

## Walk & Feel – a New Integrated Walkability Research Approach

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### 1 ABSTRACT

Walking is healthy, promotes social contacts and is a basic requirement of mobility. Nevertheless, between 1995 and 2013/14 the modal share of walking in Austria declined from 27% to 17%. However, walking is a big unknown factor in the overall transport system, as it is statistically often unrecorded. This also expresses an underestimation of the importance and positive effects of walking in the overall transport system. The term “walkability” is often used to describe the attractiveness of walking which not only includes the path quality but also attractive and animating conditions to walk.

The project presented in this paper aims to develop a methodology, which should improve the conditions for pedestrians on their daily walks and increase the quality of life. A major requirement for this purpose is a comprehensive and high-quality data basis for assessing the quality of walking – leading to more insights into the needs of pedestrians. Biosensoric technology to gather physiologic data about people’s reaction concerning walking infrastructure will support this new approach. The approach will join subjective and objective methods to create a new view about perception and emotions of pedestrians. By this means it will evaluate spatial conditions like street design, built environment, perceived safety to achieve “walkability” or a more walkable infrastructure.

This contribution introduces the topic, presents the state of research concerning walkability as well as a concept of a theoretical framework of the project. This includes a methodology to collect, analyse and visualise the collected data, and further describes technologies for sensor-based measurement of perceptions and emotions while walking. Finally, the paper gives a first glance to the web-based platform, where different data sources are combined and visualised for various user groups and purposes.

Keywords: sensors, emotion, methods, walkability, pedestrian

### 2 INTRODUCTION

Cities and municipalities in Europe are getting more and more aware of the role and importance of the quality of walking and hence increasingly aim to improve the quality of public space, road safety and other relevant infrastructure. The aim is to create attractive conditions and to motivate residents to walk more (Madanipour, 2005). As an example, in Austria, comprehensive measures were compiled to make walking more attractive. Essential fields of action are, for instance, infrastructure as well as aesthetic improvements and pedestrian-friendly traffic, settlement and urban planning. Nevertheless, between 1995 and 2013/14, the modal share of walking nationwide declined from 27% to 17% (Bundesministerium für Verkehr, 2016). The main reason for the decline might be the shift to other means of transport. The only exception in Austria is the city of Vienna, where the share of walking stayed constant (about 25%) (Bundesministerium für Verkehr, 2016). However walking is "the big unknown in the overall transport system, as it is statistically often unrecorded"(BMLFUW and BMVIT, 2015). Additionally, data is collected only on a selective basis and to answer individual questions (Sauter, 2010). This also expresses an underestimation of the importance and positive effects of walking in the overall transport system.

The concept of walkability supports urban planning processes by considering important quantitative and qualitative aspects of walking in cities. However, a variety of recent literature shows a discrepancy in the definition of walkability, its contributing factors and methods to assess these factors (Forsyth, 2015). The assessment of subjective walking quality has so far mainly been examined by qualitative methods (surveys, observations, etc.). However, human perception plays an increasingly important role in spatial planning and especially in studying walking behaviour. Perception or emotion are reflected in specific physiological

parameters such as skin temperature, skin conductance or heart rate variability (Kanjio et al., 2015; Kreibig, 2010). New technological developments allow to record physiological reactions and to map them in certain situations. The project Walk & Feel, which is funded under the programme “Mobilität der Zukunft”, has therefore the goal of creating a comprehensive and high-quality database for assessing the quality of walking.

### 3 THE CONSTRUCT OF WALKABILITY

#### 3.1 How to define walkability?

A city’s attractiveness for walking is often expressed as ‘walkability’ (Tribby et al., 2015; Weinberger and Sweet, 2012). While walkability is a commonly used term, there are numerous conflicting definitions and it is rarely defined in dictionaries (Forsyth, 2015), most of which have emerged in the USA in planning disciplines. The narrower definition of walkability encompasses an empirical concept and refers to walking as a potential modal choice for a specific purpose (e.g. walking to work, bus/train stop, grocery shopping). The integration of leisure-related mobility into the understanding of walkability has led to a broader understanding of the term, which has also changed the scope of walkability (Bucksch and Schneider, 2014). It resulted in an emerging interest in other disciplines as well, such as social science, cultural geography, anthropology (Lorimer, 2016; Middleton, 2010) and health (Grasser et al., 2016; Handy et al., 2002; Saelens et al., 2003).

Walkability studies have found “that people living in ‘traditional’ neighbourhoods — characterised by higher residential density, a mixture of land uses (residential and commercial), and grid-like street patterns with short block lengths — engage in more walking and cycling trips for transport than people living in sprawling neighbourhoods” (Saelens et al., 2003). However, it often remains unclear whether “the extent to which the observed patterns of travel behaviour can be attributed to the residential built environment itself” (Cao, 2009). For example, car enthusiasts would choose car-oriented neighbourhoods and “residents who prefer walking may consciously choose to live in neighbourhoods conducive to walking, and thus walk more” (Cao, 2009). Based on this understanding, people move independently into the spatial categories that best fit their mobility needs, which is referred to as “residential self-selection” (Bagley and Mokhtarian, 2002; Handy et al., 2006). In addition, Krizek (Levinson et al., 2018) discusses if it is possible to urge residents of formerly car-oriented districts through urban planning and infrastructural measures to rethink their mobility behaviour. He emphasises that attitude plays an important role and concludes with a modified old phrase “You can take the family out of the suburbs, but you can’t take reliance on the Chevy Suburban out of the family” (Levinson et al., 2018). Nevertheless, there is a strong interrelation between built space and the behaviour or activity patterns of the use of urban space (Handy et al., 2002). The urban form influences behaviour and vice versa (Gehl, 2011), which has already been demonstrated in numerous research projects (Cervero and Duncan, 2003; Handy and Clifton, 2001; Greenwald and Boarnet, 2001). On the contrary, the effects of residential choices in the context of walking behaviour and walkability are often neglected. Many researchers conclude that in dense, diverse, compact and green environments people generally tend to walk more and they are more physically active (Charreire et al., 2012; Schmidt and Tran, 2012; Saelens et al., 2003; Cervero and Duncan, 2003).

However, the standards for a walkable neighbourhood in the US-American context are not always transferable to the European structure. For example, the year of construction of the district and the presence of the sidewalk are characteristics to determine walkability (e.g. a neighbourhood with historical buildings has higher walkability), whereas in Europe these characteristics do not determine walkability.

The methods of walkability analysis often define an “index”. This is critical in terms of data reduction (from the final values of an index the values of the single features usually cannot be reconstructed), weighting of individual characteristics (which is partly at the discretion of the researcher), and often makes no spatial or socio-demographic differentiation (Rohwer and Pötter, 2002).

Walking is done for different (1) purposes such as transportation, exercise, and recreation (which can be also divided into non-scheduled and scheduled actions) (Keyvanfar et al., 2018; Shafaghat, 2013). Walking can also be further differentiated by (2) socio-demographic characteristics (gender, age etc.) (Titze et al., 2010; Shafay and Kim, 2017) or by (3) spatial or structural context (neighbourhood, district, city) and the aspect

of (4) spatial features that are important for residential location choice, which evolved as a relevant research topic in the relationship between active sustainable mobility and spatial planning.

### 3.2 Walkability within the Walk&Feel approach

The detection and description of “walkability” due to the background of urban and transportation planning is important, perhaps the core aspect of the Walk&Feel approach presented in this paper.

This paper aims to extend the understanding of walkability and to propose a wider methodical and practical understanding embedded in the European context: This also extends the basic means as mentioned by Forsyth (Forsyth, 2015) by adding (design) qualities and the pedestrians’ perception and/or stress level while walking. However, when defining walkability, it should also include a discussion on how to assess walkability, which probably has an even higher relevance than a universal definition. Methods to assess walkability have long been similar to empirical evaluations based on quantitative data. In addition, qualitative methods should be part of a new walkability concept and understanding.

To implement walkability principles in planning and infrastructural projects, planners and municipalities need data and evidence. We emphasise that these data should rely on the extension of methodological competence in transportation, spatial planning and GIS by linking new measurement methods to evaluate the walkability. Furthermore, a methodological discussion is also necessary, striving for an evidence-based database with increased plausibility and relevance of analysis results by considering the spatial environment and its effect on people (including their mobility behaviour).

To verify the practical applicability, a field study will be carried out in three different spatial structures in Vienna, Salzburg city and Salzburg surrounding area within total 60 participants. Based on the collected data, the test areas are evaluated with regard to their walkability. As a starting point for further evaluation and application, the project outcome includes an evaluation of the method developed, including benefits and costs, as well as concrete recommendations for use in planning and participation, as well as for technical developments (such as footpath routing).

### 3.3 Bio-sensor technology for walkability?

In addition to “traditional” methods and instruments like a questionnaire and even geodata-based methods to evaluate “walkability”, the integration of bio-sensor technology enriches the proposed walkability assessment by detecting specific patterns which provide indications on human emotions (Zeile et al., 2016; Dörrzapf et al., 2015). Typical physiological parameters to detect perceptions or emotions are skin temperature, skin conductance or heart rate variability (Kreibig, 2010; Kanjo et al., 2015). Using sensor technology to gain physiological data has the advantage of describing an emotion with objective, raw data. These objective measurements do not base on self-reports of a person but are methods in which externals or equipment collect the data. This mostly physiological measurement allows excluding subjective distortions from the participants in the study, which usually occur in reported data. The main drawback is that no direct conclusion on human experience and behaviour can be drawn from objective physiological measurement data, – for this additional reported data is needed (Döring and Bortz, 2016). In addition, data can be collected over time or in real time. Spatial localization of stress situations makes it possible to identify grievances in the environment (Exner et al., 2012). However, the new approach still lacks reliability and is difficult to use in a non-laboratory environment (see discussion). Currently, Electrodermal Activity (EDA) seems to be the most reliable parameter to derive emotions in an ambulant assessment for detecting stress situations concerning urban issues. EDA is the property of the human body that causes continuous variation in the electrical characteristics of the skin which can be an indicator of stress (Zeile et al., 2016).

## 4 OUR APPROACH AND OBJECTIVE

The overall goal of the project Walk & Feel is to improve the conditions for pedestrians and thus to increase the quality of life in urban areas. By collecting comprehensive and high-quality data basis shall be provided to accurately evaluate the quality of walking conditions (walkability). Bio-sensor technology collecting physiologic data about people’s reaction while walking will support this new approach. However, the approach will join subjective and objective methods to create a new view about perception and emotions of pedestrians. This allows to evaluate spatial conditions like street design, build environment, perceived safety in order to achieve “walkability” or a more walkable infrastructure. One central innovation is developing a

sensor-fusion method (combination of different measurement parameters) which represents significant progress compared to the current state of research. Sensor measurements ("objective" technical measurement data) and eDiary inputs ("subjective" data) are combined to identify and locate the trigger of the human physiological response. The core element, where all data will be combined and visualised for different user groups and purposes, is a web-based visualisation client that is described in section 5.

## 5 THE VISUALISATION CLIENT

Within the project Walk & Feel the main purpose of the client will be visualising and comparing the results of the gathered and processed data in order to evaluate the new methodological approach. By the time the client is fully developed, it will support mobility experts, administration and decision-makers in solving planning and design tasks aiming to improve walking conditions. Public planning institutions in the fields of transportation and infrastructure, citizens' initiatives as well as policy makers are further possible user groups of the visualisation client.

In the following paragraphs two mock-ups are described which were created in the course of the first conception of the visualisation client. These drafts show first ideas about the implementation and some basic functionalities. The mock-ups are continuously developed alongside an increasingly finer granularity of the evaluation concept.

The basic requirement of the visualisation client is comparing the results of the four main data sources of the field study: 1) bio-sensors: measured physiological parameters and derived stress-indicators, 2) integrated walkability index IWI calculated by GIS from single parameters concerning infrastructure and urban quality, 3) eDiary app allowing to record all types of observations on-site and 4) traditional paper-based questionnaires. Moreover, the results of the three field test areas shall be compared between each other, e.g. in parallel windows. Comprehensive compare functions facilitate both the interpretation of the obtained results as well as the evaluation of the new method in terms of validity and additional explanatory power.

The pivotal element of the client is the control window on the right-hand side, as shown in Figure 1. Here all the settings concerning function and layout are made. After a task has been selected the displayed windows and widgets change to the specific layout of the task so that the users are provided only with those functions and information needed to perform the task. The control window can be folded in and out to obtain a full map view if required.

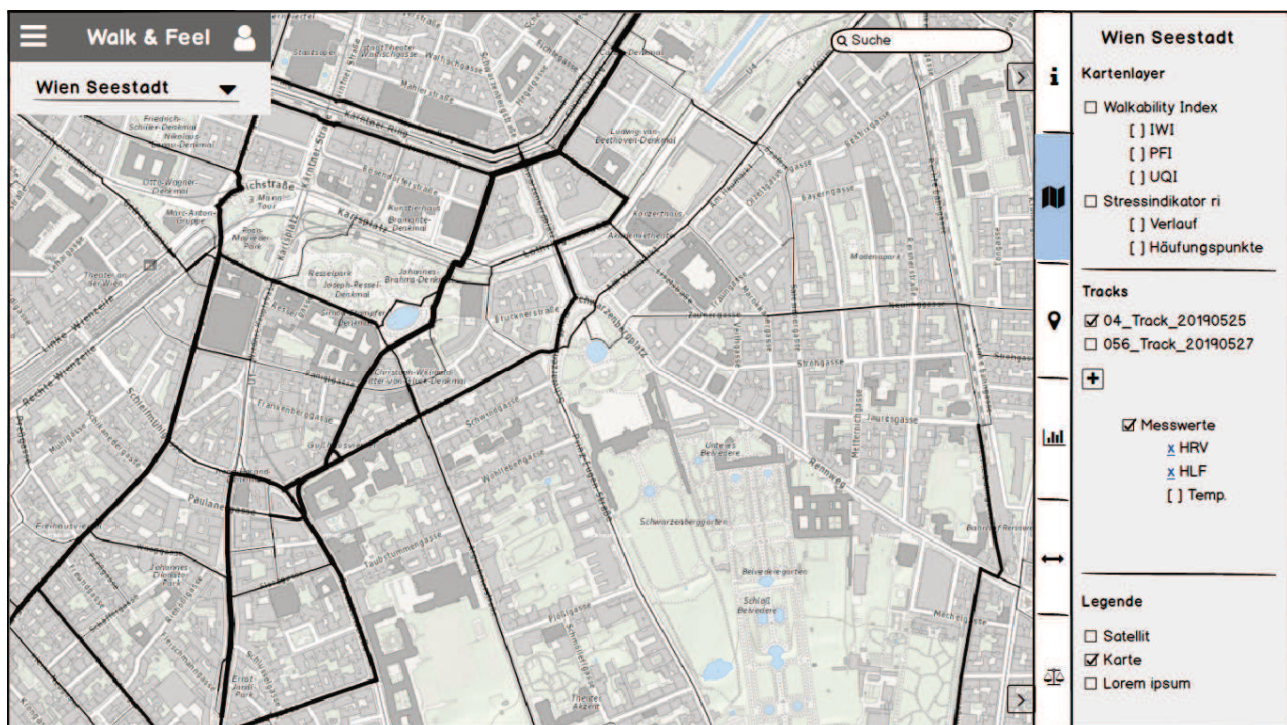


Figure 1 Mock-up of the visualisation client – Overview

The figure shows the field test area of Vienna and the task 'map' selected in the control window. This is where the user can select map layers, certain tracks and filters to be applied on the displayed data. The results

of each data source of the field study are presented in an own layer, such as the walkability index or stress indicators based on algorithms applied to the bio-sensing data. In addition, the results of the questionnaire as well as observations and memos recorded with the eDiary app can be displayed and thus be related to the results gained from bio-sensing.

In addition, various background GIS-layers as well as layers with additional spatial or infrastructural data (i.e. density, land use, traffic intensity) can be selected in order to enhance the explanation of the results.

The data collected by the participants of the field study can either be displayed as individual walking tracks or as aggregated results for each test area. When showing individual walking tracks (GPS-based) the chosen physiological parameter or stress indicator is depicted in its specific colour scale. By setting markers, stress points identified by the algorithm from the bio-sensor data can be displayed as single points. Viewing individual tracks is particularly interesting for the participants who are curious about their own physiological reactions while walking.

However, for those involved in planning, spatially aggregated results are essential to recognise accumulations of stress points in urban space. Identified stress points as well as deliberately recorded observations (eDiary app) can be visualised as single points. Due to spatial proximity, a kind of clustering is necessary. Another option for presenting the spatial density of stress points are various types of heat maps. However, the statement conveyed by the specific illustration must be clear before generating a colourful map. In any case normalisation of the recorded stress points is crucial for properly understanding the meaning of the data. Factors such as walking speed and time must be taken into account. One possibility for normalization is to divide the test area into grids of equal size and to display the number of stress moments normalized to a unit of time. Thus, locations with longer or frequent stops of the participants (e.g. crossings with traffic lights) do not automatically have a high density of stress points. It would also be possible to refer the measured stress point to the street sections taking into account the total time spent there by all participants.

The second mock-up shows the task length line ('Längenband'). A length line shows the covered distance as a straight line with corresponding dimensions and additional information such as walking speed, stress level, etc. Additionally, contents from the eDiary app can be displayed. In combination with the map, the test track with all visible features can be reproduced in detail.

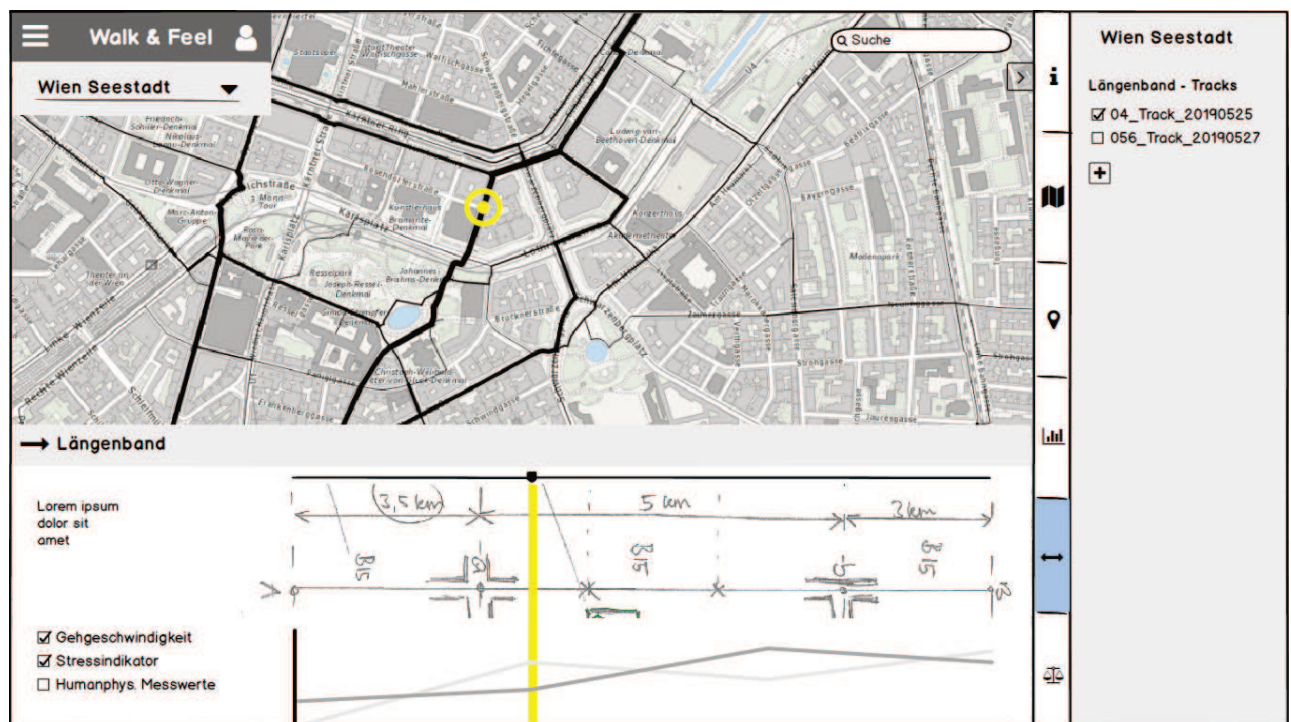


Figure 2 Mock-up of the visualisation client - Length band

The length line shows the tracks selected in the control window. Two or more selected tracks are shown one above the other. They contain the basic information about the track and the distance covered. Furthermore, the measured values of the selected tracks can be traced in a line chart. The reference between the length line

and the map is displayed as the corresponding marker. This is sketched in the figure above as a yellow line in the length line and dot on the map.

Only a small part of the results from the paper-based questionnaire will be included in the visualisation client - mainly as selected examples for diagrams and tables. Observations recorded with the eDiary app are already assigned to pre-defined categories during the manual input. These categories can be used for visualisation by showing each observation with a marker in the colour according to the category. In addition, the points drawn in the analogue map can also be assigned to the selected categories during digitisation.

Additional information on the field tests, such as the number of participants, the period of time, weather, details on the route, etc., is available in the item 'info'.

## 6 DISCUSSION AND CONCLUSION

The methods mentioned in the integrated approach have been successfully tested in different research studies, mostly in bicycle traffic research, but barely in the context of walkability. Nevertheless, there is still some limitation in the context of research criteria, data analysis, data and privacy issues.

The field tests in a real-world setting are a challenge because it is not fully possible to standardize the test situation. It is necessary to avoid outside interference factors (e.g. building sites, events) as far as possible and to keep interfering factors (weather, noises, daytime) as constant as possible during the field tests. Moreover, even if all interfering factors are limited, what if the person walking and using the sensors is distracted by something not related to the walking conditions (i.e. a stressful telephone call, an annoying encounter) or feels uncomfortable wearing a biosensor? This is also connected to the criteria of validity, where two other important questions arise. Does the instrument measure what it is supposed to measure and how can the researcher assure that the bio-sensing data is not influenced by the above-mentioned factors? Reliability should be given through the accuracy of the technology; a potential source of unreliability is the changing nature of the process being measured (Muckler and Seven, 1992). Reliability assumes that the measuring process remains relatively stable over time, which is – even if external factors are under control – not completely given in a real-world setting.

In any case, privacy issues have to be considered, such as technological measures to protect the personal privacy, guidelines for the data collecting process as well as legal aspects of location privacy. One core question arises during the commencement of the General Data Protection Regulation (GDPR). How can privacy be protected during field tests? Are there technological tools like spatial decision support system (SDSS) which “can be specified for the application domain of geo-privacy in order to help and guide “data holders”, researchers (or principal investigators in larger research campaigns) when anonymising their data?”(Kounadi et al., 2018).

The suggested approach should make progress towards a more holistic walkability understanding and rely on the extension of methodological competence in transportation, spatial planning and GIS by linking new measurement methods for walkability evaluation. There is clearly a need for reliable and practicable methods or technologies helping to improve the conditions for pedestrians and quality of life in urban areas. Therefore, it is absolutely vital to collect comprehensive and high-quality data as a basis for an accurate evaluation of the quality of walking and understand the concept of walkability. The visualisation client allows to compare and relate the different data generated with the aim to evaluate the walkability. Thereby it supports to understand the meaning of the obtained results better and to estimate the benefit and the practical applicability in planning and design tasks related to walkability.

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