Tiitu, Maija; Heikinheimo, Vuokko; Karjalainen, Linda E.; Helminen, Ville; Lyytimäki, Jari; Lehtimäki, Jenni; Paloniemi, Riikka

# A spatially explicit comparison of walkability within city-centre and suburban contexts in Helsinki, Finland

*Published in:*
Landscape and Urban Planning

*DOI:*
10.1016/j.landurbplan.2024.105196

Published: 01/12/2024

*Document Version*
Publisher's PDF, also known as Version of record

Landscape and Urban Planning 252 (2024) 105196

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

# A spatially explicit comparison of walkability within city-centre and suburban contexts in Helsinki, Finland

Maija Tiitu [a,b,*], Vuokko Heikinheimo [a], Linda E. Karjalainen [c,d], Ville Helminen [a], Jari Lyytimäki [c], Jenni Lehtimäki [a], Riikka Paloniemi [c]

[a] Finnish Environment Institute (Syke), Built environment solutions unit, Helsinki, Finland
[b] Aalto University, Department of Architecture, Espoo, Finland
[c] Finnish Environment Institute (Syke), Societal change unit, Helsinki, Finland
[d] Aalto University, Department of Built Environment, Espoo, Finland

## HIGHLIGHTS

- In the city centre, high objective and perceived walkability mostly overlapped.
- In the suburban centres, high objective and perceived walkability rarely overlapped.
- Pleasant sensory experiences across urban fabrics may induce multi-purpose walking.
- Prerequisites for walking differ between the city centre and suburbs.
- Urban fabrics should be considered in the planning of walkable cities.

## ABSTRACT

Walking and high-quality walking environments are essential for sustainable and healthy cities. Walkability depends on both objective environmental features and perceived aspects. However, less is known about how the interplay between objective and perceived walkability influences walking behaviour across different urban contexts. We conducted a spatially explicit comparison of walkability and walking routes between a city centre representing inner-city walking fabric and a suburb comprising transit and automobile urban fabrics in Helsinki, Finland. Our objective walkability index consisted of floor space ratio, functional mix, and accessibility variables, while the perceived quality index included safety, comfort, and enjoyment variables retrieved from public participatory GIS data reflecting citizens' perceptions. We also compared the characteristics of hotspots of people's reported routes for utilitarian and recreational walking, incorporating additional variables, namely green and blue index, which consisted of the NDVI and shoreline length. We found that prerequisites for walking significantly differed between city-centre and suburban contexts. In the city centre, objective and perceived walkability were high in the commercial centre, whereas in the suburb, they rarely overlapped. Suburban centres had a lower degree of perceived walkability than the city centre, but these areas were widely used for utilitarian and recreational walking. In the city centre, perceived protection was higher in utilitarian walking hotspots, which were also associated with higher building density, functional mix, and objective walkability index. Conversely, in the suburb, perceived protection was higher in recreational hotspots, associated with higher urban permeability, NDVI, and shoreline length. High perceived enjoyment, i.e., pleasant sensory experiences, induced both utilitarian and recreational walking across urban fabrics. Our results underline the importance of including citizen perceptions in walkability planning. With more limited mobility options, suburban walkability is crucial for fair mobility. Such contextual features of walkability need to be better addressed in future studies and planning practices.

## 1. Introduction

Enhancing walkability has become one of the main goals of urban planning as cities worldwide strive to reduce environmental and social problems caused by motorized traffic and physical inactivity (Bozovic et al., 2021; Giles-Corti et al., 2016; Lovasi et al., 2011; Newman & Kenworthy, 2015). Walkability is an umbrella concept that combines approaches from diverse research and planning traditions regarding urban infrastructure and the quality of the urban environment (Dovey & Pafka, 2020). It is an assemblage of environmental characteristics and perceived aspects that either support or restrict walking (Leslie et al., 2007). Considering different population groups with special needs or

* Corresponding author at: Finnish Environment Institute (Syke), Built environment solutions unit, Latokartanonkaari 11, FI-00790 Helsinki, Finland.
*E-mail addresses:* maija.tiitu@syke.fi (M. Tiitu), vuokko.heikinheimo@syke.fi (V. Heikinheimo), linda.karjalainen@syke.fi (L.E. Karjalainen), ville.helminen@syke.fi (V. Helminen), jari.lyytimaki@syke.fi (J. Lyytimäki), jenni.lehtimaki@syke.fi (J. Lehtimäki), riikka.paloniemi@syke.fi (R. Paloniemi).

https://doi.org/10.1016/j.landurbplan.2024.105196
Received 18 October 2023; Received in revised form 9 August 2024; Accepted 16 August 2024
Available online 3 September 2024

different abilities and resources, such as older people, children or poor, walkability can also be framed as a question of safety and justice (Sheller, 2018), as well as social inclusion, cohesion, and universal accessibility (Iroz-Elardo et al., 2021; Stafford & Baldwin, 2018).

Studies have shown that certain characteristics of the built environment, such as high density and mixed land use support walking, while others, such as single-use and low-density land development are negatively associated with it (Fonseca et al., 2022; Frank et al., 2005). In addition, walkability is affected by personal perceptions of prevailing conditions, such as perceived protection, including e.g. traffic safety and sense of security, aesthetics, lighting, street furniture, and maintenance (Bozovic et al., 2021; Gehl, 2010; Moura et al., 2017). In recent decades, measuring walkability has evolved from identifying general rules of thumb for vibrant streets and neighbourhoods (Jacobs, 1961) to defining absolute metrics with algorithmic scores or objective walkability indices (WI), such as Walk Score® (Shields et al., 2021). A more limited but growing number of studies also focus on or include perceived walkability and urban design perspectives (De Vos et al., 2023; Ewing & Handy, 2009; Fonseca et al., 2022). In Finland, previous walkability studies have been mostly focusing on the associations between objective walkability measures and walking behaviour among certain population groups as well as individual motivations for walking (Kajosaari et al., 2019; Laatikainen et al., 2019; Niitamo, 2023; Willberg et al., 2023).

Many studies have been comparing objective and perceived walkability in various contexts, revealing divergences but also positive associations between them (Arvidsson et al., 2012; De Vos et al., 2023; Koohsari et al., 2015, 2021; Orstad et al., 2017). In many of these comparative studies, neighbourhood walkability has been assessed by calculating a single variable or index for each neighbourhood, often spatially defined as administrative districts (Gebel et al., 2009, 2011; Van Dyck et al., 2013), or buffer zones ranging from 400 m to 1.6 km (Arvidsson et al., 2012; Jensen et al., 2017; Koohsari et al., 2021; Meng et al., 2023). Fewer studies comparing objective and subjective walkability have delved into fine-scale grid or route assessments, typically using a 100-m grid (Kim et al., 2019; Rodrigue et al., 2022; van der Vlugt et al., 2022). However, studies show that neighbourhoods defined by residents themselves or demarcations produced through participatory survey data tend to be larger and less home-centred compared to the commonly used definitions (Bödeker, 2018; Hasanzadeh et al., 2017). Furthermore, in objective WIs, there is a common assumption that all the built environment characteristics within the studied neighbourhood are homogenous or well represented by the average conditions (Arellana et al., 2020). Yet, in walkability studies, there is a growing consensus emphasising the importance of micro-scale urban design features, such as sidewalk quality and street greenery (De Vos et al., 2023; Ewing & Handy, 2009; Kim et al., 2014; Larranaga et al., 2019). This underscores the need for investigating both objective and perceived walkability at a fine spatial scale.

Spatially explicit overlaps of objective and perceived walkability have not been studied extensively. Considering spatial discrepancies, two US case studies found that areas of low WI but high perceived walkability concentrated in suburban areas with good accessibility to public open spaces, such as parks and lakes (Bereitschaft 2018; Meng et al. 2023). In contrast, in these two studies, WIs and perceived walkability were found to overlap in high-density areas, e.g., city centres and mix-use suburbs with relatively high accessibility to facilities and parks. Both studies were however conducted in the spatial scale of a city region and few interpretations could be made on the level of individual neighbourhoods or blocks (Bereitschaft, 2018; Meng et al., 2023). A study from Seoul, South Korea, found only four locations (100 m grid cells) in which objective walkability (Walk Score) diverged from the perceived one (Kim et al., 2019). However, here, the perceived walkability was only measured by a binary variable of pedestrian satisfaction, which limits the interpretation of different aspects related to perceived walkability.

Previous studies have recognised the need to separate between walking for transport (utilitarian walking) and for leisure (recreational walking), since the different types of walking are affected by different built-environment characteristics (De Vos et al., 2023; Kang et al., 2017; Rodrigue et al., 2022). Utilitarian walking has been found to positively associate with, e.g., residential density, land-use mix, and street connectivity, while recreational walking is more affected by, e.g., aesthetics, walking facilities and the presence of green spaces (Boarnet et al., 2011; Hsieh & Chuang, 2021; Kang et al., 2017). Studies investigating the impact of both objective and perceived walkability on physical activity and/or walking predominantly observed more pronounced effects associated with perceived measures, especially for recreational walking (De Vos et al., 2023; Orstad et al., 2017). In walkability studies, the type and amount of walking is most often measured with self-reported questionnaires or portable devices, such as pedometers (Bassett et al., 2008). Less focus has been on how objective and perceived walkability affects people's walking routes within urban landscape, including outside their residential environment (De Vos et al., 2023).

There is no agreed-upon definition for walkability (Tobin et al., 2022) but the concept is widely used in urban planning. In addition, a need to orientate walkability research to the specific needs of practitioners has been identified (Wang & Yang, 2019). Newman et al. (2016) argued that in order to achieve the walkability objectives in planning, a comprehensive framework of concepts and theories is needed. To this aim, they introduced a theory of three urban fabrics (walking, transit and automobile urban fabric), which acknowledges the importance of location within the city region and its implications on transportation and residents' lifestyles. The walking urban fabric, concentrated around city centres, encourages walking due to the proximity of functions. Transit urban fabric, represented with a network of connected neighbourhoods, supports high-quality public transport services and nearby services due to density. Automobile urban fabric is widespread, featuring urban forms that may exclusively require car use due to low densities and long distances (Newman et al., 2016; Helminen et al., 2020). In the context of walkability, this means that although walkability is generally important in all parts of a city, it is fundamental in city centres and transit-oriented areas (Lamour et al., 2019; Schlossberg & Brown, 2004). Walkability around city centres and railway stations have previously been studied in separate studies, e.g., through the framework of transit-oriented developments (Bornioli et al., 2019; Halldórsdóttir et al., 2017; Otsuka et al., 2021), or as part of the whole urban area (Bereitschaft, 2018; Meng et al., 2023). Along with spatial variation in walkability and walking within neighbourhoods, further investigation is thus needed to understand how the interplay of objective and perceived built environment variables and their implications on walking behaviour vary between heterogeneous urban environments and how these findings can be utilised in planning (Fonseca et al., 2022; Wang & Yang, 2019). Our hypothesis posits that significant spatial variations in walkability exist not only between different neighbourhoods but also within neighbourhoods. The main novelty of this study lies in the conceptualisation of different urban structures (city centre and suburb) within the study design.

We conducted a three-level comparison of walkability by comparing 1) a WI and perceived walkability, 2) utilitarian and recreational walking, and 3) city centre and suburb in our case city of Helsinki, the capital of Finland. We compared the prerequisites of walking using the theory of urban fabrics and a combination of data on objective and perceived walkability with a high spatial resolution to answer the following research questions (RQ):

1. Whether and how does objective and perceived walkability vary spatially within city centre and within suburb?
2. Do the spatial variations in objective and perceived walkability manifest similarly in the reported walking routes between the city centre and the suburb?

3. How do utilitarian and recreational walking environments, and environments inducing both utilitarian and recreational walking, differ between city centre and suburb?

## 2. Approaches and theoretical frameworks for measuring walkability

People walk for diverse purposes (Shields et al., 2021), and the utilitarian and recreational types of walking differ both in terms of duration, speed, temporal distribution, and location (Kang et al., 2017; Rodrigue et al., 2022). Recreational walking especially represents the optional and social uses of the walking environment as discussed by Gehl (1987). The probability of walking can be approached by examining the extent to which the built environment is walkable.

During the last decade, most research focusing on walkability has made use of neighbourhood-level i.e. meso-scale variables and indices calculated using geographic information systems (GIS), mainly capturing the objective aspects of walkability (Orstad et al., 2017; Wang & Yang, 2019). Building on widely-used frameworks by, e.g. Frank et al. (2010), Dovey and Pafka (2020) introduced a framework for objective measuring of walkability using density (D), mix (M) and access (A) variables. High density, i.e. concentrations of buildings and people shorten distances between places; the mix (M) generates alliances and synergies between different functions such as home, work and play; and access (A) concerns connections, i.e. reaching the desired destinations on foot. In addition to these aspects, green spaces and natural elements have often been overlooked in WIs (Zuniga-Teran et al., 2019) even though the green spaces and greenness of the walking environment have been increasingly found to associate with higher walking and physical activity (Juul & Nordbø, 2023; Sallis et al., 2020; Sarkar et al., 2015). In addition to neighbourhood-scale variables, streetscape characteristics and micro-scale urban design qualities discussed by e.g., Ewing and Handy (2009), have been recognised important for walkability (De Vos et al., 2023; Fonseca et al., 2022). However, developing precise objective metrics for these aspects has proved to be challenging and expensive. Consequently, a substantial portion of walkability research has been depending on neighbourhood-level variables (Fonseca et al., 2022; Kim et al., 2014). Studies including micro-scale design attributes typically rely on subjective evaluations, especially through questionnaires on pedestrians' perceptions (Fonseca et al., 2022).

The perceived aspects of walkability are only recently included in walkability studies and found to affect walking (Arellana et al., 2020; De Vos et al., 2023). These aspects include e. g., subjective quality of an area, perceived suitability for walking, perceived protection and accessibility to destinations (De Vos et al., 2023). Further, perceptions intervene (or mediate) between the physical features of the environment and walking behaviour (Ewing & Handy, 2009). There are different structured measurements for assessing perceived walkability. A comprehensive questionnaire Neighbourhood Environment Walkability Scale (NEWS) introduced by (Saelens et al., 2003) is one of most used (Orstad et al., 2017). It assesses residents' perceptions on residential aspects, facilities' accessibility, agreement on various statements, and satisfaction with neighbourhood features. Due to its extensive nature (83 items), an abbreviated version (NEWS-A) was created (Cerin et al., 2009). Additionally, people's perceptions on walkability can be gathered e.g., through interviews and audits (Adkins et al., 2019; Erturan & Aksel, 2023). The need to study perceived walkability around people's daily functions beyond their home neighbourhood, such as workplaces and commercial centres, has been recognised (De Vos et al., 2023). In this regard, public participatory GIS (PPGIS) offer the potential to investigate perceptions in a spatially explicit manner across urban areas (Alattar et al., 2021; Kyttä et al., 2013). The methodology is based on respondents indicating their positive or negative perceptions of areas on map via public online survey. As PPGIS has also gained popularity as a tool for public participation in urban planning processes (Kahila-Tani et al., 2016), the methodology serves as a valuable resource for joint gathering of planning-relevant information for walkability research and planning practices, the full potential of which is yet to be explored (Knapskog et al., 2019).

The framework by Gehl (2010) is widely used in both practical urban planning and scientific studies (Silvennoinen et al., 2022) for assessing and classifying the perceived quality of the urban environments. According to the approach, protection, especially that of pedestrians, is the most important aspect (Gehl, 2010). After protection comes comfort, the factors that make the urban environment attractive for walking, sitting, chatting and other basic functions. Finally, the enjoyment factors include human-scale planning, pleasant microclimate and enticing sensory experiences in urban spaces. The importance of these factors can vary between different urban contexts (Silvennoinen et al., 2022), for example different urban fabrics.

In the theory of urban fabrics by Newman et al. (2016), the urban environment is seen as an intertwined system of areas, elements, functions, qualities, and lifestyles representing either walking, public transport (transit) or automobile urban fabric or combinations of them. City centres represent areas of the walking fabric but have usually become combinations of walking, transit, and automobile urban fabric elements since they attract all kinds of economic and social activities. Areas dominantly representing walking fabric typically have high building densities and land use mix, as well as good access to public transport, providing easy access to diverse services, also for residents living outside the area (Helminen et al., 2020). Elements of the walking urban fabric reflect the micro-scale affordances for walking including, e.g., narrow street widths, high numbers of public spaces, high levels of street furniture for pedestrians, and short blocks (Newman et al. 2016). These elements can be measured objectively but also perceived subjectively. The elements of transit and automobile urban fabrics—often more dominant in the suburbs—are more in favour of public transport and car users, respectively. At low suburban densities, e.g., building mass becomes less important in defining urban space, while street trees have a more dominant role (Ewing & Handy, 2009). Thus, walkability across urban fabrics can be detected empirically by studying the occurrences of walking fabric elements within urban landscape. Urban design features, such as building complexity and diversity, human-scale architecture, are elements that contribute to the attractiveness of walking environment across urban fabrics (Ewing & Handy, 2009; Gehl, 2010).

Fig. 1 summarises the theoretical approach used in this study. We apply the theory of urban fabrics (Newman et al., 2016) to interpret the walking fabric elements from two case areas by first examining the spatial variations in both objective and perceived aspects of walkability across them. Secondly, we explore the qualities of the walking environments they establish for utilitarian and recreational walking.

## 3. Material and methods

### 3.1. Study area

This study focuses on Helsinki, the capital of Finland. Helsinki has over 658,000 inhabitants and it emphasises walkability in its strategy, having just developed a promotional programme for walking (City of Helsinki, 2022a). We looked at walkability in two case areas: the city centre and a suburb named Kaarela, which is a neighbourhood located roughly at 8.5 km distance and 20-min train ride from the city centre.

We use urban fabrics typology applied for the Helsinki city region (Karjalainen et al., 2023) to portray the case areas (Fig. 2). The city centre case area is dominated by central functions and much of the land area is classified as inner (up to1 km from city centre) and outer (1 to 2 km from the city centre) walking urban fabric. Kaarela case area mainly consists of districts representing transit urban fabric but also some automobile urban fabric in the north-west, meaning that the area is predominantly residential, with less mixed-uses and more car dependency. The city centre case area had 133,000 inhabitants in 2020

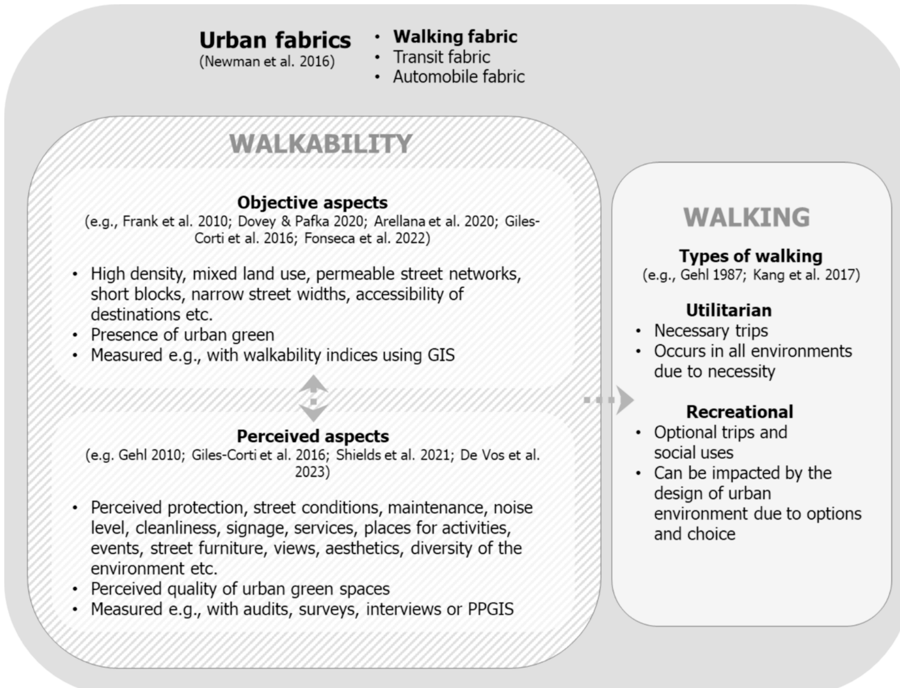



**Fig. 1.** Theory-driven components of urban walkability used in this study.

(20% of the total population of the city), and it is characterised by a dense rail-based transport system with multiple metro stations, a central railway station, and a tram network. The Kaarela suburb had 30,100 inhabitants in 2020 and it has two railway stations and multiple and frequent bus services. The train connection connecting the case areas is part of the western section of the Ring Rail Line, linking the city centre with Helsinki-Vantaa Airport. It operates at 10-min intervals during rush hours and at 15-min intervals outside of rush hours. However, the Kaarela suburb is also situated near the junction of two busy motorways: Ring Road 1 and National Road 3.

Both study areas offer various destinations for utilitarian walking. However, the number and diversity of services is significantly broader in the city centre, as the area serves not only as a place to live, but also as an essential workplace and business hub for many. The services in Kaarela are more limited, primarily catering to the needs of the local residents. In addition, recreational walking in the suburban context is more driven by the residents' needs, whereas in the city centre, there are more visitors and tourists strolling. In the city centre, there are many walking routes along shoreline and various parks. The Kaarela suburb has a river crossing the area as part of a larger recreation area, as well as smaller parks in the middle of residential areas.

### 3.2. Objective walkability

#### 3.2.1. Walkability index

We detected the occurrence of walking urban fabric elements across the study areas by calculating a spatial WI. We calculated the index in a 100-m grid using the framework by Dovey and Pafka, (2020). The index is comprised of a density variable, a mix variable, and two access variables measuring urban permeability (AwaP) and the interface catchment (IC). We chose this framework since it best considers the walking urban fabric elements, such as block sizes and street widths recognised in the urban fabrics theory (Newman et al., 2016). Since we investigated the spatial variation of walkability within our case areas, the WI and its subvariables were calculated separately for the city centre and the Kaarela suburb.

***Building density.***

Land use density stands out as a frequently identified factor influencing walking (Fonseca et al., 2022; Frank et al., 2005). While the typical approach involves employing residential density, one of our study areas represents city centre, where the presence of numerous businesses and workplaces significantly contributes to the area's density. In this context, we opted to utilise the floor space ratio of all buildings as a more suitable metric for our case studies. The variable was calculated in a 100-m grid based on the Finnish Building and Dwelling Register (BDR, 2021). The land area was calculated using the dataset for water bodies Shoreline10 (SYKE & NLS, 2021). The total floor space and land area were calculated in a 100-m grid, and a focal sum of the neighbouring cells was calculated from a total area of 300 x 300 m. The floor space ratio was then calculated by dividing the focal sum of floor space by the focal sum of land area of the corresponding grid cells.

***Functional mix.***

In addition to land use density, the mix or diversity of land uses has been proved to be an important determinant of walking and physical activity (Fonseca et al., 2022; Sallis et al., 2020). As the functional mix variable, we applied the "live, work, visit" framework representing an area's functional mix introduced by Dovey and Pafka (2020). This approach implicitly incorporates the existence of various services within the variable, considering the proximity of services as another crucial and frequently identified determinant of walking (Fonseca et al., 2022; Handy, 2020). The buildings were classified based on the intended use of buildings into three categories: live, work, and visit (Appendix A) using the Finnish Building and Dwelling Register data (BDR, 2021). Various services were encompassed in both the "work" category, such as healthcare centres, kindergartens, and schools, and the "visit" category, including shops, restaurants, cinemas, museums, and sports facilities. The uses that were not applicable into any of the categories, such as parking and civil protection facilities, and outbuildings of residential buildings, were left out from the calculation. The "visit" class was supplemented with public green spaces using the Register of public areas in the City of Helsinki (City of Helsinki, 2022b). Each green space was counted once per intersecting grid cell similarly as buildings. Like the density variable, the distribution of buildings belonging to each category was calculated as a focal sum of the neighbouring cells, from a total area of 300 x 300 m. The final variable was formed for each grid cell based on the distribution of buildings belonging to each category using Simpson

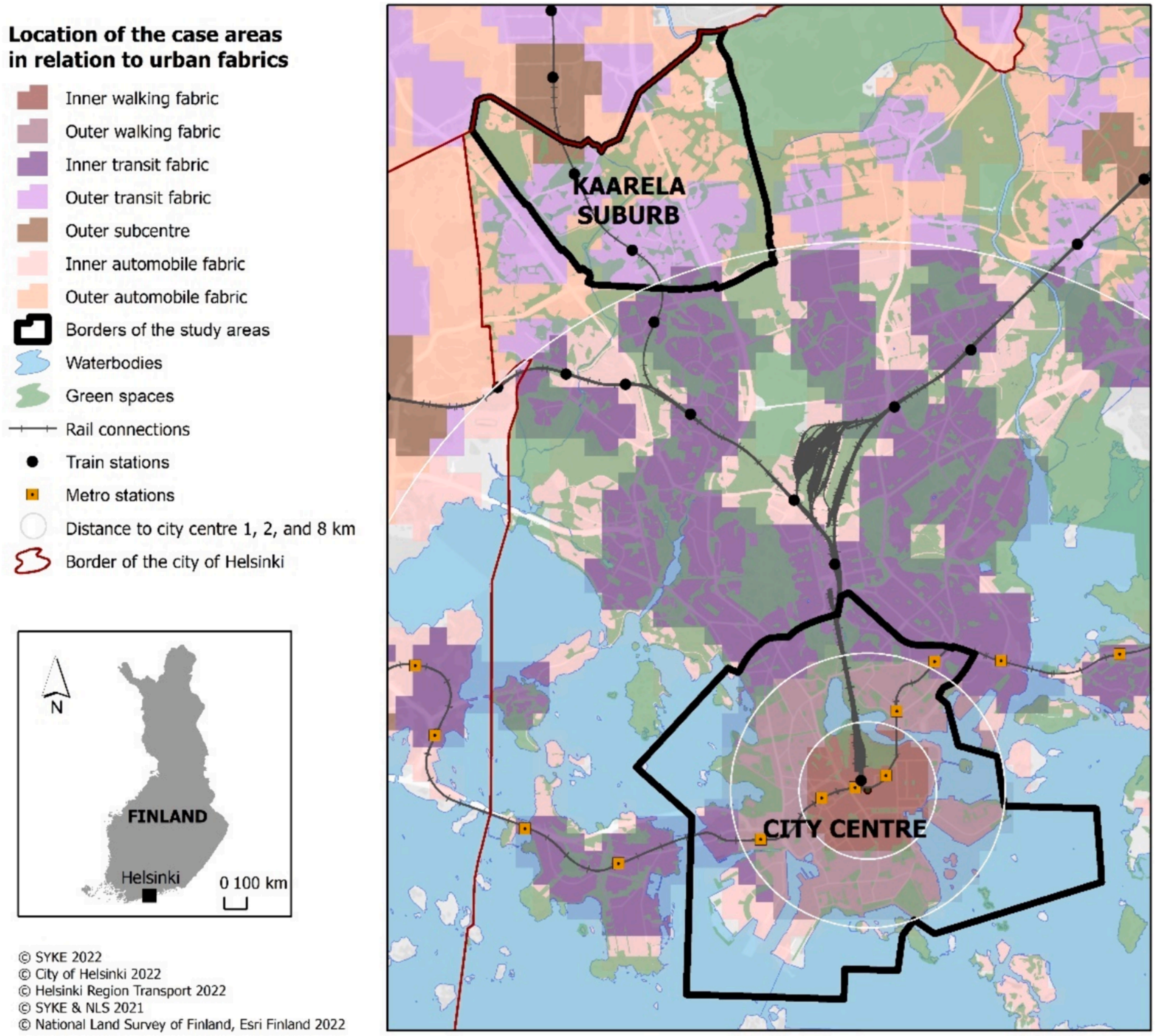



**Fig. 2.** Location of the study areas in the city of Helsinki. The typology of urban fabrics is based on the population and job density, grocery shop accessibility, public transport supply, and the distance from the city centre. Adapted from Karjalainen et al. (2023).

diversity index (SIDI) that measures the entropy of objects across space (McGarigal & Marks, 1995). The range of the index is between 0 and 1, and the higher values indicate a higher functional mix.

***Access: urban permeability and interface catchment.***

Street network accessibility and connectivity, often incorporated as a variable of intersection density, or accessibility to various destinations, has been identified as an enabler of for walking and physical activity (Fonseca et al., 2022; Frank et al., 2005; Handy, 2020). This study develops an empirical application of urban permeability and interface catchment, approaches to accessibility introduced by Dovey & Pafka (2020). This also aligns with the theory of urban fabrics, capturing block and street network characteristics that either facilitate or hinder walking. These variables encompass elements that have been previously recognised influential for walking, including block size/length and street width (Hess et al., 1999; Hooper et al., 2015).

As the first access variable, we calculated the urban permeability i.e., area-weighted average perimeter (AwaP) that describes how permeable the block structure is for pedestrians (Pafka & Dovey, 2017). The variable is calculated based on the number of blocks, the perimeter and the area of each block and the total area of all blocks (Majic & Pafka, 2019). Low variable scores indicate high permeability, and high scores indicate low permeability within the area. The unit of the permeability variable is metre (m). The variable was calculated with the AwaP QGIS plugin version 2.0.1 (Majic & Pafka, 2019) using the delineation of urban blocks (quarters of Helsinki) in 2022 by City of Helsinki as the input data. The input block layer was modified by digitising continuous segments of motorways and railroad areas inaccessible to pedestrians into the block layer (Appendix B). This way the analysis better considered the areas restricted from pedestrians. The final variable was inverted so that high values indicate high permeability (high walkability), and low values indicate low permeability (low walkability) by subtracting the variable value for each grid cell from the variable's maximum value.

The interface catchment (IC) measures the total length of public/private façades within a given walking distance (Pafka & Dovey, 2017). The IC metric complements AwaP by considering street width and open space. High IC values indicate high capacity for accommodating urban destinations. The IC metric is relevant for understanding the walkable access, since most urban destinations such as shops or workplaces are entered through a public/private interface, i.e. façade where buildings meet the street (Dovey & Wood, 2015). AwaP primarily describes the physical accessibility; if the blocks are large, walking accessibility is weak. IC, on the other hand, describes the potential accessibility of activities that can be reached, as private and public services are located as part of the façade: the more interfaces within a walking distance, the more services can potentially be reached by walking.

We calculated IC across the two case areas using a modified version of the IC QGIS plugin, version 2.0.1 (Majic & Pafka, 2019). As input, the tool takes a starting point, a block layer and settings for dead-end removal and maximum walking distance. The original tool works only with a single starting point, and we modified the tool script to work for multiple input points. Instead of exact grid square centroids, the starting points for the calculation were defined as the centroids of the streetscape of each grid cell in the 100-m grid to avoid having starting points located inside city blocks. The input blocks layer for the analysis was the original urban block data. The large transport area blocks digitised in the AwaP calculation were not included in the IC calculation since their interface do not contain the kinds of urban attractions that should be considered from a walkability perspective (Appendix B). Dead-end streets were included in the analysis, and maximum walking distance was set to 300 m, similarly to other walkability sub-variables.

***Combined walkability index.***

The four walkability sub-variables were combined using the standardised z-scores for each variable:

$$WI = z(density) + z(mix) + z(AwaP) + z(IC)$$

where

*WI*=the walkability index of a 100 m x 100 m grid square.

*z(x)* = a standardised variable (density, mix, AwaP or IC) for calculation of the index.

#### 3.2.2. Greenness of the walking environment

We calculated additional variables to objectively describe the green and blue spaces in the walking environments to complement the analysis. We first calculated the NDVI (Normalized Difference Vegetation Index), that describes how green the walking environment is. This index was calculated based on an aerial photograph provided by the National Land Survey of Finland representing land cover in 2020, using the R software package “raster” (Hijmans, 2022). The mean value of the index was calculated for each of the 100-m grid cells. Second, we calculated the total length (m) of shoreline for each grid cell based on Shoreline10 dataset (SYKE & NLS, 2021). Third, we calculated a combined green and blue index based on the NDVI and shoreline length variables using the standardised z-scores of both variables. The index was standardised separately for the city centre and Kaarela case areas.

### 3.3. Perceived walkability

#### 3.3.1. PPGIS data

We chose to leverage PPGIS data provided by the City of Helsinki, specifically designed for resident participation in ongoing planning processes (Table 1). This decision stems from the methodology’s ability to collect planning-relevant spatial data from a large number of individuals interested in a specific area, overcoming the dependence on exact home location that has been criticized in previous walkability studies (De Vos et al., 2023). We used four PPGIS datasets: the Inner-City Walkability Survey (CWS), Neighbourhood Walkability Survey (NWS), and the Kaarela Residents’ Survey (KRS), which were accessed upon request from the City of Helsinki, and the Traffic Safety Survey (TSS) that was available as open data (City of Helsinki, 2020). All the surveys were conducted by the City of Helsinki during 2018–2020 so they mainly describe the situation before the COVID-19 pandemic. The survey links where public, and people were encouraged to respond by disseminating information about it e.g., on the city’s website and on social media.

**Table 1**
Description of the PPGIS datasets used in this study.

| Name of dataset and related planning process | Time and target audience of data collection | Total number of respondents | Largest age group among the respondents (%) | Largest gender group (%) | Case area | Format used in this study | Number of respondents used in this study | Number of map entries used in this study |
|---|---|---|---|---|---|---|---|---|
| Inner-city walkability survey, **CWS**<br>(Original title for respondents: *On foot in the city – what does Helsinki feel like on foot?*)<br><br>Helsinki Walking Promotion Programme | 15 May–15 June 2018<br><br>Those who live in, work in, or visit Helsinki | 1,659 | 30–49 years (46 %) | Female (59 %) | City centre | Point, polyline | 1,301 | 2,866 places (points)<br>2,665 routes (polylines) |
| Traffic safety survey for citizens of Helsinki, **TSS**<br>Helsinki Traffic Safety Development Programme 2022–2026 | September 2020<br><br>Residents of Helsinki | 5,990 | 25–44 years (49 %) | No data | City centre, Kaarela | Point | City centre: 967<br>Kaarela: 119 | City centre: 3,148 places<br>Kaarela: 317 places |
| Neighbourhood walkability survey, **NWS**<br>(Original title for respondents: *On foot in the neighbourhoods – everyday walking environment in Helsinki*)<br><br>Helsinki Walking Promotion Programme | 14 June–3 July 2019<br><br>Residents of Helsinki | 852 | 30–49 years (46 %) | Female (71 %) | Kaarela | Point | 39 | 89 places |
| Kaarela residents’ survey, **KRS**<br><br>Kaarela area plan (guides the maintenance, development, and restoration of green spaces and streets) | 7 June–7 July 2018<br><br>Residents and users of Kaarela neighbour-hood | 976 | 30–49 years (41 %) | Female (63 %) | Kaarela | Point, polyline | 416 | 3,807 places<br>355 routes |

The City of Helsinki collected the PPGIS data using the Maptionnaire[1] online platform. The Maptionnaire surveys consisted of a map where respondents marked specific locations and answered related follow-up questions. In addition, they included traditional multiple-choice questions to gather background information of respondents. Responding to the surveys did not require any special technical skills. We refined the datasets by narrowing them down to our specific study areas within the city of Helsinki. Consequently, we extracted only the map entries that intersected with the borders of our study areas, along with the corresponding respondents, to be included in this study (Fig. 2, Table 1). We only utilised the parts relevant to our research questions from the large amount of survey data, and the selected questions are listed in Appendices C and D. We did not study the different population groups, such as age and gender, separately, since there was no comprehensive background information available for all the datasets.

### 3.3.2. Classification of the PPGIS data

We classified perceived walkability attributes (either positive or negative) retrieved from the datasets into protection, comfort and enjoyment attributes (Table 2) based on Gehl (2010). We chose this framework since it considers walkability as part of comprehensively high-quality, human-scale public spaces. We distinguished positive and negative map entries so that one positive map entry corresponded to one negative map entry for each attribute. The original survey questions and their classification are described in Appendices C and D.

The perceived attributes retrieved from CWS and TSS were based on closed options for survey questions. However, all the attributes of the NWS data and most attributes from the KRS data had to be classified based on open-ended questions, which were categorised using qualitative coding. Initially, quality attributes derived from the closed questions of the CWS were employed as preliminary descriptive codes. Subsequently, new codes were created through inductive coding. This process resulted in the generation of additional variables, such as cultural history/identity and presence of water (see Appendix D).

The CWS and NWS focused only on pedestrians. The TSS data was filtered according to the question "user group for whom the place poses the greatest danger", and only the map entries concerning "pedestrians" were included in the analysis. The map entries of the KRS data could not be filtered only by pedestrian users since it would have left out most of the map entries. However, most of the questions considered attributes that were only observable on foot. We summarised the attributes as separate protection, comfort and enjoyment variables for each 100-m grid cell. Finally, we combined protection, comfort and enjoyment variables into a perceived quality index by using standardized z-scores for the variables. The z-scores were weighted to equalise the number of sub-variables in each of the variables (protection, comfort and enjoyment):

$$QUALI = 9z(protection) + 15z(comfort) + 15z(enjoyment)$$

where

QUALI=the perceived quality index of a 100 m x 100 m grid square.

z(x) = a standardized z-score for each quality attribute (x = protection, comfort or enjoyment).

**Table 2**
Perceived quality attributes included in the PPGIS datasets. The + and – represent the wording of the question or map entry: whether a certain attribute is positive or negative/missing in the walking environment or both. An empty cell means that the attribute did not exist in the dataset.

| Classification (adapted from Gehl, 2010) | Quality attribute | Name and coverage of the dataset | | | |
|---|---|---|---|---|---|
| | | CWS City centre | TSS City centre and Kaarela | NWS Kaarela | KRS Kaarela |
| Protection | Perceived protection | +/– | – | – | – |
| | Appropriate lighting | +/– | | +/– | +/– |
| | Condition of streets and public spaces | – | – | – | – |
| | Street continuity and quality | +/– | – | | |
| | Driving speed | – | – | | |
| | Automobile parking | – | – | | |
| | Pedestrian crossings | – | – | | |
| | Separation of travel modes | +/– | | +/– | |
| | Maintenance | – | | +/– | – |
| | Path width | – | | + | |
| | Traffic | – | | – | |
| | Noise level | +/– | | – | |
| | Air quality | – | | | |
| | Cleanliness | – | | – | +/– |
| | Signage | – | | – | |
| Comfort | Meeting places | + | | | + |
| | Services (cafés, shops etc.) | +/– | | | + |
| | Crowd | +/– | | + | + |
| | Peace | + | | + | + |
| | Places for playing | + | | | + |
| | Places for exercise and leisure activities | + | | + | + |
| | Events | + | | | + |
| | Prevalence and condition of benches | – | | +/– | +/– |
| | Other street furniture and infrastructure, such as rubbish bins, stairs, piers, etc. | – | | +/– | +/– |
| Enjoyment | View / landscape | + | | + | + |
| | Window-shopping | + | | | |
| | Green elements, nature experiences | +/– | | +/– | + |
| | Presence of water | | | + | + |
| | Aesthetics | +/– | | +/– | + |
| | Microclimate | +/– | | + | + |
| | Diversity of the environment | +/– | | + | + |
| | Cultural history / identity | | | | + |
| | Art | – | | | + |

### 3.4. Self-reported walking routes

In the CWS data, the respondents mapped their walking routes in the inner-city area. The respondents were additionally asked to clarify the purpose of the mapped route either as utilitarian or recreational according to the sub-categories in Table 3. For the routes in the Kaarela suburb, we used the KRS data, where the respondents were asked to map their favourite walking routes. The purpose of the use of the routes was asked in the survey as a question "Where does your favourite route lead to?" and the responses were further classified into utilitarian or recreational walking. All the categories except for "to another place" were classified as utilitarian walking—matching the subcategories for walking purpose asked in the CWS. Open responses "to another place" were also included if they could be interpreted as belonging to some of the CWS subcategories. The rest of the mapped walking routes were interpreted as recreational walking based on open responses of the walking purpose.

As the variable to investigate the intensity of self-reported walking in

[1] https://www.maptionnaire.com/.

**Table 3**
Self-reported purposes of walking routes in CWS and KRS datasets.

| Walking purpose | CWS categories | KRS categories |
|---|---|---|
| Utilitarian | • Commute (between home and workplace)<br>• Walking during the working day (business, lunch)<br>• School / study trip<br>• Running errands / shopping trip (shopping, bank, doctor, etc.)<br>• Walking for leisure facilities (hobbies, cultural events, visits)<br>• Accompanying | • to work<br>• to school<br>• to hobbies<br>• to other place: the responses matching the CWS categories |
| **Recreational** | • Fitness/exercise<br>• Outdoor activities<br>• Relaxation / refreshment<br>• Meeting friends<br>• Walking a pet | • to another place: the responses matching the CWS categories |

different walking environments, we used the number of respondents in each 100 m-grid cell who made route entries (recreational, utilitarian, and all routes) in that specific area.

### *3.5. Statistical methods*

We compared the WI and the perceived quality index (QUALI) by defining hotspots and coldspots. For this we used the bivariate Local Indicator of Spatial Association (LISA) of the software GeoDa version 1.16.0.12. This approach builds on spatial autocorrelation that measures if nearby observations have more similar properties compared to observations in random space. LISA identifies neighbouring grid cells with similar or dissimilar values in the data and is thus able to offer a preliminary identification of statistically significant clusters in space (Anselin, 1995). We calculated the spatial autocorrelation using queen contiguity, so the values of every grid cell were compared to all neighbouring grid cell values. The analysis classifies grid cells into low or high value clusters if values around the selected grid cell are more (high) or less (low) similar to the average of the eight neighbouring values than values in random space. The statistical significance of local spatial autocorrelation is defined by *p*-value. We considered *p*-value $< 0.05$ to be significant, for 999 permutations.

Hotspots for self-reported walking were calculated using the univariate LISA method, based on the number of survey respondents who made recreational or utilitarian walking route entries in each grid cell. We compared the walking environment between 1) hotspots of recreational walking, 2) hotspots of utilitarian walking, 3) areas that belong to both the hotspots of recreational and utilitarian walking. These areas were spatially exclusive, so that one grid cell only belonged to one of these groups. We used a non-parametric Kruskal-Wallis test to compare the walkability variable distributions among these groups. To further identify which of the three groups differed from each other, we did post hoc analysis with pairwise Wilcoxon rank sum test. Statistical analyses were carried out using R version 4.1.0. All the variables used are listed in Appendix E.

## 4. Results

### *4.1. Walkability within city centre and suburb*

In order to study whether and how objective and perceived walkability vary spatially within city centre and within suburb (RQ 1), we explored the spatial variation of the WI and its sub-variables in our case areas (Fig. 3). Two of the sub-variables, the floor space ratio (building density) and interface catchment (IC) were spatially concentrated around the central locations such as railway stations and areas with lots of buildings in both areas. In contrast, functional mix and urban permeability (AwaP) were more dispersed in both areas. Given that the urban permeability variable was computed by considering the absence of large blocks, it reached its peak in areas characterised by small blocks or those entirely devoid of buildings. This includes various shorelines in the city centre and large open green spaces in the Kaarela suburb. The combined WI had its highest values in the most densely populated sections of both case areas. This is evident from the analogous spatial patterns observed between the floor space ratio and WI in both areas. For example, in the Kaarela suburb, elevated WI values can be observed in proximity to the two train stations and a relatively recently developed neighbourhood to the northeast (Kuninkaantammi). This neighbourhood, home to almost 2,900 inhabitants in 2020, features small and permeable blocks, intentionally planned as “a colourful and welcoming pedestrian city” (City of Helsinki, 2024).

We also studied the spatial variation in the perceived quality index in city centre and suburb (Fig. 4). In the city centre case area, the perceived quality index and its sub-variables (protection, comfort, and enjoyment) displayed high values in the central core and around primary recreation areas, creating distinct spatial clusters. Notably, the enjoyment variable exhibited high values along the shoreline (Fig. 4). Conversely, in the Kaarela suburb, the perceived quality index, and especially the protection variable showed a dispersed distribution without clear clustering. The comfort variable demonstrated a more concentrated spatial pattern, while the enjoyment variable exhibited the most clustered configuration, particularly around the neighbourhood’s largest green spaces.

The hotspot analysis based on bivariate LISA ($p < 0.05$) revealed a coexistence of high perceived quality and high WI values in the commercial and historical city centre, while this overlap was sporadic in the Kaarela suburb (Fig. 5). In Kaarela, these limited areas were situated close to easily accessible green spaces, residential areas surrounding the old neighbourhood centre, and in proximity to the shopping centre (Mall of Kaari). In both case areas, regions with low WI and perceived quality were typically found near motorway corridors or less accessible green spaces. In terms of discrepancies, WI hotspots with low perceived quality in the city centre were concentrated in a few primarily residential areas towards the periphery of the area. On the contrary, WI hotspots with low perceived quality in the Kaarela suburb were predominantly situated in central areas, such as the two train stations and the residential area of Kuninkaantammi. Areas characterised by low WI but high perceived quality typically corresponded to the most popular recreational areas, including Töölönlahti and Kaivopuisto parks in the city centre, and the Mätäjoki river valley, Kaarelanpuisto park, and Malminkartano landfill hill in the suburb. Additionally, the shopping centre in the suburb also fell into this category.

### *4.2. Self-reported walking within city centre and suburb*

We investigated self-reported walking routes in the two case areas to analyse whether the spatial variations in objective and perceived walkability manifest similarly in the reported walking routes between the city centre and the suburb (RQ 2). Fig. 6 shows how self-reported walking occurs within the four classes of the low/high WI and perceived quality (QUALI). In the city centre, utilitarian walking was centralised in the areas with both high WI value and high perceived quality. In contrast, the largest percentage of utilitarian walkers in the Kaarela suburb (59 %) made route entries in the areas with a high WI but low perceived quality. In both case areas, areas of low walkability in terms of both objective and perceived aspects attracted the least amount of utilitarian and recreational walking. In the city centre, most of the recreational walking occurred in the areas with a high WI and high perceived quality (77 %) or in areas with a low WI and high perceived quality (65 %). Areas with low perceived quality attracted the least number of recreational walkers. In the Kaarela suburb, most of the recreational walking entries were made in areas with a high WI value but low perceived quality (72 %) or in the areas with low WI and high

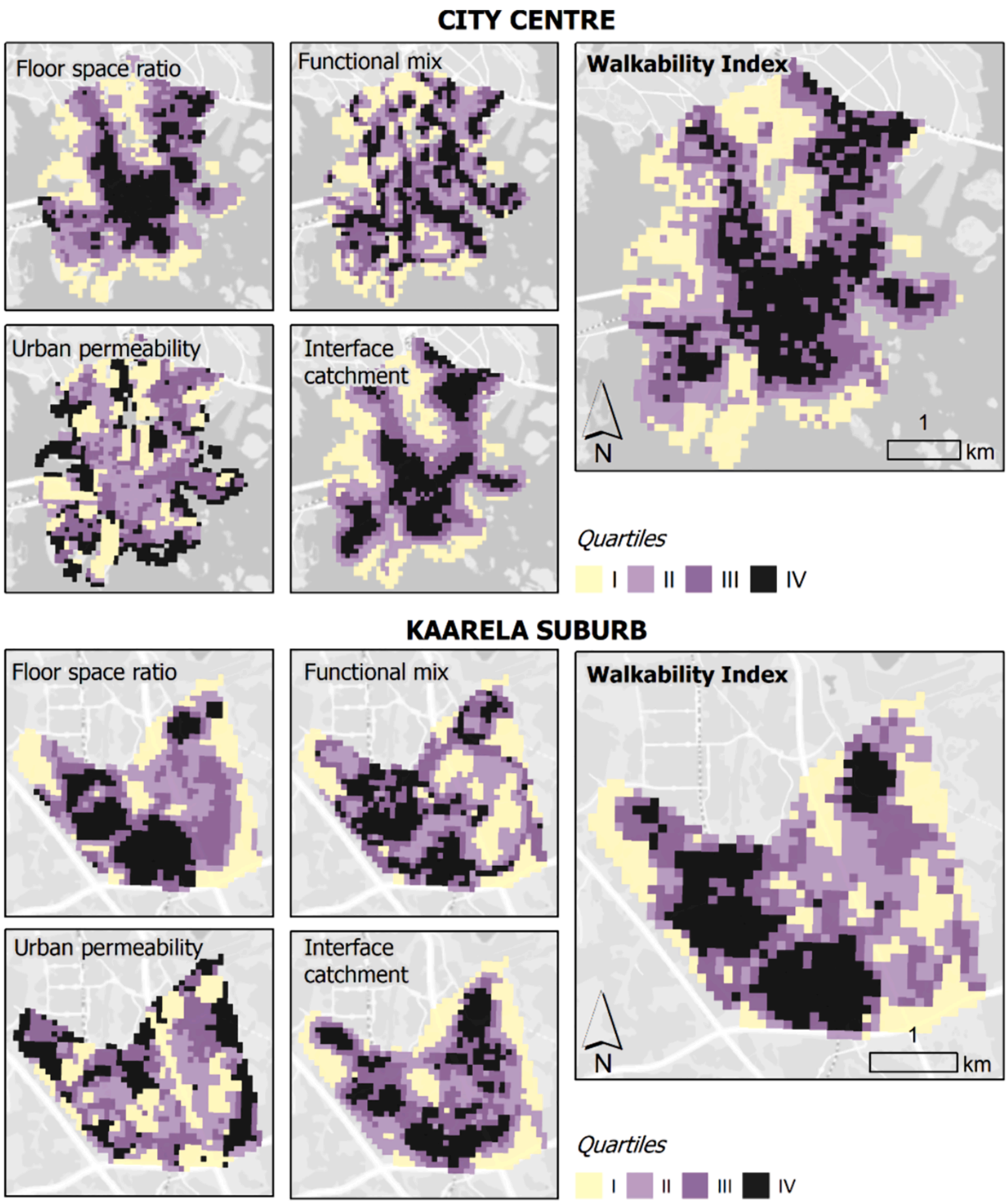



**Fig. 3.** Variables for calculating the objective walkability index for the city centre and Kaarela suburb, and a map of the summarised index based on standardized z-scores. All the maps are classified into quartiles of each variable (IV=highest values). Base map: NLS & Esri Finland 2022.

perceived quality (68 %). Areas with a high WI value and high perceived quality also gained entries from more than half of the respondents (54 %).

### 4.3. *Differences between utilitarian and recreational walking environments*

To determine how utilitarian and recreational walking environments, as well as environments that induce both types of walking, differ between the city centre and the suburb (RQ 3), we further investigated the hotspots of these environments in the two case areas. Utilitarian walking hotspots detected via univariate LISA ($p < 0.05$) were concentrated around central functions in both case areas: the commercial and historical city centre, as well as around everyday facilities such as train stations and commercial and public services in the Kaarela suburb (Fig. 7). In the city centre, the hotspots for recreational walking were not only found near green spaces and along shorelines but also within the commercial and historical city centre, coinciding with the hotspots for utilitarian walking. In the Kaarela suburb, the river valley emerged as a hotspot catering to both utilitarian and recreational walking activities.

We discovered that the objective and perceived variables of walkability differed between the hotspots of 1) recreational 2) utilitarian or 3) both recreational and utilitarian walking (Table 4 and Fig. 8). In the city centre, there were differences between the hotspots in every variable (Kruskal-Wallis test, $p < 0.001$ for all variables except $p < 0.01$ for protection, Table 4 and Fig. 8). This indicates that in the city centre, utilitarian and recreational walking occurred in different types of walking environments. Most of the variables showed significant differences in the Kaarela suburb as well, except for the functional mix ($p = 0.841$) and perceived comfort ($p = 0.310$). Thus, in the Kaarela suburb, recreational and utilitarian walking occurred in places that have similar functional mix and provision of comfort factors.


**Fig. 4.** The distribution of perceived quality attributes in the city centre (above) and Kaarela suburb (below) case area shown in quartiles. One negative map entry (point or polyline) corresponds to −1 and one positive map entry (point or polyline) corresponds to 1. The positive and negative map entries were summarised into a 100-m grid, and attribute values were classified as quartiles based on standardised z-scores (IV=highest values). Base map: NLS & Esri Finland 2022.

The hotspots of utilitarian walking had higher floor space ratio ($p < 0.001$), interface catchment ($p < 0.001$), WI ($p < 0.001$ in city centre; $p = 0.03$ in the Kaarela suburb) and in both case areas compared to the hotspots of recreational walking (Fig. 8). Additionally, functional mix displayed higher values ($p < 0.001$) in utilitarian hotspots of the city centre. The hotspots of recreational walking had higher urban permeability ($p < 0.001$ in city centre; $p = 0.027$ in the Kaarela suburb), larger NDVI ($p < 0.001$ in city centre; $p = 0.014$ in the Kaarela suburb), and higher values of green and blue index ($p < 0.001$). In addition, recreational walking hotspots exhibited greater shoreline length ($p < 0.001$) in city centre, and higher perceived quality index ($p = 0.004$) in the Kaarela suburb. In the city centre, the perceived protection was higher in the hotspots of utilitarian walking ($p = 0.003$), whereas in the Kaarela suburb, it was higher in the hotspots of recreational walking ($p < 0.001$). In both case areas, areas belonging both to recreational and utilitarian walking hotspots had significantly higher perceived enjoyment ($p < 0.001$) compared to the areas only belonging to either recreational or utilitarian walking hotspots. In the city centre, these multiple-type walking hotspots also had significantly higher perceived comfort ($p < 0.001$) and quality index values ($p < 0.001$). In the Kaarela suburb, notably the length of shoreline was elevated ($p < 0.001$) compared to the single-type walking hotspots.

## 5. Discussion

In this study, we conducted a spatially explicit comparison between city centre and suburb by investigating the interplay of objective and subjective walkability. The Helsinki city centre case area predominantly embodied a walking urban fabric, while the Kaarela suburb represented a blend of transit and automobile urban fabrics. Beyond exploring the

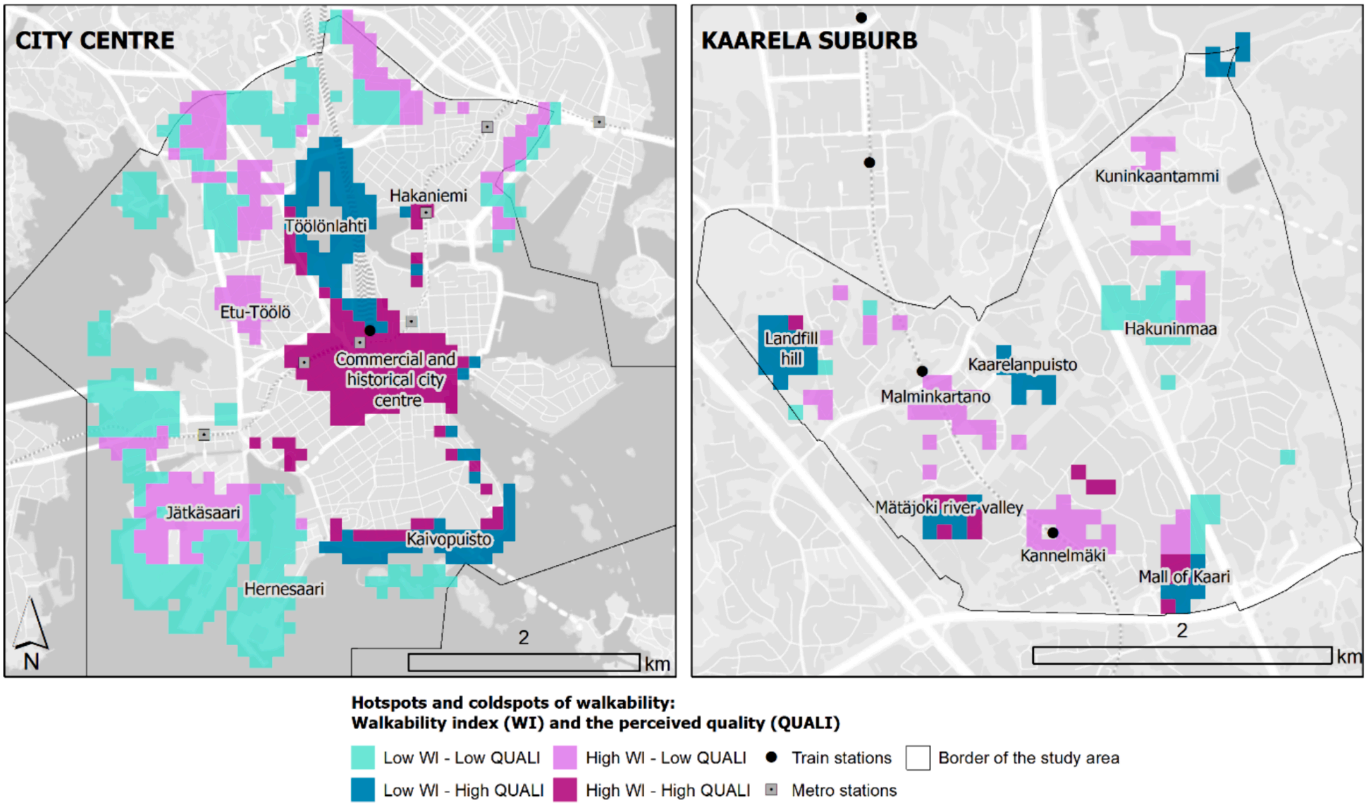



**Fig. 5.** Hotspots and coldspots of walkability, based on bivariate LISA ($p < 0.05$), in the city centre and Kaarela case areas in terms of objective walkability index (WI) and perceived quality index (QUALI). Base map: NLS & Esri Finland 2022.

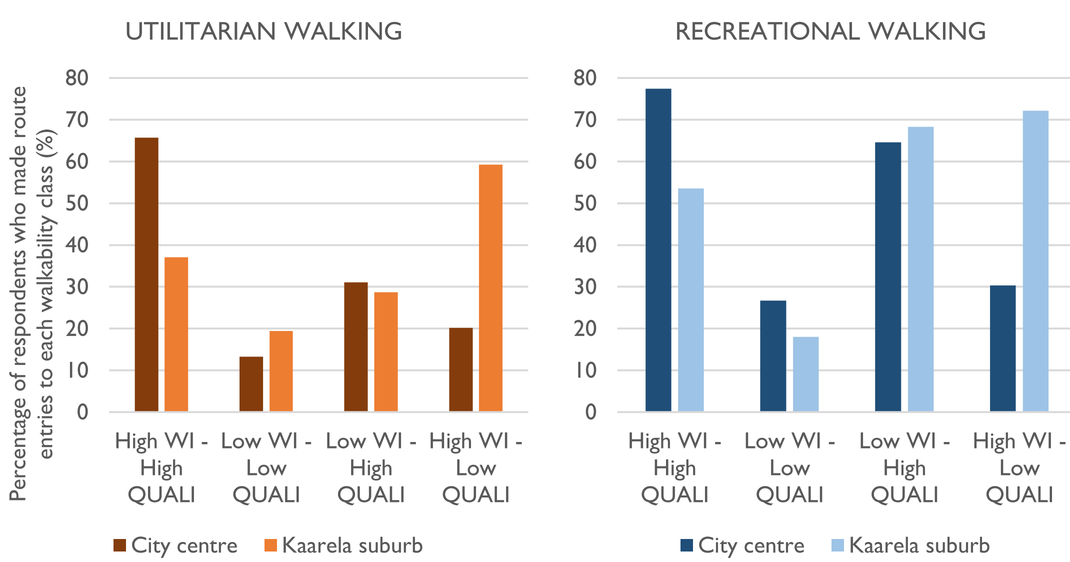



**Fig. 6.** The percentages of respondents who made route entries in each of the walkability category presented in Fig. 5: high or low objective walkability index (WI), high or low perceived quality index (QUALI). The percentages were calculated from all respondents who made route entries intersecting the case areas (city centre utilitarian N=1,161; Kaarela utilitarian N=108; city centre recreational N=607; Kaarela recreational N=183 respondents).

spatial overlaps and disparities between objective and perceived walkability, our investigation delved into utilitarian and recreational walking routes within these areas. We also examined the variations in the walking environment, encompassing green and blue spaces, in utilitarian and recreational walking hotspots in city centre and suburban contexts.

Regarding RQ 1, this study showed that high perceived walkability overlapped high WI values in the large part of the city centre, but only in a few locations in the suburb. Other scholars have also found that subjective and objective walkability measures align in dense areas and older neighbourhoods (Bereitschaft, 2018; Meng et al., 2023). Further, suburban areas with high density but good accessibility to parks and

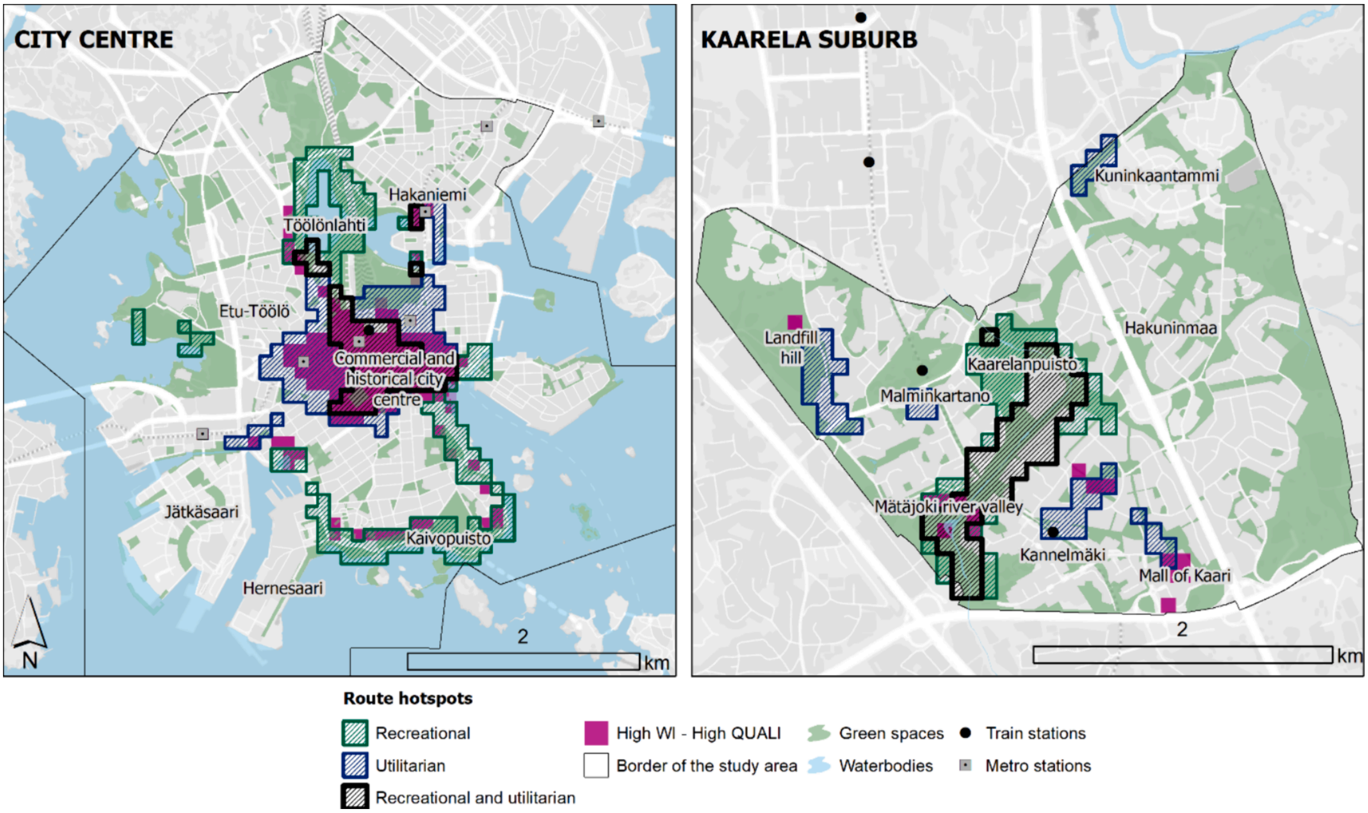



**Fig. 7.** The location of 1) recreational 2) utilitarian and 3) both recreational and utilitarian route hotspots. The map also shows the hotspots of both objective and perceived walkability presented in Fig. 5. The hotspots are calculated using univariate LISA ($p < 0.05$) based on the number of people who have mapped routes to each 100-m grid cell. Base map data: City of Helsinki (2022b); NLS & Esri Finland (2022).

**Table 4**
Kruskal-Wallis test results for variable differences between the hotspots of 1) recreational, 2) utilitarian, and 3) both recreational and utilitarian walking. Significance levels: ***= *p*-value < 0.001; **=*p*-value < 0.01; *=*p*-value < 0.05. Differences between the three types of walking hotspots according to a pairwise Wilcoxon rank sum test: R-U=between recreational, and utilitarian; R-UR=between recreational, and utilitarian + recreational; U-UR=between utilitarian, and utilitarian + recreational.

| Variable | City centre | | | | Kaarela suburb | | | |
|---|---|---|---|---|---|---|---|---|
| | Chi-squared | df | *p*-value | Types of hotspots with significant differences, *p*-value < 0.05 | Chi-squared | df | *p*-value | Types of hotspots with significant differences, *p*-value < 0.05 |
| Floor space ratio | 160.87 | 2 | < 2.2e-16*** | R-U, R-UR | 22.11 | 2 | 1.58E-05*** | R-U, U-UR |
| Functional mix | 23.61 | 2 | 7.45E-06*** | R-U, U-UR | 0.35 | 2 | 0.841 | |
| Urban permeability (AwaP) | 35.79 | 2 | 1.69E-08*** | R-U, R-UR | 7.28 | 2 | 0.027* | R-U |
| Interface catchment (IC) | 154.55 | 2 | < 2.2e-16*** | R-U, R-UR | 14.12 | 2 | 0.001*** | R-U, U-UR |
| Walkability index (WI) | 124.15 | 2 | < 2.2e-16*** | R-U, R-UR | 11.88 | 2 | 0.003** | R-U, U-UR |
| Protection | 11.81 | 2 | 0.003** | R-U, R-UR | 17.77 | 2 | 0.0001*** | R-U, R-UR |
| Comfort | 69.20 | 2 | 9.43E-16*** | R-U, R-UR U-UR | 2.34 | 2 | 0.310 | |
| Enjoyment | 83.09 | 2 | < 2.2e-16*** | R-U, R-UR U-UR | 18.23 | 2 | 0.0001*** | R-UR, U-UR |
| Perceived quality index (QUALI) | 56.44 | 2 | 5.56E-13*** | R-U, R-UR U-UR | 11.31 | 2 | 0.004** | R-U, U-UR |
| NDVI | 20.07 | 2 | 4.38E-05*** | R-U, R-UR | 8.50 | 2 | 0.014* | R-U, R-UR |
| Shoreline | 97.88 | 2 | < 2.2e-16*** | R-U, R-UR | 49.65 | 2 | 1.65E-11*** | R-U, R-UR, U-UR |
| Green and blue index | 96.32 | 2 | < 2.2e-16*** | R-U, R-UR | 14.03 | 2 | 0.0009*** | R-U, U-UR |

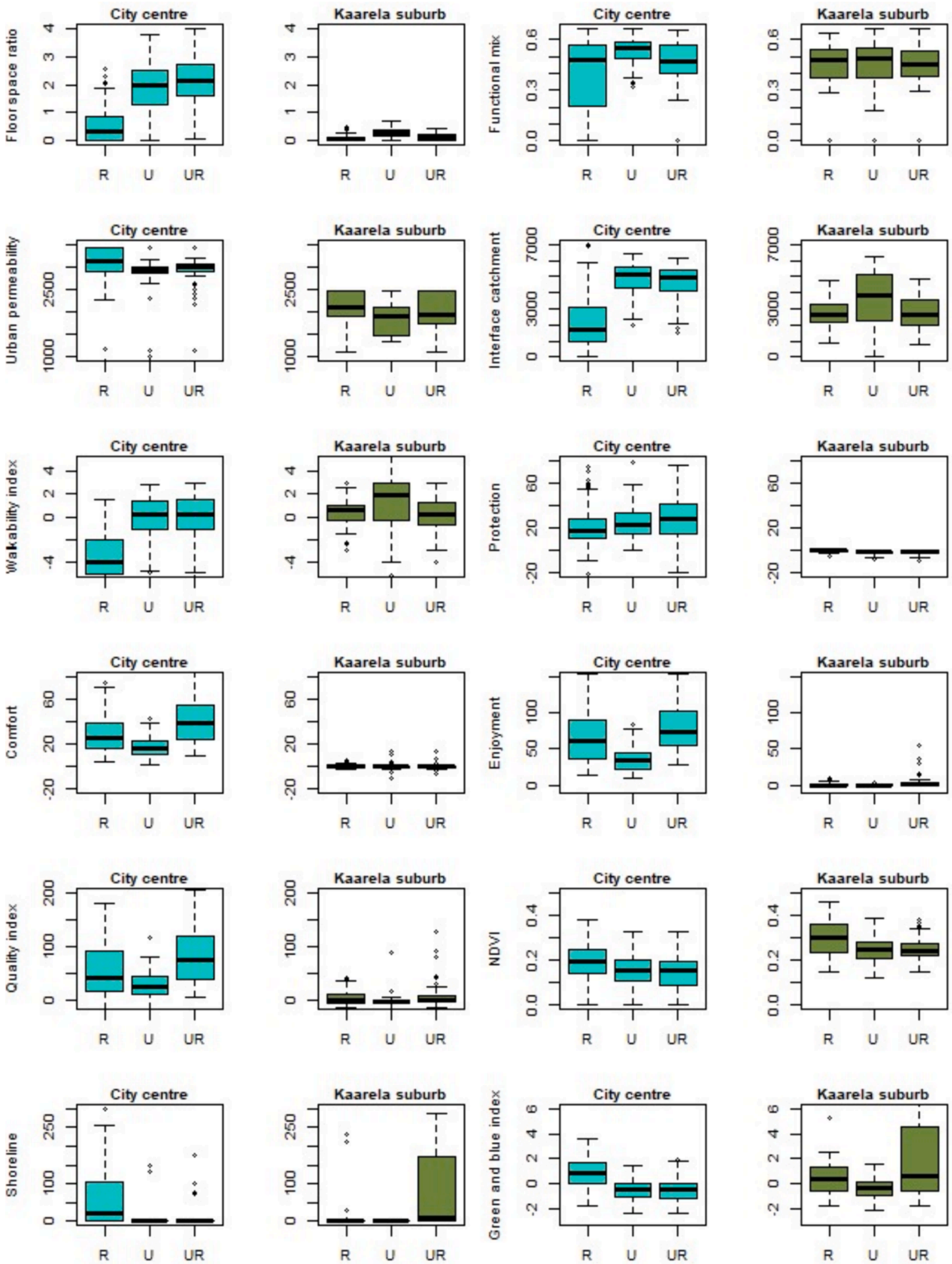



**Fig. 8.** Boxplots for the studied walkability variables in the hotspots for recreational (R), utilitarian (U), and both recreational and utilitarian (UR) walking in the city centre and Kaarela suburb.

outdoor facilities have shown spatial congruency between high objective and high perceived walkability (Meng et al., 2023), which was also reflected in our results of the suburb. Also the areas of low WI but high perceived walkability matched the descriptions of these areas in previous studies: areas with plenty of public open spaces, water bodies and trails (Bereitschaft, 2018; Meng et al., 2023). Bereitschaft (2018) associated "economically peripheral areas" and suburban "strip mall corridors" with high WI but low perceived walkability. These kinds of urban structures typical for the US cities were not present in our study areas. Instead, this kind of divergence appeared in the residential areas of the fringe areas of the city centre with a lot of drive-through traffic, and near suburban train stations.

Our findings indicated that spatial variations in objective and perceived walkability did not manifest similarly in the reported walking routes between the city centre and the suburb (RQ 2). In contrast to the city centre, the central parts of the suburb, such as areas around train stations, were not perceived as walkable and safe. Yet, these areas represented hotspots for utilitarian walking, and there was also a substantial amount of recreational walking. The result implies that suburban residents may have fundamentally different prerequisites for walking, since mobility options are more limited in areas representing transit or automobile urban fabrics (Newman et al., 2016). Therefore, if the areas around daily functions, i.e. hotspots of utilitarian walking, are not perceived safe, like in our case suburb, walkability is predominantly a matter of justice, as also discussed by Sheller (2018), especially in the case of less well-off and/or carless residents. Moreover, the issue of low perceived walkability in proximity to transit stops poses a challenge to promoting sustainable mobility. This is particularly problematic if it compels pedestrians to opt for cars in areas with robust public transport connections, such as railway stations (Halldórsdóttir et al., 2017; Otsuka et al., 2021). Interpreted through Gehl (2010) and Newman et al. (2016), these areas of transit urban fabric may be optimally dense, mixed, and accessible for walking, but if the basic need of pedestrian protection is missing, the other aspects do not matter because they are subordinate to people feeling safe. For urban planning practices, this means prioritising planning measures that aim at improving the sense of security, especially in suburban areas with high levels of utilitarian walking.

Also in the city centre, there were areas where the WI was high, but the perceived quality was low. Unlike in the suburb, these areas were much less used for walking compared to areas with high perceived quality, possibly indicating more route options in the area compared to the suburban context. In the walking urban fabric, the flows of pedestrians, and public transport and car users overlap more, in contrast to other fabrics (Newman et al., 2016). Thus, walkability in the areas of the walking fabric depends on how well the different transport infrastructures are integrated, and how well the pedestrian flows and infrastructures are prioritised. In this study, the areas in the city centre with low perceived quality potentially have shortcomings regarding the prioritisation of pedestrian infrastructure. However, Shields et al. (2021) point out that aiming for walkability is taken for granted in research. Newman et al. (2016) acknowledge that walkability cannot be a priority in every location, but it should be prioritised in both meso-scale and micro-scale planning of areas of walking fabric, such as city centres. In lower-density transit and automobile fabrics, walkability can be promoted by improving micro-scale urban design without, for example, significant efforts to increase the area's density (McGreevy et al., 2021), one of the most influential meso-scale walkability enablers.

Building upon previous research (Boarnet et al., 2011; Hsieh & Chuang, 2021; Kang et al., 2017; Rodrigue et al., 2022), our findings underscore the distinctions between utilitarian and recreational walking environments. Further, utilitarian and recreational walking environments of the city centre and suburb had certain differences (RQ 3). Interestingly, in the city centre, higher perceived protection was observed in utilitarian walking hotspots, also characterised by elevated building density, functional mix, and objective WI. Conversely, in the suburb, perceived protection was more prominent in recreational hotspots, linked to increased urban permeability, NDVI, and shoreline length. This trend, akin to the observations of Erturan & Aksel, (2023) and Zhu et al. (2023), implies that in a city centre context, the presence of a large and diverse crowd, even those not residing in the area, might contribute to heightened sense of security on streets, especially at nighttime. In contrast, in residential-focused suburbs, central areas may lack the crowd density necessary to establish a sense of security. In addition, the local characteristics of vegetation in green spaces, such as landscape design, vegetation density and maintenance may explain the difference, since these factors have proved to affect perceived personal safety (Jansson et al., 2013). The implications extend to the planning and maintenance of recreational areas in city centre, as low perceived protection has the potential to reduce physical activity and diminish social capital associated with the greenness of the environment (Hong et al., 2018; Weimann et al., 2017).

High perceived walkability in general was concentrated around recreation sites and shorelines in both case areas. Thus, as argued by previous research (Juul & Nordbø, 2023; Sallis et al., 2020; Sarkar et al., 2015), urban green and blue spaces and NDVI seem to be essential determinants of good walking environments. In our case suburb, the main recreation area was heavily used both for recreational and utilitarian walking suggesting that preserving green areas with water bodies near central functions can facilitate walking for multiple purposes, especially in suburban context. Walking decisions are influenced by desires to avoid discomfort and seek pleasure, blurring the boundaries between utilitarian and recreational walking, as argued by Dean et al. (2020). This may explain the occurrence of utilitarian walking also in the vicinity of attractive green spaces. According to our results, levels of perceived enjoyment were especially high in hotspots for both utilitarian and recreational walking both in city centre and suburb. Thus, planning urban environments with plenty of sensory experiences, such as pleasant streetscapes and nature experiences, may support walking for whatever purpose across urban fabrics.

It is important to acknowledge how the selected frameworks and walkability variables may affect the results. For example, green spaces were included in the calculation of the functional mix. In the suburban context, there were no significant differences between recreational and utilitarian walking environment in terms of functional mix and perceived comfort. The study by Rodrigue et al. (2022) representing suburban context also found that land use mix had no association to perceived walkability for recreation. It is possible that the association is predominantly a phenomenon of densely populated urban centres, which does not hold in suburbs using the same variables. In our study, the findings are also due to smaller number of respondents and the fact that elements occurring in both built and green environments (buildings, green spaces, services, crowd, peace, exercise facilities) were included in the same variable. Further methodological development is needed to better integrate green and blue spaces into walkability indices. Moreover, our theoretical framework and emphasis on areas with fundamentally distinct service provisions prompted us to prioritise accessibility variables based on urban morphology (permeability and interface catchment) over conventional destination accessibility metrics.

This study has some evident limitations. One limitation is the fact that the PPGIS map entries were provided by the same respondents who provided the information on which routes they used. This means that the areas with routes that people use got more reported walkability attributes. However, the attributes could be either negative or positive, so the routes did not necessarily appear as excessively positive or negative. In addition, the perceived measures derived from the PPGIS data focused more on micro-scale urban design, while the objective measures were more indicative of meso-scale attributes. This disparity was addressed to some extent by incorporating block-level accessibility variables (urban permeability and interface catchment) and by aggregating perceived measures into broader variables (protection, comfort, and enjoyment).

In this study, the data used for the city centre was not fully comparable with the data used for the suburb due to slightly different framing of the questions in the PPGIS surveys. In the CWS, it was asked what routes respondents actually walked, whereas the KRS investigated respondents' "favourite routes". Recreational walking, being inherently optional, tends to occur in the most favourable locations. Therefore, in this study, the disparity between actual and favourite routes may particularly concern utilitarian walking.

Dean et al. (2020) have argued that walking decisions are consistently influenced by the desire to avoid discomfort and seek pleasure. This may lead individuals to choose the most attractive routes also for utilitarian purposes. Furthermore, environmental context plays an important role in pedestrian route choice, although the exact process of this decision-making remains unknown (Tong & Bode, 2022). Different types of walkers, such as tourists, commuters, and shoppers, evaluate route attributes differently (Tong & Bode, 2022). Even among shoppers, categorised as utilitarian walkers in this study, distinctions arise between utilitarian shoppers, preferring more efficient routes, and hedonic shoppers, who enjoy leisurely strolls in the area (Kemperman et al., 2009; Mokhtarian et al., 2015). Short distances, but also personal safety, are valued along utilitarian walking routes (Guo & Loo, 2013). Among older people, the distinction between utilitarian and recreational walking is less evident, especially if daily walks involve errands (Winters et al., 2015). These examples highlight the challenge of distinguishing between the routes people actually use and those they prefer, implying that favourite and actual walking routes are comparable to some extent. However, while pedestrians may indeed harbour intentions to select paths according to their preferences, it is probable that the paths they actually choose will diverge from their favoured routes, in cases such as a commuting journey constrained by time. Due to the challenge of distinguishing the difference between used and preferred routes, more effort should be put into collecting comparable data across larger areas.

The collection of PPGIS data was not based on sampling, so their findings cannot be generalised to accurately represent the perspectives of all the citizens for whom the surveys were intended. Socio-demographic background of the respondents was not considered in this study due to lack of data. While demographic factors like age and gender haven't consistently shown a strong association with the alignment of objective and subjective walkability, unlike income, marital status, and ethnicity (Adkins et al., 2019; Orstad et al., 2017; van der Vlugt et al., 2022), certain attributes do emerge as prioritized within specific pedestrian groups, such as traffic safety among older adults (Distefano et al., 2021). Yet, the use of PPGIS data collected by the city planning authorities enabled the investigation of fine-scale, practice-oriented spatial information from a large group of people interested in contributing to walkability planning in the area.

Enhancing walkability is intricately connected to numerous practical planning challenges that cities striving for sustainability encounter (Bibri et al., 2020). These challenges may be related to meso-scale objective measures, such as inadequate density or land-use mix, or to micro-scale urban design. Thus, there is a need for integrative approaches that combine different aspects and can pinpoint locations requiring specific planning actions. Spatially explicit walkability analysis may provide information enabling the focus of planning objectives for each type of urban context. In this regard, we utilised the theoretical framework of urban fabrics, primarily based on objectively measured aspects of the urban environment. However, the functions and lifestyles they enable are integral to the theory. Therefore, it offers a useful framework for planning and studying walkability, incorporating both objective and perceived aspects across different scales and identifying walking needs in various parts of the city and within neighbourhoods.

## 6. Conclusions

This study highlights the importance of incorporating perceived aspects into walkability planning across urban fabrics. The measures of objective and perceived walkability complement each other, providing rich and relevant information for urban planning. Further, our results show that in urban planning, the context i.e. urban fabrics of the planning area should be identified in order to tailor the walkability measures to better reflect different walking conditions. Since the residents in transit and automobile urban fabrics of suburbs may have more limited mobility options than the users of city centres, planning for safe, walkable suburban environments can support fair, healthy, and sustainable mobility. Based on our results, suburban walkability should be especially enhanced around daily functions, such as train stations, and public and private services, since these areas are hotspots for necessary use of urban space (utilitarian walking). In the city centres, in turn, the priority should be on the integration of different transport modes in favour of walking.

Our results demonstrated the differences between utilitarian and recreational walking environments, revealing consistent patterns in both the city centre and suburban settings. However, perceived protection was identified as correlating with varying types of walking behaviour based on the context: utilitarian in the city centre and recreational in the suburbs. In planning for walkable urban environments, it is crucial to focus on enhancing pleasant sensory experiences across urban fabrics. Preserving green spaces with attractive water bodies near central areas may have the potential to facilitate walking for diverse purposes, particularly in suburban context.

## Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT-3 provided by OpenAI in order to improve the language and readability of the manuscript during the editing phase. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

## CRediT authorship contribution statement

**Maija Tiitu:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Vuokko Heikinheimo:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Linda Karjalainen:** Writing – review & editing, Writing – original draft, Visualization, Funding acquisition, Conceptualization. **Ville Helminen:** Writing – review & editing, Validation, Conceptualization. **Jari Lyytimäki:** Writing – review & editing, Validation. **Jenni Lehtimäki:** Writing – review & editing, Validation, Methodology, Conceptualization. **Riikka Paloniemi:** Writing – review & editing, Validation, Supervision, Project administration, Funding acquisition, Conceptualization.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The data cannot be shared openly due to their sensitive nature. The script for calculating Interface Catchment (IC) for multiple input points is available via: https://github.com/VuokkoH/IC/releases/tag/v0.0.1 (modified from https://github.com/Awapic/IC).

## Acknowledgements

Writing of this article has been funded by the Strategic Research Council (SRC) at Research Council of Finland (STYLE, project number

320402), and by Ministry of the Environment (Lähiöohjelma 2020–2022) for the project 'Spatial information and residents' experiences for development of comfortable living environments (HYVIÖ). We acknowledge Arto Viinikka from Finnish Environment Institute for calculating the NDVI for the case areas. We thank the City of Helsinki Urban Environment Division for providing several datasets to conduct this study. We would also like to thank the entire research group of the STYLE project, and Prof. Billie Giles-Corti for support and feedback on the conceptualisation of the study. Finally, the authors wish to acknowledge CSC – IT Center for Science, Finland, and the Geoportti Research Infrastructure for computational resources.

## Appendix A. The classification of buildings (BDR, 2021) into "live"," work", and "visit" categories in the calculation of functional mix

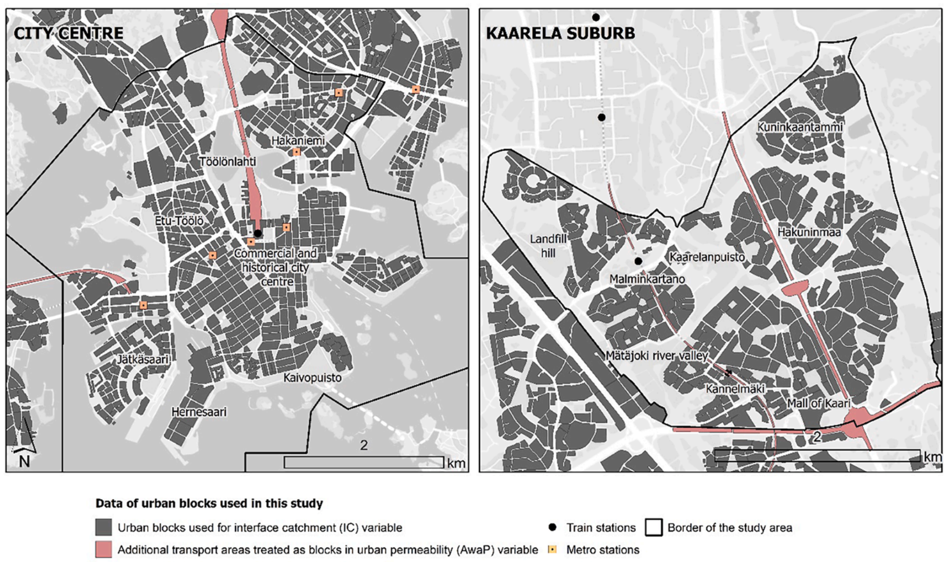
| LIVE | | WORK | | VISIT | | NOT INCLUDED | |
|---|---|---|---|---|---|---|---|
| Code | Description | Code | Description | Code | Description | Code | Description |
| 0110 | One-dwelling houses | 0400 | Office buildings | 0210 | Free-time residential buildings suitable for year-round use | 0511 | Vehicle depots for professional transport |
| 0111 | Two-dwelling houses | 0510 | Station buildings and terminals | 0211 | Free-time residential buildings suitable for use part of the year | 0513 | Car parks and multi-storey car parks |
| 0112 | Terraced houses | 0512 | Vehicle service buildings for professional transport | 0310 | Shopping halls | 0514 | Vehicle ports |
| 0120 | Low-rise blocks of flats | 0520 | Data centres and IT areas | 0311 | Shops, department stores and shopping centres | 1215 | Sheds |
| 0121 | Residential blocks of flats | 0521 | Communications buildings | 0319 | Other wholesale and retail trade buildings | 1311 | Civil defence shelters |
| 0130 | Residential buildings for communities | 0590 | Other transport and communications buildings | 0320 | Hotels | 1910 | Sauna buildings |
| 0140 | Dwellings for special groups | 0610 | Health care and wellness centres | 0321 | Motels, hostels, and similar accommodation buildings | 1911 | Outbuildings |
| | | 0611 | Central hospitals | 0322 | Holiday, rest, and recreation homes | 1919 | Buildings n.e.c. |
| | | 0612 | Special hospitals and laboratory buildings | 0329 | Other hotel buildings | | |
| | | 0613 | Other hospitals | 0330 | Restaurants and other similar buildings | | |
| | | 0614 | Rehabilitation institutes | 0710 | Theatres, music, and congress buildings | | |
| | | 0619 | Other health care buildings | 0711 | Cinemas | | |
| | | 0620 | Residential care activity buildings | 0712 | Libraries and archives | | |
| | | 0621 | Buildings for social work activities without accommodation | 0713 | Museums and art galleries | | |
| | | 0630 | Prisons | 0714 | Exhibition and trade fair halls | | |
| | | 0810 | Children's day care centres | 0720 | Association and club buildings | | |
| | | 0820 | General education buildings | 0730 | Buildings for practicing religion | | |
| | | 0830 | Vocational education buildings | 0731 | Parish halls | | |
| | | 0840 | University buildings | 0739 | Other buildings of religious communities | | |
| | | 0841 | Research institute buildings | 0740 | Indoor ice rinks | | |
| | | 0890 | Educational buildings for voluntary adult education | 0741 | Indoor swimming pools | | |
| | | 0891 | Educational buildings of organisations, unions, employers and similar | 0742 | Gymnasia | | |
| | | 0910 | General purpose industrial buildings | 0743 | Sports and ball game halls | | |
| | | 0911 | Heavy industry factory buildings | 0744 | Stadium and spectator buildings | | |
| | | 0912 | Food industry production buildings | 0749 | Other buildings for sports and exercise | | |
| | | 0919 | Other industrial production buildings | 0790 | Other assembly buildings | | |
| | | 0920 | Workshops for industry and small-scale industry | 1414 | Horse stables | | |
| | | 0930 | Processing buildings for metal ores | | | | |
| | | 0939 | Other mining and quarrying buildings | | | | |
| | | 1010 | Production buildings for electrical energy | | | | |
| | | 1011 | Production buildings for thermal and cold energy | | | | |
| | | 1090 | Energy transfer buildings | | | | |
| | | 1091 | Energy storage buildings | | | | |
| | | 1110 | Water intake, water treatment and water distribution buildings | | | | |
| | | 1120 | Waste collection, waste treatment and waste storage buildings | | | | |
| | | 1130 | Material recycling buildings | | | | |
| | | 1210 | Unheated warehouses | | | | |
| | | 1211 | Heated warehouses | | | | |
| | | 1212 | Cold and freezer warehouses | | | | |
| | | 1213 | Other warehouses with controlled conditions | | | | |
| | | 1214 | Logistics centres and other multi-purpose warehouse buildings | | | | |
| | | 1310 | Fire stations | | | | |
| | | 1319 | Other rescue service buildings | | | | |
| | | 1410 | Buildings for dairy cattle | | | | |

(*continued on next page*)

(*continued*)

| LIVE | | WORK | | VISIT | | NOT INCLUDED | |
|---|---|---|---|---|---|---|---|
| Code | Description | Code | Description | Code | Description | Code | Description |
| | | 1419 | Other animal shelters | | | | |
| | | 1490 | Greenhouses | | | | |
| | | 1491 | Grain drying and storage buildings | | | | |
| | | 1492 | Agricultural storage buildings | | | | |
| | | 1499 | Other buildings in agriculture, forestry, and fishing | | | | |

## Appendix B. Spatial representation of the two versions of urban block data used in this study for calculating the walkability index sub-variables interface catchment (IC) and urban permeability (AwaP). Data sources: Finnish Environment Institute (Syke) 2022; City of Helsinki 2022 (quarters of Helsinki); Helsinki Region Transport 2022. Base map: NLS & Esri Finland 2022




## Appendix C. Classification of quality attributes and original survey questions for the city centre case area. Datasets: Inner-city walkability survey, CWS (2018), traffic safety survey for citizens of Helsinki, TSS (2020). Classification of quality attributes: PROTEC=protection, COMFO=comfort, ENJOY=enjoyment

| Data | Title and wording of the question | Variable tag / button name | Variable classification | Map entry format | Positive/ negative map entry |
|---|---|---|---|---|---|
| CWS | **Places for lingering.** Why does this place make you stop? | Meeting place | COMFO | point | + |
| | | Services (e.g., café, terrace, kiosk, shop) | COMFO | point | + |
| | | Playground | COMFO | point | + |
| | | Exercise facilities (e.g., outdoor gym, beach) | COMFO | point | + |
| | | Peaceful place | COMFO | point | + |
| | | Possibility to rest (bench or other places to sit) | COMFO | point | + |
| | | There are frequent events | COMFO | point | + |
| | | Shop windows | ENJOY | point | + |
| | | Lovely green space | ENJOY | point | + |
| | | Beautiful view | ENJOY | point | + |
| | | There are beautiful buildings or other built destinations | ENJOY | point | + |
| | | Pleasant microclimate (e.g., shelter from the wind, sunny spot) | ENJOY | point | + |
| | **Highlights of the walking route.** Where are the favourite parts of your walking route? Why is this the high point? | This is a pedestrian street | PROTEC | point | + |
| | | There are services (e.g., ice cream kiosk or café) | COMFO | point | + |
| | | There is crowd | COMFO | point | + |
| | | This is a peaceful place | COMFO | point | + |
| | | There are frequent events | COMFO | point | + |
| | | There is a beautiful view | ENJOY | point | + |

(*continued on next page*)

(*continued*)

| Data | Title and wording of the question | Variable tag / button name | Variable classification | Map entry format | Positive/ negative map entry |
|---|---|---|---|---|---|
| | | You can do window-shopping here | ENJOY | point | + |
| | | It's lush green here (e.g., trees, bushes, or flower beds) | ENJOY | point | + |
| | | There are beautiful buildings or other built destinations | ENJOY | point | + |
| | **I use this route, because...** | The route is fast and smooth | PROTEC | route | + |
| | | The route is safe | PROTEC | route | + |
| | | The route is well lit | PROTEC | route | + |
| | | The route is not noisy | PROTEC | route | + |
| | | There are interesting events and people along the route, the route it is vibrant | COMFO | route | + |
| | | The route is not too busy | COMFO | route | + |
| | | There are green environments along the route | ENJOY | route | + |
| | | There are beautiful buildings or other built destinations along the route | ENJOY | route | + |
| | | There are interesting destinations along the route (squares, shop windows, cafés, terraces) | ENJOY | route | + |
| | | The route is varied | ENJOY | route | + |
| | **Unpleasant spot in the walking route**. Think e.g., which places you would like to avoid or run a mile from on your walking route. Why is this spot unpleasant? | Unsafe in terms of traffic | PROTEC | point | – |
| | | Frightening | PROTEC | point | – |
| | | Poorly lit | PROTEC | point | – |
| | | Poorly maintained | PROTEC | point | – |
| | | Interruption of a smooth route | PROTEC | point | – |
| | | Traffic lights | PROTEC | point | – |
| | | Too narrow sidewalk | PROTEC | point | – |
| | | Noisy | PROTEC | point | – |
| | | Too much traffic | PROTEC | point | – |
| | | Poor separation of travel modes | PROTEC | point | – |
| | | Bad air quality | PROTEC | point | – |
| | | Untidy environment | PROTEC | point | – |
| | | Deficiencies in the equipment (e.g., bench, trash can) | COMFO | point | – |
| | | Too many people | COMFO | point | – |
| | | Deserted place, too few people | COMFO | point | – |
| | | Ugly environment or buildings | ENJOY | point | – |
| | | Monotonous environment | ENJOY | point | – |
| | | Unpleasant climate (e.g., windy spot) | ENJOY | point | – |
| | **This walking route or part of the route should be improved**. This walking route is e.g., too narrow, safety should be improved, or lighting should be increased. How could this walking route be improved? | The sidewalk / walking route should be widened | PROTEC | route | – |
| | | The pavement of the sidewalk / walking route should be renewed | PROTEC | route | – |
| | | The number trash cans and the amount of cleaning should be increased | PROTEC | route | – |
| | | Different travel modes should be better separated | PROTEC | route | – |
| | | The route should be transformed into a pedestrian street | PROTEC | route | – |
| | | Lighting should be increased | PROTEC | route | – |
| | | Condition and winter maintenance should be improved | PROTEC | route | – |
| | | Car parking / service traffic on sidewalks should be restricted | PROTEC | route | – |
| | | The safety of street crossing should be improved | PROTEC | route | – |
| | | Signs should be added | PROTEC | route | – |
| | | Driving speeds should be reduced | PROTEC | route | – |
| | | Car traffic should be reduced | PROTEC | route | – |
| | | Pedestrians should be given priority at traffic lights | PROTEC | route | – |
| | | Accessibility should be improved | PROTEC | route | – |
| | | Benches or other sitting opportunities should be added | COMFO | route | – |
| | | A café, terrace or kiosk could be added along the route | COMFO | route | – |
| | | Interesting things to look at, e.g., art, should be added along the route | ENJOY | route | – |
| | | Plantings and trees should be added | ENJOY | route | – |
| TSS | **Dangerous spots on the map**. Mark on the map dangerous or difficult spots in terms of traffic safety according to the classification below. You can mark several items but focus on what you think are the most important traffic safety problems. Please note that after placing a mark on the map, you can mark the | Difficult or unsafe intersection or junction | PROTEC | point | – |
| | | Unsafe road crossing | PROTEC | point | – |
| | | High driving speeds | PROTEC | point | – |
| | | Dangerous spot related to parking | PROTEC | point | – |

(*continued on next page*)

(*continued*)

| Data | Title and wording of the question | Variable tag / button name | Variable classification | Map entry format | Positive/ negative map entry |
|---|---|---|---|---|---|
| | means of transport for which the problem causes the most danger if you wish. | Deficiencies in the condition or maintenance of the route | PROTEC | point | − |
| | **Follow-up question after marking the place**: . The user group for whom the place poses the greatest danger: Pedestrians | Shortcomings in the quality or continuity of the route | PROTEC | point | − |

## Appendix D. Classification of quality attributes and original survey questions for the Kaarela suburb case area. Datasets: Neighbourhood walkability survey, NWS (2019), Kaarela residents' survey, KRS (2018), traffic safety survey for citizens of Helsinki, TSS (2020). Classification of quality attributes: PROTEC=protection, COMFO=comfort, ENJOY=enjoyment. All the map entries were in point format

| Data | Question | Variable tag / button name | Variable classify-cation | Tag interpreted from open-ended question | Positive/ negative map entry |
|---|---|---|---|---|---|
| NWS | **Good walking environment.** Why do you think this is a good walking environment, what are the strengths of the environment? Why is it nice to stay (spend time) here? | Lighting | PROTEC | x | + |
| | | The place is carless, there are few cars | PROTEC | x | + |
| | | Maintenance of the routes and the environment | PROTEC | x | + |
| | | Good separation of travel modes | PROTEC | x | + |
| | | Route width is good for walking | PROTEC | x | + |
| | | There are people | COMFO | x | + |
| | | Tranquility | COMFO | x | + |
| | | Equipment (e.g., duckboards, trash cans, pier) | COMFO | x | + |
| | | Benches and other resting places | COMFO | x | + |
| | | Good exercise facilities | COMFO | x | + |
| | | Beautiful view or landscape, aesthetics | ENJOY | x | + |
| | | Green, lush, plants, flower beds, nature experiences | ENJOY | x | + |
| | | Varied terrain / route / landscape | ENJOY | x | + |
| | | Presence of water | ENJOY | x | + |
| | | Pleasant microclimate, e.g., sunny, cool | ENJOY | x | + |
| | **Spots to improve**. Why do you think this is a bad walking environment, what are its weaknesses? | Noisiness | PROTEC | x | − |
| | | Insufficient lighting | PROTEC | x | − |
| | | Insufficient maintenance | PROTEC | x | − |
| | | Problems caused by car traffic | PROTEC | x | − |
| | | Problems caused by poor separation of travel modes | PROTEC | x | − |
| | | Insufficient signage for pedestrians | PROTEC | x | − |
| | | Unpleasantness, insecurity | PROTEC | x | − |
| | | Untidiness, filth, rubbish | PROTEC | x | − |
| | | Too few benches or other resting places | COMFO | x | − |
| | | Insufficient equipment, e.g., trash cans | COMFO | x | − |
| | | Missing vegetation and flower beds | ENJOY | x | − |
| | | Ugliness | ENJOY | x | − |
| KRS | **Best in the area. My favourite spots in the area:** Tell us briefly what makes the place your favourite? | No light pollution | PROTEC | x | + |
| | | Good maintenance | PROTEC | x | + |
| | | Cleanliness, tidiness | PROTEC | x | + |
| | | Sports and leisure activity opportunities | COMFO | x | + |
| | | Benches and other places for sitting | COMFO | x | + |
| | | Places to play | COMFO | x | + |
| | | Opportunities for urban gardening | COMFO | x | + |
| | | Good infrastructure (incl. routes and equipment such as workout stairs, pier) | COMFO | x | + |
| | | Tranquility | COMFO | x | + |
| | | Opportunities to meet people, liveliness | COMFO | x | + |
| | | Private or public services | COMFO | x | + |
| | | Events | COMFO | x | + |
| | | Green, lush, nature experiences, plants, and animals | ENJOY | x | + |

(*continued on next page*)

(*continued*)

| Data | Question | Variable tag / button name | Variable classify-cation | Tag interpreted from open-ended question | Positive/ negative map entry |
|---|---|---|---|---|---|
| | | Novelty, modernity of the buildings / area | ENJOY | x | + |
| | | Important for the region and national identity | ENJOY | x | + |
| | | Variability, versatility | ENJOY | x | + |
| | | Pleasant microclimate | ENJOY | x | + |
| | | Presence of water | ENJOY | x | + |
| | | View, landscape, beauty, and aesthetics | ENJOY | x | + |
| | | Cultural-historical significance | ENJOY | x | + |
| | | Arts | ENJOY | x | + |
| | **Best in the area** | This is an important public meeting and socialising place | COMFO | | + |
| | | A nice landscape or view | ENJOY | | + |
| | **What should be developed and repaired in the area?** | A street or square in need of renovation | PROTEC | | – |
| | | A park or natural area in need of restoration | PROTEC | | – |
| | | Unsafe place | PROTEC | | – |
| | | More lighting is needed here | PROTEC | | – |
| | | Benches should be added or renovated here | COMFO | | – |
| | | More trash cans are needed here | COMFO | | – |
| | **What should be developed and repaired in the area?** | Littered | PROTEC | x | – |
| | **Unpleasant places (e.g., a noisy or a littered place):** | Untidy | PROTEC | x | – |
| | Why is the place unpleasant? | Restless | PROTEC | x | – |
| | | Noisy | PROTEC | x | – |
| TSS | **Dangerous spots on the map.** Mark on the map dangerous or difficult spots in terms of traffic safety according to the classification below. You can mark several items but focus on what you think are the most important traffic safety problems. Please note that after placing a mark on the map, you can mark the means of transport for which the problem causes the most danger if you wish. | Difficult or unsafe intersection or junction | PROTEC | | – |
| | | Unsafe road crossing | PROTEC | | – |
| | | High driving speeds | PROTEC | | – |
| | | Dangerous spot related to parking | PROTEC | | – |
| | | Deficiencies in the condition or maintenance of the route | PROTEC | | – |
| | **Follow-up question after marking the place:** The user group for whom the place poses the greatest danger: Pedestrians | Shortcomings in the quality or continuity of the route | PROTEC | | – |

## Appendix E. A complete list of used variables. The bolded ones are combined indices composing of sub-variables

| Variable | Description | Data provider and year |
|---|---|---|
| Floor space ratio | The ratio between the total floor space of buildings per hectare in 100-m grid cells as a focal sum (a sub-variable for the walkability index, WI) | BDR, 2021 |
| Functional mix | Simpson's diversity index (SIDI) describing the mix of functions (live, work, visit) in 100-m grid cells as a focal sum (a sub-variable for the walkability index, WI) | BDR, 2021 |
| Urban permeability (AwaP) | The permeability of urban blocks (a sub-variable for the walkability index, WI) | City of Helsinki, 2022 |
| Interface catchment | The total length (m) of block facades accessible within a 300-m walking distance (a sub-variable for the walkability index, WI) | City of Helsinki, 2022 |
| **Walkability index (WI)** | **A combined index for objective walkability including the variables floor space ratio, functional mix, urban permeability (AwaP), and interface catchment (IC)** | BDR, 2021; City of Helsinki, 2022 |
| Protection | The sum of (positive or negative) protection-related map entries within a 100-m grid cell provided by the survey respondents | City of Helsinki, 2018; 2019; 2020 |
| Comfort | The sum of (positive or negative) comfort-related map entries within a 100-m grid cell provided by the survey respondents | City of Helsinki, 2018; 2019 |
| Enjoyment | The sum of (positive or negative) enjoyment-related map entries within a 100-m grid cell provided by the survey respondents | City of Helsinki, 2018; 2019 |
| **Perceived quality index (QUALI)** | **A combined index of perceived quality attributes protection, comfort and enjoyment based on standardised z-scores** | City of Helsinki, 2018; 2019; 2020 |
| NDVI | Difference vegetation index describing the greenness of the area (averaged value for each 100-m grid cell) | National Land Survey of Finland, 2020 |
| Shoreline | The shoreline length (m / 100-m grid cell) | SYKE & National Land Survey of Finland, 2021 |
| **Green and blue index** | **A combined index of shoreline length and NDVI based on standardised z-scores** | SYKE & National Land Survey of Finland, 2020; 2021 |
| Rout_per | The number of survey respondents who made walking route entries (persons / 100-m grid cell) | City of Helsinki, 2018 |
| U_Rout_per | The number of survey respondents who made utilitarian walking route entries (persons / 100-m grid cell) | City of Helsinki, 2018 |
| R_Rout_per | The number of survey respondents who made recreational walking route entries (persons / 100-m grid cell) | City of Helsinki, 2018 |

## References

Adkins, A., Barillas-Longoria, G., Nevárez Martínez, D., & Ingram, M. (2019). Differences in social and physical dimensions of perceived walkability in Mexican American and non-hispanic white walking environments in Tucson. *Arizona. Journal of Transport & Health, 14*, Article 100585. https://doi.org/10.1016/j.jth.2019.100585

Alattar, M. A., Cottrill, C., & Beecroft, M. (2021). Public participation geographic information system (PPGIS) as a method for active travel data acquisition. *Journal of Transport Geography, 96*, Article 103180. https://doi.org/10.1016/j.jtrangeo.2021.103180

Anselin, L. (1995). Local Indicators of Spatial Association—LISA. *Geographical Analysis, 27*(2), 93–115. https://doi.org/10.1111/j.1538-4632.1995.tb00338.x

Arellana, J., Saltarín, M., Larrañaga, A. M., Alvarez, V., & Henao, C. A. (2020). Urban walkability considering pedestrians' perceptions of the built environment: A 10-year review and a case study in a medium-sized city in Latin America. *Transport Reviews, 40*(2), 183–203. https://doi.org/10.1080/01441647.2019.1703842

Arvidsson, D., Kawakami, N., Ohlsson, H., & Sundquist, K. (2012). Physical Activity and Concordance between Objective and Perceived Walkability. *Medicine & Science in Sports & Exercise, 44*(2). https://journals.lww.com/acsm-msse/fulltext/2012/02000/physical_activity_and_concordance_between.13.aspx.

Bassett, D. R. J., Mahar, M. T., Rowe, D. A., & Morrow, J. R. J. (2008). Walking and measurement. *Medicine and Science in Sports and Exercise, 40*(7 Suppl), S529–S536. https://doi.org/10.1249/MSS.0b013e31817c699c

Bereitschaft, B. (2018). Walk Score® versus residents' perceptions of walkability in Omaha, NE. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 11*(4), 412–435. https://doi.org/10.1080/17549175.2018.1484795

Bibri, S. E., Krogstie, J., & Kärrholm, M. (2020). Compact city planning and development: Emerging practices and strategies for achieving the goals of sustainability. *Developments in the Built Environment, 4*, Article 100021. https://doi.org/10.1016/j.dibe.2020.100021

Boarnet, M. G., Forsyth, A., Day, K., & Oakes, J. M. (2011). The Street Level Built Environment and Physical Activity and Walking: Results of a Predictive Validity Study for the Irvine Minnesota Inventory. *Environment and Behavior, 43*(6), 735–775. https://doi.org/10.1177/0013916510379760

Bödeker, M. (2018). Walking and Walkability in Pre-Set and Self-Defined Neighborhoods: A Mental Mapping Study in Older Adults. *International Journal of Environmental Research and Public Health, 15*(7). https://doi.org/10.3390/ijerph15071363

Bornioli, A., Parkhurst, G., & Morgan, P. L. (2019). Affective experiences of built environments and the promotion of urban walking. *Walking and Cycling for Better Transport, Health and the Environment, 123*, 200–215. https://doi.org/10.1016/j.tra.2018.12.006

Bozovic, T., Stewart, T., Hinckson, E., & Smith, M. (2021). Clearing the path to transcend barriers to walking: Analysis of associations between perceptions and walking behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour, 77*, 197–208. https://doi.org/10.1016/j.trf.2021.01.003

BDR (2021). *Building and Dwelling Register.* Digital and population data services agency. https://dvv.fi/en/real-estate-building-and-spatial-information.

Cerin, E., Conway, T. L., Saelens, B. E., Frank, L. D., & Sallis, J. F. (2009). Cross-validation of the factorial structure of the Neighborhood Environment Walkability Scale (NEWS) and its abbreviated form (NEWS-A). *International Journal of Behavioral Nutrition and Physical Activity, 6*(1), 32. https://doi.org/10.1186/1479-5868-6-32

City of Helsinki (2020). *Traffic safety survey for citizens of Helsinki.* City of Helsinki Urban Environment Division. Retrieved from Helsinki Region Infoshare service on 11 Oct 2021 under the license Creative Commons Attribution 4.0. https://hri.fi/data/en_GB/dataset/helsingin-liikenneturvallisuuskysely-asukkaille.

City of Helsinki. (2024). *Kuninkaantammi.* https://www.hel.fi/en/urban-environment-and-traffic/urban-planning-and-construction/urban-development/kuninkaantammi.

City of Helsinki (2022a). *Helsingin kävelyn edistämisohjelma (in Finnish)*. Kaupunkiympäristön julkaisuja 2022:9. City of Helsinki Urban Environment Division.

City of Helsinki (2022b). *Register of public areas in the City of Helsinki. City of Helsinki Urban Environment Division.* https://hri.fi/data/en_GB/dataset/helsingin-kaupungin-yleisten-alueiden-rekisteri.

De Vos, J., Lättman, K., van der Vlugt, A.-L., Welsch, J., & Otsuka, N. (2023). Determinants and effects of perceived walkability: A literature review, conceptual model and research agenda. *Transport Reviews, 43*(2), 303–324. https://doi.org/10.1080/01441647.2022.2101072

Dean, J., Biglieri, S., Drescher, M., Garnett, A., Glover, T., & Casello, J. (2020). Thinking relationally about built environments and walkability: A study of adult walking behavior in Waterloo. *Ontario. Health & Place, 64*, Article 102352. https://doi.org/10.1016/j.healthplace.2020.102352

Distefano, N., Pulvirenti, G., & Leonardi, S. (2021). Neighbourhood walkability: Elderly's priorities. *Active Travel and Mobility Management, 40*, Article 100547. https://doi.org/10.1016/j.rtbm.2020.100547

Dovey, K., & Pafka, E. (2020). What is walkability? *The urban DMA. Urban Studies, 57*(1), 93–108. https://doi.org/10.1177/0042098018819727

Dovey, K., & Wood, S. (2015). Public/private urban interfaces: Type, adaptation, assemblage. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 8*(1), 1–16. https://doi.org/10.1080/17549175.2014.891151

Erturan, A., & Aksel, B. (2023). Multidimensional analyses of walkability in city centres by using mobile methodologies: Beşiktaş and Delft experiences. *URBAN DESIGN International, 28*(1), 52–69. https://doi.org/10.1057/s41289-022-00209-6

Ewing, R., & Handy, S. (2009). Measuring the Unmeasurable: Urban Design Qualities Related to Walkability. *Journal of Urban Design, 14*(1), 65–84. https://doi.org/10.1080/13574800802451155

Fonseca, F., Ribeiro, P. J. G., Conticelli, E., Jabbari, M., Papageorgiou, G., Tondelli, S., & Ramos, R. A. R. (2022). Built environment attributes and their influence on walkability. *International Journal of Sustainable Transportation, 16*(7), 660–679. https://doi.org/10.1080/15568318.2021.1914793

Frank, L. D., Sallis, J. F., Saelens, B. E., Leary, L., Cain, K., Conway, T. L., & Hess, P. M. (2010). The development of a walkability index: Application to the Neighborhood Quality of Life Study. *British Journal of Sports Medicine, 44*(13), 924. https://doi.org/10.1136/bjsm.2009.058701

Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., & Saelens, B. E. (2005). Linking objectively measured physical activity with objectively measured urban form. *American Journal of Preventive Medicine, 28*(2), 117–125. https://doi.org/10.1016/j.amepre.2004.11.001

Gebel, K., Bauman, A. E., Sugiyama, T., & Owen, N. (2011). Mismatch between perceived and objectively assessed neighborhood walkability attributes: Prospective relationships with walking and weight gain. *Geographies of Care, 17*(2), 519–524. https://doi.org/10.1016/j.healthplace.2010.12.008

Gebel, K., Bauman, A., & Owen, N. (2009). Correlates of Non-Concordance between Perceived and Objective Measures of Walkability. *Annals of Behavioral Medicine, 37*(2), 228–238. https://doi.org/10.1007/s12160-009-9098-3

Gehl, J. (2010). *Cities for people.* Island press.

Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A. L., Badland, H., Foster, S., Lowe, M., Sallis, J. F., Stevenson, M., & Owen, N. (2016). City planning and population health: A global challenge. *The Lancet, 388*(10062), 2912–2924. https://doi.org/10.1016/S0140-6736(16)30066-6

Guo, Z., & Loo, B. P. Y. (2013). Pedestrian environment and route choice: Evidence from New York City and Hong Kong. *Journal of Transport Geography, 28*, 124–136. https://doi.org/10.1016/j.jtrangeo.2012.11.013

Halldórsdóttir, K., Nielsen, O. A., & Prato, C. G. (2017). Home-end and activity-end preferences for access to and egress from train stations in the Copenhagen region. *International Journal of Sustainable Transportation, 11*(10), 776–786. https://doi.org/10.1080/15568318.2017.1317888

Handy, S. (2020). Is accessibility an idea whose time has finally come? *Transportation Research Part D: Transport and Environment, 83*, Article 102319. https://doi.org/10.1016/j.trd.2020.102319

Hasanzadeh, K., Broberg, A., & Kyttä, M. (2017). Where is my neighborhood? A dynamic individual-based definition of home ranges and implementation of multiple evaluation criteria. *Applied Geography, 84*, 1–10. https://doi.org/10.1016/j.apgeog.2017.04.006

Helminen, V., Tiitu, M., Kosonen, L., & Ristimäki, M. (2020). Identifying the areas of walking, transit and automobile urban fabrics in Finnish intermediate cities. *Transportation Research Interdisciplinary Perspectives, 8*, 100257. https://doi.org/10.1016/j.trip.2020.100257

Hess, P. M., Vernez Moudon, A., Catherine Snyder, M., & Stanilov, K. (1999). Site Design and Pedestrian Travel. *Transportation Research Record, 1674*(1), 9–19. https://doi.org/10.3141/1674-02

Hijmans, R. (2022). *Raster: Geographic Data Analysis and Modeling. R package version* (p. 3.5-29.). Https://CRAN.R-project.org/package=raster.

Hong, A., Sallis, J. F., King, A. C., Conway, T. L., Saelens, B., Cain, K. L., Fox, E. H., & Frank, L. D. (2018). Linking green space to neighborhood social capital in older adults: The role of perceived safety. *Social Science & Medicine, 207*, 38–45. https://doi.org/10.1016/j.socscimed.2018.04.051

Hooper, P., Knuiman, M., Foster, S., & Giles-Corti, B. (2015). The building blocks of a 'Liveable Neighbourhood': Identifying the key performance indicators for walking of an operational planning policy in Perth, Western Australia. *Health & Place, 36*, 173–183. https://doi.org/10.1016/j.healthplace.2015.10.005

Hsieh, H.-S., & Chuang, M.-T. (2021). Association of perceived environment walkability with purposive and discursive walking for urban design strategies. *Journal of Transport and Land Use, 14*(1), 1099–1127.

Iroz-Elardo, N., Adkins, A., & Ingram, M. (2021). Measuring perceptions of social environments for walking: A scoping review of walkability surveys. *Health & Place, 67*, Article 102468. https://doi.org/10.1016/j.healthplace.2020.102468

Jacobs, J. (1961). *The Death and Life of the Great American Cities.* Random House.

Jansson, M., Fors, H., Lindgren, T., & Wiström, B. (2013). Perceived personal safety in relation to urban woodland vegetation – A review. *Urban Forestry & Urban Greening, 12*(2), 127–133. https://doi.org/10.1016/j.ufug.2013.01.005

Jensen, W. A., Brown, B. B., Smith, K. R., Brewer, S. C., Amburgey, J. W., & McIff, B. (2017). Active Transportation on a Complete Street: Perceived and Audited Walkability Correlates. *International Journal of Environmental Research and Public Health, 14*(9). https://doi.org/10.3390/ijerph14091014

Juul, V., & Nordbø, E. C. A. (2023). Examining activity-friendly neighborhoods in the Norwegian context: Green space and walkability in relation to physical activity and the moderating role of perceived safety. *BMC Public Health, 23*(1), 259. https://doi.org/10.1186/s12889-023-15170-4

Kahila-Tani, M., Broberg, A., Kyttä, M., & Tyger, T. (2016). Let the Citizens Map—Public Participation GIS as a Planning Support System in the Helsinki Master Plan Process. *Planning Practice & Research, 31*(2), 195–214. https://doi.org/10.1080/02697459.2015.1104203

Kajosaari, A., Hasanzadeh, K., & Kyttä, M. (2019). Residential dissonance and walking for transport. *Journal of Transport Geography, 74*, 134–144. https://doi.org/10.1016/j.jtrangeo.2018.11.012

Kang, B., Moudon, A. V., Hurvitz, P. M., & Saelens, B. E. (2017). Differences in behavior, time, location, and built environment between objectively measured utilitarian and recreational walking. *Transportation Research Part D: Transport and Environment, 57*, 185–194. https://doi.org/10.1016/j.trd.2017.09.026

Karjalainen, L. E., Tiitu, M., Lyytimäki, J., Helminen, V., Tapio, P., Tuominen, A., Vasankari, T., Lehtimäki, J., & Paloniemi, R. (2023). Going carless in different urban fabrics: Socio-demographics of household car ownership. *Transportation, 50*, 107–142. https://doi.org/10.1007/s11116-021-10239-8

Kemperman, A. D. A. M., Borgers, A. W. J., & Timmermans, H. J. P. (2009). Tourist shopping behavior in a historic downtown area. *Tourism Management, 30*(2), 208–218. https://doi.org/10.1016/j.tourman.2008.06.002

Kim, E. J., Won, J., & Kim, J. (2019). Is Seoul Walkable? Assessing a Walkability Score and Examining Its Relationship with Pedestrian Satisfaction in Seoul. *Korea. Sustainability, 11*(24). https://doi.org/10.3390/su11246915

Kim, S., Park, S., & Lee, J. S. (2014). Meso- or micro-scale? Environmental factors influencing pedestrian satisfaction. *Transportation Research Part D: Transport and Environment, 30*, 10–20. https://doi.org/10.1016/j.trd.2014.05.005

Knapskog, M., Hagen, O. H., Tennøy, A., & Rynning, M. K. (2019). Exploring ways of measuring walkability. *Urban Mobility – Shaping the Future Together Mobil.TUM 2018 – International Scientific Conference on Mobility and Transport Conference Proceedings*, *41*, 264–282. 10.1016/j.trpro.2019.09.047.

Koohsari, M. J., Badland, H., Sugiyama, T., Mavoa, S., Christian, H., & Giles-Corti, B. (2015). Mismatch between Perceived and Objectively Measured Land Use Mix and Street Connectivity: Associations with Neighborhood Walking. *Journal of Urban Health, 92*(2), 242–252. https://doi.org/10.1007/s11524-014-9928-x

Koohsari, M. J., McCormack, G. R., Shibata, A., Ishii, K., Yasunaga, A., Nakaya, T., & Oka, K. (2021). The relationship between walk score® and perceived walkability in ultrahigh density areas. *Preventive Medicine Reports, 23*, Article 101393. https://doi.org/10.1016/j.pmedr.2021.101393

Kyttä, M., Broberg, A., Tzoulas, T., & Snabb, K. (2013). Towards contextually sensitive urban densification: Location-based softGIS knowledge revealing perceived residential environmental quality. *Landscape and Urban Planning, 113*, 30–46. https://doi.org/10.1016/j.landurbplan.2013.01.008

Laatikainen, T. E., Haybatollahi, M., & Kyttä, M. (2019). Environmental, Individual and Personal Goal Influences on Older Adults' Walking in the Helsinki Metropolitan Area. *International Journal of Environmental Research and Public Health, 16*(1). https://doi.org/10.3390/ijerph16010058

Lamour, Q., Morelli, A. M., & Marins, K. R. de C. (2019). Improving walkability in a TOD context: Spatial strategies that enhance walking in the Belém neighbourhood, in São Paulo, Brazil. *Case Studies on Transport Policy*, *7*(2), 280–292. 10.1016/j.cstp.2019.03.005.

Larranaga, A. M., Arellana, J., Rizzi, L. I., Strambi, O., & Cybis, H. B. B. (2019). Using best–worst scaling to identify barriers to walkability: A study of Porto Alegre. *Brazil. Transportation, 46*(6), 2347–2379. https://doi.org/10.1007/s11116-018-9944-x

Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A., & Hugo, G. (2007). Walkability of local communities: Using geographic information systems to objectively assess relevant environmental attributes. *Health & Place, 13*(1), 111–122. https://doi.org/10.1016/j.healthplace.2005.11.001

Lovasi, G. S., Grady, S., & Rundle, A. (2011). Steps Forward: Review and Recommendations for Research on Walkability, Physical Activity and Cardiovascular Health. *Public Health Reviews, 33*(2), 484–506. https://doi.org/10.1007/BF03391647

Majic, I., & Pafka, E. (2019). AwaP-IC—An Open-Source GIS Tool for Measuring Walkable Access. *Urban Science, 3*(2). https://doi.org/10.3390/urbansci3020048

McGarigal, K., & Marks, B. J. (1995). *FRAGSTATS: spatial pattern analysis program for quantifying landscape structure.* U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 10.2737/pnw-gtr-351.

Meng, S., Yang, Y., & Lewis, R. (2023). Subjective Versus Objective: Divergency Between Subjective Walkability and Walk Score During the COVID-19 Pandemic. *Transportation Research Record, 03611981231165023*. https://doi.org/10.1177/03611981231165023

Mokhtarian, P. L., Salomon, I., & Singer, M. E. (2015). What Moves Us? An Interdisciplinary Exploration of Reasons for Traveling. *Transport Reviews, 35*(3), 250–274. https://doi.org/10.1080/01441647.2015.1013076

Moura, F., Cambra, P., & Gonçalves, A. B. (2017). Measuring walkability for distinct pedestrian groups with a participatory assessment method: A case study in Lisbon. *Landscape and Urban Planning, 157*, 282–296. https://doi.org/10.1016/j.landurbplan.2016.07.002

Newman, P., & Kenworthy, J. R. (2015). *The end of automobile dependence: How cities are moving beyond car-based planning.* Island Press.

Newman, P., Kosonen, L., & Kenworthy, J. (2016). Theory of urban fabrics: Planning the walking, transit/public transport and automobile/motor car cities for reduced car dependency. *Town Planning Review, 87*(4), 429–459. https://doi.org/10.3828/tpr.2016.28

Niitamo, A. (2023). Walking as urban communication: Affordances and agency in public space in a semi-lockdown city. *Cities & Health, 7*(4), 628–642. https://doi.org/10.1080/23748834.2021.1978786

Orstad, S. L., McDonough, M. H., Stapleton, S., Altincekic, C., & Troped, P. J. (2017). A systematic review of agreement between perceived and objective neighborhood environment measures and associations with physical activity outcomes. *Environment and Behavior, 49*(8), 904–932. https://doi.org/10.1177/0013916516670982

Otsuka, N., Wittowsky, D., Damerau, M., & Gerten, C. (2021). Walkability assessment for urban areas around railway stations along the Rhine-Alpine Corridor. *Journal of Transport Geography, 93*, Article 103081. https://doi.org/10.1016/j.jtrangeo.2021.103081

Pafka, E., & Dovey, K. (2017). Permeability and interface catchment: Measuring and mapping walkable access. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 10*(2), 150–162. https://doi.org/10.1080/17549175.2016.1220413

Rodrigue, L., Manaugh, K., El-Geneidy, A., Daley, J., Wasfi, R., Ravensbergen, L., & Butler, G. (2022). Factors influencing subjective walkability. *Journal of Transport and Land Use*, *15*(1), 709–727. JSTOR.

Saelens, B. E., Sallis, J. F., Black, J. B., & Chen, D. (2003). Neighborhood-Based Differences in Physical Activity: An Environment Scale Evaluation. *American Journal of Public Health, 93*(9), 1552–1558. https://doi.org/10.2105/AJPH.93.9.1552

Sallis, J. F., Cerin, E., Kerr, J., Adams, M. A., Sugiyama, T., Christiansen, L. B., Schipperijn, J., Davey, R., Salvo, D., Frank, L. D., De Bourdeaudhuij, I., & Owen, N. (2020). Built Environment, Physical Activity, and Obesity: Findings from the International Physical Activity and Environment Network (IPEN) Adult Study. *Annual Review of Public Health, 41*(1), 119–139. https://doi.org/10.1146/annurev-publhealth-040218-043657

Sarkar, C., Webster, C., Pryor, M., Tang, D., Melbourne, S., Zhang, X., & Jianzheng, L. (2015). Exploring associations between urban green, street design and walking: Results from the Greater London boroughs. *Landscape and Urban Planning, 143*, 112–125. https://doi.org/10.1016/j.landurbplan.2015.06.013

Schlossberg, M., & Brown, N. (2004). Comparing Transit-Oriented Development Sites by Walkability Indicators. *Transportation Research Record, 1887*(1), 34–42. https://doi.org/10.3141/1887-05

Sheller, M. (2018). *Mobility Justice: The Politics of Movement in an Age of Extremes.* Verso.

Shields, R., Gomes da Silva, E. J., Lima e Lima, T., & Osorio, N. (2021). Walkability: A review of trends. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability*, 1–23. 10.1080/17549175.2021.1936601.

Silvennoinen, H., Kuliga, S., Herthogs, P., Recchia, D. R., & Tunçer, B. (2022). Effects of Gehl's urban design guidelines on walkability: A virtual reality experiment in Singaporean public housing estates. *Environment and Planning B: Urban Analytics and City Science, 49*(9), 2409–2428. https://doi.org/10.1177/23998083221091822

Stafford, L., & Baldwin, C. (2018). Planning Walkable Neighborhoods: Are We Overlooking Diversity in Abilities and Ages? *Journal of Planning Literature, 33*(1), 17–30. https://doi.org/10.1177/0885412217704649

SYKE, & NLS. (2021). *Shoreline10 (Ranta10—Rantaviiva 1:10 000).* Finnish Environment Institute and National Land Survey of Finland. https://ckan.ymparisto.fi/dataset/ranta10-rantaviiva-1-10-000.

Tobin, M., Hajna, S., Orychock, K., Ross, N., DeVries, M., Villeneuve, P. J., Frank, L. D., McCormack, G. R., Wasfi, R., Steinmetz-Wood, M., Gilliland, J., Booth, G. L., Winters, M., Kestens, Y., Manaugh, K., Rainham, D., Gauvin, L., Widener, M. J., Muhajarine, N., & Fuller, D. (2022). Rethinking walkability and developing a conceptual definition of active living environments to guide research and practice. *BMC Public Health, 22*(1), 450. https://doi.org/10.1186/s12889-022-12747-3

Tong, Y., & Bode, N. W. F. (2022). The principles of pedestrian route choice. *Journal of The Royal Society Interface, 19*(189), 20220061. https://doi.org/10.1098/rsif.2022.0061

van der Vlugt, A.-L., Curl, A., & Scheiner, J. (2022). The influence of travel attitudes on perceived walking accessibility and walking behaviour. *Travel Behaviour and Society, 27*, 47–56. https://doi.org/10.1016/j.tbs.2021.11.002

Van Dyck, D., De Meester, F., Cardon, G., Deforche, B., & De Bourdeaudhuij, I. (2013). Physical Environmental Attributes and Active Transportation in Belgium: What about Adults and Adolescents Living in the Same Neighborhoods? *American Journal of Health Promotion, 27*(5), 330–338. https://doi.org/10.4278/ajhp.120316-QUAN-146

Wang, H., & Yang, Y. (2019). Neighbourhood walkability: A review and bibliometric analysis. *Cities, 93*, 43–61. https://doi.org/10.1016/j.cities.2019.04.015

Weimann, H., Rylander, L., van den Bosch, M. A., Albin, M., Skärbäck, E., Grahn, P., & Björk, J. (2017). Perception of safety is a prerequisite for the association between neighbourhood green qualities and physical activity: Results from a cross-sectional study in Sweden. *Health & Place, 45*, 124–130. https://doi.org/10.1016/j.healthplace.2017.03.011

Willberg, E., Fink, C., & Toivonen, T. (2023). The 15-minute city for all? – Measuring individual and temporal variations in walking accessibility. *Journal of Transport Geography, 106*, Article 103521. https://doi.org/10.1016/j.jtrangeo.2022.103521

Winters, M., Barnes, R., Venners, S., Ste-Marie, N., McKay, H., Sims-Gould, J., & Ashe, M. (2015). Older adults' outdoor walking and the built environment: Does income matter? *BMC Public Health, 15*(1), 876. https://doi.org/10.1186/s12889-015-2224-1

Zhu, M., Teng, R., Wang, C., Wang, Y., He, J., & Yu, F. (2023). Key environmental factors affecting perceptions of security of night-time walking in neighbourhood streets: A discussion based on fear heat maps. *Journal of Transport & Health, 32*, Article 101636. https://doi.org/10.1016/j.jth.2023.101636

Zuniga-Teran, A. A., Stoker, P., Gimblett, R. H., Orr, B. J., Marsh, S. E., Guertin, D. P., & Chalfoun, N. V. (2019). Exploring the influence of neighborhood walkability on the frequency of use of greenspace. *Landscape and Urban Planning, 190*, Article 103609. https://doi.org/10.1016/j.landurbplan.2019.103609