

The Potentials of Digital Tools to Contribute to Spatial Transformations – the Example of the Digital Twin of the City of Helsinki

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1 ABSTRACT

Spatial transformations are a key challenge for communities and regions. The term is rooted in the assumption that in the Anthropocene era, human ways of life and modern economic systems have led to an unsustainable consumption of natural resources and a failure to adhere to planetary limits, which ultimately endangers the natural basis of human life (Engel and Knieling 2018, WBGU 2011).

Nowadays we see, in particular with the example of climate change, how environmental threats of different types and intensities affect cities and regions. It creates a strong demand for action. Cities and regions are thus directly affected by transformations. At the same time, they define the spaces where approaches of action and implementation of instruments of spatial planning have the chance to make cities more sustainable and resilient to risks. Thus, active processes which include the whole society are required (Engel and Knieling 2018).

Such processes as is likely to present many municipalities with a major challenge with many difficulties, which raises the question of what options there are for providing them support. The mega-trend of digitalization affects almost all areas, including spatial planning (Pallagst et al. 2022). It can be observed that digital tools have been increasingly used in spatial planning in recent years, offering new technical possibilities. The paper will look in particular at the digital twin of the city of Helsinki and its relevant fields of application. The city faces a variety of different risks in terms of climate change (City of Helsinki 2019). Recent research by the authors investigates which potentials the digital twin of Helsinki offers to support the necessary transformative processes and triggers potential changes of strategies and methods in spatial planning.

In order to measure spatial transformations, various theories and multi-level perspective approaches from transformation research are already available (Zolfagharian et al. 2019, Bauknecht et al. 2015, Engel and Knieling 2018). On this basis, the paper discusses to what extent digital tools, can be applied in order to support transformation processes. In addition, the paper intends to contribute to a methodology for comparative case study research.

Keywords: Digital Twin, Digital Tools in Spatial Planning, Spatial Transformation, Helsinki, Climate Change Risks

2 INTRODUCTION

The Digital Twin of the City of Helsinki is a digital 3D model that can be enriched with various sectoral data. As a tool, it has already been established in urban development in Helsinki and is used, among other things, for the visualization of planning scenarios, specific analyses and public participation (Hämäläinen 2021, Tuukkanen 2023, City of Helsinki 2022, City of Helsinki 2023).

Finland is one of the leading countries when it comes to digitalization and the development of technological innovation. (Edquist and Hommen 2008).

Transition Theory teaches us that technological innovation in the social system is created at a niche level by pioneers of change. In the case of sudden shocks, crises, but also slowly advancing mega-trends, pressure is exerted on the socio-technical regime. As a result, the mainstream becomes more open and technological innovations have the opportunity to get established in the mainstream (Engel and Knieling 2018, WBGU 2011, Geels 2011, Grin et al. 2010).

Such mega-trends or crises very often have a large global relevance. In the case of Finland, these include dealing with risks related to the effects of climate change, ageing of society, social disparities, but also digitalization itself. (City of Helsinki 2017, Purkarthofer 2023).

These issues have a direct spatial reference and impact on regions and cities. Spatial planning bundles the instrumental possibilities to design the space in a way that is necessary to deal with the challenges of mega-trends and crises.

In terms of spatial transformation, climate-related challenges, especially decarbonization and adaptation to changing conditions, are particularly relevant (Engel and Knieling 2018, WBGU 2011).

The question therefore arises to what extent such new technological innovations, such as the digital twin of the City of Helsinki, that are being used in spatial planning have the potential to support transformative processes and contribute to this.

This paper first deals with the theory of spatial transformation, digitalization in spatial planning, and planning cultures as an important contextual field of research. It then looks specifically at the digital twin of the City of Helsinki. Among other things, it will be shown how this tool is used in planning and it will be analyzed to what extent a contribution to spatial transformation is made by the digital twin. On the basis of the knowledge gained, the conclusions are discussed that can be drawn from this for the methodological approach. The steps that need to be taken into account in order to be able to measure a contribution to transformation processes are identified. For the purpose of future comparative case study research, a standardized procedure is proposed.

3 THEORY BASED CONSIDERATIONS

3.1 The Phenomenon of Spatial Transformation

The term transformation goes back to the reflections on the Great Transformation. In Karl Polanyi's 1944 book of the same name, the term is used in connection with the processes of change in society related to the changing conditions of the economic system during the Industrial Revolution (Ebner 2017). However, the terminology "Great Transformation" is still used today and usually describes processes of change in society starting from mostly global mega-trends or crises. An example of this can be the mega-trend of digitalization. The social process of change that goes hand in hand with this would therefore be digital transformation in this context. The goal of the transformation can be seen here as sustainable establishment. Transformation research describes the examination of change processes of social systems towards more sustainable structures as well as their support from a scientific perspective (translated from Wittmayer and Hölscher 2017). A strong interest in the research of transformation is emerging, driven among other factors by the dramatic sociocultural, political, economic, and technological challenges society faces (Pereira et al. 2018, Bruns 2022).

Despite its applicability to many different topics and trends, the discourse as a whole is very much dominated by the topic of the environment as a resource and basis of human life. In Germany, it is the "Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen" (translated: Scientific Advisory Council of the German Federal Government on Global Environmental Change) that enjoys great attention in the scientific discourse with its publication on the Great Transformation and sees decarbonization as the main task here. The currently prevailing modern economic forms and consumption practices in the world are seen here as the main triggers for above all climate- and environment-related mega-trends and crises of today. One of the triggers identified is that resource consumption is not regenerative and planetary boundaries are not respected. Against the backdrop of the Anthropocene era, it is therefore humans themselves who are having a negative impact on the environment and thus endangering their own basis of life. On the other hand, the humans themselves also have the influence to react to the dangers with a process of change. One can differentiate here, whether this reaction from a pure survival will and danger defence happens, or whether it is an active process carried into the society, in which the change is arranged in a union of the people. The latter is seen as the actual transformation process, since it is assumed that such processes can only take place and succeed at the level of society as a whole (Engel and Knieling 2018, WBGU 2011).

Transition Theory aims to describe and explain the societal processes within the scope of transformation. The theory is based on the assumption that innovations arise primarily in niche areas through so-called pioneers of change (Engel and Knieling 2018, WBGU 2011). It goes back to Grin et al. 2010, who proposed a multi-level perspective approach to the question of how to be able to understand the process of change. The considerations in this regard have already been discussed and modified several times in the literature, for

example by Geels (2011) and by WBGU (2011). According to this theory, transformation is understood as a comprehensive change of socio-technical systems. In the theory, the dominant socio-technical regime is the meso-level. Above this is the macro-level and below it is the micro-level. Both levels affect the socio-technical regime. The macro-level forms the external context, meaning overarching themes from which mega-trends are derived (Engel and Knieling 2018). The macro-level thus influences the events of the socio-technical regime and puts pressure from it (Geels 2011). From below, on the other hand, the micro-level affects the socio-technical regime. This is the niche level. Here, the so-called pioneers of change act and develop technology and innovation outside the mainstream of the meso-level (Engel and Knieling 2018).

According to the theory, the actual process of change occurs at the moment when, at the level of mega-trends, sudden shocks or long-term but fundamental crises put the socio-technical regime under such pressure that a restructuring of the system is forced. At this moment, the socio-technical regime opens up to the developments of the niche level and enables technological innovation to become established in the mainstream (Engel and Knieling 2018).

Transition Theory with its Multi-Level Perspective approach “serves as a middle range theory” (Zolfagharian 2019). Transition research relies on creative interpretation of the result obtained through the Multi-Level Perspective method, making it clear that despite the attempt to quantify, qualitative methods have an important place (Geels 2011, Zolfagharian 2019).

The concept of spatial transformation is directly related to the great transformation and transfers the level of consideration to the spatial context. Sustainable development plays a key role in urban and regional planning (Knieling and Kreschmann 2016, United Nations n.d.). The establishment of sustainability as a planning principle, often also defined as a principle in legal documents, can be observed worldwide. However, the relevance of the spatial perspective also stems from the fact that threats directly affect spaces and create direct pressure for taking action among cities and regions. At the same time, the administrations and organized civil society have the possibility and competence to shape the space at the respective administrative level, e.g. of a city, in such a way that necessary steps to cope and manage change can be implemented. Cities or urban spaces in particular have a special potential to foster exchange between different groups and movements and thus have a particularly inventive and experimental power to develop innovations (Engel and Knieling 2018, WBGU 2011). Possible courses of taking action for municipalities include the adaptation or creation of necessary infrastructures, spatial development adapted to new needs, the adaptation or creation of new governance processes, governance structures and working methods, and an adapted prioritization of financial support and investments.

The spatial scope in the study of transformation has an important meaning in transformation research. According to Engel and Knieling 2018, transition theory raises the question of concrete spatial conditions. They identify a further need for spatial research here.

3.2 Topical Planning Cultures and digitalization in spatial planning

Pallažst et al. investigated shrinking cities as a window for possible changes in planning cultures in the frame of the EU project PlanShrinking (2010-2015). In order to derive a typology of planning cultures applicable for the context of shrinking cities, the authors modified Othengrafen’s culturized planning model (Othengrafen 2010) describing the general context of planning cultures towards shrinkage (see figure 1). Figure 1 demonstrates general criteria of planning culture, supported by a specific criterion for shrinking cities: shrinkage context. “Societal context” displays the “backbone” of a planning culture with a range of more general understandings, “planning context” describes the beliefs of the planning profession, and “planning toolset” refers to the methods at hand. The category “shrinking context” comprises those aspects which might trigger change in planning cultures due to shrinkage and its implications on urban development and planning reactions.

In addition, the PlanShrinking research traced several preconditions for the joint research of planning cultures and shrinking cities:

Both topics -- planning cultures and shrinking cities -can be labelled emerging topics in spatial planning. Just like planning cultures, shrinking cities have been widely underrepresented in international comparative urban and regional research.

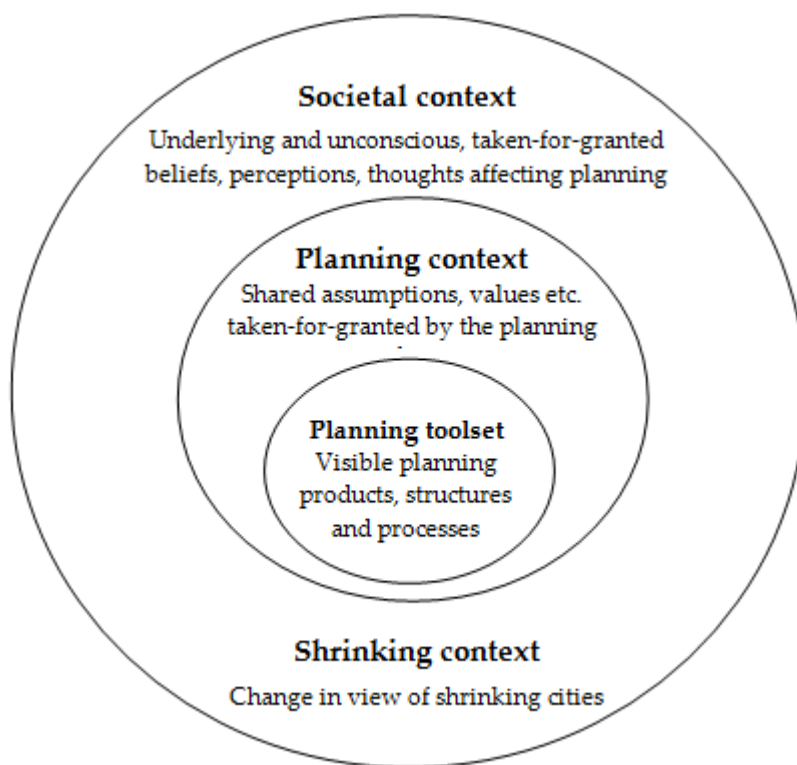


Figure 1: Facets and layers of planning culture with reference to shrinking cities, Source: Pallagst et al 2013.

The shrinking city phenomenon is a multi-dimensional process, comprising cities, parts of cities or metropolitan areas that have experienced dramatic decline in their economic and social bases. Urban decline and the loss of employment opportunities are closely linked in a downwards spiral, leading to an out-migration of population (Pallagst, 2008). However, despite the fact that globalisation is a trigger for urban shrinkage, economic transformations do not affect all cities in the same way; on the contrary, shrinkage can show very different characteristics depending on national, regional and local contexts (Cunningham-Sabot and Fol, 2007). Research on planning cultures is usually attributed to a national context of a planning system – however, this also involved different levels of planning (from national to local).

Planning cultures serve as an academic concept which is lacking an evidence base, whereas shrinking cities is a planning challenge vividly engaging practitioners and academics likewise in search of urban or regional solutions.

The author’s previous research on shrinking cities made clear that planning cultures can be investigated by evidence based research utilizing the shrinking cities phenomenon. Nonetheless, planning offers a plethora of topics potentially serving as windows of investigation for planning cultures – one of them being digitalization. Research by Sorensen (2015) further underpins this argumentation: He suggests that planning cultures might change when faced with as he calls it “critical junctures of institutional change and innovation in planning systems” (Sorensen 2015). One of these critical junctures might be the context of digitalization.

Thus one of the aims of this paper is to shift the window of investigating planning cultures from the evidence base of shrinking cities towards the realm of digitalization. The following paragraphs will make a first attempt in order to derive preconditions from shrinking cities research for the field of digitalization.

In a first attempt to conceptualize planning cultures and digitalization, the author suggests a research frame (see figure 2) derived from the facets and layers of planning culture in terms of shrinking cities (see figure 1). This research frame (figure 2) adds digitalization as a new component to the planning cultural context.

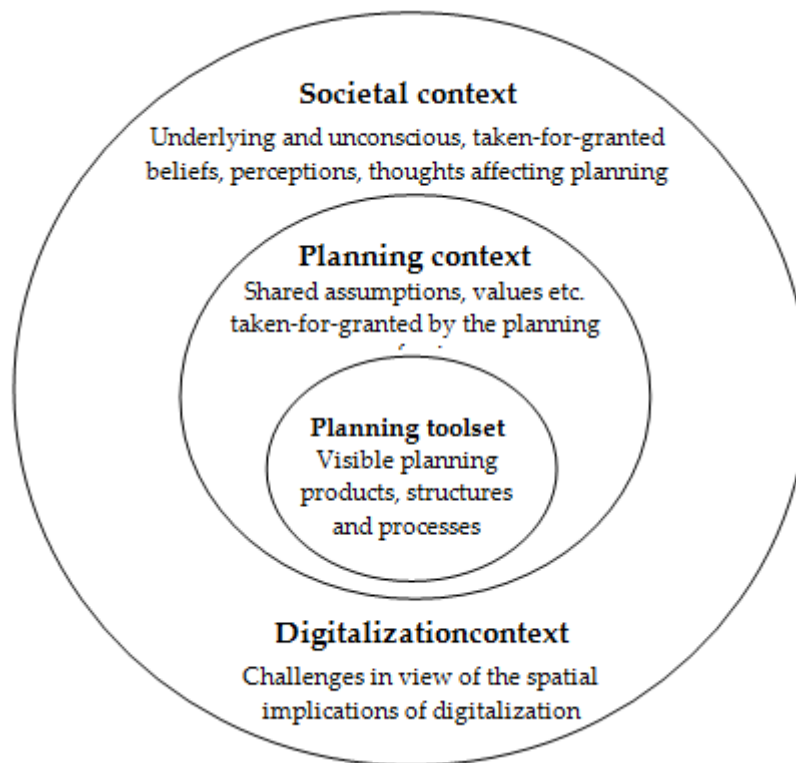


Figure 2: Facets and layers of planning culture with reference to border regions, Source: Own design based on Pallagst et al., 2013.

Pallagst et al. (2022) framed first ideas for an operative definition of planning culture. Accordingly, planning cultures are defined as follows: “Planning cultures encompass the societal aspirations towards planning – its processes and its outcomes. It refers to the values and shared beliefs of stakeholders involved in planning, and the methods and tools they are applying and producing. Planning cultures are not static but constantly evolving in line with societal changes or planning related challenges. Planning cultures as we see it can be attached to specific territorial entities, be it nations, sub-nations, regions, or cities – most likely but not necessarily within administrative boundaries. In addition, they can be attributed to cities or regions having to face specific planning problems”.

The research on changing planning cultures in view of digitalization will certainly add to the notion of topical planning cultures.

Digitalization has been a field of action in spatial development for quite some time. Building on the digitalization trend and starting from the approach of digital and networked smart cities, the synopsis of networked digitalization and spatial development has been planned and researched since the turn of the millennium (Hollands 2008). At the core of this is more efficient management but also a broader understanding of sustainable and more efficient urban development (Leitheiser and Follmann 2019; Herrschel 2013). In the highly competitive segment of smart cities, standardized platform solutions from large international IT or consulting firms are often implemented (Hollands 2015). Furthermore, an international discourse has been established in research that critically reflects the smart city movement (Grossi and Pianezzi 2017). Smart cities also continue to be an issue in German urban development policy, as manifested, among other things, in the Smart City Charter presented in 2017 (BBSR 2017). Accordingly, digital development should take place in the sense of sustainable and integrated urban development.

Digitalization has an impact on spatial planning and development in various fields of action (Spellerberg et al. 2021). With regard to services of general interest and the centrality of settlements, this enables a new perspective on the principle of equal living conditions. Likewise, the use of different digital tools such as Artificial Intelligence, visualizations and platform solutions poses new requirements for the design of planning, decision-making and participation processes. This, in turn, has consequences for the planning tools and the competencies of spatial planners and other actors in the planning and development process.

While smart cities as a concept have been widely researched, there is a lack of references and answers with regard to the design of the nexus of digitization and spatial planning and development for resilience, sustainability and transformation.

Furthermore, there is still limited research on the transformative forces of these concepts for the development of cities and regions. There is a lack of fundamental research on the effectiveness of smart tools, concepts and applications. Questions that such a conceptualization of smart spaces should encompass include:

To what extent can cities and regions use the digital transformation as an opportunity for spatial development?

What is the role of model projects? What are the spatial effects of these concepts, and where are the opportunities and limitations?

Whether and to what extent are methods, instruments and paradigms of spatial planning changing in this context in the course of digitization?

While not all of these general research questions can be covered in this paper, the following paragraphs will shed light on the digital twin as a potential tool of fostering spatial transformations with the example of the city of Helsinki.

4 THE DIGITAL TWIN OF THE CITY OF HELSINKI

4.1 Planning cultural Context of Helsinki and Finland

Helsinki is the capital city of the Republic of Finland and is located in the south of the country on the coast of the Gulf of Finland of the Baltic Sea. Administratively, it forms the Finnish capital region together with the cities of Espoo, Vantaa and Kauniainen. The cities are strongly intertwined spatially and together form a large-scale agglomeration with approximately 1.2 million inhabitants (Statistics Finland 2023a). The city of Helsinki is located in the centre of this region and has a population of just over 660,000 (Statistics Finland 2023a).

About 5.5 million people live in the entire Republic of Finland (Statistics Finland 2023a). In Finland, there are a total of 293 municipalities (Purkarthofer and Mattila 2023). In terms of administrative tasks, many areas of competence lie with the municipalities. The local identity of the people is therefore mostly strongly related to the municipality. At the medium administrative level in Finland, the country is divided into 18 regions, in which the respective municipalities are organized into regional councils on the one hand, and 15 Centres for Economic Development, Transport and the Environment on the other hand. The Swedish-speaking Åland Islands are excluded from the above stated administrative structure. They have an autonomous status and have an independent administrative structure (Purkarthofer and Mattila 2023).

Finland is very rural overall and extremely sparsely populated, especially in the northern municipalities. Overall, the country has a population density of only about 16 inhabitants per square kilometer (Statistics Finland 2023a, NLS 2018). This contrasts sharply with the highly urbanized capital region with 1,533 inhabitants or Helsinki alone with 3,073 inhabitants per square kilometer (Statistics Finland 2023a, NLS 2018). In terms of Finland's demographic structure, it is noticeable that the population is ageing. This can also be seen in the population projections. For example, the population in the 0 to 44 age groups is expected to decline by 2040. This contrasts with the population group of 75-year-olds and older, where a very strong increase is forecast. Here, too, the capital region stands out from the statistics for the country as a whole. Although the older population cohorts are also expected to increase here, at the same time there is no discernible downward trend among the younger cohorts (Statistics Finland 2021). Overall, Finland is experiencing increasing immigration from other countries, but this is most visible in the more urbanized areas, such as the capital region. At the same time, in the context of intermunicipal migration movements in Finland, it can be observed that many people move from rural areas to urbanized areas (Statistics Finland 2023b, Statistics Finland 2023c). Finland is characterized by a rural exodus.

In terms of the economy, industry and services both play an important role in Finland. In urbanized areas, however, there are particularly many employees in the service sector. In rural areas, agriculture, forestry, wood production and paper production can be identified as important in the industrial sector, in contrast to urban areas. In these areas, there are particularly large numbers of employees on the rural side (Statistics Finland 2022).

Culturally, Finland is characterized by a self-image as a country with a geographically and politically peripheral location (Purkarthofer 2023). It can be assumed that in this context, a social sense of duty to adapt to global political and economic trends and movements on the one hand and personal responsibility with

regard to growth and prosperity on the other hand lead to a country with a certain openness with regard to a culture of learning from failure, trial and error and innovation. The country's technology and innovation policy deliberately creates an environment to link science, industry and administrative authorities and to strategically promote start-ups in the innovative technology sector. Since the mid-1990s, Finland has experienced a strong economic upswing with this strategy and is considered one of the world's leading countries in terms of innovative strength (Edquist and Hommen 2008). In this context, Finland is also seen as a model country with exemplary function in the field of digitalization.

This cultural background also plays an important role in spatial planning and illustrates the mindset behind the approach of meeting solutions to existing tasks with new technological possibilities and a willingness to experiment. Furthermore, the historical background of Finland also influences the planning cultural context. In this context, the era in which Finland belonged to the Swedish kingdom and the era in which Finland was a grand duchy in the Russian Empire should be mentioned in particular (Purkarthofer 2023). Despite the country's independence since 1917, influences from both eras can still be found in culture and architecture today. Linguistically, for example, Swedish is still a widely spoken language in Finland. As a country with a very rural landscape and hardly populated areas, a close relationship to nature plays an important role in society, despite the noticeable urbanization and rural exodus since the 1950s. The contrast between the traditionally rural structures on the one hand and the modernization and investment developments in the urban areas on the other hand often leads to conflicts in society. In addition, social disparities, both within urbanized areas and between urban and rural areas, also cause tensions in society. Finland is traditionally a welfare state. The fact that the state provides for the economic security of the individual is an important value. Against this background, the aforementioned social disparities trigger social and political discourse (Purkarthofer 2023). These spatially relevant issues are crucial in the context of capturing the planning context.

On the other hand, environmental issues should not be underestimated when examining the key challenges of spatial transformation. In a publication, the City of Helsinki has analyzed how it is affected by climate change. Among the important factors identified are the risk of flooding due to rising sea levels and storms with heavy rainfall, as well as the general increase in precipitation in the winters, which can lead to dramatic amounts of snow or a high safety risk in road traffic as temperatures rise and hover around the freezing point more frequently than before. However, rising temperatures in summers are also increasingly perceived as a problem, both as a health risk for people and as a threat to native species of flora and fauna (City of Helsinki 2019). In planning, on the one hand, there is a general awareness of the need to make decisions that take the dangers into account (City of Helsinki 2019) and, on the other hand, sustainable urban development and mobility as a specific set of issues (Purkarthofer 2023).

In terms of systematizing the cultural factors mentioned, these can be applied to the extended theory according to Knieling and Othengrafen described in section 3.2. Additionally it includes the context of the spatial transformation. The following table summarizes some important factors.

General Context	Societal context	<ul style="list-style-type: none"> • Self-image as peripheral geographical and political location of Finland • Rural character and closeness to nature • Experimental mindset with an open culture of learning from failure and innovation • Welfare state
	Planning context	<ul style="list-style-type: none"> • Rural exodus and urbanization processes • Sustainable urban development and sustainable mobility • Rather low understanding of overall planning and stronger focus on single object development with focus on design and architecture
Specific Context	Spatial transformation	<ul style="list-style-type: none"> • Dealing with risks associated with climate change impacts • Ageing society • Social disparities
	Digitization	<ul style="list-style-type: none"> • Good digital infrastructure • High social relevance • High level of innovation through exploitation of digital opportunities

Table 1: General and Specific Context applied to the case of Helsinki, Finland

When dividing the various factors into the individual fields of context, it becomes clear that some points cannot be clearly assigned in terms of content and that a different division would also be conceivable. It is important to remember that the Specific Context is a more concrete part of the Planning Context and that the Planning Context is a more concrete part of the Societal Context. In the case of spatial transformation, for example, all points also fit into the planning context. Therefore, it is necessary to analyze beforehand which of the points that play an important role in connection with the planning context also represent a central mega-trend in society, and especially in world politics.

According to the theory of Knieling and Othengrafen, the planning artifacts are still missing for a complete consideration of the planning cultures. Here, the planning system is considered in particular. Especially the different administrative levels, relevant legal documents, formal planning instruments and plans with their legal effects, and relevant actors are to be considered. This structure is also followed by the so-called "Country Profiles" of the Academy for territorial Development in the Leibniz Association. In special cases, it may also be necessary to deal with exceptional informal planning instruments or working methods. The following explanations are taken from the "Country Profile" for Finland by Purkarthofer and Mattila 2023.

In the case of Finland, the relevant levels are the national level, the regional level (in particular the 18 regions with the regional councils) and the municipal level. The legal basis for the planning instruments at all these levels is the Land Use and Building Act of 1999. At the national level, there are the "National Land Use Objectives". These are general, central issues for which corresponding goals are formulated. The Finnish federal government, in particular the Ministry of the Environment, is responsible for this. The defined objectives must be observed and taken into account at the regional planning level. At the regional level, the "Regional Land Use Plan" is the central instrument. Here, non-parcel-specific representations of linear and areal structures are mapped on topics such as infrastructure routes, protected zones, settlement areas and development areas. The Regional Council is responsible for this. The plan has legal force for the development of plans at the Municipal level. At the Municipal level, there are two different formal planning instruments. First, there is the "Local Master Plan." This maps similar issues to the plan at the regional level, but has a higher degree of detail due to its scaling for only one municipality at a time, and also performs the function of zoning the various land uses. Here, the development visions of the municipalities are presented, which have a legally binding effect on the second instrument at this level, the "Local Detailed Plan". This plan has the purpose of developing a specific area within a municipality. It can define, among other things, permitted land uses, number of stories, building heights, certain design regulations, and other prohibitions and restrictions. It forms the basis for building permits for structures. The Municipal Council is responsible for both the Local Master Plan and the Local Detailed Plan (Purkarthofer and Mattila 2023).

Despite the structure of the planning system, in which specific sectoral planning topics are integrated in the sense of integrated planning, especially in the "Regional Land Use Plan" or the "Local Master Plan", the understanding of planning is rather less coordinative but more strictly local and design-oriented (Purkarthofer 2023).

In the specific case of Finland and Helsinki, in addition to the formal planning tools, it is necessary to mention that innovative digital possibilities are increasingly being applied and tried out in planning and are now established as a working method in many Finnish cities. Among these, the case study considered here, the digital twin of the City of Helsinki, should be mentioned. It will be explained in more detail in the next two sections.

4.2 Development and Technical Issues

Digital twins as a tool or software program have their origins in the industrial sector, where they are used in manufacturing to increase productivity and efficiency and are used in the fields of "designing/planning, optimization, maintenance, safety, decision making, remote access, and training, among others" (Singh et al. 2021). It is a "dynamic digital representation of a 3D-designed product or solution which, in the most optimal cases, represents the same features and provides the same information as its physical counterpart" (Hämäläinen 2021). Applied to the context of the digital twin of a city it is thus a 3D city model of the physical city. But it is a "solid data infrastructure forms the foundation for [...] digital twins" and has to be enriched by "city data, such as energy consumption or traffic data" (Hämäläinen 2021).

The beginnings of the City of Helsinki's digital twin go back to considerations in the 1980s. At that time, the city had seen the need to simplify processes related to road maintenance and construction. The many different departments responsible for different technical infrastructure, such as telephone, water pipes or electricity, was identified as a problem, as each department only had its own data available. The idea was therefore to share and connect these data with each other. This provided a first use case. However, in the early stages of development, it was a simple 2D basemap that was developed, but digital and therefore flexible in terms of how the map could be used to map data. Over time, more and more use cases were added and the map has finally evolved into a 3D model of the city (Tuukkanen 2023).

Important actors in the development of the digital twin of the city of Helsinki were and are the City Survey Department of the city administration and also the private sector. The City Survey Services of the City of Helsinki have the responsibility to provide the basic data for the creation of the model, so in particular the modeling of terrain, to map the topography, as well as the built environment. This involves, for example, taking measurements, but also flying over the built environment from various perspectives. The private sector with companies in the field of software development play an important role in the technical development of the tool, since here the City of Helsinki can access the necessary expertise and resources. In addition, however, individual pioneers or visionaries with the relevant competence function are also important in order to be able to implement existing ideas. In the case of the city of Helsinki, a mayor at the time provided the necessary budget for development due to his personal affinity for architecture and urban planning. The main user of the digital twin is the Urban Planning Department of the City of Helsinki, which uses the tool in urban development. However, there are other city departments that interface with and use the tool. Citizens also use the digital twin, on the one hand for public services and on the other hand within the context of participation processes initiated by the Urban Planning Department (Tuukkanen 2023).

The digital twin of the City of Helsinki was built specifically for the needs of the city. Two basic digital models have been created. On the one hand, there is the mesh model, which does not contain exact geodata, but offers a more detailed modeling and is therefore mainly used for visualizations, and on the other hand, the GML model, in which each object has an exact geoinformation, which can be stored with data, and in which measurements can also be performed. Therefore, the GML model is used mainly for analytical use. In particular, the terrain, building bodies, but also partly underground areas and the interior of buildings are modeled. Each object in the model has a uniquely assigned ID. This makes it possible to bundle data from different departments in the same model. The digital twin is thus also a platform for data collection and links the various application areas and users, enabling coordinated collaboration. Points, lines, surfaces and volumes in the model can be used to visualize the data. The digital twin is also linked to the portal for openly accessible data, the "Helsinki Region Infoshare" (Tuukkanen 2023, City of Helsinki 2022).

4.3 Application in Urban Planning

The digital twin of the city of Helsinki is used by the city administration for urban planning and has already established itself here as a tool and working method in spatial planning (Tuukkanen 2023).

Many different functions can be used in planning. In traditional urban development, the plans for their implementation lead to a Local Detailed Plan. In the preparatory planning process, however, the drafts are visualized with the help of the digital twin. This makes it possible to compare different planning scenarios with each other and also to use them in the context of public participation integrated in the tool (City of Helsinki 2023). At the same time, urban planners can use basic functions of the GML model, such as taking different spatial perspectives, shading at certain times of the day and year, and measurements (City of Helsinki 2022). As a result, the digital twin of the city of Helsinki is a kind of new and innovative informal planning tool that can be used as a multifunctional tool.

The tool is not only multifunctional, but also multisectoral. There are many different use cases for special topics in spatial planning. On the one hand, these can be used within the specific spatial planning sector, but on the other hand, they are also available to planners for coordinated planning, e.g. for the development of new urban areas. Planners can thus map different thematic analyses into the model and superimpose them as needed to make data- and fact-based decisions. This has happened, for example, in the development of Helsinki's Smart City lighthouse project, the revitalization of old harbour areas to develop the Kalasatama urban district (Hämäläinen 2021).

The city of Helsinki presents some of these sectoral use cases on its website (City of Helsinki 2023). These include, for example, the visualization of data on offers and possible plans in the field of mobility analysis, the visualization of radiation on building surfaces for the analysis of solar energy potential, the visualization of technical infrastructure for the optimization of maintenance and planning and execution of construction works, the modeling of inner-city trees, the so-called Urban Tree Database, for use in the maintenance of the tree population, but also in the preparation of necessary environmentally relevant documents in permit procedures in urban planning, as well as the projection of heat islands in the city, which also makes use of weather data (City of Helsinki 2023, Tuukkanen 2023).

Not all of these use cases are openly accessible. Especially in the case of data on critical infrastructures or sensitive information to which individual people could be linked, the city is the exclusive user of the tool. Despite the numerous possibilities offered by the tool, it is currently still mainly used for development and planning, especially the visualization of planning scenarios, analytical sectoral factors and citizen participation. Not yet strongly used are the possibilities in the daily city operations, which can be implemented with the help of technologies such as sensors, machine learning and artificial intelligence. In this area, the tool offers much more potential and could be the next step in the tool's development (Tuukkanen 2023).

5 CONTRIBUTION TO SPATIAL TRANSFORMATION

In order to be able to make a conclusion about the contribution of the digital twin of the City of Helsinki to spatial transformation, the first question to be asked is which transformative process exactly is being considered here. In addition to the core topic of spatial transformation, the management of issues relevant to climate change, there are other mega-trends, such as demographic change or digitalization, that are relevant in the context of societal transformative processes.

It can be stated without a doubt that the digital twin of the city of Helsinki makes an important contribution to climate-related issues related to global warming and the goal of decarbonization and adaptation to the changing conditions cities are confronted with.

There are many use cases of the Digital Twin where planning decisions are supported by data, analyses and visualizations of planning scenarios with regard to sustainable urban development. For example, the tool's application functions have the purpose of highlighting potentials for the development of emission-free energy production. The projection of heat islands in the city makes it possible to recognize where intervention is needed, for example, to create more resilient spaces with greening. Mobility analyses enable the strategic planning of sustainable mobility offers and promote therefore sustainable urban development.

The contribution to coping with a spatial environmental transformation process is definitely given, however, the impact on the consequences of the mega-trend of climate change is not extraordinarily high, and can also be compared with other projects that have a similar output without using digital twins. On the other hand, the digital twin as a technological innovation in spatial planning makes many processes easier. Considering the enormous challenges faced by municipalities, the tool offers enormous advantages and puts the City of Helsinki in a privileged position here compared to other cities. The administration of the City of Helsinki is responsible for tasks that other cities in the world are responsible for, too. In the era of crises, digitalization and increasing regulation of public tasks and competencies, the City of Helsinki has a tool in the form of the digital twin that takes away some of the complexity and enables the city administration to work more efficiently. Ultimately, this also benefits efforts to achieve sustainable and resilient urban development.

When considering digital transformation, the contribution to the transformative process can also be confirmed. Both the transformation in terms of climate change-related issues and digitalization demonstrate a direct connection with the functions and effects of the tool on the working methods in the city. Particularly with regard to the digital transformation, it can be seen that the impact is extraordinarily high, as the public tasks from different areas and departments are functionally linked with each other and the work becomes more efficient. The digital twin of the city of Helsinki is thus a project that is driving digitization in the city very strongly and has the potential of having an influential impact on other cities as well.

6 CONCLUSION FOR METHODOLOGICAL CONSIDERATIONS FOR FUTUR RESEARCH

From the example of the Digital Twin in Helsinki, it is possible to reflect on the methodological approach to analyze the contribution of an innovative digital tool used in spatial planning to spatial transformation processes.

Transition theory can be used in transformation research to identify transformative processes as such and to trace their development and course. It is important, however, that the specific element to be measured is no longer in the realm of the niche, but has already established itself at the regime level.

It is important to clearly define a coping and management objective for the mega-trend or crisis, as this is the only way to check whether the development of the niche innovation and its establishment at regime level will contribute to fulfilling the coping and management objective. The goal here should not be to fully achieve the coping objective. Since spatial transformation can be a very long process that is usually approached from many different directions, it is unlikely that the contribution of a single aspect alone will achieve the complete coping and management.

However, when comparing the impact of an innovation established at regime level with a potential contribution to a defined coping and management objective, the question arises as to its quantifiability. In order to assess the existence of a contribution, only the general knowledge of solution approaches to the mega-trend or crisis in question prevailing at the time of the analysis can be applied. This results in the necessity of naming the corresponding solution approaches in advance, at least roughly and with reference to the specific topic of the innovation. In the case of climate change, for example, a solution approach according to the prevailing current state of knowledge would be the creation of inner-city green spaces. If the impact of an innovation, such as a tool that identifies green space potentials, is matched with its contribution to addressing climate change, the contribution can be confirmed by this finding. However, the expression of a contribution can vary widely even when it exists. Therefore, it is recommended to categorize the contribution, based on different levels of expression. Possible categories could be:

- only an indirect contribution
- direct contribution with low or no extraordinary impact on the mega-trend
- direct contribution with extraordinary impact on the mega-trend

This categorization in turn creates quantifiability to a certain degree.

When considering an innovation, however, it can happen that the contribution of different sub-aspects, such as different functions of a digital tool, are also assessed in different ways. Therefore, care must be taken in the procedure not to combine different aspects to be distinguished in the investigation.

The following figure summarizes the considerations regarding the methodological approach.

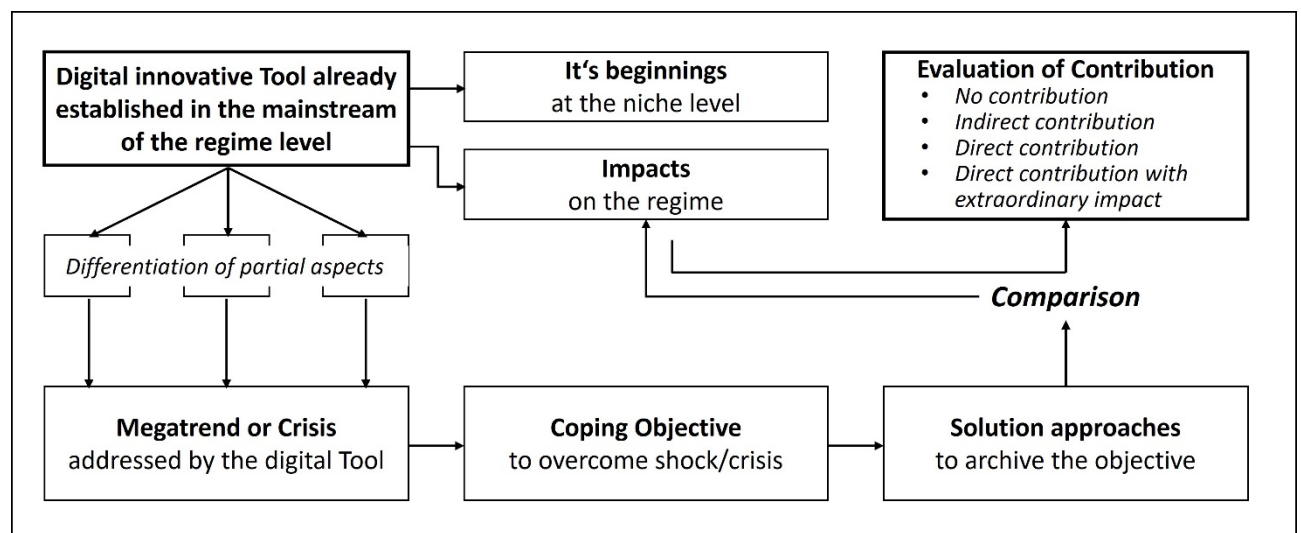


Figure 3: Proposed methodological approach to analyse and evaluate the contribution of a technological innovation in spatial planning to a transformative process by making use of the Multi-Level Perspective approach of transition theory; own design

However, it also became clear that for a holistic view of a technological innovation in spatial planning, further components must support the analysis. This includes, in particular, the identification of the planning culture context, taking into account the specific context of digitalization and the relevant mega-trend or crisis.

Another component to be added is the observation of the digital tool itself. Development, functions and actor structures must be identified. The technical dimension plays a particularly important role here. The methodology proposed so far is not yet able to accomplish enough in this regard. With the goal of applicability for future case study research, a standardised research grid is needed in this area that can measure technological, functional and data-based factors. There is a need for further research in this area.

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