRUNDLAGEN DES VULNERABILITÄTS-CHECKS

Das VESPA Tool basiert auf drei methodischen Ansätzen: 1) auf einem evidenzbasierten Bewertungssystem anhand eines strukturierten Indikatorenkatalogs 2) auf einem userinnen- und userzentrierten Designansatz, der Städte co-kreativ in die Toolentwicklung einbindet und 3) auf der Ausprogrammierung des Prototypen, der zweistufig aufgesetzt wurde (Eigeneinschätzung im „Self Check" und datenbasierte Auswertung im „Full Check"). Das folgende Kapitel stellt die derart entwickelten Methoden im Detail vor.

3.1 Entwicklung eines evidenzbasierten Bewertungssystems

Die vielfältigen Herausforderungen und Gefahren, die aufgrund bestehender Trends und veränderter Rahmenbedingungen in den nächsten Jahren zu erwarten sind, werden Österreichs Städte und Gemeinden in sehr unterschiedlichem Ausmaß betreffen. Die individuelle Betroffenheit und Verletzlichkeit ist jedoch kein

Zufall, sondern wird durch grundlegende Wirtschafts-, Gesellschafts-, Siedlungs-, Mobilitäts- und Landschaftsstrukturen sowie die lokale Verwaltung und Governance bestimmt. Im Gegensatz zu vielen vornehmlich klimawandelbezogenen Risikoabschätzungen versucht das VESPA-Tool, das Konzept der Vulnerabilität auch auf andere (z.B. ökonomische, technologische, ökologische, politische, gesellschaftliche, demographische) Herausforderungen und Gefahrenanzuwenden, und deren negativen Auswirkungen auf den Siedlungs- und Naturraum sowie die dort lebenden Menschen, Tiere und Pflanzen zu erfassen. Vulnerabilität wird damit durch zahlreiche und vielfältige Einflussfaktoren unterschiedlicher Dimensionen bestimmt, die nicht losgelöst voneinander zu betrachten sind, weil sie miteinander in Wechselwirkung treten können.

Als Grundlage für einen evidenzbasierten Vulnerabilitätscheck österreichischer Städtewird daher ein strukturierter Indikatorenkatalog entwickelt, der in der Lage ist, die spezifische Vulnerabilität einer Stadt gegenüber gegenwärtigen und zukünftigen Herausforderungen anhand lokaler und regionaler Daten abzubilden. Die Basis dafür bildet eine theoretische Auseinandersetzung mit dem begrifflichen Konzept der „Vulnerabilität", die in eine strukturierte Übersichtmöglicher Gefahren, mit den die österreichischen Städte in naher Zukunft konfrontiert sein könnten, in 4 Dimensionen (ökonomisch-technologisch, ökologisch-naturräumlich, politisch-administrativ, gesellschaftlich-demographisch) mündet. Dabei werden plötzliche Ereignisse („shocks") und dauerhafte Belastungen („stresses") unterschieden und nach der räumlichen Ebenen, auf der sie verursacht werden, (global, europäisch, national, regional, lokal) eingeteilt. Damit ist es möglich, sowohl Einzelereignisse (z.B. Naturkatastrophen, Kriege oder Pandemien), als auch langfristige Trends (z.B. kontinuierliche Preissteigerungen, fortschreitende Überalterung oder die ständige Temperaturerwärmung) zu erfassen und hinsichtlich ihrer Gefährdungspotenzials für Städte und Regionen zu berücksichtigen.

Zu diesen erfassten „shocks" und „stresses" lassen sich nun jene lokalen Bedingungen ableiten, die bestimmen, wie stark diese Bedrohungen auf einen konkreten Raum wirken und wie gefährlich sie für die lokale Entwicklung werden können. Diese Bedingungen werden in 28 „Vulnerabilitätskriterien" zu 7 Themenbereichen, die sich 3 zentralen Handlungsfeldern „Mobilitätswende", „Energiewende" und „Kreislaufwirtschaft" zuordnen lassen, beschrieben (siehe Abbildung 1).

Themenbereiche	Vulnerabilitätskriterien	Handlungsfelder		
		Mobilitäts-wende	Energie-wende	Kreislauf-wirtschaft
Siedlungs- & Naturraum	Zersiedelung			
Siedlungs- & Naturraum	Versiegelung			
Siedlungs- & Naturraum	Flächenverfügbarkeit			
Siedlungs- & Naturraum	Bausubstanz			
Siedlungs- & Naturraum	Naturraum			
Siedlungs- & Naturraum	Naturschutz			
Wirtschaft & Arbeitsmarkt	Arbeitsmarkt			
Wirtschaft & Arbeitsmarkt	Diversifizierung der Wirtschaft			
Wirtschaft & Arbeitsmarkt	Regionalität			
Wirtschaft & Arbeitsmarkt	Dynamik und Innovation			
Wirtschaft & Arbeitsmarkt	Recycling			
Gesundheit, Bildung & Soziales	Gesundheitsversorgung			
Gesundheit, Bildung & Soziales	Bildungsangebote			
Gesundheit, Bildung & Soziales	Soziale Infrastruktur			
Energie & Wasser	Energieinfrastruktur			
Energie & Wasser	Energieautharkie			
Energie & Wasser	Wasserversorgung			
Verkehr & Telekom	Verkehrsinfrastruktur und Erreichbarkeit			
Verkehr & Telekom	Mobilitätsverhalten			
Verkehr & Telekom	Telekom-Infrastruktur			
Bevölkerung	Demographische Struktur			
Bevölkerung	Qualifikation und Ausbildung			
Bevölkerung	Wohlstand und Verteilung			
Bevölkerung	Gesellschaftliche Diversität			
Governance	Kommunales Budget und Eigentum			
Governance	Kommunale Planungs- und Sicherheitskonzepte			
Governance	Beteiligung und Repräsentativität			
Governance	Kommunale Informationsangebote			

Abbildung 1: Vulnerabilitätskriterien nach Themenbereichen

Da sich diese Kriterien nie auf alle, sondern immer nur auf bestimmte Herausforderungen und Gefahren beziehen, wurden diese in einer „Vulnerabilitätsmatrix" einander zugeordnet. Dort ist einerseits ersichtlich, welche lokalen Bedingungen für welche Bedrohungen in welcher Weise relevant sind und andererseits, welche Herausforderungen und Gefahren von welchen Vulnerabilitätskriterien bestimmt werden. Alle Vulnerabilitätskriterien liegen weitgehend im Handlungsspielraum der Stadtregionen und lassen sich durch Planungsmaßnahmen auf lokaler oder regionaler Ebene (zumindest teilweise) verändern und steuern. Herausforderungen und Gefahren, denen viele Vulnerabilitätskriterien zugeordnet sind, bieten eine größere Auswahl an Eingriffs- und Steuerungsmöglichkeiten als solche, die nur mit wenigen Kriterien verknüpft sind.

Zur datenbasierten Bewertung wurden auf Grundlage potenziell verfügbarer Informationen und Daten mögliche Indikatoren festgelegt, anhand derer die lokale Ausformung der Kriterien beschrieben werden kann. Der Aufwand und die Komplexität für eine solche evidenzbasierte Bewertung ist in Anbetracht der Verfügbarkeit relevanter Daten jedoch sehr unterschiedlich: Zu manchen Vulnerabilitätskriterien gibt es viele Möglichkeiten, diese anhand von allgemein zugänglichen Daten abzubilden, bei anderen ist der Analyse- und Erhebungsaufwand wesentlich höher. Letztendlich konnte zu jedem Kriterium zumindest ein Indikator identifiziert werden. Die insgesamt 68 möglichen Indikatoren zu den 28 Vulnerabilitätskriterien wurden nach der Verfügbarkeit von geeigneten Daten bewertet (Skalenniveau, räumliche Ebene, mögliches Erhebungsintervall) und danach nach Relevanz und Erhebungsaufwand in Kern- und Ergänzungsindikatoren eingeteilt. Die 32 Kernindikatoren, die 21 der Kriterien abdecken, sind dabei trotz hoher Aussagekraft mit relativ geringem Aufwand zu erheben bzw. zu berechnen, während die anderen 36 Indikatoren entweder eigene Analysen oder zusätzliche Erhebungen erfordern, weniger relevant sind oder nur verbale Beschreibungen zulassen.

3.2 Einbindung in einen partizipativen Prozess

In VESPA wurde der Ansatz des userinnen- und userzentrierten Designs verfolgt: Die städtischen Praxisakteurinnen und Praxisakteure als zukünftige Anwenderinnen und Anwender standen von Anfang an im Mittelpunkt des Entwicklungsprozesses. Eine gelingende laufende Konsultation von Städten war daher essenziell für die Tool-Entwicklung. Dazu war es notwendig, eine attraktive Beteiligungsvereinbarung zu bieten: den involvierten Städten sollte durch die Mitwirkung am Projekt auch ein unmittelbarer Nutzen entstehen, denn sie konnten dadurch (unabhängig von Hinweisen für das Tool) unmittelbar Einschätzungen und Denkanstöße zur Vulnerabilität erhalten. Auf dieser Basis ist es gelungen, eine Reihe von Städten zur Mitarbeit zu gewinnen. Dabei haben wir immer auch versucht, mehrere Personen in der Verwaltung der Städte anzusprechen, da Vulnerabilität ja ganz unterschiedliche Fachbereiche betrifft. Insgesamt haben Zuständige für Stadtplanung, Klima, Zivilschutz, Stadtmarketing, Kommunikation oder auch Infrastruktur mitgewirkt.

In einer Online-Umfrage (TypeForm) wurden zu Beginn die Praxisanforderungen an den City-Check von mehreren Städten (Lienz, Graz, Linz, Innsbruck, Baden, Mödling, Klagenfurt, Krems) abgeholt. Dies folgt dem Prinzip des co-creative Design Thinking: sich zunächst im Dialog mit der Praxis über Designkriterien zu verständigen, also zu klären, welche Anforderungen an ein solches Tool gestellt werden bzw. was einer Nutzung in der Praxis entgegenstehen könnte. Anschließend wurde ein entsprechendes Roh-Konzept entwickelt und in einem Online-Workshop von den Praxisakteurinnen, Praxisakteuren und dem Projektteam diskutiert. Dies stellte die Grundlage für den ersten Programmierungsschritt dar.

Ein vor Ort durchgeführter Intensiv-Workshop mit Akteurinnen und Akteuren der Lienzer Stadtverwaltung unter Einbeziehung der verantwortlichen Politik (in Lienz der für Zivilschutz zuständige Vizebürgermeister) diente der detaillierten Bearbeitung des Indikatorenkatalogs und Vulnerabilitätsprofils. Für Lienz wurde ein entsprechendes Profil erstellt. Abschließend wurden in drei Praxislaboren mit 5 Städten die Praxistauglichkeit des Tool Prototypen erprobt und Nutzungsmöglichkeiten erarbeitet. Dabei wurde der Vorgang des „Self Check" möglichst realitätsnah in einem Setting mit interdisziplinärer Besetzung in den Städten simuliert. Das anschließende Feed-back hat den Nutzen und die Praxistauglichkeit des Tools bestätigt und Hinweise für die Optimierung der Usability geliefert. Für die Online- Workshops und Praxislabore zog das Projektteam interaktive kollaborative Online-Tools wie z.B. Zoom, Padlet, Slido und Miro heran.

3.3 Entwicklung eines Tools zur Vulnerabilitätsanalyse

Das Vulnerabilitätsanalyse-Tool wurde in Zusammenarbeit mit österreichischen Städten mit einem nutzerzentrierten Design-Ansatz konzipiert, entwickelt und getestet, um seine Praxistauglichkeit und Anwendbarkeit sicherzustellen. Dabei stand die Notwendigkeit einer schnellen und unkomplizierten Erstbewertung im Vordergrund, um die wichtigsten kommunalen Schwachstellen zu identifizieren und den Bedarf an einer detaillierteren Analyse zu ermitteln. Daher umfasst das Tool zwei Stufen: eine subjektive Bewertung der Vulnerabilitäten („Self Check") und eine umfassendere, datengestützte Bewertung („Full Check"). Dieser Ansatz ermöglicht den Vergleich beider Bewertungsstufen und liefert neue, oft überraschende Erkenntnisse. Die technische Umsetzung der VESPA-Tools erfolgte mittels R-Shiny-Programmierung[1]. Die notwendige Infrastruktur zur Benützung als Web-Applikation wurde im Rahmen des Projektes aufgesetzt.

4 ANWENDUNGDES VULNERABILITÄTS-CHECKS

In Kapitel 4 wird die Anwendung des Vulnerabilitäts-Checks beschrieben. Der Vulnerabilitäts-Check ist zweistufig aufgebaut: In einem ersten Schritt absolvieren die Teilnehmerinnen und Teilnehmer einen Self Check, bei dem in Gruppenarbeit eine themenblockbezogene Selbstbewertung der jeweiligen Indikatoren erfolgt. In einem zweiten Schritt erfolgt ein indikatorengestützter Full Check, der die Eingabe von Daten erfordert und einen Vergleich zum nationalen Durchschnittswert ermöglicht. Abschließend stellt eine Differenzanalyse dar, inwieweit die Selbstbewertung und Datenauswertung übereinstimmen oder voneinander abweichen. Im Folgenden werden die einzelnen Stufen des Verfahrens detailliert erläutert.

4.1 Self Check

Das Design für das User Interface und der zweistufigen Toolaufbau (Self Check und Full Check) wurde co-kreativ gemeinsam mit Städten entwickelt und umfasste eine Befragungen, einer Recherche zu ähnlichen Tools, ein Ausloten der programmtechnischen Möglichkeiten und Entwurfsdiskussionen mit Stakeholderinnen und Stakeholdern. Der qualitative Self Check wurde in einer einfachen Dashboard Struktur mit Fragen zu verschiedenen Themenbereichen wie Natur- & Siedlungsraum, Wirtschaft & Arbeitsmarkt, Bildung & Gesundheit etc.(siehe Abbildung 2) untergliedert. Für die einzelnen Kriterien (z.B. Zersiedelung) kann mittels Schieberegler eine qualitative Eigenbewertung erfolgen, wobei Infoboxen Hilfestellungen zur Beantwortung der Fragen (z.B. „Wie schätzen Sie die Zersiedelung ihrer Stadt?") bieten. Wie sich in den Diskussionen mit den beteiligten Städten herausgestellt hat, ist eine Dokumentation der Teilnehmerinnen und Teilnehmer zur Bewertung ein wesentlicher Bestandteil, um auch später noch nachvollziehen zu können, wie diese Selbsteinschätzung erfolgt ist. Dafür wurde im Tool die Dokumentationsfunktion (Textbox) integriert.

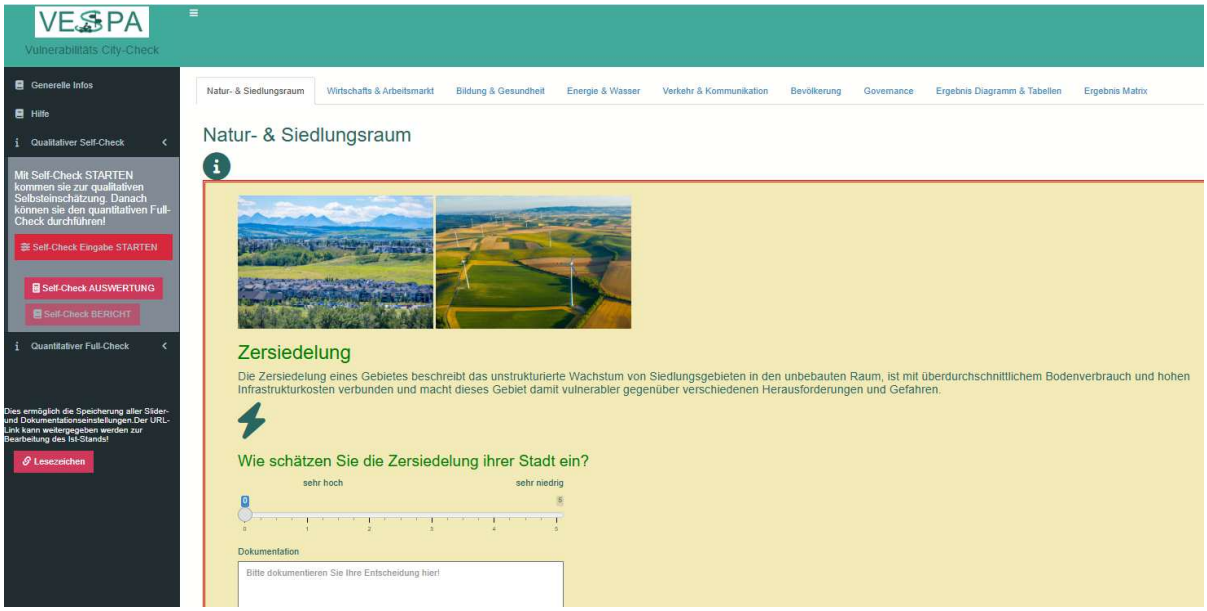


Abbildung 2: VESPA-Web-Tool User Interface Self Check (Ausschnitt)

[1] https://shiny.posit.co/

Die Vulnerabilitätsanalyse soll ein möglichst umfassendes Bild des Status Quo einer Stadt widerspiegeln. Daher müssen die Städte alle Themenbereiche durchlaufen und sich mit verschiedensten Vulnerabilitätsaspekten auseinandersetzen. Um den Prozess möglichst niederschwellig zu halten, wurden pro Themenbereich jedoch nur 2-3 „Pflicht-Kriterien“, die obligatorisch ausgefüllt werden müssen, vorgegeben. Wenn zu allen Themenbereichen eine Selbstbewertung inklusive Dokumentation durchgeführt wurde, kann eine Auswertung des Self Checks mittels sogenannter Sunburst-Diagramme und in tabellarisch erfolgen. Zudem können diese Ergebnisse auch als interaktiver Bericht (im HTML Format) heruntergeladen werden.

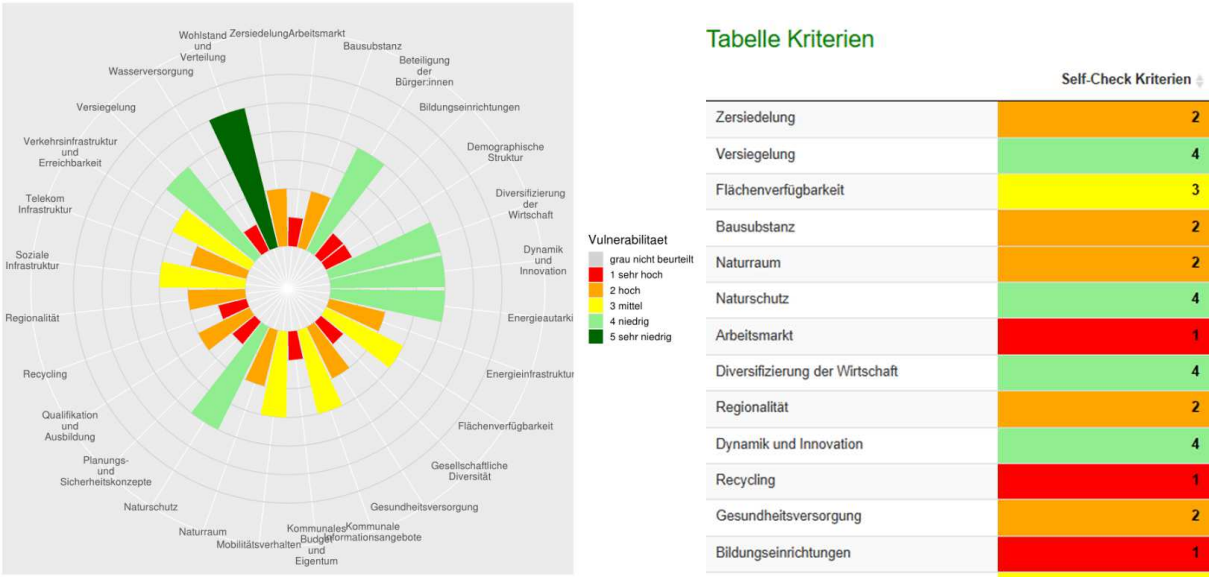


Tabelle Kriterien

	Self-Check Kriterien
Zersiedelung	2
Versiegelung	4
Flächenverfügbarkeit	3
Bausubstanz	2
Naturraum	2
Naturschutz	4
Arbeitsmarkt	1
Diversifizierung der Wirtschaft	4
Regionalität	2
Dynamik und Innovation	4
Recycling	1
Gesundheitsversorgung	2
Bildungseinrichtungen	1

Abbildung 3: VESPA-Web-Tool Ergebnisdarstellung Self Check (Sunburst Diagramm links – tabellarische Darstellung rechts)

Die farbige Darstellung wurde an den Ampelfarben angelehnt und soll rasch und intuitiv einen Überblick über die Vulnerabilitäten liefern. Zusätzlich zu diesen Auswertungen gibt es noch eine sogenannte Gefahrenpotential-Matrix, welche die Themenbereiche, die Kriterien aber auch Herausforderungen und Auswirkungen darstellen. Das Gefahrenpotential ergibt sich dabei als gerundeter Durchschnittswert aus den einzelnen Kriterien. So wird beispielweise das Gefahrenpotential durch Versiegelung (Kriterium) im Themenbereich Natur-&Siedlungsraum in der Verschränkung mit den ökologisch-naturräumlichen Herausforderungen aufgrund von Temperaturanstieg und Hitzewellen (Auswirkung) bewertet. Im gegebenen Beispiel in Abbildung 4 wurde das Gefahrenpotenzial als relativ gering (Durchschnittswert 4) beurteilt.

Matrix Kriterien

Aus der Bewertung der einzelnen Vulnerabilitätskriterien leitet sich das spezifische Gefahrenpotential einer Stadt gegenüber jeder einzelnen der betrachteten Herausforderungen ab In der Spalte 'Gefahrenpotential' sehen Sie daher, gegenüber welchen Herausforderungen Ihre Stadt besonders vulnerabel ist.

Excel Print

Herausforderungen und Gefahren (unterschiedliche raeumliche Ebenen	AUSWIRKUNGEN	Gefahrenpotential	Natur- & Siedlungsraum						Wirtschaft & A	
Herausforderung	Warnung	Gefahrenpotential	Zersiedelung	Versiegelung	Flächenverfügbarkeit	Bausubstanz	Naturraum	Naturschutz	Arbeitsmarkt	Diversifizierung der Wirtschaft	Reg
	Fachkräftemangel / Arbeitslosigkeit	3							3	0	
	Blackout	4								0	
	Cyber Angriffe	4									0
	Wirtschaftlicher Strukturwandel	3			2	5		0	3	0	0
	Technologische Innovationen / Digitalisierung	4							3		0
ökologisch - naturräumlich	Temperaturanstieg / Hitzewellen	4		5		5	5				
	Unwetter / Überschwemmungen / Stürme	4		5	2	5	5				
	Wassermangel / Dürren / Waldbrände	3				5	5				
	Erdrutsche / Lawinen / Erdbeben	4	5	5	2	5	5				
	Artensterben / Biodiversitätsverlust	4	5	5	2		5	0			
	Emissionen (Luft / Lärm)	3		5		5	5	0			
politisch - adminstrativ	Umbrüche in Politik und Verwaltung	3								0	0
	Reduktion von Förderungen und Budgets	3								0	
	Änderungen rechtlicher Rahmenbedingungen	3			2					0	

Abbildung 4: VESPA-Full Check Gefahrenmatrix-Darstellung (Ausschnitt)

4.2 Full Check

Nach Abschluss des Self Checks ist es möglich einen Full Check durchzuführen.

Der Full Check ist vom optischen Aufbau bewusst sehr ähnlich gestaltet, um in einem abschließenden Schritt einen Vergleich zwischen Selbstbewertung und datenbasierter Auswertung zu ermöglichen. Der wesentliche Unterschied im Full Check ist jedoch, dass für die Themenbereiche und Kriterien (z.B. Zersiedelung) im Rahmen des Projektes quantitative Indikatoren (hier z.B. Siedlungsdichte) erarbeitet wurden, die im Tool mit einem Schieberegler eingegeben werden. Das VESPA-Tool hat eine integrierte Hilfefunktion[2], die zum einen bei der Bedienung helfen soll, aber vor allem zu den quantitativen Indikatoren Beschreibungen und Datenquellen angibt. Somit können die notwendigen Daten direkt über Links zu den Datenquellen abgefragt und danach für die Eingabe verwendet werden, falls die Informationen nicht unmittelbar bekannt sind. Falls für ein Kriterium ein Indikator nicht beurteilt werden kann oder soll, besteht die Möglichkeit dies explizit anzugeben. Dafür ist auch im Full Check eine einfache Dokumentationsfunktion eingebaut. Zur Unterstützung sind Pop-up-Infoboxen im Tool eingebaut, die Informationen zu den Kriterien und Indikatoren liefern oder direkt zur Hilfe führen. Um sofort zu sehen, wie die jeweilige Stadt abschneidet, werden für die einzelnen Indikatoren Referenzwerte (z.B. österreichische Mittelwerte) angezeigt.

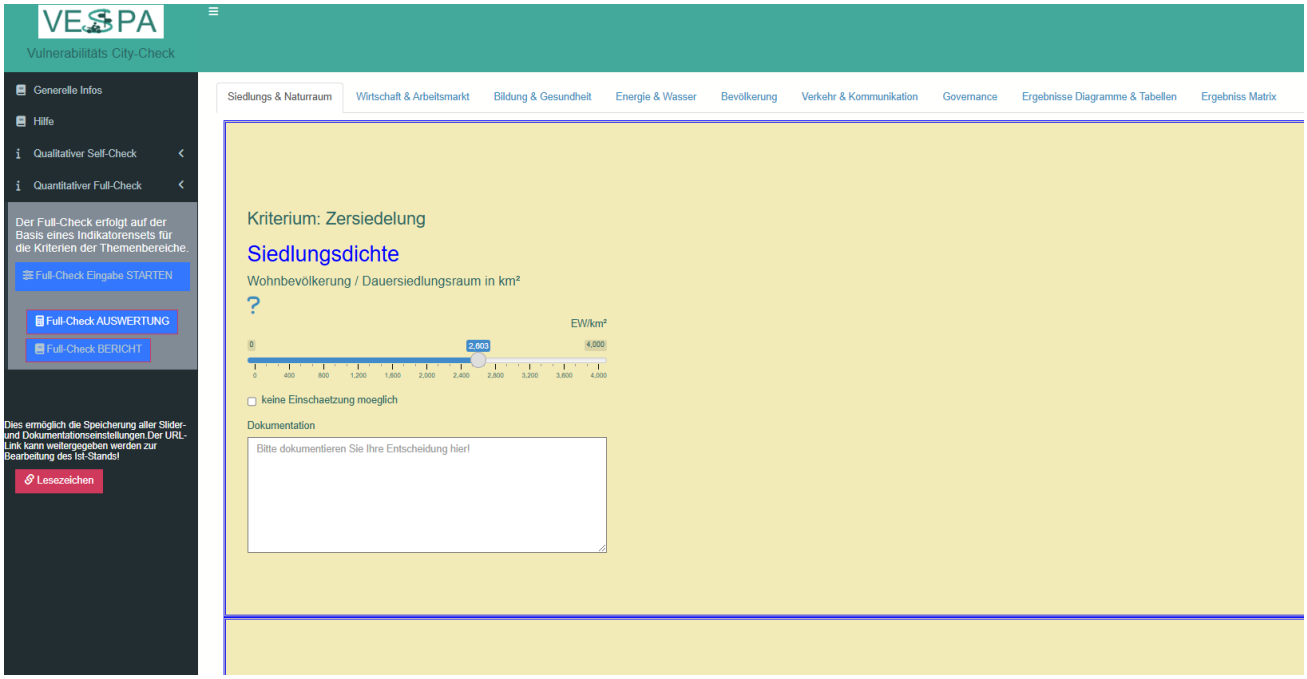


Abbildung 5: VESPA-Web-Tool User Interface Full Check (Ausschnitt)

Hat man den Full Check durchgeführt, kann man eine Auswertung mit einem Vergleich zwischen der qualitativen Selbsteinschätzung und der objektiveren (datengestützten) quantitativen Vulnerabilitätsbeurteilung durchführen (siehe folgende Abbildung).

Die Differenzdarstellung ermöglicht es, intuitiv zu sehen, wo der Self Check vom Full Check wesentlich abweicht. Dort, wo Daten fehlen oder keine Selbsteinschätzung dieses Kriteriums durchgeführt wurde, erfolgt keine Darstellung, da kein Vergleich möglich ist.

Neben der Differenzdarstellung in Form eines Sunburst-Diagramms wird auch ein interaktiver Bericht erstellt, der die Sicherung und Weitergabe[3] der beiden Checks inkl. der Dokumentation zu den einzelnen Indikatoren, die während des Prozesses eingegeben wurden, gewährleistet. Dieser Bericht ist in der folgenden Abbildung 7 dargestellt. Diese Zusammenfassung der Bewertung, Ergebnisse inkl. Dokumentation erlaubt es, dass auch zu einem späteren Zeitpunkt nachvollzogen werden kann, wie die Bewertung zustande gekommen ist. Das ermöglicht einen Monitoring-Prozess und einen Vergleich der Einschätzungen zwischen einzelnen Durchführungszeitpunkten.

[2] https://cities.ait.ac.at/projects/vespa/help/Einfuhrung.html
[3] per E-Mail oder als HTML-Dokument in einer Website integriert

5 LESSONS LEARNED

Die Anwendung des Vulnerabilitäts-Checks in österreichischen Teststädten hat eine Reihe grundlegender Einsichten hervorgebracht, die sowohl für die Weiterentwicklung des Tools als auch für dessen erfolgreiche Implementierung in der kommunalen Praxis von Bedeutung sind.

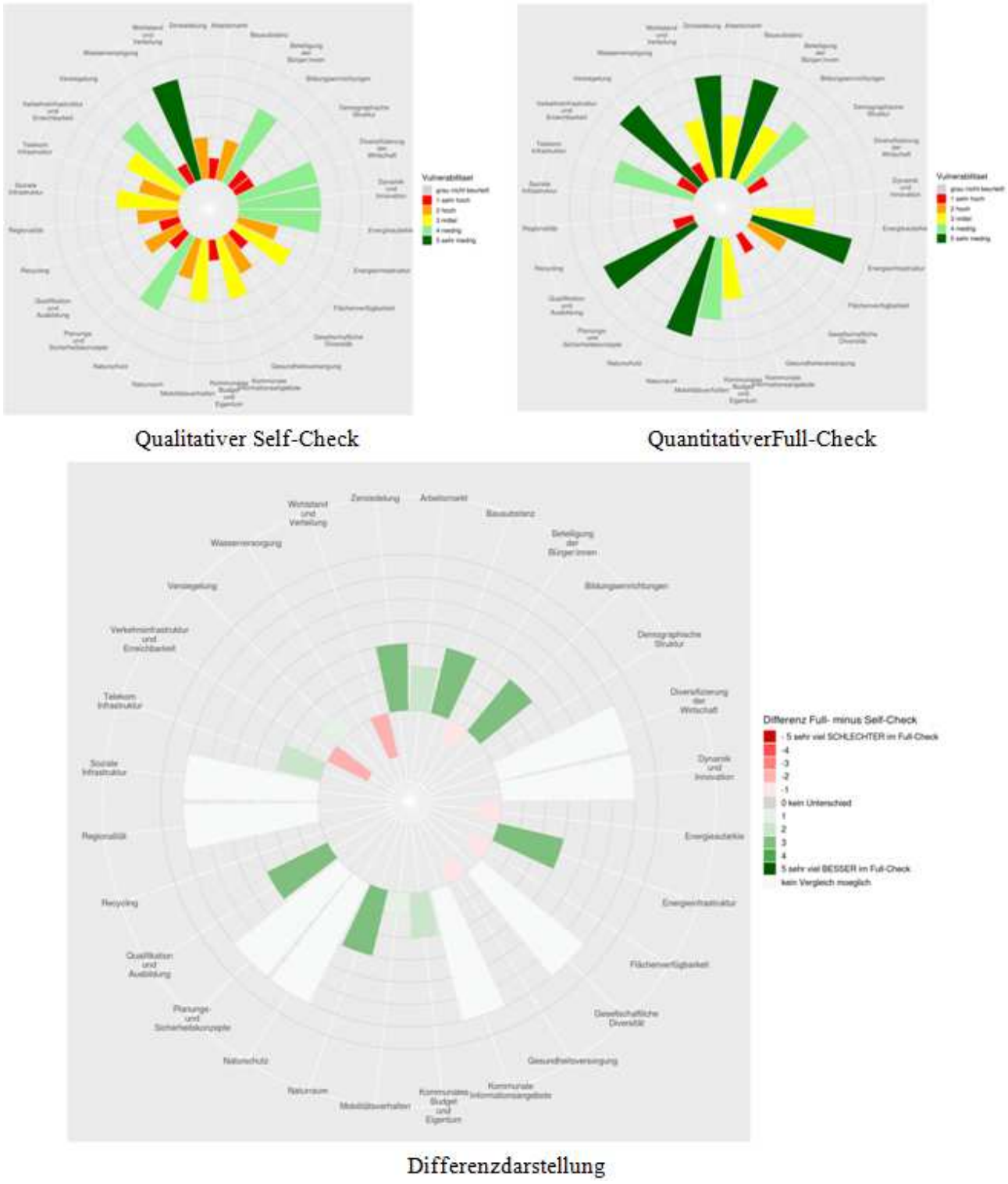


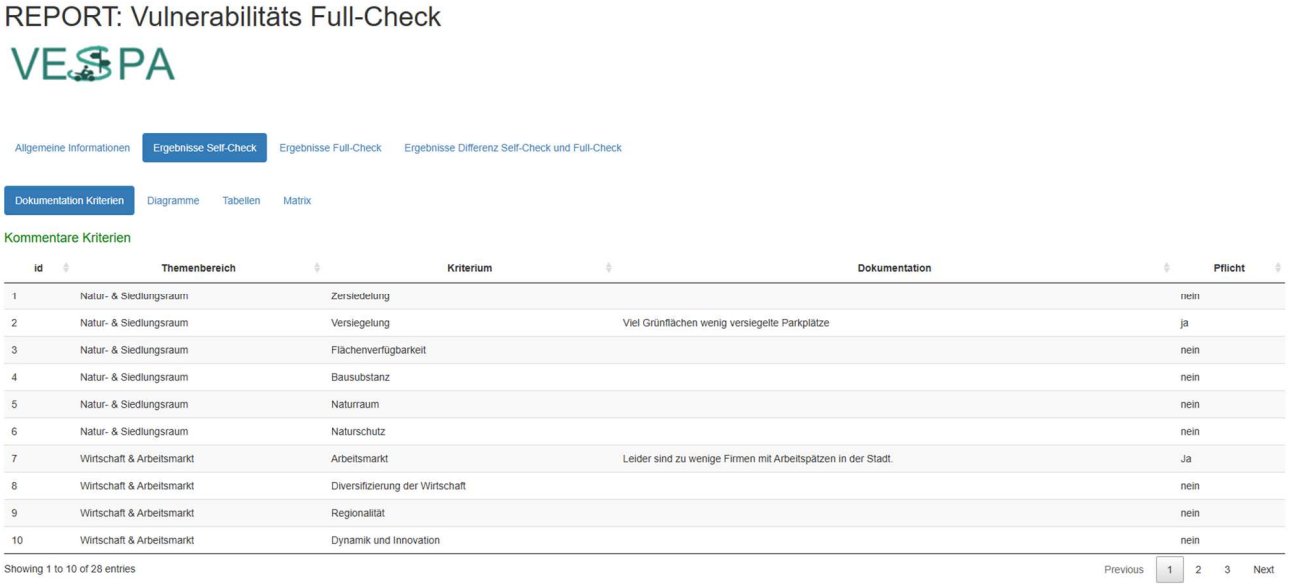
Abbildung 6: Ergebnisdarstellung Differenz Self- vs. Full Check

5.1 Konzeptionelle Erkenntnisse

- Bewusstsein für das Konzept der Vulnerabilität: Grundsätzlich war die Erfahrung, dass sich Städte ungerne mit ihren Schwächen auseinandersetzen. Es bedarf eines Umdenkens, um das Erkennen von

Vulnerabilitäten und Ableiten von Resilienz als strategisches Ziel zu verankern. Erst wenn diese Erkenntnis vorhanden ist, kann ein zielführender Prozess initiiert werden.

- Monitoring als Lernprozess: Die lokalen Strukturen und Bedingungen sind teilweise sehr stadtspezifisch und individuell, was einen generellen Vergleich verschiedener Städte im Sinne eines komparativen Benchmarkings erschwert. Wesentlich zielführender für Lernprozesse innerhalb der Städte ist hingegen ein Monitoring der lokalen Entwicklung über die Zeit. Durch ein regelmäßiges Update der Vulnerabilitätsprofile anhand der gleichen Indikatoren können Veränderungen aufgezeigt und die Wirksamkeit von Maßnahmen überprüft werden.


REPORT: Vulnerabilitäts Full-Check

VESPA

Allgemeine Informationen | Ergebnisse Self-Check | Ergebnisse Full-Check | Ergebnisse Differenz Self-Check und Full-Check

Dokumentation Kriterien | Diagramme | Tabellen | Matrix

Kommentare Kriterien

id	Themenbereich	Kriterium	Dokumentation	Pflicht
1	Natur- & Siedlungsraum	Zersiedelung		nein
2	Natur- & Siedlungsraum	Versiegelung	Viel Grünflächen wenig versiegelte Parkplätze	ja
3	Natur- & Siedlungsraum	Flächenverfügbarkeit		nein
4	Natur- & Siedlungsraum	Bausubstanz		nein
5	Natur- & Siedlungsraum	Naturraum		nein
6	Natur- & Siedlungsraum	Naturschutz		nein
7	Wirtschaft & Arbeitsmarkt	Arbeitsmarkt	Leider sind zu wenige Firmen mit Arbeitsplätzen in der Stadt.	Ja
8	Wirtschaft & Arbeitsmarkt	Diversifizierung der Wirtschaft		nein
9	Wirtschaft & Arbeitsmarkt	Regionalität		nein
10	Wirtschaft & Arbeitsmarkt	Dynamik und Innovation		nein

Showing 1 to 10 of 28 entries

Previous 1 2 3 Next

Abbildung 7: Interaktiver HTML-Report

- Ganzheitliche Betrachtung von Vulnerabilität: Die Workshops mit den Städten haben gezeigt, dass das Tool eine gute Hilfestellung bietet, Vulnerabilität in einem gesamtheitlichen, systemischen und interdisziplinären Ansatz zu erfassen. Das VESPA-Tool gibt einen umfassenden Überblick über spezifische Risiken und Schwachstellen von Gemeinden oder Regionen und kann damit als empirische Grundlage für planerische Entscheidungen auf lokaler und regionaler Ebene herangezogen werden, in denen die spezifischen Anforderungen einzelner Fachdisziplinen integrativ verknüpft werden.
- Fokus auf lokale Potenziale: Wegen der Heterogenität der betrachteten Städte und der schwierigen Vergleichbarkeit der verfügbaren Daten ist der interkommunale Vergleich nur bedingt sinnvoll und zielführend. Vielmehr sollte die Ermittlung der spezifischen Problemlagen einer Gemeinde im Vordergrund der Analyse stehen, da nur durch eine individuelle Auseinandersetzung mit dem Thema ein Bewusstsein für lokale Vulnerabilitäten geschaffen und die Bereitschaft zur Umsetzung geeigneter Maßnahmen gefördert werden kann.

5.2 Kommunikation und Anwendung des Tools

- Kommunikation als Schüsselfaktor: Eine effektive Kommunikation zwischen den verschiedenen Stakeholdern ist essenziell, um Verständnis für das Thema Vulnerabilität und gegenseitiges Vertrauen zu schaffen, gemeinsame Lösungsansätze zu erarbeiten und eine nachhaltige Zusammenarbeit zu ermöglichen. Die subjektive Einschätzung der Vulnerabilität erfordert jedoch eine klare Struktur in den Workshops, um valide Ergebnisse zu erzielen.
- Einbindung relevanter Stakeholder: Für die Weiterführung des Prozesses sind klare Verantwortlichkeiten notwendig. Es braucht zentrale Akteure, die den weiteren Prozess leiten und unterschiedliche Stakeholder einbinden, denn verschiedene Akteursgruppen tragen Verantwortung für unterschiedliche Aspekte städtischer Vulnerabilität. Eine erfolgreiche Bearbeitung setzt daher die aktive Einbindung aller relevanten Stakeholder voraus.

- Governance und Management als kritischer Faktor: Im Krisenfall ist funktionierende Governance ein zentraler Erfolgsfaktor. Dies erfordert ein abgestimmtes Management sowie klare Kommunikations- und Entscheidungswege in den betroffenen Städten unter Berücksichtigung der Interessen aller relevanten Akteurinnen und Akteure.
- Partizipation als Erfolgsfaktor: Die frühzeitige Einbindung relevanter Akteurinnen und Akteure spielt eine zentrale Rolle bei der Entwicklung eines „passgenauen" Tools, das von den Städten tatsächlich genutzt wird. Wäre das Tool ausschließlich wissenschaftlich entwickelt worden, wäre es umfassender und komplexer, aber weniger praxisnah konzipiert worden. Nur durch co-kreative Miteinbeziehung kann sichergestellt werden, dass das Tool praxisnah und an die spezifischen Bedürfnisse der Städte angepasst ist.
- Self Check als niederschwelliger Einstieg: Die Erfahrungen mit den österreichischen Teststädten haben deutlich gemacht, dass sich eine qualitative Selbstbewertung („Self Check") als effektiver Einstieg erweist. Durch die Selbstbewertung der lokalen Vulnerabilitäten wird die gemeinsame Diskussion und die Auseinandersetzung mit dem Thema Vulnerabilität gefördert. Das erleichtert die anschließende datengestützte Analyse ("Full Check").

5.3 Methodische Umsetzung

- Sensibilität im Umgang mit Daten: Da die Auseinandersetzung mit Vulnerabilität für Städte ein sensibles Thema ist, wurde bei der Toolentwicklung besonderer Wert auf Transparenz und Datenschutz gelegt. Die Städte wünschten sich, eine umfassende Dokumentation (wer war dabei, warum wurde der jeweilige Indikator so beurteilt?) sowie den Verzicht auf externer oder Cloud-Speicherung. Aus Sicht der Entwickler wird die Verwendung dadurch erschwert, da keine einfache Zwischenspeicherung zwischen Self und Full Check möglich ist, aber die Akzeptanz und das Vertrauen in die Vulnerabilitätsanalyse wird dadurch gefördert.
- Relevanz und Aussagekraft der Indikatoren: In der Interpretation und Anwendung der Ergebnisse zeigt sich deutlich, dass für eine gesamtheitliche Analyse nicht die Menge, sondern die Relevanz und Aussagekraft der Indikatoren im Vordergrund stehen muss. Für eine fundierte und gemeindespezifische Analyseist daher die sorgfältige Auswahl von Indikatoren, mit denen die Städte tatsächlich arbeiten können und die eine praxisnahe Analyse und Steuerung ermöglichen, ausschlaggebend.
- Berücksichtigung weicher Standortfaktoren: Die Überführung von Vulnerabilitätskriterien in konkrete Indikatoren gestaltet sich oft schwierig, da verwertbare Informationen begrenzt verfügbar sind und nicht alle Aspekte umfassend durch quantitative Daten erfasst werden können. Insbesondere „weiche" Faktoren (etwa im Bereich der Governance) müssen ebenfalls berücksichtigt werden, um ein realistisches Bild der städtischen Widerstandsfähigkeit zu erhalten und Ansatzpunkte für konkrete Maßnahmen zu liefern.

6 CONCLUSIO

Im Rahmen des Projekts VESPA wurde eine fundierte Methodik zur Entwicklung eines strukturierten Indikatorenkatalogs und eines Prozesses zur Bestimmung der Vulnerabilität österreichischer Städte erarbeitet. Dies ermöglicht eine umfassende Analyse lokaler Verwundbarkeiten und liefert wertvolle Erkenntnisse am Weg zu urbanen Resilienzstrategien.

Die Ergebnisse zeigen, dass Vulnerabilität ein sensibles Thema für Städte darstellt, das immer im Zusammenhang mit den lokalen Gegebenheiten gesehen werden muss. Eine praxisnahe Bewertung erfordert nicht nur die Festlegung passender Kriterien, sondern auch die Definition aussagekräftiger Indikatoren sowie eine belastbare Datenbasis. Dabei ist die Messbarkeit einzelner Aspekte eine Herausforderung, insbesondere wenn es um schwer bewertbare Faktoren (wie etwa im Bereich der Governance) geht.

Die enge Zusammenarbeit mit mehreren österreichischen Städten war ein zentraler Erfolgsfaktor des Projekts. Durch den co-kreativen Designprozess und die interdisziplinäre Einbindung unterschiedlicher Fachbereiche konnte ein praxisnahes, anwenderfreundliches Tool entwickelt werden. Besonders wertvoll war die Anwendung und Kombination verschiedener Partizipations- und Beteiligungsformate (z.B. Workshops, Interviews, Reflexionsgespräche) in der Arbeit mit den relevanten lokalen Stakeholdern. Diese

Herangehensweise war nicht nur ein Teil der fachlichen Qualitätssicherung, sondern bot den beteiligten Städten auch einen unmittelbaren Nutzen durch Erkenntnisse über ihre eigene Vulnerabilität.

Der zweistufige Bewertungsprozess des Tools, der neben einer qualitativen Selbstbewertung („Self Check“) auch eine datenbasierte Analyse („Full Check“) umfasste, wurde von den Städten mit großem Interesse angenommen und erwies sich in der Umsetzung und Anwendung als zielführend und praktikabel. Die Selbstbewertung ermöglichte eine ganzheitliche Auseinandersetzung mit dem Thema, die mit einer datenbasierten Bewertung ergänzt wurde. Die sieben Themenbereiche, in denen vielfältige Vulnerabilitäten erfasst, analysiert und bewertet wurden, erlauben einen strukturierten Zugang zu diesem komplexen Thema und erweitern damit die bisher oft auf Katastrophenmanagement fokussierte Perspektive um soziale, wirtschaftliche und ökologische Aspekte und beziehen die politische Handlungsebene (Governance) ein.

Neben der inhaltlichen Struktur ist auch die Prozessunterstützung entscheidend für den Erfolg des Tools. Anleitungen, Moderationshinweise und ein klarer Rahmen für dessen Anwendung sind Grundlage einer effektiven und problembezogenen Anwendung in der lokalen und regionalen Strategieentwicklung. Die Weiterentwicklung des Prototyps zu einem umfassenden Bewertungstool soll daher allen interessierten Gemeinden und Regionen nicht nur die Möglichkeit bieten, ihr Bewusstsein und Wissen über externe Gefahrenpotenziale zu erhöhen, sondern auch eine fundierte und evidenzbasierte Grundlage für gezielte Maßnahmen zur Erhöhung der Resilienz darstellen.

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Zukunft Otto-Wagner-Areal – Transformation vom Spital zum New-European-Bauhaus-(NEB)-Quartier

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1 ABSTRACT

Das Otto-Wagner-Areal (OWA) soll in den kommenden Jahren eine substanzielle Transformation erfahren. Nach mehr als einem Jahrhundert klinischer Nutzung soll das von Otto Wagner entworfene, denkmalgeschützte Ensemble zu einem zukunftsweisenden und innovativen Standort für Wissenschaft, Bildung, Kunst und Kultur, Soziales, Gesundheit und Tourismus transformiert werden. Für den Erfolg dieser Transformation wurden in den vergangenen Jahren bereits wichtige Grundlagen geschaffen. Das FFG-Projekt „Zukunft OWA“ schafft nun die Möglichkeit für einen weiteren, entscheidenden Schritt zur Entwicklung eines New European Bauhaus (NEB)-Quartiers. Damit soll das denkmalgeschützte Areal und dessen gelungene Transformation zu einem Vorbild und zu einer Inspiration für eine nachhaltige und ästhetische Aufwertung von Bestandsquartieren werden.

Dabei sieht das Projekt eine breite Stakeholder-Einbindung vor: Zur Umsetzung kommt ein dialogorientiertes Prozessdesign, in dessen Zentrum die Umsetzung von interdisziplinär zusammengesetzten Expert-Foren stehen. In diesen wird an der Entwicklung von Planungszielen anhand der NEB Grundwerte Ästhetik – Nachhaltigkeit – Inklusion sowie der NEB Arbeitsprinzipien Partizipation – Transdisziplinarität – Skalierbarkeit gearbeitet.

Mit der Entwicklung präziser quantitativer und qualitativer Planungsziele sowie einer Umsetzungsstrategie für das NEB Quartier OWA wird nicht nur ein Rahmen für die weitere Transformation und Entwicklung des OWA geschaffen, es werden darüber hinaus auch wichtige Erkenntnisse für die notwendige Transformation von Bestandsgebieten und Bestandsgebäuden in anderen Städten gewonnen. Neben (1) Fragen der Dekarbonisierung und der thermisch-energetischen Ertüchtigung gehören dazu insbesondere auch die Themen (2) neue Formen der Nutzungsmischung bzw. innovative Formen der Mehrfachnutzung, (3) die Neuinterpretation und den Bedürfnissen einer vielfältigen Stadtgesellschaft entsprechende Gestaltung von Grün- und Freiflächen sowie (4) die Aneignung und die Forcierung von Ownership-Prozessen, um Quartiere zu vollwertigen Teilen einer Stadt zu machen.

Keywords: Transformation historischer Bestandsareale, Otto-Wagner-Areal OWA, New European Bauhaus NEB, Key-Performance-Indikatoren KPI, Denkmalschutz

2 DAS OTTO-WAGNER-AREAL – EIN BLICK ZURÜCK FÜR DEN BLICK NACH VORN

Das unter Denkmalschutz stehende Otto-Wagner-Areal auf der Baumgartner Höhe hat eine lange, wechselvolle Geschichte. Seit der Eröffnung 1907 wurde es vor allem als psychiatrische Klinik und zur Behandlung von Lungenerkrankungen genutzt. Während der NS-Zeit (1939–1945) diente ein Teil der Anlage als Euthanasie-Anstalt „Am Spiegelgrund“ und ist heute ein wichtiger Gedenkort. Zuletzt firmierte das Krankenhaus als Otto-Wagner-Spital, ab 2020 als Klinik Penzing. 2012 wurde die schrittweise Absiedlung beschlossen.

Die Aufwertung und Umnutzung historischer Spitalsbauten ist in Europa ein aktuelles Thema. Das Otto-Wagner-Spital war einst ein Vorzeigeprojekt modernen Klinikbaus. Ähnliche Anlagen, die sich teilweise

heute noch in der ursprünglichen Nutzung befinden – wie z.B. die Klinik in Prag Bohnice (CZ) oder Mauer Öhling (AT) – oder die sich wie das OWA in einem Transformationsprozess befinden – wie z.B. das Ospedale San Giovanni in Triest (IT) oder Beelitz Heilstätten südlich von Berlin (DE) – verbindet ein längerer Sanierungsstau und der Status als historisches Bauerbe unter strengem Denkmalschutz einerseits und der dringende Anpassungsbedarf an die klimatischen und bauphysikalisschen Anforderungen unserer Zeit andererseits. Gleichzeitig bieten sie aufgrund ihrer räumlichen und funktionalen Qualitäten großes Potenzial für neue Nutzungen.

Während Standorte, wie das Felix-Platter-Spital in Basel (CH) hauptsächlich Wohnnutzungen vorsahen, besteht die zentrale Herausforderung, auch aber der hohe Innovationsgehalt des Otto-Wagner-Areals in der Zielsetzung ein öffentlich zugängliches vollwertiges Stadtquartier mit vielfältigen Nutzungen zu entwickeln.

Für den Erfolg dieser Transformation wurden in den vergangenen Jahren bereits wichtige Grundlagen geschaffen. Im Rahmen eines partizipativen Mediationsverfahrens (2012/2013) wurden erste Festlegungen zu möglichen künftigen Nutzungen getroffen, die 2020 durch den Wiener Gemeinderat konkretisiert wurden – etwa zur uneingeschränkten Zugänglichkeit des Areals.

Die WSE Wiener Standortentwicklung GmbH koordiniert die Stadtentwicklung. Ihre Tochtergesellschaft, die Otto-Wagner-Areal Revitalisierung GmbH, wird in den kommenden Jahren die Pavillons sanieren, die Infrastruktur erneuern und den Grünraum aufwerten.

3 PROJEKT „ZUKUNFT OWA“ – ZIELSETZUNGEN UND RAHMENBEDINGUNGEN

Im FFG-Projekt „Zukunft OWA“[1] werden die bisherigen Entwicklungsziele des Otto-Wagner-Areals weiter konkretisiert und strategisch vorbereitet. Ziel ist es, klare Entwicklungs- und Handlungsparadigmen zu definieren und die Transformation des Areals gezielt voranzutreiben.

Die bestehenden Projektziele stehen bereits stark im Einklang mit den Grundwerten des New European Bauhaus (NEB). Durch einen interdisziplinären Prozess soll das OWA als NEB-Quartier weiterentwickelt werden. Dabei werden präzise Planungsziele und Key-Performance-Indikatoren (KPIs) definiert, um nicht nur die Transformation des Areals zu steuern, sondern auch Erkenntnisse für die Weiterentwicklung von Bestandsgebieten in Städten zu gewinnen.

Neben (1) Fragen der Dekarbonisierung und der thermisch-energetische Ertüchtigung gehören dazu insbesondere auch die Themen (2) neue Formen der Nutzungsmischung bzw. innovative Formen der Mehrfachnutzung, (3) die Neuinterpretation und den Bedürfnissen einer vielfältigen Stadtgesellschaft entsprechende Gestaltung von Grün- und Freiflächen sowie (4) die Aneignung und die Forcierung von Ownership-Prozessen, um Quartiere zu vollwertigen Teilen einer Stadt zu machen.

Das Projekt startete im Juni 2024 und läuft zwölf Monate. Das Konsortium besteht aus der UIV Urban Innovation Vienna – Klima- & Innovationsagentur Wien, der Otto-Wagner-Areal Revitalisierung GmbH und der TU Wien, Forschungsbereich „Hochbau & Gebäudeerhaltung“.

3.1 Initiative „New European Bauhaus“

Die Basis für die Projektentwicklung bilden die Leitlinien des New European Bauhaus (NEB). Diese Initiative der Europäischen Kommission stellt die Verbindung zwischen dem European Green Deal mit der Gestaltung unserer Lebensräume her. Ihr Ziel ist es, zukünftige Lebensweisen an der Schnittstelle von Kunst, Kultur, Inklusion, Wissenschaft und Technologie zu entwickeln.

Das New European Bauhaus ist vom historischen Bauhaus inspiriert, das Kunst, Handwerk und Technologie vereinte, um funktionale und ästhetische Designs zu schaffen. Die Bauhaus-Schule wurde 1919 in Weimar von Walter Gropius gegründet und prägte maßgeblich das moderne Design und die Architektur des 20. Jahrhunderts.

Das New European Bauhaus adressiert damit zentrale Herausforderungen unserer Zeit, wie:

- Klimawandel: Die Initiative setzt auf umweltfreundliche Lösungen zur Reduzierung des CO_2-Ausstoßes und die Nutzung nachhaltiger Materialien und Baupraktiken.

[1] Ausschreibungsschwerpunkt FIT4NEB – Vorbereitung auf die geplante EU Mission „New European Bauhaus“.

- Soziale Ungleichheit: Sie fördert die Schaffung zugänglicher Lebensräume, die die Lebensqualität aller Menschen verbessern, insbesondere marginalisierter Gruppen.
- Kulturelle Identität: Sie stärkt die kulturelle Vielfalt in europäischen Städten, indem sie lokale Traditionen und Materialien in die Architektur integriert.

NEB-Projekte rücken die Grundwerte Ästhetik, Nachhaltigkeit und Inklusion sowie die Arbeitsprinzipien Partizipation, Transdiszplinarität und Skalierbarkeit in den Fokus der Bearbeitung. Für jeden dieser Werte und Prinzipien werden zudem drei Ambitionsniveaus definiert.

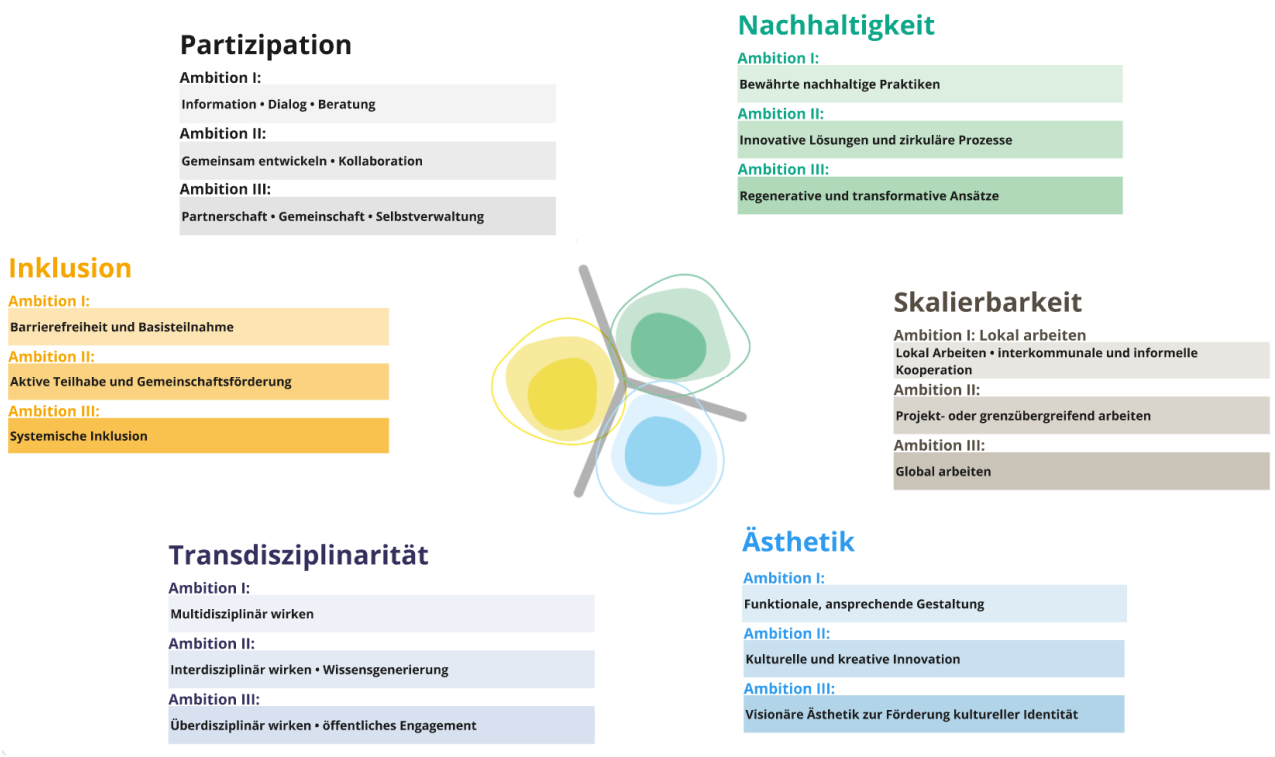

Abbildung 1: NEB-„Bausteine“: Werte, Arbeitsprinzipien und Ambitionslevels, © NEB Compass, eigene Bearbeitung

Mit Abschluss des Projekts erhält die OWA Revitalisierung GmbH Handlungsleitlinien für die zukünftige Entwicklung des Otto-Wagner-Areals, die auf den Grundwerten Nachhaltigkeit, Ästhetik und Inklusion als auch auf bestehenden Dokumenten und Entwicklungsfestlegungen basieren.

Die Entwicklungsgesellschaft erhält somit ein Instrumentarium, um die weiteren operativen Schritte gezielt an den definierten Zielsetzungen sowie an quantitativen und qualitativen Planungszielen auszurichten. Dies unterstützt die Zielorientierung und ermöglicht eine regelmäßige Überprüfung der Zielerreichung. Dadurch lassen sich notwendige Anpassungen frühzeitig erkennen und umsetzen.

Hier kann daher im Hinblick auf die Ertüchtigung der Anlagen oder auch allgemein im Zusammenhang mit der Nachnutzung historischer Großstrukturen im urbanen Kontext eine prototypische Herangehensweise in technologischer, immobilienstrategischer aber auch prozessualer Hinsicht entwickelt werden. Damit kann das denkmalgeschützte Ensemble als Vorbild und Inspiration für die nachhaltige und ästhetische Aufwertung bestehender Stadtquartiere dienen.

4 ZENTRALE HERAUSFORDERUNGEN UND LÖSUNGSANSÄTZE

Das Otto-Wagner-Areal soll sich durch den Transformationsprozess zu einem lebendigen, grünen und innovativen Stadtteil für alle entwickeln. Trotz einzigartiger Qualitäten für zukünftige Nutzerinnen, Nutzer, Besucherinnen und Besucher stellt die denkmalgeschützte Bausubstanz und veraltete Infrastruktur eine Herausforderung dar. Die zu entwickelnden Lösungsansätze orientieren sich an zentralen Themenstellungen und Herausforderungen, die für den Erfolg des Projekts entscheidend sind.

Die Quartiersentwicklung ist das Herzstück der Entwicklungen am Areal für künftige Nutzerinnen und Nutzer. Ein attraktives Quartier erfordert eine ausgewogene Nutzungsmischung, um Menschen anzuziehen.

Kunst, Kultur, Bildung und Tourismus sind zentrale Elemente, die gezielt weiterentwickelt werden. Aufgrund der dezentralen Lage und der Weitläufigkeit des Areals – 88 % der 27 ha sind Freiflächen – ist die Integration neuer Nutzungen komplex. Gleichzeitig macht dieses Verhältnis den besonderen Charakter und Erholungswert des Areals aus.

Die Entwicklung eines offenen und frei zugänglichen Quartiers erfordert zudem Strategien zum Schutz des historischen Gebäudebestands vor Vandalismus und Verfall. Neben technischen Lösungen spielen dabei auch Konzepte wie Awareness, Ownership und kreative Aneignung eine wesentliche Rolle.

Quartiersentwicklung an peripheren Standorten mit geringer städtebaulicher Dichte haben oft Schwierigkeiten, eine nachhaltige Mobilität zu etablieren, da öffentliche Verkehrsmittel erst mit wachsender Bevölkerung rentabel werden. Frühzeitig integrierte Mobilitätsangebote, wie Sharing-Modelle, E-Ladezonen und innovative Logistiklösungen, sollen am Otto-Wagner-Areal von Anfang an berücksichtigt werden. Das Projekt liefert damit nicht nur Vorgaben für die Quartiersentwicklung, sondern auch wertvolle Erkenntnisse zur Erschließung vergleichbarer Stadtgebiete ohne leistungsstarke ÖPNV-Infrastruktur.

In verschiedenen Umsetzungsphasen sollen Zwischennutzungen ermöglicht werden. Solche Zwischennutzung können als Katalysator dienen und mehrere Vorteile bieten: (1) Erhöhung der Frequentierung bereits in frühen Entwicklungsphasen, (2) Stärkung der Identifikation mit dem Areal und Steigerung seiner Bekanntheit, (3) Schaffung von Raum für experimentelle Nutzungen und (4) Förderung neuer, dauerhafter Nutzungen, die aus erfolgreichen Zwischennutzungen entstehen.

Ein zentraler Aspekt des Projekts ist die Vernetzung mit Innovationslaboren und Forschungsinitiativen, um Synergieeffekte und Wissenstransfer zu sichern. Besonders relevant sind dabei:

- future.lab: Förderung sozialer Innovationen in der Stadtentwicklung.
- GeoDatKlim: KI-gestütztes Datenmanagement für klimaneutrale Städte.
- Green Energy Lab: Entwicklung nachhaltiger Energielösungen und Wärmeversorgungsstrategien.
- Renowave: Innovationslabor für klimaneutrale Sanierungen von Gebäuden und Quartieren.

Eine nachhaltige Quartiersentwicklung muss barrierefrei und inklusiv gestaltet sein. Das bedeutet, dass Gebäude und öffentliche Räume für alle Menschen zugänglich, nutzbar und erlebbar sein müssen. In der Planung werden daher unterschiedliche Bedürfnisse verschiedener Nutzerinnen- und Nutzergruppen berücksichtigt – je nach Lebenslage, sozialem oder kulturellem Hintergrund.

Das Otto-Wagner-Areal soll so zu einem Modellquartier werden, das nachhaltige, soziale und technologische Innovationen vereint und als Vorbild für die Umgestaltung historischer Stadtgebiete dient.

5 METHODIK UND HERANGEHENSWEISE

Das Projekt verfolgt einen partizipativen Ansatz, bei dem verschiedene Stakeholder aktiv eingebunden werden, um unterschiedliche Perspektiven in den Transformationsprozess zu integrieren. Die Umsetzung erfolgt durch ein dialogorientiertes Prozessdesign, dessen zentrale Elemente interdisziplinär zusammengesetzte Expert-Foren sowie eine universitäre Lehrveranstaltung sind.

5.1 Expert-Foren – Entwicklung von Planungszielen und Key-Performance-Indikatoren

In den Expert-Foren werden, basierend auf bereits definierten Entwicklungszielen, quantitative und qualitative Planungsziele sowie Key-Performance-Indikatoren (KPIs) für das NEB-Quartier Otto-Wagner-Areal erarbeitet. In 4 Expert-Foren zu den Themen (1) Mobilität und Betrieb, (2) Öffentlicher Raum und Grünraum, (3) Nutzungs- und Funktionsmischung und (4) Gebäude- und Energieplanung werden verschiedene thematische Schwerpunkte behandelt.

Abbildung 2: Expert-Foren und Themenschwerpunkte

Durch die breite Einbindung von Expertinnen und Experten im Rahmen dieser Foren wird gewährleistet, dass State-of-the-Art-Wissen zu den jeweiligen Themenbereichen für das Projekt nutzbar gemacht werden. Die Entwicklung der KPIs orientiert sich an den Werten und Arbeitsprinzipien des NEB. Dabei wird angestrebt, ein sehr hohes beziehungsweise das höchstmögliche Ambitionsniveau gemäß den Vorgaben des NEB-Kompasses zu erreichen.

Die einzelnen Projektschritte werden regelmäßig durch eine Projekt-Steuerungsgruppe reflektiert, bewertet und eingeordnet. Diese Steuerungsgruppe entwickelt auf Basis der Ergebnisse aus den Expert-Foren:

- einen Vorschlag für eine Liste von quantitativen und qualitativen Planungszielen anhand der Grundwerte Ästhetik – Nachhaltigkeit – Inklusion
- eine Vision für die Umsetzung des NEB-Quartiers Otto-Wagner-Areal, die sich an den Arbeitsprinzipien Partizipation, Transdisziplinarität und Skalierbarkeit orientiert. Diese Vision beinhaltet zudem einen Finanzierungs- und Zeitplan für die weiteren Abstimmungen mit politischen Entscheidungsträgerinnen und Entscheidungsträgern und der Verwaltung in Wien.

5.2 Konstruktive Erhaltung und Erneuerung der Pavillons – Lehrveranstaltung

Um zusätzlich wissenschaftliche Expertise in die Erarbeitung von Konzepten zur Gestaltung, Ertüchtigung und Nutzung des Quartiers einzubeziehen, wird eine universitäre Lehrveranstaltung in das Projekt integriert.

Der Forschungsbereich „Hochbau und Gebäudeerhaltung“ der TU Wien befasst sich mit der Entwicklung technologischer Methoden und Strategien zur ressourcenschonenden Transformation von Bestandsgebäuden für eine zukunftsorientierte Nutzung. Im Rahmen des Forschungsprojektes „Zukunft OWA“ wird die wissenschaftliche Auseinandersetzung mit konstruktiven Fragestellungen gezielt mit der Ausbildung zukünftiger Tragwerksplanerinnen und Tragwerksplaner verknüpft. Dazu werden die aktuellen konstruktiven Forschungsfragen des OWAs in bestehende Lehrveranstaltungen des Fachbereiches integriert.

Die Lehrveranstaltung „Erhaltung und Erneuerung von Hochbauten" ist als Vorlesung mit integrierter Übung (VU) konzipiert. Während in der Vorlesung die theoretischen Grundlagen zur konstruktiven Ertüchtigung und Nachbemessung historischer Bauwerke vermittelt werden, dient die Übung der praxisorientierten Anwendung dieser Kenntnisse. Die Studierenden erwerben die Fähigkeit, bestehende Bauwerke konstruktiv zu analysieren, statische Nachweise zu führen und geeignete Ertüchtigungsmaßnahmen zu entwickeln. Ein besonderer Schwerpunkt liegt auf der Tragwerksbeurteilung und Nachbemessung historischer Bauwerke. Im Rahmen der Übung werden zwei Pavillons des Otto-Wagner-Areals untersucht. Die Studierenden führen eine statische Beurteilung unter Berücksichtigung unterschiedlicher Nutzungen durch und entwickeln Ertüchtigungsmaßnahmen für verschiedene Bauteile wie Flachdächer, Decken, Mauerwerkswände und Fundamente.

Die angewandten Berechnungsverfahren umfassen verschiedene Lastfallanalysen, Materialkennwertbestimmungen, statische Berechnungen für Bestands- und Ertüchtigungsmaßnahmen sowie die Bemessung nach aktuellen Normen und neuesten wissenschaftlichen Erkenntnissen. In regelmäßigen Workshops werden die durchgeführten Berechnungen und Ertüchtigungsmaßnahmen diskutiert, analysiert und optimiert.

6 FAZIT UND AUSBLICK

Das Forschungsvorhaben sowie die zugrunde liegenden Leitprinzipien des New European Bauhaus (NEB) bieten einen idealen Rahmen, um die geplante technische, energetische und thermische Ertüchtigung des Bestandsquartiers Otto-Wagner-Areal (OWA) qualitativ zu operationalisieren. Durch die Entwicklung einer strategischen Governance, die Implementierung eines Qualitäts- und Monitoringprozesses sowie die Erarbeitung eines Maßnahmenbündels zur Umsetzung wird zum einen eine nachhaltige Quartiersentwicklung des Areals sichergestellt, und zum anderen ein Modell für die Transformation von Bestandsquartieren geschaffen. Die dabei erarbeiteten Prinzipien lassen sich auf weitere NEB-Quartiere übertragen.

Die definierten Zielsetzungen für das OWA orientieren sich nicht nur an den Grundwerten des New European Bauhaus, sondern repräsentieren allgemein ein zukunftsweisendes Modell der Stadt- und Quartiersentwicklung. Dabei stehen Nachhaltigkeit, Ressourcenschonung und soziale Verantwortung im Mittelpunkt. Die erfolgreiche Transformation des Otto-Wagner-Areals kann somit als Inspiration und Vorbild für andere Städte und ähnliche Entwicklungsprojekte dienen.

Das Projekt hat das Potenzial, über den aktuellen Stand der Transformation historischer Bestandsgebiete hinauszugehen. Der energetisch-thermischen Ertüchtigung denkmalgeschützter Gebäude stehen in der Praxis häufig technische, wirtschaftliche und organisatorische Herausforderungen entgegen, die insbesondere private Eigentümerinnen abschrecken können. Als Eigentümerin im öffentlichen Besitz kann die OWA Revitalisierung GmbH durch die Entwicklung innovativer Instrumente und Lösungen eine Vorreiterrolle übernehmen. Gleichzeitig trägt das Projekt dazu bei, Investitionsrisiken für private Akteurinnen und Akteure zu reduzieren und ihre Investitionsbereitschaft zu erhöhen.

Ziel des Vorhabens ist es, die geplante technische, energetische und thermische Ertüchtigung des Otto-Wagner-Areals sowie seine behutsame Weiterentwicklung zu einem vollwertigen, nutzungsgemischten Stadtteil mit hoher ökologischer Qualität und Freizeitwert professionell vorzubereiten. Durch die Definition und Schärfung quantitativer und qualitativer Planungsziele wird eine präzise Grundlage für die Umsetzung geschaffen. Durch einen holistischen Ansatz (den Prinzipien des NEB entsprechend), die Interdisziplinarität des Projektteams und einer breiten Stakeholder-Einbindung werden in dem Projekt Learnings und Erkenntnisse gewonnen, die über den Nutzen für die Entwicklung des Otto-Wagner Areal hinaus, für die Entwicklung und Operationalisierung des NEB in der Stadt-/Bestandstransformation von hohem Wert sind.

In Bezug auf effiziente Energiekonzepte wurden für das Otto-Wagner-Areal bereits erste Überlegungen angestellt und Investitionen getätigt. Die dabei gewonnenen Erkenntnisse werden im Rahmen des Projekts weiter vertieft, reflektiert und systematisch aufbereitet. Dies trägt einerseits dazu bei, die Voraussetzungen für eine vollständige, wirtschaftlich effiziente und zeitnahe Dekarbonisierung des Energiesystems im Otto-Wagner-Areal weiter zu verbessern. Andererseits kann das an diesem Standort generierte und aufbereitete Wissen Eingang in die Planung und Umsetzung von nachhaltigen Energiesystemen an Standorten mit vergleichbaren Rahmenbedingungen einfließen.

In Summe generiert das Vorhaben umfassende positive Effekte. In gesellschaftlicher Hinsicht durch die Schaffung von Voraussetzungen für eine offene, vielfältige und variable Nutzung. In ethischer Hinsicht durch Maßnahmen für einen sorgsamen Umgang mit einem schützenswerten Bestand sowie durch einen sensiblen, zeitgemäßen Umgang mit der Funktion des OWA im NS-Regime. In umweltrelevanter Hinsicht insbesondere durch die Vorbereitung der vollständigen Dekarbonisierung eines historischen Bestandsareals sowie durch den dauerhaften Schutz hochwertiger Grün- und Freiräume.

Eine wesentliche Erkenntnis aus der Lehrveranstaltung ist die große Streuung der Berechnungsergebnisse. Diese Streuung ist in erster Linie auf Unsicherheiten hinsichtlich der geometrischen und materiellen Zusammensetzung der Konstruktion zurückzuführen. Für eine detaillierte Überprüfung und Verifizierung aller relevanten Parameter ist daher eine Freilegung der Konstruktion bis auf den Rohbau erforderlich. Diese Maßnahme wird im nächsten Projektschritt durchgeführt, so dass die gewonnenen Erkenntnisse in die weiteren Untersuchungen einfließen können.

Die durchgeführten Berechnungsmodelle, die erzielten Ergebnisse sowie internationale Vergleichsprojekte zeigen ein erhebliches Potenzial im Bereich des konstruktiven Ingenieurbaus. Insbesondere können durch verbesserte Berechnungsmodelle signifikante Einsparungen bei den Ausführungskosten erzielt werden. Die

wissenschaftliche Validierung dieser Modelle durch experimentelle Belastungsversuche liefert zudem eine fundierte Grundlage für die Weiterentwicklung effizienter Bauweisen.

Zudem müssen Methoden für Prüfkonzepte und Sicherheitsbetrachtungen entwickelt werden, um die Erkenntnisse aus der detaillierten Untersuchung eines einzelnen Pavillons systematisch auf weitere Gebäude übertragen zu können. Aufgrund der hohen Anzahl baugleicher Pavillons bieten sich systematische Lösungsansätze an, die sowohl einen effizienteren Umgang mit der Größe des Projektes ermöglichen als auch zusätzliche Einsparpotentiale erschließen. Durch die Anwendung optimierter Berechnungsmethoden auf eine größere Anzahl von Bauwerken können nicht nur Skaleneffekte genutzt, sondern auch wissenschaftliche Erkenntnisse auf breiter Basis validiert werden.

Indem die gewonnenen Erkenntnisse auf internationaler Ebene für vergleichbare Bauwerke nutzbar gemacht werden, kann die Vernetzung innerhalb der Fachwelt gestärkt und langfristig neue Standards für nachhaltiges und kostenoptimiertes Bauen gesetzt werden.

Das Projekt „Zukunft OWA“ leistet somit einen wesentlichen Beitrag zur nachhaltigen Stadtentwicklung und setzt neue Maßstäbe für die Transformation historischer Bestandsareale.

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A Comprehensive Evaluation Framework for Smarter Cities and Real Estate

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1 ABSTRACT

The terms smart city and smart real estate are often used with different definitions and scopes, as several fields and experts are involved in developing them, and each expert defines them based on their field. This study traces the concept of smart cities and identifies what a smart city and smart real estate are. There is a need for a framework that identifies what makes a city or real estate "smart" and aligns the definition to be suitable across different fields. Integrating smart technologies in urban development is crucial for enhancing cities' and real estate projects' smartness, efficiency, and sustainability. Although real estate technology-based companies have grown significantly, the global real estate industry still lags several years behind the technology curve. This study introduces a comprehensive evaluation framework to assess the smartness and integration of cities and real estate. The study identifies key success features and indicators. The developed framework is based on seven identified categories: smart governance, smart people, smart infrastructure, smart energy, smart environment, smart technology, and real estate status. A comparative benchmark analysis was utilized to demonstrate the practical application of the framework and to assess the current stages of smartness worldwide, revealing significant integration of smart solutions and highlighting improvement areas. The findings highlight the correlation between indicators and the strategies for integrating smart real estate into smart cities. The developed framework provides valuable insights for urban planners, municipalities, real estate developers, and other stakeholders to achieve smarter development and improve urban living conditions.

Keywords: smart city, smart buildings, smart real estate, smart technologies, evaluation framework

2 INTRODUCTION

Smart cities (SCs) and smart real estate (SRE) are rapidly becoming focal points of interest for countries worldwide. SCs leverage advanced Information and Communication Technology (ICT) infrastructure to enhance urban development, public services, and citizen engagement, promoting sustainability, productivity, transparency, and efficiency (Samarakkody & Kulatunga, 2019). The efficiency of SCs heavily depends on SRE and smart buildings; Smart buildings build SCs (Al-Rimawi & Nadler, 2023). By 2026, the global SB market will grow to 121.6 billion USD, with a compound annual growth rate of 10.9% (MarketsandMarkets, n.d.). The revenues and growth of the German SC market 2017 – 2022 had an increase of 16.5%, with building automation having the highest share of 21.1% of the market (Arthur D. Little GmbH & eco, 2022). The integration of SC and SRE is crucial for creating a connected, efficient, and sustainable urban environment, addressing global environmental and socioeconomic challenges. Countries like Japan and China are investing heavily in SC and SRE initiatives to rebuild and transform urban areas, aiming to improve the quality of life and promote sustainable urbanization (Schipper & Silvius, 2018; Washburn & Sindhu, 2010). The synergistic integration of SC and SRE is essential for achieving these goals.

3 BACKGROUND

3.1 Smart City Definition and Concept

The origin of the term SC can be traced back to the 1990s, as many related concepts appeared within that period. This evolved from the concept of a knowledge-based city in 1990, which emphasized the shift towards knowledge-driven urban development. In 1991, the term global city emerged, linking cities to global socio-economic impacts. By 1993, the term ubiquitous city was introduced, highlighting digital networks in the urban environment (Šiurytė, 2015). The late 1990s saw the rise of smart growth, emphasizing technology-driven urban development. In 2006, two key concepts emerged: the Intelligent city, focusing on

high learning and innovation capacities, and MESH city (Mobile, Efficient, Subtle, Heuristics), associating ICT with modern urban infrastructure (Samarakkody & Kulatunga, 2019; Schipper & Silvius, 2018).

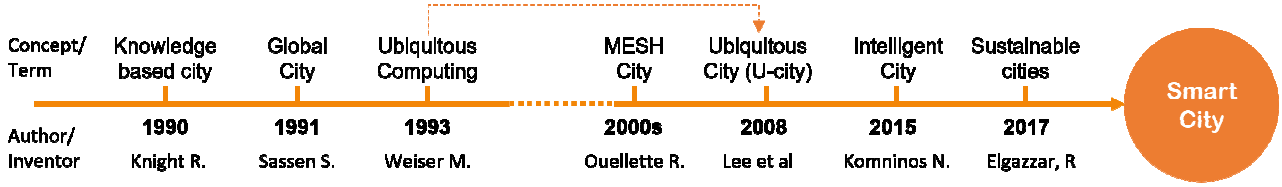

Fig. 1: Smart City Concept Evolvments, Author, 2025.

The definition of SC has been used in different ways, and it is defined based on different fields. However, researchers have not agreed upon what SC is based on in their field. Washburn and Sindhu are used, as they define SC as the use of smart computing technologies to make the critical infrastructure components and services of a city – which include city administration, education, healthcare, public safety, real estate, transportation, and utilities – more intelligent, interconnected, and efficient (Washburn & Sindhu, 2010).

3.1.1 Smart City Components

In comparison between SC and a traditional city, SC integrates Information and Communication Technology (ICT) infrastructure with its various components, these components work together to ensure urban development, efficient public services, and enhanced citizen engagement, making the city more sustainable, productive, transparent, effective, and efficient. In contrast, a basic city relies on conventional methods and infrastructure with minimal tech integration, often resulting in less efficiency and sustainability (Samarakkody & Kulatunga, 2019). Based on the review of various sources, Figure 2 identified SC components, seven components are interrelated with SC and SRE: smart governance, smart people, smart environment, smart infrastructure, smart energy, smart technology, and smart buildings. These components, linked by SC technologies, are critical for developing the evaluation framework. Smart governance includes public participation, data transparency, internet of things (IoT) devices for quality of life, and health and safety measures through e-health and telecare. Smart energy integrates sustainable sources, efficient distribution with smart infrastructure, grids, meters, and information infrastructure collecting and sharing energy data. Smart technology links all components with state-of-the-art technologies. Smart environment includes pollution control, water quality monitoring, and waste management with sensors, policies, and strategies. Smart buildings, equipped with IoT sensors, enhance user satisfaction. Smart infrastructure, fundamental to SCs, includes communication infrastructure. The smart transportation system shifts to Mobility-as-a-Service, connecting users through IoT infrastructure (Al-Rimawi & Nadler, 2023).

Fig. 2: Smart City Concept Evolvments, Author, 2025.

3.2 Smart Real Estate

SRE refers to the integration of advanced and disruptive technologies into the real estate sector to enhance the functionality, efficiency, sustainability, and user experience of buildings and properties. This includes the use of smart technologies such as big data, artificial intelligence (AI), ICT, IoT, clouds, drones, 3D scanning, wearable technologies, virtual reality and augmented reality (VR and AR), geographic information systems (GIS), building information modeling (BIM), digital twin, blockchain and smart contracts. Smart real estate aims to optimize energy consumption, improve security, enhance comfort, and provide real-time data for better decision-making. It encompasses smart buildings, smart homes, and smart cities, all working together to create a more connected, efficient, and sustainable urban environment (Al-Rimawi & Nadler, 2025).

SRE involves the broader application of advanced technologies across the entire real estate ecosystem, including residential, commercial, and industrial properties. In contrast, smart buildings concentrate on applying technology within individual structures to enhance their internal systems and operations, leveraging sensors, software, and networked devices to monitor and control aspects like energy usage, lighting, heating, ventilation, and security. While SRE aims to provide a sustainable, innovative, and user-centered environment for consumers, smart buildings focus on optimizing performance, comfort, and sustainability within the building itself. Thus, SRE covers the entire ecosystem, whereas smart buildings emphasize automation and monitoring within individual structures. While traditional buildings lack the technological integration of smart buildings and SRE. Traditional buildings rely on manual controls for heating, lighting, and security, and don't use real-time data or automation. This results in less optimized energy consumption, higher utility costs, and a larger environmental footprint, with lower levels of user experience and comfort.

3.2.1 Real Estate Integration into Smart Cities

The level of real estate (RE) integration into smart cities (SC) depends on the SC network's capabilities and the resources provided by the RE developer. Various RE developments in SC strategies exist, each differing in smartness and intelligence levels. All strategies should be part of a coherent plan to ensure effective integration into SC (Al-Rimawi & Nadler, 2023). Three integration strategies are identified:

(1) Leading Strategy: RE development becomes the dominant factor in smartness, influencing its surroundings and setting new standards for others to follow, (2) Following Strategy: Developments use, dominant and leading benchmarks, potentially located elsewhere; (3) Waiting Strategy: Developments incorporate fragmented features of intelligence and smartness.

4 MATERIALS AND METHODS

4.1 Evaluation framework development

4.1.1 Smart Evaluation Framework Purpose

The evaluation framework aims to identify success indicators for SCs and SRE. It assesses performance, identifies deficiencies, and highlights potential improvements. The framework reveals interoperability capabilities between SCs and SRE, emphasizing future trends. It's flexible, modifiable, and can include new indicators for future technologies. The framework benefits municipalities, RE developers, contractors, and owners in building SCs and SRE and aids in making informed investment decisions. Researchers and other entities can also use it to evaluate and develop smart developments. It evaluates existing cities and real estate to determine their current status and identify measures to increase their smartness. Additionally, it helps in planning SCs and SRE by providing a roadmap and requirements for their creation.

4.1.2 Evaluation Framework Development Process

The evaluation framework for SCs and SREs is constructed on multiple layers, analyzing existing classifications and SC components. Seven interrelated categories were selected: smart governance, smart people, smart infrastructure, smart energy, smart environment, smart technology, and RED status. Both SCs and SRE share these main categories. The framework also includes sub-categories with specific indicators chosen based on theoretical background, desk studies, indexes, and other publications. At the SC level, indicators were selected based on SC components, solutions, and technologies. Evaluation schemes like Smart City Index (SCI 2021), City in Motion Index (CIMI 2020), EU Taxonomy 2020, (Kaluarachchi, 2022), and (Shari, 2020) significantly influenced the selection process, along with other frameworks and

references. At the SRE (project) level, indicators were based on SRE components, solutions, and technologies. Schemes like SBISC (Apanaviciene et al., 2020), Jain's smart building evaluation system (Jain, 2019), and the Big 9 study (Ullah et al., 2018) played a major role, alongside other indexes, tools, Sustainability certification such as LEED and BREEAM and references including EU Taxonomy 2020 and the EU Smart Readiness Indicator (SRI) scheme. Both frameworks consist of seven categories, each containing multiple sub-categories. Each sub-category includes several indicators, with each indicator assigned a weighted score based on its importance and relevance to the evaluation criteria.

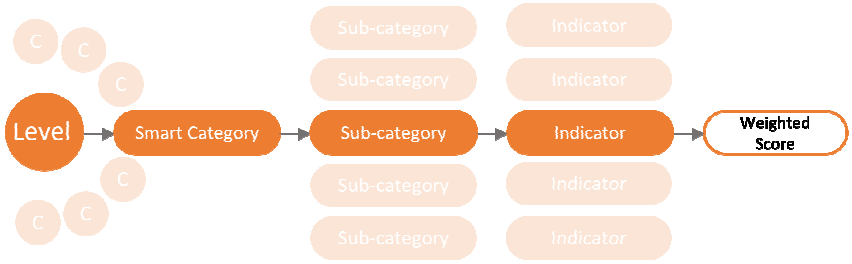

Fig. 3: Evaluation Framework Main Elements Illustration, Author, 2025.

The indicator score is determined based on its importance and relevance. The justification and scoring criteria incorporate several elements and are primarily derived from three sources. Indexes: the score is based on published indexes and subsequently calculated according to the indicator weight. figures and percentages: the score is derived from element counts or percentages, categorized within a developed range specific to each indicator, and scored accordingly. Various sources: utilized for indicators with multiple elements that cannot be evaluated based on a single element, where each element and source is listed, representing specific points, providing a maximum achievable score for the indicator. For all sources, the minimum and maximum performance are considered to develop a proper and realistic scoring and evaluation System.

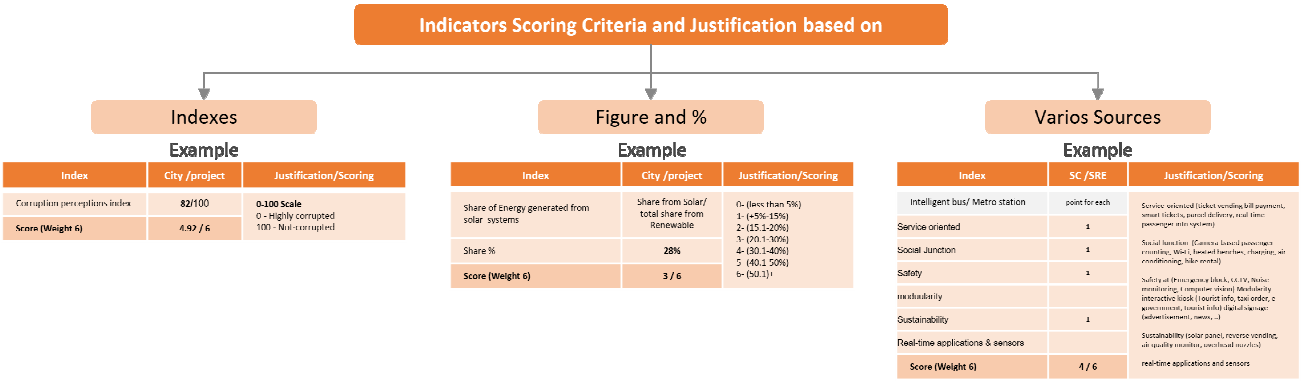

Fig. 4: Scoring Justification and Sources, Author, 2025.

4.2 Evaluation Framework

4.2.1 City Level

A total of 28 sub-categories and 85 indicators were used to evaluate the SC. The weighted score of each indicator is among these ranges (4, 6, 8, 10 points), it is identified based on its importance and relevance to the evaluation criteria. The total score was 560 points, distributed equally, with 80 points for each category.

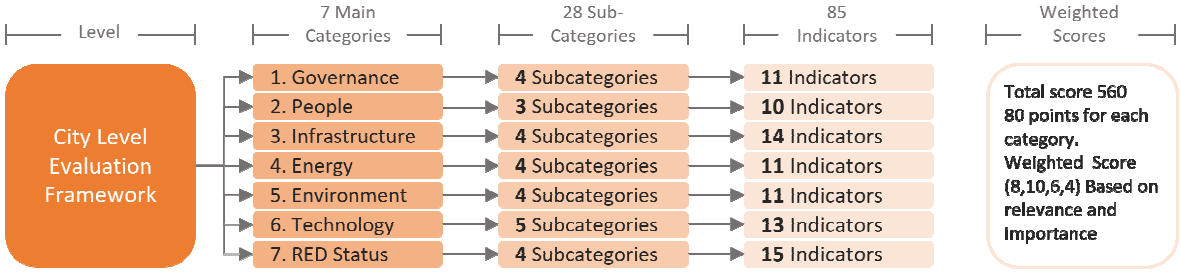

Fig. 5: Smart City Level Evaluation Framework Main Elements, Author, 2025.

Figure 6 represents a simplified illustration of the SC level evaluation framework, based on the developed framework of the authors (Al-Rimawi & Nadler, 2023) illustrating the main categories and sub-categories, with hints of the number of indicators, sub-category scores, and category score, to briefly represent which areas does the framework cover and target.

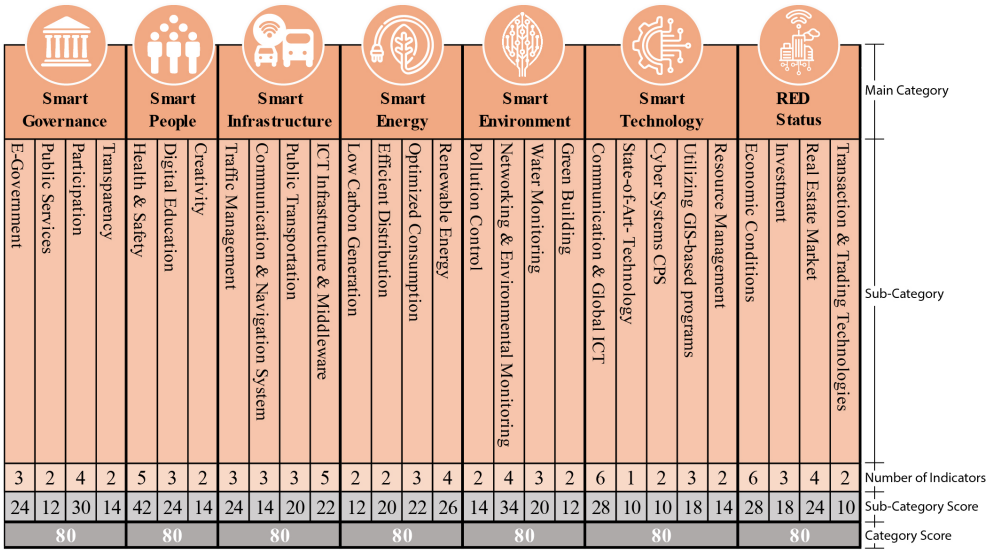

Fig. 6: Smart City Level Simplified Evaluation Framework, Author, 2025.Based on (Al-Rimawi & Nadler, 2023)

4.2.2 Real Estate (Project) Level

The smart project was evaluated using 90 indicators across 28 sub-categories, with an overall score of 255 points, distributed based on their relevance to SRE. Central to SRE, smart technologies had the highest share with 60 points. Smart energy and smart environment received 40 points each, while smart infrastructure and RED status had 35 points each. Smart people and smart governance, with indirect relevance, received 30 and 15 points, respectively. Each indicator's score weight was determined based on its importance and relevance to the SRE evaluation criteria, the weighted score is among these range of (1 – 5 points). It is worth noting that the ranges and total scores in the evaluation frameworks of the city level are different, to be able to assess elements at a more focused range, the maximum score at the project is out of 5, but in the calculations and measurements the results are based on percentages, where the range is not affected by the importance of the scale, it is only used for suitability in calculations, to ease the evaluation system for each case.

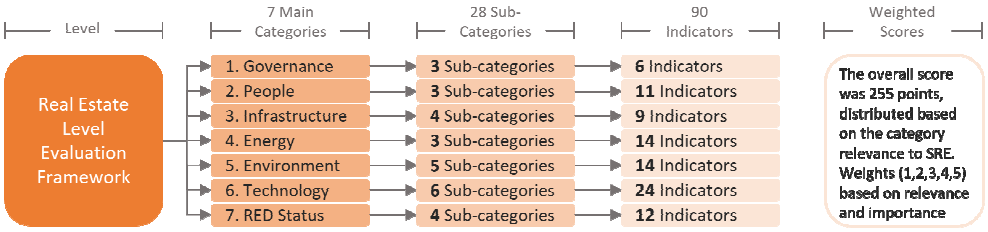

Fig. 7: Smart Real Estate (Project) Level Evaluation Framework Main Elements, Author, 2025.

The SRE level evaluation framework is represented in a simplified illustration in Figure 8, based on the developed framework by Al-Rimawi and Nadler (2023), illustrating the main categories and sub-categories, with hints of the number of indicators, sub-category scores, and category score, to briefly represent which areas does the framework cover and target.

5 BENCHMARKS ANALYSIS

The benchmark analysis was vital for this study to test the evaluation framework, understand how SC functions, and determine their impact and integration with SRE. It provides insights that help define SC principles in both theory and practice, aiding in the assessment of smartness status worldwide.

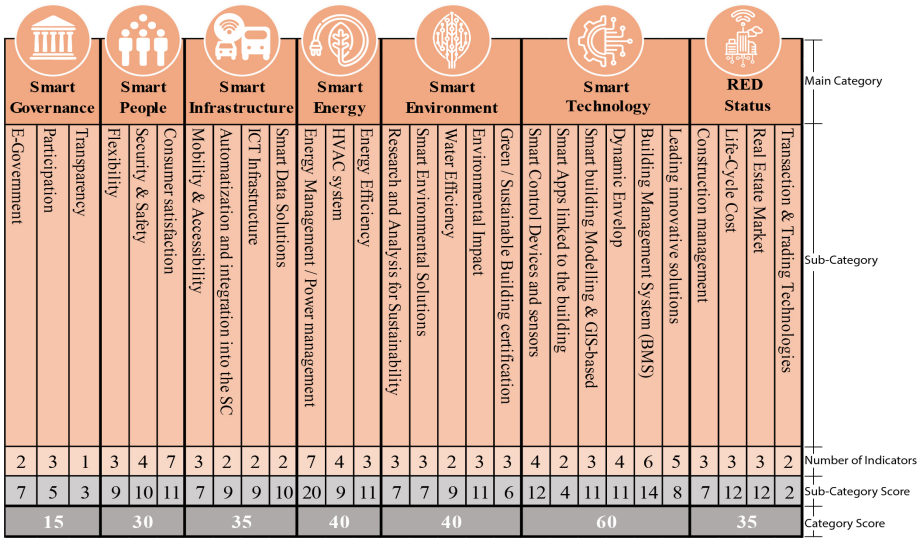

Fig. 8: Smart Real Estate Level Simplified Evaluation Framework, Author, 2025.Based on (Al-Rimawi & Nadler, 2023)

5.1 Benchmarks Selection Criteria

Table 1 illustrates the selection criteria for both levels. These benchmarks aim to identify and measure the current status of leading SCs and SREs. This provides insights into achievements and areas needing improvement and sets realistic goals for cities and projects within today's smart market.

Level	Criteria		Description	Justification
Smart City Level	Location		Worldwide/different continents	To measure location impact
	Scale		Diverse scale	To measure scale impact
	Population		More than 1.5M	To obtain large-sized cities
	Smartness		Include minimum core components	To locate SC
	Smart Technology		Utilizing smart technologies	To ensure suitability as an SC.
	Indexes	Smart City Index 2021	Ranked within the top 60–118	To ensure suitability as an SC.
		Cities in Motion Index 2020	Ranked within the top 60–174	To ensure suitability as an SC.
		The Global Financial Centres Index GFCI -2022	Ranked within the top 60–119	To capture a leading financial center, reflecting the financial aspect
		Innovation Cities 2021	Ranked within the top 60–500	To integrate innovative solutions
		Quality of Living City Ranking	Ranked within the top 60–231	To ensure adequate quality of life
Smart Real Estate Level	Location		In the selected Smart City	To ensure a clear SC/SRE link
	Project Type		Commercial RE project	To identify impact factors on RE
	Scale		Building scale	To assess projects at a transitional scale
	Project Status		Implemented	To evaluate the project operation Utilizing
	Smart Technologies		Utilizing Smart technologies as part of its operations	To ensure smartness and to be linked to SC
	Sustainability		Certified LEED or equivalent	Ensure Sustainability

Table 1: Benchmark Selection Criteria Description and Justification, Author, 2025.

5.2 Selected Benchmarks

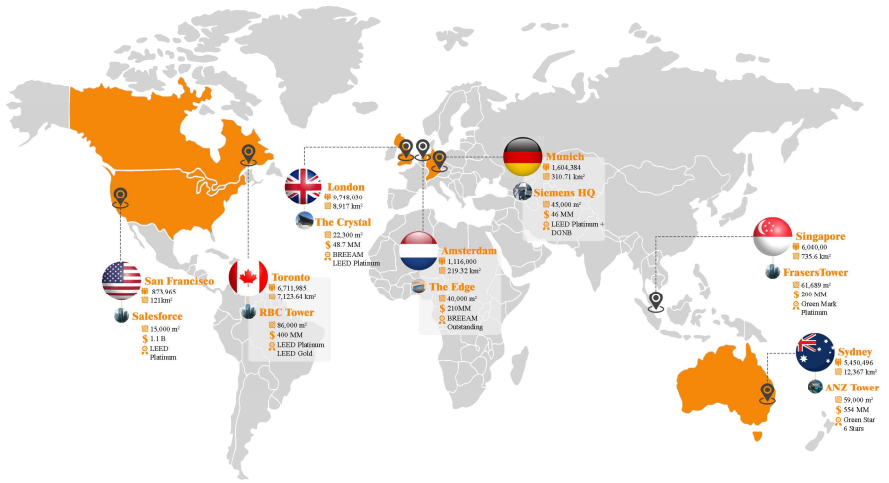

Fig. 9: Selected Benchmarks noth levels, Author, 2025.

Seven SRE were selected within seven SCs as shown in figure 9. The Edge in Amsterdam is the world's smartest and greenest building, achieving a 98.4% BREEAM score in 2015. It features IoT-based smart technologies, an efficient aquifer thermal energy storage system, and 28,000 sensors. The Crystal in London is the first building to achieve both Outstanding BREEAM and Platinum LEED accreditations. It adapts to the environment, generating 20% of its energy using photovoltaic cells. Siemens Headquarters in Munich is a certified Platinum LEED and DGNB building, using geothermal and photovoltaic systems for energy efficiency. Frasers Tower in Singapore is Green Mark Platinum-certified, with sustainable solutions and real-time data management. ANZ Tower in Sydney has a 6 Star Green Star rating, integrating smart grid and ventilation technologies. Salesforce Tower in San Francisco is LEED Platinum pre-certified, with sustainable solutions and a converged network. Using energy-efficient and sustainable design, RBC Waterpark Place in Toronto achieved LEED Platinum CandS and LEED Gold for OandM certifications.

6 RESULTS AND DISCUSSION

Based on the evaluation frameworks, London ranks as the smartest city among selected benchmarks with a score of around 70%, while the average SC level score is 65%. The Edge in Amsterdam ranks as the smartest RE, scoring 84%, with the average benchmark score being 72%. The framework aims for ultimate performance, considering future evolution. Only an ideal SRE in an ideal SC would achieve a full score, so the selected benchmarks are considered good to very good.

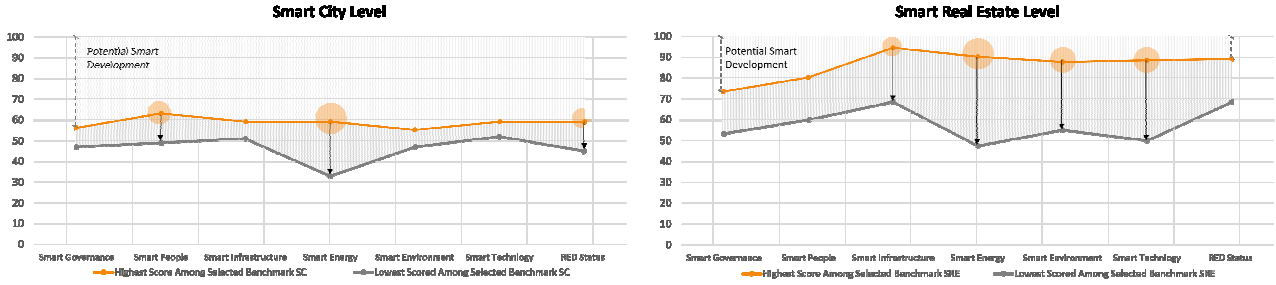

Fig. 10: Performance range between highest and lowest scores (city and real estate levels), Author, 2025.

Figure 10 shows the highest and lowest scores, creating a smart performance range to guide evaluators in assessing SCs and SREs. Some categories have insignificant range differences, while others, like smart energy, show significant drops, indicating potential technique failures or neglected elements. The evaluation framework revealed gaps in SCs and SRE, even for selected benchmarks. Further improvements are needed to reach a smarter state on both levels.

Figure 11 illustrates the SRE and SCs level performance in each smart category based on the average performance of the selected benchmarks. On average, the leading category at the SC level is smart technology and smart infrastructure for the SRE level.

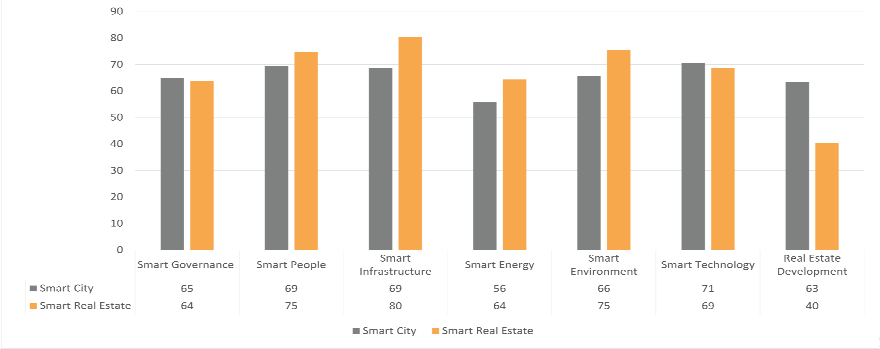

Fig. 11: Selected Benchmarks' average performance in the main smart categories, Author, 2025.

Figure 12 presents the sectional analysis of selected benchmarks' SRE integration into SCs and the performance of both levels in each category. SREs in Amsterdam, Munich, and London followed a leading strategy, being more developed than several SC categories. Projects in Singapore and Toronto adopted the following strategy, enhancing existing elements and exceeding in some areas. San Francisco and Sydney SREs followed the waiting strategy. The analysis shows that SC performance limits smart governance at the SRE level, with no selected SRE exceeding that limit. On average, projects adopted the leading strategy in

RED status, smart people, and smart infrastructure, and the following strategy in smart governance, smart environment, and smart energy. Smart technology followed the waiting strategy, with a decline in performance, indicating that the SRE technologies are still behind the curve

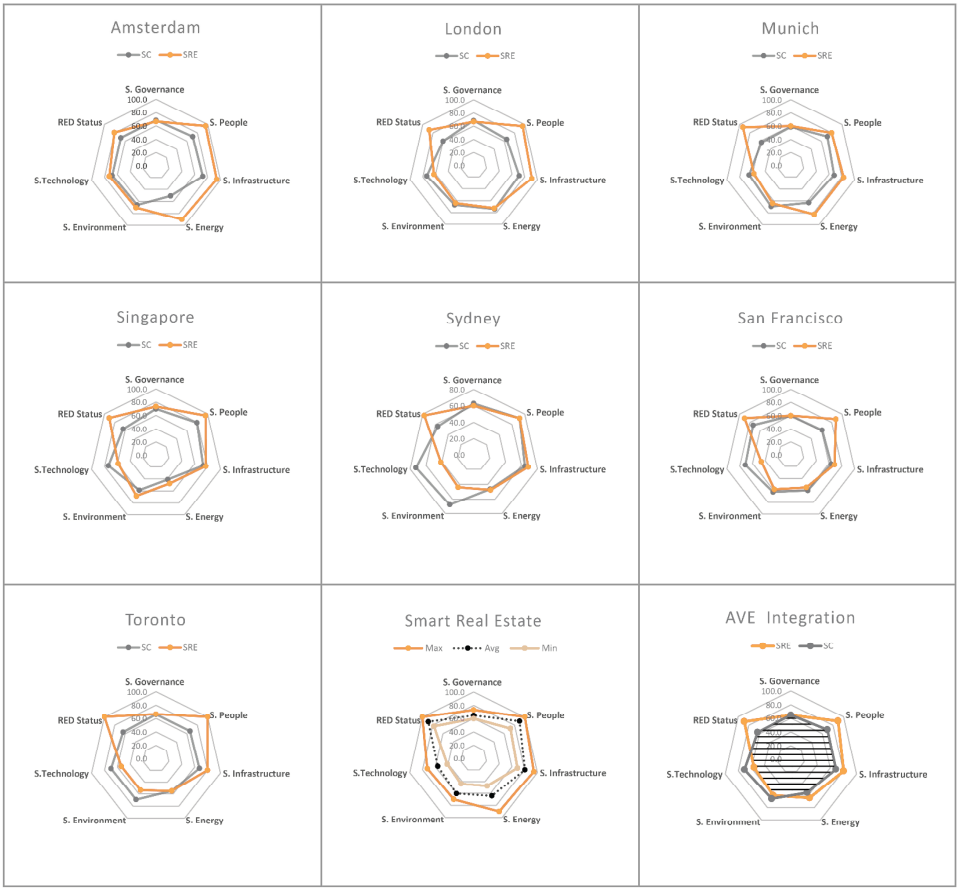

Fig. 12: Sectional analysis of selected Smart Real Estate integration into Smart Cities and the performance, Author, 2025.

In this study, a correlation analysis was performed on both SC and SRE levels and their integration using SPSS (Statistical Product and Service Solutions) software. The analysis covered three classifications: main categories, subcategories, and indicators. Results revealed significant integration and mutual impact between SC and SRE, with correlations detected across most elements. Notably, smart infrastructure, smart governance, and smart technology demonstrated the highest correlation and impact on various categories within both levels and their influence on each other.

Significant correlations were identified within the subcategory classification. At the SC level, e-government, transparency, and ICT infrastructure showed the highest correlations. At the SRE level, the highest correlations were found in ICT infrastructure, smart data solutions, and BMS. Integrated subcategories with high correlations included public transportation, transparency, cyber systems, mobility and accessibility, environmental impact, and smart apps linked to buildings.

7 CONCLUSION

The real estate sector is constantly evolving, requiring city management and developers to stay updated with advancements to create smart and leading developments. Both academic and practical sectors should invest in developing smarter cities and real estate through a coordinated approach. Given that smartness levels cannot be easily measured and compared, the developed evaluation tool addresses this issue by identifying the smartness level of cities and real estate developments. This tool provides clear gap identification, allowing stakeholders to focus on enhancing smartness.

This study developed and applied a comprehensive evaluation framework for smart cities (SC) and smart real estate (SRE), comprising 85 and 90 indicators, respectively. Applied to seven benchmarks per level, the analysis showed that cities and real estate developments are adopting smart principles and progressing towards smarter statuses. The smart performance of selected benchmarks ranged from good to very good,

with SRE projects achieving an average of 72% and SCs averaging 65%. Achieving a full score would not be realistic; only an ideal smart real estate in an ideal smart city could reach that score.

The results indicated a high correlation between smart cities and smart real estate developments, highlighting the necessity of investing in both scales as their impact is proportional. The development strategies varied: three projects followed a leading strategy, two adopted a following strategy, and two employed a waiting strategy. On average, smart real estate tends to adopt the leading strategy, except in smart governance, technology, and environment. To achieve smarter development and improve users' quality of life, efforts should focus on enhancing both levels due to their significant interdependence.

Future research should integrate the evaluation framework with existing systems such as SmartScore certification and smart building certification, adapting to evolving technology. This flexible framework can evolve into a recognized rating and certification system for smart cities and real estate, guiding municipalities, developers, and stakeholders in making informed investment decisions.

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Climate Change and Green and Blue Infrastructure

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1 ABSTRACT

The living environment faces challenges and risks due to the consequences of globalisation. Climate change and its crisis set a complex scenario, leading us to rethink about planning solutions and how to adapt our living spaces. In order to mitigate current social and environmental challenges, cities play an essential role and have big potential to promote a different (and better) scenario. Often, denser cities are the focus of such climate adaptation, but what about smaller cities and rural areas? How does globalisation affect these places? This paper intends to build analysis from literature about the influences of globalisation on the current living environment, how public spaces in small cities could potentially be adapted to mitigate climate change challenges, and how Green and Blue Infrastructure (as a strategy and scalable method of adaptation) could help cities (local and regional level) to promote liveability for more than humans in the future. Furthermore, two different scenarios are presented and analysed in order to develop a reflection on the consequences of globalisation in Jaboticabal (Brasil) and a public space project in Horn (Austria) as examples of how public spaces in smaller cities could be adapted in order to tackle socio-ecological aspects.

Keywords: urban landscape, climate change, globalisation, public space, green and blue infrastructure

2 INTRODUCTION

Climate change is a multilayer phenomenon. As Neyran Turan says, climate change "is an environmental, cultural, and political phenomenon that is reshaping the way we think about ourselves, about our society, and about humanity's place on Earth." (Turan 2016). In the field of architecture and urbanism, these aspects are also leading professionals to rethink about how to overcome this phenomenon within built spaces.

Certainly, "there is more to say about climate" (Graham et al. 2026), specific activities from human activities on the planet intend to intensify the climate change as well as social and environmental injustices, leading the existence of several beings into deeper vulnerability towards the future.

Therefore, different aspects regarding 'how we do things' and 'how we live' (as professionals and as civilians), must be critically reviewed in order to develop functional adaptation plans for the current built spaces. As Keenan says, "a diverse set of disciplines and perspectives is required to understand the impact of climate change and to exercise some measure of agency over its causes and ills." (Keenan 2026), it emerges the question of what is architecture's and urbanism's role in this scenario. How to adapt everyday life spaces in order to tackle wellbeing and climate change? How is the transformation of spaces happening in smaller cities? How is the scenario in smaller cities and rural areas away from mainstream cities?

Architecture and urbanism play as stronger influences on the built environment. The climate and the environmental need to be restored and tackle contemporary and future socio-ecological challenges. There is the urge to think about Earth as a host to life itself rather than only a host to cultural diversity (Graham et al. 2026) and to take into consideration ecological systems, the cohabitation of beings (human and nature), and the efficiency of sources (use and consumption).

In order to develop the analysis of this paper, a literature review mainly from political ecology perspectives should be developed. Firstly, a review on globalisation and the influences on climate change. Secondly, the literature addresses the topic of how to better integrate nature-based solutions in public space planning, highlighting how relevant it is to enable public spaces as part of society's engagement aspect as well as for coexistence with nature. In the final part of this paper, two different scenarios in small cities are presented in order to develop analysis and reflection on the consequences of globalisation in a small city in Braziland a public space project in a small city in Austria.

3 GLOBALISATION, CLIMATE CHANGE AND ITS CRISIS

Globalisation has highly influenced society's ways of living, and with the predominant focus on the economic development, our living environment has changed and faces negative impacts. The environment

started to change rapidly after 1850, but especially after 1945 (Moore 2017). From a political ecology perspective, Ulrich Brand et al. (2020) outline the influences on the rapid change, as "the ongoing expansion of the unsustainable production and consumption of commodities and the accelerated use of resources at the globe scale, a focus on economic growth at almost any cost and fierce world competition, the development model of resource extractivism in Latin America and elsewhere" (Brand et al. 2020). The consequence of a predominant capitalist society is clearly, as Brand complements, the accelerated "climate change, loss of biodiversity, the economics crisis, rising inequality within many societies, the crisis of democracy" (Brand et la. 2020) and more.

James Roberts also notes about the consequences and negative impacts from the processes of globalisation (production and consumption), he says, "generations of increasing fossil fuel use, industrial development, population growth, and related processes of population and resource degradation have led to broad scale ecological and climatic changes that are no longer easy to deny." (Roberts 2020). The way entire ecosystems and ways of living are increasingly threatened, it is a reality that should not be taken as ordinary or denied, even though it seems complex to be solved.

Regarding diagnosis and care, Fitz and Krasny also present a perspective on the dramatic socioecological scenario of our planet. As they borrow from the medical term of critical care, they discuss the world's environment condition and urge of care (Fitz & Krasny 2019). Our living environment is in danger and our ways of living and doing things need to be rethought. Fitz and Krasny call it the violence of petro-capitalism and say how it led our planet to suffer, to experience an accelerated environmental crisis and to lead human life and the environment to a war with our economy system, meaning that "not all human activity, but very specific "activities of corporate industry" cause the present day catastrophic ecological disruptions." (Fitz & Krasny 2019). After technological and economic transformations – industrialisation, globalisation, urbanisation – it is time to review the consequences of the process and acknowledge factors that are leading our living space and our environment to collapse and review tactics to overcome the contemporary threats, mitigating climate change.

Climate change is a phenomenon and can be acknowledged in different ways. As Hulme analyses, climate change can be observed, quantified and measured (Hulme 2010), and one of the ways to analyse, is as an inspiration for global networks of reinvigorated social movements. He says, "Seeing climate change as a manifestation of the nefarious practices of globalisation, this framing warrants the emergence of new forms of activism, both elite and popular, to change these practices and to catalyse change in political, social and economic behaviour." (Hulme 2010).

As architecture and urbanism "are always concerned with the future" (Fitz & Krasny 2019), and in order to promote a better future for all, it is necessary to consider "a long-term commitment to planetary care based on human and non-human livability" (Fitz & Krasny 2019) and in different scales, from private to public, from houses to schools, from neighbourhoods to cities and regions.

4 GREEN AND BLUE INFRASTRUCTURES AND PUBLIC SPACES

4.1 Green and Blue Infrastructure

More than fifty years ago, Odum said that society should – and must – find a way to deal with landscape as a whole (Odum 1969). Climate change and its crisis can lead to the extinction of different species, including human beings. It is necessary to acknowledge that humans do not live only by food and fiber, but also "need a balanced CO_2-O_2 atmosphere, the climate buffer provided by oceans and masses of vegetation, and clean (that is unproductive) water for cultural and industrial uses." (Odum 1969). The predominant economic development system influences on the dynamics of the urban and non-urban, transforming the space and quality of living. As example of a strong factor from the current system is the development and predominance of monocultures. The preoccupation of "obtaining as much production from landscape as possible", is leading to an unbalanced ecosystem, which strongly influences the acceleration of climate change and still do not provide fair livelihood, food, water or safe environment for many people in the world. Additionally, the stronger climate crisis' impacts on everyday life are, the bigger the need for action by various stakeholders, politicians and civil society to take action towards climate-friendly and biodiverse urban development adaption (Ahn & Knierbein 2023). The time for radical action is now.

The non-urban is every time more occupied by the urban fabric, and oppressing the urban hinterlands with a loss of wildness (Brenner & Schmid 2012). Nowadays, many cities are not only lacking quality public spaces but experience the absence of green spaces and are facing consequences of the ongoing economic development system, even by the influence on weather seasoning and air quality. “Every year, more than seven million people die from pollution-related causes” (Vieira et al. 2023), despite the several further challenging consequences from current times.

The contemporary city presents much of sealed area, lacking on green spaces, trees and permeable soil, which is costing a lot for its dwellers (Abuje et al. 2023). Within the accelerated climate change occurrences, people are becoming more vulnerable to extreme nature hazards and living insecurity. The stronger climate change impacts the biosphere, the harder it gets to tackle its crisis and restore biodiversity and dignity of living. Abuje et al. mention that “climate change reinforces the need to make changes in the cities so they can handle new situations and implement green urban development initiatives. Large green areas and more sustainable responses are crucial in dense cities to avoid natural catastrophes and make cities more livable for all.” (Abuje et al. 2023). But, even though it is essential to tackle dense cities (where the urban population tends to grow), adaptions must be approached in different scales: rural areas, smaller cities and even the wildness must be restored, adapted and secured. The opposite from the competitive mindset of neoliberal cities, it is necessary that urban spaces cooperate with one another, promoting from a smaller to a larger green and blue infrastructure that can in sync contribute with the development of an urban ecological system of neighbourhood cities and regional hinterlands.

As Abuje et al. say, “mitigating climate change does not mean, however, that it will not happen.”(Abuje et al. 2023), but it is a reality and new practices must be adapted and implemented as soon as possible in order to mitigate it. Furthermore, Abuje et al. talk about the specific role of public spaces in the adaption of the urban. To have the accessibility to public green spaces and adaption to climate change at the same time might be the share of a common approach: “nature-based solutions in urban planning.” (Abuje et al. 2023).

Green and Blue Infrastructure (GBI) can be beneficial on different levels to the city and its surrounding. Nature-based design solutions can potentially tackle not only challenges during drought and flood seasons, but also by implementing functionality in public spaces, guaranteeing the wellbeing of future generations, to promote space for biodiversity and livelihood as well as improve urban metabolism systems. GBI became strongly known as a concept of stormwater management (Hoyer et al. 2011). As Lamont and Everett explain, “the phrase ‘blue-green’ or green/blue’ infrastructure emerged (…) from a growing awareness of the need for an integrated systems-approach to the management of Green and Blue Infrastructure” (Lamont & Everett 2019). This could be a matter that can provide not only technical solutions for nature hazards, but to benefit thewhole living environment in its socioecological sense. GBI can potentially improve urban ecosystem services through different sets of land uses such as, “parks and reserves, gardens and backyards, waterways and wetlands, pathways and greenways, farms and orchards, buffers and windbreaks, squares and plazas, roof gardens and living walls.” (Bellezoni et al. 2020), enabling quality public spaces and social interaction through nature.

4.2 The Need of Public Spaces

The spatial organisation of cities and its hinterlands has drastically changed through structural shifts in economical and technological aspects (Madanipour 2019). From a critical analysis of the modernist manifesto and the Charter of Athens, public spaces where considered as "breathing spaces in the overcrowded and badly built cities” (Madanipour 2019), with the main idea to support and serve buildings – a thinking of design from inside out. In the 1960s, when spatial organisation mainly started to be transformed, Jane Jacobs acknowledged the relevance and impacts of the urban landscape on the life of New York City’s dwellers (Hurting et al. 2023), especially when there is no proper public space at all. The modern city and its processes of globalisation have strongly influenced the quality and existence of public spaces. Debates around private and public sector as well as maintenance and management of public spaces became more lively ever since.

The political, economical and cultural significance of the public space has been known since ancient times integrally as part of the city (Madanipour 2019), the urban. As Friedmann explains, there is a relevance of spaces in the cities that conduct everyday life, social reproduction and construction of social meanings (Friedmann 1999). It is also where some of the scales of cohabitation happen; to others (bodies), to

buildings, public spaces, to the city. In spite of the fact that political aspects (necessarily) unfold in the public space arena.

Humans have been influencing these scales of cohabitation, "creating, inhabiting, and readjusting theses spaces over centuries." (Sarkis 2021), and regarding the public spaces, through the development of modern cities, public spaces became often poorly designed, maintained or managed as a leftover space (Bravo 2023). A reality that is unfortunately even more common in the Global South, but also, common to be seen in smaller cities around the world that are not considered as a mainstream city.

The acknowledgment of Jane Jacobs about the relevance of urban landscape, in the 1960s, from a female voice, she also argued about how urban development practices were detached from real human needs (Hurting et al. 2023). Hence, thinking of public spaces as a potential urban space to adapt and tackle climate change (also a current human need), it could also mean to tackle everyday life struggles in social and environmental matters. An example of a social aspect, which design must think about regarding public spaces and the urban environment, is the vulnerability of certain groups as feminized bodies, LGBTIQ+ groups, or people with low incomes (Hurting et al. 2023), disabled and older people. It is necessary to develop planning that is socially and environmentally sensitive and to introduce gender-sensitive planning. On the other hand, climate matters regarding air quality and seasonal aspects.

5 TWO DIFFERENT CONTEMPORARY SCENARIOS

In August 2024, a dramatic occurrence of many simultaneous fire spots occurred in many cities and regional parts of Brazil. One of these places was in Jaboticabal, a small countryside city in São Paulo State, located in a Cerrado biome. With approximately 71.000 inhabitants, the city has mainly of its hinterlands' landscape occupied by monocultures (mostly private owners and local sugar industry). At this time of the year, the dry season, the fire occurrence had an even faster spread turning the situation harder to control. The devastation of small forests as well as of agro-industrial monocultures was predominant, but also, the bad air quality led some families to leave their houses or to stay inside, covering their door and window gaps with wet towels.

Besides this specific event from 2024, it became "common" for cities in the central region of Brazil to have sand storms between July and October (dry season), not only due to the larger area without protection of vegetation cover and native vegetation (BBC News Brasil 2021), but also, from commercial activity affecting the air quality, "from biomass burning, which releases large quantities of gas particles into the atmosphere." (Vieira et al. 2023). Regarding the enormous influence from the agro-industrial sector, Brazil displays an overall challenging social and environmental scenario for its inhabitants. Jaboticabal is only one example of many small countryside cities that lack government attention to the environmental consequences due to patterns of globalisation. The modernisation of mainstream cities also led to small cities lacking quality green public spaces and wilderness, that could potentially improve social and (living) environmental matters (such as during dry seasons).

Regarding a social aspect of social interaction with the city in such countryside areas, it is common to drive (usually with private vehicles) from private to semi-public spaces and to have almost zero interaction with the city, which is a common routine of everyday life. For these citizens, a common type of public life during a free time varies from visiting local public events (such as yearly church events, the city's anniversary events or rodeos' concerts). Lower income inhabitants enjoy to sit in front of their houses and watch the street (specially when the weather is too hot to stay inside). The younger population usually meets at gas stations with friends or drive to a neighbour city and visit indoor shopping malls. The lack of quality green public spaces and urban liveability is a common character of these cities, influencing a bigger alienation within the citizens, a weak relationship with the city (and with nature even) and possibly the migration to mainstream cities. The need to enable quality public spaces is essential to unfold social interaction and cultural meaning. Public spaces are also necessary in order to coexist with the built environment on a public level. Generally, to pursue safe public spaces is crucial to promote a human-oriented approach to cities (Bravo, 2023), including the possibility to reestablish the relation and cohabitation of humans with nature and biodiversity.

A different scenario, now in Horn, a small city in Lower Austria, shows how smalls cities can restore public spaces promoting quality public space combined with green and blue infrastructure and climate change adaptions. The project Stadtsee Horn, designed by the landscape architecture office YEWO LANDSCAPES

(located in Vienna). Around 150 years old, the city lake Horn was once a paid access swimming area and the access was only possible during summer season. Even as private, the lake usually had an importance for the city inhabitants as a place for social interaction. Through time, the lake area became outdated, both in its function as well as its appeal. The access to the lake became deteriorated and partially risky for elderly and disabled people. The main goals of renovating the area were to open up the restricted swimming area to everyone all year round and to create appealing spaces for sports, play, culture, leisure and gastronomy. Furthermore, the aim was to restore the area promoting social interactions for locals and visitors, as well as to become a climate adapted space.

The project presents in its concept the implementation of additional trees, the improvement of water quality with natural and technical filtering, including chosen materials like wood and light colour stones that complement natural aspects of the space. In addition, a playground and sports area, a bicycle path and various design details provide multigenerational accessibility into the space, developing an area that improves social and environmental aspects.

Fig. 1: Fire along road in country city hinterlands of São Paulo State (Foto: Marcelo Moraes/EPTV, 2024). Fig. 2: Sandstorm in Ribeirão Preto (Brazil). City around fifty-nine kilometres away from Jaboticabal (2023).

Fig. 3: Project Stadtsee Horn, Austria (2022). Renovated swimming lake. Foto: Kurt Hörbst. Fig. 4: Project Stadtsee Horn, Austria (2022). Renovated swimming lake, the cultural deck. Foto: Kurt Hörbst.

6 CONCLUSION

Globalisation and economic development have set a scenario that strongly influences the transformation of spaces. The dynamics of this development – methods of production and consumption – lead into increasing social and environmental issues. The complexity of climate change as a phenomenon and the consequences of globalisation drive us, civilians and professionals, to rethink contemporary ways of living and ways of doing things.

In the field of architecture and urbanism, social, ecological and long-term design aspects must be taken into consideration in order to plan adaptations of spaces. The dynamics of everyday life, for example, include having safe access to spaces in order to fulfil daily activities. Hence, in order to enable the quality of transitional spaces, it also means to enable the quality of air, water, land, shelter, health, social interaction and wellbeing for all, in dense cities and in rural areas. In order to tackle climate change challenges, it is necessary to adapt smaller cities as much as denser cities with the mindset of socio-ecological aspects and that long-term solutions is not only about making cities for people, but also for the functionality of ecological systems.

Green and Blue Infrastructure as a nature-base solution and public spaces as a spatial and social matter, together, can potentially develop climate-environmental adaptations in the cities and to improve liveability,

which enables not only the mitigation of climate change but also as a chance to restore human relations with nature and to cohabitate it experiencing nature as part of the daily life.

The case in Jaboticabal presents some of the consequences of globalisation processes and how they negatively impact the people living in Brazil. Beyond the deforestation reality, central region countryside cities additionally face the scarcity of nature and quality of public space as the focus remains (mainly) on the development of agro-industrial systems. The project in Horn, Austria, shows not only how a project can facilitate biodiversity and social interaction in the same space, as part of daily life, but also how relevant it is for decision makers and planning influencers to provide meaningful social interventions.

Could Green and Blue Infrastructure also improve and contribute to cities metabolism in order to decentralise resources extractivism from hinterlands? How can scalable Green and Blue infrastructure potentially contribute to denser cities' metabolism? Are questions to be rethought as further steps of this paper.

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8 IMAGES

Fig. 1: Accessed on: https://oglobo.globo.com/brasil/noticia/2024/08/24/sao-paulo-registrou-mais-focos-de-incendio-do-que-a-amazonia-veja-video.ghtml

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Fig. 4: HÖRBST, Kurt. Project Stadtsee Horn, 2022. Accessed on: https://www.yewo.at/projects/stadtsee-horn/

Co-Creation of a Prototypical Climate Service Product to Support Climate Change Adaptation in the City Forest of Karlsruhe

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1 ABSTRACT

Climate change presents severe challenges to forests, impacting ecosystems, biodiversity, and overall forest health. To address these challenges, the German forestry sector is exploring various adaptation strategies, including promoting the cultivation of more climate-resilient tree species, implementing sustainable forest management practices, and developing early warning systems for pest outbreaks and extreme weather events. Additionally, efforts are underway to enhance public awareness and engagement, fostering a collaborative approach to both mitigate climate change as well as to adapt to the impacts of climate change.

Our research adopts an integrative approach, based on transdisciplinary processes and co-creation, to understand the needs of forest practitioners and develop a user specific climate service product. Focusing on climate extremes such as drought, heat, and heavy rain, we investigate diverse perceptions among authorities, scientists, and forest users. Drawing insights from the research project ClimXtreme, we engaged in a collaborative case study with foresters from the City Forest Karlsruhe. The transdisciplinary research aims to address specific climate information needs, inform society about climate change impacts and adaptation strategies, and facilitate communication with various forest users.

The resulting climate service product – an easy understandable and scientifically sound brochure of twelve pages – covers a range of topics from climate change scenarios to specialized climate indices for forestry as well as practical adaptation measures initiated by the City Forestry office of Karlsruhe. To support the usability and to enhance the societal and scientific impacts based on our case-study, a multi-level approach has been chosen. Thus, in addition to the published brochure, all data and methods used are comprehensively explained and additional indices, analyses, methods, data, and literature have been made freely accessible online.

The outcome of our efforts emphasizes the important role of co-creation to enhance inter- and transdisciplinary capacities for climate change adaptation in a city forest. By fostering dialogues with key practice partners and co-creating climate information, particularly tailored for a city forestry office in south-western Germany, our efforts inform society about climate change impacts and adaptation strategies and facilitate communication with diverse forest users and visitors (e.g. cyclists, joggers, walkers, riders). This integrated approach ensures a meaningful contribution to climate resilience in the German forestry sector and beyond.

Keywords: climate extremes, climate change adaptation, forestry sector and city forests, integrative research, stakeholders

2 INTRODUCTION

Climate extremes pose significant challenges to the German forestry sector, impacting ecosystems, biodiversity, and overall forest health (Knutzen et al. 2025a). Extreme weather events such as droughts, heat waves, and heavy rainfall are expected to occur more frequently and/or with increased intensity (Cardell et al. 2020). In fact, heat waves and many rainfall events have already been made much more likely due to human interference with the climate system (IPCC 2021). Additionally, droughts have become more likely as recently shown by Bevacqua et al. (2024) for Germany. Extended periods of drought fundamentally increase the stress level of trees, making them more vulnerable to pests and diseases (Frank 2020), while heat waves further add to this stress, reducing growth and raising mortality (Haberstroh et al. 2022). Heavy precipitation is also known to affect forest soil and infrastructure (Schauwecker et al. 2019). Moreover,

rising temperatures may disadvantage native species and favor non-native or invasive species, shifting forest composition (Martinez del Castillo et al. 2022). Warmer conditions could also expand the spread of pests, like bark beetles, which can kill off vast forest areas in a single season (Hlásny et al. 2021). While forest fires are less common in Germany, climate change may increase wildfire risks, adding challenges for management and firefighting (Fekete & Nehren 2023; Grünig et al. 2023). The economic impacts of climate extremes are significant, as forestry relies on sustainable wood production, and climate-induced challenges demand effective adaptation strategies to ensure long-term viability and profitability in forest enterprises (Rosenkranz et al. 2023). Additionally, occupational safety is a growing concern, with increased tree mortality creating more hazardous conditions for workers (FAO, ILO, UN, 2023).

To address the challenges, efforts are also needed to enhance public awareness and engagement, fostering a collaborative environment to mitigate and adapt to the impacts of climate change. Central to these efforts is the aim to sustainably balance economic, protective, and recreational functions, ensuring that the provision of forest services is tailored to the specific characteristics and priorities of each region. Since the implementation of an adapted forest management is reliant on the commitment of forest practitioners, it is essential to understand their perceptions of the various climate related challenges and impacts on the forests they manage as well as what strategies they consider suitable to achieve the desired adaptation targets.

In this paper we describe a collaborative approach with stakeholders from the City Forest Karlsruhe to assess and quantify perceptions of practitioners by employing a transdisciplinary research approach. The Karlsruhe City Forest is diverse and rich in species. It spans approximately 2,250 hectares and includes four distinct natural regions: the water-influenced Rhine meadows, the sandy Hardt plains and the Kinzig-Murg-Rinne, the hilly loess landscapes of Kraichgau and Pfinzgau, and the foothills of the Black Forest. Broadleaf species dominate the landscape, accounting for about 90 percent of the trees. Around 30 tree species make up the ecologically valuable mixed deciduous forests in various combinations. The trees in the City Forest have a positive impact on Karlsruhe‘s climate and the wellbeing of its inhabitants. They improve local air quality by filtering pollutants, store water, and protect against erosion and flooding. Additionally, they produce oxygen, provide cooling shade, and capture carbon dioxide from the atmosphere.

Hence, the City Forest is a vital part of Karlsruhe’s green lung and also provides a place for people to relax and serves as a habitat for animals, plants, and fungi. However, the impacts of climate change are already noticeable here: prolonged heat and drought during the past summers have caused lasting damage. This is especially visible in the Oberreut Forest, where certain tree species, such as European beech, are showing clear signs of stress. The City Forest Office is working hard to preserve, restore, and strengthen the resilience of the diverse forest ecosystems in Karlsruhe.

Against this background, the paper presents the joint development of a prototypical climate service product to support climate change adaptation in the City Forest of Karlsruhe, with a strong focus on explaining the need for adaptation as well as possible adaptation measures to society. The paper is structured as follows. Chapter three describes the methodological background as well as the interaction with stakeholders from the Karlsruhe Forestry Office. The main content of the brochure “Karlsruhe City Forest in a changing climate – The forest today and in the future“ is highlighted in chapter four. A summarizing conclusion is presented in chapter five.

3 METHODOLOGICAL BACKGROUND AND STAKEHOLDER INTERACTION

3.1 Methodology

One main aim of the research project CS4eXtremes was to identify the practical needs for climate change information in order to provide forest users with the best possible support in dealing with new adaptation challenges. Considering inter- and transdisciplinary work, we follow suggestions that have been developed with particular focus on the intersection between scientists and practitioners or stakeholders (Bammer et al. 2020). They are often referred to as integrative research. The two main concepts within this framework are the concept of transdisciplinarity and the approach of co-creation(Schuck-Zöller et al. 2023).

Transdisciplinarity is seen as a bridge between science and action (Renn 2021; Lang et al. 2012). In addition to classical features of interdisciplinary cooperation, the linking of research to relevant contexts and a focus on complex and socially controversial problems promotes a deliberative methodology to combine scientific knowledge with the experience and contextual knowledge of affected groups and people. Co-creation

focuses on transdisciplinarity as a merger of scientific and practical knowledge, whereby dialogues should occur on an equal footing in a learning process involving scientists and practitioners (Renn 2021). In this case, scientific knowledge and practical expert knowledge are complementary. Both forms of knowledge are essential for a common understanding of the challenges and possible solutions.

Our dialogue-based approach acts as a merger of scientific and practical knowledge, which has shown to work in a forest management context (Ciccarino et al. 2023). The relevance of stakeholder participation is growing as also demonstrated by Jacobsson et al. (2020) for southern Sweden, where forests are also under an increasing pressure which bears the risk of conflicts between stakeholder groups with different interests. As part of the overall research project, we focused on interviews with forest practitioners as a well established method of transdisciplinary work with stakeholders (Kujala et al., 2022; Steger et al. 2021;OECD 2020), which is true from the perspective of academics as well as practitioners in the forest sector (Jakobsen et al. 2021).

In sum, interviews with 28 forest practitioners have been carried out (Knutzen et al. 2025b, submitted). Furthermore, two workshops have been conducted, reflecting on the science-practice dialogue as part of the tdAcademy initiative (Schäfer et al. 2024).

3.2 Interaction with stakeholders from the Karlsruhe Forestry Office

As a result of the second workshop as part of the overall research project and the conducted interviews, further discussions were carried out with key stakeholders to explore opportunities for the joint development of climate service products. The needs of the Karlsruhe Forestry Office have been identified as particularly urgent due to the severe pressure from climate extremes, combined with public demands for action. Additionally, urban forests are particularly important due to their impact on densely populated areas, providing essential ecosystem services such as recreation, local climate regulation, and serving as "green lungs" that improve air quality and well-being in surrounding settlements. Forests in the Karlsruhe/Upper Rhine Graben region are under considerable stress from climate extremes, particularly due to spring and summer droughts and the cumulative effects of successive dry years. These factors have had, and continue to have, a drastic impact on forest vitality.

Central task for the coming years are a targeted replanting of damaged and regeneration-needing areas. Unlike past forest damage events, regeneration in the context of climate change presents unique challenges. The objective is to establish stable, site-appropriate, and climate-adaptive mixed forests that enhance biodiversity, maintain a characteristic forest microclimate, continue carbon sequestration through tree growth, and fulfil expected social functions. As part of the research project, near-natural forest conservation in the Karlsruhe municipal forest has been supported by providing and processing climate change information. This forest-specific climate data aids in planning adaptation measures, such as determining optimal replanting times and selecting suitable tree species.

Collaboration with the Karlsruhe Forestry Office was maintained throughout the project. The Forestry Office specifically requested an information sheet to inform society about the effects of the changing climate on Karlsruhe's City Forest and to outline how it can be adapted and further developed. Therefore, the "GERICS Climate Outlook for Karlsruhe" (Pfeifer et al. 2021) has been presented as part of a workshop and afterwards served as a scientific basis to take into account possible future climate developments based on regional climate simulations. In all its efforts, the forestry office was committed to preserving the forest and shaping it into a climate-resilient, diverse, and adaptable ecosystem. This represents a significant challenge not only for the forest's flora and fauna but also for visitors.

The primary goal of the jointly developed information brochure (Bülow et al. 2024) described in the next chapter, is to inform about the impacts of climate change on Karlsruhe. Raising awareness is crucial, as some areas have suffered such severe damage that they are no longer accessible for recreational use. During interviews, workshops, and reflection sessions, specific climate indicators relevant to forestry were identified in partnership with the Karlsruhe Forestry Office. These indicators will assist foresters and other stakeholders in planning effective adaptation measures, ensuring the preservation and restoration of a healthy, resilient forest despite escalating climate challenges. In addition to forestry-specific indices, basic information on future climate developments were required, including for example annual and seasonal temperature, precipitation, the number of dry days, and the annual number of frost and summer days.

4 MAIN CONTENT OF THE BROCHURE "KARLSRUHE CITY FOREST IN A CHANGING CLIMATE – THE FOREST TODAY AND IN THE FUTURE"

The goal of this jointly developed climate service product is to inform about the effects of the changing climate on Karlsruhe's City Forest, about projected future changes of climate variables which drive impacts on forests and to outline how the forest can be adapted and further developed. The brochure includes (1) a title page and imprint, (2) an introduction to the brochure itself and the City Forest Karlsruhe, (3) a map of local forestry areas and specific impacts of climate change, (4) information about climate parameters and their future changes under different global warming levels, and (5) examples of adaptation measures as well as (6) a tiny survey.

Besides a map highlighting examples of the effects of climate change in forest districts in the city of Karlsruhe, one key element of the brochure is the provision of state-of-the-art information on climate indicators relevant to the urban forest and their possible future changes, based on the use of climate models as essential tools to simulate these potential scenarios (Bülow et al. 2024).To address the uncertainties in climate modelling and the range of possible futures, numerous climate simulations of various models are considered. This results in a range of potential climate changes. To assess the reliability of these outcomes, the climate indicators are supplemented with expert evaluations. When a majority of climate models indicate a statistically significant increase or decrease for an indicator, the change is classified as robust. If most models suggest a clear direction of change, but the changes themselves are not significant, this is marked as a trend towards increase or decrease. When models show both increases and decreases in roughly equal proportions, the change is considered unclear.

The analysis includes climate indicators and their projected 30 year mean changes compared to the period from 1971to 2000, and for scenarios where the future global mean temperature increases by 1.5 °C, 2 °C, 3 °C, and 4 °C compared to pre-industrial levels. Also the average observed value over the years 1971 to 2000 has been included. The climate changes were calculated using a variety of models, with results ranging between the specified minimum and maximum, with a special focus an the median value, which is the point where half of the models fall below and half above. Based upon this information, six selected climate indicators – (1) late frost, (2) precipitation, (3) wind, (4) heat, (5) heat wave, and (6) drought period – and their impacts on the Karlsruhe City Forest have been highlighted in detail.

Regarding for example late frost – the number of days between April and June when the daily minimum temperature drops below 0 °C– which after bud burst poses risks to fresh greenery and young blossoms, can slow down tree growth and, in extreme cases, lead to the death of young plants. Climate simulations indicate that fewer days with late frostier expected in the future, but it can still occur, and the risk of damage from late frost will remain.

Focussing on heat stress, the results regarding future heat waves – at least three consecutive days with maximum temperatures above30°C – show a robust increase, whereby heat waves affect the health of the City Forest, particularly in spring and summer. In autumn, however, trees can better cope with heat stress through leaf shedding. The frequency and duration of heat waves are crucial factors. Climate simulations suggest that both the number and length of heat waves in the Karlsruhe region are increasing. As a result, the City Forest will also increasingly suffer from heat stress and its associated impacts in the future.

Regarding the need to adapt to the unavoidable impacts of climate change, the creation of stable, site-appropriate, and long-term adaptable mixed forests is key, as the brochure highlights in a chapter on specific adaptation measures. Within this chapter the description of the local adaptation measures is divided into (1) the overall goal of achieving long-term adaptable, stable and site-appropriate mixed forest, (2) selected measures for maintaining the vitality of the forest through near-natural forest management as well as (3) risk management including adaptation and the further development of existing strategies.

Furthermore, a brief evaluation of the brochure has been offered by using a QR code leading to a short online survey with six questions.

5 CONCLUSION

The Karlsruhe City Forest Office has already been working extensively towards the forest of tomorrow, whereby the overarching focus is on the ecological diversity and vitality of the forest and its individual trees. Through multiple workshops and face-to-face interviews within the overall frame of the research project

ClimXtreme, stakeholders from the City Forest Karlsruhe have also been identified as key partners for the co-creation process of a novel prototypical climate service product to support climate change adaptation in the City Forest of Karlsruhe. Thereby the practical need was highlighted, that the forestry office requires this specific brochure for purposes like (1) reducing pressure from public on forestry practitioners, (2) informing the public about the impacts of climate change and local adaptation measures, (3) addressing specific user groups, (4) facilitating the dialogue with politicians, companies, and society as well as (5) supporting foresters and other stakeholders in the forest sector to develop suitable adaptation strategies for the preservation and reforestation of a robust and healthy forest.

Taking this need for support into account, the scientist involved as well as key stakeholders progressed jointly through several stages of developing a climate service product. Although these stages are typically sequential, iterative feedback loops have proven beneficial. Thereby the co-creation process can be summarized as follows: (1) collaboratively identifying the local information needs regarding climate change and its impact on the City Forest, (2) preparing examples of how to leverage climate model results, (3) discussing the objectives for the brochure, (4) presenting the first draft of the brochure to the City Forest Office for review and gathering feedback on elements like climate indicator descriptions, (5) using the feedback to refine the brochure to better meet the practitioner needs, and vi) presenting a second draft of the flyer to the City Forest Office. This prototype process was continued until all participants were satisfied with the outcome, after which the final version was printed and utilized by the City Forest Office Karlsruhe.

Printed versions of the brochure have been distributed for example in the town hall, strategic places in the forest (e.g. visitor centres, forest entrances and meeting points), at local companies and organisations as well as at events in or about the City Forest. Digital versions of the brochure have been provided online and promoted by articles in local newspapers as well as press releases and social media channels. In addition to the published brochure, all data and methods used are comprehensively explained and additional indices, analyses, methods, data, and literature have been made freely accessible online.[1]

The outcome of this case-study and prototype development, emphasizes the important role of co-creation to enhance inter- and transdisciplinary capacities for climate change adaptation in a city forest. By fostering dialogues with key stakeholders and co-creating practice-specific climate information, particularly tailored for a city forestry, we inform society about climate change impacts and adaptation strategies and facilitate communication with diverse forest users and visitors (e.g. cyclists, joggers, walkers, riders). This integrated approach ensures a meaningful contribution to climate resilience in the German forestry sector and beyond.

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Common Goods and Modern Commons: Insights on Energy Communities from the Energy4All Project

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1 ABSTRACT

The concept of the commons, emphasizing shared and sustainable resource management, is gaining relevance in addressing global challenges such as climate change and the energy transition. Energy Communities (ECs) exemplify this modern commons approach by enabling citizens to collectively produce, share, and consume renewable energy, promoting sustainability, social equity, and decentralized energy systems.

The EU-funded Energy4All project explores different EC and Positive Energy District (PED) models through pilot cases in Norway, Austria, Hungary, and Italy. These include private-public collaborations, energy poverty initiatives, and community hubs fostering local engagement. The project aims to identify best practices, analyze stakeholder behavior, and establish replicable governance models. It also supports policy advocacy, knowledge exchange, and cross-border collaboration to advance EC models.

This paper presents interim findings from the project's first year, highlighting pilot cases and key lessons. Early results reveal differences in regulatory frameworks and diverse national and local approaches. Looking ahead, Energy4All seeks to refine its roadmap for replicating successful EC models across Europe, integrating stakeholder engagement, policy analysis, and practical insights to support sustainable and socially just energy solutions.

Keywords: planning, participation, energy communities, PED, energy transition

2 THE OBJECTIVES AND METHODOLOGY

One of the aims of the Energy4All project is to compare the legal frameworks for ECs and PEDs in Norway, Austria, Hungary and Italy. By analyzing these frameworks, we seek to identify the factors that facilitate or hinder the development of such initiatives, as well as to determine the key stakeholders involved and effective strategies for their engagement. In order to do so, this paper will rely on the idea of the energy as a commons (Ostrom 2015; Ostrom 2011; Hess 2008), which advocates for a more collective and democratic management of energy resources, where communities play an active role in production, distribution, and governance (Soto-Acosta et al., 2018). This concept further alignes with the Quintuple helix model of governance (Carayannis and Campbell 2010; Carayannis, Barth, and Campbell 2012), which integrates five key societal subsystems – academia, industry, government, civil society, and the environment – to drive sustainable innovation. This model provides a structured way to understand how different actors can collaborate to decentralize energy production, democratize access, and promote sustainability through community-driven energy initiatives. One of the main aspects under investigation is the extent to which national regulations and policies support or constrain the establishment of energy communities. Legal provisions, financial incentives, and administrative procedures vary significantly between countries, influencing the feasibility and attractiveness of energy-sharing models. By understanding these differences, we can highlight best practices and potential barriers that need to be addressed.

Another critical focus is the identification of relevant stakeholders and their roles in the implementation and operation of energy communities. These stakeholders include government agencies, municipalities, energy providers, technology companies, and civil society organizations. Understanding their interests, incentives, and potential conflicts is essential for designing inclusive and effective governance models.

This paper's methodology examines case studies through regulatory frameworks, institutional context, key stakeholders, and the quintuple helix model. Analyzing these elements will yield preliminary insights after the project's first year, identifying effective strategies and governance models for broader application. These findings will support the development of replicable models for long-term impact. The study employs

qualitative and comparative methods, combined with institutional analysis of the commons (Ostrom 1986), aligned with ENERGY4ALL's objectives.

3 PILOT CASES

The project has six different pilot cases in four European countries: Norway, Austria, Hungary and Italy. A description of pilots follows.

3.1 Hillevåg, Stavanger (Norway)

The PED Hillevåg explores public-private partnerships to repurpose waste heat from industrial animal feed production, creating opportunities for local energy supply optimization. So far, public-private partnerships and industrial processes have received limited attention in PED initiatives. PED Hillevåg examines how synergies between industry, municipal authorities, and other stakeholders can be fostered to enhance local energy flexibility. Industrial processes are major urban carbon emitters, posing a key challenge for decarbonization. Reusing waste energy, transitioning to cleaner sources, and cross-sector coordination are essential for PED development. These efforts require public-private partnership models to enable cooperation across different sectors and achieve ambitious urban climate targets. Key stakeholders involved in the project include two local heavy industrial partners, Felleskjøpet and Skretting, as well as Stavanger Municipality, the University of Stavanger and citizen interest groups near PED Hillevåg.[1] The expected impact of this pilot extends beyond local benefits, aiming to contribute nationally and even at the EU level. By developing an innovative public-private partnership model for PED development, the project seeks to advance understanding of the challenges and opportunities associated with cross-sector collaboration.

3.2 Lebring- St. Margarethen and Graz-Umgebung-Süd (Austria)

In Austria, there are two pilot projects: Lebring-St. Margarethen and the region Graz-Umgebung-Süd (GU-Süd). Both are located in Styria. The regional Renewable Energy Community Lebring-St. Margarethen has a legal form of an association ("Erneuerbare Energiegemeinschaft (EEG) Lebring-St. Margarethen"). This association aims to promote energy from renewable sources while considering environmental, economic, and social benefits for the region and its partners – particularly through the regional production, storage, use, and sale of renewable energy. Additionally, purchasing renewable energy from members of the association is a key component (EEG 2023, 2–3). The energy community was established as a private initiative, with private individuals as members. In September 2024, the municipalities of Lebring-St. Margarethen, Lang, and Hengsberg joined the energy community.[2]

The six municipalities of Fernitz-Mellach, Gössendorf, Hart bei Graz, Hausmannstätten, Raaba-Grambach, and Vasoldsberg have been cooperating since 2001 within the inter-municipal, non-profit development association "Graz-Umgebung-Süd" (GU-Süd, n.d.). The six municipalities of GU-Süd are organized as the cooperative "Erneuerbare Energiegemeinschaft GU Süd eGen". The goal is to establish two regional renewable energy communities to enhance regional energy autonomy, especially in times of crisis. Additionally, the initiative aims to reduce energy costs – not only for the municipalities themselves but also for SMEs and private households. In this case, the initiative is led by the municipalities, which differs from the approach in Lebring, where the initiative came from the citizens. A comparison after a longer support phase will help identify the key success factors for each approach.

3.3 Kazán and Ascend (Hungary)

The primary goal of the project Kazán is to collaboratively develop an energy plan, enhance the energy efficiency of the building, and maximize PED performance by leveraging the 36 kW solar panels already installed on the rooftop. Additionally, Kazán aims to establish a human-centered approach to business and co-governance models for PEDs that are both scalable and replicable. The Kazán Community Center hosts various organizations. The center already operates under a well-established collaborative management system, which has been instrumental in shaping the energy community's governance structures. Solidarity

[1] Energy4All project, DUT call 2022, Deliverable 3.2 – Energy community engagement, delivery date: January 2025, classified as confidential.
[2] Energy4All project, DUT call 2022, Deliverable 4.2 – Energy community engagement, delivery date: December 2024, classified as public.

and co-ownership are the core principles of the building's management, and these values extend to the energy community initiative as well. The key stakeholder are the various organizations and the Alliance for Collaborative Real Estate Development (ACRED) as the key partner managing daily operations. As one of Hungary's first energy community initiatives, the project aims to establish a sustainable collective management model that can serve as a blueprint for similar energy communities.[3]

The pilot case Ascend focuses on the transformation of a disused school building into social housing units. The primary goal is the energetic refurbishment of the former school to create sustainable and affordable housing while integrating it into a locally developed Clean Energy District as part of the ASCEND project. This initiative aims to accelerate the deployment of PEDs and foster energy-efficient urban development. A key project focus is refurbishing the school building with photovoltaic panels to boost renewable energy. Plans also include EV charging points, traffic-calmed "school streets", and citizen-focused initiatives with the Climate Agency, fostering a more sustainable urban environment.[4]

3.4 Quarticciolo (Italy)

This pilot project aims to combat energy poverty by developing an energy community in the Quarticciolo social housing estate. This neighborhood is located in the peripheral urban area of eastern Rome and it has long been associated with social struggles, economic difficulties, and limited access to resources. However, in recent years, Quarticciolo has emerged as a laboratory of grassroots initiatives aimed at fostering local empowerment, urban regeneration, and sustainability. Quarticciolo's transformation is driven by a strong network of social enterprises and community-led initiatives, including cooperative businesses, cultural spaces, and projects promoting circular economy practices. Through collective action, it seeks to provide affordable and sustainable energy solutions while empowering residents socially and environmentally. The pilot highlights the power of self-organised communities, where collective action fosters resilience, local knowledge drives innovative solutions, and bottom-up approaches ensure ownership and adaptability. Key stakeholders include local inhabitants, city and regional administrations, socially responsible enterprises, financial backers, and other self-organised citizen entities like cooperatives. The expected impact ranges from creating a replicable local model for energy communities to establishing a national network and contributing to similar European projects.[5]

4 DISCUSSION ON REGULATORY FRAMEWORKS

The case studies differ in structure, stakeholder engagement, and financial and governance models, largely due to variations in national legal frameworks for ECs and PEDs. While all fall under the EU's Clean Energy for All Europeans Package (CEP)[6], national regulations vary significantly. This analysis focuses on ECs rather than PEDs, as they overlap but have distinct scopes – PEDs are an urban planning concept without a unified EU legal framework, relying instead on national and local regulations. Additionally, ECs in this context refer to Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs), the terms adopted in some national legislations.

In Norway, the regulation of energy communities is governed by national legislation, primarily through the Energy Act (Energiloven)[7], Energy Regulations (Energilovforskriften)[8], Grid Regulation and the Energy

[3] Energy4All project, DUT call 2022, Deliverable 5.2 – Energy community engagement, delivery date: February 2025, classified as public.

[4] These data were extracted from different internal documents and individual reports of the Energy4All project, as well as the project proposal.

[5] Energy4All project, DUT call 2022, Deliverable 6.2 – Energy community engagement, delivery date: January 2025, classified as public.

[6] Of which the most important documents are: The Renewable Energy Directive 2018/2011 (RED II), (Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)), Official journal of the European Union, L328/82 and Directive on common rules for the internal market for electricity 2019/944 (IEM), (Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast)), Official journal of the European Union, L158/125.

[7] Energy Act (Energiloven), (1990:50) – Lov om produksjon, omforming, overføring, omsetning, fordeling og bruk av energi m.m., LOV-1990-06-29-50, Norway.

[8] Energy Regulations (Energilovforskriften), (1990) – Forskrift om produksjon, omforming, overføring, omsetning, fordeling og bruk av energi m.m., FOR-1990-12-07-959, Norway.

Market Regulation (Nettregulering og Energimarkedet-forskriften – NEM)[9]. As Norway is not a member of the European Union, its legislation does not apply directly (McElhinney et al., 2022) and as such, energy communities conforming to the definitions of CECs and RECs in accordance with the EU law have not yet been implemented. Consequently, Norway has developed its own legal frameworks. A distinctive feature of Norway's approach is the emphasis on licensing and governmental oversight. This means that various energy-related activities obtain licenses, ensuring that all interests are considered and that projects are evaluated on a case-by-case basis. Several legislative and practical barriers hinder the implementation of energy communities in Norway. Besides the Energy Act and related regulations restrict energy production, sharing, and storage among residential buildings, historically low energy prices and a well-functioning energy system have limited public awareness of alternative energy solutions. Overall, it can be said that the development of energy communities regulatory framework in Norway is still in its early stages (weak development).

In Austria, energy communities are regulated under the Renewable Energy Expansion Act (Erneuerbaren-Ausbau-Gesetz, EAG)[10] and Complete Legislation for Electricity Markets and Organization Law (Gesamte Rechtsvorschrift für Elektrizitätswirtschafts- und -Organisationsgesetz, short ElWOG)[11]. The EAG provides a legal framework for RECs, enabling citizens, small and medium-sized enterprises (SMEs), and local authorities to collaboratively produce, consume, store, and sell renewable energy within a localized area. A Renewable Energy Community is permitted to generate energy from renewable sources for self-consumption, storage, or sale. A REC must be legally structured as an association, cooperative, partnership, corporation, or a similar legal entity. Its primary objective cannot be financial profit. The main priority of a REC is to deliver environmental, economic, or social benefits to its members and the local community where it operates. The legal requirement that an energy community's primary purpose cannot be financial profit has led to confusion among stakeholders about its permissible activities and limitations. Overall, it can be said that the development of energy communities regulatory framework in Austria is very developed (strong development).

The Hungarian 2021 amendment to Electricity Act LXXXVI[12] established a framework for energy communities, recognizing Renewable Energy Communities (RECs) as a specific category. RECs are granted rights and responsibilities solely within the electricity sector, allowing them to engage in activities such as production, storage, consumption, distribution, aggregation, electromobility services, and electric charging operations. However, the law excludes heating and cooling, diverging from EU regulations that permit RECs to operate across all renewable energy sources, not just electricity. RECs in Hungary can generate, consume, store, and sell electricity from renewable sources. While a registry for RECs has been created, additional implementing regulations are still required to fully define the operational framework for energy communities. Energy communities must be organized as legal entities, such as associations, cooperatives, partnerships, or corporations. Their primary objective cannot be financial profit but environmental, economic, or social community benefits to their members or the local areas in which they operate. While the existing legislation provides a foundation for energy communities, there is a recognized need for further implementing acts to clarify operational details. Overall, the development of energy communities regulatory framework in Hungary is complex and unstable (medium development).

In Italy, the regulation of energy communities has evolved significantly since 2019, aligning with the European Union's directives. The prompt response of Italy to the RED II Directive has led to a flourishing of RECs. The key legislative milestones are The “Milleproroghe” Decree[13], ARERA Resolution[14] and MiSE

[9] Energy Market Regulation (Nettregulering og Energimarkedet-forskriften – NEM) – Forskrift om nettregulering og energimarkedet., FOR-2019-10-24-1413, Norway.
[10] Federal Act on the Expansion of Energy from Renewable Sources (Renewable Energy Expansion Act) – Bundesgesetz über den Ausbau von Energie aus erneuerbaren Quellen. (Federal Law Gazette, FLG) I no 150/2021 (National Council: GP XXVII RV 733 AB 982 p. 115. Federal Council: 10690 AB 10724 p. 929.) [CELEX no: 32018L2001, 32019L0944, 32019L0692]. Austria.
[11] Complete Legislation for Electricity Markets and Organization Law – Gesamte Rechtsvorschrift für Elektrizitätswirtschafts- und -Organisationsgesetz, No. 110/2010. CELEX-Nr.: 32019L0944. Austria.
[12] Act No. LXXXVI of 2007 on electricity and Governmetnal Decree No. 273 of 2007 (X.19.) – 2007. évi LXXXVI. törvény a villamos energiáró. Hungary.
[13] Decree Law No 198/2022 – Millepropoghe, 29 December 2022, Official Gazette no. 18, Italy.
[14] ARERA Resolution no. 318/2020 August 2020. Italy.

(Ministry of Economic Development) Implementing Decree[15]. The Milleproroghe Decree defines the characteristics of jointly acting self-consumers and RECs. According to it, individuals, businesses, local authorities, and communities are permitted to take part in RECs; however, their participation cannot be their primary professional activity (Di Silvestre et al., 2021). Italian law supports these initiatives by providing incentives and regulatory frameworks, encouraging the development of decentralized energy systems that empower communities to actively participate in the transition to clean energy. Governed through cooperative and association-based models, RECs prioritize open and voluntary participation, reinforcing a sense of shared responsibility among members. RECs also face several challenges and limitations that can hinder their development and effectiveness as financial and technical barriers. Although incentives exist, the initial investment costs for infrastructure can be high. Another limitation is the geographical constraint: since energy sharing is restricted to members connected to the same low-voltage distribution substation, expansion opportunities are limited. Market competition and grid dependency pose risks for RECs, as they operate in a market dominated by large utility companies with greater influence and rely on national grid infrastructure, making them vulnerable to fees and regulatory changes. Nonetheless, Italy's regulatory framework for energy communities is highly developed (strong development).

5 PRELIMINARY FINDINGS

This analysis explores the relationship between regulatory and societal elements to better understand different national approaches. Insights from objectives, case studies, and regulatory frameworks informed the design of the analytical grid (Table 1) and the establishment of key Analytical Framework Areas: ECs' main goals, institutional structure, stakeholder involvement (five helices), and regulatory development.

This analysis identifies three key factors influencing the success of the study cases: the institutional structure of ECs, the diversity of stakeholder involvement, and the level of national regulatory development. Ideally, a balanced bottom-up and top-down approach (Sareen et al., 2022), supported by a fully developed quintuple helix model within a strong regulatory framework, would create optimal conditions for EC success. However, this is not always the case, as not all study cases exhibit these elements simultaneously. The analytical grid suggests a correlation between strong regulatory frameworks and high public administration involvement, as seen in the Austrian pilots and, to some extent, in Italy. However, in Italy, inconsistent administrative approaches and weak horizontal coordination create challenges. Conversely, in cases where top-down intervention is weaker, a strong community engagement strategy involving diverse stakeholders can help compensate for this gap, as demonstrated by the Kazán case in Hungary.

	Stavanger, Norway	**Lebring- St. Margarethen, Austria**	**GU Süd, Austria**	**Kazán, Hungary**	**Ascend, Hungary**	**Quarticciolo, Italy**
Main goal behind EC	Optimize local energy supply	Promote energy from renewable sources	Enhance regional energy autonomy	Adopt human-centered business and co-governance models for PEDs.	Create sustainable and affordable housing	Provide solutions for energy poverty in social housing estates
Institutional structure of EC, type of initiative	Public-private partnership between industry and municipality	Private initiative; following expansion to municipalities	Municipal association, with future expansion to citizens and SMEs.	Collectivly owned building with various organizations	Top-down initiative with a strong presence of public administration	Private bottom-up initiatives
Key stakeholders and presence of five helices	Two industrial partners, Municipality and University Stavanger	Private households, municipalities, So-Strom	Six municipalities, So-Strom	Organizations in community center, ACRED	Municipality of Budapest	Local inhabitants, small businesses, local civic organizations
Regulatory Framework	Weak	Strong	Strong	Medium	Medium	Strong

Table 1: Analytical grid.

5.1 Limitations and and challenges

This project undertakes a comparative analysis of the legal frameworks and approaches to energy communities across four European countries. It seeks to identify successful solutions for promoting the development of ECs, while also pinpointing key obstacles and barriers hindering their implementation. It is important to note that the project's scope does not extend to a detailed analysis of the dynamic developments

[15] "Ministry of Economic Development Implementing Decree." MiSE, September 2020. Italy.

and price variations within the broader energy market. Furthermore, the project acknowledges the significant variations in socio-economic conditions across the studied countries, recognizing their influence on the motivations and incentives driving the establishment and success of energy communities.

6 PROJECT OUTLOOK

A key aspect of this research is to understand the regulatory and institutional conditions, as well as stakeholder engagement strategies, that facilitate or hinder the establishment of successful ECs. The preliminary observations of the project strongly suggest that creating the necessary conditions for thriving ECs and PEDs requires a multi-faceted approach: a robust stakeholder engagement strategy, proactive policy and law-making, and the adaptation of project experiences and results – such as those from Energy4All – to specific national contexts and necessities. Given the significant variations in national legal frameworks, as highlighted in the case studies across Norway, Austria, Hungary, and Italy, strengthening cross-border collaboration and knowledge-sharing becomes crucial to bridge existing gaps. However, effective cross-border learning necessitates a common definitional ground. Achieving a shared understanding of what constitutes an EC and a PED is paramount to ensure the comparability of energy communities across Europe. This, in turn, requires further harmonization of national regulations within the overarching framework of EU directives, such as the Clean Energy for All Europeans Package. Such harmonization would not only clarify the landscape of facilitators and barriers to EC and PED development but also promote greater investment certainty and scalability.

In this context, projects like Energy4All serve as valuable catalysts and should be replicated and scaled up strategically. One of the key outcomes of Energy4All will be its transfer and implementation plan, which offers a structured approach to adapting successful EC models to diverse contexts across Europe. By systematically applying these plans and continuing to learn from pilot projects, we can unlock the full potential of energy communities to drive a sustainable, equitable, and decentralized energy transition.

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Concrete Solutions for Climate Resilient Built Environments

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1 ABSTRACT

Concrete is the most widely used building material worldwide. That is one reason why it is very often associated with high CO_2 emissions, although on the base of mass [kg] or volume [m³], the specific CO_2 footprint of concrete is relatively low compared to other building materials. This is in particular true for modern cement and concrete. In 2022, the Austrian Cement Industry published its roadmap towards CO_2 neutral production of cement. Various measures are foreseen and projects have already been undertaken to move the CO_2 footprint of cement in Austria towards zero.

This applies to all types of cement, regardless of the application – and there are many of them. Every construction project requires a special type of concrete; there are different mix designs for buildings, civil engineering, and specialised applications. Water-impermeable concrete is required for so-called "white tanks", whereas in urban planning – in view of increasingly hot summers and heavy rainfall – the opposite, water-permeable concrete, is advantageous in terms of infiltration capacity. This can take the form of "drain concrete" or concrete paving stones, which must be laid in such a way that infiltration can take place via the paving joints.

Infiltration-capable surfaces, trees and plants are essential for the resilience and important design elements of our cities. Innovative approaches in the use of concrete and holistic planning can make cities more ecological, liveable, and sustainable, Therefore, such approaches have an important function as instruments for adapting to climate change. However, concrete can be used innovatively not only for "green infrastructure", but also for "blue infrastructure", the use of water in urban spaces.

The "sponge city" is a concept designed to help urban trees gain more vitality. The underground construction is crucial for the sponge city effect: the concept gives the trees more room to grow roots below the paved surface in interconnected gravel bodies. The substrate acts like a sponge: on the one hand, the trees are supplied with water and, on the other, water is stored and does not flow unused into the sewage system. A high infiltration rate is also important on the paved surfaces. The concrete paving stones play a central role in the functioning of the sponge city concept – they provide more climate protection, a pleasant atmosphere, and thus counteract the urban heat island effect, Due to their light surface and a higher albedo of concrete compared to asphalt, they can contribute to a more pleasant micro-climate in urban areas.

In Austria, the sponge city concept has been successfully implemented in several projects: In Vienna, the first sponge city project was in Pelzgasse in Vienna's city district of Rudolfsheim-Fünfhaus. In addition to the paving of the areas, further design measures were implemented to make the public space more attractive.. The project is being scientifically monitored by the University of Natural Resources and Life Sciences, the BOKU Wien.

In Vienna, the sponge city concept was also implemented near the "Bildungscampus Aspern Nord", where around 10,000 m2 of concrete block pavement were built in the neighbourhood "Am Seebogen". The sponge city concept has also been successfully realised in several small and medium-sized towns in Lower and Upper Austria, some of which are presented below. A video series by the Lower Austrian Association of Municipalities shows best practice from the cities Amstetten, Lanzenkirchen, and Tulln.

The presentation ranges from the production of CO_2-reduced cement in Austria to the sustainable use of concrete for planning and design of innovative open spaces in urban areas following the sponge city principle, which enables adaptation to climate change.

2 CEMENT AND CONCRETE – CONTRIBUTION TO SUSTAINABILITY

2.1 The Austrian cement industry's roadmap to CO_2 neutrality

The Austrian cement industry is committed to the Paris climate targets. In 2022, based on the production figures from 2020, the roadmap outlined a way in which the production of cement in Austria can be climate-neutral by 2050 (Spaun et al. 2022). The 5C strategy of the European cement association Cembureau serves as the basis for the Austrian cement industry's roadmap. The 5Cs as focus areas for measures are: Clinker, Cement, Concrete, Carbonation and Construction (Cembureau 2020). These five areas are briefly described below and their implementation in the roadmap of the Austrian Association of the Cement Industry VÖZ is explained in more detail.

2.1.1 Clinker

Clinker is the most important component in the production of Portland cement. It is produced from the raw materials lime, clay and marl in a rotary kiln at 1,450 degrees Celsius. The major part of CO2 emissions in cement production arise from this process: around one third originates from the fuels, and around two thirds are geogenic emissions, as CO2 is released from the limestone by turning calcium carbonate into calcium oxide. By reducing the proportion of clinker in cement significant contribution to reducing emissions can be made.

2.1.2 Cement

The production of one tonne of cement in Austria released 503 kg of CO_2 in 2023 (VÖZ 2024). This makes Austria one of the countries with the lowest specific CO_2 footprint of cement worldwide. The good values are based on the high efficiency of Austrian cement plants and on a high share of secondary materials: alternative raw materials, alternative fuels as well as alternative additives. The main additives used are granulated blast furnace slag and fly ash, which are residual materials from other industries that will no longer be available to the usual extent in the coming years or decades. Research is therefore being carried out into new additives, e.g. calcined clays showing great promise. In line with the roadmap, the Austrian cement industry is researching new types of cement that offer the same performance with less clinker. So-called CEM II/C cements have already been developed and are ready for use thanks to technical approvals.

2.1.3 Concrete

The Austrian cement industry's CO_2 roadmap sees the potential for reducing CO_2 emissions of concrete primarily in reducing the proportion of clinker or cement used in the concrete, i.e. in the concrete mix design. Cement and concrete are therefore shown together in one column in the roadmap.

2.1.4 Carbonation

Carbonation is a process in which concrete reabsorbs CO_2 from the ambient air on the air-exposed surface. In chemical terms, this process is to a certain extent the reverse of the process of calcination of the limestone, where the CO_2 is emitted when the clinker is burnt. Carbonation can be accelerated as part of concrete recycling, the crushed concrete charged with CO_2 can be reused as a recycling fraction in the aggregate, or the fines can be used as a component of cement. An important approach to combining circular economy and decarbonization of the cement and concrete sector.

2.1.5 Construction

The area of construction itself lies outside the sphere of influence of cement production, but holds potential for reducing the CO_2 footprint on many levels. Constructions can be made leaner and more efficient, and the use of less material also reduces CO_2 emissions.

In addition, technologies such as building component activation can help to reduce the energy required for heating and cooling buildings and thus again help reducing CO_2 emissions, especially during building operation.

2.1.6 CCUS

In the Cembureau's 5C strategy, carbon capture technology (CC) is seen as part of clinker production. The Austrian cement industry identifies CCUS as a separate pillar, which primarily represents the geogenic

emissions that arise during the calcination of limestone. These emissions must be captured and then either stored (Carbon Capture and Storage CCS) or used (Carbon Capture and Utilization). Both capture and further utilization are quite energy-intensive processes, which is why the potential of the other levers should be exploited first.

2.2 Sustainable use of concrete

Concrete is the most widely used material in the world, thanks to properties such as load-bearing capacity, durability, performance and great flexibility in use. Concrete is fire-resistant and its mass contributes to sound insulation as well as to the efficient operation of buildings for heating and cooling. A major advantage of concrete in terms of social sustainability is its affordability.

Another strength of cement and concrete is a very efficient use of resources and contributions to circular economy. Concrete is a man-made stone. Like a stone, concrete can therefore be reused and recycled at the end of its service life. It can replace primary material in fill or be crushed and reused as recycled aggregate for the production of concrete. Precast concrete can be separated again and reused as a whole if the joining technology has been designed accordingly.

Concrete is sustainable if it is well planned and used efficiently according to its strengths – from the choice of the right mix design to integration into well thought-out structural concepts and the efficient use of materials. Many projects are already demonstrating that this is possible. The positive properties for resilient urban design are discussed in the following chapter using the concept of the sponge city and the example of water retention.

3 CONCRETE FOR RESILIENT URBAN PLANNING

Green spaces, parks and squares are important design elements, especially in cities, and at the same time they have an important function as instruments for adapting to climate change in times of climate crisis. Trees and plants contribute positively to the microclimate in cities through their cooling effect. In urban areas in particular, however, surfaces also need to be paved, as they need to be accessible in bad weather conditions or for emergencies such as fire or rescue operations. Concrete ensures such trafficability and, with its light-colored surface, has clear strengths compared to other materials: Concrete has a high albedo and heats up less than dark paved surfaces (EU PAVE). Designed in the form of paving stones or as so-called drainage concrete with continuous cavities, surfaces can be paved with concrete and still be made permeable. The urban microclimate can be positively influenced by the retention of water and, as a result, more evaporation.

The sponge city concept can help urban trees to achieve greater vitality. The decisive factor is the underground construction: below the paved surface, the trees are given more space for root formation in interconnected gravel bodies. The substrate acts like a sponge: on the one hand, the trees are supplied with water and, on the other, water is stored and does not flow unused into the sewer system. The paved surfaces above these bodies must allow a high level of infiltration, which is why concrete paving stones play a central role in the functioning of the sponge city principle.

3.1 The sponge city principle – examples in Vienna

One of the first sponge city projects in Vienna was implemented in Pelzgasse in Rudolfsheim, it has been opened as “cool street” in summer 2020. The street and sidewalk were raised to the same level and designed to be barrier-free with around 1,700 square meters of concrete paving stones. In addition to the tree planting, further improvements were implemented: new benches, a drinking hydrant, a play table and a water feature in the form of ground-level spray nozzles. The project is being scientifically supported by the University of Natural Resources and Life Sciences. (Gary 2022, p. 27)

In Seestadt Aspern, the sponge city was implemented in the “Am Seebogen” district at the Bildungscampus Nord, where around 10,000 square meters of road surface were paved with concrete blocks. There is a layer of coarse-grained gravel and water-retaining materials underneath to care for the trees. The trees are planted in the tree grates as usual, but have direct contact with the gravel layers and can root through them. The following graphic by 3:0 Landschaftsarchitekten, also involved in implementing the sponge city in Aspern, shows how the system works.

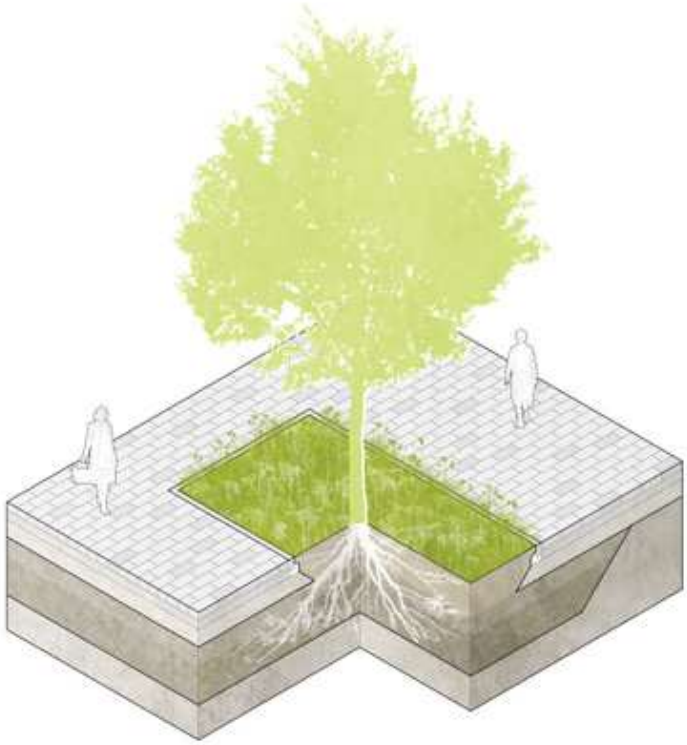

Fig. 1: Sponge City principle shown around and underneath a tree. (Source: 3:0 Landschaftsarchitektur)

Numerous other sponge city projects have already been and are being implemented in Vienna. One current project is Bruno-Marek-Allee in the Nordbahnhof district, which is designed as a “climate boulevard” with green spaces, trees, unsealed surfaces and wide sidewalks for a relaxed stroll.

3.2 The sponge city principle in medium-sized cities

Small cities are also affected by heat and drought. Greening and the unsealing of surfaces also help to counteract overheating here. The sponge city principle enables urban trees to survive even during long periods of heat and drought. At the same time, it relieves the burden on the sewage system during heavy rainfalls and thus prevents flooding.

A current example of climate-friendly redesign is the city of Tulln in Lower Austria: following a comprehensive public participation process and a referendum in 2021, Nibelungenplatz in Tulln was extensively redesigned from May 2023 to June 2024. Before the redesign, the few trees on Nibelungenplatz offered hardly any shade and 80 percent of the total area was not permeable – which led to temperatures of more than 40 degrees Celsius in summer. In order to naturally shade as much of the square as possible, large trees were planted according to the sponge city principle: Thanks to the large root space and well thought-out road base, rainwater can be stored, allowing large-crowned, healthy trees to develop. After the redesign, 70 percent of the total area are open to infiltration (green areas, gravel, etc.) and an additional 23 percent of the total area are permeable (paving). The paving is done with light-coloured stones. The choice of paving stones and their sizes depends on the type of use of the respective area. For example, ecological paving with high permeability and green joints is used on the car parking areas (Stadtgemeinde Tulln 2025).

The sponge city principle had already been implemented in several municipalities in Lower Austria before, for example on the main square in Lanzenkirchen, where 30 trees have been planted. Since then, heavy rainfalls in the municipality remained without consequences. Videos on the YouTube channel of the NÖ Gemeindebund, the Lower Austrian Association of Municipalities, show relevant stakeholders from the municipalities of Amstetten, Tulln and Lanzenkirchen reporting on their experiences and the benefits of the sponge city principle, like inner-city infiltration areas, unsealing of villages and towns, sustainable use of rainwater and promotion of biodiversity.

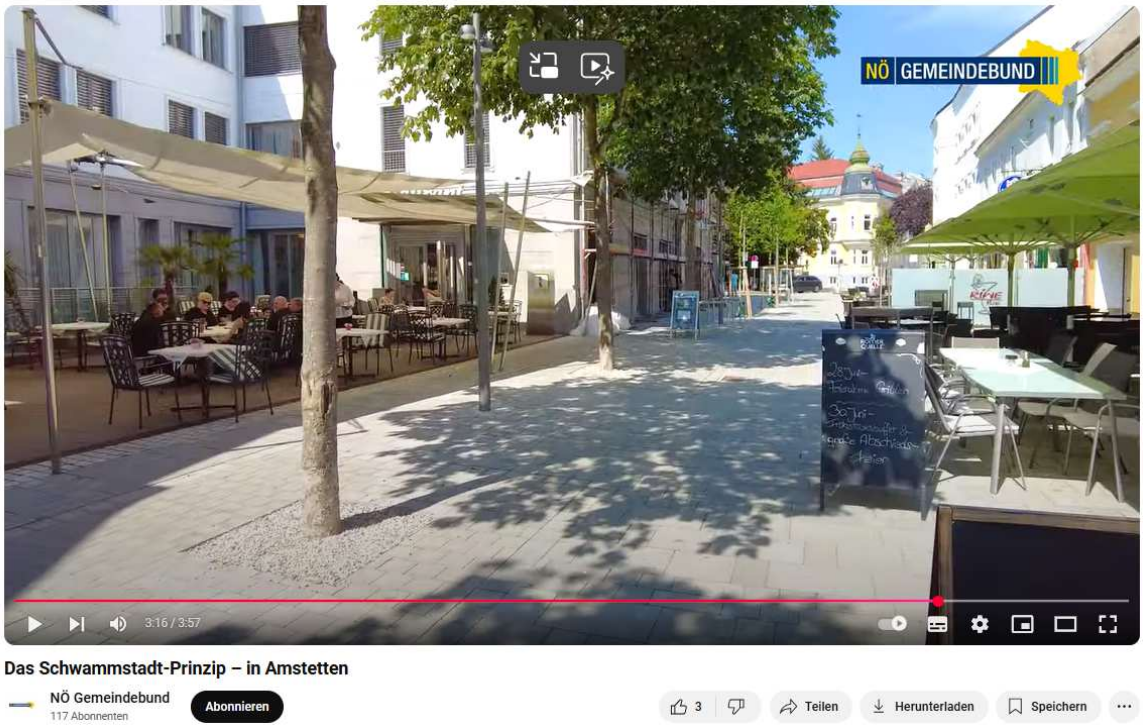

Fig. 2: Snapshot from the YouTube video of the Sponge City in Amstetten, Lower Austria (Source: https://www.youtube.com/watch?v=7ij4FUDjUIM).

3.3 Water storage

In addition to being used for surface pavings, concrete is also used underground in connection with the water management. The sewer system in Vienna is relieved during heavy rainfall events with three large concrete storage basins. These protect the city from flooding, while the retention of the water and its subsequent purification in the sewage treatment plant also protects nature. The concrete storage basin in Simmering, was opened in 2016 and it is 90 meters long, 45 meters wide and seven meters deep. A sports ground is located on the reservoir, which is situated at a topographical low point in the district and was the ideal location for the construction of the reservoir. Directly below the main pitch, up to 28.5 million liters of water are temporarily stored during rainy weather. The Gelbe Haide reservoir near the Inzersdorf freeway junction can hold around 10 million liters of water. The reservoir absorbs the first flush of rain and is considered a highly efficient climate change adaptation measure. After construction, the structure was covered with a six-metre-thick layer of soil from the excavation. A 4,500 square meter green area was created on top. The green roof ensures a pleasant microclimate. This storage basin is 70 by 40 meters in size. The “floodgates” are only opened after the heavy rain has stopped and the water can flow through the sewer system to the sewage treatment plant in Simmering (Gary 2022).

3.4 Concrete for vertical greening

Planting can also contribute to mitigating the urban heat island effect in buildings in a simple but very effective way: plants photosynthesize with the help of solar energy, releasing moisture and thus cooling themselves and their surroundings. The greening of buildings helps to integrate nature into urban living spaces. Concrete is a material that is well suited to planting, as it is less sensitive than other building materials to moisture and other “biological attacks”, i.e. damage that the roots of plants can do. The “Bosco verticale” in Milan by Stefano Boeri is a vivid and well-known example of how concrete structures can be turned into a green landscape in innovative urban and neighborhood planning. At “Bosco verticale” two towers are housing a total of 800 trees, providing an amount of vegetation equivalent to 30,000 square meters of woodland and undergrowth, concentrated on 3,000 square meters of urban surface (Stefano Boeri Architetti).

4 CONCLUSION

Topics and examples in this contribution range from the sustainable production of CO2-reduced cement in Austria to the sustainable use of concrete in urban areas. Innovative planning with the sponge city principle is shown, as well as other examples of how concrete can contribute to climate change adaptation in cities. Concrete can be used above and below ground, thus contributing to the efficient use of space, which is particularly important where space is scarce. A best-practice example for an efficient use of space is an underground water storage basin in Vienna, which provides relief during heavy rainfall events and at the same time offers a sports field on its surface for leisure activities – an excellent example of stacked multifunctional surfaces. It is important to assess building materials holistically over their entire life cycle. Cement and concrete offer numerous advantages in terms of greening and the water balance in cities, putting other building materials in the shade.

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Das Schwammstadt-Prinzip – in Lanzenkirchen https://www.youtube.com/watch?v=nuaqmiKa0Ig,

Das Schwammstadt-Prinizip – in Tulln https://www.youtube.com/watch?v=jlYtIGfOlcI&t=1s

Consumer Willingness to Pay for Autonomous Vehicles in Japan

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1 ABSTRACT

In recent years, autonomous vehicle (AV) technology is expected to play an important role in the construction of next-generation, efficient and sustainable urban transport systems by integrating with electric vehicle (EV) technology. In Japan, in particular, the spread of autonomous vehicle technology is attracting a great deal of attention as a means of solving social issues such as traffic congestion, environmental impact in urban areas, and the shortage of drivers due to the declining birthrate and aging population. On the other hand, in order to promote the spread of automated vehicles, it is essential to create a social and institutional environment that takes into account not only technological progress but also consumer acceptance and willingness to pay (WTP). In particular, in the Japanese market, it is not yet fully clear how unique consumer characteristics such as strong expectations of safety, a cautious attitude towards new technology, high price sensitivity, and strong trust in domestic manufacturers affect acceptance of automated vehicles and WTP. In this paper, we review previous research from Japan and overseas, and focus on the Japanese market in particular, to organize and consider the factors that determine people's acceptance of and willingness to pay for (WTP) autonomous vehicles. Furthermore, we present hypotheses for future empirical analysis from the perspectives of politics, economics, society, culture, and technology acceptance, and aim to provide insights that will contribute to the development of the foundations for AV acceptance research in Japan by presenting future research issues and an analytical framework.

Keywords: Autonomous Vehicles (AV), Consumer Acceptance, Willingness to Pay (WTP), Social and Cultural Factors, Japan

2 INTRODCTION

In recent years, autonomous vehicle (AV) technology has been attracting attention as an important element supporting the next-generation sustainable transportation system through technological integration with electric vehicle (EV) technology (Todorovic, et al., 2017). In particular, Japan faces a number of social issues, such as chronic traffic congestion, environmental impact in urban areas, and a shortage of labor due to the declining birthrate and aging population, and the social implementation of autonomous driving technology has the potential to contribute significantly to solving these issues (Japan Research Center for Transport Policy, 2020).

On the other hand, in order for autonomous vehicles to become widespread, it is essential to not only focus on the technological aspects, but also to create a social and institutional environment that takes into account consumer acceptance and willingness to pay (WTP). In particular, in the Japanese market, it is difficult to say that sufficient knowledge has been accumulated on how consumer attitudes such as strong expectations of safety, a cautious attitude towards new technology, brand orientation and price sensitivity will affect the acceptance of automated driving technology. Furthermore, the direction of government regulations and policies, as well as structural changes in the automobile industry as a whole, are also thought to have a complex impact on the spread of AVs.

In this paper, we will review existing research on the factors that determine the acceptance of autonomous vehicles, and consider them in the context of the Japanese market, particularly from the perspectives of politics, economics, society, culture, and technology acceptance. In addition, we will present a framework for the empirical approach and data collection needed to test these hypotheses, and suggest future research directions.

3 LITERATURE REVIEW

3.1 Acceptance of automated vehicles (AVs) and willingness to pay (WTP)

Many international surveys have been conducted to date on attitudes towards and willingness to pay (WTP) for automated vehicles (AVs), mainly in Europe and the United States. According to existing research, consumers generally tend to have positive attitudes towards AVs, and expectations of improved safety, particularly collision avoidance functions, are a factor that increases acceptance (Shin et al., 2015; Du et al., 2021).

In terms of AV acceptance, technology trust is an important determinant, and the higher the trust in the technology, the higher the acceptance and WTP (Xu et al., 2018; Liu et al., 2019). In addition, it has been confirmed that the benefits that consumers perceive in AVs have a stronger impact on acceptance than risk perception (Liu et al., 2019).

On the other hand, there are large differences in WTP depending on the country and market characteristics. For example, according to Ellis et al. (2016), the average WTP in the United States was reported to be $6,903, but in Japan it was only around 400,000 to 800,000 yen, showing a relatively low trend (Jiang et al., 2019; Shin and Managi, 2017; Morita and Managi, 2020).

Factors that affect acceptance and WTP include media influence (Du et al., 2021), perceived ease of use (Jiang et al., 2021), and demographic characteristics such as age and gender (Ellis et al., 2016). These factors interact with each other to shape acceptance patterns in each country.

3.2 Acceptance of AVs in the Japanese market

While existing research has accumulated a wealth of knowledge on acceptance factors and WTP determinants, particularly in Europe and the United States, there is still a lack of comprehensive analysis of cultural and policy factors specific to the Japanese market (Shin and Managi, 2017). In particular, there is a limited amount of systematic empirical research on the extent to which factors such as Japan's unique culture of safety and security(Taniguchi et al., 2022; Asia Business Law Journal, 2024), trust in domestic manufacturers(Tamaki and Managi, 2018; Chikaraishi et al., 2020), and mobility needs in an aging society(Taniguchi et al., 2022) affect acceptance of and WTP for automated vehicles.

Furthermore, since the traffic conditions and reliance on modes of transport differ greatly between urban and rural areas even within Japan, detailed analysis that takes regional differences into account is also required. In addition, there is a need for empirical investigation into how unique Japanese consumer psychology, such as price sensitivity and a tendency to follow the crowd (Ogura,2024), affects the acceptance process for new technologies such as automated vehicles.

In these proceedings, based on the above review of previous research, we will present hypotheses for a multifaceted examination of consumer acceptance of and willingness to pay (WTP) for automated vehicles, with a focus on factors specific to the Japanese market, with the aim of laying the groundwork for future empirical analysis.

4 HYPOTHESES

In this chapter, based on a review of previous research, we will present hypotheses that should be focused on in examining the main factors that determine the acceptance of and willingness to pay for (WTP) automated vehicles (AVs) in the Japanese market. In particular, we will extract hypotheses that are essential for future empirical analysis from three categories: attribute factors, external factors, and factors specific to Japan, and organize them as follows.

First, with regard to attribute factors, we will focus on age and interest in new technology (Wang et al.2020; Kaye et al., 2021 ;Taniguchi et al.,2022). Existing research has shown that younger people are more receptive to new technology and have a higher WTP. In particular, while younger people in Japan have high expectations for automated vehicles, older people may have mixed expectations for convenience and concerns about safety. In addition, people who are highly interested in new technology are also thought to have a positive attitude towards automated vehicles.

Next, we will look at external factors such as trust in technology and safety concerns (Asgari & Jin, 2019; Rahimi et al., 2020; Liu et al.,2019; Choi and Ji., 2015; Ellis et al., 2016). Trust in automated driving

technology is an important factor that directly affects acceptance and WTP. In Japan, there is a strong tendency to prioritize safety and security above all else, and concerns about safety are thought to have a significant impact on acceptance and WTP. Therefore, the key to popularization is to increase trust in the technology and at the same time, to reduce concerns about the risk of accidents and system failures.

In addition, we will focus on Japan-specific factors such as trust in domestic manufacturers and price sensitivity(Morita and Managi 2020; Shin & Managi, 2017). Japanese consumers traditionally have a high level of trust in domestic manufacturers, and it is predicted that WTP for AV products made by domestic manufacturers will be higher than for those made by overseas manufacturers. In addition, in the Japanese market, where price sensitivity is high, the impact of policy support such as subsidies and tax incentives on WTP cannot be ignored. In addition, the "herd mentality", in which the opinions of others and usage conditions influence individual decisions, is also thought to play an important role in the diffusion process.

The above hypotheses will form the basis for future empirical research to examine AV acceptance and WTP in the Japanese market from a variety of perspectives. In this paper, we will present an analytical framework that takes into account the unique social and cultural background of Japan through these hypotheses, and indicate the direction for future research.

5 CONCLUSION

In this paper, we review previous studies on consumer acceptance of and willingness to pay for (WTP) automated vehicles (AVs) in Japan and overseas, and present hypotheses focusing on cultural and social factors specific to the Japanese market.

The review of previous studies confirmed that concerns about safety and trust in technology are important factors that affect consumer acceptance and WTP, and that these are common factors internationally. On the other hand, in the Japanese market, it was suggested that unique factors such as trust in domestic manufacturers, the needs specific to an aging society, a culture of safety and security, and a sense of conformity are likely to be significantly involved in the acceptance process of AVs.

The hypotheses presented in this paper can be positioned as a theoretical foundation for understanding the structure of AV acceptance and WTP in the Japanese market from multiple perspectives. In the future, we plan to clarify the determinants of WTP in the Japanese market by collecting and analyzing empirical data from consumer questionnaire surveys based on the hypotheses presented in this paper.

Ultimately, we aim to provide policy implications and insights that will contribute to the formulation of market strategies by automobile manufacturers, as well as to contribute to the development of the foundations of AV acceptance research in Japan.

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Data-driven Municipal Resilience Quantification for Extreme Weather Events – Application of Dataspace Functionalities for Disaster Management

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1 ABSTRACT

The climate change led to extreme weather events that can cause extensive catastrophes. The consequeneces for urban areas and municipalities have become much more complex and requires an assessment and an increase of their resilience. Reliable information builds the basis for decision maker to be prepared and to get in front of the situation in case of an event occurrence. But the availability and the structure of data sources include also an increasing complexity. This paper presents a developed dataspace concept for a data-driven resilience assessment of urban areas or municipalities. Different sources like social data, infrastructure networks, building models, financial assests as well as weather data are combined for a extensive data analysis. Statistical and stochastic methods are applied to generate an understanding between the cause and the effect with respect to extreme weather events. The data analysis is applied to quantify urban key performance indicators for the disaster management. Examples are the availability, usability or the expected damage. The dataspace concept allows an assessment before, during and after the occurrence of a disruptive event. Single resilience phases, like preparation, prevention, protection, response and recover can be easily characterized. The methodology identifies potential weak spots and increases the coping capacity. Several use-cases for different urban areas and municipalities are presented and underline the applicability. Heavy rain and flood events are exemplary investigated.

Keywords: dataspace, extreme weather, disaster management, resilience, data analysis

2 INTRODUCTION

Current hazard situations led to complex crises and catastrophes. A highly technological society that is interwind in global trade has new challenges to cope with such adverse events. The Covid-19 pandemic or certain extreme weather events are exemplary events that have significantly influenced and continue to change the society and the politics [1]. The multi-layered and federal civil protection system in Germany is also confronted with hugh challenges, due to the occurrence of such crises or catastrophes. On example of this is the establischment of methods to decrease consequences, to response as fast as possible or to initiate an effeicient recovery[2].

Thesecircumstances underline the need of an assessment and an increase of municipal resilience. Different information characterizing the municipial resilience, but requires the availability of structured data which is also an complex challenge. The German Federal Office for Civil Protection and Disaster Relief (BBK) calls for “firmly agreed ways of exchanging data and information” which has to be “evaluated and improved” [3].

Based on these aspects, this paper presents a dataspace concept that merges heterogeneous data sources. Statistical and stochastic methods are applied to analyse the merged data and to quantify municipal resilience. Applications exampels show results of the demonstrator to evalute the occurrence of potential extreme weather events. Several use-cases are coordinated with different emergency management and disaster control authorities.

3 CONCEPT OF A RESILIENCE DATASPACE

The concept of the datadriven municipal resilience assessment aproach is shown in Figure 1. There are two main components: dataspace functionalities and methods for resilience analysis.

A dataspace is a federeated and open infrastructure for a sovereign data excchange, which is based on comon rules and standards [4]. This concept uses decentral data storage and a demand-oriented integration of data. The guarantee of data sovereignty is a central element of data spaces and they are an innovative digital ecosystsm that enable the open, secure and transparent use of data. They play a key role in the European digital strategy and the expansion of the European data economy [5].

According to Figure 1, connectors are used to combine different data sources. The pipeline transforms the data for the subsequent data analysis. Within a data catalogue, a potential user can extract different information concerning the availability, the format or the soluation of the connected data.

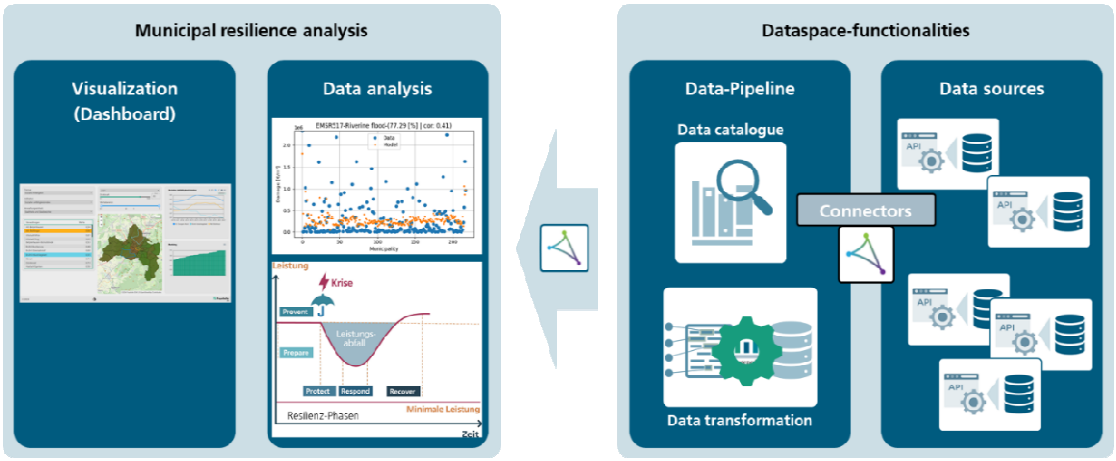

Fig. 1: Overview of single components for the data-driven resilience analysis of regions or municipalities.

The second part of the concept consists the data analysis as basis to derive quantitative resilience measures. Finally, the results are visualized within a dashboard. Different options, like GIS-based results, diagrams or time series are summarized to give a broad understanding and a contribution for municipal decision-makers.

4 DATA-DRIVEN RESILIENCE ANALYSIS

The characterization of possible disruptions and the resulting consequences can be quantified and evaluated using classic risk analysis methods [6]. The application of protective measures reduces the expected damage or the probability of occurrence and results in acceptable risks [7]. According to [8], increasing complexity and process dependencies are reasons why the application of risk-reducing measures is not necessarily sufficient. The aspects of resilience provide a holistic, adaptable and interdisciplinary concept to counter unforeseeable disruptions. Also a fast recovery after a disruption is an essential part concerning the prosperity of a society [9] and motivates the assessment and the increase of the municipal resilience. Based on the interdisciplinary application of resilience, several definition of that term are available [8].Within this paper the established definiton of [10] is used which includes five cyclic phases, see the left picture of Fig. 2. Therefore resilience "[…] is the ability to prepare for adverse events, to prevent them if possible, to cope with them, to react and recover as quickly as possible and to adapat to further future events if possible". Adverse events are disasters or change processes with far-reaching consequences that are of human, technical or natural origin.

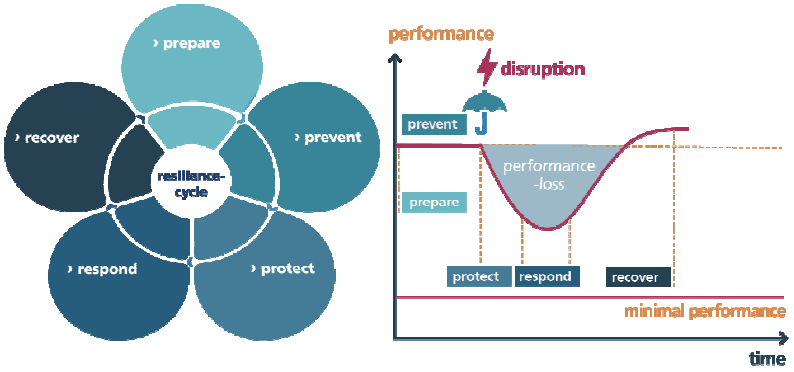

Fig. 2: Cyclic phases for the definition of resilience (left) and their interpretation on a performance-time relation to quantify resilience (right).

According to [11], the resilience of any systems can be measured using a performance-time relationship, as indicated with the right picture of Fig. 2. The five cyclic phases can be projected on this functional relationship before, during and after the disruption. The area in this relation measures the performance loss and indicates a quantitative resilience measure, i.e. the smaller the area, the higher the resilience.

The generalized concept of resilience is applied to the present requirements concerning the assessment of municitpalities subjected to hazards. Fire fighters and municipal decision makers from 12 different German districts and cities were involved in several workshops. They helped with their expert knowledge to identify key performance indicators (KPIs) for a resilience assessment of municipalities. Table 1 summarizes the results in alignment to the use-cases pandemic and extreme weather.

KPI	**Use-case pandemic**	**Use-case extreme weather**
Affected persons	Number of test/recovered/fatalities	Number of affected persons
Coping capacity	Nurse per patient/hospital	Availability first responder Number of applications
Availability	Bed occupancy/capacity (hospitals)	Critical infrastructure
Robustness	Unemployment	Usability/damage of buildings
Economy	Economic damage (direct/indirect)	

Table 1: Derived performance measures for the municipal resilience assessment in alignment to different use-cases.

The results concerning the municipal resilience assessment in Table 1 are listed according to their priority from the perspective from civil protection. Hence, the first KPI is the number of affected persons. The coping capacity and the availability are separated in dependency of the use-case. The usabiliy of buildings is a further essential KPI for the use-case extreme weather. Finally, economic damage was mentioned but is of lesser importance from a civil protection perspective.

5 APPLICATION EXAMPLES

The KPIs in Table 1 formed the basis for the review to data sources and approaches for the quantification of the performance targets. The identified datasources are coupled in alignment to the introduced scheme in Figure 1 for the quantification of single resilience metrics. The needs from the emergency management and first responder builds the basis to derive different use-cases. Subsequent, selected examples are presented to demonstrate the applicability and practical use of the introduced approach. The examples characterize single resilience phases (Figure 2).

5.1 Preparation and protection – Weak spot identification before and during the event occurrence

The first application example investigates within a what-if analysis the consequences of a hundred-year flood event. Flood maps [12] are consolidated with information concerning the road network [13, 14], points of interest, fire stations [15], digital buildings models [16]as well as landscape and usage models [17].

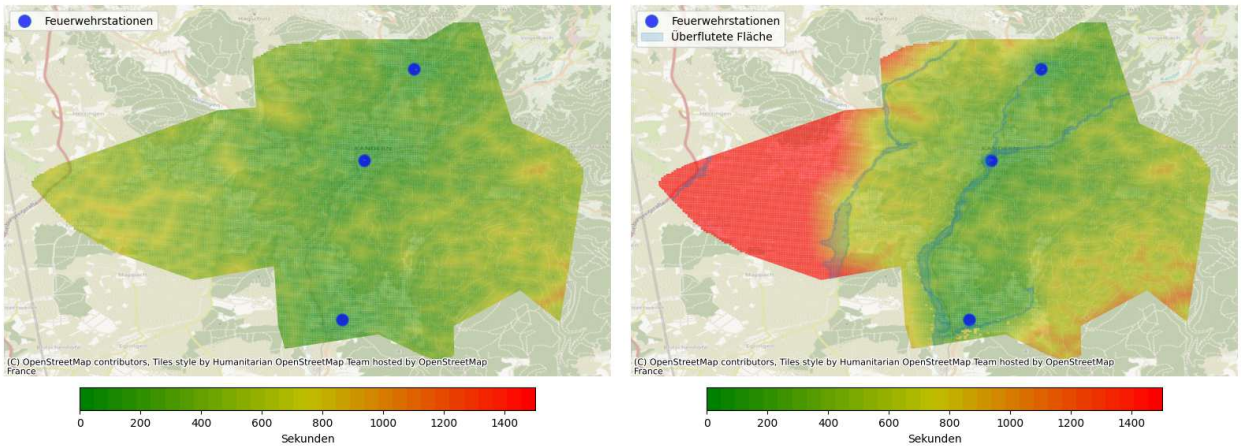

Fig. 3: Availability of all locations within a community with view from fire stations (blue points) before (left) and during (right) a flood event.

In alignment to the identified KPIs form Table 1, the availability of fire stations is calculated. A knot edge model is derived in with respect to the included road network. Afterwards, the travel times from single fire stations to each location in the municipality are calculated and the shortest pathes are identified. Finally, all results are merged and visualized in an isochrone map. The consideration of the flood map identifies blocked roads and influence the availability. The approach visualizes the changes caused by a flood and supports for a preparation in case of an event. The comparison is shown for a community in Baden-Württemberg in Figure 3. In this example, the eastern part of the region is strongly affected in case of a flood event.

The digital building models are applied to identify the number of affected buildings in combination with the flood map. The inclusion of the landscape and usage model helps to assign the buildings to single resilience dimensions according to[11]. Hence, the approach helps to identify, which parts of the municipality are affected. Figure 4 shows the results of the presented application example, the community in Baden-Württemberg, where most of the buildings are assigned to the social part, e.g. residential buildings, followed by technical infrastructure and buildings in the range of industry, sales and services. The resilience dimension organizational, e.g. administrative buildings, have a very small proportion in this example.

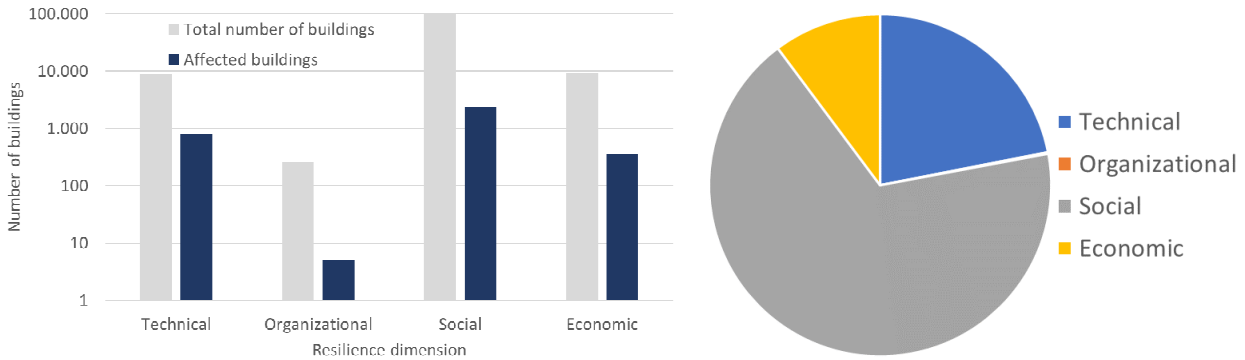

Fig. 4: Identification of affected buildings and the assignment to single resilience dimensions in dependency on the buildings use.

Beside the preparation for a disruptive event, there is also the need for a best practice protection, if an event happens. The next example was developed with a water board from North Rhine-Wesphalia. In case of potential dam failures there is the question what the consequences for the population are and how they can be protected. Figure 5 shows the results from a hydrodynamic simulation [18]. The black dot in the left map identifies the position of the broken dam and the color code indicates the time-dependent flood propagation. The right picture shows the predicted flood level. This information is coupled digital data concerning the road network [13, 14] and population data [19, 20].

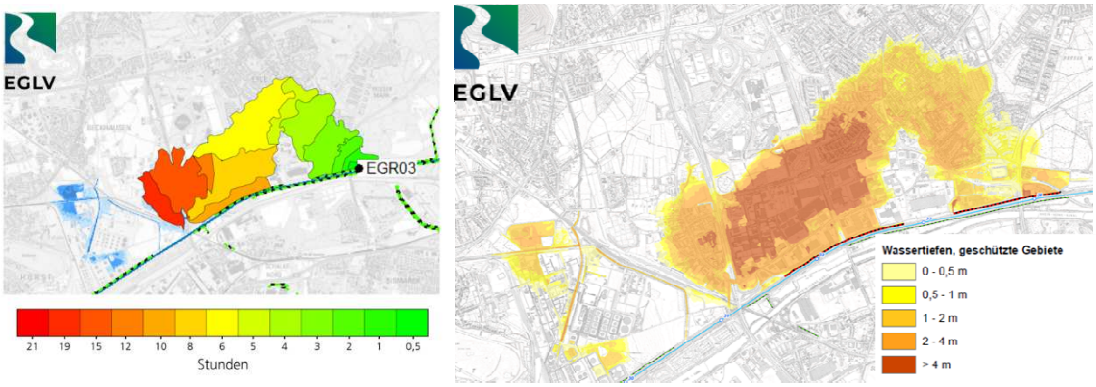

Fig. 5: Hydrodynamic simulation of a dam failure to estimate the flooding in terms of time-dependent propagation (left) and the flood heigt(right) according to [18].

The left picture of Figure 6 shows the static estimation of persons in the affected area. In this example, there are almost 13,00 persons involved. The introduced approach to estimate the availability (Figure 3) is applied with a walking speed and helps to estimate how long does it take to leave the endangered area. The results are currently applied for decision support by the city administration to install a rescue route system.

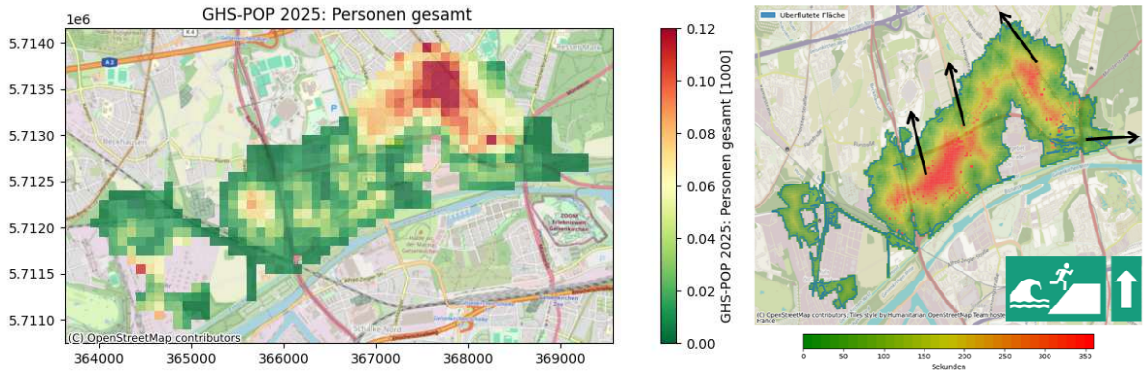

Fig. 6: Estimation the number of affected people (left) and the analysis of rescue pathes (right) in case of a dam failure.

The examples demonstrate that single resilience phases and dimensions are directly addressed with the introduced data-driven approach. The results give decion support for administrative authorities and crisis manager.

5.2 Response – Situational awareness after the hazard event occurence

The next example shows how the introduced approach supports after the occurrence of a disruptive event and contributes to the resilience phase “response”. The emergency manamangement service (EMS) is a module from the European earth observation programme “Copernicus” [21]. In case of an extreme weather event, satelitte images can be directly requested by first responders. The information of floodes areas of past events are combined with digital terrain model [22] to estimate the flood level as missing information. The consolidation with digitalbuildingmodels[16]helps to identify the number of affected buildings and the development of fragility curves estimate potential building damage. Figure 8 shows the assement of the affected buildings and the corresponding damage that is dependent on the estimated flood height. The example is based on satellite images that were captured during the flood event in the Ahr valley in 2021.

Fig. 7: Estimation of building damage based on the calculated flood height and the digital building models.

This use-case demonstrates the contributin of the introduced approach to generate further information for a situational awareness picture.

6 CONCLUSION

This paper introduces a new approach that uses data space functionalities for the resilience assessment of municipalities. Generalized standards of the International Dataspace Association (IDSA) guarantees data sovereignty and data protection. Connectors couple several external data sources and a developed data pipeline transform the digital information for analyses. The results of the data analysis are visualized in a user-friendly dashboard.

Existing solutions needs more effort for the merging of different information and their interpretation. The introduced approach includes efficient algorithms for data consolidation, automated analysis and corresponding visulazation.Different data analysis appraoches helps to identify potential weak spots and contributes for the resilience analysis of communitites or municipalities.

The use of the resilience cycle and the corresponding five phases of preparation, prevention, protection, response and recovery results in a clear definition and adresses all relevant aspects including resilience dimensions and properties.

The application examples demonstrates the applicability for extreme weather events concerning the resilience phases preparation, protection and response. The results are verified in alignment to the needs of municipal decision makers, first responders and crisis manager.

Further work will focus on the validation of the data analysis approach. Examples are verification of flood height estimation and calcultation of expected building damage. The estimation of person density based on static population data. In case of further data with dynamic population data, this data source can be replaced.

7 ACKNOWLEDGEMENTS

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Datengestützte Optimierung der ÖV-Anbindung zwischen Salzburger Flughafen und Tourismusregionen

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1 ABSTRACT

Um den Flughafen als Mobilitätsknoten zu stärken und die verkehrliche Situation vor Ort zu verbessern, arbeitet die Salzburger Flughafen GmbH im Projekt Flughafen 4.0 mit den Forschungspartnern RSA FG iSPACE und IDA-Lab der PLUS zusammen. Gemeinsam untersucht man – gefördert durch die WISS25 des Landes Salzburg – mittels GIS und statistischer Verfahren, wohin Gäste weiterreisen, welche Rolle das Herkunftsland dabei spielt und welches die besonders relevanten Zielgebiete sind. Ein weiterer Fokus liegt auf der Analyse der ÖV-Konnektivität vom Flughafen in die Regionen des Einzugsgebiets. Es wird untersucht, wie die schnellste Reisezeit, die notwendigen Umstiege und das Intervall an verschiedenen Wochentagen zu bewerten sind und in der Folge aufgezeigt, welche Regionen bereits gut angebunden sind und wo Verbesserungsbedarf besteht. Die Gegenüberstellung der Verteilung der Fluggäste auf Zielregionen mit der der ÖV-Konnektivität ermöglicht wichtige Erkenntnisse zur Bedarfslage. Durch die Kombination unterschiedlicher Datenquellen lassen sich transparente Planungsgrundlagen entwickeln, die helfen, den Flughafen als zukunftsfähigen Mobilitätsknoten zu etablieren, besser an umliegende Regionen anzubinden und wichtige Reiseketten in ihrer Durchgängigkeit zu optimieren.

Keywords: statistische Modellierung, GIS, Tourismusmobilität, Bedarfserhebung, ÖV-Planung

2 HINTERGRUND

Der Flughafen Salzburg liegt verkehrsgünstig am Rande der Stadt Salzburg und dient als wichtiger Knotenpunkt für internationale Gäste, die v.a. die Tourismusregionen im Salzburger Land besuchen möchten. Zwar verbinden Stadt- und Regionalbusse regelmäßig den Flughafen mit der Innenstadt, dem Hauptbahnhof und einigen Zielregionen, die Haltestellensituation ist jedoch unübersichtlich und die Abfahrten zu wenig auf die Flugverbindungen abgestimmt. Die besonders relevanten Zielgebiete sind der Flughafen GmbH bislang unbekannt. Weiters erzeugen gerade Spitzensamstage im Winter viel Individualverkehr, Staus und sonstige Belastungen für die Wohnbevölkerung entlang der Trassen. Die Weiterreise wird oftmals durch Hotels, private Unternehmen (z.T. aus den Herkunftsländern) oder den motorisierten Individualverkehr abgewickelt.

Durch **intelligente Verknüpfung verschiedener Datenquellen** kann die Planung von wirksamen und effizienten öffentlichen Verkehrsanbindungen zwischen Flughäfen und Zielregionen erheblich profitieren. Neben Daten zum bestehenden Mobilitätsangebot bieten Tourismusdaten, Pendlerdaten und Flugverkehrsdaten wertvolle Einblicke in die Bedarfslage: Tourismusdaten ermöglichen es, die Anzahl und Verteilung von Reisenden zu erfassen und saisonale Schwankungen besser zu berücksichtigen, während Pendlerdaten Aufschluss über regelmäßig genutzte Verkehrsströme und bevorzugte Routen geben. Flugverkehrsdaten bieten Informationen zu Ankunfts- und Abflugmustern, Passagierzahlen sowie Spitzenzeiten, die eine präzise Abstimmung des ÖV und weiterer Mobilitätslösungen auf die Fluggäste ermöglichen. Mittels Szenariosimulationen und Potenzialmodellierungen sollen emissionsarme Mobilitätslösungen und neue Qualitätsstandards entwickelt werden, um die Regionalentwicklung und das Destinationsmanagement zu stärken (Salzburger Flughafen GmbH 2021). Im Vorfeld wurde beispielsweise von Kovacs-Györi et al. (2025) untersucht, wie sich touristische Ankünfte im Land Salzburg clustern lassen, um von Herkunft und Saison beeinflusste Muster zu identifizieren. Besonders in der Wintersaison spielen saisonale Flüge, etwa aus Großbritannien und Skandinavien, eine wichtige Rolle, während ganzjährig regelmäßige Verbindungen zu europäischen Hauptstädten und einigen außereuropäischen Zielen bestehen (Salzburger Flughafen GmbH 2023).

3 METHODIK

3.1 Daten und Untersuchungsgebiet

Das Einzugsgebiet des Flughafens als Untersuchungsgebiet im Projekt erstreckt sich über das Bundesland Salzburg, Teile von Oberösterreich, Tirol und der Steiermark sowie angrenzende Gebiete in Deutschland. Aufgrund von Datenbeschränkungen wurde bei den Modellierungen auf österreichische Gemeinden fokussiert. Den Ausgangspunkt bildete eine Sonderauswertung der Statistik Austria, welche die **touristischen Ankünfte** aus 54 Ländern und Regionen weltweit je Gemeinde monatlich aufgelöst für die **Tourismusjahre 2018/19 und 2022/23** umfasst. Die Daten wurden GIS-gestützt aufbereitet und Karten zu den Ankünften je Herkunftsland und Saison erstellt. Dadurch konnten räumliche und zeitliche Muster sowie saisonale Unterschiede im internationalen Tourismus zwischen Sommer- und Wintermonaten sichtbar gemacht werden. Auf Seiten der **Flugdaten** standen detaillierte Informationen zu den täglichen Flugbewegungen zur Verfügung, einschließlich Herkunft (Land und Abflughafen), Flugzeugtyp mit Kapazität sowie Sitzbelegung. Diese Daten lagen für dieselben Tourismusjahre vor und ermöglichten u.a. eine Analyse der Auslastung nach verschiedenen Zeiträumen. Eine Einschränkung dieser Daten besteht darin, dass der Abflugort nicht zwangsläufig dem Herkunftsland der Passagiere entspricht. Um die Flugdaten mit den touristischen Ankunftsdaten im Untersuchungsgebiet verknüpfen zu können, war die zeitliche Auflösung der Statistikdaten nicht ausreichend. Daher wurden als alternative Quelle tägliche Ankunfts- und Nächtigungsdaten nach Herkunftsländern aus den **Gästeverzeichnissen der Gemeinden** identifiziert. Nach Genehmigung konnten diese anonymisierten Daten für 86 Gemeinden im Land Salzburg für die oben genannten Tourismusjahre bezogen werden.

Abbildung 1.

3.2 Flughafenrelevante Herkunftsländer und Zielgebiete

Um die Komplexität der Datensätze zu verringern und gleichzeitig eine repräsentative Stichprobe sicherzustellen, wurde eine gezielte Auswahl der zehn relevantesten Herkunftsländer getroffen. Diese Auswahl basierte auf dem **Volumen der Touristen und Flugpassagiere**, die aus diesen Ländern nach Salzburg reisen. Zu beachten ist, dass nicht alle touristischen Ankünfte über den Flughafen Salzburg anreisen. Ziel war es, einen signifikanten Anteil der touristischen Ankünfte im Untersuchungsgebiet und der Ankünfte am Flughafen Salzburg abzudecken. Zu den ermittelten flughafenrelevanten Herkunftsländern zählen Deutschland, Großbritannien, Niederlande, Dänemark, Schweden, Irland, Norwegen, Israel, Finnland und Frankreich. Diese zehn Länder machen 82 % der Flugpassagiere und 70 % der Touristen aus (Kovacs-Györi et al. 2025).

In der Folge wurden von Kiefel et al. (2025) **Korrelationsanalysen** zwischen Herkunftsländern von Flugpassagieren und der Tourismusstatistik in Zielgebieten durchgeführt, um eindeutig flughafenrelevante Zielgebiete herauszuarbeiten. Dabei wurden zunächst die zeitlich hochaufgelösten Daten verwendet und die Methodik in weiterer Folge mit den monatlichen Strukturdaten der Statistik Austria und für einen **Vergleichszeitraum** in den Jahren 2022/23 evaluiert. Es konnten im Jahresvergleich (wohlgemerkt vor und nach der Covid19-Pandemie) auch mit den gröberen Daten eindeutige **raumzeitliche Muster der**

Gästeverteilung selbst für einzelne Herkunftsländer ermittelt werden, die auch für zukünftige Prognosen mittels (angepassten) Flugplänen dienlich sind.

3.3 ÖV-Konnektivität

Im Rahmen des Projekts wurden Konnektivitätsindikatoren entwickelt, um die aktuelle Qualität der ÖV-Anbindung vom Flughafen in alle Gebiete des Untersuchungsgebiets zu analysieren. Darauf aufbauend können Wegeketten zwischen dem Flughafen und den verschiedensten Destinationen in seinem Einzugsgebiet bewertet sowie Stärken und Schwächen aufgezeigt werden.

Dazu wurde ein Python-Skript erstellt, das durch Anfragen an einen lokalen Server mit **OpenTripPlanner 2.0** ÖV-Verbindungen berechnet. Grundlage sind ein österreichweiter Haltestellendatensatz (ÖV-Güteklassen), das Wegenetz aus der Graphenintegrationsplattform (GIP) sowie GTFS-Fahrplandaten verschiedener Verkehrsverbünde, der ÖBB und der Westbahn für 2022. Das Skript analysiert Verbindungen zwischen dem Flughafen Salzburg und Haltestellen im Untersuchungsgebiet, basierend auf Abfahrten bzw. Ankünften mittwochs und samstags zwischen 9:00 und 17:00 Uhr, und liefert eine Tabelle mit wesentlichen Attributen wie Anzahl und Dauer der Verbindungen für alle angefragten Start-Ziel-Paare. Die **schnellste Verbindung** und die Verbindung mit den **wenigsten Umstiegen** pro Start-Ziel-Paar werden ermittelt und auf Gemeindeebene aggregiert. Über die Anzahl und die zeitliche Verteilung der Verbindungen werden zusätzlich die **Taktfrequenzen** abgeleitet. Um die Verbindung mit der frühestmöglichen Ankunft am Flughafen aus der jeweiligen Gemeinde bzw. die letztmögliche Abfahrt am Flughafen, mit der man noch am selben Tag ein Ziel in der Gemeinde erreichen kann, wurde dasselbe Skript noch einmal mit einem 24-Stunden-Zeitfenster ausgeführt (2 Uhr morgens bis 2 Uhr am Folgetag, um Fahrten nach Mitternacht zu berücksichtigen).

Um die **Konkurrenzfähigkeit mit dem MIV** zu ermitteln wurde ein weiteres Skript erstellt, das die schnellsten MIV-Routen mithilfe der GIP ermittelt. Die Ergebnisse wurden schließlich mit den ÖV-Reisezeiten für jedes Start-Ziel-Paar verglichen. Für die **Planungsregionen** (Salzburgwiki 2023), die in den Ergebniskarten zur Anwendung kommen, wurde jeweils der Median der schnellsten Verbindungen in alle zumutbar erreichbaren Gemeinden der Region mit Stichtag 14.09.24 berechnet. Zwischen Saison, Wochentag und Samstag wurde jedenfalls für die Reisezeit und erforderlichen Umstiege kein signifikanter Unterschied festgestellt, wohl aber für die Taktfrequenzen.

4 ERGEBNISSE

4.1 Verteilung von Fluggästen und Verschränkung mit ÖV-Konnektivität

Die auf statistischer Basis auf das Land Salzburg und augewählte benachbarte Regionen verteilten Fluggastzahlen lassen sich kartographisch visualisieren. Insgesamt wurden aus den Flugdaten (mit Abschlagsfaktoren der Auslastung und des Reisezwecks) für das Tourismusjahr 2022/23 ca. 350.000 jährliche touristische Ankünfte ermittelt, von denen etwa 280.000 ins Salzburger Land weiterreisen. Weil sich bei der statistischen Modellierung eine charakteristische Zwischensaison gezeigt hat (die zahlenmäßig eher geringere Bedeutung hat), definieren wir die Sommersaison vom 1.6. bis zum 30.9. und die Wintersaison vom 1.12. bis zum 31.3. – im Gegensatz zur gängigen Definition. Etwa die Hälfte dieser Gäste entfallen auf die Wintersaison und die Variabilität, d.h. der Faktor zwischen stärkster und schwächster Tourismuswoche, ist mit über 12 in den Wintersport-Hotspots oberes Saalachtal, Gasteiner Tal und Enns-Pongau am größten. Hier liegen auch die höchsten Wochenmittel an Fluggästen während der Wintersaison mit rund 1400 (vgl. Abb. 2). Tirol hat laut Modellierung noch ca. 400 wöchentliche Gäste mehr, die über den Salzburger Flughafen anreisen.

In Kombination mit den ÖV-Konnektivitätsindikatoren ergeben sich wertvolle Planungsgrundlagen zur Bewertung der aktuellen ÖV-Qualität und möglichen Optimierungen im Hinblick auf den fluggastbezogenen Mobilitätsbedarf. Eine Kartenserie unterlegt die Zahl der Fluggäste mit dem Indikator Reisezeit für drei markante Zeiträume: Wochenmittel Sommersaison, Wintersaison (Abb. 2) sowie die Kalenderwoche 6 im Februar als stärkste Flugtourismuszeit des Jahres in Salzburg. Neben der Verteilung auf Planungsregionen, kann das statistische Modell mit kleineren Adaptionen auch Ergebnisse für Gemeinden generieren. Zur Verschränkung mit dem ÖV wurde die schnellste Verbindung zu einer Zielhaltestelle in der Gemeinde ermittelt. In der KW 6 strömen mehr Gäste in einzelne Gemeinden wie Saalbach und Zell am See als im

Wochenmittel der Wintersaison in die gesamte Planungsregion. Außerdem wird deutlich, welche Korridore (zumindest saisonal) für die Weiterreise vom Flughafen gefragt sind und dass die ÖV-Anbindung in Anbetracht der Distanz und Topographie mit max. 120 Minuten in den Enns-Pongau und ins Gasteiner Tal durchaus gut ist. Der notwendige Umstieg am Hauptbahnhof fällt aber ins Gewicht.

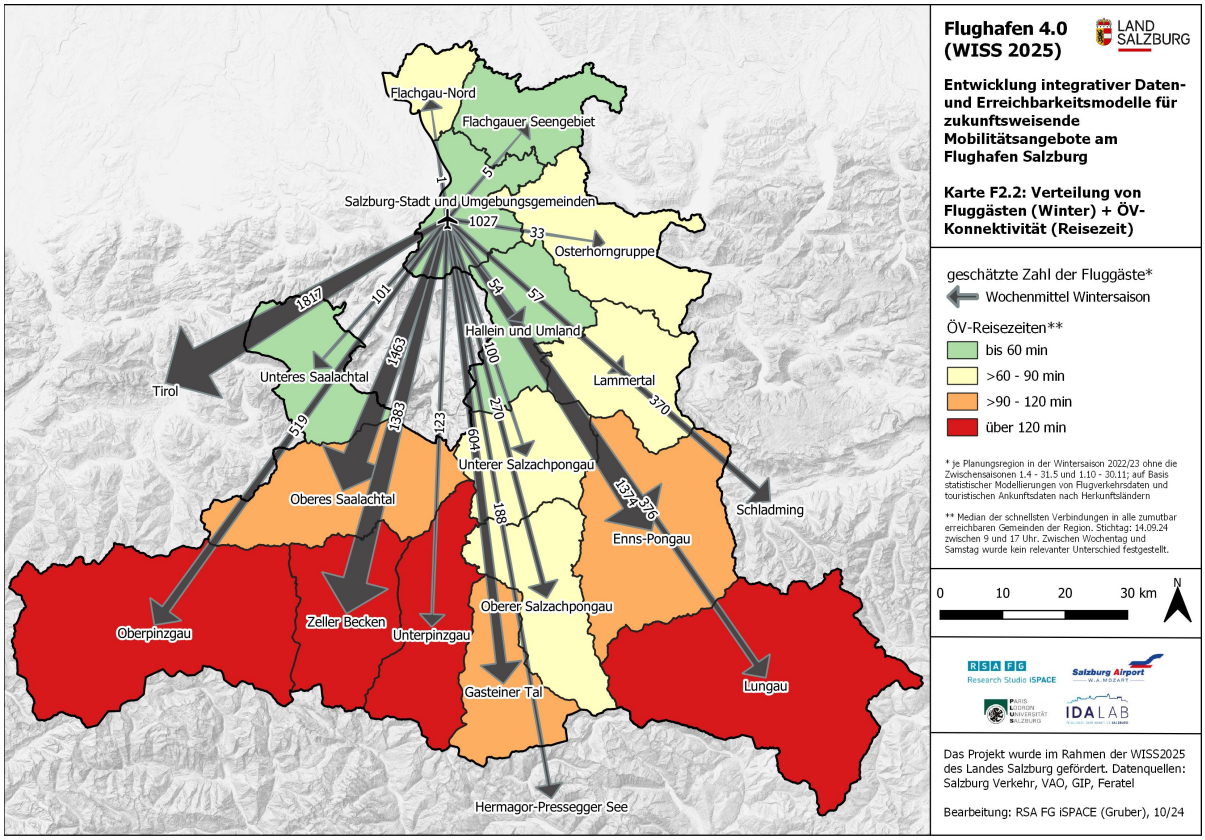

Abb. 2: Modellierte Fluggastverteilung im Wochenmittel der Wintersaison und ÖV-Reisezeiten in Planungsregionen

4.2 Abgleich von Flugzeiten und ÖV-Verbindungen

Eine wichtige Verbindung auch für den Pendelverkehr ist die Regionalbuslinie 260 in den Pinzgau (bspw. nach Zell am See, Saalbach), die als nachhaltige und durchgängige Weiterreisemöglichkeit für Flugpassagiere noch mehr genutzt werden könnte. Im Zuge einer Neuausschreibung 2023 wurden die Abfahrten am Flughafen den Flugankünften und Abflügen gegenübergestellt und Plandaten einer Taktverdichtung integriert, um aufzuzeigen, wie diese aktuell aufeinander abgestimmt sind und wo eine Verbesserung sinnvoll ist. In Abb. 3 werden die Busabfahrten vom Flughafen Richtung Zell am See an Samstagen mit den Passagierankünften verglichen. Dazu wird von einer durchschnittlichen Aufenthaltsdauer (Gepäck, Zoll, Wege) von 50 min ab Landung ausgegangen und für den Weg zur Haltestelle 2 min (Terminal) bzw. 5 min (Kröbenfeldstraße) veranschlagt. Die Einfärbung der Balken entspricht der modellierten Wartezeit, die für die ankommenden Passagiere nach Landung und Aufenthaltsdauer am Flughafen bis zur nächsten Busabfahrt zu erwarten ist, wobei grüne Balken einen optimalen Übergang von Flugzeug zu Bus bedeuten, hingegen orange bis rote eine kaum bis nicht mehr akzeptable Wartezeit. Wir sehen u.a. dass zahlreiche Fluggäste gerade am Vormittag und über Mittag schlecht an den ÖV angebunden waren (oben), was sich in der Folge durch eine Taktverdichtung optimieren ließ (unten). Die Kapazität der Fahrzeuge und tatsächliche Nachfragesituation wird jedoch nicht berücksichtigt.

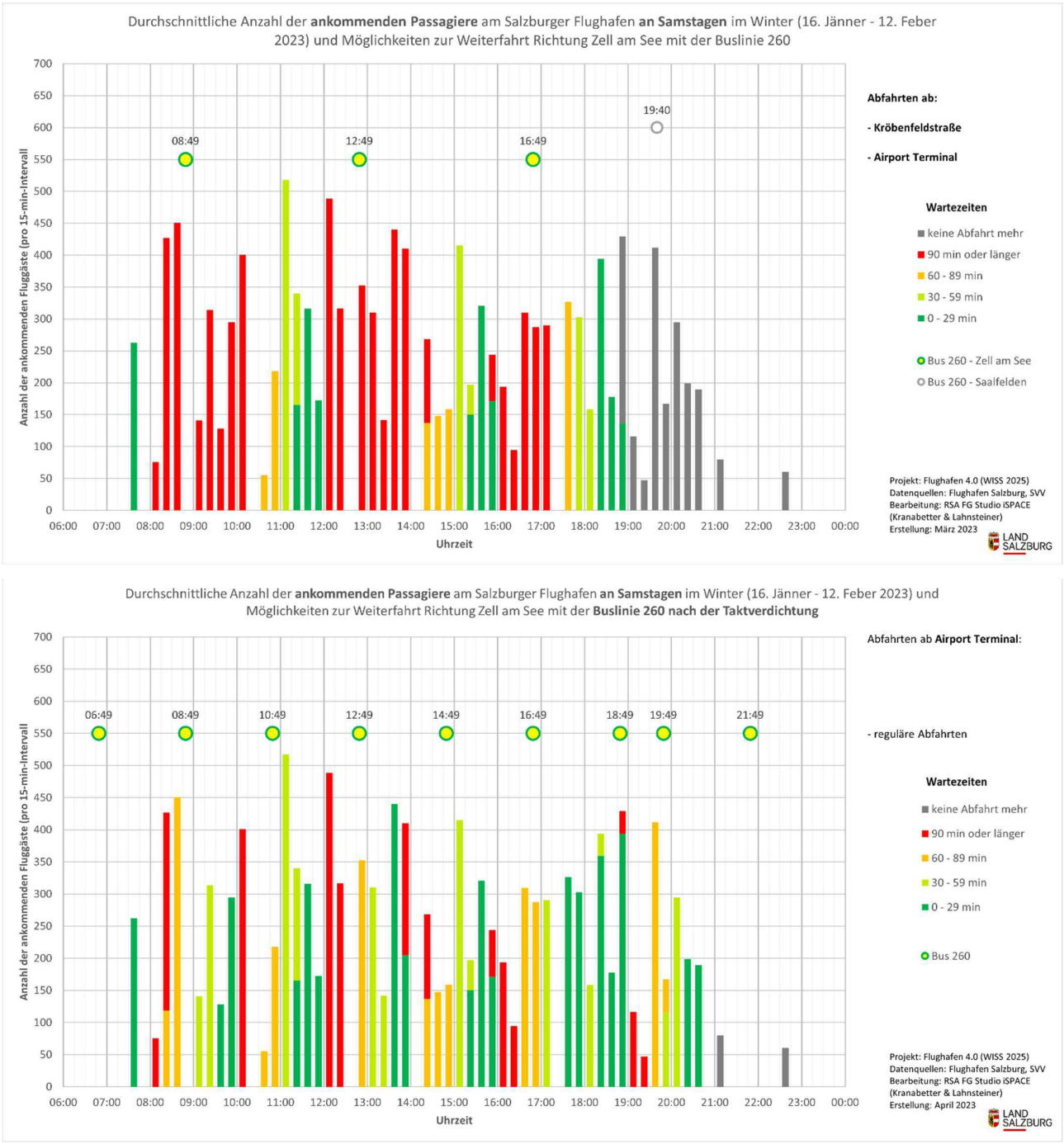

Abb. 3: Wartezeiten zur Weiterfahrt mit der Linie 260 vor und nach Taktverdichtung 2023

5 DISKUSSION

Es wurde aufgezeigt, dass die Verschränkung von flughafeninternen Daten mit touristischen Strukturdaten einen markanten Informationsgewinn ermöglicht. Die Anwendungspotenziale der Verteilungsmuster von Fluggästen gehen weit über neue Erkenntnisse für die Flughafen GmbH hinaus und könnten u.a. im Gast- und Beherbergungsgewerbe oder Ortsmarketing in Wert gesetzt werden. Aus Fahrplandaten von offenen Schnittstellen können Indikatoren der ÖV-Konnektivität abgeleitet werden, mit denen sich ein noch besser auf die Bedürfnisse von Flugreisenden abgestimmtes ÖV-Angebot entwickeln lässt. Oft reicht eine Taktverdichtung um wenige Fahrten, um eine beträchtliche Zahl von Touristen besser zu durchbinden. Das statistische Verfahren eignet sich zur Abbildung von zeitlichen und herkunftsbezogenen Variabilitäten, die in der ÖV-Planung bzw. für das Mobilitätsangebot zur und an der Destination berücksichtigt werden können. Hierzu bedarf es einer verfeinerten Untersuchung und Ausgestaltung sinnvoller Anwendungskontexte.

Natürlich gibt es in der heutigen Flugreisen-Industrie zahlreiche private Angebote durch Shuttle-Dienste oder Gruppenreisen per Bus in die begehrten Destinationen, die man oft pauschal bucht. Deren

Zugänglichkeit ist allerdings gerade an Spitzentagen oft chaotisch und wenig inklusiv und barrierefrei. Zudem entsteht ein immens hohes Verkehrsaufkommen im Flughafenbereich und entlang der Reiserouten. Hier könnten Verkehrsverbünde mit ihrem öffentlichem Auftrag steuernd eingreifen. Zugleich scheint die Umweltfreundlichkeit der Weiterreise vernachlässigbar, wenn man ohnehin mit dem Flugzeug anreist. Dennoch hilft die Schaffung einer Wissensbasis mit quantifizierbaren Aussagen zu Verteilungsmustern attraktive öffentliche Verkehrsangebote oder geteilte (E-)Mobilität zu entwickeln. Dies führt zu einer besseren Bündelung des Verkehrs, einer Reduzierung des motorisierten Individualverkehrs und weniger Staus. Gleichfalls profitieren Reisende, Pendlerinnen und Pendler von einem verbesserten Angebot und höherem Komfort, während die Wohnbevölkerung durch die Entlastung der Verkehrssituation an Lebensqualität gewinnt. Die Förderung von durchgängigen und nachhaltigen Wegeketten für An- und Abreise trägt zudem zur Stärkung des Wirtschafts- und Tourismusstandorts Salzburg und dessen Nachbarschaft bei.

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Die Entwicklung des Grazer Straßenbahnnetzes

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1 ABSTRACT

Die Stadt Graz ist mit rund 300.000 Menschen die größte Landeshauptstadt Österreichs. Dazu kommen noch rund 170.000 Personen, die täglich über die Stadtgrenzen fahren. Graz feiert in einigen Jahren sein 900 jähriges Bestehen und hat das Glück, dass das historische Stadtzentrum weitgehend erhalten geblieben und durch die UNESCO als Weltkulturerbe geschützt ist. Dies sind auch wesentliche Rahmenbedingungen für die Bewältigung der Mobilitätsanforderungen. Graz ist auch ein bedeutender Universitäts- und Industriestandort, wobei hier vor allem die lange Tradition der Herstellung von Schienenfahrzeugen und deren Komponenten sowie der Fahrzeugentwicklung und -produktion zu erwähnen sind.

Keywords: Netzausbau, Straßenbahn, öffentlicher Verkehr, umweltfreundliche Mobilität, Planung

2 DIE STRASSENBAHN IN GRAZ

2.1 Die geschichtliche Entwicklung bis 1990

Graz kann auf eine fast 150-jährige Geschichte des Straßenbahnbetriebes zurückblicken. Bereits im Jahre 1878 fuhr die erste Straßenbahn vom Zentrum zum heutigen Hauptbahnhof, damals noch von Pferden gezogen. Die erste elektrische Straßenbahn wurde abweichend zur Pferdestraßenbahn als Schmalspurbahn von Mariatrost bis zum Glacis errichtet und erst während des Zweiten Weltkrieges umgespurt und an das bestehende Straßenbahnnetz angebunden. Im Laufe der Jahre entstanden weitere Strecken sowie eine Ringlinie und auch Verknüpfungen, die eine flexible Betriebsführung ermöglichten. Mit ca. 45 km Netzlänge erreichte das Netz nach dem Zweiten Weltkrieg seine größte Ausdehnung.

Mit Beginn der Motorisierung änderte sich die Verkehrspolitik und einige Linien wurden auf Autobusbetrieb umgestellt und die Straßenbahn von Hauptverkehrsstraßen entfernt. Dies bewirkte eine Verkleinerung des Netzes auf ca. 27 km.

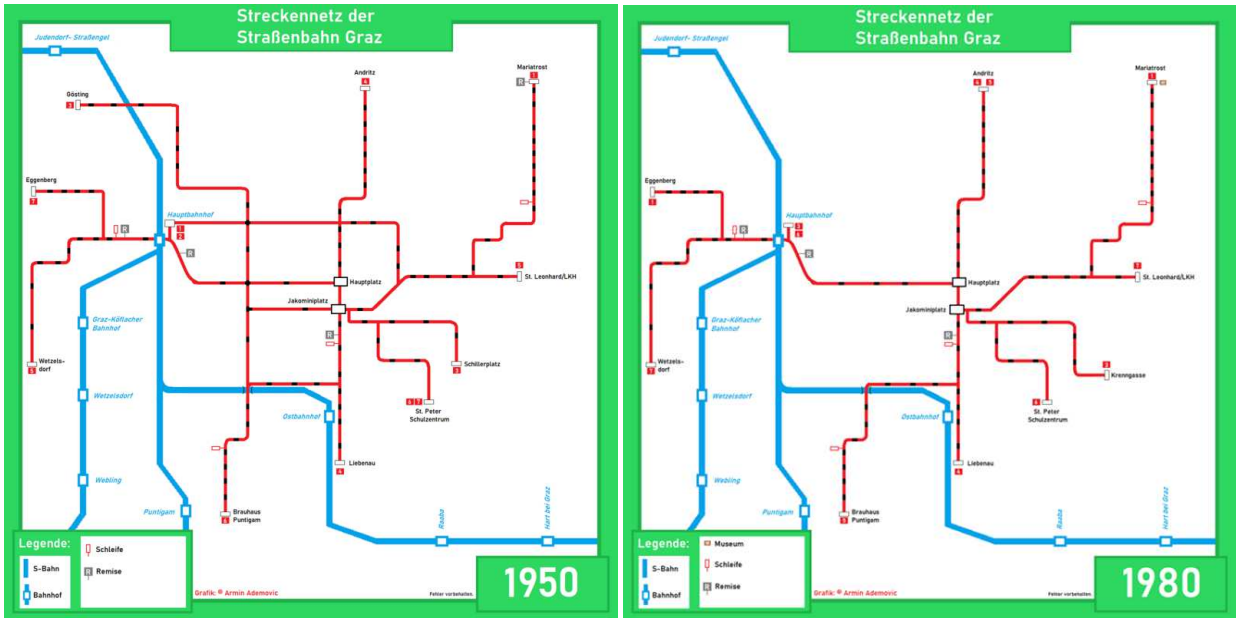

Fig. 1: Straßenbahnnetz 1950 und 1980. Quelle: Wikipedia.

Erst nach dem ersten Ölpreisschock und der Erkenntnis, dass unsere Städte nicht für den massiv zunehmenden Autoverkehr geeignet sind, wurde die Renaissance der Straßenbahn aus der Taufe gehoben. Gemeinsam mit dem neuen Slogan der „Sanften Mobilität“ und der erstmals in Europa flächendeckenden Einführung von Tempo 30 ausgenommen auf Vorrangstraßen bekam der Ausbau der Straßenbahn einen

neuen Auftrieb. Parallel zu Überlegungen das Netz weiter auszubauen, werden auch erstmals Planungen angestoßen, den Straßenbahnbetrieb zu beschleunigen und Haltestellen zu verbessern.

2.2 Die Entwicklung von 1990 bis heute

Die erste Verlängerung einer Straßenbahnstrecke nach der großen Einstellungswelle im Zuge der Motorisierung erfolgte 1990. Damals wurde die Linie 1 in Eggenberg um knapp einen Kilometer zum einige Jahre davor gebauten neuen Unfallkrankenhaus erweitert. Damit konnte auch ein damals an der Strecke liegendes Sanatorium ebenfalls attraktiv angebunden werden. Das letzte Streckenstück zur ursprünglichen Endstation war eingleisig und konnte im Zuge des Ausbaus zweigleisig ausgebaut werden. Heute befindet sich an der neuen Endstation nicht nur das Unfallkrankenhaus, sondern auch eine Zweigstelle des Landeskrankenhauses Graz.

Der nächste große Wurf gelang mit der Neugestaltung des Jakominiplatzes, an dem sich alle Linien treffen. Bis 1996 gab es keine Möglichkeit von Kurzführungen von Linien und auch nur eingeschränkte Möglichkeiten, Fahrzeuge auf andere Linien umzuleiten. Dies machte den Straßenbahnbetrieb sehr unflexibel und störanfällig. Mit dem großen Umbau in den Jahren 1995 und 1996 enstanden neben der markanten architektonischen Neugestaltung zwei Wendeschleifen im Nahbereich des Platzes, zusätzliche Haltestellen für die Straßenbahnen in Richtung Osten mittels eines Vorsortiergleises und Gleisverbindungen, die nunmehr alle Fahrbeziehungen ermöglichen. Die Bauabwicklung erfolgte in mehreren Etappen, musste doch der Umbau weitgehend unter Aufrechterhaltung des Betriebes erfolgen. Damit wurde auch der Grundstein für weitere Streckenneubauten gelegt, insbesonders die Anbindung des Südwestens von Graz an das Straßenbahnnetz war bereits damals als Ziel formuliert. Vom Jakominiplatz bis zum Nahverkehrsknoten Don Bosco, der damals noch nicht existierte, fahren drei Buslinien mit Gelenkbussen betrieben in dichten Intervallen parallel und teilen sich dann auf.

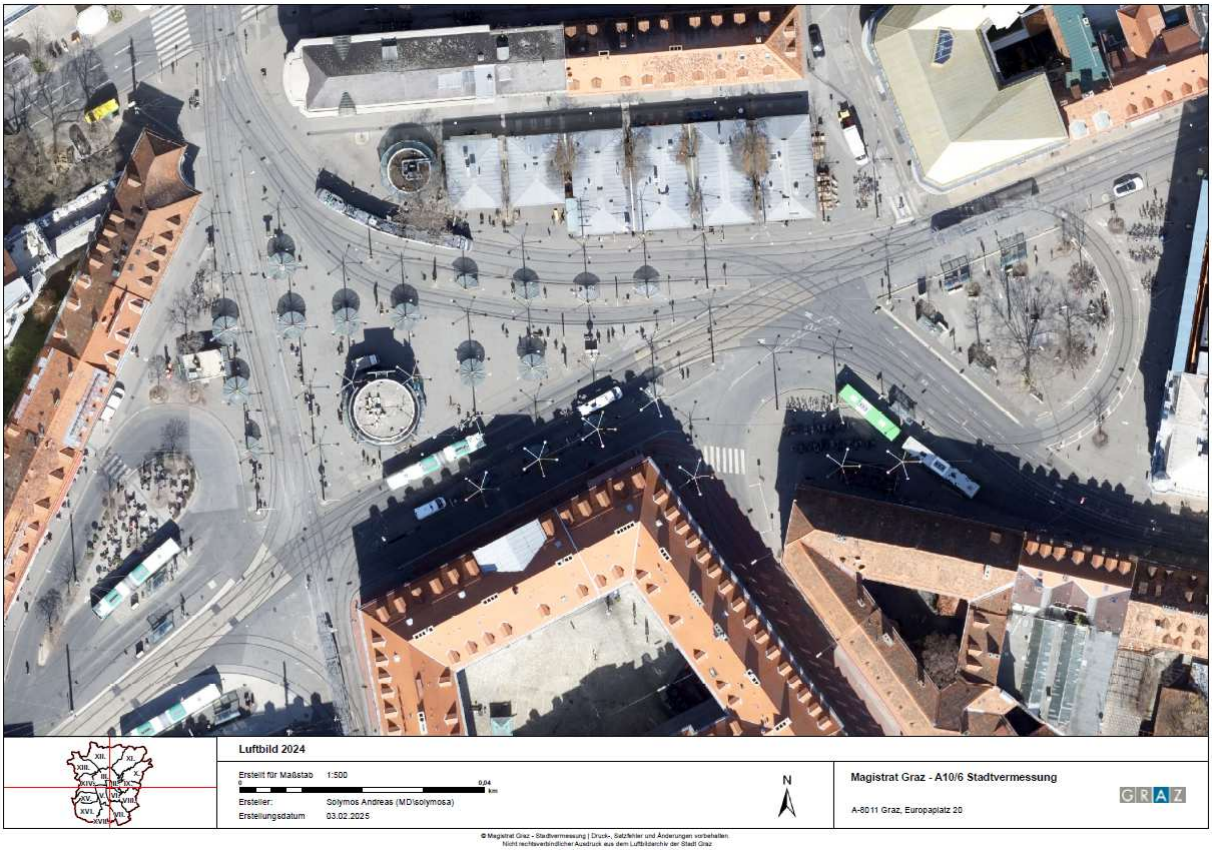

Fig. 2: Luftbild Jakominiplatz nach der Neugestaltung, die zweite Wendeschleife befindet sich links außerhalb des Bildes.

In den Jahren danach entstanden Projekte, die unterschiedliche Zielsetzungen verfolgten. Neben der Verbesserung der Anbindung bestehender Siedlungsschwerpunkte standen auch neue städtebauliche Entwicklungen im Zusammenhang mit einem am Autobahnzubringer Graz Ost zu bauenden

Einkaufszentrum in Kombination mit Park+Ride und die Verknüpfung mit regionalen Verkehrssystemen im Fokus. So entstanden bis 2007 drei Verlängerungen von Straßenbahnlinien:

- Die Linie 4 wurde um ca. 1,5 km zu einem neuen Einkaufszentrum verlängert, bei dem auch ein Park+Ride-Haus errichtet wurde. Neben der Verknüpfung mit weiteren innerstädtischen und regionalen Buslinien entstand einige Jahre später auch ein Übergang zur S-Bahn durch den Bau einer neuen Haltestelle an der Steirischen Ostbahn. Bemerkenswert ist, dass die Straßenbahn nicht nur zum Einkaufzentrum geführt wird, sondern zwischen dem Lebensmittelmarkt und dem Shoppingtrakt mittig durch den Gebäudekomplex fährt.

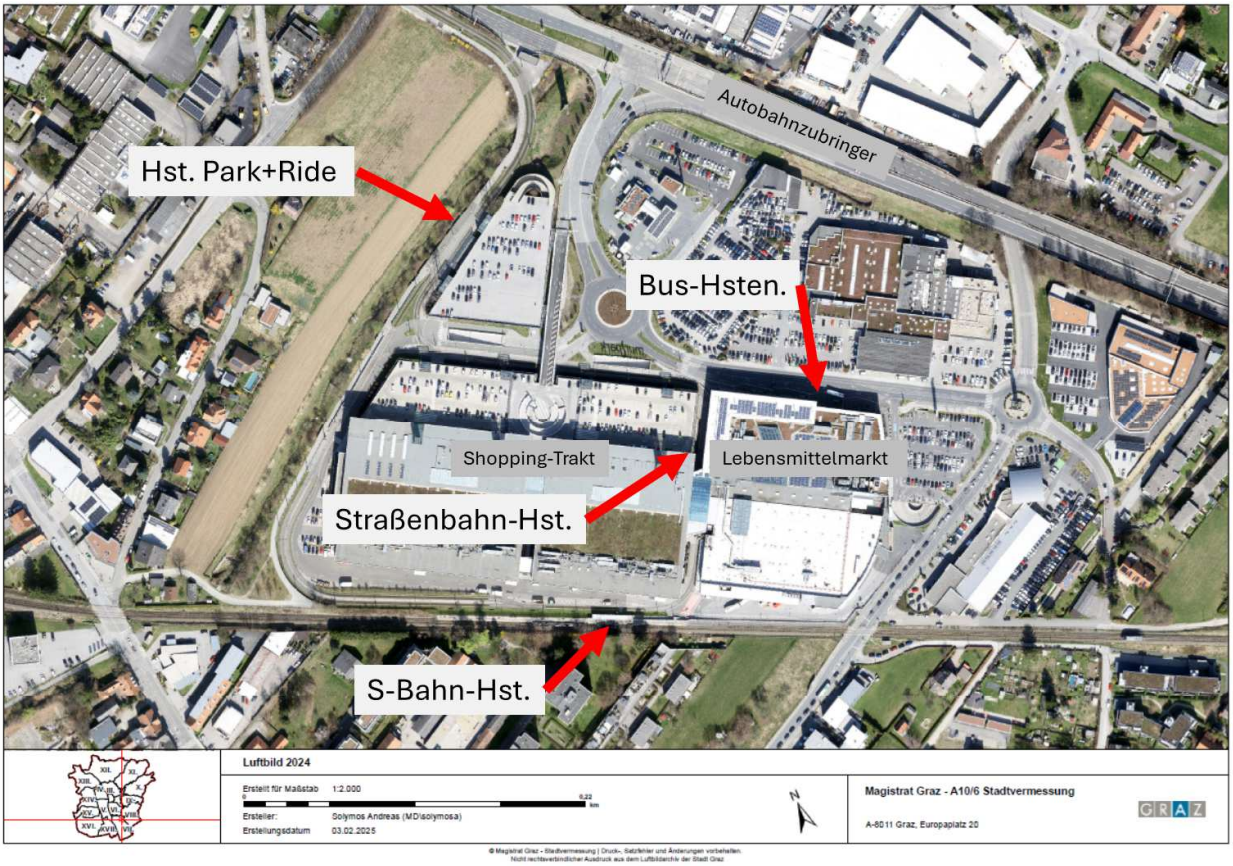

Fig. 3: Luftbild Murpark mit ÖV-Haltestellen.

- Die Linie 5 wurde um einige hundert Meter zum neu errichteten Bahnhof Puntigam verlängert und ein großer Nahverkehrsknoten mit weiteren innerstädtischen wie auch regeionalen Busanschlüssen konzipiert. Dies erfolgte im Zuge des Baus der Koralmbahn als neue Verbindung zwischen Graz und Klagenfurt und stellt für den Zeitpunkt für deren Eröffnung 2025, sowie für den S-Bahn-Verkehr generell, einen attraktiven Übergang für Fahrgäste auf das innerstädtische Netz und auch umgekehrt sicher. Dazu ist zu ergänzen, dass im Laufe der Jahre mehrere Tangentialbuslinien eingeführt wurden, die eine direkte Verteilung der Fahrgäste zwischen den äußeren Bezirken ermöglichen und damit Umwegfahrten über das Zentrum entfallen. Dieser Effekt führt auch zu einer Erhöhung der Kapazitäten im radial ausgerichteten Straßenbahnbetrieb.
- Die Linie 6 erschließt im Zuge der 2 km langen Verlängerung einen Siedlungsschwerpunkt im Südosten von Graz mit mehr als 10.000 Menschen. Der um viele Jahre nach dem Einzug der Bewohnerinnen und Bewohner zeitlich versetzte Bau der Straßenbahn führte im Vorfeld zu vielen Protesten und Verzögerungen. Es gab Bürgerinitiativen pro und kontra Straßenbahn, eine Volksbefragung mit einer verwirrenden Fragestellung mit doppelter Verneinung und einem knappen Ergebnis gegen das Projekt. Auch die Rechtsverfahren benötigten eine lange Zeit, da alle Bescheide angefochten wurden und bis zu den Höchstgerichten gingen. Letztendlich lagen aber alle Genehmigungen vor und es konnte mit der Bauumsetzung begonnen werden.

In Don Bosco wurde ebenfalls im Zuge des Baus der Koralmbahn ein Nahverkehrsknoten errichtet, der bis zum Bau der Südwestlinie von den bestehenden Buslinien angefahren wird.

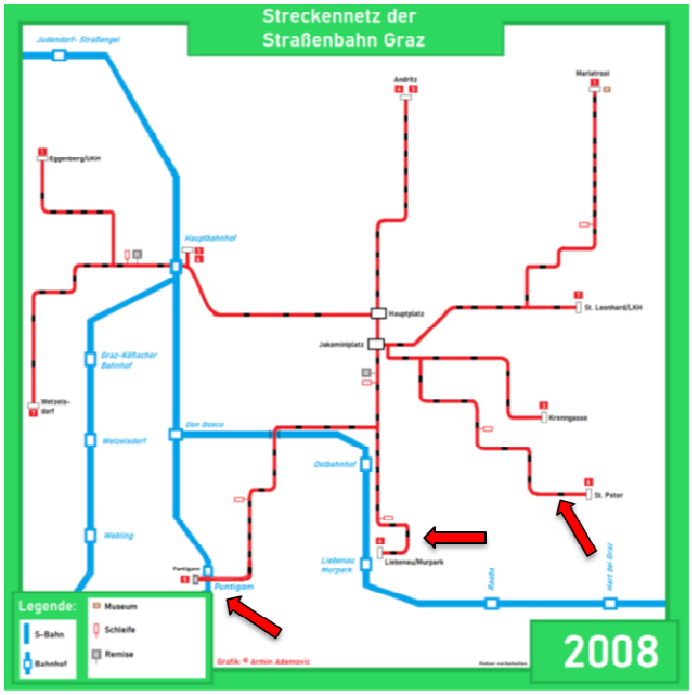

Fig. 4: Straßenbahnnetz 2008. Quelle: Wikipedia.

Nach diesen Verlängerungen folgte in den Jahren 2011 und 2012 wieder ein zentrales Projekt, von dem 4 Linien betroffen waren: der Bau einer neuen auf Niveau -1 gelegenen Haltestelle für den Grazer Hauptbahnhof. Mit diesem Projekt gelang nicht nur eine Unterquerung des stark befahrenen Gürtels, sondern auch eine direkte Anbindung des Hauptbahnhofes der Linien 1 und 7, die bislang am Bahnhof quasi vorbei fuhren. Durch den Entfall der bisher am Vorplatz situierten Wendeschleife für die Linien 3 und 6 war es erforderlich, an der Westseite der Gleisanlagen der ÖBB eine neue Wendeschleife zu errichten. Die für den Bau der Koralmbahn erforderlichen Maßnahmen im Bereich des Hauptbahnhofes beinhalteten auch eine Neugestaltung des Vorplatzes und verliehen dem Bahnhof sein heutiges Erscheinungsbild.

Im Jahre 2016 erfolgte die Verlängerung der Linie 7 um rund 500 m im Bereich des Landeskrankenhauses Graz. Auch die Medizinische Universität übersiedelte an die neue Strecke. Die Graz Linien verfolgten bereits seit Jahren das Ziel, im Zuge von Neuanschaffungen von Straßenbahnwagen längere Fahrzeuge anzuschaffen. Daher wurden bei allen Baumaßnahmen im Netz die dafür erforderlichen Schritte für die Infrastruktur berücksichtigt, vor allem der Bau längerer Haltestellen. Da die Linie 7 jene mit den meisten Fahrgästen ist, muss sie als erste für längere Fahrzeuge fit gemacht werden. Die alte Wendeschleife war zu kurz und in dieser Lage auch nicht adaptierbar. So nutzte man die anstehende Sanierung für eine Verlegung der Endhaltestelle und erreichte damit auch eine bessere Erschließung des Krankenhausareals. Als Vorgaben aus den Forschungstätigkeiten und des Medizinbetriebs wurde auf Erschütterungsschutz ein besonderes Augenmerk gelegt.

Danach folgten gleich zwei Projekte, die 2018 in Betrieb gingen und dadurch hervorstechen, dass hier neue Stadtentwicklungsgebiete einen Straßenbahnanschluss erhielten, bevor die Bebauung begann bzw. fertig gestellt wurde. Bei beiden Stadtentwicklungsgebieten enstanden auch neue Schulstandorte und Kinderbetreuungseinrichtungen sowie Parkanlagen. Speziell in Reininghaus erfolgt der weitere Ausbau der Infrastruktur auch noch in den nächsten Jahren, so dass das Potenzial für den öffentlichen Verkehr vorerst nicht voll ausgeschöpft werden kann. So hatten aber die neuen Bewohnerinnen und Bewohner von Anfang an die Straßenbahn als Verkehrsmittel zur Verfügung.

- Die Verlängerung der Linie 4 um rund 1,8 km erschließt den neuen Stadtteil Reininghaus, der auf ca. 15.000 Einwohnerinnen und Einwohner anwachsen wird. Hier wird ein ÖV-Anteil von 40 % erwartet. Durch die Befahrung der zentralen ÖV-Erschließungsachse auch mit Bussen war es leider nicht möglich, ein Rasengleis zu bauen.

- Die Verlängerung der Linie 6 in die Smart City führt auf rund 1,1 km durch ein ehemaliges Industriegebiet, auf dem eine komplett neue Wohninfrastruktur inklusive aller damit verbundenen Erfordernisse und auch einer Konzerthalle entstand. Eine eigene Gleistrasse konnte aufgrund der vorhandenen Querschnitte nicht realisiert werden.

Zuletzt wurde ein 1,3 km langer Abschnitt der Linie 5 in Puntigam zweigleisig ausgebaut und im November 2024 eröffnet. Die Ausführung erfolgte in Form eines Rasengleises. Nunmehr sind auch dichtere Intervalle als 7,5 Minuten möglich, was in Zusammenhang mit der Inbetriebnahme der Koralmbahn und des dichteren S-Bahn-Verkehrs von großer Bedeutung ist.

Fig. 5: Strecke der Linie 5 vor und nach dem Ausbau.

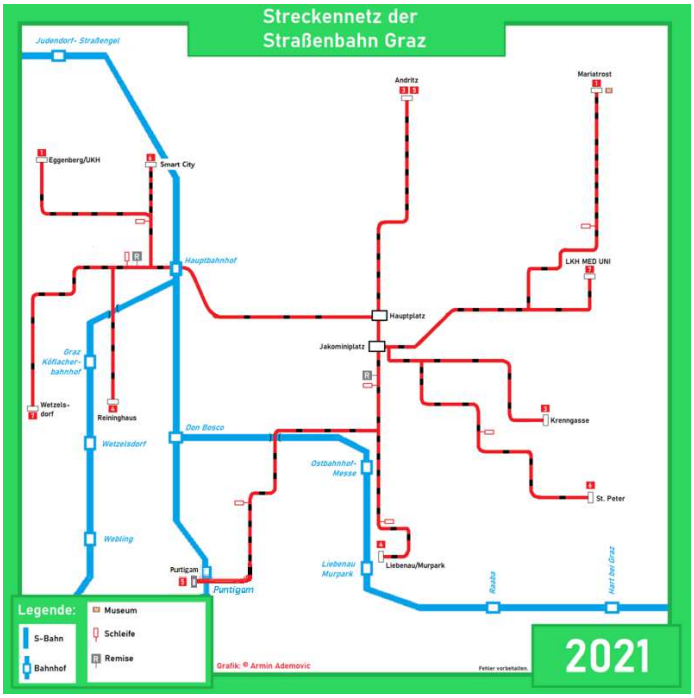

Fig. 6: Straßenbahnnetz 2021. Quelle: Wikipedia.

2.3 Heute (2025)

Aktuell in Bau ist die 1,2 km lange Innenstadtentlastungsstrecke. Dieser Bypass zur Herrengasse dient einerseits der Entlastung der Fußgängerzone vom Straßenbahnbetrieb mit bis zu 60 Straßenbahnen pro Stunde und Richtung und andererseits als Ausweichroute bei Veranstaltungen oder Behinderungen in der Herrengasse oder am Hauptplatz. Zumindest zwischen dem Zentrum und dem Hauptbahnhof kann der Straßenbahnbetrieb bei Unterbrechungen in der Innenstadt aufrecht erhalten werden. Diese Strecke mit den dann neuen Linien 16 und 17 wird Ende November 2025 eröffnet.

Fig. 7: Baustelle Innenstadtentlastung in der Neutorgasse.

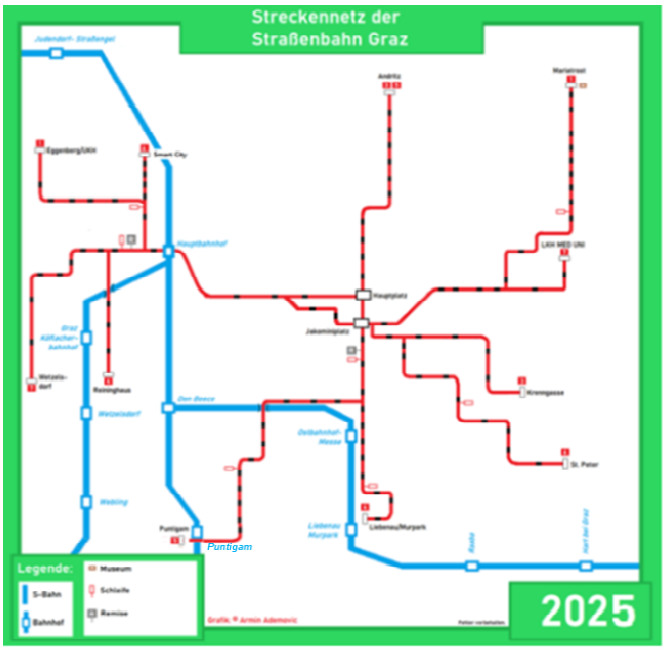

Fig. 8: Straßenbahnnetz 2025. Quelle: Wikipedia.

Ebenfalls bereits beschlossen ist der weitere selektive zweigleisige Ausbau der Linie 1 im Bereich Mariatrost. In den Jahren 2026 und 2027 werden zwei Abschnitte mit einer Länge von insgesamt rund 1,5 km ausgebaut, so dass auch auf der Linie 1 Intervalle bis zu 6 Minuten möglich werden.

Für die Projekte der Linien 4 und 6 sowie die Innenstadtentlastung und die zweigleisigen Ausbauten erhalten die Graz Linien auch Fördermittel des Landes Steiermark und erstmals teilweise auch Mittel vom Bund.

2.4 Ein Ausblick

Auf Basis eines Gemeinderatsbeschlusses aus dem Jahr 2019 zur Systementscheidung über den weiteren Ausbau des ÖV in Graz sowie auch gestützt auf den neuen Mobilitätsplan 2040 der Stadt Graz sind weitere Streckenerweiterungen für die Straßenbahn beabsichtigt. Die höchste Priorität kommt einer neuen Südwest-Nordwest-Linie zu, soll sie doch im Norden wie auch im Südwesten neue Nahverkehrsknoten anbinden. Der Ausbau der Strecke in die Weststeiermark wurde mit der Elektrifizierung bereits gestartet und auch der selektive zweigleisige Ausbau im Stadtgebiet mit dem Bau von vorerst fünf Unterführungen anstelle von Eisenbahnkreuzungen ist finanziell gesichert. Der Nahverkehrsknoten im Nordwesten in Gösting ist Bestandteil des ÖBB-Zielnetzes 2040. Der Beschluss im Nationalrat steht noch aus. Der Planungsstart durch den Gemeinderat für die Straßenbahnlinien nach Südwest und Nordwest wird im Laufe des Jahres 2025 erwartet.

Hier eine Auflistung möglicher neuer Strecken:

- Südwest-Nordwest-Linie über das Stadtzentrum
- Neue Verbindung vom Hauptbahnhof zur Universität und möglicherweise weiter zum Landeskrankenhaus
- Linie in Richtung Liebenau West, abzweigend von der Linie 5 am Schönaugürtel
- Zusammenschluss der Linien 3 und 6 im Südosten
- Verlängerung der Linie 5 zum Center West und eventuell weiter nach Webling
- Erschließen der Technischen Universität im Bereich der westlichen Inffeldgasse

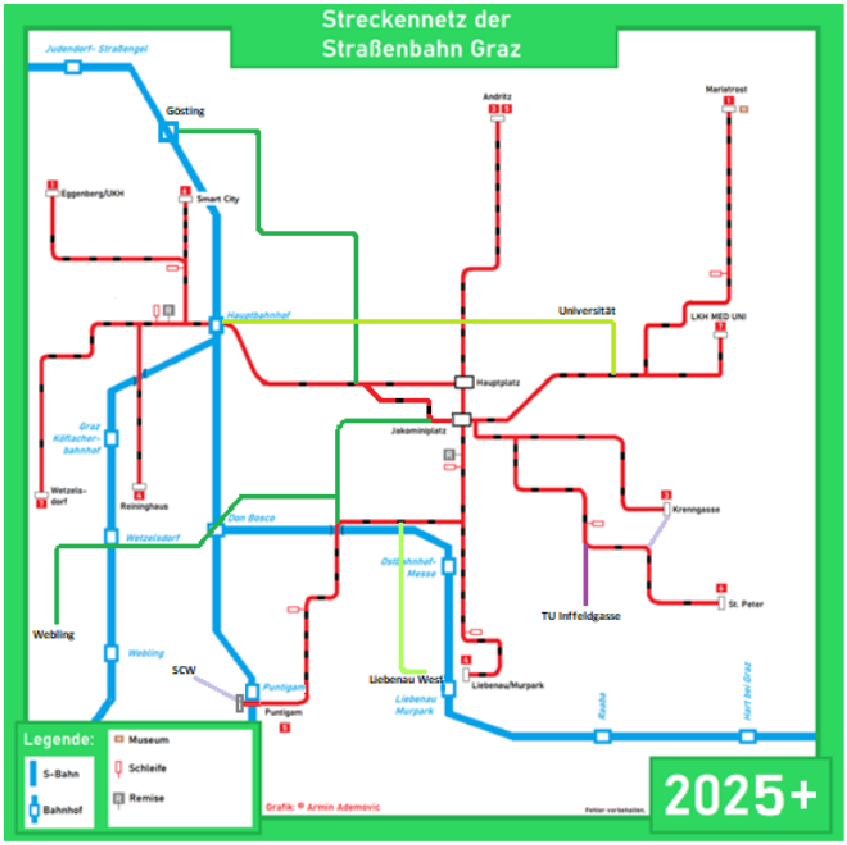

Fig. 9: Straßenbahnnetz mit möglichen neuen Strecken. Quelle: Wikipedia.

Seit 1990 konnte das Netz sukzessive verbessert und ausgebaut werden. Mittlerweile hat die Netzlänge wieder die 40-km-Marke erreicht. Mit dem beabsichtigten Bau der Südwest- bzw. Nordwestlinie erhalten Bereiche von Graz – der Griesplatz und auch Gösting – einen Anschluss an das Straßenbahnnetz, den sie in der Vergangenheit schon einmal hatten. Auch die in der Übersichtsgrafik dargestellte Linie vom

Hauptbahnhof zur Universität ist größtenteils ident mit der ehemaligen Ringlinie 2, die bis heute im Nummernschema des Straßenbahnnetzes fehlt.

2.5 Anpassung der Infrastruktur

Abschließend ist noch darauf hinzuweisen, dass diese Ausbauten des Straßenbahnnetzes auch zusätzliche Fahrzeuge erfordern. Um die Kapazitäten zu erhöhen, beschaffen die Graz Linien aktuell 15 zusätzliche Fahrzeuge mit einer Länge von ca. 34 m und schaffen so Platz für ca. 200 Fahrgäste pro Zug gegenüber heute 145. 40 ältere Garnituren müssen ebenfalls in den nächsten Jahren durch diese Neufahrzeuge ersetzt werden. Dafür sind auch zusätzliche Abstellanlagen und weitere Arbeitsstände in den Werkstätten erforderlich. Derzeit in Bau ist eine Erweiterung der Remise 3 für die ersten 15 langen Wagen. Weitere Abstellanlagen und zusätzliche Werkstattkapazitäten entstehen am Standort Steyrergasse. Dieses Projekt wurde Ende 2024 vom Gemeinderat bewilligt und soll bis Ende 2029 in Betrieb gehen.

Dann besteht der Wagenpark der Straßenbahn aus heutiger Sicht aus 45 Variobahnen (Stadler) mit rund 27 m Länge, sowie aus 55 Flexity (Alstom) mit rund 34 m Länge. Wenn zukünftig neue Strecken gebaut werden, führt dies widerum zu einer weiteren Aufstockung der Flotte. Mit den derzeit genehmigten Ausbauten der Infrastruktur können bis zu 126 Fahrzeuge abgestellt und serviciert werden. Darüber hinaus gehende Anforderungen bedingen Überlegungen über einen dritten Remisenstandort und weitere Ressourcen für die Werkstätten.

3 CONCLUSION

Graz gilt als Straßenbahnstadt. Mit den beschriebenen Ausbauten erfährt der ÖV eine wesentliche Attraktivierung und soll vermehrt nicht nur die zusätzlichen Fahrgäste infolge des Wachsens der Stadt Graz selbst aufnehmen, sondern vermehrt auch Personen, die derzeit ihr Auto für die Wege in und nach Graz nutzen. Dies erhöht die Lebensqualität in der Stadt Graz und verbessert die Umweltsituation nachhaltig.

Die Straßenbahn in Graz hat nicht nur eine bewegte Vergangenheit, sondern auch eine gesicherte Zukunft.

Energy Optimised Settlements – Enabler for Necessary Civilization Targets

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1 ABSTRACT

"Net-zero-emission and all will be good again" is scientific not holdable. We need to target far beyond towards planet renovation back to 350 ppm CO_2. This requires worldwide wealth. Worldwide wealth is only possible with great cost reductions for renewable energy and housing. Energy optimized settlements target this by synergy and cost optimized construction methods.

"Net-zero-emission and all will be good again": 2021 changed the balance of the Amazonas to more GHG emission than absorption. 2023 absorbed the land nearly no CO_2. Time to reevaluate our strategies to deal with the climate change.

350 ppm CO_2 is considered a stable climate situation, so we have to target reducing CO_2 until we are back to 350 ppm CO_2. We call this planet renovation. It requires about 47,000 TWh electricity to filter 1 ppm out of the atmosphere and split it into carbon and oxygen.

Reducing the CO_2 level in the atmosphere is complete different from reducing CO_2 emissions and requires complete different strategies.

The current strategy for reducing CO_2 emissions is increasing energy prices, promoting reduce, restrict, renounce, stopping everything what could grow fast, holding great parts of humanity in poverty. This causes social unrest and strengthen the climate change deniers.

The planet renovation strategy requires cheap renewable energy and the whole mankind to contribute. This means worldwide wealth and is the opposite of the current strategy.

When 10 billion people contribute an average of 10,000 kWh/a we can reduce CO_2 by 2 ppm per year. Hope that this is enough. GHG emissions from unfreezing permafrost could require even more.

The GEMINI next Generation house and the energy optimized settlements targets to make renewable energy and housing cheap enough to enable worldwide wealth and the planet renovation.

Keywords: climate change, planet renovation, 350 ppm CO_2, cheap energy, worldwide wealth.

2 INTRODUCTION

The concept of using the same space twice for cost and land use reduction started 1991 with the project "GEMINI inhabited solar power plant". The book "Aufstieg zum Solarzeitaler" (Advance to solar age) published 1993 was about this project.

Only one “GEMINI inhabited solar power plant” was built in Weiz as the main attraction of the Styria country exhibition about energy in 2001. Unfortunately, the prototype was reduced from an annual yield of 30,000 kWh to just 8,500 kWh.

The project “cheap housing” 2018 evolved 2019 into the project “GEMINI next Generation”.

3 ENERGY TRANSITION BY CHEAP HOUSING

Everybody needs housing. So how to combine this existential necessity with as much energy production as possible? How much energy could a house produce? How much energy could a settlement produce?

A conventional settlement of one family houses could be about 14 per hectare. Even with 20 kW peak photovoltaic per house, only 280 kW peak.

An energy optimized settlement has 1,200 kW peak photovoltaic per hectare, more than 4-times more than a conventional settlement.

In addition to all the photovoltaic, only central power to methane systems, underground gas storage and CCPP are necessary. Germany already has 25 km³ underground gas storage.

4 LAND FOR ENERGY

There are countries with extreme high prices for building ground. There is this building ground for 1,000 €/m² unaffordable and some meters away is this photovoltaic in the field. People question, why here 1,000 €/m² and there only 10 €/m².

This can and will cause social unrest. Also, the cost of the energy transition. Renewable energy is cheaper than fossil energy, only problem to have to pay it for the next 20 years upfront.

A solution can be, that the government purchases green land and changes it to building land, but only to lease, and the lease price has to be paid in electricity feed in according to demand into the grid.

For example, Germany has 26,000 km² only for energy plants. Only 10,000 km² energy optimized settlements would be 1,200 GW peak photovoltaic, 3,600 GWh batteries, 1,200 TWh/a yield 16 million houses. 16,000 km² more for nature instead of 100% human usage for energy plants.

If all this were “Land for Energy” areas and the lease would be 60 kWh/m²/a, the government would have 600 TWh/a lease.

This lease could be used for cheap electricity for the industry to avoid that the industry is leaving the country.

5 RECYCLING BY ENERGY INSTEAD OF BIOLOGY

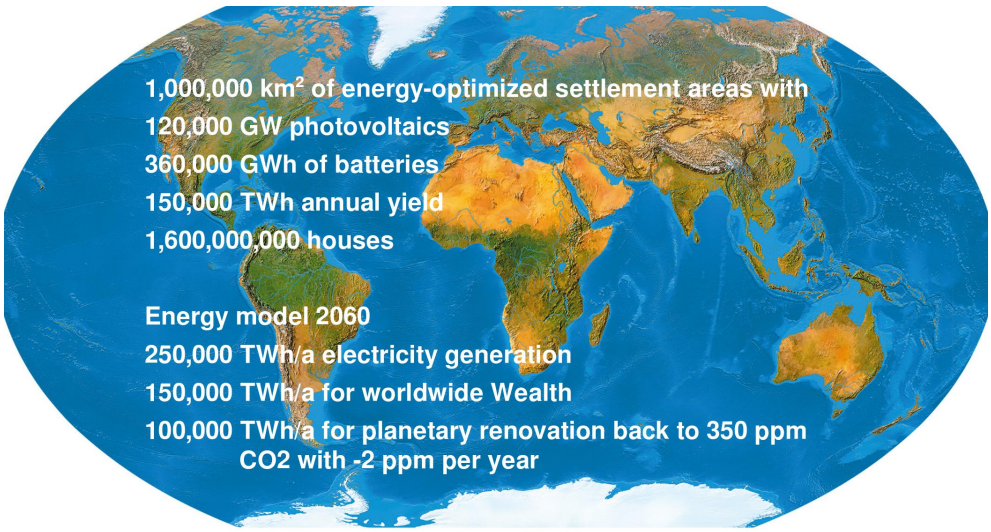
The current idea of a sustainable circle economy is based on the biological recycling. But this concept is very limited, as the Earth overshot day and the spell “We need 2 planets” shows.

Austria has much wood, but we think international. Building with wood in areas where even collecting firewood for cooking is a major problem? There is about 50 times more iron than carbon in the Earth's crust.

Having enough energy means far more recycling is possible. The first huge recycling will be the recycling of the CO_2 in the atmosphere until we reach again 350 ppm CO_2.

The longer a civilization exists, the more perfect recycling must become. Maybe we will throw in the future an old smartphone into a gas centrifuge to recycle all the materials by investing 500 kWh of electricity into this action.

So we think PU-steel composite and a steel frame is more sustainable than a wooden construction. The energy from one square meter photovoltaic can recycle more steel and PU than 10 square meter of forest can recycle wood.



6 FAST CHARGING AT EACH SETTLEMENT

The houses will be mainly DC oriented, with about 3 kWh batteries per kW peak photovoltaic. So demand oriented grid feed in is possible. But this also enables fast charging. When one hectare of settlement has 3.6 MWh batteries, even fast charging of trucks is possible.

The inhabitants can offer fast charging at lower costs as usual. Much more fast charging stations with a lower price could accelerate the change to electric mobility.

7 TARGETS FOR 2060

Humanity will succeed if it does not allow itself to be stopped. From 30,000 TWh/a to 250,000 TWh/a in 35 years, only 6.2 % more electricity production per year is required. The raw materials for this are available in abundance: Silicon for photovoltaics and sodium for batteries.

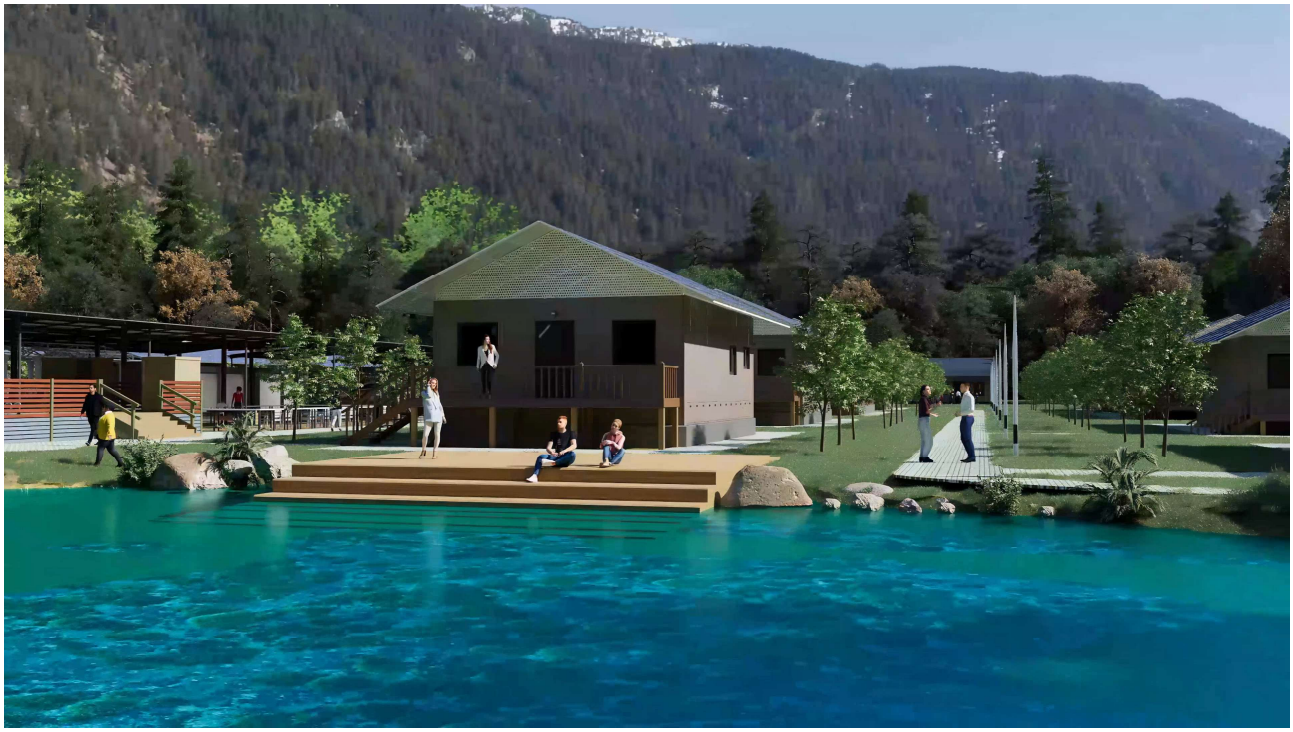
Worldwide wealth and a limitless future are possible if we overcome the destructive mindset of limitism. Previous attempts to fend off limitism have led to unsustainable ideas such as “perpetual oil” and “let's carry on as before”, which we must also overcome.

8 CONCLUSION

The climate protection movement is in a sever crisis. A reinvention of the entire climate protection movement is essential. We cannot leave it to fossil energy fans to shape our future.

Previous approaches must be reviewed in terms of their feasibility and effectiveness against climate change.

The GEMINI next generation project with energy-optimized residential areas has the scope to be a very significant part of the energy transition and climate protection and, by contributing to planetary renovation back to 350 ppm CO2, is also pursuing much more efficient goals to get climate change under control.



Let's imagine an opinion poll in a 10-storey apartment block in a poor neighborhood. Very likely that a majority here votes for climate change denier parties. What would you be willing to do for climate protection? Then there is a list of the usual demands and finally a photo of an energy-optimized residential area. Would you be willing to move into your own home in such an area to protect the climate? Sure, if I could afford it! Rent plus running costs plus electricity plus fuel for the car is more expensive than the loan installment minus the proceeds from the sale of electricity, you would have more money left over. Imagine what the answer will be.

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Exploring Residents' Attitudes Towards Participation in Urban Renewal: A Case Study in the Xiaopenghu Area in Chiayi, Taiwan

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1 ABSTRACT

Urban renewal not only transforms the spatial structure of a city but also impacts its social, cultural, and economic structures. Many factors shape residents' attitudes toward urban renewal, influencing their acceptance and willingness to participate throughout the long process. This paper aims to investigate the followings: 1) whether and how residents' attitudes toward urban renewal change over time, 2) the differences in residents' awareness of urban renewal, and 3) the key factor that influences residents' attitude toward urban renewal. This examination is based on interview data regarding residents' reactions to urban renewal in the Xiaopenghu Area in Chiayi, Taiwan, where renewal has been under discussion for a long time. Several things are concluded below. First, residents' attitudes evolve over time, at first, they may support urban renewal, but as they gain more information, they often become more doubtful, further influencing their willingness to participate in the urban renewal. Second, residents' awareness of urban renewal varies depending on property ownership. Landowners knew more details about two plans, while non-landowners often only have limited knowledge, mainly about resettlement measures in the second plan. Third, attitudes toward urban renewal are primarily influenced by resettlement measures. Fourth, expressed support in surveys does not always reflect residents' true attitudes. This paper highlights the need for planners to focus more on residents' actual needs, particularly securing adequate housing. It is also crucial to ensure transparency of urban renewal information, allowing all residents to access information equally and participate in the decision making process. Furthermore, more comprehensive methods should be adopted to better capture the complexity of residents' attitudes and improve policy effectiveness.

Keywords: urban renewal, residents' attitudes, public participation, Xiaopenghu Area, Taiwan

2 INTRODUCTION

Urban renewal in Taiwan aims to redevelop urban land, revitalize urban functions, and improve living environments and landscapes for the public interests. The implementation of urban renewal in Taiwan, however, often focuses more on real estate interests rather than the diverse and heterogeneous voices of residents. It tends to simplify the complex socio-cultural and residents' rights into a singular narrative dominated by property owners or implementers (Wang, C. H.,2012). Urban renewal brings significant transformations to an area. McKercher et al. (2015) argue that when the spatial environment changes, residents' attitudes toward these changes evolve over time based on their perceptions of impact, satisfaction, expectations, and place attachment (Bonaiuto et al., 2002; Younis et al., 2018). Frequent policy changes further shape residents' attitudes, influencing their willingness to participate. Moreover, residents' attitudes differ from person to person, which may lead to conflicts and contradictions, or foster communication and discussion. This situation ultimately affects the outcome of urban renewal.

This study focuses on the Xiaopenghu Area in the West District of Chiayi, Taiwan, where urban renewal has been under discussion for years. We aim to explore whether and how their attitudes change over time, exaime the differences in residents' awareness of urban renewal, and identify the key factor that influences their attitude toward urban renewal. By understanding these changes, we can help planners integrate diverse perspectives, improve communication, and adjust plans to promote more inclusive and sustainable urban development.

3 LITERATURE REVIEW

3.1 Urban renewal

Urban renewal policies have evolved around the world, especially in the U.S. and the U.K. In the U.S., urban reconstruction began in the 1930s to improve living conditions and eliminate slums. The concept of "urban

renewal" was officially introduced in the 1950s, which included redevelopment, rehabilitation and conservation (Wedge, 1958). However, because it focused too much on demolition and rebuilding while neglecting social issues, it led to problems such as class segregation and racial discrimination. By the 1960s, policies shifted toward community development, historic preservation, and the creation of more human centered environments. By the 1980s, sustainability became a key focus (Wang, C. K.,2021). In the U.K., large scale slum clearance began in the 1930s, and by the 1960s, attention turned to addressing social issues. In the 1980s, Margaret Thatcher's government promoted market-driven urban regeneration (Furbey, 1999), but by the late 1990s, the focus shifted to "urban renaissance," which prioritized planning and sustainability (Lees, 2003).

Taiwan's urban renewal policies emerged in the 1990s, with the "Urban Renewal Act" enacted in 1998. However, Taiwan adopted an approach similar to the U.S. model from the 1940s to 1960s, which focused mainly on demolition and rebuilding rather than community development and sustainability (Wang, C. K.,2021). As a result, early urban renewal in Taiwan primarily focused on land and building redevelopment while overlooking environmental, social, and economic benefits, which led to many controversies in the urban renewal process. Although Taiwan has gradually adjusted its urban renewal policies in recent years, emphasizing government leadership, social equity, and community participation (Wang, C. K.,2021). Nevertheless, several challenges remain, including information asymmetry among stakeholders, difficulties in property integration, and conflicts of interest. Additionally, urban renewal is often viewed as a real estate investment tool by implementer, neglecting public interests and making social inequality worse. Consequently, residents remain skeptical about the effectiveness of urban renewal, which affects their willingness to participate. These challenges ends up complicating the renewal process and causing delays.

3.2 The theory of attitude

Attitude is a response to external stimuli and a key determinant of behavior (Fishbein & Ajzen, 1975). It comprises three components: cognition, affect, and conation, which interact to shape individual reactions (Kwon & Vogt, 2010). Cognition refers to what a person knows or thinks about something, based on their experiences or external information. Affect involves emotional responses toward an object, such as joy, satisfaction, fear, or unease. Conation refers to the behavioral intentions rather than actual behavior, which shows the direction and likelihood of future behavior (Trafimow, 2004). Since attitude is a crucial factor influencing behavior, understanding people's attitudes can help us predict their actions (Trafimow, 2004).

Spatial settings themselves may serve as attitude objects (Jorgensen & Stedman, 2001). During periods of spatial change, such as urban renewal, residents' attitudes evolve over time , continuously shaped by their perceptions of these changes (McKercher et al., 2015). Various factors influence residents' attitudes toward environmental changes, including community satisfaction, expectations for the future environment, the extent of their involvement in the change process (Younis et al., 2018), perceptions and evaluations of the impacts of change, attachment to place (Bonaiuto et al., 2002), and socio-economic characteristics (Bonaiuto et al., 2002; Lewis & Albrecht, 1977; Younis et al., 2018). These factors not only show how residents directly react to changes but also reveal the deeper psychological reasons behind their reactions. Since residents' attitudes toward changes are not fixed and influenced by multiple interacting factors, fully understanding them requires considering these multiple factors. This approach helps us grasp residents' responses to urban renewal and develop more effective planning strategies.

4 METHODOLOGY

4.1 Case study area

The Xiaopenghu Area is located near Chiayi Railway Station. Chiayi City is a regional urban area located in the south of Taiwan, and the Xiaopenghu Area is relatively more crowded with a higher population density. It is also one of the city's early developed zones and is now primarily a residential area. However, the district faces several challenges, including a lack of proper planning, a large number of unsafe and aging buildings, insufficient public facilities, and narrow alleys. These issues have negatively impacted living conditions and urban development, causing problems such as public safety, limited emergency access, and transportation challenges. To address these problems and revitalize the area around the station, the city government has designated the Xiaopenghu Area as a priority for urban renewal.

	Area (ha)	Population (people)	Population density (people per hectare)
Chiayi City	6,002.56	262,153	43.67
The Xiaopenghu Area	0.9452	410	92.78

Table 1: Area and population statistics table for Chiayi City and the Xiaopenghu Area

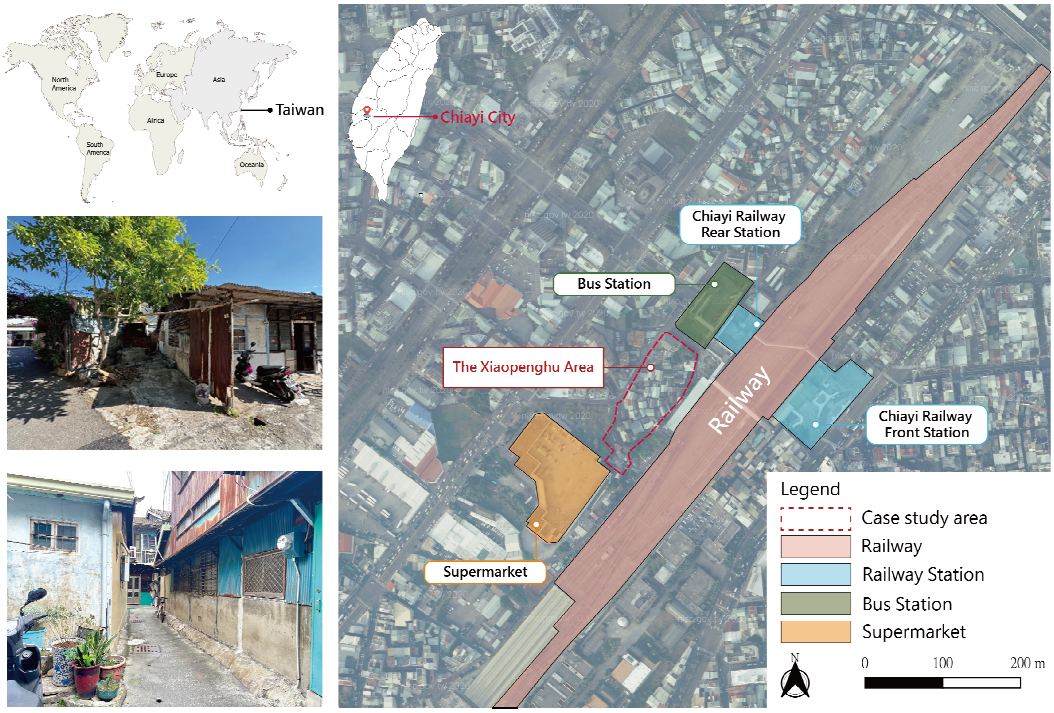

Fig. 1: Map of the location and current condition photos of the study area

4.2 Materials and methods

This study adopts a conceptual model based on three components of attitude – cognition, affect, and conation – to analyze how residents' attitudes form in response to triggering events during the urban renewal process. It employs two primary methods for data collection: textual analysis and in-depth interviews.

(1) Textual Analysis: This study reviews materials related to urban renewal in the Xiaopenghu Area, including policy documents and planning reports, and use textual analysis to outline the development context and dynamics of urban renewal in the area. The analysis highlights how urban renewal initially caught residents' attention and raised their awareness.

(2) In-depth interviews: Since the first urban renewal plan was proposed in 2009, 15 years have passed. Therefore, residents who have lived in the Xiaopenghu Area for at least 15 years and are aged 35 or older were selected as interviewees. The interviews focus on residents' perceptions and attitudes toward urban renewal at different stages of the process, as well as the underlying factors that influenced changes in their attitudes over time.

4.3 Interviewees

A total of seven residents participated in this study. Among them, four are both land and building owners, one is solely a landowner, one is solely a building owner, and one is a tenant.

Serial number	Sex	Period of residence (years)	Property ownership
01	Female	22	Landowners/Buildingowners
02	Female	40	Landowners/Buildingowners
03	Female	52	Tenant
04	Female	63	Landowners/Buildingowners
05	Male	73	Landowners
06	Male	50	Landowners/Buildingowners
07	Male	77	Building owner

Table 2: Interviewee information summary table

5 RESULTS

5.1 The development of urban renewal plan in the Xiaopenghu Area

The first urban renewal plan was proposed in 2009 to address living environment issues such as a large number of aging buildings, insufficient public facilities, and public safety concerns. However, it was put on hold due to the elevated railway project. The government considered that urban renewal in this area should be discussed alongside the railway elevation, therefore, the urban renewal plan was terminated in 2014. After the elevated railway project was approved, the government introduced the second urban renewal plan in 2023 to promote the redevelopment of land around the station and improve the urban landscape. To understand residents' willingness to participate and discuss future planning with them, the government held three information sessions between 2023 and 2024 and conducted interviews with residents in February 2024.

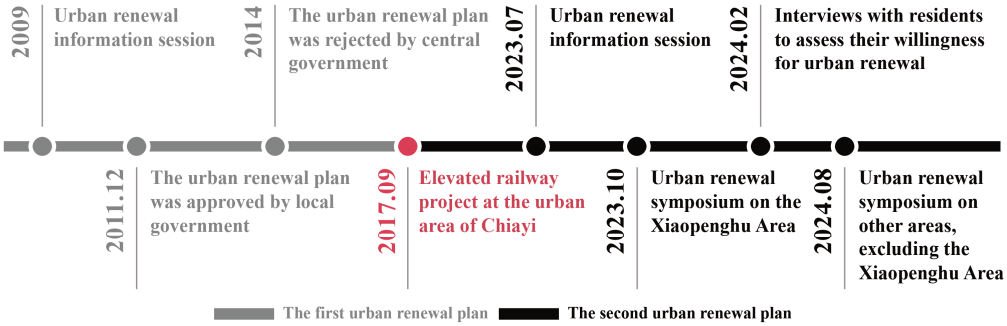

Fig. 2: Timing of objective triggering events in the two urban renewal plans

5.2 Residents' attitudes toward urban renewal

First, we explore when residents became aware of triggering events for urban renewal. Next, we examine residents' attitudes toward the first and second urban renewal plans separately. This includes their understanding of the plan's content, their assessment of their impact, and their emotional and behavioral responses based on different perceptions.

5.2.1 The urban renewal triggering events perceived by residents

All interviewees were aware of the urban renewal plan in the Xiaopenghu Area, but they learned about it at different times. Some residents knew about it when the government first proposed the plan in 2009, while all were aware of the second plan. During the first urban renewal plan, a resident who is a tenant said he/she had never received any relevant notifications about the plan and felt he/she had no right to participate, so he/she didn't pay much attention until the government conducted household interviews in February 2024. One resident, who only owns the building realized the urban renewal later than other residents. He/She mentioned that about 10 years ago, a landowner attempted to reclaim land to rebuild houses. Additionally, a resident recalled that discussions about urban renewal could be traced back more than 20 years, when landowners launched a petition to collaborate with a construction company on redeveloping the community.

"(Q: Did you attend any information sessions?) No. (Q: Why not?) Because this house doesn't belong to us, it wouldn't matter if I went to the session. (Q: Weren't you curious?) I wasn't curious. But after the session, two people came to ask me. I'm not sure if they were from the local government. (Q: Did they come for a household interview?) Yes, they asked if the house we live in gets demolished, how many rooms we would need for a new house?..... Like, if we were to rent, how many rooms would we need to live comfortably?" (Interviewee's serial number: 03)

"(Q: You said you didn't attend any information sessions. Did you receive any noticification about it, like a letter?) No! They only came to the temple……to say the house would be demolished. I didn't go" (Interviewee's serial number: 03)

"About twenty years ago, someone launched a petition to invite residents to participate in urban renewal and tried to invite a construction company to reconstruct the area. Then, about ten years ago, another resident got a few others involved. They also discussed urban renewal and tried to invite a construction company to reconstruct the area, but in the end, the plan went nowhere." (Interviewee's serial number: 04)

"It was probably more than ten years ago. A landowner came back then, but it wasn't about urban renewal. The landowner wanted to reclaim the land and even brought a construction company along to rebuild houses." (Interviewee's serial number: 07)

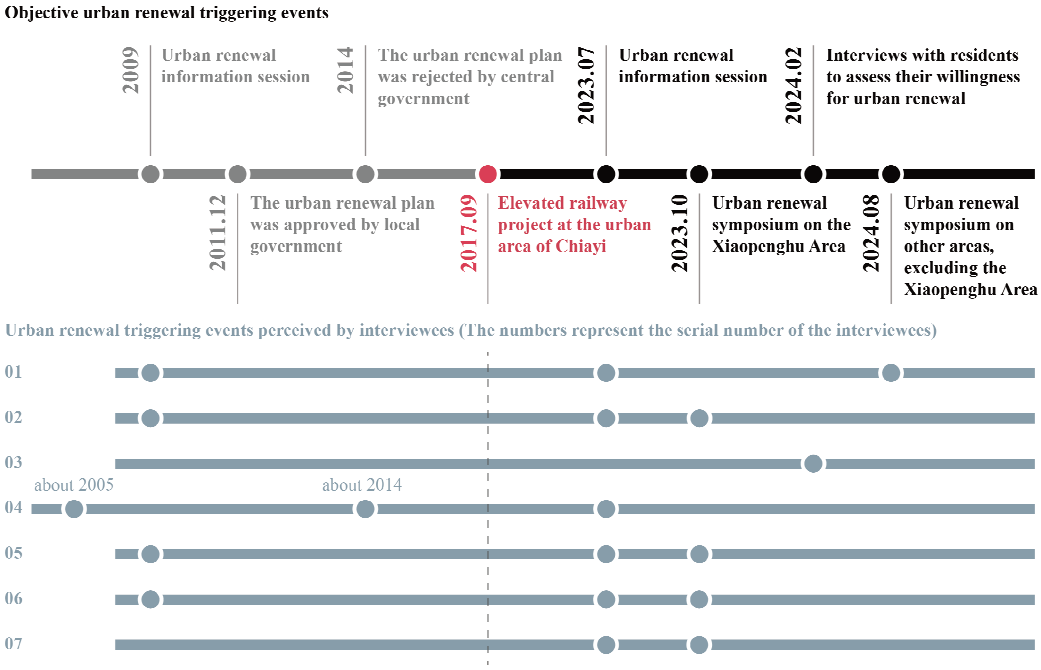

Fig. 3: The time each resident became aware of urban renewal

The timing of when residents became aware of urban renewal reveals a clear inequality in access to information. During the first urban renewal plan, only those who own both land and building knew about it, while tenants and residents who only own building were mostly left uninformed. It wasn't until the second urban renewal plan that they became aware of the triggering events. This shows that, in Taiwan's urban renewal system, landowners are often given priority, while tenants and residents who don't own land are less valued. This results in an information gap and unequal participation.

5.2.2 Residents' attitude toward the first urban renewal plan

In terms of conation, among the five residents who were aware of the first plan, most thought the plan was only about demolishing and rebuilding houses, and didn't know the details of the plan. Only one resident mentioned that the plan also included building new roads. One resident thought that urban renewal might make them homeless and force them to move away from their neighbors, while others felt it was just a political tool used by the government during elections.

"My father got involved in the first plan, so I didn't really know much about it. There were information sessions, and he went to listen. (Q: Didn't you go?) No! My father agreed, but a lot of our neighbors didn't. agree" (Interviewee's serial number: 05)

"I thought, well, if they demolish the houses, that's fine. But, on the other hand, I also thought that if they demolish them, all my neighbors and friends will be separated." (Interviewee's serial number: 02)

"Before, they used to say... demolish the houses! But where are we supposed to live? It's a big impact. They said they would demolish them and give us money. But still, where would we stay?" (Interviewee's serial number: 02)

"Rumour has it that the government was going to demolish the houses. At that time, they came to measure and said they would construct new roads. That was over ten years ago, but nothing has happened" (Interviewee's serial number: 06)

"When he/she was running for mayor, he/she asked us if we are interested in urban renewal, and he/she would propose it in the Legislative Yuan (Q: Do you think the urban renewal plan at that time would affect your life or bring any changes to this area?) No, because it was just empty talk. How could it bring about any change? He/She only proposed this plan for the elections." (Interviewee's serial number: 01)

"I think urban renewal will definitely make this place better since it's in a great location." (Interviewee's serial number: 04)

Even though residents lacked a clear understanding of the details of the first plan, they still had different emotional reactions based on their own perceptions. Some thought urban renewal would promote local development, so they had high expectations for it. In terms of conation, due to their positive outlook, these residents expressed a willingness to participate in the urban renewal plan or even signed the petition.

"(Q: What was your opinion when you first heard about the urban renewal plan?) Of course, I was willing. If it could be conducted quickly, that would be even better." (Interviewee's serial number: 01)

"When I first heard about the urban renewal plan, I was looking forward to it. I thought that the area was going to develop." (Interviewee's serial number: 06)

"Actually, I was glad to see the outcome." (Interviewee's serial number: 04)

"(Q: Did you take any action to express your support or opposition to urban renewal? Like filling out the willingness questionnaire? Did you?) Yes, I did. I also signed a petition." (Interviewee's serial number: 04)

In addition to the positive emotional reactions, one resident also felt concerned. This resident was worried about not having a place to live and being separated from neighbors and friends. During the interview, the resident mentioned the importance of neighborhood relationships, and this concern may be linked to the emotional reactions he/she had. These concerns led to conflicting feelings about the plan. As a result, the resident couldn't clearly express his/her willingness and oscillated between support and opposition.

"My opinion is... don't demolish the houses." (Interviewee's serial number: 02)

"I thought, well, if they demolish the houses, that's fine. But, on the other hand, I also thought that if they demolish them, all my neighbors and friends will be separated." (Interviewee's serial number: 02)

"On one hand, it's okay if they demolish the houses, but on the other hand, it's also fine if they don't demolish them." (Interviewee's serial number: 02)

"People who live here greet each other, take care of each another, and share things with each other. (Q:So, do you like this kind of relationship?) Yes, I do." (Interviewee's serial number: 02)

Residents' attitudes toward the first urban renewal plan varied based on their cognition, affect, and conation. Some residents were hopeful for the development and supported it. Others were worried about being displaced and losing their community, which made it hard for them to decide whether to support or oppose the plan. It shows that attitudes were shaped by factors such as expectations for the future, attachment to the area, and satisfaction with their current environment.

5.2.3 Residents' attitude toward the second urban renewal plan

After the second plan was proposed, all interviewees were aware of it and believed it would lead to the demolition and reconstruction of their houses. Every resident participated in triggering events, such as information sessions and household interviews, which helped them gain a deeper understanding of the plan. Based on the interviews, residents' perceptions can be categorized into three aspects: the connection to the elevated railway project, resettlement measures, and the perception of the inevitability of the plan. We will explore these perceptions, along with the emotional and behavioral responses.

(1) The connection to the elevated railway project

Six residents understood that this plan was related to the elevated railway project. Since the elevated railway project is already being implemented, some of them believed that urban renewal was inevitable. Although they had no emotional response to it, their conation showed active engagement. To better understand the plan details, they actively participated in information sessions, discussed it with their neighbors, and even contacted city council members to inquire about more details.

"Like I said, I can't rush the urban renewal because it's not just an issue for the developers: it's more closely related to the government. Everything is interconnected with the elevated railway, so there's no way to speed it up." (Interviewee's serial number: 01)

"Since the elevated railway is already being implemented, it feels like urban renewal here is inevitable." (Interviewee's serial number: 04)

"Because of the construction of the elevated railway, the area will be renovated to improve the appearance of the city. In this way, the overall look of our city will be better" (Interviewee's serial number: 05)

"(Q: If the government holds another information session in the future, would you want to go?) If they present a concrete plan, I'd probably go to listen. After all, with the railway elevated, there will be big changes here, so I'd want to hear how they plan to handle it." (Interviewee's serial number: 04)

"I asked the city council member about this area then, asking what the plans were for it after the railway will have been elvated." (Interviewee's serial number: 04)

Based on the residents' conations, their main goal was to gather information. Although they recognized that urban renewal is closely linked to the elevated railway project, they have not developed further emotional responses yet , as they did not fully understanding the impact of the elevated railway project.

(2) Resettlement measures

Five residents mentioned that the government proposed possible measures for resident resettlement, but they understood the details differently. Some thought the resettlement options were only available to landowners or low-income households, while others believed that all indigenous residents of the Xiaopenghu Area would have priority for resettlement.

"They're going to build social rented housing for us to live in….. Landowners can be assigned to live in, but those who don't own land have no chance. The government will only offer them some compensation, since they don't own land." (Interviewee's serial number: 02)

"Yeah, they will arrange a place for us to live. They said they would build social rented housing, and the people here would have priority, which is what we hope for." (Interviewee's serial number: 03)

"Before, I didn't hear clearly if they would arrange for us to live temporarily in the social rented housing being built in front of the supermarket. I'm not sure." (Interviewee's serial number: 05)

"At that time, they mentioned that the social rented housing is being built across from the supermarket, but there are certain restrictions for who can live there." (Interviewee's serial number: 06)

"I asked for priority for the social rented housing here. I heard that they might give priority to low-income households or something like that." (Interviewee's serial number: 07)

After learning about the resettlement options, some residents had emotional reactions and intentions to act. Emotionally, some were worried they wouldn't meet the requirements for resettlement, so they adopted a wait-and-see attitude toward the urban renewal. A few even contacted the city council members to ask for details or express their concerns, hoping to get more information about the resettlement.

"I'm more worried about not having a place to live. Because there isn't a clear plan, it's hard to say whether I completely support it or oppose it." (Interviewee's serial number: 07)

"I called the city council members and asked them to help us get priority for the social rented housing, especially for those who are being relocated due to demolition." (Interviewee's serial number: 07)

From the interviews, we found that emotions strongly influence how people act. When residents feel more worried about the resettlement measures, they are more likely to actively seek additional information or guarantees. Additionally, one resident expressed that if the government fails to properly plan the resettlement measures in the future, they would be unwilling to participate in the urban renewal.

"I'm willing to participate now, but if the government doesn't present reasonable resettlement options, then I think... I might consider not participating." (Interviewee's serial number: 06)

In fact, there is a gap between residents' understanding of the resettlement measures and what the government actually stated in the information session. According to the presentation provided by the government, it mentioned that a resettlement measurement would be provided in the future and that social rented housing would be an option. However, the government did not clarify the eligibility or whether there would be a priority order. This lack of clarity has led to different interpretations among residents, influencing their attitudes toward the urban renewal plan.

(3) Perception of the inevitability of the plan

Some residents thought that even if they disagree with the urban renewal, the government will go ahead and finish the urban renewal plan forcibly, and there is no way to change the outcome. Additionally, when most

residents agree, individual opposition does not have a significant impact. Therefore, despite some residents being reluctant or unsure, they still express their agreement to participate in the urban renewal during the willingness survey.

"The government sent a letter asking if I agree to participate in the urban renewal, and I wrote 'agree'. I thought if I had written 'disagree', they'd still go ahead with the demolition. So I figured it was better to agree." (Interviewee's serial number: 02)

"I didn't oppose it, but I didn't really have an opinion either, because the house isn't ours... So if the government is going to demolish it, there's nothing we can do." (Interviewee's serial number: 03)

"(Q: Is there any reason for you to oppose the urban renewal?) No, we can't do anything about it. The government is going to enforce it, and there's nothing we can do." (Interviewee's serial number: 04)

"But if I disagree... honestly, I still can't resist it. If the government really want to demolish the houses, there's nothing I can do. If everyone agrees and I'm the only one who disagrees, it doesn't matter. I'll still be forced to participate. (Interviewee's serial number: 06)

Since residents believed that urban renewal was inevitable and beyond their control, they felt helpless. Even though they had different emotions about it, in the end, they simply expressed support for the plan.

In the second plan, residents gained a deeper understanding through information sessions, recognizing its inevitability. Their growing awareness led to more complex emotional responses and actions. Many expressed concerns about resettlement measures, worrying about whether the government would provide sufficient security. These emotional reactions led some to adopt a wait-and-see attitude and take steps to secure their right to adequate housing. Overall, residents' affect and conation in the second plan showed more cautious and conditional attitudes toward urban renewal.

6 CONCLUSION

In this study, we explore the shifts in residents' attitudes toward urban renewal, examining how their cognition, affect, and conation evolved throughout the process. First, we integrate cognition, affect, and conation to analyze their variability in residents' response to urban renewal. Next, we discuss the cognitive aspects of residents' awareness. Finally, we critically evaluate the limitations in how the government understands residents' opinions and attitudes during their participation in the process.

First, as urban renewal plans progress, residents learn more about them, which brings out more complicated feelings and reactions. Initially, some residents supported the first plan based on positive expectations. However, during the second renewal plan, after learning more about its details, their attitudes became more cautious, and some even began to have doubts. The uncertainty of the information made residents uneasy, prompting them to actively seek more security and clearer explanations. Resettlement issues, in particular, triggered strong emotional reactions, with many residents concerned about whether the government would provide adequate resettlement plans. Some even took action to secure their housing rights. This suggests that, compared to the government's vision for future urban development, residents are more concerned about whether their housing needs will be properly addressed.

Second, we found that residents' awareness of urban renewal was influenced by their property ownership. Landowners knew more details about two plans, while non-landowners often only have limited knowledge, mainly about resettlement measures in the second plan. Non-landowners are often only considered during the compensation and resettlement stages, which limits their access to information and participation rights. This exclusion puts them at a disadvantage and often disregards their needs and concerns. Moreover, many residents still associate urban renewal primarily with "demolition and reconstruction," overlooking other approaches like rehabilitation and conservation, which have become more common. This information gap shows problems in how policies are communicated and highlights the need for more transparency and fair access to information in future urban renewal plans.

Finally, we critically examine the limitations in how the government understands residents' opinions and attitudes during the participation process. While willingness surveys indicate residents' support for urban renewal, this does not necessarily reflect full agreement with the plan. In fact, residents' attitudes toward urban renewal are shaped by multiple factors, including expectations for future development, satisfaction with their current environment, attachment to the place, access to complete information, and how the policy

affects different stakeholders. Therefore, relying solely on willingness surveys may fail to capture the complexity of residents' attitudes, impacting the accuracy and legitimacy of policy decisions.

Given these findings, this study emphasizes that urban renewal plans should focus more on what residents truly need, not just on what policymakers or planners think is best. Additionally, adopting more comprehensive methods to understand residents' attitudes can lead to policies that are both more inclusive and effective in addressing community issues, making urban renewal more widely accepted.

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Grüne Haltestellengestaltung am Beispiel Graz

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1 ABSTRACT

Haltestellen sind der erste physische Berührungspunkt von Fahrgästen mit öffentlichen Verkehrsmittel. Daher kommt ihnen bei der subjektiven Beurteilung der Attraktivität des öffentlichen Verkehrsangebotes – neben der Fahrplan- und Liniengestaltung – auch ein besonderer Stellenwert zu. Das System eines öffentlichen Verkehrs bringt es mit sich, dass es zu Wartezeiten für die Fahrgäste kommt. Eine attraktive Haltestellengestaltung kann dazu beitragen, dass diese Wartezeiten weniger negativ von den Fahrgästen wahrgenommen werden. Neben ausreichend Platz, Witterungsschutz und dynamischer Fahrgastinformation vor Ort spielen auch die Beschattung sowie das lokale Kleinklima hierbei eine immer größere Rolle.

In diesem Zusammenhang ist die Ausstattung von Haltestellen für Straßenbahnen und Busse mit Bäumen eine äußerst sinnvolle Maßnahme im Hinblick auf die aktuelle Klimaentwicklung. Durch den Klimawandel erleben Städte zunehmend das Phänomen der Hitzeinseln, bei dem urbane Gebiete deutlich höhere Temperaturen aufweisen als das umliegende ländliche Gebiet. Bäume an Haltestellen bieten nicht nur natürlichen Schatten und reduzieren somit die Hitze, sondern verbessern auch die Luftqualität durch die Absorption von CO_2 und die Freisetzung von Sauerstoff. Darüber hinaus schaffen sie eine angenehme Warteumgebung für die Fahrgäste und tragen zur ästhetischen Aufwertung des städtischen Raums bei. Diese grünen Oasen helfen dabei, die Auswirkungen von Hitzewellen abzumildern und fördern gleichzeitig ein gesünderes und lebenswerteres Stadtklima.

Eine der Herausforderungen bei der Gestaltung von Haltestellenbereichen mit Bäumen ist das Platzproblem, denn einerseits benötigen die Fahrgäste ausreichend befestigte Geh- und Wartebereich, andererseits soll den Bäumen entsprechend Freiraum zum Wachsen gegeben und auch das Heranführen von Niederschlagswässern ermöglicht werden. Unterirdisch können hier diverse Leitungen die bauliche Umsetzung mitunter erschweren und gegebenenfalls unmöglich machen.

Dieser Fachvortrag informiert über die gemeinsamen Bestrebungen der Stadt Graz sowie der Holding Graz Linien zur Ausgestaltung von Haltestellen mit Bäumen und berichtet anhand von Fallbeispielen über die ersten Gehversuche von vor rund zehn Jahren und die seither gewonnenen Erfahrungen.

Keywords: Aufenthaltsqualität, Beschattung, Begrünung, Haltestelle, Planung

2 DIE BEDEUTUNG VON ATTRAKTIVEN HALTESTELLEN

Haltestellen sind der erste physische Berührungspunkt von Fahrgästen mit öffentlichen Verkehrsmittel. Daher kommt ihnen bei der subjektiven Beurteilung der Attraktivität des öffentlichen Verkehrsangebotes – neben der Fahrplan- und Liniengestaltung – auch ein besonderer Stellenwert zu. Dabei sind vor allem zwei Faktoren wesentlich:

- Wie können Fahrgäste Haltestellen erreichen?
- Wie gestaltet sich der Aufenthalt an der Haltestelle selbst?

Während der erste Punkt hier nicht näher behandelt werden soll, fokussiert sich dieser Artikel auf die Gestaltung des unmittelbaren Haltestellenumfelds im urbanen Oberflächenverkehr und hier vor allem auf die Grünraumgestaltung.

Das System eines öffentlichen Verkehrs bringt es mit sich, dass es zu Wartezeiten für die Fahrgäste kommt. Eine attraktive Haltestellengestaltung kann dazu beitragen, dass diese Wartezeiten weniger negativ von den Fahrgästen wahrgenommen werden. Neben ausreichend Platz, Witterungsschutz und dynamischer Fahrgastinformation vor Ort spielen auch die Beschattung sowie das lokale Kleinklima hierbei eine immer größere Rolle.

3 KLIMAENTWICKLUNG, HITZEINSELN

Die Ausstattung von Haltestellen für Straßenbahnen und Busse in Graz mit Bäumen ist eine äußerst sinnvolle Maßnahme im Hinblick auf die aktuelle Klimaentwicklung. Durch den Klimawandel erleben Städte zunehmend das Phänomen der Hitzeinseln, bei dem urbane Gebiete deutlich höhere Temperaturen aufweisen als das umliegende ländliche Gebiet. Bäume an Haltestellen bieten nicht nur natürlichen Schatten und reduzieren somit die Hitze, sondern verbessern auch die Luftqualität durch die Absorption von CO2 und die Freisetzung von Sauerstoff. Darüber hinaus schaffen sie eine angenehme Warteumgebung für die Fahrgäste und tragen zur ästhetischen Aufwertung des städtischen Raums bei. Diese grünen Oasen helfen dabei, die Auswirkungen von Hitzewellen abzumildern und fördern gleichzeitig ein gesünderes und lebenswerteres Stadtklima.

4 BAULICHE HERAUSFORDERUNGEN

Eine der Herausforderungen bei der Gestaltung von Haltestellenbereichen mit Bäumen ist das Platzproblem, denn einerseits benötigen die Fahrgäste ausreichend befestigte Geh- und Wartebereich, andererseits soll den Bäumen entsprechend Freiraum zum Wachsen gegeben und auch das Heranführen von Niederschlagswässern ermöglicht werden. Unterirdisch können hier diverse Leitungen die bauliche Umsetzung mitunter erschweren und gegebenenfalls unmöglich machen. Doch auch der Blick nach oben ist in diesem Zusammenhang eine wichtige Perspektive, gerade bei Straßenbahnprojekten. Oberleitungsmaste sowie diverse Abspannungen können mögliche Baumstandorte sowie deren Entwicklungsmöglichkeiten ebenso einschränken. Ein zusätzliches Thema ist dann im wahrsten Sinne des Wortes die „Schattenseite“ der Bäume. So erstrebenswert der kühlende Schatten von Bäumen an heißen Sommertagen ist, so ergeben sich zu anderen Jahres- und Tageszeiten dadurch schlecht ausgeleuchtete Aufenthaltsräume, die wiederum zusätzlicher Beachtung bei der öffentlichen Beleuchtung bedürfen.

All diese Aspekte von Grünraum, Leitungen, Straßenraum, Beleuchtung, Verkehrsbetrieb usw. werden durchwegs von unterschiedlichen Abteilungen betreut. Das gegenseitige Verständnis für diese Anforderungen der zuständigen Abteilungen untereinander reifte auch in Graz mit der zunehmenden Anzahl an Projekten.

4.1 Die ersten Schritte

Bereits vor mehr als zehn Jahren war es das Bestreben der Abteilung für Verkehrsplanung der Stadt Graz Haltestellenbereiche mittels Bäumen aufzuwerten. Diese Vorgehensweise hat sich 2019 durch einen formalen Beschluss der Stadt Graz im Zuge von Klimaschutzmaßnahmen manifestiert.

Abb. 1: Endstation „Laudongasse“ – Ausbau 2010, Foto aus 2024

Die ersten Gehversuche waren eher nach dem Schema „try-and-error“ und die damaligen Projekte sind vielleicht nicht die erfolgreichsten, spielen aber dennoch eine wichtige Rolle im stetigen Lernprozess. Im Jahr 2010 wurde im Zuge des Umbaus der Nahverkehrsdrehscheibe Hauptbahnhof eine neue Wendeschleife für die Straßenbahn errichtet, bei der auf der Haltestelleninsel Bäume mit entsprechenden Baumscheiben – aber ohne weitere unterirdische Vorkehrungen – berücksichtigt waren. Allerdings war das Pflanzen einer Stieleiche (Quercus robur) im Nachhinein nicht die beste Wahl und baulich ist einerseits die Baumscheibe zu klein und andererseits nicht gewährleistet, dass ausreichend Regenwasser im direkten Umfeld versickern

kann. Dementsprechend war die Entwicklung dieses Baumstandortes in den mehr als zehn Jahren seit der Pflanzung nicht im gewünschten Ausmaß gegeben.

2017 wurde in Graz im Zuge einer Gleissanierung und Straßenraumgestaltung in der Eggenberger Allee erstmals das „Stockholm System“ (auch als „Schwammstadtystem“ bekannt) angewandt. Bei dieser speziellen Bauweise wird grobschotteriges Material als tragfähiges und verdichtungsstabiles Gerüst unter versiegelten Flächen eingebaut. In den Zwischenräumen werden durch ein luftdurchlässiges Feinsubstrat aus Pflanzenkohle und Kompost, Wasser und Nährstoffe gespeichert und stellen damit einen idealen Wurzelraum für Bäume dar. Anfallendes Oberflächenwasser kann über Einlaufschächte in den Untergrund eingeleitet, verteilt, retendiert, durch die Bäume wieder verdunstet bzw. zur Versickerung gebracht werden. Damit erreicht man zukunftsfitte Baumstandorte in räumlich sehr beengten Bereichen und eine Entlastung der Kanalinfrastruktur.

Aufgrund des Fachhochschul-Standortes in der Eggenberger Allee besteht ein entsprechend hohes Fahrgastaufkommen, weshalb im Haltestellenbereich relativ viel versiegelte Flächen vorhanden sind. Dennoch bietet das Stockholm System hier die Möglichkeit für mehr Bewässerung bzw. Wurzelentfaltung. Aber auch an diesem Standort hat sich die Baumwahl mit dem Spitzahorn (Acer platanoides) im Nachhinein nicht ausreichend bewährt.

Abb. 2, 3: Haltestelle „FH Joanneum“ in der Eggenberger Allee – Ausbau 2017 – Fotos aus 2018 (links) bzw. 2024 (rechts)

4.2 Lernen aus Erfahrungen

Im Zuge weiterer Haltestellen-Neubauten konnten die ersten Erfahrungen aus dem Stockholm-System verfeinert werden. Durch die konsequente Wahl klimafitter Baumarten wie zum Beispiel Resista – Ulmen konnten die erhofften Erfolge erzielt werden. Das Beispiel in der Münzgrabenstraße zeigt, dass sich die dortigen Bäume im Haltestellenbereich sehr gut entwickelt haben und sogar die neu gepflanzten Bäume außerhalb des Haltestellenbereichs, die in kleinen Grüninseln ohne Stockholm-System gepflanzt wurden, übertreffen.

Alternativ sind auch Projekte mit entsprechend großen Grünscheiben zur Umsetzung gelangt, wie bei der Gleissanierung 2023 in der Burenstraße. Hier wurde auf unterirdische Einbauten verzichtet und die Versickerung der Oberflächenwässer erfolgt über große Grünbereiche, die auch entsprechend attraktiv gestaltet sind. Als Baumart wurden dort Platanen (Platanus x acerifolia) gewählt. Die eingebauten Substrate müssen jedenfalls unbedingt dauerhaft durchlässig und sickerfähig bleiben, dies legt die Anwendung von

mineralischen Gesteinskörnungen mit einem geringen Anteil Kompost gegenüber herkömmlichem Oberbodenmaterial nahe. Die Einsaat erfolgte in der Burenstraße mit einer sehr reichhaltigen Blühwiesenmischung, die auch für eine entsprechend tiefreichende und intensive Durchwurzelung im Untergrund sorgt und die Bäume zusätzlich in ihrer Entwicklung fördert.

Abb. 4: Haltestelle „Münzgrabenkirche“ in der Münzgrabenstraße – Ausbau 2021 – Foto 2024

Abb. 5: Endstation „Wetzelsdorf“ in der Burenstraße – Ausbau 2023 – Foto 2024

In manchen Situationen geht es nicht darum, neue Bäume in Haltestellen anzupflanzen, sondern eine neue Haltestelle im direkten Umfeld von bereits bestehenden Bäumen einzurichten. Dabei ist ein behutsames Bauen unter Beiziehung einer ökologischen Bauaufsicht erforderlich. Ein Beispiel dafür ist die Bushaltestelle in der Alten Poststraße, wobei der etablierte Standort der dortigen gefestigten Platanen (Platanus x acerifolia) sicher zum Erfolg beigetragen hat.

4.3 Baulicher Umfang und Kosten

Derartige Neugestaltungen sind entsprechend aufwändig in der Umsetzung. Daher werden diese Umbauten in Graz vorzugsweise an den Orten durchgeführt, an denen ohnehin Baumaßnahmen vorgesehen sind. Zumeist handelt es sich dabei um Gleissanierungen der Holding Graz Linien, die jährlich mehrere Hundert

Meter Gleise im Streckennetz sanieren. Dies ist regelmäßig Anlass dafür, nicht nur die betroffenen Haltestellenbereiche mit auszubauen, sondern auch weitreichendere Umgestaltungen im Straßenbereich (Ausbau Gehsteige, Radwege, Beleuchtung usw.) durchzuführen sowie unterirdische Leitungen zu erneuern. Die dabei entfallenden Kosten teilen sich die Holding Graz Linien mit der Stadt Graz sowie den Leitungsträgern.

Abb. 6: Haltestelle „Bodenfeldgasse“ in der Alten Poststraße mit Bestandsbäumen – Ausbau 2022 – Foto 2024

Abb. 7: Haltestelle „Georgigasse“ in der Alte Poststraße – Ausbau 2022 – Foto 2024

Des Weiteren gibt es ein regelmäßiges Ausbauprogramm der Holding Graz Linien zur Qualitätsverbesserung an Haltestellen, primär im Busbereich. Dort sind die platztechnischen Gegebenheiten aber oft sehr herausfordernd. Die Verkehrsplanungsrichtlinie der Stadt Graz sieht bei Haltestellen einen frei zu haltenden Bereich von zwei Meter ab der Bordsteinkante vor. Befinden sich angrenzend an die Haltestelle beispielsweise Gebäude oder ist der Grund dahinter in Privatbesitz, so verbleibt für Baumpflanzungen häufig nicht ausreichend Platz. Ist dieser Platz gegeben, sind Baumpflanzungen aber mittlerweile ein fixer Bestandteil der Planungen, wie im Beispiel der Haltestelle „Georgigasse“.

Der Mehraufwand der reinen Baumpflanzung ist überschaubar. Für die Lieferung der Bäume, (Hochstamm ungefähr drei Meter hoch) die Pflanzung inklusive herkömmlichem Substrat und einer dreijährigen Anwuchspflege sind ungefähr netto € 2.000,- anzunehmen. Das Aufwändige daran ist die Herstellung der erforderlichen Infrastruktur für das Stockholm-System. Je nach Standortverhältnissen und der Ausführungsvariante sind hierfür netto etwa € 250/m³ fertig eingebautes System im Untergrund exklusive der Wiederherstellung der befestigten Flächen zu veranschlagen. Bei größeren Haltestellenbereichen können in diesem Zusammenhang auch mehr als 100 Kubikmeter erforderlich werden.

5 RESÜMEE UND AUSBLICK

Der öffentliche Verkehr wird weitgehend als Rückgrat für eine zukunftsfähige Mobilität, vor allem im urbanen Umfeld, angesehen. Dessen Attraktivität entscheidet sich aber auf Seiten der Nutzer:innen oft an den ersten Metern am Weg zur Haltestelle. Gleichzeitig sinkt aufgrund der Klimaerwärmung die gefühlte Aufenthaltsqualität in traditionellen Straßenräumen und es bilden sich Hitzeinseln. Bäume werten nicht nur optisch das Straßenumfeld auf, sondern leisten auch einen wichtigen Beitrag zur Beschattung und positiver Entfaltung des Mikroklimas im direkten Umfeld. Durch das Schwammstadtprinzip ist es möglich, auch bei beengten Platzsituationen die Funktionen „Haltestelle“ sowie „grüne Oase“ zu kombinieren. Die Wahl der Umsetzungsmethode hängt dabei von den Erfahrungen und dem gegenseitigen Verständnis der Projektbeteiligten ab.

Innovationen in die Praxis! Wie die österreichische Mobilitätslaborinitiative Innovationen fördert

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1 ABSTRACT

Wichtige Mobilitätsinnovationen für die Mobilitätswende können nur im Zusammenspiel von Wirtschaft, Wissenschaft, Zivilgesellschaft und Verwaltung entwickelt und erfolgreich in die Praxis eingeführt werden. Für die Zusammenarbeit dieser unterschiedlichen Akteurinnen und Akteure braucht es eine vermittelnde Akteurin oder einen vermittelndern Akteur, der oder die nicht nur mit den örtlichen Mobilitätsgegebenheiten und aktuellen Bedarfslagen der unterschiedlichen Akteurinnen und Akteuren vertraut ist, sondern zudem über innovative Methoden zur Begleitung von Innovationsprozessen verfügt. Genau solche Vermittler stellen in Österreich die Mobilitätslabore der Mobilitätslaborinitiative des Bundesministeriums für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK) dar. Die aktuell 11 Mobilitätslabore sind durch ihre Verortung und Vernetzung in urbanen und regionalen Gebieten in ganz Österreich ein wichtiger Treiber und Vermittler für Mobilitätsinnovationen. Während die Urbanen Mobilitätslabore (UML) auf jahrelange Erfahrung zurückblicken, starteten die Regionalen Mobilitätslabore (RML) 2023 mit dem Aufbau ihres Mobilitätslabors, um die spezifischen Herausforderungen ländlicher Mobilität mithilfe von Mobilitätsinnovationen anzugehen. Damit sich die räumlich und thematisch verschiedenen Mobilitätslabore gemeinsam austauschen und voneinander lernen können, unterstützt die AustriaTech im Rahmen eines Begleitprozesses die Mobilitätslaborinitiative mit verschiedenen Formaten. Die Präsentation bei der Konferenz und dieser Artikel sollen einen Überblick über die Angebote der Mobilitätslabore sowie über die Arbeitsweise der „Kooperations- und Austauschplattform der Mobilitätslabore Österreich“ geben.

Keywords: Mobilität, Mobilitätslabor, Open Innovation, Living Lab, Co

2 WAS IST EIN MOBILITÄTSLABOR?

Die österreichischen Mobilitätslabore greifen Ideen und Methoden auf, die im wissenschaftlichen Diskurs unter den Begriffen „Living Lab“ oder „Reallabor“ behandelt werden. Für die Begriffe gibt es viele unterschiedliche Definitionen. Um die Vielseitigkeit von „Living Labs“ aufzuzeigen, wurde von der working group mobility des European Network of Living Labs (ENoLL) ein Mapping Tool entwickelt (ENoLL Mobility Working Group, 2022). Beiden Begriffen liegt jedenfalls die Einsicht zugrunde, dass in den vergangenen Jahren zahlreiche vielversprechende Lösungsansätze – nicht nur im Bereich der Mobilität – entwickelt wurden, diese allerdings meist in Schubladen verschwanden und so nie mit den Menschen und ihren tatsächlichen Bedürfnissen in Berührung gekommen sind. Dem wollen die österreichischen Mobilitätslabore entgegenwirken. Sie eröffnen Wege, die Potenziale von Innovationen durch den Austausch von Wissenschaft und Praxis in die reale Umgebung zu übersetzen und zu optimieren. Uwe Schneidewind, ein Nachhaltigkeitsforscher, der den Begriff des Reallabors mitgeprägt hat, formuliert das so: „Ein Reallabor bezeichnet einen gesellschaftlichen Kontext, in dem Forscherinnen und Forscher Interventionen im Sinne von „Realexperimenten“ durchführen, um über soziale Dynamiken und Prozesse zu lernen. Die Idee des Reallabors überträgt den naturwissenschaftlichen Labor-Begriff in die Analyse gesellschaftlicher und politischer Prozesse.“ (Schneidewind, 2014:3)

Dementsprechend unterstützen die österreichischen Mobilitätslabore Forschung und Entwicklung dabei, ihre Potenziale in einer realen Umgebung möglichst gut zu entfalten. Wie schaffen sie das? Indem Wissenschaft und Praxis manchmal schon bei der Ideenfindung auf Augenhöhe zusammenarbeiten, Menschen mit unterschiedlichen Hintergründen dazu beitragen, dass Innovationen gemeinsam verbessert werden und schließlich auch prüfen, ob ein neues Angebot den Praxistest in diversen Alltagen bestehen kann. Im Kern geht es immer darum, attraktive Ideen und Angebote zu entwickeln, damit eine Transformation zu mehr Nachhaltigkeit in der Mobilität Realität werden kann.

Menschen mit unterschiedlichen Hintergründen – von der Technologieentwicklerin oder dem Technologieentwickler über die Stadtplanerin oder den Stadtplaner bis hin zur Bewohnerin oder dem Bewohner einer Stadt – an einen Tisch zu bringen passiert nicht ohne weiteres Zutun. Es braucht Zeit und

Ressourcen bis eine gemeinsame Gesprächsbasis gefunden wird und zielgerichtet gemeinsam probiert und gearbeitet werden kann. Die zentralen Merkmale der österreichischen Mobilitätslabore sind:

- Sie spannen einen kooperativen Rahmen, der den Austausch von unterschiedlichen Akteurinnen und Akteuren erst ermöglicht.
- Sie bieten die notwendige Forschungsinfrastruktur, um die Mobilität der Zukunft zu entwickeln.
- Sie sind Testumgebungen, in denen unter realen Bedingungen geprüft und optimiert werden kann.
- Sie führen Innovationen in die Praxis, weil sie im engen Austausch mit zukünftigen Nutzerinnen und Nutzern, Bedarfs- und Entscheidungsträgerinnen sowie Bedarfs- und Entscheidungsträgern stehen.

Die österreichischen Mobilitätslabore fördern dadurch gezielt neue Mobilitätsmuster, stärken die lokale Innovationskraft und tragen zur Erreichung der Klimaziele bei, indem sie als Plattformen für Technologieentwicklung, Wissensaustausch und Politikgestaltung agieren.

3 DIE VIELFÄLTIGEN ANGEBOTE DER ÖSTERREICHISCHEN MOBILITÄTSLABORE

Die Mobilitätslabore in Österreich bilden eine vielseitige und innovative Landschaft, die gezielt auf die unterschiedlichen Mobilitätsherausforderungen eingeht. Von urbanen Quartieren bis hin zu ländlichen Regionen und speziellen Infrastrukturen wie schienenzentrierter Mobilität bieten diese Labore in unterschiedlichen räumlichen Gegebenheiten Möglichkeiten, innovative Lösungen in realen Umgebungen zu entwickeln, zu erproben und zu verbessern. Sie verbinden wissenschaftliche Expertise mit praxisnahen Ansätzen und legen besonderen Wert auf Nutzerinnen- und Nutzerbedürfnisse und -anforderungen, Digitalisierung und Nachhaltigkeit. Aktuell gibt es vier „Urbane Mobilitätslabore“, sechs „Regionale Mobilitätslabore“ und ein standortungebundenes Mobilitätslabor (siehe Abbildung 1). Sie verfügen über Fachwissen vor Ort und kennen die lokalen und regionalen Herausforderungen.

3.1 aspern.mobil LAB (AML)

Das AML konzentriert sich auf quartiersbezogene Mobilität in der Seestadt Aspern und fördert durch aktive Beteiligung der Nutzerinnen und Nutzer die Entwicklung nachhaltiger Mobilitätskonzepte. Hier werden innovative Mobilitätslösungen getestet, die eine neue Mobilitätskultur vor Ort und darüber hinaus anstoßen sollen.

3.2 Centre for Mobility Change (CMC)

Das CMC unterstützt Gemeinden, insbesondere ländliche Regionen, in der nachhaltigen Mobilitätsverhaltensänderung und Digitalisierung. Durch Wissensaufbau und gezielte Schulungen fördert das CMC die Umsetzung lokaler Mobilitätsinitiativen und schließt Wissenslücken hinsichtlich der Mobilitätstransformation.

3.3 KAR-IN Innovationslabor

KAR-IN bietet eine Bahnstrecke als Testfeld für schienenzentrierte Mobilität und alternative Antriebe in einer realen Umgebung. Neben Batterie- und Wasserstoffantrieben können hier auch autonome Systeme und Smart Vehicles getestet werden.

3.4 MobiLab 2.0

Im Zentrum Oberösterreichs erforscht das MobiLab 2.0 innovative Lösungen für Personen- und Gütermobilität, vor allem im wirtschaftsinduzierten Verkehr. Durch Design-Thinking und Prototypentests unterstützt das Labor lokale Unternehmen und Kommunen in der Umsetzung nachhaltiger Mobilitäts- und Logistiklösungen.

3.5 Policy Lab

Das Policy Lab entwickelt in Zusammenarbeit mit Politik und Verwaltung evidenzbasierte Mobilitätslösungen für österreichische Städte und Regionen. Im Fokus stehen politische Entscheidungen und Maßnahmen zur Erreichung der Klimaziele durch gezielte Mobilitätsmanagement-Ansätze und innovative Governance-Strukturen.

3.6 thinkport VIENNA

Thinkport Vienna setzt sich in Wien mit den Herausforderungen urbaner Logistik auseinander und unterstützt als Testplattform Innovationen in der emissionsfreien Güterlogistik. Neben der Vernetzung von Start-ups fördert das Labor Konzepte, die den öffentlichen Raum und die Effizienz der städtischen Logistik verbessern.

3.7 zukunftswege.at

Dieses Labor bietet in Salzburg multimodale Testräume und digitale Infrastruktur für innovative Mobilitätsprojekte. Mit Testkorridoren und Haltestellen 4.0 ermöglicht zukunftswege.at die Entwicklung und Erprobung vernetzter Mobilitätslösungen, die auf regionale Mobilitätsbedürfnisse zugeschnitten sind.

3.8 land.mobil:LAB

Das land.mobil:LAB ist im Waldviertel verankert. Gemeinsam mit dem Land Niederösterreich, Waldviertler Gemeinden, Mobilitätsdienstleistern, Betrieben, Veranstalterinnen und Veranstaltern sowie Bürgerinnen und Bürgern aus der Region werden innovative Mobilitätslösungen getestet, um die Mobilitätswende im ländlichen Raum voranzubringen und die Forschungslandschaft zur ländlichen Mobilität zu stärken.

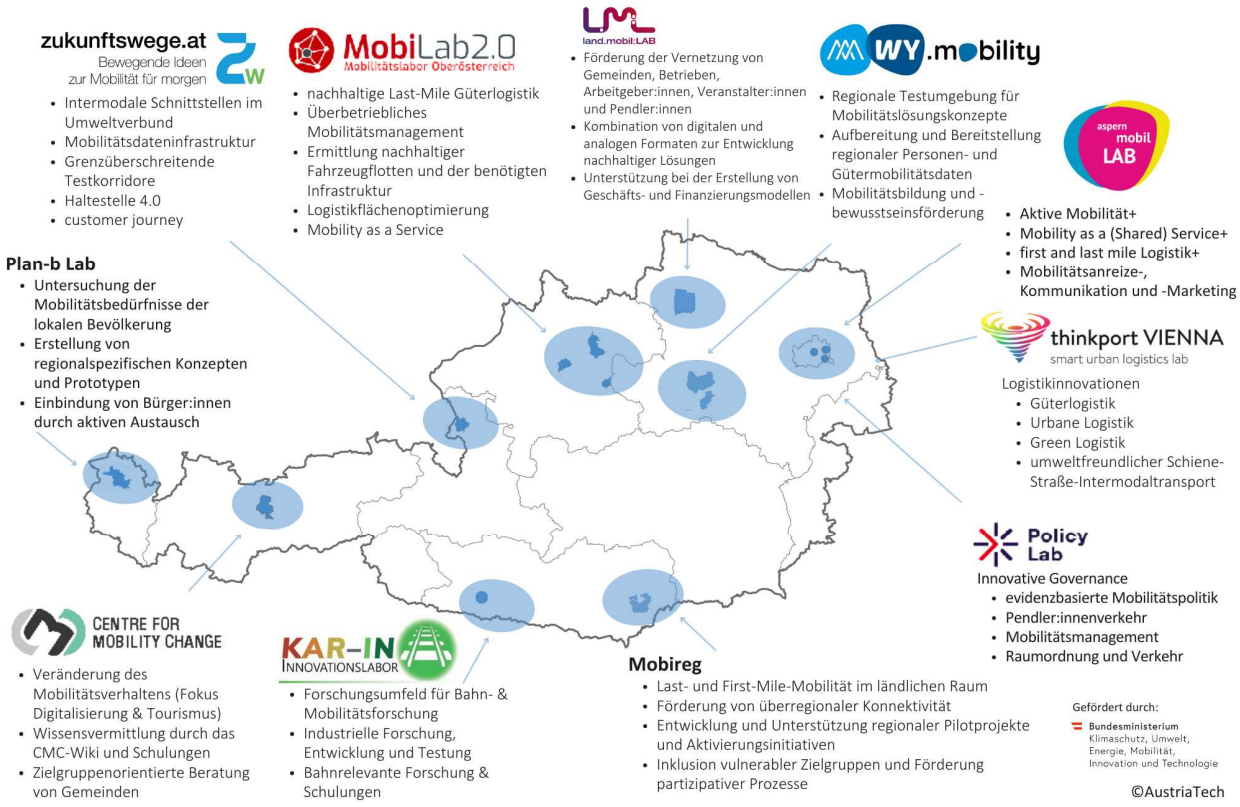

Abbildung 1: Übersichtskarte Mobilitätslabore Österreich; eigene Darstellung (© AustriaTech).

3.9 AmWy.mobility Lab

Das AmWy.mobility Lab, das regionale Mobilitätslabor Amstetten – Waidhofen an der Ybbs, bildet einen idealen Experimentierraum für das rasche Testen innovativer Mobilitätslösungen. In enger Zusammenarbeit mit den regionalen Stakeholdern der teilnehmenden Gemeinden und darüber hinaus bietet AmWy.mobility den Rahmen für die Entwicklung koordinierter regionsübergreifender Mobilitätsstrategien. Wesentliche Beiträge dafür sind die Aufbereitung und Bereitstellung von regionalen Personen- und Gütermobilitätsdaten sowie die Schaffung von Formaten zur Mobilitätsbildung und -bewusstseinsförderung.

3.10 Mobireg

Mobireg fördert nachhaltige Mobilität im ländlichen Raum mit Fokus auf Mikro-ÖV und überregionale Konnektivität. Das Lab identifiziert Potenziale für Synergien und unterstützt Gemeinden, Unternehmen, NGOs und andere regionale Stakeholder bei der Entwicklung von Projektumsetzungen, Gruppenprozessen

und Geschäftsmodellen. Ein besonderer Fokus liegt dabei auf der Inklusion vulnerabler Zielgruppen und der Förderung partizipativer Prozesse.

3.11 Plan b-Lab

Das Plan b-Lab arbeitet im unteren Vorarlberger Rheintal und konzentriert sich auf die Mobilitätsbedürfnisse der lokalen Bevölkerung. Es entwickelt praxisnahe Lösungen durch engen Austausch mit Bürgerinnen, Bürgren, regionalen Akteurinnen und Akteuren.

4 DIE ÖSTERREICHISCHE MOBILITÄTSLABORINITIATIVE

Mit der Mobilitätslaborinitiative hat das österreichische Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK) im Rahmen des Programms Mobilität der Zukunft (MdZ) den Aufbau und Betrieb der Mobilitätslabore initiiert. Mit der 2014 gestarteten Sondierungsphase für Urbane Mobilitätslabore wurde der Grundstein gelegt und ein umfassender Wissenspool angelegt. In einer zweiten Phase, von 2017 bis 2021, wurde der Aufbau und Betrieb von sechs Mobilitätslaboren gefördert.

Die Laufzeit der Mobilitätslabore in der zweiten Phase endete 2021. Aufbauend auf der 2020 durchgeführten externen Wirkungsprüfung der Mobilitätslabore wurde im Frühjahr 2021 die dritte Phase der Mobilitätslabore ausgeschrieben. Vier urbane Mobilitätslabore und das Centre for Mobility Change werden seitdem weitergeführt und -entwickelt. Seit 2018 werden das Centre for Mobility Change und seit 2022 das Policy Lab vom BMK gefördert. 2023 startete das Regionale Mobilitätslabor KAR-IN sowie die Sondierungsphase für Regionale Mobilitätslabore. Seit 2024 werden die vier weiteren Regionalen Mobilitätslabore gefördert.

Im Rahmen der Mobilitätslabor-übergreifenden „Kooperations- und Austauschplattform Mobilitätslabore Österreich“ (KAMÖ) wird mit Unterstützung der AustriaTech ein Lern- und Austauschprozess realisiert. Durch diesen Prozess werden Synergien zwischen den einzelnen Mobilitätslaboren genutzt und Kompetenzen zu experimentellen Umgebungen im Mobilitätskontext fortlaufend erweitert. Die Zusammenarbeit läuft unter 5 Charakteristika. Diese umfassen: die Funktion einer Begleit- und Monitoringplattform, den Aufbau strategischer Intelligenz im BMK, das Kümmern um die Dachmarke der Mobilitätslabore, die Weiterentwicklung der Mobilitätslabore selbst und das Fördern des gemeinsamen Lernens.

Die Plattform dient grundsätzlich einem Ideen- und Erfahrungsaustausch. Es werden Fragen zu Organisation, Prozessen, Methoden, Dienstleistungen und Herausforderungen behandelt. Auch förderrechtliche Fragen werden bei Bedarf von der österreichischen Forschungsförderungsgesellschaft (FFG) beantwortet. Außerdem unterstützt die KAMÖ durch den Austausch dabei, einen gegenseitigen Informationsfluss zwischen den Mobilitätslaboren, BMK und AustriaTech zu fördern und somit die Potenziale aller Mobilitätslabore optimal zu nutzen. Dieser Austausch findet zweimal im Jahr im Rahmen der KAMÖ-Sitzungen statt. Durch die KAMÖ können zusätzliche Bedarfslagen identifiziert und bilaterale Kooperationen angeregt werden. Durch diese Prozesse wird ein gemeinsames Lernen gefördert, wodurch sich die Mobilitätslabore durch stetig wachsende Expertise weiterentwickeln und positionieren können. Die KAMÖ erhöht außerdem durch zahlreiche Disseminationstätigkeiten die (inter-)nationale Sichtbarkeit der Mobilitätslabore sowie der Mobilitätslaborinitiative.

5 MÖGLICHKEITEN DER KOOPERATION

Die Angebote der Mobilitätslabore stehen prinzipiell allen Akteurinnen und Akteuren offen, richten sich mehrheitlich aber an Forscherinnen, Forscher, Innovatorinnen, Innovatoren, Entwicklerinnen, Entwickler, Mobilitätsdienstleisterinnen, Mobilitätsdienstleister, Bürgerinnen, Bürger, Mitarbeiterinnen und Mitarbeiter aus der Verwaltung. Sie können mit den Mobilitätslaboren wie folgt kooperieren:

- Diskutieren und lernen Sie über Mobilitätsthemen und Reallabor-Methoden (Co-Creation, Design-Thinking, Citizen Science, Bürgerinnen- und Bürgerengagement)
- Lassen Sie die Mobilitätslabore Sie bei Ihrem Projekt inhaltlich, prozessual, organisatorisch und methodisch unterstützen
- Testen Sie Ihre Mobilitätslösungen und -innovationen in den realen Umgebungen unserer Mobilitätslabore mit unterschiedlichen Zielgruppen

- Übertragen Sie Mobilitätslösungen und -innovationen, die in den österreichischen Mobilitätslabors entwickelt wurden, auf Ihre Stadt oder Region
- Erkundigen Sie sich über unsere Erfahrungen beim Aufbau und Betrieb von Reallaboren in unterschiedlichen demo- und topographischen Gebieten.
- Lernen Sie von unseren Erfahrungen beim Aufbau einer Mobilitätslaborinitiative und -plattform
- Kooperieren Sie im Rahmen von (EU-)Projekten

Kontakt und mehr Informationen zu den Mobilitätslaboren sowie deren Websites finden Sie über folgenden Link: https://fti-mobilitaetswende.at/de/artikel/mobilitaetslabore/

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Integration of Flexibilities to Energy Performance Contracting Business Models

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1 ABSTRACT

The revised Energy Performance of Buildings Directive (EPBD) aims for a fully decarbonized European building stock by 2050. (EC, 2024) Energy Performance Contracting (EnPC) offers a promising solution to enhance renovation rates, yet long payback periods remain a barrier. This paper presents a novel EnPC business model incorporating implicit and explicit flexibility services to reduce payback time and enhance profitability. The study utilizes literature reviews and stakeholder interviews from the EBENTO project to develop and validate this approach. Findings indicate that integrating flexibility services can generate additional revenue streams, optimize energy consumption, and shorten contract durations, making EnPCs more viable for residential applications.

Keywords: demand response, flexibilities, business model, energy performance contracting, planning

2 INTRODUCTION

The European building stock is currently responsible for 36% of all energy-related CO_2 emissions in the EU. The entire building stock will need to be highly energy efficient and carbon-neutral by 2050 to achieve the EU's climate objective. In 2020, the European Commission published the Renovation Wave strategy and action plan, an initiative aiming to double annual energy renovation rates in the next ten years and renovate 35 million buildings in Europe by 2030. Together with a very ambitious decarbonisation of heating this should enable to cut direct building sector greenhouse-gas emissions by 60% until 2030 (based on 2015 levels) as laid down in the Climate Target Plan 2030 (EC, 2020). The current Energy Performance of Buildings Directive (EPBD) is an essential element of the EU renovation strategy. It upgrades the existing regulatory framework to reflect higher ambitions and more pressing needs in climate and social action. These ambitious targets in the building sector require a high amount of capital and suitable financing mechanisms.

Energy Performance Contracting (EnPC) is one promising option to boost renovation rates and help to achieve the ambitious EU decarbonization targets in the building sector. EnPCs are contracts between building owners and Energy Service Companies (ESCOs) that target to facilitate energy efficiency improvements in buildings that are financed from guaranteed energy savings. This means that EnPCs are a financial and technical mechanism that enables organizations to implement energy efficiency measures and renewable energy projects without upfront capital investment. It is a contractual agreement between an energy service company (ESCO) and a client, typically a commercial or public sector entity, to improve energy efficiency and reduce energy costs. So far the EnPC market has stagnated in many Member States (Mayer, et al., 2023). The latest revision of the Energy Efficiency Directive (EED) however foresees to promote the energy services market and access to it. Member States shall promote and ensure the use of EnPCs for the renovation of large buildings. (EC, 2023)

However, a central barrier to the adoption of EnPCs are long payback periods and contract durations, which are not reasonable for many clients, especially in the residential sector (Mayer, et al., 2023). Newly constructed or renovated buildings typically have a potential for energy flexibilities, due to the installation of smart and flexible technologies (e.g. heat pumps, PV, batteries, EVs, ...). These energy flexibilities represent an additional revenue stream that could reduce payback time and increase the profitability of building renovations. The aim of this paper is to present a new EnPC business model that integrates savings and revenues from implicit and explicit flexibilities in the EnPC to reduce the payback period and improve the

profitability of EnPCs. The new business model was developed as theoretical concept in the course of the Horizon Europe project, outlining the roles and responsibilities of different actors in the process.

3 METHODOLOGY AND POLICY BACKGROUND

3.1 Policy Background

The energy services sector in the EU, including ESCOs and EnPCs, follows a clear regulatory framework. This framework supports energy service contracts, financial tools, certified providers, and monitoring methods. The EED is the main driver, requiring Member States to strengthen the energy services market. Over the years, EU policies like the EED have increased interest in this sector. As a result, ESCO markets have grown steadily across Member States. Many countries have introduced laws to support these markets, including rules for ESCOs and EnPCs. However, implementation varies. Some rules are not yet fully adopted, and in some countries, the energy services market is still developing. The policy framework for flexibilities in buildings focuses on enhancing energy efficiency, demand response, and integration with renewable energy sources. EU regulations, such as the EPBD and the Electricity Market Design, encourage smart energy use by promoting digitalization, smart meters, and energy storage. These policies support the deployment of demand-side flexibility, allowing buildings to adjust energy consumption based on grid conditions. Financial incentives and regulatory measures, including dynamic pricing and flexibility markets, further encourage participation. However, implementation varies across Member States, requiring harmonized efforts to unlock the full potential of building flexibilities.

3.2 Methodological approach

This study used a multifaceted methodological approach to develop the new business model. A comprehensive literature review was conducted to identify existing EnPC business models and the general availability and potential of flexibility services in buildings. In addition to the desk research, in-depth interviews with a diverse range of stakeholders were conducted to verify the findings from the literature research and gain additional qualitative insights on the general market uptake of EnPCs in the European Union. Interview partners included (ESCOs), building owners, building managers, policy makers, and industry experts from several EU countries.

3.3 Market status of EnPCs in the European Union

Within the project EBENTO, a market analysis was done to assess the current state of development of EnPCs in the European Union. The analysis of the current market situation showed that an initial EnPC market development took place in all European countries but there is only a slight market growth. The main barriers that were identified in the analysis are a lack of awareness and understanding, lack of trust, high complexity, high payback periods and contract durations as well as high transaction costs and the split incentive dilemma. Legislative barriers often hinder progress, suggesting that a more standardised approach could facilitate market growth, streamline transactions, and reduce costs. Improving information dissemination and raising awareness are crucial steps forward. Lists of ESCOs prove highly valuable for customers seeking to understand the market. Facilitators specialising in EnPCs and energy agencies have pivotal roles to play, particularly within the public sector. The most relevant drivers of EnPCs in the residential sector are increasing energy costs, supportive schemes and the availability of competent facilitators or support services (e.g. one-stop-shops). Financial support and incentives, such as tax incentives, continue to be essential, particularly in countries with less mature markets. Member States are encouraged to utilise European Funds effectively, employing a smart mix of financial schemes that promote EnPCs and ESCOs. Furthermore, sharing best practices at the national and regional levels, along with lessons learned from EU-funded projects, can enhance collaboration among Member States. (Mayer, et al., 2023)

4 FLEXIBILITIES IN ENERGY PERFORMANCE CONTRACTING

4.1 Basic Elements of Energy Performance Contracting

EnPCs are agreements between building owners and contractors, usually ESCOs, to improve energy efficiency. These projects are funded through guaranteed future energy savings. ESCOs have the expertise to offer complete solutions that reduce energy costs. They can manage projects, arrange financing, install and

maintain equipment, and work with other market players. EnPCs shift both the financial and technical risks of energy efficiency investments from the building owner to the ESCO. Since ESCOs have the necessary funds, skills, and experience, they can carry out the project and ensure the promised energy savings are achieved. (Csaszar, et al., 2015)

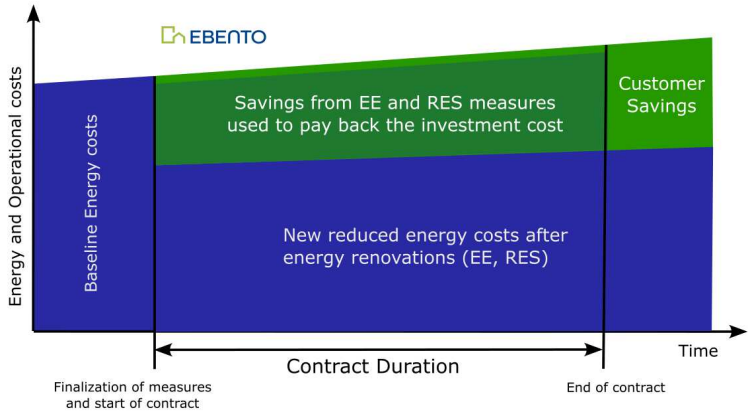

Figure 1: Energy savings and costs of a typical EnPC

The basic idea of the EnPC business model is that the ESCO will be renumerated based on the energy savings generated through the contract. Figure 1 illustrates this model, showing how energy efficiency measures reduce baseline energy consumption. Baseline energy costs represent the energy costs before the renovation measures are started. In this model, energy costs are expected to increase over time, which explains the steady rise in baseline costs and overall costs. After the energy efficiency measures are implemented, energy costs decrease, which is shown as “new reduced energy costs after energy renovations” in figure 1. The savings generated are used to repay the investment costs. Once the investment is paid back, the contract ends and the customer benefits from lower energy costs. Typically, not all savings are used to pay back the investment costs. A small portion of the savings favours the customer also during the contract duration, which represents the thin light green part above the savings within the contract duration.

4.2 Integrating Flexibilities in EnPCs

Flexibilities in buildings refer to the ability to adjust energy consumption based on demand, price signals, or grid conditions. By integrating smart technologies, energy storage, and demand response mechanisms, buildings can optimize energy use, reduce costs, and support grid stability. The incentive for shifting demand can be either price-based (implicit flexibilities) or market-based (explicit flexibilities). Implicit flexibilities shift demand to times with lower electricity prices, while explicit flexibilities adjusts demand based on signals from network operators to alleviate grid congestion. This adjustment is typically managed by an aggregator, who sets the baseline and modifies demand as needed.

4.2.1 Implicit flexibilities in EnPCs

Implicit flexibilities means that electricity demand is shifted based on price signals. There are two typical use cases for implicit flexibilities. The first implicit flexibilities use case is the demand optimization with fixed electricity tariffs. This means that flexible demand such as heat pumps or EV charging is shifted to increase self-consumption rate of on-site renewable energy sources (PV). In this use case, electricity prices for purchasing and selling electricity are assumed to be fixed (no hourly changes). As the electricity price for consumption is typically higher than the electricity price for electricity feed-in, electricity costs are reduced by increasing the self-consumption of the PV generation. Batteries could further increase the self-consumption rate and improve the business case.

The second use case of implicit flexibilities is the demand optimization with flexible electricity tariffs. In this use case also, flexible energy tariffs based on the day-ahead market have to be considered in the optimization. It is assumed that the electricity selling price is a fixed tariff and just the electricity purchasing price is flexible. Flexible energy prices provide another incentive for load shifting. Flexible tariffs could be either tariffs with hourly variable electricity prices linked to the spot market prices or tariffs with fixed period prices (peak-/offpeak-/shoulder-price). The combination of batteries with flexible electricity tariffs further increases the possibilities (charging in low-price hours) and potential cost savings.

Optimization according to flexible electricity prices is typically more relevant in the winter period, where not enough PV production for self-consumption optimization is available. For the realization of this use case, a multi-objective optimization with a building energy management system is needed to find the overall optimum consumption strategy. Batteries could further improve the potential energy cost savings in this use case as they increase the self-consumption rate and also further decrease costs as they could be charged from the grid in low price periods. Additionally, flexible grid tariffs (capacity-based tariffs) could further increase the complexity and the potential revenues.

Figure 2 shows the schematic of energy savings and costs of an EnPC with savings from implicit flexibilities. It can be seen that the savings from implicit flexibilities could further reduce the payback time of the investment costs and therby reduce the contract duration.

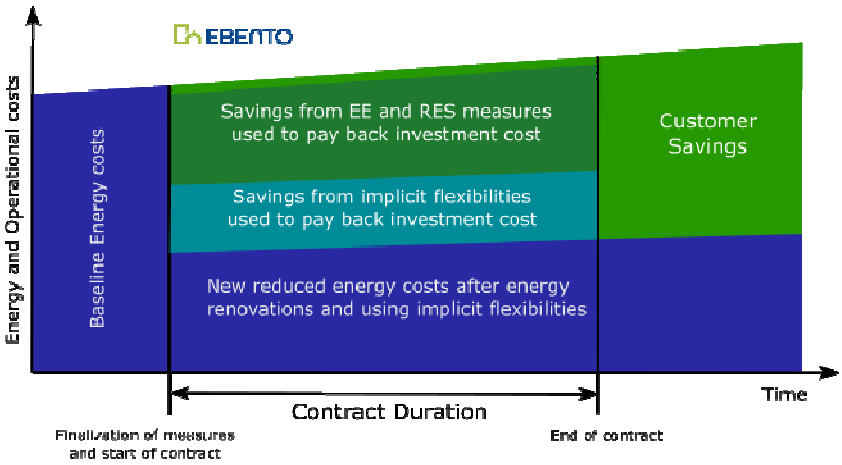

Fig. 2: Energy savings and costs of EnPC with implicit flexibilities

The main actors of typical EnPCs are the building owner and the ESCO. EnPCs with implicit flexibilities requires that the ESCOs have full control of flexible devices. Only if the ESCO can control the flexible devices, savings from implicit flexibilities could be considered in the contract. The electricity suppliers also play an important role as they have to offer dynamic tariffs, allowing the owner/occupant to adjust demand based on the investment by the ESCO, resulting in reduced energy costs. The latest recast of the EMD requires member states to force electricity suppliers to offer flexible electricity tariffs.

Facilitators represent another important actor in EnPCs. They could support to overcome the complexity barrier of EnPCs which is especially relevant if implicit flexibility savings are considered in the contract. Additionally, a smart meter for real-time measurement and billing is required. Monitoring tools and building energy management systems system for optimized control could further support the flexible control of loads and thereby increase the potential savings. For a proper consideration of flexibility savings in the EnPC, a detailed calculation and forecasting of the expected flexibility savings has to be done in the EnPC planning phase.

4.2.2 Explicit flexibilities in EnPCs

Explicit flexibilities means that flexible demand is shifted based on signals from network opoerators to alleviate grid congestion. This adjustment is typically managed by an aggregator, who sets the baseline and modifies demand as needed. ESCO can either act as the contractual party for an external aggregator, serve as the aggregator, or have no connection to the aggregator. In the latter, the owner contracts directly with the aggregator. The aggregator's role is to pool flexibility from various customers for flex requestors, typically distribution system operators (DSOs), Transmission System Operators (TSOs), or other balance responsible parties (Vanstraelen et al., 2021).

Figure 3 shows the schematic of energy savings and costs of an EnPC with additional revenues from explicit flexibilities. These external flexibilities do not reduce the energy costs but generate additional revenues that could be used to payback the investment costs and further reduce the contract duration. After the contract duration, the customer receives all revenues from explicit flexibility services (except the service fee if ESCO acts as an aggregator or operator).

EnPCs with explicit flexibilities involve multiple actors. Building owners act as contractual partner of the ESCO. Building owners, building managers or tenants provide flexibility by adjusting their energy consumption based on agreed-upon strategies. Aggregators combine the flexibility potential of many consumers and prosumers and and bundle it to a portfolio. The aggregator offers the bundled flexibility to different flexibility or energy markets. ESCOs could either have a contractual relationship with an aggregator or take over the capabilities and responsibilities of aggregators. If ESCOs act as technical aggregators, they bundle the flexibilities of their clients and control the flexible assets of multiple buildings. Therefore, the ESCOs need the control over flexible loads if the expected explicit flexibility revenues are integrated in the EnPC. Facilitators could support the whole process. Grid operators (DSOs/TSOs) are another important actor in this model as they provide the external signal to which aggregators and building owners respond during explicit flexibility actions. Policymakers create supportive regulations to ensure a fair and functional energy market. By working together, these actors enable EnPCs to maximize savings and efficiency while contributing to a more flexible and reliable energy system.

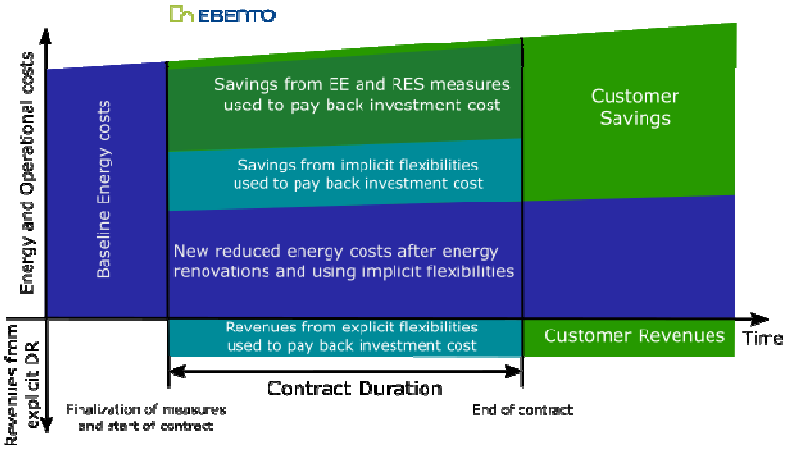

Fig. 3: Energy savings and costs of EnPC with external flexibilities

5 CONCLUSION

The results of the analysis show that the integration of flexibility services in EnPCs could shorten payback time and contract duration. Flexibility services in buildings can be categorized into implicit and explicit flexibilities. Implicit flexibilities generate electricity cost savings from a shift of demand to times with lower electricity prices, which could be either times with high PV production or times with low flexible electricity tariffs. Explicit flexibility services generate revenues from demand adjustments based on external signals from network operators to alleviate grid congestion. ESCOs can either act as the contractual party for an external aggregator or serve as an aggregator for the network operator. To integrate savings and revenues from flexibility services in the EnPC business model, the ESCO must have control over the building's energy management system and energy-flexible devices (e.g. heat pump or electric boiler). Figure 1 presents a schematic of energy savings and costs for an EnPC that includes flexibilities. It can be seen that the energy consumption is reduced through energy efficiency measures and savings from implicit flexibilities. Furthermore, revenues are generated from explicit flexibilities. The new EBENTO EnPC business model uses energy cost savings and flexibility revenues to pay back the investment costs and thereby reduce the contract duration of EnPCs.

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Lebenswelten internationaler Arbeits- und Fachkräfte am Innovationsstandort Heilbronn

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1 ABSTRACT

Der demografische Wandel und die zunehmende Digitalisierung stellen Deutschland vor große Herausforderungen bei der Sicherung des Fachkräftebedarfs (Bundesagentur für Arbeit, 2024). Besonders in Bereichen wie der künstlichen Intelligenz und anderen zukunftsweisenden Technologien wird der Mangel an qualifizierten Arbeitskräften zunehmend spürbar (BMAS, 2022). Als Reaktion hat die Bundesregierung ein umfassendes Maßnahmenpaket initiiert, dessen Kernstück das reformierte Fachkräfte-Einwanderungsgesetz darstellt. Dieses wird durch gezielte Anwerbestrategien für qualifizierte Arbeitskräfte aus EU-Ländern und Drittstaaten flankiert (BMI, 2023). Vielversprechendes Potenzial liegt in der Zunahme internationaler Studierender an deutschen Hochschulen, deren Zahl nach Angaben des DAAD (2024) im Wintersemester 2024/2025erstmals die Marke von 400.000 Studierenden überschritten hat. Die akademisch qualifizierten Fachkräfte verfügen bereits über wichtige Grundlagen für eine erfolgreiche Integration in den deutschen Arbeitsmarkt. Die nachhaltige Integration internationaler Fachkräfte erfordert jedoch einen ganzheitlichen Ansatz, der über arbeitsmarktpolitische Maßnahmen hinausgeht. Während bereits punktuelle Unterstützungsangebote wie Sprachkurse oder Jobvermittlung existieren, fehlt es häufig an einer systematischen Einbindung der Stadtentwicklung in den Integrationsprozess (BMAS 2021). Die Stadtplanung steht vor der Herausforderung, die spezifischen Bedürfnisse internationaler Fachkräfte zu erfassen und bei der Gestaltung des urbanen Lebensraums zu berücksichtigen (BBSR, 2024). Diese Herausforderung gewinnt zusätzlich durch die Transformation der Arbeitswelt im Zuge der Digitalisierung und Flexibilisierung an Bedeutung. Die damit einhergehenden veränderten Anforderungen an Arbeitsorte, Mobilität und Wohnkonzepte erfordern innovative städtebauliche Lösungen, die sowohl den beruflichen als auch den sozialen Bedürfnissen internationaler Fachkräfte gerecht werden.

Keywords: Integration, Stadtentwicklung, Innovationsstandort, Fachkräftemangel, Partizipation

2 EINLEITUNG

Städte sind dynamische Lebensräume, die sich stetig an gesellschaftliche, wirtschaftliche und technologische Veränderungen anpassen müssen. Die GroßstadtHeilbronn steht in den kommenden Jahren vor weitreichenden Herausforderungen, die durch den demografischen Wandel, den Fachkräftemangel und die Digitalisierung geprägt sind (Stadt Heilbronn, 2019). Diese Entwicklungen beeinflussen nicht nur die wirtschaftliche Wettbewerbsfähigkeit der Region, sondern auch die Art und Weise, wie Menschen leben, arbeiten und sich in städtischen Räumen bewegen (Deutscher Städtetag, 2019).Besonders der zunehmende Fachkräftemangel stellt eine zentrale Herausforderung für die nachhaltige Entwicklung der Stadt dar (Umweltbundesamt, 2013). Die Verfügbarkeit qualifizierter Arbeitskräfte entscheidet über Innovationskraft und Wirtschaftswachstum, während gleichzeitig urbane Strukturen geschaffen werden müssen, die diesen Arbeitskräften ein attraktives Lebensumfeld bieten. Hier kommt der Stadtplanung eine Schlüsselrolle zu. Sie kann nicht nur durch moderne Wohn- und Mobilitätskonzepte dazu beitragen, Heilbronn als Standort für Talente und Unternehmen zukunftsfähig zu machen, sondern auch die soziale und kulturelle Integration internationaler Fachkräfte aktiv fördern (Deutsches Institut für Urbanistik, 2019). Während wirtschaftspolitische Maßnahmen wie gezielte Fachkräfteeinwanderung und berufliche Qualifizierung bereits in den Fokus rücken, fehlt es häufig an einer systematischen Verzahnung mit der Stadtplanung (SVR 2024). Wie müssen urbane Räume gestaltet sein, damit sie den Bedürfnissen einer zunehmend internationalen, digitalen und mobilen Gesellschaft gerecht werden? Das vorliegende Forschungsvorhaben untersucht, wie Stadtentwicklung gezielt zur Bewältigung des Fachkräftemangels beitragen kann und welche Konzepte notwendig sind, um Heilbronn als attraktiven Lebens- und Arbeitsstandort weiterzuentwickeln.

3 INTERNATIONALE ARBEITS- UND FACHKRÄFTE IN DEUTSCHLAND

3.1 Status Quo: Zuwanderung nach Deutschland

Internationale Zuwanderung spielt eine entscheidende Rolle bei der Bewältigung des Fachkräftemangels und der demografischen Herausforderungen in Deutschland. Im Jahr 2023 betrug die Nettozuwanderung 663.000 Personen, was trotz eines Rückgangs im Vergleich zum Vorjahr weiterhin eine bedeutende Zahl darstellt (Statistisches Bundesamt, 2024). Besonders gefragt sind qualifizierte Fachkräfte, 2023 blieben 570.000 Stellen aufgrund fehlender Fachkräfte unbesetzt (KOFA, 2024). Prognosen zeigen, dass bis 2035 etwa 7,2 Millionen Erwerbspersonen fehlen werden (IAB, 2021, KOFA, 2024). Internationale Fachkräfte und Studierende tragen wesentlich zur Reduzierung des Fachkräftemangels bei (Portal der Bundesregierung für Fachkräfte aus dem Ausland, 2023). Laut Bundesagentur für Arbeit (2024) besitzen 15,3 % der sozialversicherungspflichtig Beschäftigten eine ausländische Staatsangehörigkeit. Gleichzeitig waren im Wintersemester 2023/24 rund 470.000 der 2,4 Millionen Studierenden internationaler Herkunft (Statista, 2024). Diese erwerben nicht nur fachliche Qualifikationen, sondern entwickeln interkulturelle Kompetenzen und Sprachkenntnisse, die für den deutschen Arbeitsmarkt wertvoll sind. Langfristig verbleiben viele internationale Studierende in Deutschland, nach einem Zeitraum von zehn Jahren sind 38,2 % noch immer im Land ansässig, während 28 % die deutsche Staatsbürgerschaft erlangen (Statistisches Bundesamt, 2022).Die gezielte Förderung der Migration von Fachkräften ist daher von entscheidender Bedeutung, um wertvolle Kompetenzen in den Arbeitsmarkt zu integrieren und den Fachkräftemangel der durch den demografischen Wandel bedingt ist, langfristig auszugleichen.

3.2 Der Standort Heilbronn

Die Region Heilbronn-Franken gehört zu den wirtschaftsstärksten Regionen Deutschlands und ist besonders für ihre Innovationskraft im verarbeitenden Gewerbe und in der produzierenden Industrie bekannt (Heilbronn-Franken, 2025). Heilbronn hat sich dabei von einem traditionellen Produktions- und Industriestandort zu einem führenden Wissenschafts- und Innovationsstandort entwickelt. Ein wesentlicher Treiber dieser Entwicklung ist der Innovationspark Künstliche Intelligenz (IPAI), der als größtes europäisches KI-Ökosystem geplant ist. Gefördert durch das Land Baden-Württemberg, spielt der IPAI eine zentrale Rolle in der regionalen Zukunftsstrategie (Stadt Heilbronn, 2023).

Trotz einer vergleichsweise niedrigen Arbeitslosenquote von 4,1 % (Stand Dezember 2024) bleibt der Fachkräftemangel eine bedeutende Herausforderung. In der Region wurden 2024 6.517 offene Stellen verzeichnet, während gleichzeitig 22.491 Menschen als arbeitslos angemeldet waren (Stand Dezember 2024) (IHK, 2025) Diese Zahlen verdeutlichen, dass die Nachfrage nach Arbeitskräften weiterhin nicht in ausreichendem Maße gedeckt werden kann, was eine systemische Problematik für die künftige wirtschaftliche Entwicklung darstellt. Ein zentraler Aspekt der regionalen Arbeitsmarktsituation ist die Prognose, dass bis 2035 rund 81.000 Fachkräfte in Heilbronn unbesetzt bleiben könnten. Insbesondere wird ein Defizit von 75.000 Fachkräften mit abgeschlossener Berufsausbildung prognostiziert, ergänzt durch einen Mangel an ungelernten Arbeitskräften und Helfern, mit voraussichtlich 11.600 offenen Stellen(Netzwerk Transformotive, 2024).Diese Prognose unterstreicht die Notwendigkeit, dem Fachkräftemangel sowohl durch verstärkte Initiativen als auch durch gezielte Maßnahmen zur Fachkräftesicherung und -gewinnung entgegenzuwirken. Die Region Heilbronn-Franken befindet sich im Spannungsfeld zwischen einem robusten wirtschaftlichen Wachstum und den Herausforderungen eines zunehmenden Fachkräftemangels.

3.3 Integrative Stadtentwicklung

Die Gestaltung urbaner Räume umfasst mehr als bauliche Maßnahmen. Ihre Entwicklung trägt zum gesellschaftlichen Zusammenhalt und wirtschaftlichen Dynamiken bei. In einer Zeit, in der Städte zunehmend von globalen Mobilitätsströmen geprägt sind, wächst die Verantwortung der Stadtplanung, integrative Strukturen zu schaffen. Dies gilt besonders für Wirtschaftsstandorte wie Heilbronn, die sich im Spannungsfeld zwischen traditioneller Mittelstandsprägung und internationaler Innovationsdynamik bewegen. Eine erfolgreiche Stadtentwicklung verfolgt einen interdisziplinären Ansatz. Sie berücksichtigt soziale, kulturelle und wirtschaftliche Aspekte, um ein Umfeld zu schaffen, das sowohl bestehende Stadtbewohnende als auch Zugezogene einbindet (Deutscher Städtetag, 2016). Moderne Städte müssen daher Antworten auf zentrale Fragen der Integration liefern. Wie können urbane Räume gestaltet werden, damit sie

den Bedürfnissen einer diversifizierten, digital vernetzten und zunehmend mobilen Gesellschaft gerecht werden? Die Herausforderung besteht darin, eine Balance zwischen den Bedürfnissen der ansässigen Bevölkerung und den Zugezogenen zu finden. Integrative Stadtentwicklung bedeutet, Diversität nicht als Problem, sondern als Chance für Innovation, kulturelle Bereicherung und gesellschaftliche Vielfalt zu begreifen (Deutsches Institut für Urbanistik, 2019).In der integrativen Stadtentwicklung werden internationale Fachkräfte und Migranten als Innovationstreiber und Bereicherung städtischer Dynamiken begriffen. Entscheidend für die Umsetzung sind partizipative Ansätze, die alle Stadtbewohner in Entwicklungsprozesse einbezieht. So können Städte ihre Potenziale entfalten und als Orte der Begegnung, des Austauschs und der gemeinsamen Zukunftsgestaltung dienen. Integrative Stadtentwicklung ist dabei mehr als eine Strategie – sie ist eine Haltung des respektvollen Miteinanders(Beckmann, 2000; Selle, 2011).

3.4 Forschungsgegenstand

Die bisherigen Forschungsarbeiten widmen sich vornehmlich den Aspekten arbeitsmarktpolitische Integration, Sprachförderung sowie Abbau administrativer Hürden (SVR 2024, BAMF2024, Schammann et al., 2020). Der Einfluss stadtplanerischer Maßnahmen auf die nachhaltige Integration internationaler Arbeits- und Fachkräfte ist bislang unzureichend erforscht. Dabei kommt der Stadtplanung durch die physische Gestaltung und soziale, kulturelle und wirtschaftliche Teilhabeprozesse eine entscheidende Rolle zu. Die Bundeszentrale für politische Bildung betont, dass Integration in erster Linie auf kommunaler Ebene stattfindet. In Städten und Quartieren werden die Grundlagen für Vertrauen, Anerkennung und sozialen Zusammenhalt gelegt (BpB, 2020). In diesem Kontext stellt sich die Frage, wie Heilbronn den spezifischen Bedürfnissen der Zielgruppen gerecht werden kann. Besonders im Hinblick auf die Lebenswelten internationaler Fachkräfte, die als zunehmend global vernetzt und digital nomadisch beschrieben werden, ist die intensive Auseinandersetzung mit der Zielgruppe relevant. Eine zentrale Methode ist die Skizzierung der Lebenswelten durch User Journeys. Darauf basierend lassen sich Maßnahmen ableiten, um die Integration zu erleichtern und Fachkräfte langfristig an einen Standort zu binden.

3.5 Zielsetzung

Die vorliegende wissenschaftliche Untersuchung analysiert die Lebenswelten junger, internationaler Fachkräfte in Heilbronn. Im Fokus steht die Frage, mit welchen Herausforderungen sie konfrontiert sind und welche Faktoren ihre Wahl des Wohn- und Arbeitsorts beeinflussen. Dabei werden sowohl ihre individuellen Erfahrungen mit Lebensqualität, Karrierechancen und integrativen Praktiken als auch die strukturellen Rahmenbedingungen betrachtet, die ihre Mobilitätsentscheidungen prägen. Vor diesem Hintergrund untersucht die Studie insbesondere:

- Wie sich die Lebenswelten internationaler Fachkräfte anhand der User Journey in Heilbronn gestalten.
- Welche Maßnahmen der Innovationsstandort Heilbronn ergreifen kann, um den Bedarfen dieser Fachkräfte besser zu begegnen.
- Welche konkreten Handlungsempfehlungen sich aus den Herausforderungen und der Analyse ihrer Lebenswelt ableiten lassen.

Ziel ist es, fundierte Empfehlungen für Stadt- und Regionalentwicklung sowie die Wirtschaft zu formulieren. Durch einen methodisch pluralistischen Ansatz sollen strategische Maßnahmen identifiziert werden, um Heilbronn als inklusiven, lebendigen und nachhaltigen Standort zu etablieren.

3.6 Methodisches Vorgehen

Die Studie folgt einem mehrstufigen Forschungsansatz mit vier Kernphasen. Zunächst wurde ein Interviewfragebogen entwickelt, um systematisch Daten zur Zielgruppe (Alter, Geschlecht, Bildung, Beruf, Wohnsituation) zu erfassen. Anschließend wurden schriftliche Interviews zur Customer Journey durchgeführt, um den Wohnwechsel- und Nutzungsprozess besser zu verstehen. Darauf folgten offene Interviews, die Trendfelder im Bereich Future Living identifizierten, darunter moderne Wohnkonzepte, Technologieintegration und alternative Wohnmodelle. Abschließend wurden Leitfragen zu Future Living Services analysiert, um künftige Wohn- und Lebensstile umfassend zu erfassen. Die Auswertung der Interviews erfolgte nach der qualitativen Inhaltsanalyse nach Mayring (Mayring, 2015), um zentrale Muster und Schlüsselkategorien systematisch abzuleiten. Parallel wurden Schlüsselthemen wie Digitalisierung,

Pluralisierung der Lebensstile, multilokale Räume und Arbeitsorte untersucht. Die qualitative Forschung ermöglichte so ein tiefes Verständnis der sich wandelnden Wohnlandschaft und lieferte wertvolle Erkenntnisse für innovative, nachhaltige Wohnkonzepte der Zukunft. Für zukünftige Studien könnte das im Rahmen des Forschungsprojekts „Future Living“ entwickelte Format „Scribbles AI“, das Urban Sketching mit KI-unterstützter Bild-zu-Bild-Synthese verbindet, als partizipative Methode zur vertieften Erfassung räumlicher Präferenzen internationaler Fachkräfte eingesetzt werden. Die qualitative Forschung ermöglichte so ein tiefes Verständnis der sich wandelnden Wohnlandschaft und lieferte Erkenntnisse für innovative, nachhaltige Wohnkonzepte der Zukunft.

4 ERGEBNISSE

Die Analyse der Lebenswelten junger internationaler Arbeits- und Fachkräfte in Heilbronn wurde thematisch strukturiert, um ein ganzheitliches Verständnis der Situation zu ermöglichen. Die Untersuchung erstreckte sich über verschiedene Bereiche, darunter Gastronomie, Bildung und Wissen, Verwaltung, Mobilität, Freizeit, Wohnen, Natur, Innenstadt, Architektur und das soziale Gefüge. Im Bereich Bildung und Wissen zeigt sich Heilbronn als „Regional Hidden Champion“ mit einem positiv wahrgenommenen Wandel zum Innovationsökosystem, wobei diese Entwicklung international noch nicht ausreichend sichtbar ist. Das familiäre Bildungsumfeld wird besonders geschätzt, charakterisiert durch kurze Wege und enge Vernetzung. „Es tut sich in vielen Dimensionen was, insbesondere in der Bildung und darauf kann man gut aufbauen. (…) Ich glaube in Deutschland, und vielleicht sogar nicht Europa, gibt es kaum eine Region, die Zukunftsthemen so adressiert und einen so deutlichen Blick in die Zukunft hat.“ (Fachkraft in Heilbronn, gebürtig). Allerdings wurde kritisch angemerkt, dass sich die Innovation hauptsächlich auf den Bildungscampus konzentriert und eine flächendeckende Konzeption fehlt. Die Innenstadt wird von den Befragten als entwicklungsbedürftig wahrgenommen, insbesondere hinsichtlich der Einzelhandels- und Gastronomiequalität. Internationale Arbeits- und Fachkräfte vermissen vor allem Nutzungsvielfalt und Begegnungsräume. Gleichzeitig besteht große Offenheit für innovative Konzepte wie urbane Manufakturen und Pop-up Stores.“For me, retail in the city center just looks too samey. For example, there are 10 different kebab stores in the same area and just as many nail salons and €1 stores and that's it.“ (Fachkraft in Heilbronn, zugezogen).Die Idee einer Mischnutzung in der Innenstadt wird positiv bewertet. Im Bereich Wohnen zeigt sich eine deutliche Präferenz für alternative Wohnformen, insbesondere bei internationalen Fachkräften. Co-living-Spaces und Guesthouses in Campusnähe werden als attraktive Optionen gesehen. Der Mangel an bezahlbarem Wohnraum wird als zentrales Problem identifiziert. „Ich glaube es bräuchte langfristig einfach mehr Wohnraum, der attraktiv und bezahlbar ist. (…) Viel Potenzial liegt in der Innenstadt, Wohnraum würde hier ein Stadtleben erzeugen und einen Ort, wo man sich zu jeder Tageszeit gerne aufhält.“ (Fachkraft in Heilbronn, zugezogen). Interessant ist die unterschiedliche Wohnortpräferenz, während Zugezogene häufig in Wohngemeinschaften in Innenstadt- oder Campusnähe leben, bevorzugen Heilbronner eher traditionelle Wohnformen am Stadtrand. Die Freizeitgestaltung erfolgt überwiegend selbstorganisiert und individuell, Internationale Arbeits- und Fachkräfte nehmen Sprachbarrieren und unübersichtliche Angebotsstrukturen als Hindernisse wahr. Das Nachtleben wird als verbesserungswürdig eingestuft, was zu vermehrten Wochenendausflügen führt. Regionale Events werden besonders von internationalen Fachkräften geschätzt, während Heilbronner sich mehr für alternative Formate interessieren. Für alle Befragten ist das soziale Leben und „Community-Gefühl“ von essentieller Bedeutung für ihre langfristige Zufriedenheit in Heilbronn. Die Ergebnisse zeigen zentrale Herausforderungen und Potenziale für Heilbronn entlang der Aufenthaltsphasen internationaler Fachkräfte – von der Ankunft bis zur langfristigen Perspektive. Bereits vor dem Umzug fehlen Unterstützung bei der Wohnungssuche und soziale Anschlussmöglichkeiten. Eine zurückhaltende Willkommenskultur und administrative Hürden tragen dazu bei, dass Heilbronn zunächst als vorübergehender Aufenthaltsort wahrgenommen wird. Nach der Ankunft erschweren fehlende Begegnungsräume, infrastrukturelle Defizite und eine überwiegend deutschsprachige Bürokratie die Integration. Im Alltag wird die Innenstadt als wenig attraktiv empfunden, während die Kluft zwischen Bildungscampus und Stadt die Vernetzung hemmt. Sprachbarrieren und ein begrenztes kulturelles Angebot erschweren zudem die soziale Teilhabe. Langfristig fehlt vielen die Identifikation mit Heilbronn, verstärkt durch einen angespannten Wohnungsmarkt und eine verbesserungswürdige ÖPNV-Infrastruktur. Handlungsbedarf besteht in digitalen Plattformen zur Erleichterung des Erstkontakts, Community-Wohnkonzepten und mehrsprachigen Verwaltungsstrukturen. Begegnungsorte im Zentrum, ein verbessertes

ÖPNV-Angebot und partizipative Prozesse könnten Heilbronn als Standort für internationale Fachkräfte stärken und langfristig seine soziale und räumliche Attraktivität erhöhen.

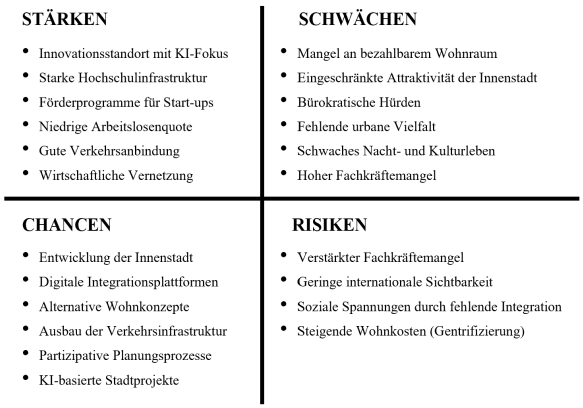

Abbildung 1: SWOT-Analyse, Zusammenfassung der Ergebnisse. Quelle: eigene Darstellung.

5 DISKUSSION

Die Ergebnisse der Untersuchung werfen wichtige Fragen zur zukünftigen Entwicklung Heilbronns als Standort für internationale Arbeits- und Fachkräfte auf. Die Herausforderung besteht darin, dynamische, vernetzte Nachbarschaften zu schaffen, die den Bedürfnissen einer zunehmend mobilen und digitalen Arbeits- und Lebenswelt gerecht werden. Ein Schlüsselfaktor in diesem Transformationsprozess ist die Rolle innovativer Technologien. Das im Rahmen des Forschungsprojekts „Future Living“ entwickelte Format „Scribbles AI“ demonstriert beispielhaft, wie künstliche Intelligenz für partizipative Stadtentwicklung genutzt werden kann. Die Bedeutung dieses Ansatzes liegt in seiner Fähigkeit, Barrieren zwischen Stadtplanern und Bürgern abzubauen und einen niederschwelligen, kreativen Dialog zu initiieren. Die Diskrepanz zwischen der lokalen Wahrnehmung Heilbronns als Innovationsstandort und seiner internationalen Sichtbarkeit unterstreicht die Notwendigkeit einer strategischen Neuausrichtung. Digitale Technologien wie „Scribbles AI“ könnten als Brückenbauer dienen, um neue Formen der Partizipation und des gemeinschaftlichen Gestaltens zu ermöglichen. Ein weiterer Aspekt ist die Innenstadtentwicklung. Traditionelle Konzepte passen oft nicht mehr zu den Erwartungen internationaler Arbeits- und Fachkräfte. Pop-up-Räume und urbane Manufakturen könnten neue Impulse geben, erfordern jedoch strukturelle Anpassungen. Es erfordert neue Kooperationen zwischen Stadtverwaltung, Wirtschaft und Zivilgesellschaft, um innovative Nutzungskonzepte langfristig umzusetzen. Die integrative Stadtentwicklung nimmt dabei einen hohen Stellenwert ein, sie verbindet soziale, kulturelle und wirtschaftliche Aspekte zu einer ganzheitlichen Strategie und erweitert traditionelle Planungsansätze. Die Integration internationaler Arbeits- und Fachkräfte ist ein vielschichtiger Prozess, der nicht nur bauliche Maßnahmen umfasst, sondern auch soziale und wirtschaftliche Aspekte berücksichtigt. Sprachbarrieren, bürokratische Hürden und fehlende inklusive Begegnungsräume erfordern eine umfassende Strategie. Die Entwicklung von Reallaboren und Use Cases könnte als Testfeld dienen, um neue Integrationskonzepte zu erproben und anzupassen. Der Erfolg von Heilbronns Transformation in einen zukunftsfähigen internationalen Standort hängt in hohem Maße davon ab, wie innovative Technologien mit traditionellen Planungsinstrumenten kombiniert werden und wie konsequent soziale Integration als zentrales Element der Stadtentwicklung verstanden wird.

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Machine Learning Approaches for Designing Sustainable Planning Regulations

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1 ABSTRACT

Quantitative and qualitative assessment is essential for identifying levers for sustainable development processes and the impact of planning decisions. Small and medium-sized municipalities in particular struggle with a lack of resources and expertise in the creation and preparation of strategic, forward-looking decision-making bases. AI promises to help automate some of these processes, create a data base and provide planning support that will save time and money in the longrun.

This paperillustrates the possibilities of Machine learning (ML) approaches to evaluate quantitative data for qualitative outcomes within planning and decision processes. Furthermore, it provides a basis for discussing possible implications for planning practice based on ML approaches dealing with the impact prediction of planning regulations. In which planning steps and processes can the use of ML bring added value? Which questions can be answered and which prerequisites need to be created? How reliable are results and what can be derived from them?

In answering those questions, a special focus will be placed on the needs of small and medium-sizedmunicipalities. The use of the technologies in early planning phases will be analysed, to allow assessment for holistic sustainable developments., in terms of environmental, economic, social and design aspects.

ML approaches enable impact prediction based on impact assessment of past regulatory frameworks. Within planning processes, ML-based analysis and predictions allow informed decisions to be made that have analysed future effects and interactions and take holistic considerations into account. AI and big data make it possible to tap into ‘new data sources’ with a view to evaluating and predicting future developments, with the aim of making more resilient planning decisions. This changes the role of planning, as it is all the more required to help interpret the data and draw the right conclusions for future measures and solutions.

Keywords: small and medium-sized municipalities, decision support, planning regulations, machine learning, planning

2 INTRODUCTION: AI METHODS IN SPATIAL PLANNING

2.1 Premise and Research Question

There are already numerous international AI and ML applications across various thematic areas and stages of planning processes. The “Akademie für Raumentwicklung in der Leibniz-Gemeinschaft” (ARL) recommends that public administration and planning make sustainable use of AI in spatial development for the common good.(ARL, 2024)

However, for many small and medium-sized municipalities in Austria, practical implementation remains challenging due to limited competencies and resources. These municipalities, in particular, face difficulties in acquiring the necessary expertise and resources to develop and prepare strategic, future-oriented decision-making frameworks.

This leads to the key question for this paper. What possibilities does AI offer to help small and medium-sized municipalities to formulate and adopt sustainable planning regulations? Where can interfaces for the use of AI be identified in the area of local spatial planning instruments (ÖEK, FWP, BPL) that bring comprehensible added value for municipalities?

2.2 Literature Review

Remote sensing data is crucial for ML applications in spatial planning. Satellite imagery time series aid in segmenting and classifying objects like roads, buildings, and vegetation (Dornaika et al., 2016; Shorter & Kasparis, 2009; Zhou & Chang, 2021). These methods also enhance urban zone classification (Chen et al.,

2021). Model accuracy depends on annotated datasets, created automatically (Karila et al., 2023) or manually (González-Collazo et al., 2023). When available, pre-existing vectorized datasets with rich attributes are preferred, but ML methods can help fill gaps where structured data is lacking.

Nagappan and Daud (2021) highlight that while ML has advanced in detecting land-use and land-cover patterns from various data sources and temporal analyses, it seldom considers their correlation with planning regulations.

In their study on possible applications of AI in urban planning (2025), Otengrafen et al. identified five different types of AI: Analytical, Functional, Textual, Visual and Interactive AI. They present their possible applications of AI in a matrix along the 5 planning phases according to Diller et al. 2017: See Figure 1.

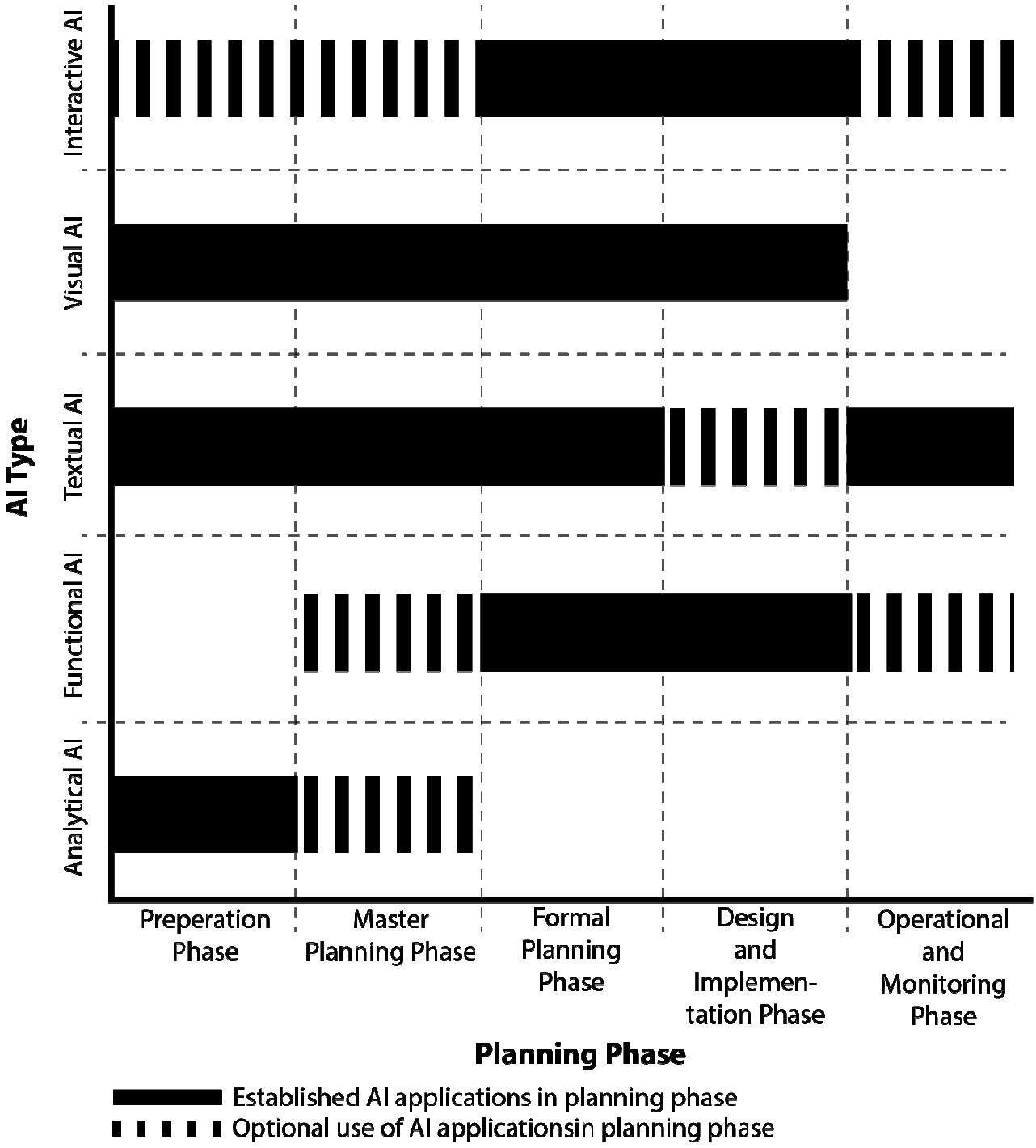

Fig 1: Use of AI Tools in different planning phases. A proposal by Othengrafen et al. 2025 for "the use of AI tools related to urban planning in different planning phases". Source: Own illustration based on Othengrafen et al. (2025).

Rural areas, in particular, face critical challenges that demand planning support tools capable of accurately estimating the outcomes of decisions and their complex interactions. As the need for sustainable development becomes increasingly urgent, robust methods leveraging ML can offer insights into soil quality, land-use changes, and the role of natural structures as nature-based solutions (NBS). The method by Forster et al. (2025) plays an interesting role in this context and will be examined in more detail in this paper. Forster et al. investigate how existing planning regulations have influenced the spatial distribution of land use, with a particular focus on green spaces in settlement areas. To achieve this, a finely structured analysis of current land distributions and their underlying planning regulations is conducted. Based on this analysis, a test dataset is created for a machine learning model. This model aims to predict the impact of "new" planning regulations on soil sealing and land distribution patterns (Forster et al., 2025). In Othengrafen's classification, this form of AI application would be characterized as "Functional AI."

2.3 Main Planning Processes in Municipalities in Austria

Local spatial planning in Austria is based on three central planning instruments: the local development concept, the zoning plan and the development plan. A good overview of the instruments is provided by Stöglehner (2023). Here is a brief summary:

The local development concept (ÖEK) is the strategic guiding document of a municipality and defines the long-term development goals for the next ten to fifteen years. It is not directly legally binding for citizens, but serves as a basis for further planning. The concept defines which areas are earmarked for settlements, commerce, transport infrastructure or nature conservation and is based on sustainable and functional development principles.

The zoning plan (FWP) is a binding instrument that regulates the use of all land in the municipal area. It divides the entire municipal area into various zoning categories, including building land, transport areas and grassland. The zoning plan must be based on the specifications of the local development concept and can only be amended by a municipal council resolution. The federal state is the supervisory authority and monitors the legal status of the plans, but has no authority to shape their content.

Finally, the development plan (BP) regulates the specific structural use of individual plots or sub-areas within the building land. It determines, for example, how high and in what way buildings may be erected, where building lines run or which design specifications must be adhered to. The development plan is directly legally binding for property owners and ensures that construction projects are in line with the overarching plans of the municipality.

The spatial planning laws of the federal provinces stipulate how local development concepts, zoning plans and development plans must be drawn up, amended and approved. Supervision of the municipalities is also the responsibility of the federal provinces, which ensure that municipal spatial planning is in line with overarching provincial objectives. Together, these three instruments form a graduated planning structure that ranges from strategic development and large-scale utilisation allocation to detailed building specifications.

Small and medium-sized municipalities in Austria face several challenges in spatial planning. They often lack financial resources and expert staff, requiring external planners. Coordination with authorities, neighboring municipalities, and citizens can be time-consuming, especially for zoning plan changes. While some municipalities struggle with depopulation and vacant buildings, others must rapidly develop residential and commercial areas. Conflicts often arise between economic development and environmental protection. Many municipalities rely on investors, which can hinder sustainable planning. Stricter environmental regulations and climate protection measures pose additional demands for future-oriented spatial planning.

Although the three instruments have different focal points, time horizons and spatial scales, they are subject to ‘similar’ processes in terms of content, which can essentially be divided into these (very simplified) phases:

(1) Inventory and problem analysis

(2) Design phase

(3) Determining a decision and finalising the design

(4) (Public) Review phase

(5) Approval and enactment of the planning resolution

We now examine the application case proposed by Forster for further research questions. We primarily place the applications of such an "impact prediction tool" in the (iterative) design phase (2.). However, the necessary data collection and processing are certainly also part of the inventory (1.).

3 PREDICTING THE IMPACTS OF PLANNING REGULATIONS

As already outlined in Section 2, Forster et al. (2025) demonstrated how ML models can be used to generate concrete predictions, for example, regarding soil sealing rates or the distribution of specific land types. The training data consists of detailed land use analyses combined with existing planning and zoning regulations. However, the practical application of this approach is still pending. Figure 2 illustrates the basic concept behind the demonstration example. The correct classification of areas and spatial objects is crucial for this type of supervised machine learning. In Austria, numerous attributed vector datasets are already available for similar types of research questions. However, the quality of these attributes, particularly in terms of completeness and accuracy, still has room for improvement.

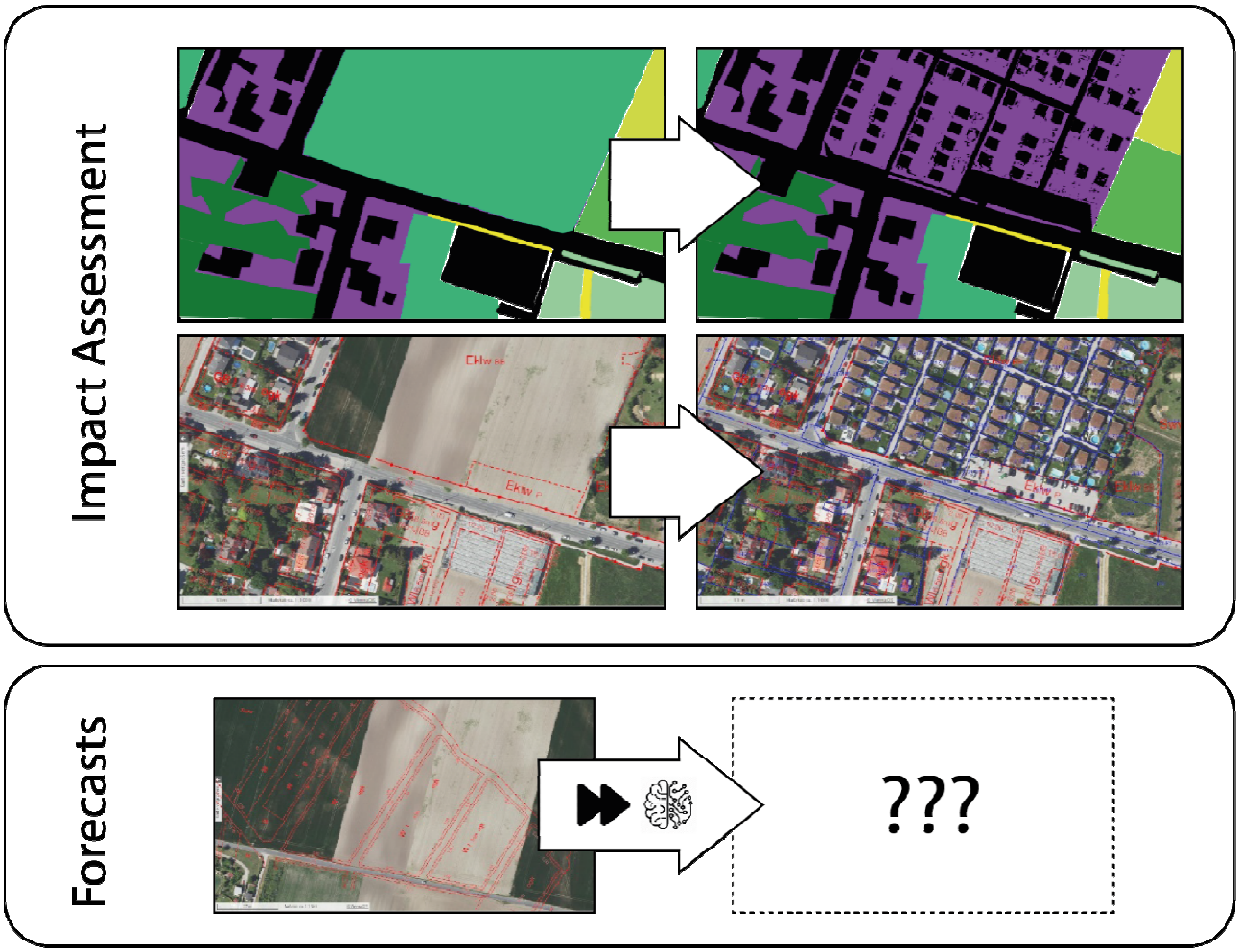

Fig 2: Schema of methodological concept of impact assessment and forecasts of planning decision using ML models as proposed by Forster et al, (2025), own illustration.

The following two examples illustrate the issues addressed in the impact assessment:

1. Impact of zoning changes on specific land uses and distributions (paved areas, green areas, development areas). Analysis of the development of existing dedicated areas, derivation of characteristic values, historical analysis of building files with regard to the time of dedication or time of development. Application: Compare the impact of the dedication of different areas/land use categories on the land balances.

2. The impact of building regulations: Similar to land use planning, ML models can be used to test and predict specific indicators. However, it is important to ensure that the classification of existing data is as accurate and correct as possible and that previous planning decisions are processed as fully as possible. As shown in Figure 2 above, the “before” situation is recorded in the training data and the areas are evaluated

qualitatively and quantitatively. The same process is carried out for the “after” situation. These data form the “ground truth” or the basis of the ML dataset. These data are used to train ML models. As new planning variants emerge, they can be analysed with the ML models to predict which “after” situations will result from the plans.

These planning games only make sense if concrete actions and checklists for planning are generated from these historical trends and findings.

Large cities such as Vienna are already working on accelerating and improving certain planning procedures using algorithm-supported processes based on digitally available building regulations. In the future, submission documents for building projects will be subject to automated checks.

In order to transfer such methods into planning practice, it is important that planning regulations are also mapped in digital, geocoded data formats (2D and 3D) in the future to enable computer-aided evaluations. When transforming existing regulations and data, AI can help to derive processable data from historical datasets in a variety of formats by implementing textual and verbal planning regulations in digital geometries. This could be implemented in a process chain involving different types of AI (analytical, textual, functional). However, the processing for a single small or medium sized municipality is rather difficult due to the small number of cases and the amount of data. In this case, an inter-municipal association or, better still, a national initiative would be more appropriate to achieve more reliable results.

4 DISCUSSION & OUTLOOK

The use of these specific algorithms for impact prediction appears to be technically feasible across all three instruments of local spatial planning for the early detection of effects and interactions. The most promising application seems to be in the area of zoning regulations, as each developed property in Austria represents a potential entry for a test dataset. Predictions regarding land-use changes based on modifications to the local development concept (ÖEK) are likely to be less meaningful due to the limited number of cases available in the training data.

The use of other AI types (see Othengrafen) in the many other areas of spatial planning can be made efficient and useful for municipalities even without large quantities of high-quality data. ML approaches enable impact prediction based on impact assessment of past regulatory frameworks. Within planning processes, ML-based analysis and predictions allow informed decisions to be made that have analysed future effects and interactions and take holistic considerations into account.

The new automatable, machine-assisted capabilities require a reconsideration of rigid, linear planning processes, where temporal aspects and dynamics are only limitedly considered in the evaluation of planning options. Simulating planning variants and scenarios presents a great opportunity to make more sustainable and future-oriented decisions. Engaging with this topic both conceptually and on a data level leads to the following positive outcomes:

(1) Quantitative and qualitative "land inventory" for the municipalities. That data can act as a future planning basis.

(2) The process creates reliable data on the impact of planning regulations on the future quality of land and the environmental impact and climate resilience

(3) The process fosters reflection processes on previous planning

(4) And supports a transfer of expertise for climate-resilient planning to the decisions makers and involved stakeholders.

It definitely changes the role of planning, as it is all the more required to help interpret the data and draw the right conclusions for future measures and solutions. Therefore, the ARL’s recommendations for action, particularly in the area of capacity building and cooperation, should be implemented at least across municipalities, ideally across federal states or even nationwide.

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Making Space for Work in Urban Growth: The Case of Zaanstad Municipality, The Netherlands

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1 ABSTRACT

An Austrian architect and senior strategist shares his insights from his experience in the Netherlands. His case study describes how municipalities can make space for work within the tension of addressing urgent global transitions, using the Urban Development Plan until 2040 of Zaanstad municipality called "Making Space" as an example. Zaanstad is a Dutch city next to Amsterdam and her 170.000 inhabitants will rapidly grow with 25% in the coming fifteen years. Their spatial vision, entitled "Making Space", focuses on growth with quality within the existing built environment: a "no-net-land-take" urban development plan. The vision establishes five basic principles: 1. Climate-adaptive design; 2. Promoting walking, cycling and public transport; 3. Developing space for work within the city; 3. Embracing energy transition and, as a 5th principle: Investing spatially for social return. The urban development plan emphasizes nature-inclusive design and attention to biodiversity and climate adaptation are the foundations for a prosperous urban development.

This paper stresses the importance of developing space for work within the urban weave. As the cradle of Dutch industry, Zaanstad has a history with more work than housing. In recent years, old factories have been transformed into purely residential areas – while keeping employment within reach would have been important. The aim of the spatial vision is to reserve substantial amounts of space for work in all new urban developments. This is not self-evident in the Netherlands, because the business model of constructing houses is much more attractive in the short term. On the other hand, realizing space for work in the city contributes to fewer commuters, better use of public transport and a better work-life balance in the entire metropolitan region around Amsterdam, of which Zaanstad is a part.

The vision "Making Space" proposes intensifying peripheral industrial estates (where 20% space can be gained), adding space for work in currently monofunctional residential areas and dedicating 30% of all new surfaces to work in new transit oriented developments around stations. The paper also hints on appropriate planning strategies and instruments such as building codes and zoning. The vision entails that jobs come closer, become more accessible to less privileged residents contributing to equity, and commutes decrease. Spatial quality and the quality of life in the city increase, and the ecological footprint becomes smaller. Drawing up the vision was a long and complex process. But it was freshly adopted at the end of 2024. This case shows that future-proof urban development is also possible in medium-sized cities through discussion, integral cooperation and a long-term approach

Keywords: spatial planning, land use, economy, work, combining functions

2 SHARING KNOWLEDGE AND LEARNING TO THINK ACROSS BORDERS

2.1 Learning from medium sized cities

This paper is a case study by an Austrian architect and senior strategist who studied in Vienna and Delft and worked half his life in the Netherlands. This case brings an interesting combination to Graz, to a conference on urban development for medium-sized cities in which global urgencies and growth are taking hold. This paper is about making space for the current global urgencies, such as climate adaptation, mobility and energy transition, but focuses on the need to make space for work within the city. It presents a case from Zaanstad, a rapidly growing medium-sized city of 170,000 inhabitants in the Amsterdam Metropolitan Area, that will grow more than 25% within the next 15 years. More about that later. This paper is not about the architectural design of buildings, but brings food for thought about architectural and strategic thinking in systems and transitions to this year's REAL CORP conference. At the same time, the case of Zaanstad shows that second and third tier cities can also make an important contribution when it comes to qualitative growth, flexibility and innovation.

2.2 Mandatory thinking ahead to 2040 and beyond

In the Netherlands, with the introduction of the Environment Act ("Omgevingswet") on January 1st, 2024, it is mandatory for all governments to draw up a vision on the physical living environment that looks ahead until 2040. This applies to all 342 municipalities in the Netherlands, such as Zaanstad, but also to the 12 Dutch provinces and even the Kingdom as a state (17 million inhabitants). In practice, many smaller cities hire a consultancy firm to write such a vision, often due to a lack of staff. In Zaanstad, it was decided to write the vision in-house, and to tackle it thoroughly. In earlier years, the city had worked with smaller spatial plans aiming to relieve the housing shortage in the densely populated West of the Netherlands (the "MAAK.Zaanstad" programme). The vision "Making Space" is the first urban development plan that encompasses the entire municipality of 83 km2 (of which 50% are open landscape), and for a long term: until 2040 and beyond. The thorough approach of the municipality of Zaanstad for this vision included testing the vision by means of an environmental impact assessment ("milieu effect rapportage", MER). This assessment was then double-checked by the national MER committee. This paper is also brought to the attention of the REAL CORP conference audience because that MER committee stated in its explanation that this vision is one of the best of its kind in the Netherlands. So there were plenty of challenges, but also smart strategies that are worth sharing.sagittis non. Nulla id turpis vel leo cursus vulputate. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas.

3 MAKING SPACE FOR TOMORROW

3.1 Urban growth with quality

Zaanstad gave its vision the title "Making Space" in the last phase of its conception. The title indicates that the vision does not intend further urbanisation and sealing green fields, but focuses on creating space for qualitative growth within the current built environment: a "no-net-land take" urban development. This is special for two reasons. Firstly, such an approach requires clever design solution and coordination with many stakeholders; it is therefore not the "easy way". Secondly, the Dutch national government had a rather pragmatic and short-sighted vision: growth, according to them, was "adding just another street" ("straatje erbij"). However, the current housing shortage with waiting times of up to 14 years for an apartment in Zaanstad represents a fundamentally different urgency, which also requires a fundamentally different strategy, and thinking for a longer time frame than an election period.

3.2 Five principles address global urgencies and transitions

Housing shortages and exploding apartment prices in the Amsterdam Metropolitan Area are just a few of the urgent developments to which the vision "Making Space" must provide answers. In a country below sea level (100% of Zaanstad is below zero, and the soft peat soil is continuously subsiding), climate adaptation is one of the greatest urgencies. In addition, the region requires answers to a whole range of other urgencies; the road network is already overloaded and requires a mobility transition; the dependency on gas from abroad and the stop of domestic gas extraction in the Netherlands (Groningen) require an energy transition, also due to the sustainability ambitions, the nitrogen crisis and the war in Ukraine. The ageing society makes the healthcare system unsustainable in the long term, which requires a transition for healthcare. The poor water quality in European comparison, or the radical decline in biodiversity have not been mentioned then. In short, there are many reasons for more future-proof urban development. The vision "Making Space" tries to find answers to these urgencies and necessary transitions. With regard to the spatial factors, five principles have been drawn up, which form the heart of the vision. These will now apply always and everywhere. These five are: 1. Designing space invitingly, green-blue and climate-adaptive 2. Making way for walking, cycling and public transport 3. Further developing space for work within the city 4. Taking initiative in the energy transition, and last but certainly not least: Principle number 5. Investing spatially to yield social returns. These five principles have been developed by talking to residents, entrepreneurs, social and institutional partners in the city and the region. The authors of the environmental vision, held spatial ateliers to draw together, and during covid-19 there were interactive webinars. As soon as it was allowed again, the writers went into the neighbourhoods to talk to the citizens. Together they looked for "Key Projects", clearly defined areas where a major contribution to the qualitative growth of the entire city could be concentrated. Ultimately, fourteen of these areas were pointed out; but it was also discovered that some ambitions were actually needed everywhere, not just in a specific area; from these ambitions the five principles of the spatial

vision have been developed. Today, there are even t-shirts with these five principles printed upon them. The alderman for Spatial Planning even wore such a shirt during the debates over the vision in the town hall.

4 ZAANSTAD, A CITY OF WORK

4.1 The ecosystem as the base for sustainable development

The vision "Making Space" is extensive, with many maps, artist impressions and photographs of municipal Natura 2000 areas on display. It does not make sense to try to discuss the entire vision in a concise paper. It would be obvious to explain the principle number one of "green-blue spaces" in more detail. Nature inclusivity helps to build a solid foundation, as the "wedding cake" model of the sustainability goals of the United Nations (UN SDGs) drawn by the Stockholm Center of Resilience shows. A strong and stable ecosystem is the prerequisite for future-proof development. In the Netherlands, attention is now being paid to biodiversity and climate adaptation; that is also necessary in a country below sea level. What we can learn from this process, is that conversations about complex topics are possible, also with a wide range of stakeholders and supposed opponents. People learn from each other and come up with practical and applicable solutions. They do that for the benefits generated for the planet, the economy, real estate value, for a positive impact on health, even for more safety against climate disasters; and that's a good thing.

4.2 A city with a tradition of working and industry

For the REAL CORP audience, this paper zooms in on another Zaanstad principle, namely the "development of space for work within the city". Why is that necessary? How do you make space for work? And what does making space for work require in developed countries, in the European Union? These aspects are particularly relevant for medium-sized cities, such as Zaanstad, because their organizations are large enough to shape such a transition, but also small enough to be flexible and innovative. In an overarching sense, making space for work concerns the balance of functions. This entails not only spatial aspects, but also aspects of a larger ecologic and economic system. Let's start with a brief description of Zaanstad. From a tourist perspective, the Zaanse Schans is an international top attraction. This collection of historic windmills along the Zaan river is destination number five according to internet searches for the most important sights in the Netherlands. What makes this open-air museum so interesting (apart from the 2.5 million visitors per year) is its history. It is the remnant of the once more than one thousand mills that stood in the region. The wind-powered mills were used for all kinds of things: paint pigment, mustard seed or grain were ground, wood was sawn and of course water was pumped. All in all, the region was perhaps the cradle of European, and certainly the Dutch industry; easy supply and removal of goods via the river, and plenty of entrepreneurship and free wind energy made the area of today's Zaanstad a concentrated industrial estate. After the transition to steam engines, large factories and industrial estates arose along the river Zaan. Until a few decades ago, there were probably more jobs than houses in the city. Locals traditionally went to live right next to their mills and factories. Without any objections and close to your work! For a period Zaanstad was the main working city of the Netherlands, and generations of local citizens called "Zaankanters" worked in the industries, from cleaners to machinists and directors. The industry today has a strong focus on "food", vegetable oils, and almost all cocoa that is processed in Europe comes from Zaanstad (next to Antwerp). Verkade is a well-known chocolate and biscuit brand. And of course, Albert Heijn Delhaize, an international supermarket chain, has its origins in Zaanstad.

4.3 Work got pushed out of the city

In recent years, factories have merged, modernized, relocated or sometimes completely failed to keep up with the times and therefore went bankrupt. And like everywhere else, in Zaanstad too, the economic focus is shifting from the manufacturing to the service sector. For decades, old factory sites, warehouses and business premises were transformed into residential areas. The demand for houses in the region around Amsterdam is enormous. Zaanstad is easily accessible by motorway and has six train stops, a legacy of the sub-municipalities that merged exactly 50 years ago to form the "City on the Zaan": "Zaanstad" is an invented name from 1974. In Zaanstad, as in other cities, work was removed from old port areas and densified city centres, shifting it from the heart to the edge of the city; in Zaanstad, the work moved towards the North Sea Canal. In Amsterdam towards the sea; and in Rotterdam, new land was even reclaimed in the sea, approximately 42 km by car from the old location in the city centre. The example of Rotterdam shows,

moving work to the edge of the city involves considerable distances and many additional transport movements, certainly for employees. But in the densely populated West of the Netherlands today there are no “edges” left where work could be moved towards. On the contrary, in the Amsterdam Metropolitan Area, there is demand for hundreds of hectares of industrial estate. Transformation of the green landscape is not an option; these are often protected European Natura 2000 areas. Apart from the breeding grounds of the national bird, the black-tailed godwit, the open landscape in Zaanstad is also the basis for the well-functioning ecosystem, and a much-needed recreational area in the immediate vicinity, also for people on a tight budget (of which there are plenty in Zaanstad).

5 MAKING SPACE FOR WORK IN CITY

5.1 Good reasons why to make space for work

As we see from the huge demand it is necessary to make space for work. But how? The colleagues at the city hall in Zaanstad would prefer that 30% of the newly developed surfaces is intended for work. A wish that can easily be understood, if you see that the balance of employment compared to living space has become skewed due to the focus on transformation into residential areas in the past years. This happened of course also because in the urbanized area of the Dutch Randstad, where Zaanstad is located, developing homes is financially much more attractive than developing space for work. The quick money is in the construction of homes. Price hardly matters, let alone quality: prices of homes are regularly outbid, and an average home in the Netherlands already costs 420,000 EUR in 2024. In the West of the Netherlands, that price is almost half a million now, and out of reach for many. Building houses remains necessary, but building only homes is not enough. It offers comfort to administrators and developers, but it is short-sighted. In fact, nobody wants cities to grow monofunctionally, but qualitatively. In such a way that employment remains in the city, and more jobs are added. Not only affordable housing, but also affordable business space is necessary. In the ideal city, there is also space for work nearby, in addition to amenities and greenery. Employees do not have to commute long distances. You can walk, cycle (certainly with a comfortable e-bike) or take public transport to work, perhaps even reachable within 15 minutes. That is not only a desirable vision of the future. There is also no alternative: The car-based traffic system has already reached its limits, not talking about sustainability or emissions, but simply about the traffic volume of the cars itself. The regional transport authority has calculated that one of the major access roads to Zaanstad can handle the car traffic of one thousand additional homes. And we know that there are already 16,000 homes on the drawing board. So there is another transition required besides the mobility transition: making space for work.

5.2 How do you practically create space for work in the city?

The goal of making space for work is of course not mainly to prevent a traffic collapse, but also to contribute to an attractive economic and social ecosystem. Developing cities with quality, where high spatial quality goes hand in hand with the quality for a working environment in order to promote an attractive business climate, innovation and inclusiveness. This ensures an economic ecosystem that is ready to anticipate upon the upcoming protein transition, and all the other transitions and innovations, which we can now only suspect are coming. From the perspective of the design of the physical living environment, the further development of Zaanstad this means making space for work by a couple of practical steps: Firstly, on a larger planning scale this can be done by welcoming companies from future-proof sectors of the industry. Secondly, when it comes to planning tools for a plot, it is necessary to include not only maximum but also minimum building heights in urban development and, for example in zoning plans. Thirdly, in industrial estates this means not only allowing maximum nuisance contours, but also allocating companies that actually need the contours for these emissions. By allocating “the right company on the right spot” 20% extra space can be created, according to the experts from the economic department. Fourthly, on the architectural scale, space can be created by stacking functions. Better use of space, by densifying, and a higher Floor Space Index (FSI). For example: Solar cells above a roof top parking lot on top of offices placed above a manufacturing hall. Developing stacked, sustainable and flexible business complexes will be the building type for work for the future.

5.3 In which parts of the city a focus on work is feasible

In addition to the five basic principles, the vision "Making Space" also lists a number of concrete "key projects" that contribute to qualitative growth with an emphasis on work. Firstly, this means, for example, that peripheral industrial estates will not be transformed into residential areas, but that employers and business owners will have the certainty of doing business there and to be able to invest for the next 25 years. So the vision is making a transformation possible, but then within industrial estates from an FSI of 0.6 to an FSI of 2: more square meters of work on the same plots. And more sustainability. Secondly, in existing monofunctional residential areas, work is added according to the new urban typology of the "productive neighbourhood". This new form of development combines living and working. This can be done by reorganizing ground floor parking in built form, topping up lower buildings and by doing so realizing affordable business space in the central areas of the neighbourhoods. Thirdly and finally, the locations around the six train stops that have been largely neglected up to now will be redeveloped. They will become destinations where easily accessible space for living, working and facilities come together. This includes housing, shops, restaurants and hotels, but certainly also co-working, small scale and innovative manufacturing and easily accessible office locations.

6 CONCLUSION

The reactions upon this spatial vision from local and regional partners were mainly positive. Parties such as the housing corporations want to actively participate in learning how to work with the vision. It took three exciting evenings in which the vision "Making Space" was discussed in the municipal council. One thing stood out: for one politician the vision was too detailed, and for another too general. For yet another, it was a vague mirage, and for their opponents not visionary enough. All in all, the vision was pulled into all directions, but did not move in any particular way. Such long evenings are part of the political game, which anyone who works for government will recognize. But it also meant one thing: That the direction of this spatial vision was right in the middle of all party politics, and therefore in fact their common denominator. Just before Christmas 2024, the vision was adopted. That moment of joy was the concrete reason to write this paper. Because if the medium-sized Zaanstad can work integrally, think of the long term and come up with a vision for future-proof urban development, if this city can involve many stakeholders and finally thirteen local political parties embrace the vision … in short: If a medium-sized, poor city like Zaanstad, where the ground is literally disappearing from under your feet, can make a truly sustainable urban development plan: Then it can be done elsewhere too. If we can do it, so can you!

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Reclaiming Public Space: Traffic Areas as a Game Changer for Future-Oriented Urban Planning

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1 ABSTRACT

This paper investigates the transformative potential of reclaiming urban traffic areas for sustainable urban planning. It examines the historical dominance of car-centric planning since the mid-20th century and its impact on mobility, urban spaces, and environmental sustainability. Addressing challenges such as mobility poverty and greenhouse gas emissions, the study highlights the critical role of reallocating public spaces from vehicles to human-centered uses to promote social cohesion, inclusivity, and ecological resilience.

Case studies, including Barcelona's "superblocks" and Copenhagen's cycling infrastructure, illustrate successful interventions that improve public health, reduce emissions, and support biodiversity. The findings emphasize the necessity of integrated policies – such as compact urban development, congestion pricing, and multimodal mobility – combined with community engagement to create resilient, inclusive, and sustainable cities, aligned with the United Nations Sustainable Development Goal 11.

Keywords: Sustainable Urban Planning, Mobility Poverty, Car-Centric Infrastructure, Human-Centered Design, Environmental Resilience

2 INTRODUCTION

2.1 The car's victory lap

Cities and towns are built environments where individuals live, interact, and engage in social activities. For centuries, the city center was the focal point of these interactions. However, since the 1960s, this dynamic has shifted. Economic prosperity in the Western world enabled widespread car ownership, and the automobile gradually became the dominant mode of transport (Newman, 2015). Urban spatial planning adapted to accommodate this transition. Cars, requiring significantly more space than walking, cycling, or public transportation, created spatial constraints within cities. The built environment, particularly building facades, could not easily be altered to accommodate new mobility demands. Consequently, public spaces were redesigned, prioritizing cars over pedestrians and cyclists. This reallocation diminished urban attractiveness and degraded the social quality of cities, transforming public spaces into traffic spaces (Gehl, 2010).

2.2 The research question

This critical analysis culminates in the formulation of the central research question that underpins this paper: "How can urban planning be reimagined to transform public spaces from car-oriented infrastructure into social interaction spaces that prioritize the needs of pedestrians, cyclists, and community engagement, and what are the social, environmental, and political benefits of such a transformation?"

This research question is designed to address both the practical and theoretical dimensions of urban reconfiguration. It seeks to explore innovative strategies and frameworks that can enable a paradigm shift in urban planning, transitioning from a focus on vehicular-centric infrastructure to the creation of inclusive, human-centered public spaces. The question further aims to evaluate the multifaceted benefits of this transformation, with a particular focus on its social, environmental, and political implications.

2.3 Historical Context of Mobility and Urban Development

Human mobility has historically shaped urban development. The invention of the wheel expanded transportation possibilities, allowing goods and people to traverse distances beyond walking (Mumford, 1961). The industrial revolution and the advent of steam engines and electricity introduced trams and trains, enabling urban expansion along transportation corridors (Hall, 2002). The automobile, however, facilitated unrestricted mobility, leading to urban sprawl in all directions (Newman et al., 2017).

Mobility, while essential for accessing basic functions, is not a primary human need as defined by Maslow's hierarchy. It supports foundational functions identified in Dieter Partzsch's Daseinsgrundfunktionen, which include living, working, provisioning, education, and recreation (Partzsch, 1961). These categories outline the essential demands on human habitats. Since spatial planning cannot concentrate all basic functions within a single area, mobility becomes a necessity, connecting individuals with locations where their needs can be met, such as workplaces, educational institutions, or recreational facilities. Therefore, it can be concluded that mobility is not a direct need in itself – almost no one travels just for the sake of traveling; it is always connected to one of the basic needs.

2.4 Mobility Poverty: An Overlooked Challenge

Mobility poverty, defined as the lack of access to adequate transportation, represents a critical barrier to societal participation, particularly for vulnerable populations. It arises from various factors, including physical disabilities, economic constraints, and infrastructural inadequacies such as limited availability of public transit during off-peak hours (Lucas, 2012). The effective application of urban planning is essential to mitigate mobility poverty and ensure equitable access to transportation.

In Austria, low-income households are disproportionately affected by traffic-related externalities, such as air and noise pollution, despite being less likely to own or use cars. For example, 44% of households in the lowest income quartile do not own a car, compared to just 9% in the highest income quartile (VCÖ, 2023), as illustrated in Figure 1. This disparity underscores the intersection of economic vulnerability and mobility poverty. Approximately 17.3% of individuals in private households – equivalent to 1.5 million people – were classified as being at risk of poverty or social exclusion in 2021 according to EU definitions (Klima- und Energiefonds, 2024).

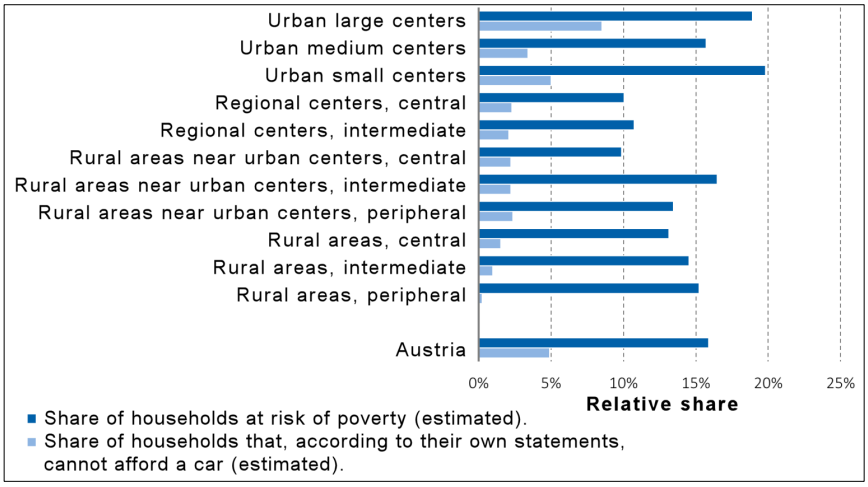

Fig. 1: Share of households at risk of poverty and share of households that, according to their own statements, cannot afford a car. Source: Modified based on (Klima- Und Energiefonds, 2024).

The lack of affordable and sustainable transportation options intensifies the challenges faced by economically disadvantaged groups, exacerbating existing inequalities. Urban sprawl, driven in part by the relocation of essential services such as supermarkets to suburban or peripheral areas, plays a significant role in perpetuating mobility poverty. These developments not only alter shopping behaviors and increase greenhouse gas emissions but also degrade the social fabric and reduce the quality of life in affected communities. The peripheral placement of services weakens the functionality and appeal of city centers, particularly in terms of local provisioning. Low-income households are disproportionately impacted by this shift, as alternative transportation modes such as walking and cycling become less viable due to extended distances and insufficient infrastructure. Consequently, these groups become increasingly dependent on motorized transport, which imposes additional financial burdens and further restricts their ability to participate in social and economic activities.

Thus, people cannot fulfill their basic functions if travel is required and transportation is unavailable. Rural areas are particularly vulnerable, given their sparse transportation infrastructure. While realized mobility – quantified through transport data – is well-documented, unmet mobility needs are harder to measure and require comprehensive surveys (Pyrialakou et al., 2016) and is therefore, most often not paid attention to in

traffic planning. Addressing mobility poverty demands inclusive Sustainable spatial planning and equitable mobility solutions.

3 SUSTAINABLE URBAN DEVELOPMENT

3.1 The Role of Mobility

Sustainable Urban Development is the process of designing and managing urban, rural, or organizational development in a way that meets present needs without compromising the ability of future generations to meet their own (United Nations, 1987). Sustainable development must be pursued in urban planning and is often framed through the "three Ps" – people, planet, and profit – first articulated by (Elkington, 1997). Nowadays it is known as environmental conservation, social equity, and economic viability as its core principles. Sustainable planning emphasizes efficient resource use, renewable energy integration, biodiversity preservation, and inclusive community engagement. (Campbell, 1996) Therefore, urban sprawl should be minimized in favor of compact, mixed-use developments, to reduce commuting distances, the promotion of public transit over car dependency, and the integration of green spaces to enhance quality of life and mitigate climate change. The Paris's "15-minute city" model aligns with this principle, which promotes local accessibility and reduces car dependency (Moreno et al., 2021).

For mobility, the three Ps mean that mobility should only be offered if it is economically viable. Public transport often struggles to operate cost-effectively or profitably, so it is partially funded by society. How much of the general budget can and should a state contribute here? Furthermore, it is important for society to have a choice of transportation modes that minimizes mobility poverty without creating excessive costs. Currently, the most important P is the environment. The environmental implications of transportation are significant. In Austria, the mobility sector accounted for 28% (20.62 million tons of greenhouse gases) of greenhouse gas emissions in 2022, predominantly from passenger cars and freight transport. Emissions are mainly caused by cars and road freight transport (vehicles weighing 3.5 to 38 tons), 11.98 and 6.56 million tons of CO_2 equivalents, respectively. Car emissions increased by 4.9% from 2021 to 2022, while freight transport emissions decreased by 15.8%. (Federal Ministry for Climate Action, 2023). A modal shift toward sustainable transportation, such as walking, cycling, and public transit, is essential. Although public transit has higher total emissions compared to individual cars, its per-person emissions are substantially lower due to higher passenger capacity (International Energy Agency, 2021).

Cars are thus one of the largest contributors to greenhouse gas emissions, which must be minimized. To reduce these emissions, the following recommendations apply to mobility: avoid mobility, shift mobility to environmentally friendly modes, and, if the first two are not feasible, improve or clean the car – shared cars or new types of propulsion, such as electric driving.

Avoiding mobility is often not possible. As mentioned earlier, mobility is not a need in itself but ensures that basic human needs can be satisfied. Information technology allows certain functions to be decoupled from a location, such as streaming services that enable people to watch movies at home instead of going to the cinema. The same applies to home office work. You no longer need to travel to work but can work from home. Direct mobility in public space is thus avoided. However, this does not mean that people are not mobile. Mobility occurs through data transmission, where data is moved instead of people. Consequently, fewer people are physically on the move, but infrastructure (internet cables) and energy are still consumed.

The best option is to change the choice of transportation modes away from cars to more sustainable modes, such as walking, cycling, or public transport, which have higher emissions than cars but lower emissions per person and kilometer due to higher occupancy rates. According to (VCÖ.b 2023), every tenth car trip covers a distance that can be walked, and four out of ten car trips are shorter than 5 kilometers and can be easily covered by bike. Active urban planning can increase the number of short trips and the attractiveness of sustainable transportation modes. In urban planning, this means counteracting urban sprawl – building on greenfields – and promoting the densification of urban structures. Increasing functional diversity is extremely important, meaning that in addition to living, other basic needs can be met within a short distance, such as working, education, green and recreational opportunities, and local supply structures.

3.2 Optimizing Urban Design for Sustainable Mobility

For a city, this means that vertical urban planning – building upwards – becomes more important than horizontal urban planning – large-scale built areas with low density. However, the goal is always to create as much functional diversity locally as possible. In some Asian cities, there is high-density urban sprawl defined by residential blocks for monofunctional use of largely identical units clustered in isolated superblocks. Other life needs are not locally available, and people must travel to other locations to satisfy them. (Calthorpe, 2025) Offering a mix of functions within walking or cycling distance can ensure that sustainable transportation modes are chosen.

Walter Christaller's central place theory provides a framework for structuring urban areas. Functions catering to daily and weekly needs should be localized, while less frequent needs, such as cultural or administrative services, can be accessed through efficient public transit systems (Christaller, 1933). This hierarchy encourages multimodal mobility, combining walking, cycling, and transit as primary modes, with cars reserved for secondary roles, such as shared or electric vehicles.

4 RECLAIMING PUBLIC SPACE: SOCIAL AND ENVIRONMENTAL BENEFITS

The reallocation of urban spaces from vehicles to pedestrians, cyclists, and other human-centered uses has profound implications for both social cohesion and environmental sustainability. Public spaces, once dominated by traffic, are increasingly recognized as vital for urban life, offering opportunities for social interactions, recreation, and cultural activities as well as enhance urban resilience, public health, and environmental quality.

4.1 Social Benefits

Reclaimed public spaces contribute to fostering social connections and community engagement. Spaces previously occupied by vehicles can be redesigned into plazas, pedestrian promenades, or parks, creating environments where people can meet, interact, and build relationships. Jan Gehl (2010) emphasizes that lively public spaces encourage "staying" activities – such as sitting, dining, and conversing – essential for urban vitality and cultural exchange. For instance, Barcelona's "superblocks" initiative, which limits traffic in certain urban areas, has led to increased pedestrian activity, reduced noise pollution, and enhanced neighbourhood cohesion (Mueller.a, 2020). The implementation of Superblocks in Barcelona is estimated to lead to an average increase in life expectancy of approximately 200 days for the adult population. Additionally, this intervention is projected to generate an annual economic benefit of €1.7 billion (Mueller.b, 2020). Public spaces also provide a platform for inclusivity, enabling marginalized groups to participate in urban life. Accessibility improvements, such as barrier-free designs and multimodal connections, ensure that individuals with disabilities, the elderly, and families with young children can benefit equally. Furthermore, well-designed public spaces support cultural events, markets, and artistic performances, enriching community life and promoting local economies.

Inclusive public spaces also ensure equitable access for marginalized groups, such as individuals with disabilities, the elderly, and families with young children. Barrier-free designs and multimodal connections expand accessibility while supporting cultural events, markets, and artistic performances, which enrich community life and promote local economies. Active community involvement is a critical factor in ensuring public spaces meet the diverse needs of their users. Studies demonstrate that public participation enhances the acceptance and sustainability of urban development initiatives (Deutscher Städtetag, 2024). For example, the "Help Shape Graz" (Graz mitgestalten) project in Austria enables citizens to participate actively in urban planning and decision-making processes (Stadt Graz, n.d.).

However, challenges remain, including ensuring balanced representation of all social groups. Marginalized populations, such as migrants, low-income households, and the elderly, are often underrepresented. Low-threshold and barrier-free participation formats, including hybrid methods combining analog and digital approaches, are crucial for broad engagement. Regular evaluation and adaptation of these processes can help align outcomes with community needs, ensuring the long-term success and acceptance of urban projects.

4.2 Environmental Benefits

The transformation of traffic-dominated areas into green spaces provides numerous environmental advantages. Urban green spaces, such as parks and vegetated corridors, effectively reduce the urban heat

island effect by lowering surface temperatures (Bowler et al., 2010). Additionally, trees and vegetation improve air quality by absorbing pollutants like nitrogen dioxide and particulate matter while acting as carbon sinks to mitigate climate change (Baró et al., 2014).

Minimizing vehicle dominance also leads to significant reductions in greenhouse gas emissions. Shifting to sustainable modes of transportation, such as walking, cycling, and public transit, lowers per capita carbon footprints compared to private car use (International Energy Agency, 2021). Further, the integration of permeable surfaces and green infrastructure improves urban water management, mitigating flood risks during heavy rainfall events (Kazemi et al., 2009).

Ecological redesigns that prioritize native plant species and wildlife habitats contribute to increased biodiversity in urban areas. Native vegetation supports a higher diversity of insects and birds, which are vital for urban ecosystems, and helps improve the microclimate while supporting climate adaptation (Tartaglia, 2024). Research emphasizes the importance of trees in reducing urban heat islands and highlights their role in public perceptions of effective climate adaptation strategies (Doussard, 2023). Policies that advance green infrastructure also enhance resilience to extreme weather events and improve urban quality of life (European Environment Agency, 2015).

These findings demonstrate that reclaiming traffic spaces for green infrastructure and active mobility provides dual benefits: improving environmental sustainability while enhancing urban livability..

4.3 Policy and Planning Considerations

A shift towards sustainable public spaces requires coordinated efforts by urban planners, policymakers, and communities. Effective policies should prioritize reducing car dependency through measures such as congestion pricing, parking restrictions, and incentives for sustainable mobility. For example, cities like London and Stockholm have implemented congestion charges, resulting in a 30% and 20% reduction in private car use, respectively (Vital city, 2024). These measures have improved air quality, reduced congestion, and encouraged a modal shift toward public transport, cycling, and walking. Revenue from such policies is reinvested into sustainable transport infrastructure, enhancing long-term urban mobility (Leihs, 2014; Environmental Administration Stockholm City, 2024).

Targeted funding programs also play a pivotal role in transforming public spaces. Copenhagen's consistent investment in cycling infrastructure, such as bike lanes and parking, has significantly increased cycling rates while reducing car traffic (C40Cities, 2016). Additionally, funding for electric vehicles and shared mobility solutions, such as car-sharing programs, supports the transition to low-emission transport and boosts public acceptance of sustainable mobility (Umweltbundesamt, 2015). These investments are crucial for achieving climate-neutral transport systems.

Urban planning initiatives must align with broader sustainability frameworks, such as the United Nations Sustainable Development Goal 11, which aims to create inclusive, safe, resilient, and sustainable cities (Bebbington et al., 2018). Evaluating reclaimed spaces through metrics such as foot traffic, air quality, and community feedback ensures projects meet environmental and social goals while allowing for iterative policy adjustments. By integrating these strategies, cities can transform public spaces into sustainable, accessible, and vibrant environments.

5 CONCLUSION

A paradigm shift in mobility patterns, facilitated by sustainable urban planning, is essential for mitigating mobility poverty, reducing environmental impacts, and revitalizing urban social structures. By transforming car-dominated infrastructure into human-centered public spaces, cities can foster social cohesion, inclusivity, and environmental resilience while addressing challenges like mobility poverty and urban degradation. Reimagined spaces for pedestrians, cyclists, and green infrastructure generate substantial social, environmental, and economic benefits, supporting the creation of resilient, inclusive, and sustainable communities.

Achieving these outcomes requires the consistent implementation of effective strategies, including congestion pricing, targeted funding, and community-driven planning, to reduce car dependency, emissions, and congestion. Successful interventions in cities like Barcelona, Copenhagen, and London demonstrate the

importance of aligning urban planning with broader sustainability goals, such as the United Nations Sustainable Development Goal 11.

Ultimately, this transformation demands a coordinated, multidimensional approach that integrates policy innovation, environmental stewardship, and active community participation. By adopting these principles, cities can enhance livability, address inequality, and pave the way for a more equitable and sustainable urban future.

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Shrinking Cities or Resilient Communities? The Future of Kuzbass Coal Towns in the Post-Coal Era

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1 ABSTRACT

Amid the global energy transition, coal-producing regions are forced to rethink their development trajectories. Kuzbass – Russia's largest coal-mining region – remains structurally dependent on the coal industry despite a growing crisis: falling production volumes, rising export risks, and weakening economic indicators. This article examines the conflicting narratives surrounding the future of coal-dependent towns, drawing on official policy documents, regional strategies, and media discourse. While the challenges facing the industry are increasingly recognized, the fate of the towns themselves – and the people living in them – remains largely absent from the public conversation. The paper argues that without explicit planning and differentiated territorial strategies, these cities risk entering a phase of unmanaged shrinkage. Territorial master plans are discussed as a potential instrument for more realistic and adaptive approaches to transition.

Keywords: Kuzbass, coal industry, mono-industrial towns, energy transition, shrinkage

2 KUZBASS TOWNS: COAL DEPENDENCE AND SPATIAL VULNERABILITY

The Kemerovo Region, also known as Kuzbass, is Russia's most important coal-producing territory. It is home to the country's largest open-pit mines and underground operations, including those owned by major companies such as SUEK, Kuzbassrazrezugol, Mechel, Evraz, and Yuzhkuzbassugol. Kuzbass accounts for over 55% of Russia's total hard coal production, including a significant share of metallurgical (coking) coal.

Historically, the region developed as a typical industrial basin: cities emerged around mines, processing plants, and rail infrastructure. Today, Kuzbass has a population of over 2.5 million people and leads the country in the number of officially recognized mono-industrial towns – 17 by status, and more than 20 with mono-profile characteristics. As of 2022, over 1.5 million residents – around 60% of the region's population – lived in such towns. According to the Ministry of Economic Development, coal and related sectors account for over 35% of the regional gross product, and in some municipalities, up to 60% of the working-age population is employed in mining. Over 80% of urban economies in Kuzbass depend on the coal and metallurgical sectors, with more than half of all coal produced in 2023 destined for export. This creates a critical exposure to fluctuations in global demand and pricing.

Such a high concentration of industry and reliance on exports has resulted in significant social and spatial vulnerability. The region is already facing a demographic decline, youth outmigration, increased social burdens, and structural dependence of municipal budgets on coal export revenues. Between 2021 and 2024, regional coal production fell from 255 to 198 million tons, leading to a sharp drop in tax revenue and the temporary closure of several operations.

Despite political rhetoric around a "green Kuzbass" and modernization, the reality remains unchanged: most local economies are still tightly bound to coal.

This economic model, centered around exports and infrastructure-dependent supply chains, makes these towns especially fragile amid global market volatility.

So far, there is no clear program for economic transformation. The regional development strategy offers no structured plan for diversification, and existing measures remain fragmented, continuing to operate within the logic of the coal economy.

This study compares official strategies, regional and municipal planning documents, media narratives, and expert commentary – all of which offer conflicting interpretations of the current situation. The aim is to identify the gap between declarations, real-world trends, and the absence of a coherent long-term strategy.

3 KUZBASS AND THE GLOBAL ENERGY TRANSITION

Despite global trends toward energy transition, 2023 marked an all-time high in global coal production: 179 EJ. Nearly 80% of this output came from the Asia-Pacific region, with China, India, Indonesia, and Australia

accounting for around 97% of regional production. China alone was responsible for over half of the global total. Meanwhile, other regions – including Europe, the CIS, North and South America – continued to experience year-on-year declines in production.

Coal consumption also reached a record high, exceeding 164 EJ. China remains the world's largest coal consumer, accounting for roughly 56% of global demand. India became the second-largest consumer in 2023, surpassing the combined coal use of Europe and North America for the first time.

Until 2022, Russia's coal exports were primarily directed toward Europe and China. However, following sanctions and the EU's coal embargo, Russia's export strategy pivoted entirely to Asia-Pacific markets. A return to European demand appears unlikely, even if sanctions were eased, as the EU continues to pursue decarbonization and a green energy transition. In 2023, Russia exported an estimated 112–115 million tons of coal out of a total 198 million tons mined. Of this, 45–50 million tons (about 43.5%) were sent to China, and 12–15 million tons (13%) to India.

The long-term reliability of China as an export destination is also in question. Despite current demand levels, China has announced plans to peak coal consumption by 2030 and reach carbon neutrality by 2060. In recent years, it has become a global leader in renewable energy, driven by both climate policy and falling technology costs. In the first 10 months of 2023 alone, China commissioned 142.56 GW of new solar capacity. For comparison, the IEA estimates that global solar additions in 2023 totaled around 375–405 GW. As of mid-2024, China had already exceeded its 2030 target of 1,200 GW in combined solar and wind capacity. By the end of 2024, solar and wind made up 42% of the country's installed power capacity.

Other importers – such as India, Vietnam, and Bangladesh – are increasing coal purchases, but they are unlikely to compensate for the loss of European and, potentially, Chinese demand. This is particularly true given competition from other major exporters like Australia and Indonesia. India, while still expanding coal use, is also rapidly investing in renewables. By the end of 2024, renewables accounted for 50% of India's installed power capacity. The country is now among the world's leaders in both solar deployment and panel manufacturing. Its energy strategy aims to increase non-fossil sources to 50% of capacity by 2030, while reducing coal's share in generation from 73% to 50%.

Across Asia, many countries continue to develop both coal and renewables. However, long-term strategies increasingly include targets to reduce coal dependence. This shift exerts structural pressure on the future of global coal exports. For coal-producing regions far from export terminals – such as Kuzbass – the outlook remains highly uncertain.

An additional domestic challenge is that Russia's reorientation toward Asian markets has been accompanied by growing state support for coal production in Eastern Siberia and the Russian Far East. New mining hubs in Yakutia, Zabaykalsky Krai, and the Taymyr Peninsula are receiving preferential subsidies, infrastructure access, and strategic backing. This raises the risk that Kuzbass may gradually lose its foothold in export flows – even within Russia itself.

4 OFFICIAL AND MEDIA RHETORIC: WHO IS SHAPING THE FUTURE OF KUZBASS?

As the coal industry faces mounting pressure from global trends and internal constraints, it becomes especially important to examine how the present and future of coal-dependent towns are articulated in public and policy discourse. How governments, experts, media, and businesses describe the situation directly shapes political priorities, budgetary decisions, and institutional readiness for change.

This section analyzes various levels of discourse – from federal strategies and ministerial statements to media coverage and expert commentary. The aim is to compare diverging narratives about the future of Kuzbass, identify which scenarios are dominant or omitted, and assess how these representations influence concrete decisions (or the lack thereof).

4.1 Federal Rhetoric: Betting on Exports Despite Losses

At the federal level, coal remains a central pillar of Russia's energy and export strategy. The official *Coal Industry Development Program to 2035* emphasizes Russia's potential to increase coal production and expand its share of the global market – despite sanctions and the loss of European demand. Coal is framed as a competitive advantage, with the strategic focus shifting toward Asian markets, particularly through new

deposits in Eastern Siberia and the Russian Far East. Kuzbass, by contrast, is mentioned less frequently and no longer holds priority status.

By 2025, however, this rhetoric began to shift under pressure from economic realities. The Ministry of Energy officially acknowledged that the coal industry was experiencing a protracted crisis driven by multiple factors: international sanctions, logistical challenges in reorienting exports eastward, falling global prices, and the structural pressures of the global energy transition. The average netback price (the price at the destination port minus transport and handling costs) fell below production costs for nearly all coal grades. In response, the ministry drafted an anti-crisis program including transport subsidies, tax deferrals, interest rate compensation, and other support measures. Although not yet adopted, the document marked a rhetorical turn – from expansion to emergency stabilization. Yet the underlying strategic logic remained unchanged: the goal is not restructuring, but preserving the export model, even at a loss.

By the end of 2024, coal became the only sector in Russia's economy to be officially classified as unprofitable – a fact that highlights both the depth of the current crisis and the institutional inertia that shapes the federal response.

The role of Energy Minister Sergey Tsivilyov is particularly significant in this context. Formerly the governor of Kemerovo Region, his appointment formally links the region's interests with federal decision-making. In practice, however, it illustrates the limits of influence. As governor, he failed to initiate meaningful structural reforms, and as minister, he continues to defend the same export-oriented model.

In March 2025, Tsivilyov stated: *"We are obliged to do everything to ensure that the coal industry in Russia continues to grow... According to the Energy Strategy to 2050, our benchmark for coal production is no less than 600 million tons per year."*

This rhetoric stands in sharp contrast to the actual situation: in 2024, total coal production in Russia amounted to around 370 million tons, and the industry posted aggregate losses exceeding 100 billion rubles, with forecasts predicting a further 10% drop in output next year.

4.2 Regional Strategies Without Strategic Change

In regional and municipal development strategies, coal continues to occupy a central place. While officials in Kemerovo Region speak of a "green Kuzbass," modernization, ecology, and logistics development, these narratives are still anchored in preserving the current coal-based model. Problems such as environmental degradation, population decline, labor shortages, and dependence on export revenues are acknowledged – yet they are not treated as reasons to reconsider the region's core economic trajectory.

An analysis of development strategies in Kuzbass's mono-industrial towns reveals a similar pattern. Even in the most vulnerable cases – such as Kiselevsk, where abandoned territories are expanding and resettlement is underway – coal remains the main and often unquestioned foundation. Diversification is mentioned, but rarely developed as an independent direction. The future is imagined as a slightly improved version of the present – with no alternative pathways and no transition to a post-coal reality.

4.3 Media Discourse

Unlike official strategies that continue to describe the coal industry in terms of growth and modernization, independent and regional media increasingly adopt the language of stagnation and systemic crisis. In sources such as VSE42, Forbes, NEFT Research, and RenEn, coal regions are portrayed as spaces of decline: mine closures, population loss, deteriorating living conditions, and declining profitability have become recurring themes.

A Forbes report, for example, depicts Kuzbass as a region where industrial infrastructure has displaced everyday life – coal dust, explosions, and the relocation of entire settlements near open-pit mines. Analysts at RenEn and the Center for Energy Development point to a declining export outlook and growing logistical barriers that make Kuzbass increasingly uncompetitive. Against this backdrop, direct statements of hopelessness are also emerging: Natalia Zubarevich, professor at Moscow State University and a leading expert on regional socio-economic development in Russia, warns against investing in coal regions, calling them economically unviable and socially unstable.

Experts broadly agree that there is no coherent federal or regional policy for transition or scenario-based planning in mono-dependent territories. Even in the most critical and independent publications – where

issues such as unprofitability, shrinking exports, and logistical bottlenecks are well documented – the fate of the towns themselves is rarely discussed.

Although the crisis directly impacts urban life and long-term prospects, it remains largely absent from public debate. Mono-industrial towns are left "offstage" – as if their decline were not a crisis in itself, but merely a side effect.

The attempt to frame this crisis not only as an industrial problem but as a spatial one – with a focus on cities and communities – helps to fill a critical gap in the current discourse. In this context, the clearest, if still fragmented, representation of Kuzbass's future emerges from independent media and expert commentary: not as a zone of growth, but as a region where the crisis has already begun – even if it has yet to be officially recognized.

Discourse Category	**Role of Coal**	**Framing of Problems**	**Imagined Future**	**Tone**
Official (federal)	Core element of energy and axport strategy; source of competitive advantage; focus on Asian markets	Not openely acknowledged or framed as temprorary / logistical issues	Export-oriented modernization without structural transformatiom	Optimistic / industrial-mobilization
Official (regional)	Key sector for employment and economy; foundation of green Kuzbass and logistics expansion	Acknowledged but not leading to a reconsideration of the model	Digitization and "green" coal without changing the underlying model	Cautiously positive / adaptive
Official (municipal)	Economic core of mono-towns; coal as the only realistic foundation	Recognized (e.g. depopulation, pollution), but addressed through sectoral improvements rather than economic diversification	A better version of the present: same coal-based structure with local upgrades	Pragmatic / inertia-driven
Independent media	Source of crisis and social pressure; object of criticism and public concern	Clearly voiced: unprofitability, stagnation, shrinking workforce, declining exports, falling competitiveness	Post-coal decline without coordination or support	Critical / concerned
Experts	Exhausted sector with no long-term competitiveness; strategic vulnerability of coal-dependent areas	Structural: vulnerability of mono-towns, lack of alternatives, state inaction	Need for a transition to a new model – not yet formally articulated	Analytical / cautionary

Table 1: Discourse Analysis Table

5 CONCLUSION

The discourse surrounding the future of Kuzbass's coal towns reveals more than just a gap between official and expert narratives – it reflects a deeper divergence in how the situation is understood. In official documents, declining production, demographic shrinkage, and logistical barriers are framed as manageable challenges. In contrast, independent media and expert commentary increasingly describe these issues as symptoms of systemic exhaustion – the result of a collision between Kuzbass's export-oriented economic model, the global energy transition, falling demand in key Asian markets, and internal structural weaknesses. No clear strategic response has been proposed to address this exhaustion.

The concern here is not only economic. It also reflects an institutional silence – the absence of any public recognition that the old model has run its course. Media sources capture not just outmigration, but a loss of belief in the future: investors are leaving, young people are moving away, and the language of "development" no longer resonates. Experts increasingly point to the lack of any meaningful transition scenario in regional strategies – only modernization efforts that avoid rethinking the fundamentals.

Kuzbass, however, is not a monolith. It is a constellation of cities with differing densities, economic structures, and resilience. In some, planned shrinkage may be appropriate. In others, continued support for viable industries, gradual transition, or targeted modernization could be viable. Elsewhere, new directions – in processing, tourism, or small business – may be more promising. But such responses require carefully developed master plans, grounded in honest diagnostics, community participation, and input from external experts. This cannot be a top-down campaign; it must be a subtle, context-sensitive process rooted in local realities.

Otherwise, the issue will not be one of transition – but of quiet, unmanaged, and ultimately irreversible decline.

reviewed paper

Towards Multimodal Mobility Hubs in Austria: Typology, Standards and Cooperation

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1 ABSTRACT

In this paper, we propose a typology of Multimodal Mobility Hubs (MMH) for Austria, set equipment standards for each of the six types and check their current provision in an explorative quantitative analysis (5 examples for each type). Finally, we argue that cooperation between a big variety of actors is needed to live up to the potential of MMH.

Keywords: multimodal mobility hubs, railway stations, transport system, spatial planning, sharing

2 INTRODUCTION

Multimodal Mobility Hubs (MMH) play a pivotal role in modern mobility systems, as they integrate different modes of transport and facilitate the transition between them. With ongoing urbanization and efficient, user-friendly and environmentally sustainable transport solutions becoming ever more important, harmonized further development of MMH is crucial. In Austria, the individual federal states and regions are at different development stages. Therefore, a comprehensive approach is needed that takes into account functional standards and cooperation models between different stakeholders to avoid inefficiencies in planning and implementation.

This paper proposes a new typology for multimodal hubs, focusing on functional standards and their application to different MMH types. Additionally, it argues for deepened collaboration between key stakeholders. The proposed typology is developed through a combination of literature review and utilizing existing categorizations of space structure and public transport in Austria. By establishing a structured approach for Austria, this study aims to provide a framework that enhances the efficiency, accessibility, and integration of multimodal transport systems.

The paper is structured as follows: Section 3 provides a theoretical background on multimodal hubs. Section 4 highlights distinctive features of the Austrian mobility and spatial planning system. Section 5gives an overview of actors that need to cooperate for a functional MMH ecosystem. Section 6 introduces the new typology, explains classification criteria and offers recommendations. In Section 7, we present the results of an explorative quantitative analysis of the status quo in Austria. In Section 8, conclusions are drawn.

3 CONCEPT AND DEFINITION OF MULTIMODAL MOBILITY HUBS

An MMH is a connection point between different means and modes of transport which also offers non-transport facilities (SVI 2013).Typically, the modes encompass public transport (railway, subway, tramway, bus...), sharing services and infrastructure for walking and cycling. The British sharing support platform CoMoUK emphasizes the modularity of the concept, in which components can be combined in different variations to meet the needs of individual locations and networks (CoMoUK 2019). In addition to transport services these components can include practical facilities like lockers, toilets, eateries; and community facilities like appealing public spaces with green and blue infrastructure or a playground. Since adaption to future development plays a key role, the modules must be flexible enough to add or remove components (CoMoUK 2021).

Success factors of MMH are a wide choice of sustainable travel modes that are physically and digitally well linked; design and facilities that create a safe public space with enough practical facilities; and a visual, social and community appeal of the MMH. Also, hubs need to be part of a clearly identifiable network with services easily accessible by all (CoMoUK 2025).

They are set up in public or semi-public spaces where there is a high concentration of workplaces, shopping and recreational facilities, such as existing public transport transfer points, multi-storey car parks, ground

floor zones or the forecourts of buildings. There are also types that are set up in private residential buildings (Möller et.al. 2018).

With their location at highly frequented places, MMH encourage both a multimodal and an intermodal travel behaviour. The term multimodality is more general and refers to the use of different means of transport on different routes at different times, while intermodality refers to using different means of transport for different parts of a single journey (Pfaffenbichler and Vorstandlechner 2016). The availability of integrated mobility options in close vicinity supports choosing the best mode for a journey and offers a low-threshold alternative to the private car as default choice. Alongside the quality of the offered services themselves, the quality of MMH is the decisive factor for the attractivity of multimodal and intermodal travel behaviour.

In his Node-Place model (Bertolini 1999), Bertolini stresses the importance of the non-transport facilities for MMH, arguing for an equilibrium between their function as a transfer point between transport modes and the spatial function of a place itself, where different needs (e.g. shopping, education, recreation, meeting point) can be fulfilled. Since traffic can be explained as a sign of a shortage at a certain place (Knoflacher 2009),MMH with diverse facilities can avoid traffic, as people do not need to move elsewhere to compensate for their deficiency. Subsequently, they fulfil a centre-forming function themselves and encourage compact settlement structures around them. Additionally, appealing facilities attract people to MMH who would fulfil their needs by car otherwise, which in turn invigorates the hubs' node function.

4 PUBLIC TRANSPORT AND SHARING MOBILITY IN AUSTRIA

In 2021, 51.1% of Austria´s population had access to public transport connections of at least "good" quality in the public transport quality grade system "ÖV-Güteklassen" (departures minimum every 40min) (ÖROK 2022). The country is EU leader in passenger rail performance (Gratzer 2024) and has the 11th densest railway network per capita among EU states, with further investments of 21,1 billion € to be made until 2029 (ÖBB Infrastruktur 2023). While those indicators already show a competitive public transport system, the share of passenger km in eco-mobility (public transport and active mobility) that amounted to 30% in 2021 should increase further to 47% according to the Mobility Master Plan 2030. At the same time, unnecessary traffic should be avoided to impede the trajectory of constantly rising passenger km per person (BMK 2021).

The last figure is agreed upon to be connected to the relatively weak spatial planning regime in Austria, that fosters uncontrolled splinter development and car dependency (Dumke u. a. 2024). The main responsibility for spatial planning lies with the 9 federal states, with competences for local spatial planning for municipalities and only limited competences in specific areas for the federal state (ÖROK 2024). While bigger municipalities are more likely to use their know-how and economic leverage to impose a stricter spatial planning regime on private investors, and more often follow the concept of transport-oriented development, smaller municipalities that lack those resources still tend to develop car-friendly new infrastructures (Zuckerstätter-Semela 2011).

5 COOPERATION

To facilitate the integration of services and assets that is the core idea of Multimodal Mobility Hubs, a wide range of fields and stakeholders must cooperate. Currently, the main actors driving the development in Austria are large municipalities, the national railway company ÖBB (ÖBB Personenverkehr 2025) and the public autobahn financing corporation ASFINAG with its Park&Drive concept (ASFINAG 2025). Currently, these actors do not have an integrated approach on the strategic level though.

In the public sector, policy instruments 1. for different transport modes, 2. involving infrastructure provision, management, and pricing, (3) for transport, spatial planning and land-use (4) regarding policy areas such as health and education need to be coordinated and aligned (May, Kelly, und Shepherd 2006). In the Austrian three-level-governance system, this requires horizontal cooperation between municipalities, the nine states and the federal state.

On the operative level, many roles and responsibilities come together in the design, implementation and operation of an MMH. While CoMoUk stresses the importance of involving all actors and clarifying responsibilities from the beginning of the planning process (CoMoUK 2021), this can be challenging in practice. Except for neighbourhood hubs in new development areas, most Austrian MMH are not designed from scratch but developed by adding new services and assets to existing public transport stations. However,

including new responsibilities to an existing scheme like the ÖBB station and property management (ÖBB Immobilien 2025) offers the advantage of a "natural" hub manager.

Depending on size and type of the hub, responsibilities can be split between municipality, public or private providers of mobility infrastructure or services, public sector services like education or healthcare available at the hub, property developers, business/industrial parks, leisure or tourist attractions or even community groups (CoMoUK 2021).

To operate and develop not only the "node" but also the "place" function of the hub, we argue for an integrated property management that exceeds the public transport station property. Assuring spatial development with an appealing mix of functions (e.g. business, health, consumption-free space) and coordinating public and private interests around the hub could be a role similar to the one of "city-centre-coordinators" established in some Austrian municipalities (Österreichischer Städtebund 2015).

Effective cooperation between those actors should lead to a physical, digital and democratic integration of the hub. The Smarthubs integration ladder (Geurs u. a. 2024) proposes universal design standards, visibility and branding; routing, booking and payment, service offers, integration of societal goals and policies, conflict-free & place making, stakeholder engagement including (vulnerable) user groups, integration of different knowledge, societal learning as highest possible level of integration.

6 TYPES OF MULTIMODAL MOBILITY HUBS IN AUSTRIA

In the United Kingdom, Switzerland and other countries, typologies of MMH have been created to take account of the range of the concept (CoMoUK 2019; Bisang, Witter, und Scherrer 2023). A typology adjusted to the national mobility system of Austria can fulfil a variety of useful functions. It allows to plan services and facilities in reference to a target system (regarding both the transport node and the place function) ; to estimate the effects of an MMH on mobility behaviour, spatial development and ecology; to estimate investment and operating costs for individual MMH or corridors; and it offers an argumentation basis for setting framework conditions in the field of mobility and land use policy.

We propose six types of Multimodal Mobility Hubs for Austria that are defined according to two criteria: The significance of the hubs transport intersection according to the Austrian public transport quality grades "ÖV-Güteklassen" (measured by the highest-ranking transport category of the stop) (ÖROK 2022), and the urbanity of the area it is located in. The latter criteria follows the urban-rural typology of Statistics Austria that classifies all Austrian municipalities in 11 types from "major urban centres" to "peripheral rural area" according to population density, commuting relations and accessibility of centres (Statistics Austria 2024). Our typology adds to the aforementioned ones by ARE and CoMoUK by not restricting itself to hubs in (sub) urban areas, but also considering rural MMH. However, we limit the typology to publicly accessible types. A possible 7th category of private MMH (in buildings and firms) is not dealt with.

6.1 Type I – Main node in major urban centres

This type represents exclusively railway main stations of the six Austrian large urban centres that have the "ÖV-Güteklassen" category I: the regional capitals Vienna, Graz, Linz, Innsbruck, Salzburg and Klagenfurt and the city-region Bregenz-Dornbirn-Feldkirch with Feldkirch as most important public transport intersection. They already provide excellent regional and national transport connections and direct international links. Their urban integration has grown historically but does not always meet modern requirements. In future, as multimodal hubs, they should enable a seamless connection between long-distance, regional and urban transport, supplemented by sharing services such as bike, scooter and car sharing as well as taxi services. Switching from motorised private transport to public transport plays a subordinate role here. The aim is to create close links with the urban fabric so that these stations not only become mobility hubs, but also vibrant urban centres.

6.2 Type II – Secondary node in major or main node in medium-sized urban centres

Apart from long distance or regional express trains ("ÖV-Güteklassen" category I), also (inter) national bus lines can be the highest-ranking transport mode at this type of hub. Secondary hubs in large and medium-sized urban centres – railway stations or (inter) national bus terminals – play an important role in Austria's regional transport network. While they already complement the traditional public transport system with sharing services, there are deficits in terms of connections for pedestrians and cyclists as well as urban

integration. In future, these stations should make it easier to switch from high-level public transport to local transport services and the 'last mile'. The switch from motorised private transport to public transport is becoming increasingly important. Close links with the city centre and neighbouring business locations as well as the establishment of centre-forming functions should integrate the railway stations more strongly into urban life.

6.3 Type III – Node in small urban centres and regional centres

Hubs of this type include railway stations for long distance or regional express trains ("ÖV-Güteklassen" category I) in small urban and regional centres that have a wide variety of functions in Austria. In addition to everyday mobility, they play an important role in the organisation of tourist route chains. Currently, on-demand transport services supplement the development of areas, but railway stations are often characterised by a certain distance from the settlement structure – a relic of historical planning patterns. The infrastructure for cycling does not meet today's standards and local amenities are often lacking. In the future, these hubs should make it easier to switch from high-level public transport to local transport services and the 'last mile', with the switch from motorised private transport also gaining in importance. Better urban integration, centre-forming functions and improved connections to business locations should further strengthen their regional importance.

6.4 Type IV – Node in rural areas in the environs of centres

Hubs of this type are represented by suburban or regional railway or express bus stops ("ÖV-Güteklassen" category II) in rural areas around centres. They are currently strongly focused on transport, with no recognizable integration into the settlement structure or complementary functions. Large Park&Ride facilities underline the importance of motorised private transport as a feeder to public transport. In the future, rail-bound public transport and bus services on motorways could achieve almost equal importance, particularly through improved parallel routing and integration of both systems. In view of the extensive, coarse-grained settlement structure, cycle highways should ensure better connections to the nodes. In addition, subjective local safety plays a central role in the attractiveness and usability of these transport hubs.

6.5 Type V – Node in rural areas

This type represents railway stations or bus terminals in rural areas that are not in the environs of centres. In terms of public transport quality these nodes are diverse, the highest-ranking mode spans from regional express train ("ÖV-Güteklassen" category I) via regional train (category II) to bus (category IV).

Multimodal transport hubs in Austria's rural areas have a wide range of functions. While some locations already offer infrastructure such as local shops and services within walking distance, others are historically characterised by agriculture or serve as freight hubs. The example of Hermagor shows a successful interplay of different services, including shopping facilities, charging infrastructure and close integration of bus and rail transport. In the future, the switch from motorised private transport to public transport will play a central role, with on-demand services primarily supplementing tourist and everyday mobility needs. Improvements to the accessibility of these nodes must be carefully planned to avoid uncontrolled urban development.

6.6 Type VI – Local neighbourhood node

This type subsumes a diverse range of local hubs in residential areas. The highest-ranking public transport can be a suburban or regional train, underground or bus in urban centres ("ÖV-Güteklassen" categories II, III or IV) or bus in rural areas (category IV). Mostly, (sharing) services are added to well-established public transport stops. In other cases, neighbourhood mobility stations have been set up from scratch with a modern understanding of planning. Examples of the latter type implemented to date in Austria come from model communities or lighthouse projects. In the future, these stations should complement an already well-developed public transport service and facilitate mobility in the local area and the surrounding countryside – for example through sharing services for transporting goods or shorter journeys. Their integration into lively public spaces plays a central role in this, so that they are not only perceived as functional transport hubs, but as a natural part of the urban living space.

7 EXPLORATIVE QUANTATIVE ANALYSIS

After having defined standards for services and facilities for each type of MMH, an explorative quantitative analysis gives exemplary insights into the status quo. The analysis encompasses 30 hubs – five in each category – that are geographically distributed throughout Austria. In each category, we chose hubs located in five different federal states. If not marked specifically as bus terminal (Busbahnhof), the name of the hub for types I-V refers to railway stations. For type VI, the name refers to the station of the sharing service provider.

The data collection was conducted between October 2024 and February 2025 with a mix of on-site-visits and online analysis (e.g. ÖBB website, OpenStreetMap, Google Street View...).

In our explorative analysis we did not assess the integration of assets (e.g. common branding), but their mere existence. An asset is marked as existent if it can be found within 200m from the hub (entrance), otherwise it is marked as non-existent. For each hub type, assets are defined either as required, optional or undesirable.

		ASSET																				
		PT			Transport Services					Transport Infrastructure						Facilities						
HUB		long distance	regional	local	car-sharing	bike-sharing	e-scooter sh.	on-demand	bike/car rental	bike parking	separated. infra.	e-charging	high rank. road	motorway	car park	housing	public spaces	business	offices	hotel/camp	food
Type I	Feldkirch Hbf.	●	●	●	●			●	●	●		●	●		●	●		●	●	●	●
	Graz Hbf.	●	●	●	●	●			●	●	●	●	●		●	●	●	●	●	●	●
	Innsbruck Hbf.	●	●	●	●	●	●	●		●		●			●	●		●	●	●	●
	Salzburg Hbf.	●	●	●	●			●	●	●	●	●			●	●	●	●	●	●	●
	Wien Hbf.	●	●	●	●	●	●		●	●	●	●	●		●	●	●	●	●	●	●
Type II	Bludenz	●	●	●	●				●	●		●	●		●	●		●	●	●	●
	Graz Don Bosco		●	●					●	●	●		●		●	●	●	●			
	Villach	●	●	●	●	●	●	●	●	●		●	●		●	●		●	●	●	●
	Vöcklabruck	●	●	●						●					●	●					●
	Wien Floridsdorf		●	●		●	●			●		●				●	●	●	●		●
Type III	Bad Ischl	●	●	●	●			●	●	●	●	●	●		●	●	●	●	●	●	●
	Landeck-Zams		●	●						●			●		●	●		●		●	●
	Leibnitz	●	●					●		●		●	●		●	●		●	●		●
	Mattersburg		●	●						●		●	●		●	●	●	●			●
	Neunkirchen N.Ö.		●	●						●		●	●		●	●					●
Type IV	Maria Saal Bhf.		●							●			●	●	●			●			●
	Matrei am Brenner		●					●	●	●		●	●	●	●			●		●	●
	Seekirchen am Wallersee		●	●									●		●	●	●				●
	Stübing		●					●		●					●						
	Wulkaprodersdorf		●					●		●		●			●	●		●	●		
Type V	Deutschkreutz		●					●		●			●		●			●			
	Eisenerz Busbahnhof		●					●				●	●		●	●			●		●
	Hermagor		●		●			●	●	●		●	●		●			●			●
	Riezlern			●									●		●	●	●	●		●	●
	Voitsdorf		●										●		●		●	●			
Type VI	Hernals (S-Bahn)		●	●	●	●	●			●	●	●				●	●	●			●
	Strandbad Klagenfurt			●		●	●			●	●	●			●		●			●	●
	tim Grüne Mitte Linz			●	●	●	●			●	●	●			●	●	●	●	●		●
	tim Reining. Graz			●	●					●	●					●	●	●	●		●
	VMOBIL Göfis Gemeindeamt		●		●			●		●	●				●		●	●		●	●

● existent	required	optional	undesirable

Table 1: Public Transport: 1.Long distance, 2. Regional, 3. Local; Transport Services: 1. Car-sharing (station-based), 2. Bike-sharing (station-based), 3. E-scooter sharing, 4. On-demand transport, 5. Car or bike rental; Transport Infrastructure: 1. Bike parking, 2. Separated pedestrian and bike infrastructure, 3.E-charging station (publically accessible), 4. Higher-ranking local road, 5. Motorway, 6. Car park; Facilities: 1. Housing, 2. Green, open and public spaces 3. Industry or other business, 4. Offices, 5. Hotel/Camping, 6. Food retail and eateries.

8 CONCLUSION

Against the backdrop of the well-developed Austrian public transport system, comprehensively planned, implemented and operated MMH are the most promising infrastructural instrument to both avoid traffic and facilitate the shift from private car dependency towards a more sustainable mobility system. This, however, requires a revisiting of Austrian spatial planning practices and the involvement of new actors in established (public) transport management processes.

The explorative analysis gives exemplary insights into multimodal mobility hubs (MMH) throughout Austria. Most of the examined hubs in small centres and rural areas (types III-V) offer a limited variety of transport services and lack separated cycling and walking infrastructure. Car- and bike sharing should be implemented here as last-mile-options to make public transport more attractive. At hubs in bigger centres (types I and II), car parks should be reduced to strengthen the role of transport services and active mobility as feeder for long-distance connections. The potential centre-building function of smaller hubs (types IV-VI) remains partly untapped and can be further utilised by aligning spatial development around the node with further improvement of transport options.

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Urban Climate Futures Lab (UCFL): Advancing Inter- and Transdisciplinary Research for Sustainable Urban Development

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1 ABSTRACT

The Urban Climate Future Lab (UCFL) is a multidisciplinary research initiative designed to investigate and address the complex interplay between urban development, climate change impact as well as mitigation and adaption, with a particular focus on Lower Saxony and its transferability to wider global contexts. It is funded by zukunft.niedersachsen, a funding program of the Lower Saxony Ministry of Science and Culture and the Volkswagen Foundation. UCFL's unique value lies in bridging the gap between fundamental and transformative research, aligning academic excellence with real-world implementation and stakeholder engagement, reflected within a global perspective.

Keywords: Urban development, climate change adaptation, climate change mitigation, interdisciplinary research, sustainability

2 INTRODUCTION

The Urban Climate Future Lab (UCFL) targets some of the most pressing issues of our time: climate change mitigation and adaptation. Because climate change will increasingly affect urban spaces, the project focuses on urbanization, integrating its different facets: from livability, sustainable mobility, urban production, green infrastructure, resource and energy consumption, climate change risk perception, needs and behaviors of citizens, and efficient and just governance. With UCFL we want to create fundamental knowledge and progressive methods to address holistic, multi-scalar urban solutions, leveraging cross-sector expertise across architecture and planning, social sciences, engineering, and climate science. It seeks to develop and refine new models and tools for assessing and transforming urban areas in light of climate change. This approach is not limited to theoretical exploration; it also addresses practical application, with a focus on both holistic mitigation and adaptation strategies in urban settings. The UCFL project set to span six years is structured

into two distinct but interconnected phases: In phase (I), we focus on system knowledge and method development: How do different settlement types in the Lower Saxony urban and rural systems contribute to climate change, and how are they affected by it? In phase (II), we will focus on transformation knowledge: How can the Lower Saxony urban system, and its constituting elements be transformed to reduce climate impacts and increase its overall resilience and sustainability? Over and beyond the project the aim of UCFL is to evolve into a competence center for research and practice in questions of sustainable urban adaptation to climate change and other tackling emerging aspects of future urban and regional development.

The UCFL's innovative approach is distinguished by its comprehensive and interdisciplinary nature. It brings together a team from several research institutions, including Technische Universität Braunschweig, Leibniz University Hannover, Leuphana University Lüneburg, the ARL – Academy for territorial development in the Leibniz Association, and the Climate Service Center Germany (GERICS), an institution of Helmholtz-Zentrum Hereon. This expertise is supplemented by a distinguished international and interdisciplinary advisory board, ensuring the project's critical reflection from a global perspective. To increase the impact, UCFL strategically partners with researchers, civil society, planning entities, industry and NGOs to address the various facets of urban and climatic dynamics in a holistic way. Methodologies adopted are inter- and transdisciplinary, merging insights and techniques from a large range of disciplines.

UCFL sets out to establish a joint model-based and knowledge-driven approach to continuously analyze, evaluate and refine urban development strategies, thereby creating a dynamic framework for urban adaptation to climate change. Another key objective is to influence policy and practice by providing politically and socially negotiable scenarios, actionable recommendations and guidelines for policymakers and industry stakeholders. The project is structured around several key sub projects (SPs). URB explores settlement patterns and their interlinkages and development scenarios along the urban-rural gradient. MOB focuses on the integrated planning of mobility, analyzing how urban structures influence travel behavior and transport-related climate impact. SYM investigates urban factories and industrial symbiosis. RES addresses urban resource and energy management. OPEN focuses on the holistic accounting and climate-friendly transformation of different types of urban open spaces. CLIM involves climate change impact assessment. CIT captures citizens' narratives of climate change risks. GOV addresses integrative governance for resilient and climate-just spatial transformations. KNOW integrates all SPs by facilitating data exchange, modeling, and scenario building. COLAB manages project organization, infrastructure, and communication, coordinating activities like workshops, science communication, and research proposals while developing a strategic road map for UCFL, aligning stakeholder efforts, securing funding, and planning for its long-term regional and international impact.

This paper outlines UCFL's conceptual framework, methodologies, and ongoing work-streams, emphasizing its role as a model for synergistic research ecosystems. This contribution aims to introduce the project to a wide audience of academics and practitioners in the field fostering international collaboration and knowledge exchange with the UCFL. By addressing knowledge gaps and promoting innovation in sustainable urban and regional planning with specific focus on climate change mitigation and adaptation, UCFL sets the foundation for shaping sustainable urban regions worldwide.

3 THE PROBLEM

The effects of climate change on urban areas are multifaceted and far-reaching (IPCC, 2022). Historically, there has been a correlation between urbanization, industrialization, mobility, population growth, globalization and the rise of carbon emissions (van den Berg., 1987). While urbanization can be associated with many positive effects for societies and individuals, like the increase of living standards, negative effects concern e.g., the unbalanced concentration of resource consumption in urban areas, the associated loss of biodiversity and space (Zucaro, Maselli & Ulgiati., 2022; Wilting et al., 2017; Kim et al., 2021), increased climate change risks, such as heat islands, heavy rain events, floods, droughts, storm surges etc. (IPCC, 2022; Bertrand-Krajewski, 2021), and a lack of resilience through the urban form itself (ZSK, 2022). Urban development can lead to landscape fragmentation, urban sprawl, changes in forest resources as well as land use, with negative consequences for biodiversity (Ünal Steg & Gorsirg, 2018). The expansion of urban areas can also exacerbate environmental problems such as air pollution, heat islands, and the loss of natural habitats (Richards & VanWey, 2015). While cities and urban areas are home to a larger proportion of the population and therefore proportionally more resources are consumed, they are also most threatened by

climate change (IPCC, 2022; Kim et al., 2021; Ye & Niyogi, 2022), but may embody high potential for positive impact (Liu et al., 2023; Kraas et al., 2016). Additionally, the construction industry, the expansion of urban infrastructure, and the increasing energy demand in cities lead to high greenhouse gas emissions (Elmqvist et al., 2021; Seto et al., 2016).

However, cities are also hubs for innovation and adaptation to climate change. Green and blue infrastructure approaches, such as urban parks, hybrid spaces, decentralized storm water management, or vertical green, have been shown to mitigate the impacts of extreme weather events like floods and heat (Tauhid & Zawani, 2018). Furthermore, mitigation strategies that focus on reducing energy demand and land-based resources can reduce trade-offs with sustainable development (IPCC, 2022).

According to the IPCC (2022), urban areas are expected to experience increased temperatures and changes in precipitation patterns due to climate change. Lower Saxony's settlement units will also be heavily affected by this, which may lead to more frequent heatwaves, droughts, and heavy rainfall events, which can have devastating impacts on urban infrastructure and human health. Overall, understanding the complex relationships between urbanization, climate change, and environmental degradation is crucial for developing effective mitigation and adaptation strategies (IPCC, 2022).

Understanding urbanization's role in environmental degradation requires a nuanced approach. Different urban morphologies – shaped by their economic structures, infrastructure, and governance – leave distinct environmental footprints. A large city reliant on coal power plants has a vastly different impact compared to a small agricultural town, where pesticide runoff affects surrounding water bodies. While both contribute to environmental degradation, they do so through different modes of environmental degradation and at different scales, making direct comparisons difficult. Furthermore, Phase I focuses on assessing how climate change will affect different settlements, while Phase II identifies the interventions needed to transform them into more resilient and sustainable spaces, which may vary significantly in scope and strategy.

4 THE APPROACH

The project focuses on analyzing the diverse environmental impacts of settlement units across Lower Saxony – from urban to rural forms – and their inter-linkages along the urban-rural gradient, exploring plausible social-ecological transition scenarios, and assessing who is likely to be disproportionately affected by these transitions. At the same time, the project investigates how different settlement types across the federal state will experience the effects of climate change.

Crucially, climate change impacts cannot be understood solely through the quantification of changing climate variables at a coarse spatial scale – although this remains a fundamental part of the project. Instead, UCFL incorporates additional parameters such as:

- Existing green infrastructure within settlements, which influences local climate regulation.
- Urban morphology, which affects vulnerability to extreme weather events.
- Socio-economic structures, which shape communities' ability to adapt and respond to climate risks.

By combining methodologies from urban planning, sociology, global and regional climate models, socio-economic analysis, and environmental modeling, UCFL seeks to provide a holistic understanding of the interrelationships between urbanization and climate change. The insights generated will support evidence-based policy making, helping cities and regions navigate a transition toward more sustainable and resilient futures.

The Urban Climate Future Lab (UCFL) aims to set up a research- and cooperation-platform systematizing this complex challenge by integrating multiple disciplines to develop interdisciplinary approaches that examine two key aspects: (1) The environmental impact of different urban settlements and their urbanization patterns, and (2) the ways in which these different settlements are expected to be affected by a changing climate.

To address the challenges of climate change in urban areas, UCFL proposes a multifaceted approach that blends knowledge creation, technological innovation, policy frameworks, community engagement and seeks to understand the research objects as coupled human-environment systems. The solutions we recommend aim to reduce urban carbon footprints, enhance resilience, and promote sustainable development and livable

environments through coordinated efforts across various sectors. One of the key areas for intervention is land uptake, the functional layout of settlement types and their interconnections within the urban system to create or discourage synergies between land use types and everyday life actions. This is related to all of the other facets of sustainable development. Transportation also plays a major role in urban carbon emissions. Transport oriented planning of settlements and the development of infrastructure that supports electric or hybrid vehicles, along with good public transportation options and cycling networks, can reduce dependence on fossil fuels. As more people adopt sustainable and more active travel behavior urban settlements can lower their transportation-related carbon footprint, contributing to cleaner air and a more sustainable urban mobility system and significantly reduce the sealing of land and consumption of space.

Another key topic is the industry sector. We approach this topic by looking at urban factories and urban in industrial symbiosis (UrIS), which refers to the communal sharing of physical and intangible resources among diverse urban entities, such as businesses and public institutions. By integrating circular economy practices, where materials are reused and recycled, urban systems can minimize their environmental footprint and create a more sustainable, closed-loop economy.

Another critical solution is urban greening, which involves expanding green spaces through tree planting, green roofs, rainwater retention and other forms of urban greening. These green spaces function as carbon sinks, improve air quality, and reduce the urban heat island effect, which can exacerbate the impacts of climate change. In addition to these environmental benefits, urban green-blue spaces enhance biodiversity and offer recreational areas for residents, improving the quality of life in urban settlements.

Building infrastructure and associated energy supply systems play a significant role in terms of emissions as energy efficient building design as well as decarbonization of operational energy demand for heating and electricity usage are key drivers for climate neutrality. Therefore, the significant share raise of renewable energy sources, such as solar, wind, and geothermal as well as district energy networks in urban settlements can substantially reduce greenhouse gas emissions. Retrofitting existing buildings to improve insulation and energy performance is another vital step in curbing overall energy consumption. This shift not only addresses climate change but also helps create a more energy-resilient urban landscape. Within UCFL, we aim to develop energy-efficient transition scenarios for the different settlement types across Lower Saxony.

The integration of data and digital technologies is another key solution. By simulating, for example resource consumption patterns like energy and water use, or other aspects or urban systems like transport networks, cities can better manage resources and identify inefficiencies. Contextualized urban data also enables better preparedness for extreme weather events, improving cities' ability to respond to climate impacts in real time. Advanced data driven methods support cross-scale and cross-domain planning and helps to optimize the allocation of resources, enhancing the resilience of cities to changing climatic conditions and understanding the impacts on a local scale.

Effective policy and governance are crucial in driving change. Policies that provide incentives for sustainable practices, such as sustainable territorial and land use planning, green building standards or low-carbon transportation options, help create a framework for climate action. At the same time, penalizing high-emission behaviors and rewarding low-carbon alternatives will steer urban settlements toward a more sustainable path. Data and digital technologies serve as key enablers, providing real-time insights, optimizing resource use, and enhancing decision-making for more effective policy implementation. Governments play a pivotal role in shaping the regulatory environment that encourages sustainable development while mitigating the risks of climate change.

Lastly, community engagement is vital for ensuring that these solutions are inclusive and effective. In the context of UCFL, a key focus is understanding how residents perceive climate change, their personal contribution to environmental impacts, and their sense of risk associated with climate change. By gathering insights on these aspects, we can better tailor interventions that resonate with local populations and encourage meaningful action. Educating and involving communities in sustainability efforts fosters a culture of climate action that extends beyond top-down policies. Grassroots movements complement governmental and technological strategies, creating a sense of ownership and accountability among residents. Local energy communities are another opportunity for communal residential involvement. When communities are actively engaged, they contribute to long-lasting change that reflects local needs and priorities.

5 THE TEAM

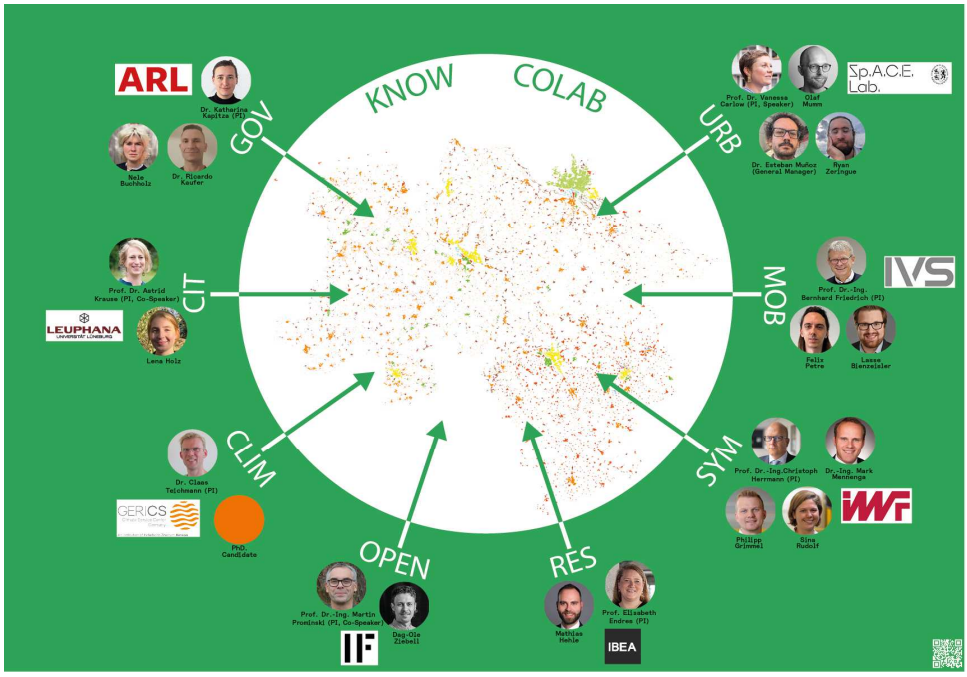

Fig. 1: Diagram showing the teams of the sub-projects. Source: Map in the background, settlement units of Lower Saxony (Initial TOPOI classification at cluster depth 75) based on the TOPOI method (Carlow et al., 2022)

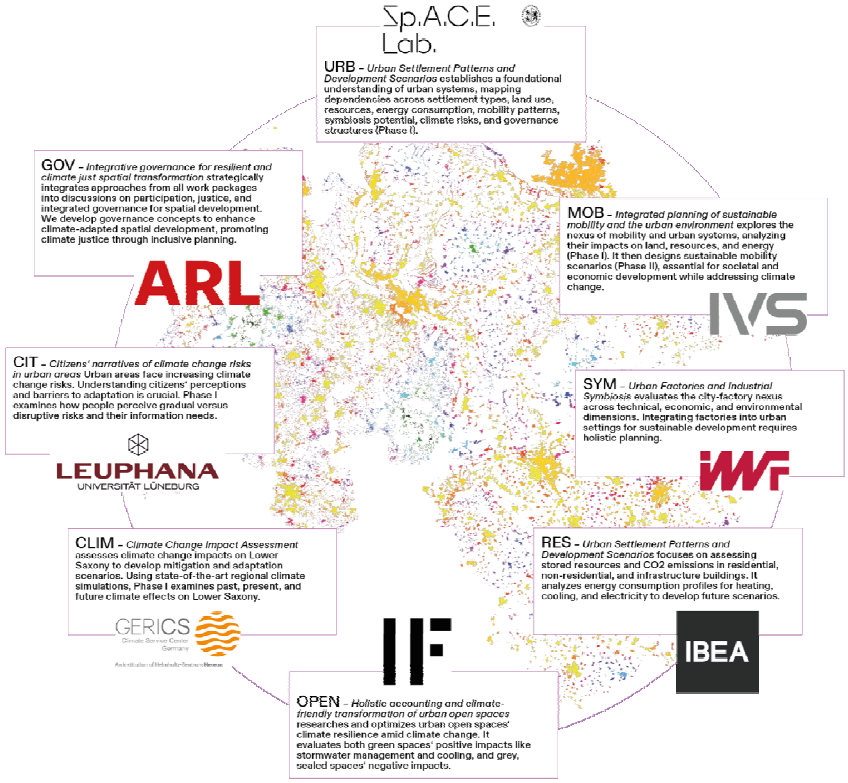

Fig. 2: Diagram showing the different sub-projects. Source: Map in the background, settlement units of Lower Saxony (PRTS – Proximity to Regional Train Station) based on the TOPOI method (Carlow et al., 2022)

UCFL brings together a diverse and highly experienced team of researchers with expertise from various fields, including urbanism, planning, sustainability, climate science, transportation, engineering as well as psychology and behavioral decision research, to develop integrated solutions for climate-resilient urban areas. The principal investigators represent renowned research institutions such as the ISU – Institute for Sustainable Urbanism at Technische Universität Braunschweig, the Institute of Sustainability Psychology (ISP) at Leuphana University Lüneburg, the Institute of Open Space Planning and Design (IF) at Leibniz

University Hannover, the Institute for Building Climatology and Energy of Architecture (IBEA), the Institute of Transportation and Urban Engineering the Institute of Machine Tools and Production Technology (all Technische Universität Braunschweig), the ARL – Academy for territorial development in the Leibniz Association, and the Climate Service Center Germany (GERICS) at the Helmholtz-Zentrum Hereon.

Each sub-project within the project focuses on different dimensions of urban climate challenges, from understanding urban settlement patterns and mobility to assessing climate change risks and governance strategies. Figures 1, and 2 showcase the collaborative spirit of the UCFL team, including a diagram of the working teams and one of the SPs. These visual elements highlight the close coordination and multidisciplinary approach that underpin the project's success.

Figure 2 provides an overview of the sub-project (SPs) that form the foundation of our research, each addressing a critical aspect of urban sustainability and climate adaptation. URB examines urban settlement patterns and development scenarios, mapping dependencies across land use, resources, energy, mobility, and governance structures. OPEN focuses on the role of urban open spaces in enhancing climate resilience, assessing both the benefits of green spaces and the challenges posed by gray infrastructure. SYM explores industrial symbiosis, evaluating the integration of factories into urban environments for sustainable development. CIT investigates citizen perceptions of climate risks, identifying barriers to adaptation and strategies to improve acceptance of sustainable urban transformations. MOB studies the interconnections between mobility and urban systems, designing sustainable mobility scenarios to address resource and energy consumption. CLIM assesses climate change impacts on Lower Saxony, using regional climate simulations to develop mitigation and adaptation strategies. RES analyzes energy consumption in buildings and infrastructure, modeling future scenarios for energy use and emissions reduction. Finally, GOV synthesizes insights from all SPs, developing integrative governance approaches that enhance participation, justice, and resilience in climate-adapted spatial planning. Together, these SPs provide a comprehensive framework for understanding and advancing sustainable urban transformation.

To further enhance the interdisciplinary nature of the project, two dedicated SPs have been established. The first, COLAB, focuses on fostering coordination and collaboration between the various research teams and investigators, ensuring that all SPs are aligned in their objectives and methodologies. The second, KNOW, is dedicated to the integration of data and knowledge across disciplines, enabling a seamless exchange of insights and promoting the synthesis of findings from different SPs. These efforts are key to ensuring that the project benefits from a truly holistic and interdisciplinary approach to urban climate challenges.

6 THE CHALLENGE AHEAD

The challenge ahead lies in navigating the complex and interconnected nature of urban systems and climate change. With urbanization continuing to intensify across the globe, understanding the environmental impacts of different urban settlements and their vulnerability to climate change is crucial. However, this task is far from straightforward, as urban settlements are diverse, with varying socio-economic fabrics, infrastructure, and resource management strategies. Developing effective, context-specific solutions requires not only technical expertise across a range of disciplines but also the ability to navigate differing local conditions, governance structures, and public attitudes. Integrating data from various sources, assessing the impact of climate change under different scenarios, and designing effective adaptation and mitigation strategies presents a multifaceted challenge that will require close collaboration and constant iteration.

7 EXPECTATIONS

The UCFL project has set ambitious goals for understanding and addressing the climate risks faced by urban settlements in Lower Saxony. By applying interdisciplinary approaches and advanced methodologies, we aim to gain new insights and develop tailored strategies that will allow urban areas to transition toward greater climate resilience and sustainability. Through the integration of diverse data sources, collaboration among research institutions, and active involvement of local stakeholders, we expect to create a comprehensive, actionable knowledge base that informs climate-friendly policies and practices in Lower Saxony while serving as a model for other regions facing similar challenges. To learn more about our research, methodologies, and ongoing initiatives, visit urbanclimatefuturelab.de. Ultimately, we anticipate that the project will contribute significantly to advancing the field of sustainable urbanism, offering new insights and tools for building cities that are better equipped to face the impacts of climate change.

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Urban Corridors as a Tool for Sustainable Development: Case Studies from Brazil and Greece

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1 ABSTRACT

Urban corridors offer a scalable and flexible framework for sustainable urban development, integrating mobility, public space, and environmental resilience. Unlike isolated interventions, corridor planning structures urban transformation along defined spatial axes, ensuring coherence between citywide strategies and localized implementation. This paper examines the methodology through case studies in Rio de Janeiro and from three waterfront cities in Greece. In Rio, a pilot project tested the integration of multiple Sustainability Corridors through a neighborhood-scale route, linking key public spaces and enabling distributed interventions. In Greece, the corridor approach was adapted to different urban challenges: revitalizing a historic district in Heraklion, structuring a new district in Kavala, and requalifying the waterfront in Kalamata. The findings highlight the importance of designing urban and green corridors as a replicable tool for inclusive, strategic urban development.

Keywords: case study analysis, urban corridors, urban regeneration, strategic urban planning, sustainable urban development

2 INTRODUCTION

Urban corridors have become a defining strategy in contemporary urban planning and urban design, offering a structured yet flexible framework for sustainable and integrated urban development. By aligning mobility networks, public spaces, and environmental systems, corridors facilitate integrated urban transformation that extends beyond isolated interventions. Unlike traditional planning models that segment cities into distinct zones, the corridor approach embraces continuity, connectivity, and scalability, enabling both large-scale planning and localized, incremental improvements.

This paper explores the role of urban corridors as a strategic planning tool, drawing on case studies that illustrate their adaptability across different typologies of urban conditions. It examines how the methodology has been applied in Rio de Janeiro, where a citywide sustainability plan defined priority corridors, and in Greece, where three medium-sized cities adopted corridor-based strategies for revitalization, expansion, and waterfront redevelopment. By comparing these contexts, the paper demonstrates how corridors can shape urban development by structuring interventions along key spatial axes, ensuring a cohesive relationship between strategic goals and on-the-ground implementation.

By assessing the effectiveness of this approach, the paper argues that urban corridors provide a replicable and scalable model for urban development. Their ability to integrate multiple sectors – mobility, public space, ecology, and social infrastructure – positions them as a critical tool for cities striving for sustainability, resilience, and inclusivity in an era of rapid urban transformation.

3 URBAN CORRIDORS AS A PLANNING STRATEGY

Urban corridors are an essential urban planning strategy that integrates transportation with land use, supporting sustainable urban development. Unlike traditional zoning, which separates functions into distinct areas, corridor-based planning fosters more connected and dynamic urban environments that align with sustainability goals such as climate resilience, mobility, and social equity (Jurkovic, Lovokovic 2023). Defined as linear spaces where transport, economic, and social processes interact, urban corridors include roads, railways, and waterways, along with their surrounding built and natural environments. Their multifunctionality promotes accessibility, connectivity, and balanced land use (ibid.). Historically, corridor-based development has roots in models like Soria y Mata's Ciudad Lineal (1882), which structured urban growth along a central transit axis (Tufek-Memisevic, Stachura 2015), and later adaptations such as Le Corbusier's Plan Obus and Kenzo Tange's Tokyo Bay project. While these models demonstrated how transportation and urban expansion can be integrated, critics like C.A. Doxiadis emphasized the need for multi-directional growth rather than strictly linear development (ibid.).

While urban corridors have been widely explored in literature as a way to structure entire cities, Superwien's experience suggests that they are particularly effective as tools for urban regeneration and strategic planning. Rather than functioning as isolated structures, corridors act as interconnected networks that can be adapted to a wide range of urban contexts, making them a powerful mechanism for urban requalification.

A key characteristic of corridor planning is its flexibility, allowing it to function across different scales. Jurkovic and Lovokovic (2023) highlight that urban corridors strengthen public transport, promote active mobility, and contribute to economic clustering. From a sustainability perspective, they enhance environmental resilience through green infrastructure and urban forestry (ibid.). Superwien's application of the corridor approach builds upon these theoretical principles, but with a particular focus on how corridors structure urban growth at different levels. At a metropolitan scale, corridors align urban expansion with transport and infrastructure investments, particularly in mid-sized cities where integrated mobility solutions are crucial. At the neighborhood scale, they enable phased, incremental urban improvements, ensuring that interventions are not isolated but remain part of a broader, adaptable vision.

Unlike traditional radial urban expansion, which concentrates development around a central point, corridor planning allows for linear urban development that connects multiple centralities, fostering more dynamic and well-integrated urban structures. This aligns with contemporary concepts such as the 15-minute city and compact urbanism, which emphasize accessibility, mixed-use development, and sustainable growth. Furthermore, structuring interventions along a corridor rather than focusing on a single location allows for diversified interventions – some replicable along the route, others context-specific to key nodes. This strategy proves particularly beneficial in small and medium-sized cities, where corridors provide a structured yet adaptable approach to urban expansion.

Superwien's approach does not claim that corridor planning is superior to other methods, but recognizes its distinct advantages, particularly in ensuring long-term connectivity, coordinated urban improvements, and integration across different urban systems. By creating a framework for interventions that can evolve over time, corridor planning remains a dynamic and scalable tool for sustainable urban transformation. The following case studies illustrate its application across diverse urban contexts, demonstrating how corridors support more sustainable, connected, and adaptable urban environments.

4 CASE STUDIES OF SUPERWIEN'S URBAN CORRIDOR PROJECTS

4.1 Implementing the Corridor-Based Urban Strategy in Greece: Urban Transformation Across Three Contexts

As part of an initiative led by the World Bank, in collaboration with the European Commission's DG REGIO, a pilot project was developed to test practical methods for strengthening the capacity of Greek cities in implementing Sustainable Urban Development (SUD) strategies. Recognizing the challenges faced by small and medium-sized cities, including urban sprawl, aging populations, inadequate public space, and a lack of integrated mobility solutions, the project introduced an approach based on corridors of development. These corridors serve as spatial frameworks for guiding urban growth and regeneration in a more structured and strategic manner.

The project was piloted in three cities – Kalamata, Kavala, and Heraklion – each representing a different urban condition in which the corridor-based methodology was applied. In Kalamata, the focus was on the requalification of the waterfront, aligning with strategies for active mobility, cultural activation, and green infrastructure. In Kavala, the intervention was aimed at the development of a new district, ensuring a sustainable urban expansion with integrated transport and public space solutions. Meanwhile, in Heraklion, the methodology was tested through design-based research in a historically dense neighborhood, targeting urban revitalization through social and environmental improvements.

In all three cases, the corridor approach allowed long-term strategic planning, identifying key development axes while integrating short-term interventions that could catalyze transformation. By combining different sectors – mobility, public space, green infrastructure, cultural heritage, and economic activation – the corridors established a framework for multi-scalar urban development.

4.1.1 Kalamata: Transforming the Waterfront into a Sustainable Public Space

Kalamata, a historic Mediterranean port city, has long relied on its waterfront as a central economic and social hub. However, the area faced fragmented urban spaces, a lack of accessibility, and car-dominated streetscapes, which limited its potential as a vibrant public space. The corridor strategy in Kalamata focused on redefining the waterfront as a connected and accessible urban environment that prioritizes pedestrians, cyclists, and cultural activities.

A series of actions were identified to enhance connectivity, improve public spaces, and introduce green infrastructure and climate resilience measures. The requalification of Navarinou Street was one of the central proposals, with the goal of transforming it into a shared space that adapts to seasonal variations, allowing for pedestrian-friendly zones in the summer while maintaining limited traffic during the rest of the year. This was complemented by the proposal of a continuous pedestrian and bicycle connection along the waterfront, ensuring accessibility and fostering sustainable mobility. Proposals for public space improvements included the revitalization of Limenikou Park, the redesign of the Kilometer Pier, and the reclamation of the port warehouse as a cultural and economic hub. Climate adaptation played a key role in the strategy, with interventions addressing coastal erosion, flood management, and biodiversity restoration. The corridor also allowed for the integration of waste management solutions and sustainable tourism initiatives, ensuring that the waterfront transformation would be both environmentally and economically sustainable.

By structuring the redevelopment of the waterfront along a clear spatial axis, the corridor approach enabled Kalamata to develop a cohesive vision for its future. The transformation was not limited to a single intervention but rather consisted of a network of connected public spaces that together created a more livable, inclusive, and resilient urban environment.

Fig. 1 and Fig. 2: Comprehensive Planning for Kalamata's Waterfront and Port Area. The left image presents a large-scale map of Kalamata's waterfront, highlighting all proposed projects from the long list. The right image provides a detailed axonometric view of the port area, illustrating specific interventions for its redevelopment. Source: Superwien, 2024.

4.1.2 Kavala: Developing a Sustainable New District in Perigiali

In Kavala, the corridor methodology was applied in a different urban context: a new district development. The city is undergoing an urban expansion in Perigiali, an area with a mix of vacant land, industrial uses, and scattered residential developments. Without a clear design framework, there was a risk of uncontrolled growth and fragmented infrastructure. The corridor-based approach provided a structured development strategy, ensuring that new urbanization would be sustainable, well-connected, and integrated into the city's broader mobility and public space networks.

The corridor plan for Perigiali focused on establishing a strong spine for mobility and public space development. A Main Active Corridor was introduced to link the new district to the existing city, ensuring integration with Kavala's public transport system. This corridor was designed to prioritize pedestrian and cycling infrastructure, incorporating green spaces, urban furniture, and shaded pathways to create a human-scaled environment.

Public space played a central role in shaping the identity of Perigiali. A new central public square, adjacent to a planned cultural center, was designed as the social and economic heart of the district. This space was planned to host cultural events, markets, and recreational activities, fostering community engagement and

economic activation. Additionally, the strategy included the transformation of underutilized areas, such as the stadium parking lot, into public plazas and sports facilities.

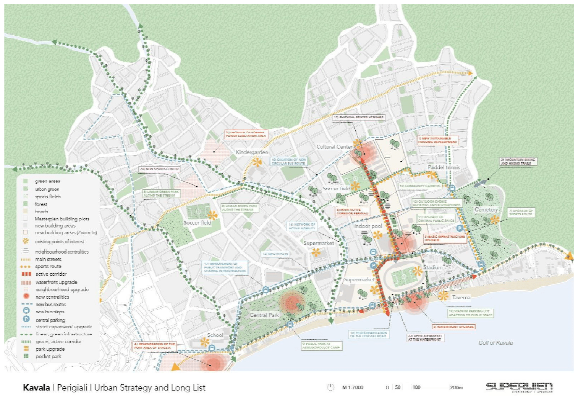

Fig. 3 and Fig. 4: Strategic Development for Kavala's Perigiali District. The left image presents an overview of the long list of proposed projects for the Perigiali district, outlining key interventions for sustainable urban growth. The right image illustrates an axonometric view of the proposed corridor, showcasing Superwien's approach to structured urban expansion and connectivity. Source: Superwien, 2024.

A key innovation of the Perigiali corridor was its integration of green and blue infrastructure. The revitalization of the stream running through the area introduced a linear park, combining flood protection, biodiversity restoration, and public space creation. Similarly, new community gardens and pocket parks were proposed throughout the district, enhancing the environmental quality of the urban fabric.

By applying the corridor methodology to a new district, the project demonstrated how structured urban expansion can be sustainable and inclusive. Instead of isolated developments, the framework ensured that Perigiali evolved as a cohesive urban environment, balancing residential, cultural, and economic functions within a walkable and interconnected public space network.

4.1.3 Heraklion: Revitalizing a Historic Neighborhood Through a Corridor-Based Approach

Unlike Kalamata and Kavala, where the corridor strategy was applied to large-scale interventions, Heraklion's Agia Triada district required a small-scale urban revitalization approach. This historic neighborhood, characterized by dense urban fabric and narrow streets, was facing declining building conditions, underutilized public spaces, and mobility challenges. The corridor methodology provided a framework to reorganize the urban structure, enhance social cohesion, and preserve the neighborhood's architectural identity.

The key intervention in Agia Triada was the creation of a pedestrian-oriented active mobility corridor, linking cultural landmarks, historic squares, and community spaces. The rehabilitation of dilapidated buildings played a crucial role in preserving the area's unique character, while at the same time introducing new cultural, social, and economic functions into underutilized structures.

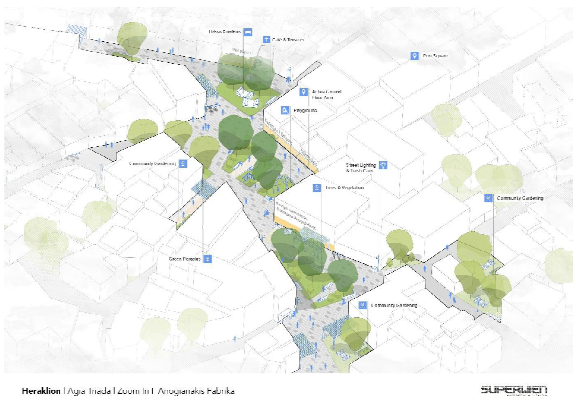

Fig. 5 and Fig. 6: Urban Regeneration Strategy for Heraklion's Agia Triada. The left image provides an overview of the long list of proposed projects aimed at revitalizing the Agia Triada neighborhood. The right image presents an axonometric view of the proposed corridor, highlighting key interventions for enhancing mobility, public space, and heritage preservation. Source: Superwien, 2024.

Mobility improvements focused on reducing car dependency and enhancing pedestrian connectivity. A key strategy was the transformation of key streets into shared spaces, limiting vehicle access and prioritizing walking and cycling. The plan also introduced a cultural heritage route, guiding residents and visitors through significant historic sites, public art installations, and renovated community spaces.

Environmental sustainability was embedded in the corridor approach, with pocket parks, urban greening projects, and climate-adaptive infrastructure integrated into the revitalization process. Public space upgrades included new urban furniture, street lighting, and recreational areas, ensuring that the neighborhood remained inclusive and accessible for all.

Through this context-sensitive application of the corridor methodology, Agia Triada's revitalization strategy successfully balanced heritage preservation with contemporary urban needs. Instead of large-scale demolition or redevelopment, the project focused on incremental improvements, adaptive reuse, and participatory urbanism.

4.2 Pilot Implementation of Rio de Janeiro's Plan

Rio de Janeiro faces significant challenges in integrating sustainability into its urban planning strategies. To address these challenges, the Sustainable Development and Climate Action Plan (PDS) was developed by the Planning Office of Rio de Janeiro (EPL) as a long-term strategy to guide the city's sustainable development. One of the most interesting aspects of the plan is its use of corridors to define priority areas for urban transformation. These Sustainability Corridors structure the city's development strategy, categorizing different regions by thematic priorities, which are represented by colors. Green corridors emphasize urban forestry and climate adaptation, blue corridors focus on water management and river restoration, while brown corridors address mobility, infrastructure, and transport-oriented development. This approach provides a structured yet flexible way to integrate sustainability goals across different areas of the city, ensuring that interventions align with broader urban development objectives.

While the PDS sets a citywide vision, the challenge was to bring these large-scale strategies into implementation at a citizen scale. To bridge this gap, C40 and the Inter-American Development Bank (IDB) collaborated with the city to implement the project, with Superwien as the consulting office responsible for leading the design and pilot implementation, and, developing a methodology for future applications of urban corridors in Rio de Janeiro. The strategy focused on defining a route within a neighborhood that intersected multiple corridors from the PDS, serving as a structured development path where interventions could take place along a defined trajectory rather than being limited to a single location. The Oswaldo Cruz neighborhood was selected as the site for the pilot project, with a route that connected key public spaces, ensuring a multi-sectoral and integrated approach to sustainability.

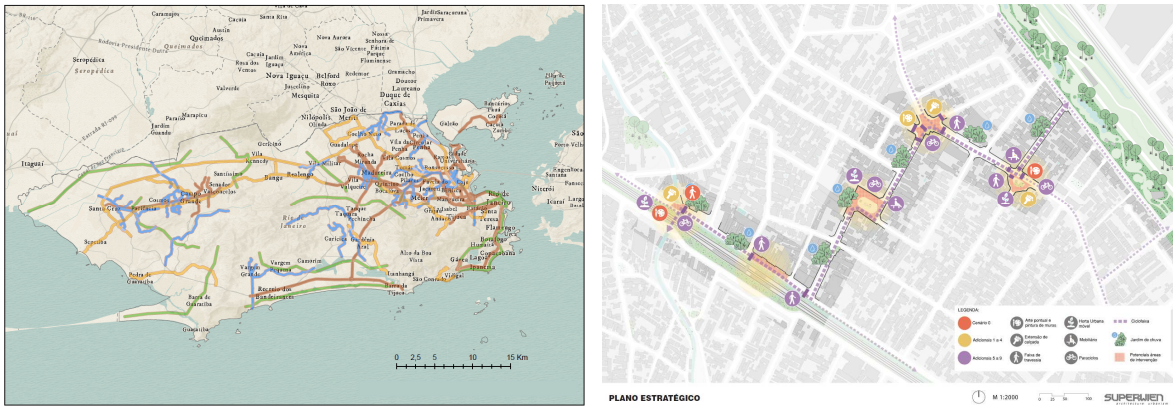

Fig. 7: and Fig.8: Sustainability Corridors and Pilot Implementation Strategy in Rio de Janeiro. The left image displays the spatialized Sustainability Corridors from Rio de Janeiro's Sustainable Development and Climate Action Plan (PDS). Source: EPL, n.d..The right image illustrates the strategic plan for implementing sustainability interventions along the designated route in Oswaldo Cruz during the pilot project. Source: Superwien, 2024.

By establishing this route, the project ensured that the implementation was not concentrated in a single intervention point but rather unfolded as a sequence of interventions along the route. Some elements were replicated throughout the entire path, reinforcing a coherent identity and structure, while others were designed specifically for key locations identified during the participatory planning process. This flexibility

allowed a variety of urban improvements to be implemented simultaneously, including street transformations, landscape enhancements, community engagement activities, and mobility improvements. The fact that the project was structured along a route also created opportunities for other municipal offices and public institutions to contribute. Different departments and agencies of the city administration could align their own agendas with the project's framework, identifying areas within the route where they could implement complementary interventions, further expanding the impact of the initiative.

The methodology for defining the route was based on participatory and dialogue-oriented planning, ensuring that the most relevant intervention points responded directly to the needs of the neighborhood. Through workshops and spatial analysis, key locations such as Paulo da Portela Square and the Rio das Pedras riverbank emerged as focal points for public space activation. The route also incorporated elements of multiple Sustainability Corridors: it enhanced green infrastructure and urban forestry, addressed mobility challenges and transport accessibility, and integrated river restoration and flood mitigation efforts. This combination of priorities allowed for a comprehensive approach that linked environmental, social, and mobility improvements within a single framework.

To translate the broad sustainability goals into concrete actions, the implementation relied on placemaking and tactical urbanism interventions that could demonstrate immediate, visible change while fitting into the larger development strategy. These included community gardens to promote urban agriculture and environmental education, temporary street closures and painted crosswalks to improve pedestrian accessibility, artistic murals with sustainability themes to strengthen local identity, and vertical gardens made from recycled materials to expand green infrastructure. These interventions acted as low-cost, high-impact solutions, showcasing how large-scale sustainability frameworks could be brought to life through community-driven, localized improvements.

The experience in Rio de Janeiro highlights how corridors can serve as adaptable, multi-scalar planning tools in low-income neighbourhoods, not only structuring urban development at a metropolitan scale but also enabling localized, incremental improvements at the neighborhood level. Rather than treating corridors as rigid urban infrastructures, this project demonstrated that they can function as flexible networks that evolve with community needs, fostering a dynamic relationship between strategic planning and on-the-ground action. The corridor approach, when combined with routes as development paths, ensures that sustainability efforts are not just planned at a citywide level but also felt and experienced in the daily lives of residents.

Fig. 9: and Fig.10: The project in the Oswaldo Cruz neighbourhood in Rio de Janeiro exemplified the participatory design of integrated urban corridors, but also showcased a concrete interaction with the society though placemaking workshops and implementtation. Source: Superwien, 2024.

This project also provided key insights into how sustainability-focused urban regeneration can be effectively implemented. First, large-scale (strategic) planning must be adaptable to local conditions to ensure that sustainability strategies translate into meaningful change. Second, a route-based approach allows for distributed local, place-based interventions, ensuring a broader impact and enabling different stakeholders to contribute over time. Third, corridor planning should not be limited to broad city-scale interventions but must integrate localized, community-driven improvements. Lastly, collaborative engagement with different municipal departments and stakeholders expands the potential for long-term success, as the structured route allows multiple actors to align their efforts within a shared framework.

By demonstrating how city-scale sustainability frameworks can be implemented incrementally through localized action, the Rio de Janeiro case study provides a replicable model for cities seeking to balance strategic urban planning with tangible, citizen-scale improvements. The integration of participatory planning, flexible urban strategies, and targeted interventions establishes a new way of thinking about corridor-based development – one that is not only strategic but also rooted in community needs and lived experiences.

5 CONCLUSION

Urban corridors offer a versatile and structured approach to urban development, bridging large-scale strategic planning with localized, citizen-focused implementation. The case studies explored in this paper – from Rio de Janeiro's sustainability corridors to the tailored applications in Greek waterfront projects – demonstrate how this methodology provides a flexible yet cohesive framework for urban transformation. By structuring interventions along defined spatial axes, corridors ensure that urban development aligns with mobility networks, public space improvements, and environmental sustainability.

The key advantage of the corridor approach lies in its scalability and adaptability. Whether applied to a dense historic neighborhood, a waterfront redevelopment, or the expansion of a new district, corridors create systematic yet context-sensitive pathways for development. Furthermore, their multi-sectoral integration enables cities to align various policy agendas within a single, interconnected strategy.

As cities continue to face pressing challenges such as climate change, social inequality, and urban sprawl, corridor planning emerges as an effective tool for achieving sustainable and inclusive urban growth through place-based urban design solutions. By fostering connectivity, prioritizing active mobility, and supporting community-driven improvements, urban corridors serve as a replicable model for cities worldwide, ensuring urban development that is deeply rooted in the everyday experiences of its residents.

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Urban Village

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1 ABSTRACT

This paper is about a concept "Urban Village" as a new perspective for layered building in the densified city of tomorrow. The concept is a development of Living Lab 040 in Eindhoven. This paper explains the Living Lab 040 initiative, discusses the currently appliedapproach of appartment buildings and methods of densification as well as the reasons why innovation is desired here. And of course the concept itself will be presented and explained in images and in words, This includes the status quo, the context and the R&D ambitions. Finally there is a callfor companies and knowledge institutions to join forces in developing this concept.

Keywords: Experiment, Densification, Livability, Industrial, Innovation

2 LIVING LAB 040

The initiators of Living Lab 040 (including the author of this paper) have extensive experience in building innovation. From that position, a plan was developed with the municipality of Eindhoven in which a space of 8,500 m2is made available for experiments with the aim of gaining insights relevant to the city of tomorrow.

Experiments touch all current transformation topics that trigger accelerated change among consumers, in society and thus the market. It is challenging to speed up change within existing construction frameworks. Innovation requires courage, risk-taking, and letting go of traditional boundaries. In practice this is hardly possible and many projects started with firm ambitions, end up with a strongly reduced innovation agenda. That's why a protected zone (a living lab) is crucial. A place where initiators are allowed to discover and to learn from failures. The Living Lab 040 is unique because of its holistic approach but also because it's part of a real neighbourhood where ordinary people live in developed experimental homes, contributing to learnings.

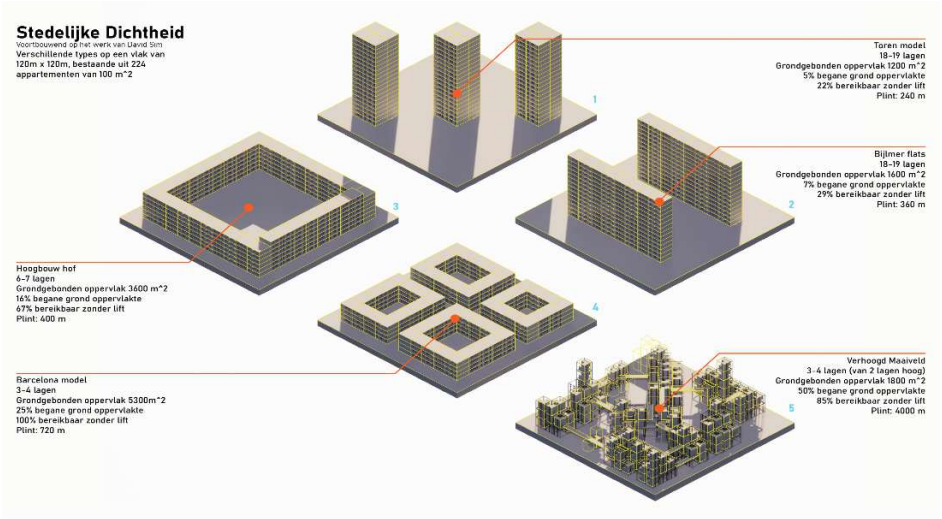

Fig 1: Impression of the Living Lab 040 to come. The first 10 houses are meanwhile realised

The experiments can be technical in nature, focused on products or processes, but certainly also have a strong social character. Consider themes such as energy, carbon reduction, climate adaptation, biobased, affordability, biodiversity, security, mobility, sustainability, circularity, etc., but also social challenges such as how to promote social cohesion. It is for this reason that the lab eventually becomes a small neighbourhood with almost 120 inhabited houses. The lab only started recently, right now 10 experimental houses have been realised.

The realisation of experiments takes place from two angles. Namely, the “bottom-up” approach, where one or a few companies propose an experiment, develop an R&D programme for it and then proceed to realisation and further development. These experiments are then embedded in the overall development of the area.

A second approach is “top down”, in which a vision-based usually disruptive concept is developed from a core team, municipality or from third parties. And only then involving businesses and other stakeholders. This top-down approach is a reaction to the fragmentation in the market, with parties acting exclusively from their own parten detailed topic and thus not being able, nor having the power, to develop solutions on a holistic level.

The lab will ultimately accommodate approximately 120 test homes and innovations at district level. Some of the homes targeted at suburban (low-rise) developments and some at multi-storey inner-city developments. The projects landing in the lab comprise mostly small numbers. No more than is necessary to achieve the set learning objectives. This creates room for many and diverse experiments.

In this innovative lab environment, the Urban Village concept, subject of this paper, will be realized as a first pilot. Referring to the above, the concept touches on many of the current trends and challenges. The scope of the experiment includes 24 houses and additional collective facilities, it is mainly focused on inner-city development (multi-storey). Furthermore, it is one of the top-down experiments in the lab, born from a vision from the core team, supported by the municipality of Eindhoven and other stakeholders like Amvest, industrial parties, knowledge institutions, designers and a group of citizens (the Citizens Think Tank).

3 CONVENTIONAL APPARTMENT BUILDINGS

High-rise and apartment buildings in cities are basically using the third dimension to achieve densification. In the past, apartment buildings consist of stacked houses with necessary accesses (galleries, corridors, staircases, lifts) to provide access to the apartments. Often downstairs with a collective front door with mailboxes and doorbells. The said accesses are herewith collective and not public. Actually, the conventional apartment concept arose from technology and cost efficiency (the stacking and minimising collective space). A major objection to such objects is that they often promote social problems such as loneliness. By nature, people have no mutual contact in such buildings and therefore no sense of ownership, causing the collective area and its surroundings to deteriorate. In many places this leads to insecurity and crime. And all these problems entail a lot of social costs, due to deployment of social workers, health organisations and the necessary attention of the municipality, the owner and the police. In addition, this form of high-rise construction contributes only little to the densification task. Much less than one would expect. Stand-alone apartment buildings should keep some distance. This is because of daylight, views, greenery and parking space. In this context, high-rise and apartment concepts have been compared. In figure 2, this is done for several typologies (after David Sim) in which the Urban Village as a fifth typology was added. All five situations having the same number of housing units, the same number of people living there and the same surface/area. What is striking is that the fifth typology seems to be the least dense.

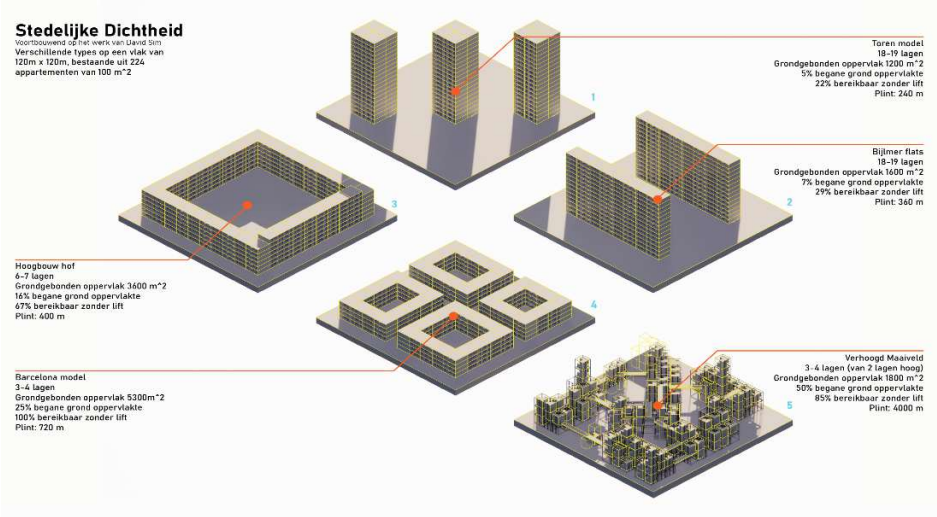

Fig 2: Comparison several densifying approaches. They all have the same surface and number of dwellings/inhabitants. Down-right the Urban Village concept. After David Sim (The Urban Village was added).

4 URBAN VILLAGE

Compared to conventional apartment buildings, the Urban Village has some different characteristics. Access to the building does not consist of a traditional stairwell, but residents gradually walk up via a path (trail). The houses are all located along this path. This creates the feeling of living on a street even on higher levels. This feeling is reinforced by assigning more functions to the path, such as meeting places, playgrounds, view points, small shops, like a hairdresser's, shared spaces, etc. Residents are thus challenged to move around more and furthermore the opportunity to meet each other, is substantially increased. The path up or trail is a public area where also non-residents are welcome to go up and enjoy the view. Maybe they can even buy a cup of coffee upstairs or enjoy an exhibition. During the development, comparisons with a Mediterranean mountain village were frequently made as an image, and because such a residential structure can start to function as a village in the city, the project was named "Urban Village".

Another starting point is the carrier-infill conception by Habraken (Habraken, 1961) and the division in building layers by Slimbouwen (Lichtenberg, 2005). This means that the building consists of a carrier (a system of columns and beams with plateaus), the path upwards (the trail) including all main services The infill consists of the dwellings and housing clusters and also the collective functions and street furniture, that are placed on the plateaus or can be hung in the carrier (rack).

Fig 3-5: Impressions of the Urban Village concept: living at a street next to a garden and playgrounds also on higher floor levels

The split between carrier and infill is an important starting point for industrialisation, as the carrier can be systematized very well, and the same appears to work well for the trail (outcome of research by design). For

the houses, the idea is that they can be developed specifically for the concept, but also existing concepts meant for building on a building plot at ground level can probably also be used for this purpose. As a result, the concept of plateaus has also been given a second name, namely “elevated building lots”. Apart from the industrial advantages of the separation carrier-infill, this concept also provides much more flexibility regarding future adaptations.

Where traditional buildings are rigid, in this concept it is possible to make structural adjustments in case of non-functioning or desired changes in use, such as extending the support, moving the trail, creating a plaza, etc. The reason for change can also be the changes in the environment, for example in inner cities. The concept is able to fill in empty spaces and to be realised against or on top of existing structures. And so the Urban Village can be a tissue in motion that folds organically into the city.

What also can be seen is a development, where residents want to move their homes. Within the very same structure or to take them elsewhere. Perhaps in another similar structure or on a foundation on a traditional building plot, where they are able to extend it.

There are opportunities for temporary housing. For instance, there are many sites in the city, which need to be developed with larger buildings, but where the preparation phase often take a long period, typically 8-10 years. So those sites remain undeveloped for a long time. In those cases, an Urban Village is also suitable for temporary realisation. Indeed, the aim is to be able to relocate the houses and make the support structure demountable (circular). After a first life the structure can then be dismantled and, as like with K’nex and Lego, given a second life in a different location in a different configuration.

An additional interesting option for cities is to make the carrier also fulfil a bridge function, thus covering sections of roads, canals and railways, contributing quite directly to the densification of the city. After all, in the conventional world, roads and canals are places where no living space are planned. Such overpasses can also create connections (ecoducts for humans/fauna) between now often strictly separated areas of the city.

Fig 6 Images from design research result based on shaping the trail and the collective areas, based on a developed catalogue of outer spaces (see fig 8).

5 RESEARCH

The design of the Urban Village is quite different from the conventional design of high-rise buildings. Therefore an R&D step is necessary. In a normal project development, risk elements would be eliminated and ambitions would be pushed aside. This would in case of the Urban Village affect the concept to such an extent, that only a weak copy of the total concept would be realised. That in itself could become the reason, that the concept in that limited form, does not work and would then be discarded on incorrect grounds. It is

therefore logical to realise the first Urban Village in a lab environment, where mistakes are allowed, where we can refine the concept for a couple of years. Testing and discovering what the values of the concept are. Whether an effect can be measured as a basis for valorisation of values and thus feeding the business case regarding this concept.

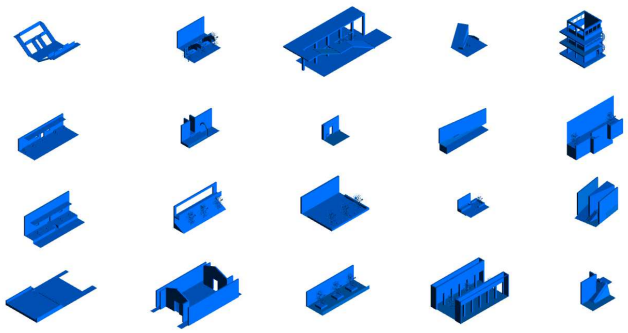

Fig 7 and 8 In this approach (also presented in fig 6) the outside area was standardized based on a number of outer sceneries (the catalogue of outer spaces).

The images accompanying this article are part of research by design conducted since late 2022 on how the concept can land in the city and what we need in the pilot to pick up learnings. One question, for example, is to what height the concept is feasible and how porous the building mass should be, so that enough effective daylight can enter the lower layers, in order to provide also there a comfortable and healthy living environment. Design studies indicate as a first conclusion that one can build at least up to a height of about 20-25m.

The R&D programme includes in a nutshell:

- Social experiments
- Impact analysis (on surroundings, environment and effects on e.g. health)
- Technical development (e.g. wind, noise, fire, light, odors, ...)
- Process development (assembly, disassembly, reassembly)
- Development of the (Circular) business case including legal aspects

6 STATUS QUO

The status of the concept (the experiment) is that the desk studies are in completion, feedback has/is been collected from stakeholders, such as the municipality that embraces the potential of the concept. The sketch design of the configuration as we intend to realise it in the lab is currently being elaborated. Realisation of the carrier will start within a year. The pilot is expected to be realised by the end of 2026. R&D will take place throughout the process. Design research is already being carried out now, but process development and product development will also take place prior to and in parallel with the realisation, including measuring and thus gathering evidence to research questions and hypotheses. In particular, R&D will continue for several years during the utility phase, focusing on social aspects. It is also foreseen that, if measurement results warrant it, a major adjustment will take place after a few years.

During this process, the concept will be released. The ongoing R&D will then still yield optimisations, but the concept can then be rolled out in the market.

This does not mean that the very same buildings are going to appear everywhere. It is the system, especially of the carrier and the trail, that will find its way to the market in all kinds of configurations. Compare it to Lego or K'nex, where with a limited number of parts, completely different structures can be realised. And then there is the fact that especially the infill (houses and collective facilities) can lead to a completely different character per building. For example, detached objects are possible, with a lot of freedom of form, or the building consists of pre-designed units, which may also adjoin each other in clusters like a group of terraced houses. Not to mention the use of different materials and colours.

7 CONCLUSION

We are on the eve of starting to land the ideas as presented here in the protected environment of the lab. The purpose of realisation is “learning” and optimisation. With that, the Urban Village is in this phase, a test object. Its funding will be raised by the participants, such as producers, developers and/or housing corporations. We are now at the stage of involving parties in the project and the lab. Different parties are involved for the carrier the trail, the installations and the houses and other objects. The investment is reduced, because during, say, 10 years of residence time, there are also rental returns and the object has a high residual value due to its disassembly and reuse. The municipality can, for example, at this stage designate a place where the structure to be realised now, in modified or unmodified form, can be given a second life.

The enticing prospect for participants is, of course, that this kind of project can be scaled up. Invest now, benefit later. This paper is therefore also aimed at parties from industry, municipalities and scientific research institutes, which may be interested in applying the concept in the future and to contribute to this R&D project.

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