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Determinants and effects of perceived walkability: a literature review, conceptual model and research agenda

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ABSTRACT

For decades, accessibility – i.e. the ease of reaching destinations – has been an important concept in transport planning, resulting in many studies trying to measure it and put it into practice. Also walkability, a mode-specific type of accessibility referring to how easy it is to walk (to destinations) received increased attention in the last two decades. In recent years, a new focus has been on how people perceive their accessibility as this may be a stronger predictor of travel behaviour than objective elements of accessibility (such as built environment characteristics). Perceived walkability, i.e. how walk-friendly people experience a certain area, however, has only been explored by a limited number of studies. In this review paper, we give an overview of existing studies analysing perceived walkability, which mostly have focused on its effects on walking frequency/duration, physical activity and various aspects of mental well-being. Based on this literature review, a conceptual model is created, emphasising the determinants and effects of perceived walkability and how it is related to objective walkability. We end this paper by providing avenues for further research, including the introduction of a Short Perceived Walkability Scale (SPWS) and recommendations for data collection and analysis. Doing so can create new insights into perceived walkability and links with related elements, and therefore can contribute to stimulating walking trips and improving the experience of these trips.

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1. Introduction

Providing people with access to different activities has long been recognised as the ultimate goal of any transport system (Handy, 2020). Consequently, accessibility has been an essential ingredient in transport planning and evaluation since Hansen (1959) introduced it as a concept, i.e. as a two-component accessibility model including the attractiveness of the destination and the travel impedance. Today, accessibility has become more

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commonly viewed as a multidimensional concept, often including a transportation, a land-use, a temporal and an individual component in line with the conceptualisation by Geurs and Van Wee (2004). However, a consensus on how to define accessibility is still lacking (Handy, 2020; Miller, 2018), although two widely used definitions are "the extent to which the land-use transport system enables (groups of) individuals or goods to reach activities or destinations by means of a (combination of) transport mode(s)" (Geurs & Van Wee, 2004, p. 128), and "the ease of reaching destinations" (e.g. Boisjoly & El-Geneidy, 2017, p. 38). Many studies have captured accessibility empirically, resulting in an array of measures evaluating different dimensions or components in relation to different transport modes (for an overview, see for instance Geurs & Van Wee, 2004; Handy & Niemeier, 1997; Kwan, 1998; or recent work by Siddiq & Taylor, 2021). Due to the multitude of accessibility dimensions and definitions, its determinants are diverse, although the proximity of destinations (as a function of density and land-use diversity) and travel options (as a function of transport infrastructure and access to different travel modes) are regarded as two essential determinants (Handy, 2020). As a result, accessibility may strongly influence people's travel mode choice, travel distance and duration, and trip frequency. Over the years, empirical findings have linked accessibility to a number of social outcomes, such as positive effects on activity participation and well-being (e.g. Allen & Farber, 2020; Lucas, 2012; Preston & Rajé, 2007). Although accessibility has been around for a long time, researchers are pointing out remaining research gaps, including links with multimodal transport and ICT, but also with short-distance travel and the use of slow modes such as cycling and walking (Handy, 2020; van Wee, 2016).

As a specific type of accessibility, walkability (or walking accessibility) refers to the ease of walking in a certain area and the ease of reaching destinations on foot (e.g. Wang & Yang, 2019).[1] Walkability was primarily introduced and applied in the field of public health, where physical activity, obesity and other health outcomes were discussed in combination with the walk friendliness of the built environment (Frank et al., 2006). Mainly since the 2000s, the multidimensional walkability research has also been applied for walking as a travel mode in the field of transportation. Since activities may often be too far to walk to, distance is often regarded as an important component of walkability (Saelens, Sallis, Black, & Chen, 2003). Walkability is therefore strongly influenced by built environment characteristics affecting walking distance to destinations, such as residential density, street connectivity and land use mix, but also by micro-scale elements, such as the quality of pavements, street furniture and the presence of trees and greenery (e.g. Otsuka, Wittowsky, Damerau, & Gerten, 2021; Park, Choi, & Lee, 2015). The effect of the built environment on walkability is well analysed and translated into measurements. Especially with regard to location-differentiated potential of walking, measurements such as the Walk Score® or the Walkability Index (e.g. Frank et al., 2009) have been developed.

A perspective of accessibility which until recently has often been overlooked is its subjective dimension or "perceived accessibility" (Lättman, Friman, & Olsson, 2016; Tiznado-Aitken, Lucas, Muñoz, & Hurtubia, 2020; van der Vlugt, Curl, & Wittowsky, 2019). Perceived accessibility, or the perceived ease of reaching destinations, has been recognised since the seventies in terms of (the perceived accessibility to) travel opportunities (Burns & Golob, 1976; Morris, Dumble, & Wigan, 1979). More recently, the research interest in perceived accessibility has gained ground, describing it as "the subjective dimension of the accessibility concept (which) measures the extent to which individuals consider the service accessible" (Wang, Brown, Liu, & Mateo-Babiano, 2015, p. 87), or "the perceived potential to participate in spatially dispersed opportunities" (Pot, van Wee, & Tillema, 2021, p. 1). Unlike objective perspectives of accessibility, perceptions of accessibility differ between individuals (Curl, Nelson, & Anable, 2011; Lättman, Olsson, & Friman, 2018; Tiznado-Aitken et al., 2020), due to the diversity in individualś past experiences, preferences for travel, as well as personal limitations, values, and culture (Ma & Cao, 2019; Martens, 2016). Determinants of perceived accessibility include characteristics of the built environment, travel attitudes, and individual abilities (Lättman et al., 2018; van der Vlugt et al., 2019). It is important to acknowledge perceived accessibility since it can, among others, influence the choice of travel mode and the frequency and duration of their use (Curl, Nelson, & Anable, 2015; Morris et al., 1979; Scheepers et al., 2016). Furthermore, the level of perceived accessibility may also have social consequences. For instance, individuals who experience the transport system as accessible also consider themselves less socially excluded (Currie & Stanley, 2008; Hui & Habib, 2014), while perceived accessibility may also influence travel satisfaction and well-being (Lättman et al., 2018). Approaches for assessing perceived accessibility include quantitative survey measurements such as the Perceived Accessibility Scale (Lättman et al., 2016), or the use of qualitative and mixed methods (Tiznado-Aitken et al., 2020). Recently, Pot et al. (2021) have indicated that there exists an inherent mismatch between objectively measured accessibility and the perceived accessibility of individuals, even suggesting to avoid the term "objective accessibility" altogether.

Perceived walkability, i.e. how easy people find it to walk (in an area or to destinations), has only received limited attention. It is only recently that studies have found that walking (frequency and duration) is not only affected by objective elements, but also by the subjective quality of an area, and perceived suitability and ease for walking (e.g. Otsuka et al., 2021; van der Vlugt, Curl, & Scheiner, 2022). In addition, aspects such as perceived safety and the atmosphere of an area may also have great influence on walking (Bornioli, Parkhurst, & Moregan, 2019; D'Orso & Migliore, 2020). However, perceived walkability needs to be explored further, especially in regard to its determinants and outcomes as well as its implementations into measurements. This paper will try to address these needs, thereby creating insights which can help in increasing the share of walking and improve the walking experience. In section 2, we present a literature review regarding perceived walkability measurements and determinants, the effects on walking, well-being and quality of life, as well as the comparison of objective and perceived walkability. Based on the review we develop a conceptual model in section 3 and finally present and discuss a research agenda for future studies in section 4.

2. Literature review

We searched for studies in Web of Science using the following keywords: "perceived walkability", "subjective walkability" and "perceived walking accessibility" (final search date: 12 May 2022). The latter two keywords only resulted in two studies found (i.e. Zhang, Loo, and Wang (2021) and van der Vlugt et al. (2022), respectively), while "perceived walkability" resulted in 40 articles. Hence, 42 studies were kept for further analysis (see Table 1 for an overview). No date restrictions or snowballing techniques were applied in our search, and searches were limited to English and full (peer-reviewed) journal articles.[2] The

Table 1. Chronological overview of studies analysing perceived walkability.

Study	Used data	Perceived walkability measure	Main result(s)
Gebel et al. (2009)	2650 adults from Adelaide (Australia)	NEWS	Perceived and objective walkability are mostly aligned; perceived walkability has stronger effects on walking time than objective walkability
Bias et al. (2010)	1355 adults from West Virginia (U.S.)	LWI	The LWI is a reliable, concise and easy to use instrument to assess perceived walkability
Brown and Werner (2011)	51 residents of Salt Lake City (U.S.)	NEWS	A new rail stop and developments around the station increases perceived walkability
Perez et al. (2011)	401 adult women from Toronto (Canada)	NEWS-A	Perceived walkability has no significant effect on physical activity
Arvidsson et al. (2012)	1925 adults from Stockholm (Sweden)	NEWS	Perceived and objective walkability are mostly aligned; perceived walkability has stronger effects on recreational/ utilitarian walking than objective walkability
Stamps (2013)	112 adult U.S. citizens	Agreement rating on 1 statement	Pave and turf surfaces result in high – and rocks and water surfaces in low – perceived walkability
Van Dyck et al. (2013)	1166 adults from Ghent (Belgium)	NEWS	Perceived walkability has a positive effect on the frequency and duration of walking and cycling
Oreskovic et al. (2014)	45 young adults from Massachusetts (U.S.)	Evaluation of photographs	Perceived walkability is mainly affected by the presence of building windows, focal points, pedestrians and cars
Hanibuchi et al. (2015)	2395 Japanese adults	Agreement ratings on 6 statements	Perceived walkability positively affects leisure-time physical activity, while objective walkability does not
Hernandez et al. (2015)	570 older Latino adults from Los Angeles (U.S.)	15 items from NEWS	A greater neighbourhood walkability is associated with lower chances of symptoms of depression
Jun and Hur (2015)	837 homeowners from Ohio (U.S.)	Agreement ratings on 4 statements	Perceived walkability stimulates neighbourhood social environment while objective walkability does not
Chen et al. (2016)	400 older adults from Hong Kong (China)	LWI	Walkability negatively affects depression levels
Chor et al. (2016)	14,749 civil servants from six Brazilian states	Agreement ratings on 9 statements	Perceived walkability positively affects leisure time physical activity and transport-related physical activity
Sealy-Jefferson et al. (2016)	399 African American women from Detroit (U.S.)	Agreement ratings on 6 statements	Perceived walkability negatively affects depressive symptoms, which in turn influence preterm delivery
Berry et al. (2017)	2402 adults from South Australia	6 items from NEWS-A	Residential area has significant effect on walking frequency, perceived walkability only in urban areas
Hinckson et al. (2017)	524 adolescents from Auckland and Wellington (New Zealand)	NEWS-Y	Both perceived and objective walkability positively affect physical activity, but strongest effects of perceived walkability
Jensen et al. (2017)	536 adults from Salt Lake City (U.S.)	NEWS-A	Living closer to a complete street improves perceived walkability; both perceived and objective walkability influence active travel engagement
Notthoff and Carstensen (2017)	74 older adults from Oakland (U.S.)	NEWS-A	Messages promoting walking are more effective when perceived walkability is high.
Root et al. (2017)	469 residents of Denver (U.S.)	Agreement ratings on 4 statements	Perceived walkability is positively associated with neighbourhood aesthetic ratings
Alidoust et al. (2018)	54 older adults from Gold Coast (Australia)	Interview questions	Both perceived walkability and the residential neighbourhood impact recreational/ utilitarian walking

(*Continued*)

Table 1. Continued.

Study	Used data	Perceived walkability measure	Main result(s)
Bartshe et al. (2018)	410 students of the University of Nevada, Las Vegas (U.S.)	NEWS-A	Perceived walkability has no significant impact on meeting physical activity recommendations
Bödeker (2018)	97 older adults from Bielefeld (Germany)	Mental mapping interviews	Both objective and perceived walkability positively impact walking; partial spatial overlap between perceived neighbourhood and pedestrian network
Solbraa et al. (2018)	972 Norwegian adults	Walking time to 4 services/ amenities	perceived walkability has a positive effect on physical activity
Adkins et al. (2019)	190 pedestrians from Tucson (U.S.)	Agreement ratings on 6 statements	Perceived walkability (especially perceived safety) varied according to environments with different ethnicity
Brown et al. (2019)	536 adults from Salt Lake City (U.S.)	Agreement ratings on 23 statements	Perceived walkability has a positive effect on the intention to use light rail
Calise et al. (2019)	1500 households from Missouri (U.S.)	PANES	High perceived walkability results in greater selection of – and greater access to – fresh fruit and vegetables
Kwon et al. (2019)	1392 residents of Ohio and Texas (U.S.)	Agreement ratings on 6 statements	Perceived walkability has positive effects on recreational well-being, happiness, and life satisfaction
Marquet and Hipp (2019)	119 workers from Missouri (U.S.)	PANES	Both perceived and objective walkability of the worksite environment positively affect physical activity at work.
Brown and Jensen (2020)	536 adults from Salt Lake City (U.S.)	NEWS-A	Objective walkability has stronger effects on walking (to activities and for leisure) than perceived walkability
Consoli et al. (2020)	573 inactive adults in Calgary (Canada)	NEWS-A	Perceived walkability positively impacts daily walking, objective walkability does not
Suarez-Balcazar et al. (2020)	96 pedestrians from Chicago (U.S.)	NEWS	Perceived walkability positively impacts walking to neighbourhood activities
Zeng and Shen (2020)	23 residents of Zhangzhou (China)	Agreement ratings on 7 statements	Urban regeneration positively affected perceived walkability, which in turn stimulates recreational walking
Gan et al. (2021)	748 residents of Nanjing (China)	Agreement ratings on 3 statements	Both perceived walkability and objective built environment characteristics impact walking to and from metro stations
Koohsari et al. (2021)	1010 adults from Nerima Ward and Kanuma City (Japan)	Agreement ratings on 3 statements	Perceived population density has a negative effect on contact with neighbours, overall perceived walkability has no effect
Lucchesi et al. (2021)	1884 adults from Rio de Janeiro and São Paulo (Brazil)	Agreement ratings on 7 statements	Perceived walkability has a positive effect on life satisfaction
Lui and Wong (2021)	70 older adults from Hong Kong (China)	NEWS-A	Perceived walkability is positively related with walking speed, balance and gait performance, but not with walking time
Mitra and Hess (2021)	1640 adults from Toronto (Canada)	Agreement ratings on 8 statements	Perceived walkability/bikability has a positive effect on the intention to use e-scooters
Syafriharti et al. (2021)	1349 motorcyclists from Bandung City (Indonesia)	Agreement ratings on 3 statements	Perceived walkability has a positive effect on the preference for walking (rather than riding a motorcycle)
Yin et al. (2021)	782 residents of Xi'an (China)	Agreement ratings on 3 statements	Perceived walkability positively affects life satisfaction, both directly and indirectly through travel satisfaction
Zhang et al. (2021)	302 older adults from Hong Kong (China)	Agreement ratings on 3 statements	Perceived walkability has a positive impact on the sense of community (especially place attachment and neighbourhood satisfaction) and life satisfaction

(*Continued*)

Table 1. Continued.

Study	Used data	Perceived walkability measure	Main result(s)
Blackwood et al. (2022)	132 older adults from Flint (U.S.)	NEWS-A	Perceived walkability (especially perceived land use mix) is negatively associated with recent falls
van der Vlugt et al. (2022)	217 residents of Hamburg (Germany)	Agreement ratings on 3 statements	Perceived walkability (which is affected by travel attitudes) has a positive effect on walking

selected articles are relatively recent with the oldest one being published in 2009 and more than half of them (23 papers) being published since 2018. Half of the selected studies (21 papers) were published in journals in health-related fields, while others were published in journals in the field of spatial sciences (e.g. Geography, Urban Studies), or environmental studies. Only seven of the selected studies were published in Transportation journals. A search for papers on (objective) walkability, and a detailed description of the findings, is beyond the scope of this study since (i) a large number of studies have analysed walkability (a search resulted in more than 2400 journal articles), and (ii) some studies have already provided a review of existing walkability studies (e.g. Arellana, Saltarin, Larrañaga, Alvarez, & Henao, 2020; Wang & Yang, 2019). For similar reasons, we have also chosen for a rather narrow interpretation of perceived walkability, thereby excluding articles focusing on elements such as perceived neighbourhood (for which a search resulted in more than 900 journal articles).

2.1. Perceived walkability measurements

Different ways of measuring perceived walkability have been used in the selected papers (see Table 1). Six studies (Arvidsson, Kawakami, Ohlsson, & Sundquist, 2012; Brown & Werner, 2011; Gebel, Bauman, & Owen, 2009; Hernandez et al., 2015; Suarez-Balcazar et al., 2020; Van Dyck, De Meester, Cardon, Deforche, & De Bourdeaudhuij, 2013) used the Neighbourhood Environment Walkability Scale (NEWS), developed by Saelens et al. (2003). This extensive scale asks respondents for information regarding the residences in the residential neighbourhood, walking time to 23 types of facilities in the neighbourhood, to what extent respondents agree on statements regarding access to services, streets, walking/cycling infrastructure, surroundings, traffic safety, and (perceived) crime in the neighbourhood, and satisfaction with 17 aspects of the neighbourhood. Due to the extensive nature of the scale (i.e. 83 items in total), an abbreviated scale has been developed, i.e. Neighbourhood Environment Walkability Scale – Abbreviated (NEWS-A; Cerin, Conway, Saelens, Frank, & Sallis, 2009). This scale does not include questions regarding residences in the neighbourhood, walking time to facilities and satisfaction with neighbourhood characteristics, resulting in 37 items. Several studies have used this shortened scale (Bartshe, Coughenour, & Pharr, 2018; Berry, Coffee, Nolan, Dollman, & Sugiyama, 2017; Blackwood, Suzuki, & Karczewski, 2022; Brown, Jensen, & Tharp, 2019; Consoli et al., 2020; Jensen et al., 2017; Lui & Wong, 2021; Perez, Ritvo, Brown, Holowaty, & Ardern, 2011). Yet another version of the scale, i.e. the Neighbourhood Environment Walkability Scale – Youth (NEWS-Y), uses simplified wordings of the NEWS-A

(Rosenberg et al., 2009), and was used by Hinckson et al. (2017) to measure adolescents' perceived walkability.

Another measure that has been used to examine perceived walkability is the Leyden Walkability Instrument (LWI). This short measure asks respondents if they are able to walk to nine types of pre-selected amenities/activities and asks to assign an overall neighbourhood walkability score (Bias, Leyden, Abildso, Reger-Nash, & Bauman, 2010; Leyden, 2003), and has been used by Chen et al. (2016) to measure perceived walkability. Finally, the Physical Activity Neighbourhood Environment Scale (PANES) has been used to quantify perceived walkability by Calise, Chow, Ryder, and Wingerter (2019) and Marquet and Hipp (2019). This scale asks respondents to what extent they agree on 17 statements regarding residential density, land use mixture, street connectivity, proximity to facilities, pedestrian and bicycling infrastructure, traffic safety, etc. (Sallis et al., 2010). Several studies did not use one of the scales described above, but measured perceived walkability by asking respondents to what extent they agree on statements regarding the residential environment and the ease of walking (to certain destinations), or what their walking time is to various amenities. Most studies used (online) surveys to measure perceived walkability, while some also used telephone surveys (Berry et al., 2017; Consoli et al., 2020) or interviews (Adkins, Barillas-Longoria, Martinez, & Ingram, 2019; Alidoust, Bosman, & Holden, 2018; Bödeker, 2018; Hernandez et al., 2015).

2.2. Perceived walkability and walking/physical activity

Many studies measuring perceived walkability analyse the effect of perceived walkability on walking frequency/duration or physical activity, and mostly found positive effects. Van Dyck et al. (2013) found that perceived levels of density, land use mix, cycling safety and walkability (retrieved from NEWS) had a positive effect on the frequency and duration of walking and cycling for 1166 adults in Ghent (Belgium). Zeng and Shen (2020) found that – for 82 adults in Zhangzhou (China) – perceived positive elements of the neighbourhood significantly promote recreational walking trips, especially among middle-aged and older adults. Suarez-Balcazar et al. (2020) indicated that perceived elements of walkability (including safety, community participation and neighbourhood pleasantness) positively impact walking to several activities, for 96 pedestrians in Chicago (U.S.). Some studies focused on physical activity effects of perceived walkability. Solbraa et al. (2018) found that perceived walkability (i.e. walking time to various amenities) has a positive effect on both total physical activity and moderate-to-vigorous physical activity for 972 Norwegian adults. Chor et al. (2016), using data from 14,749 Brazilian civil servants, indicated that perceived walkability is positively associated with both leisure-time and transport-related physical activity. Bartshe et al. (2018), on the other hand, found no significant effects of perceived walkability (measured by NEWS-A) on meeting physical activity recommendations among 410 students of the University of Nevada-Las Vegas (U.S.). Also Perez et al. (2011) did not find any considerable effects of (NEWS-A measured) perceived walkability on physical activity among 401 ethnic minority women in Toronto, Canada. Lui and Wong (2021), on the other hand, found significant effects of perceived walkability on walking speed, balance and gait performance, but no significant effects on walking time for 70 older adults from Hong Kong (China). In Flint (U.S.), Blackwood et al. (2022) noticed that perceived walkability is negatively associated with recent falls of 132 older adults.

Several studies examined the combined effects of objective and perceived walkability on walking or physical activity, and these are described in Section 2.4.

In addition to studies focusing on the effect of perceived walkability on walking (frequency/duration), Notthoff and Carstensen (2017) showed that – for 100 older adults in Oakland (U.S.) – messages promoting walking are more effective for those indicating high levels of perceived walkability compared to those indicating low perceived walkability levels, while Syafriharti, Kombaitan, Syabri, and Dirgahayani (2021) indicated that perceived walkability has a positive effect on the preference to walk (rather than riding a motorbike) for 1349 motorcyclists from Bandung City (Indonesia). Brown and Jensen 2020 found that perceived walkability (i.e. perceived walking barriers, desired improvements, perceived problems and global perceptions of the route to rail stops) had a significant impact on the intention to use light rail for 536 residents of Salt Lake City (U.S.). Finally, Mitra and Hess (2021) discovered that perceived walkability/bikeability increases the intention to use shared e-scooters for 1640 adult residents in Toronto (Canada).

2.3. Perceived walkability and well-being

Although the majority of perceived walkability studies focused on physical activity/walking impacts, some also analysed effects of perceived walkability on people's subjective well-being and quality of life. Six studies found links between perceived walkability and psychological well-being. Using 1392 respondents from Ohio and Texas (U.S.), Kwon, Pickett, Lee, and Lee (2019) found that the ease of walking had a positive effect on recreational well-being, and that the comfort of walking is positively correlated with recreational well-being, happiness, and life satisfaction. In a similar vein, Lucchesi, Larranaga, Cybis, Silva, and Arellana (2021) found for 1884 adults in Rio de Janeiro and São Paulo (Brazil), that perceived walkability has a positive impact on people's satisfaction with life. Also Yin, Cao, and Huang (2021) – focusing on 782 residents from Xi'an (China) – found that perceived walkability positively impacts life satisfaction, both directly and indirectly through travel satisfaction. Direct and indirect effects of perceived walkability on life satisfaction, through the sense of community (especially place attachment and neighbourhood satisfaction), were also found among 302 older adults from Hong Kong (China) (Zhang et al., 2021). In Los Angeles (U.S.), Hernandez et al. (2015) observed among 570 older adults that higher levels of perceived walkability (especially perceived levels of crime safety) are associated with lower risks of symptoms of depression. In Detroit (U.S.), Sealy-Jefferson, Giurgescu, Slaughter-Acey, Caldwell, and Misra (2016) found that perceptions of neighbourhood safety and perceived walkability can negatively affect preterm delivery among 399 African American women, indirectly through depressive symptoms (e.g. stress, sadness, loneliness). Finally, Chen et al. (2016) found a negative correlation between the ease of walking in the residential neighbourhood and symptoms of depression for 400 older adults in Hong Kong (China). Other studies analysed relationships between perceived walkability and diverse elements related to well-being and quality of life. Jun and Hur (2015), for instance, discovered that perceived walkability enhances neighbourhood social environment (e.g. social interaction with neighbours, sense of community) for 837 homeowners in Ohio (U.S.). In contrast, Koohsari et al. (2021) found that perceived population density negatively impacts the neighbourhood's social interaction, but no significant effects were found for overall perceived walkability of 1010 adults in Tokyo and Kanuma (Japan). Calise et al. (2019) found that high perceived walkability resulted in having both better access to, and a greater selection of, fresh fruits and vegetables, when studying 1500 households in Missouri (U.S.).

2.4. Perceived versus objective walkability

Most of the selected studies also include measures of objective walkability, some of them by just comparing respondents living in different types of neighbourhoods (e.g. Berry et al., 2017; Van Dyck et al., 2013), but some also included more detailed measures of objective walkability (e.g. using density and land use mixture). Some studies analysed the correlation between objective and perceived walkability. Arvidsson et al. (2012), using 1925 respondents from Stockholm (Sweden), found that objective and perceived walkability were in line with each other for two-thirds of the respondents, while one-third of the respondents living in neighbourhoods with high levels of objective walkability perceived it as low. Gebel et al. (2009) also found a fair general agreement between objective and perceived walkability, for 2650 adults in Adelaide (Australia). Around two-thirds of the respondents living in a neighbourhood with low or high objective walkability perceived it as low or high, respectively. Similarly, Van Dyck et al. (2013) found that objective and perceived walkability are positively related with each other, as those living in objectively-high-walkable neighbourhoods perceived their environment as more walkable than those living in objectively-low-walkable neighbourhoods. Bödeker (2018) found that for most of the 97 older respondents in Bielefeld (Germany), there is at least a partial spatial overlap between the perceived (walkable) neighbourhood and the 400 m radius buffer around the place of residence (representing the objective walking area). Adkins et al. (2019) indicated that the correlation between the perceived and objective built environment can differ according to ethnicity. In Tucson (U.S.), they found that the perceived walkability was largely consistent with objective walkability in non-Hispanic areas, while this was not the case in Hispanic-dominated areas. Some studies also suggest that perceived walkability may be impacted by objective walkability. Jensen et al. (2017) found that perceived levels of walkability decreased as distance to a "complete street" (a street with high objective walkability levels) increased for 536 participants living in Salt Lake City (U.S.). In an older study in the same city, Brown and Werner (2011) found that perceived walkability levels of 51 residents increased after the construction of a new rail stop and related (transit-oriented) developments around the station. Also Zeng and Shen (2020) found that an urban regeneration project in Zhangzhou (China) positively influenced the perceived walkability. van der Vlugt et al. (2022), on the other hand, did not find a significant effect of objective walkability on perceived walkability for 217 residents of Hamburg (Germany).

Studies analysing the effect of both objective and perceived walkability on physical activity and/or walking mostly found stronger effects of perceived walkability compared to objective walkability, although both types of walkability mostly have significant effects. Marquet and Hipp (2019), for instance, found that for 119 workers in metropolitan areas of Missouri (U.S.), both the objective and perceived walkability of respondents' worksite environment had positive effects on minutes of physical activity while at work. For 748 residents of Nanjing (China), Gan, Yang, Zeng, and Timmermans (2021) found that walking to and from metro stations is influenced by both perceived walkability and objective built environment characteristics. Bödeker (2018) observed that objective walkability significantly impacts walking, but that the variance in walking was better explained when the objective walkability score of the perceived neighbourhood area was used instead of the score of a classical 400 m buffer around the place of residence. Hinckson et al. (2017) found that both objective and perceived walkability influence physical activity for 524 adolescents in Auckland and Wellington (New Zealand), but that the effect of perceived walkability is somewhat stronger. Similar outcomes were found in Sweden (Arvidsson et al., 2012), and Australia (Gebel et al., 2009). Alidoust et al. (2018) suggest that 54 older adults from Gold Coast (Australia), living in suburban neighbourhoods walk less compared to those living in more compact and mixed-use neighbourhoods because the former group has lower levels of perceived walkability (including perceived levels of safety, proximity to services, attractiveness of the neighbourhood). Hanibuchi, Nakaya, Yonejima, and Honjo (2015), using 2395 Japanese respondents, even found that only perceived walkability has an impact on leisure-time physical activity, while no effects were found of objective walkability. Similarly, van der Vlugt et al. (2022) discovered a significant impact of perceived walkability on walking, but not of objective walkability, while Consoli et al. (2020) only found significant impacts of perceived walkability on the number of steps per day, but no effects of objective walkability, for 573 physically inactive adults in Calgary (Canada). A study focusing on the neighbourhood social environment, found that perceived walkability stimulates the social environment, while objective walkability does not (Jun & Hur, 2015). Two studies, however, found stronger effects of objective walkability on walking than of perceived walkability. Berry et al. (2017) found that urban residents walk more than suburban residents, while the perceived walkability only has an impact on walking for those living in urban areas for 2402 adults in South Australia. Finally, Brown and Jensen (2020) found that objective walkability has stronger effects on walking (to activities and for leisure) than perceived walkability among 536 adults in Salt Lake City (U.S.).

2.5. Determinants of perceived walkability

Despite some studies having indicated that objective walkability can impact perceived walkability (see Section 2.4), not a lot of studies have focused on the determinants of perceived walkability. Some studies found that certain built environment characteristics can influence the ease of walking. Oreskovic et al. (2014) – presenting images to 45 adults in Massachusetts (U.S.) – found that uniformity in building plane, the presence of street focal point, and the presence of windows on buildings' ground level had positive effects on perceived walkability, while no significant effects were found for building height. This study also discovered that the presence of people positively – and the presence of cars negatively – influences perceived walkability. Using 112 participants for three experiments, Stamps (2013) found that the type of surface can impact perceived walkability, i.e. water, rocks and dunes were perceived as least walkable, while pave and turf were regarded as easy walkable. Root, Silbernagel, and Litt (2017) indicate that the aesthetics of the neighbourhood (e.g. perceived presence of trees, interesting things to look at, attractive sights and buildings) positively affects perceived walkability for 469 Denver (U.S.) residents, an outcome also found by Jensen et al. (2017). Socio-demographic characteristics may also influence how walkable people perceive a neighbourhood. Those being highly educated mostly perceive their neighbourhood as more walkable compared to those with lower levels of educational attainment (e.g. Arvidsson et al., 2012; Chor et al., 2016; Gebel et al., 2009; Notthoff & Carstensen, 2017; van der Vlugt et al., 2022). The effect of age is less clear. Besides studies finding insignificant effects of age on perceived walkability (Lucchesi et al., 2021; Notthoff & Carstensen, 2017; Suarez-Balcazar et al., 2020; van der Vlugt et al., 2022), Arvidsson et al. (2012) and Gebel et al. (2009) found that young adults (<30 years old) had higher perceived walkability levels compared to older adults, while Chor et al. (2016) and Oreskovic et al. (2014) discovered (moderate) positive effects of age on perceived walkability. Gender was mostly found not to play an important role (Arvidsson et al., 2012; Gebel et al., 2009; Oreskovic et al., 2014; van der Vlugt et al., 2022), although Chor et al. (2016) and Suarez-Balcazar et al. (2020) found that men – compared to women – experience somewhat higher levels of perceived walkability. Some studies found a positive effect of income, being employed, being single, not having children in the household, residence time in neighbourhood and being healthy on perceived walkability (Arvidsson et al., 2012; Chor et al., 2016; Gebel et al., 2009; Lucchesi et al., 2021). Finally, Adkins et al. (2019) found that perceived walkability can differ according to ethnicity. They found that non-Hispanic Whites had higher levels of perceived walkability compared to Mexican Americans.

In sum, the studies described above indicate that perceived walkability is influenced by several elements (e.g. objective walkability and socio-demographics), but that it can also function as a predictor of other components (such as walking and well-being). However, a comprehensive overview of the determinants and effects of perceived walkability is currently lacking. Based on the existing perceived walkability studies, but also on existing travel behaviour studies (and theories/concepts often used in these studies), we present and describe a conceptual model in Section 3.

3. A conceptual model

The studies described in Section 2 indicate that perceived walkability can be affected by objective walkability (created by built environment characteristics such as density, diversity, and walking infrastructure). Perceived walkability in turn can influence walking/physical activity and people's well-being. Most studies, however, still found significant direct effects of objective walkability on walking after controlling for perceived walkability. Nevertheless, certain constructs related to perceived walkability remain underexplored. First of all, travel attitudes may impact perceived walkability. For instance, a person who lives in a walkable neighbourhood may not perceive the environment as walk friendly because of negative attitudes towards walking. Since people often tend to live in a neighbourhood stimulating their preferred way of travelling (transport-related residential self-selection), it can be assumed that walking attitudes will mostly be in line with objective walkability.[3] A person that likes to walk (to destinations) will often live in a walk-friendly neighbourhood (see e.g. Handy, Cao, & Mokhtarian, 2006), and will also perceive that neighbourhood as walkable. On the other hand, a neighbourhood being perceived as walkable may also improve attitudes towards walking and in turn stimulate walking (Figure 1). Despite many studies having analysed the effects of attitudes on travel behaviour (e.g. Handy, Cao, & Mokhtarian, 2005; Kitamura, Mokhtarian, & Laidet, 1997),

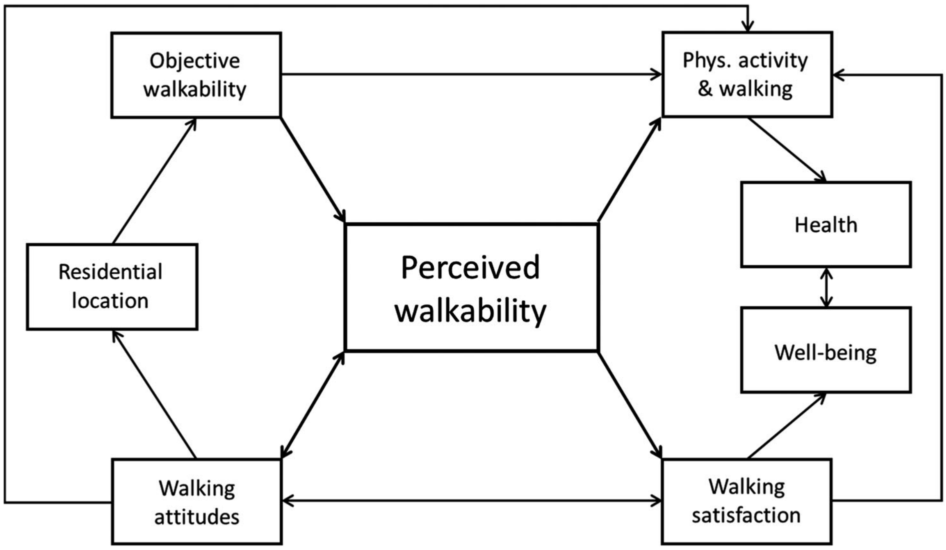

Figure 1. Conceptual model of the determinants and outcomes of perceived walkability.

studies analysing perceived walkability have ignored the possible effect of (walking) attitudes on perceived walkability. Some studies focusing on perceived accessibility, however, found that travel attitudes have an impact on perceived accessibility (e.g. Friman, Lättman, & Olsson, 2020; Pot et al., 2021; van der Vlugt et al., 2019). A recent study, found in our paper search, also indicates that travel attitudes have a significant indirect effect on walking through perceived walking accessibility (van der Vlugt et al., 2022).

Links can also be made to the theory of planned behaviour (Ajzen, 1991). According to this theory, actual behavioural control (how easy somebody can perform a certain behaviour given certain constraints and opportunities) can influence perceived behavioural control (how easy somebody thinks s/he can perform a certain behaviour). The performance of a behaviour is affected by both actual and perceived behavioural control and additionally depends on the extent to which the perceived behavioural control is aligned with the actual control of the behaviour. In terms of walking, this means that objective walkability influences perceived walkability, and that both influence walking (Figure 1). The consonance between perceived and objective walkability will also play a role. When perceived and objective walkability are aligned with each other, the outcome is clear, low objective/perceived walkability will likely result in low levels of walking, while high objective/perceived walkability will likely result in high levels of walking. In case of a disagreement between perceived and objective walkability, the outcomes may be less clear. Studies analysing both objective and perceived walkability effects on walking mostly indicate that perceived walkability has stronger effects than objective walkability, i.e. those with high perceived walkability levels living in neighbourhoods with low walkability walk more than those with low perceived walkability levels living in walkable neighbourhoods (Arvidsson et al., 2012; Gebel et al., 2009).

Some studies described in Section 2 indicate that perceived walkability can influence people's well-being. However, we only found one (recent) study analysing how people perceive their walking trips in relationship with perceived walkability. This study found that perceived walkability has a positive effect on travel satisfaction, which in turn positively impacts life satisfaction (Yin et al., 2021). Walking satisfaction, i.e. perceived emotions during walking and the evaluation of walking trips, is likely to be directly affected by perceived walkability and walking attitudes. A person who perceives his/her neighbourhood as walkable (e.g. finding it easy/comfortable to walk) is likely to be more satisfied with walking trips compared to a person finding his/her neighbourhood difficult to walk in. Similarly, a person with a positive attitude towards walking is more likely to be satisfied with a walking trip compared to a person with a negative stance towards walking (De Vos, Mokhtarian, Schwanen, Van Acker, & Witlox, 2016; St-Louis, Manaugh, van Lierop, & El-Geneidy, 2014; Ye & Titheridge, 2017). Some studies focusing on perceived accessibility found that perceived accessibility has a positive effect on satisfaction with travel (Cao, 2013; Lättman, Olsson, Friman, & Fujii, 2019). It is likely that the effect of perceived walkability on well-being is indirect, through walking satisfaction. Positive emotions perceived during walking and a walking trip being evaluated positively can enhance well-being levels (e.g. De Vos & Witlox, 2017; De Vos, Schwanen, Van Acker, & Witlox, 2013). A similar train of thought can be created for physical health. Both perceived and objective walkability (in combination with walking attitudes) influence the frequency and duration of walking trips and physical activity, which in turn positively affect people's physical health. As a result, it can be stated that both objective and perceived walkability influence health indirectly, through walking and physical activity. Finally, studies have indicated that walking satisfaction can positively influence the share of walking trips (both directly and indirectly through walking attitudes) (De Vos, Schwanen, Van Acker, & Witlox, 2019), and that subjective well-being and physical health positively affect each other (e.g. Diener & Chan, 2011; Penedo & Dahn, 2005) (Figure 1). In sum, improving objective walkability, and in turn also perceived walkability, can positively impact people's quality of life. As a result, policy makers should try to create more walkable neighbourhoods, e.g. by increasing density and land use mix, and by creating better and more attractive infrastructure for pedestrians.

4. A research agenda

In this section, we present a research agenda which can help future studies to explore underexplored aspects and links of perceived walkability. In Section 4.1, we will focus on data collection and measurement, while in section 4.2 the focus will be on data analysis.

4.1. Data collection and measurement

Most studies measuring objective walkability focus on macro- and meso-scale elements of the built environment, such as population density and land use mix. Micro-scale elements such as zebra crossings, quality of sidewalks, benches, presence of green, etc. are often not taken into account (with some exceptions, such as Ewing and Handy (2009) and Otsuka et al. (2021)). As a result, these elements should also be regarded as potential determinants of perceived walkability. For perceived walkability, existing scales are often not adequate or too long. For instance, the NEWS and its abbreviated version

NEWS-A have 83 and 37 items respectively, and a lot of the questions are not related to the ease of walking (e.g. types of streets and residences in the neighbourhood). NEWS also asks for the time it takes (in minutes) to walk to certain destinations. However, this does not give indications of people's intentions of walking as some may find 20 min of walking feasible, while others do not. Furthermore, these scales do not make a distinction between different types of walking. We suggest future scales to make a distinction between (i) walking to destinations, (ii) walking to public transport stops, and (iii) recreational walking without a destination. Taking into account the latter two types of walking is important as most public transport trips include walking to and from public transport stops (Daniels & Mulley, 2013; Lachapelle & Noland, 2012), and many people undertake (undirected) walking trips for recreation, partly to enhance their physical and mental health (Hook, De Vos, Van Acker, & Witlox, 2021; Mokhtarian & Salomon, 2001). Regarding perceived walkability itself, measurements should only focus on the ease of walking, and not on elements such as satisfaction with walking trips (which is included in NEWS), which we feel is not an aspect of perceived walkability, but a potential outcome. We suggest a Short Perceived Walkability Scale (SPWS) with 15 items and making a distinction between different types of walking trips. This scale would ask respondents (on a 5-point scale from *totally disagree* to *fully agree*) to what extent they agree on the following statements:

- In my neighbourhood, it is feasible to walk (1) to my destinations; (2) to public transport stops; (3) recreationally
- In my neighbourhood, it is convenient to walk (1) to my destinations; (2) to public transport stops; (3) recreationally
- In my neighbourhood, it is comfortable to walk (1) to my destinations; (2) to public transport stops; (3) recreationally
- In my neighbourhood, it is pleasant to walk (1) to my destinations; (2) to public transport stops; (3) recreationally
- My neighbourhood stimulates me to walk (1) to my destinations; (2) to public transport stops; (3) recreationally

The terms feasible, convenient, comfortable, and pleasant refer to different levels of walking needs, going from basic needs (i.e. is it possible to walk) to higher-order needs (i.e. is it pleasant/enjoyable to walk), respectively (see, e.g. Alfonzo, 2005; ITDP, 2018).[4] The final statement refers to the extent an area can stimulate walking, and therefore can improve the share of walking. The scale can be applied to respondents' residential neighbourhood (as in the example above), but also to respondents' work or school environment or other areas people often visit (e.g. shopping areas). The SPWS is a brief scale which would result in minimal respondent burden, while it should be able to provide researchers with detailed information on perceived walkability which they can use for further analysis. We recommend future studies to test the reliability of this SPWS and see whether modifications, extensions or reductions of the scale are desirable.

Another limitation of many perceived walkability studies is that they focus on the residential neighbourhood and not on, for instance, the workplace location, or shopping centres/streets. We only found one study – though with a small sample size – focusing on the perceived walkability of the workplace location (Marquet & Hipp, 2019). The main reason for this is that it is easy to recruit a high number of respondents from specific neighbourhoods (e.g. with low and high objective walkability) and provide them with an invitation to fill in an (online) survey. For workplace walkability this is also possible, although large employers may be needed to get to a large sample. The main problem refers to major shopping streets, streets in (touristic) city centres, etc. First of all, when giving pedestrians an invitation to fill in a survey at a later time (e.g. at home), recall bias may occur and respondents may (i) not accurately remember how exactly they perceived the environment a couple of hours or days before filling in the survey, and (ii) confound the walkability of that one specific street/neighbourhood with adjacent streets/neighbourhoods they walked in before or after. A possible solution for this is to perform interviews with pedestrians along a walking route, also referred to as on-street intercept interviews or walk-along interviews. When performing interviews, pedestrians can indicate how walkable they perceive their surroundings at the time of the interview (using brief scales, such as the suggested SPWS) and which built environment elements improve or worsen the perceived walkability. Doing so may provide urban planners and policy makers with valuable information on how to increase perceived walkability – and increase walking levels and reduce motorised traffic – in areas in cities attracting many visitors, workers, and residents (e.g. shopping streets, public spaces, touristic areas, streets nearby railway stations).

4.2. Data analysis

Future walkability studies should focus on links proposed in Figure 1. Studies should analyse how attitudes towards walking correspond with objective walkability (through self-selection processes, e.g. people who prefer to walk choosing to live in walkable neighbourhoods) and influence perceived walkability. Since perceived walkability may not only be affected by walking attitudes, but may in turn also influence attitudes, longitudinal data (with at least two waves) may be desired to capture the true causality between attitudes and perceived walkability. Future studies should also analyse to what extent walking attitudes influence walking frequency/durations and walking satisfaction, and how strong the effects of objective/perceived walkability on walking/satisfaction remain after controlling for walking attitudes. Finally, the indirect effects of objective/perceived walkability (and walking attitudes) on physical health and subjective well-being, through walking and walking satisfaction should be analysed. A structural equation modelling approach can capture indirect effects of (perceived) walkability on health and well-being and indicate whether these effects are stronger than potentially significant direct effects. It is possible for instance that perceived walkability only has a significant indirect effect on subjective well-being, through walking satisfaction, but no direct effect (as suggested in Figure 1). Yin et al. (2021), the only study from our literature search measuring indirect effects, found that perceived walkability has both significant direct and indirect effects (through travel satisfaction) on life satisfaction. However, more evidence, from various regions and using various methodologies is needed to gain more insights into the links between perceived/objective walkability and elements related to subjective and objective well-being and health, preferably for different population groups (e.g. older adults, people with disabilities).

5. Conclusion

In this paper, we have presented an overview of existing studies analysing perceived walkability and its determinants and outcomes. Based on this literature review a conceptual model was created, describing both well-established and underexplored links between perceived walkability and related constructs. Finally, a research agenda was created, introducing a new, user-friendly, perceived walkability scale (i.e. SPWS) and providing suggestions to efficiently conduct perceived walkability studies in the future, focusing on sample recruitment, data collection and data analysis. This paper consequently contributes to the understanding and (future) research of perceived walkability and its effects on walking (satisfaction), with the ultimate goal of improving people's (mental and physical) health and creating sustainable (non-motorised) travel patterns.

Notes

1. Although walkability generally refers to how easy and convenient it is to walk in a certain area, and walking accessibility mostly refers to the ease of reaching a certain destination on foot, both terms are often used interchangeably. In this study, we will use the more common term walkability.
2. Conference papers and review articles were excluded.
3. These residential self-selection processes may not always by dominant, especially in unaffordable housing markets. Frank, Kershaw, Chapman, Campbell, and Swinkels (2015), for instance, found that a significant share of respondents in Toronto and Vancouver (Canada) were forced to live in a car-oriented neighbourhood despite having preferences for living in a walkable neighbourhood.
4. Despite (perceived) safety (i.e. protection from crime and traffic) is often regarded as one of the walking needs, we have chosen not to include it in the SPWS since safety (especially fear of crime) is often temporal. For instance, an area may be regarded as safe to walk in during the day, but not at night when streets may be dark and empty, and no social control is present. However, since perceived safety may affect how comfortable/pleasant it is to walk in a certain area, not feeling safe (at certain times) may negatively influence the score respondents will give on the statements regarding comfort and pleasantness in the SPWS.

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