Journal of Transport & Health 44 (2025) 102151

Contents lists available at ScienceDirect

Journal of Transport & Health

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

Route choice to inform navigation system design and accessibility analysis for older pedestrians: a scoping review

Nir Fulman [a,b,*], Johannes Huber [a,b], Armağan Teke Lloyd [c], Kathrin Foshag [d,f,g], Yulia Grinblat [b], Umut Türk [c], Sven Lautenbach [a,b,g], Jan Amcoff [e], Marina Toger [e], Johanna Jokinen [e], Alexander Zipf [a,b,g]

[a] *Institute of Geography, GIScience Chair, Heidelberg University, Heidelberg, Germany*
[b] *HeiGIT at Heidelberg University, Heidelberg, Germany*
[c] *Political Science Department, Abdullah Gül University, Kayseri, Türkiye*
[d] *TdLab Geographie, Heidelberg University, Heidelberg, Germany*
[e] *Department of Human Geography, Uppsala University, Uppsala, Sweden*
[f] *Heidelberg School of Education (HSE), Heidelberg University, Heidelberg, Germany*
[g] *Heidelberg Centre for the Environment, Heidelberg University, Heidelberg, Germany*

ARTICLE INFO

Keywords:
Older pedestrians
Route choice
Walkability
Navigation systems
15-Min-city

ABSTRACT

Introduction: Routing systems can support older adults by helping them overcome barriers to walking, promoting independence and well-being. The paths generated by these systems also inform urban accessibility metrics, such as those used in 15-min-city planning. Yet current systems rarely reflect the preferences or constraints of older pedestrians. Empirical studies of route choice can help close this gap by revealing how people trade off different route attributes in real settings.

Methods: We conducted a scoping review, following PRISMA-ScR guidelines, of empirical studies analyzing pedestrian route choice among adults. The goal was to identify findings that could inform the design of more age-inclusive routing tools.

Results: Eleven studies met the inclusion criteria, eight of which focused exclusively on older adults. Despite varied contexts, three consistent themes emerged: (i) sidewalk quality and manageable gradients; (ii) aesthetic and sensory comfort, including greenery, low noise, and good lighting; and (iii) access to benches, transit, and everyday amenities. However, most studies relied on qualitative methods, limiting direct integration into routing algorithms.

Conclusions: Future work should prioritize hybrid qualitative-quantitative designs, large-scale sampling of routes, and fine-grained mapping of micro-barriers. Analyses should account for age, gender, and functional ability, and consider circular leisure walks as a distinct travel pattern. These directions can enhance the usability and equity of routing systems and urban planning frameworks.

1. Introduction

Walking is a cornerstone of active aging, providing a wide range of physical, cognitive, and emotional benefits. It supports the

---

[*] Corresponding author. Institute of Geography, GIScience Chair, Heidelberg University, Heidelberg, Germany.
E-mail address: nir.fulman@uni-heidelberg.de (N. Fulman).

https://doi.org/10.1016/j.jth.2025.102151
Received 7 July 2025; Received in revised form 3 August 2025; Accepted 5 August 2025

management of chronic conditions such as cardiovascular disease, diabetes, and osteoporosis, while also contributing to psychological well-being, stress reduction, and cognitive resilience (Saelens and Handy, 2008; Frank et al., 2010; Shigematsu et al., 2009). As populations age and urbanize, the public health relevance of walking continues to increase. According to the United Nations, 830 million people worldwide were aged 65 or older as of 2024, a figure projected to double to 1.7 billion by 2054 (United NationsDepartment of Economic and Social AffairsPopulation Division, 2024). In the European Union, older adults currently represent 21.6 % of the population—the highest share on record (European Commission, 2025). The UN Decade of Healthy Ageing (2021–2030) calls for coordinated action across health systems, urban planning, and social protection to extend healthy life expectancy and reduce exclusion (Thiyagarajan et al., 2022). Because walking often remains the last feasible activity after cycling or sport become impractical, promoting regular walking, which is low-cost, accessible, and adaptable to changing abilities, directly supports these goals (Jarzebski et al., 2021; Thiyagarajan et al., 2022).

The built environment plays a key role in shaping the attractiveness of walking across all age groups; however, for older adults, it can determine the feasibility of walking. Physical and sensory changes associated with aging—such as reduced mobility, impaired vision, fear of falling, and heightened sensitivity to extreme temperatures—make older individuals especially vulnerable to environmental barriers (Arnberger et al., 2017). In this context, elements like continuous and well-maintained sidewalks, manageable slopes, adequate lighting, shaded areas, benches, and safe street crossings are not just conveniences but essential features that enable or deter walking (Menz et al., 2003; Cerin et al., 2017). When infrastructure is inadequate or poorly designed, it can severely restrict outdoor mobility, contributing to physical inactivity and social isolation. Therefore, urban planning must incorporate tools and frameworks that explicitly address the needs of older adults.

Routing technologies—systems that compute paths through street networks using shortest-path algorithms—now shape mobility decisions at two scales. At the individual level, smartphone apps such as Google Maps and Komoot deliver turn-by-turn guidance (Rădăcină et al., 2023); at the planning level, tools like Walk Score and the "15-min-city" indicators batch-compute shortest pedestrian routes from every dwelling to key amenities to label neighborhoods "walkable" (Carr et al., 2010). In both use-cases the optimization target is almost always distance or travel time, implicitly assuming that everyone can, and will, follow the direct route. For many older adults, however, route quality matters more than speed: they may avoid cracked pavements, steep gradients, heavy traffic, or poorly lit blocks (Moran et al., 2017). By ignoring such preferences, navigation engines can mislead individual users, and the accessibility scores built on them can systematically overestimate true reachability.

Navigation research is beginning to acknowledge these preferences, but solutions remain ad-hoc. Prototype platforms such as the U. S. Department of Transportation's AccessMap (Bolten and Caspi, 2019) let users avoid stairs or steep inclines, while commercial platforms have begun to offer route options based on scenic value or lighting conditions (Siriaraya et al., 2020). Under the hood, however, these engines rely on fixed heuristics—for example, adding a blanket penalty per percentage point of gradient or per block without lighting—derived from designers' intuition or generic accessibility guidelines. No system yet calibrates those penalties against observed trade-offs (e.g., "how many extra meters will a 75-year-old accept to remain on level pavement?"). Without empirically estimated weights, attribute-based routing may still rank paths poorly for the users it is meant to support.

Pedestrian route-choice research already provides tools for data-driven routing. These studies analyze individual route choices to understand how personal attributes, environmental conditions, and trip purposes interact to shape route decisions (Bovy and Stern, 2012; Moran et al., 2017). A recent review identified over forty such studies published since 1985, reflecting growth in this area (Basu et al., 2022). However, most of this research has focused on the general population. Only two studies centered on adults aged 65 and over, and just one reported findings broken down by age group.

To help fill this gap, we carried out a scoping review of studies on pedestrian route choice that include older adults. The review focuses on two main questions: (1) Which environmental and personal factors, and how strongly, influence the routes older adults choose? (2) What are the remaining research gaps that limit the application of these findings in routing tools and walkability measures? By answering these questions, the review aims to support both research on aging and mobility, and practical efforts in transport planning to create better tools for assessing walkability and guiding older adults in their travel.

The remainder of the paper is structured as follows: The methods section outlines the scoping review process, conducted in accordance with PRISMA-ScR guidelines, detailing the search strategy, inclusion criteria, and data extraction procedures. The results present a synthesis of the existing literature on pedestrian route choice among older adults, identifying key determinants that influence their path selection. Finally, the discussion interprets these findings in light of their implications for age-inclusive routing technologies, highlights gaps in the current evidence base, and proposes directions for future research.

2. Methods

This scoping review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines (Tricco et al., 2018) to ensure transparency and methodological rigor. The review protocol was developed following the framework proposed by Arksey and O'Malley (2005) and Levac et al. (2010).

2.1. Eligibility criteria

Definitions of "older adults" vary considerably across disciplines and contexts. While 65 years is the most commonly used cutoff, age 60 or even 50 is frequently applied in global health and policy research to reflect demographic realities and maximize relevance across settings (Lloyd-Sherlock et al., 2012). We adopted a $\geq$50 years cutoff to maximize inclusivity given the sparse evidence base, while recognizing that most included samples still cluster around 65 years and above.

Papers were considered regardless of how study design nor how environmental attributes were recorded. Studies that did not differentiate older adults as a separate sociodemographic group were excluded. Conference abstracts and grey literature were excluded as well.

2.2. Search strategy

A systematic search was conducted in Web of Science, Scopus, TRID (Transport Research International Documentation), ProQuest (including General, Dissertations, and Theses Global), and Google Scholar from 1985 (the earliest known publication on pedestrian route choice) to August 2024. The search terms required variations of "older adults", "pedestrian route choice", and "built environment", to appear in the title, abstract, or keywords. Only English-language articles were considered. Some studies include an older age group in their analysis but do not focus on older adults specifically, and subsequently they may not be explicitly mentioned in titles or abstracts. Hence the search strategy did not strictly filter for age-related terms; instead, potentially relevant studies were retrieved through broad route choice terms, then manually screened to identify those differentiating older adults. Reference lists of relevant reviews and included articles were also examined to identify additional sources.

2.3. Study selection and screening

Two independent reviewers (NF, JH) screened titles and abstracts, followed by full-text screening based on the eligibility criteria. Disagreements were resolved by discussion with a third reviewer (YG).

2.4. Data extraction and synthesis

Extracted variables included study setting, sample characteristics, design, and measured attributes. These were tabulated for comparison. Given the heterogeneity of methodologies and outcome measures across studies, and the small number of studies, results were synthesized narratively rather than quantitatively. A table provides a structured summary of key study characteristics (Table 1). This summary serves as a foundation for the subsequent synthesis.

3. Results

3.1. Study selection

The initial database search yielded 458 records. After removing 87 duplicates, 325 unique articles remained for title and abstract screening. Based on the eligibility criteria, 315 articles were excluded at this stage for the following reasons: Lack of focus on pedestrians; absence of specific analysis on older adults; lack of environmental analysis related to route selection; assessment of neighborhood rather than route-level characteristics; not published in English; and conference abstracts or grey literature sources.

3.2. Participant characteristics

Eleven studies met all inclusion criteria and were synthesized. Of these, eight focused exclusively on older adults and provide the evidence base for Sections 3.2–3.5, and their key characteristics appear in Table 1; the remaining three, which treated older adults as a subgroup within a broader sample, are summarized separately in Section 3.6. Most authors defined "older" as $\geq$ 65 years, with two exceptions: Borst et al. (2009) set the cutoff at 50 years (mean age 68), and Moran et al. (2017) at 55 years, although 80 % of their participants were still 65+. Sample sizes ranged from 14 to 364. Sex distribution was generally even, except in Buman et al. (2013) and Mitra et al. (2015), where women made up 73 % and 86 % of participants, respectively. Only two studies explicitly reported the proportion of mobility-aid users—Joseph & Zimring (2007) (13 %) and Buman et al. (2013) (42 %)—and just two provided ethnicity data (Borst et al., 2009: 9 % non-Dutch; Moran et al., 2017: 35 % non-Jewish).

3.3. Study settings and geographic scope

All eight dedicated studies were conducted in high-income countries, covering six national contexts: Belgium, Canada, Israel, the Netherlands, the United Kingdom, and the United States. Three sampled compact urban districts; Van Cauwenberg et al. (2012) also sampled semi-urban municipalities near Ghent, Antwerp, and Halle, and Mitra et al. (2015) focused on suburban Mississauga. Most sites were ordinary residential neighborhood with relatively complete pedestrian networks, but Joseph and Zimring (2007) and Buman et al. (2013) examined continuing-care or low-income housing campuses for older adults in Atlanta and San Francisco. Only three studies deliberately contrasted multiple built forms: Van Cauwenberg et al. (2012) (urban vs. semi-urban), Moran et al. (2017) (four Haifa neighborhoods varying in socio-economic status, ethnicity, and topography), and Mitra et al. (2015) (conventional suburb vs. downtown-adjacent condominiums).

Table 1
Key characteristics of the reviewed studies that targeted older adults.

Reference	Study Setting	Participants	Preference approach	Study design - main approach	Environmental data list source
Borst et al. (2009)	Schiedam, Netherlands, urban	Sample size: 364 Ages: 55+ Gender: 60 % female	Revealed	Utilitarian routes marked on maps. Street segments were manually ranked by expert observers on 23 characteristics, supplemented by GIS data. These characteristics were then used to estimate link resistance factors within a stochastic route choice model, which simulates pedestrian route selection based on perceived walking costs and individual variability.	Literature
Moran et al. (2017)	Haifa, Israel, residential	Sample size: 59 Ages: 50+	Revealed	Walk along interview: Participants walked one route they use for leisure or utilitarian purposes with a worker, who recorded their narratives regarding perceived environmental barriers and facilitators for walking. The interviews were coded into themes through content analysis.	Literature with updates based on audio narratives
Brookfield and Tilley (2016)	Edinburgh, UK, residential	Sample size: 19 Ages: 65+ Gender: 53 % female	Revealed	Walk-along interview: Participants undertook a typical journey, without imposing a purpose, which was recorded by an interviewer. The routes were audited using the virtual FASTVIEW tool on 9 categories of environmental characteristics. Descriptive statistics of route characteristics are provided.	FASTVIEW (Brookfield and Tilley, 2016)
Van Cauwenberg et al. (2012)	Ghent, Belgium, Urban and semi-urban	Sample size: 57 Ages: 65+ Gender: 47 % female	Revealed	Walk-along interview: An interview along utilitarian routes was coded through content analysis into perceived environmental facilitators and barriers that influence walking.	NEWS (Saelens et al., 2003; Cerin et al., 2010) with updates based on interview
Mitra et al. (2015)	Mississauga, Canada, suburban	Sample size: 14 Ages: 65+ Gender: 86 % female	Revealed	Photovoice variant: Participants recorded photos of facilitators and barriers and they were contextualized in subsequent interviews. Content analysis was conducted to identify facilitators and barriers to walking, as well as visual examination of the routes on Google Maps.	Not predefined
Buman et al. (2013)	San Francisco, California, older adult housing communities	Sample size: 27 Ages: 65+ Gender: 73 % female	Revealed	Photovoice variant: Participants walked regular leisure or utilitarian routes and recorded audio narratives and photographs about neighborhood features affecting their route choices. The narratives and photographs were coded into themes, which were analyzed with descriptive statistics at two levels: individuals and sites.	Not predefined
Joseph and Zimring (2007)	Atlanta, Georgia, retirement communities	Sample size: 112 Ages: 68 % over 72 Gender: 59 % female	Revealed	One of each utilitarian and leisure routes were marked on a map and path segments were coded binary into those used and not used. Environmental data on path characteristics was manually audited by an expert, supplemented by building plan analysis. Chi-square and logistic regression were used to explain the relationship between environmental path-segment characteristics and usage.	Custom based on SPACE (Pikora et al., 2003) and IMI (Boarnet et al., 2006) with additions based on local conditions
Li and Zhang (2024)	Not disclosed	Sample size: 384 Ages: 60+ Gender: 30 % female	Stated	Stated preference of hypothetical routes. Participants answered a stated preference questionnaire featuring ten environmental attributes, each with 2–3 levels, of hypothetical routes. The routes were presented through text and schematic images. Binary logistic regression model was fitted to assess the relative importance of environmental elements, with stratification by age and health condition.	Literature

3.4. Study design

Seven of the eight core papers used revealed preference (RP) methods to record the routes older adults actually walked. These RP studies fall into three methodological clusters.

(i) Sketch-map/travel-diary (two studies): Participants drew regular routes on base maps; trained auditors then coded environmental attributes. The studies involved relatively large samples (100+ participants each) and employed statistical modeling to quantify the influence of environmental characteristics on path selection. Joseph and Zimring (2007) analyzed the use/non-use of individual path segments with χ^2 tests and logistic regression. Borst et al. (2009) compared reported walking routes to the shortest possible paths between the same points; when older adults took longer or different routes, those deviations were interpreted as higher "resistance" on certain street segments. These resistance scores were then statistically analyzed against 23 observed street features.
(ii) Walk-along survey (two studies): Researchers accompanied participants and recorded real-time commentary about the environment (Van Cauwenberg et al., 2012; Moran et al., 2017).
(iii) Photovoice survey (three studies): Participants provided geocoded photographs with audio narratives describing their routes (Mitra et al., 2015; Buman et al., 2013).

Studies in clusters (ii) and (iii) had smaller samples (fewer than 60 participants) and employed thematic analysis, occasionally supplemented by summaries of GIS data. Brookfield and Tilley (2016) stands out in combining a walk-along method with a summary of environmental characteristics based on an audit using Google Street View. Most RP studies did not distinguish trip purpose; Borst et al. (2009) mapped utilitarian trips only, whereas Joseph and Zimring (2007) analyzed both utilitarian and leisure routes.

The sole stated-preference (SP) study, Li and Zhang (2024), asked 384 respondents to choose between six pairs of schematic leisure routes that differed across ten attributes, presented through text descriptions and diagrams. Using binary logistic regression models, the study derived utility weights for each feature, indicating how strongly each one influenced participants' preferences.

Environmental attribute selection strategies clustered into three patterns:

(i) Ready-made checklists borrowed from prior walkability tools (Borst et al., 2009; Li and Zhang, 2024; Brookfield and Tilley, 2016; Joseph and Zimring, 2007).
(ii) Studies that began with standard checklist and added items raised by participants (Van Cauwenberg et al., 2012; Moran et al., 2017).
(iii) Ground-up photovoice themes where all attributes emerged from participant narratives (Mitra et al., 2015; Buman et al., 2013).

3.5. Route choice determinants

Tables 2–4 catalogue all factors reported in the 11 studies and group them into three themes: (1) street-infrastructure and structural attributes, (2) environmental quality and aesthetics, and (3) facility access plus other contextual features. For qualitatively coded studies a "+" (facilitator) or "–" (barrier) is shown; quantitative studies list only attributes that reached statistical significance. Below, we synthesize the main findings.

Table 2
Street infrastructure and structural attributes.

Study	Route length	Curb width/ presence	Curb quality	Stair/ ramp quality	Obstructions	User separation	Lighting	Connectivity	Pedestrian crossing	Other
Borst et al. (2009)	X	X		X						
Moran et al. (2017)	X+	X+	X + -	X-	X-	X+	X-			Road quality-
Brookfield and Tilley (2016)	X	X	X		X	X	X			
Van Cauwenberg et al. (2012)		X+	X + -	X-	X-	X+	X + -	X+	X + -	
Joseph and Zimring (2007)			X	X						Road segment length, Network centrality, outdoor vs. indoor
Mitra et al. (2015)		X+	X + -				X + -	X-		Signage-
Buman et al. (2013)	X		X	X			X	X	X	
Li and Zhang (2024)	X	X	X							Shade

+, - indicate facilitaros and barriers, respectively, in studied that coded factors as such.

Table 3

Environmental quality and aesthetics attributes.

Study	Building appearance	Streetscape appearance	Greenspace	Waterscape	Enclosure	Noise pollution	Air pollution	Traffic density	Litter
Borst et al. (2009)			X		X			X	X
Moran et al. (2017)	X + -	X + -	X+	X+		X-	X-		X
Brookfield and Tilley (2016)	X		X	X					
Van Cauwenberg et al. (2012)	X+	X+	X+	X+	X + -	X-	X-	X-	X-
Joseph and Zimring (2007)		X	X	X					
Mitra et al. (2015)			X+					X-	
Buman et al. (2013)			X					X	
Li and Zhang, 2024			X		X			X	

+, - indicate facilitaros and barriers, respectively, in studied that coded factors as such.

Table 4

Facility access and additional environmental attributes.

Study	Land use mix and amenities	Benches	Public transit stops	Personal safety	Other
Borst et al. (2009)	X*				
Moran et al. (2017)	X + -	X + -	X + -		
Brookfield and Tilley (2016)				X	
Van Cauwenberg et al. (2012)	X+	X+	X+	X + -	Familiarity+, wayfinding/legibility + -
Joseph and Zimring (2007)	X				
Mitra et al. (2015)	X + -	X + -		X-	
Buman et al. (2013)	X		X	X	
Li and Zhang, 2024	X				Pedestrian flow

+, - indicate facilitaros and barriers, respectively, in studied that coded factors as such.

3.5.1. Street infrastructure and structural attributes

(i) Distance and detours: Four studies provided distance data. Utilitarian or mixed-purpose trips averaged 0.7–0.8 km, while leisure walks stretched to ≈ 2–2.5 km; men generally walked the longer legs (Borst et al., 2009; Moran et al., 2017; Buman et al., 2013; Brookfield and Tilley, 2016). Older adults often accepted modest detours: in Borst et al. (2009) 80 % of utilitarian routes deviated from the geometric shortest path, but 82 % of those were ≤20 % longer. Moran et al. (2017) linked longer utilitarian routes to more positive perceptions, whereas Li and Zhang (2024) detected only a weak statistical preference for shorter leisure routes.

(ii) Surface quality and width: Every study flagged well-maintained, sufficiently wide pavements as key facilitators. Smooth and wide surfaces reduce the need to step into the carriageway and lower fear of tripping (Mitra et al., 2015). Obstructions (litter, parked cars, encroaching cyclists) repeatedly appeared as barriers; Moran et al. (2017) noted that such conditions amplified fear of falling among mobility-aid users.

(iii) Crossing and level changes: Marked zebra crossings were preferred features (Van Cauwenberg et al., 2012). Steep ramps, long stairs, and poorly maintained steps generally deterred walking and contributed to fear of falling, yet slope effects were context-dependent: in hilly Haifa, Moran et al. (2017) recorded frequent use of steep routes, and Joseph and Zimring (2007) found gentle slopes could encourage leisure walking on retirement-campus paths.

(iv) Lighting: Adequate street lighting, especially for early-morning or evening walks, improved perceived safety wherever measured.

3.5.2. Environmental quality and aesthetics

(i) Vegetation and water: Every study reported that attractive greenery—street trees, front gardens, or small parks—pulled walkers onto a route. The only counter-example was the Dutch “green strips” noted by Borst et al. (2009), which participants saw as unsafe because they limited visibility. Water features (ponds, fountains, seafronts) and, in one study, the chance of meeting animals further boosted route appeal (Van Cauwenberg et al., 2012).

(ii) Cleanliness, noise, and air: Litter-free streets and well-maintained façades were repeatedly linked to comfort, whereas noise and exhaust fumes discouraged walking (Moran et al., 2017; Van Cauwenberg et al., 2012).

(iii) Traffic volume: Findings on traffic counts were mixed: heavy flows were associated with danger, yet Borst et al. (2009) observed the opposite in some Dutch streets, suggesting that clear, predictable vehicle streams can make a route easier to navigate.

(iv) Sight-lines and vistas: Visual openness mattered. Blind walls (without windows) and tight enclosures reduced use (Borst et al., 2009); routes offering long sight-lines or low-rise skylines fostered feelings of safety and relaxation (Van Cauwenberg et al., 2012).

3.5.3. *Access to facilities and other environmental attributes*

(i) Everyday amenities: Routes that passed cafés, food shops, banks, or health services were consistently favored, largely because they enabled multipurpose trips (e.g., exercise plus errands).
(ii) Rest opportunities and transit links: Benches, shade, and other rest areas let participants extend their walking range, while nearby public-transport stops helped them combine walking with longer journeys (Moran et al., 2017; Van Cauwenberg et al., 2012).
(iii) Perceived personal safety: Fear of unfamiliar people, poor surveillance, or “street disorder” diminished route attractiveness in four studies (Van Cauwenberg et al., 2012; Mitra et al., 2015; Brookfield and Tilley, 2016; Buman et al., 2013).

3.5.4. *Individual and neighborhood factors*

(i) Neighborhood context: Only three studies linked route choice to neighborhood characteristics. Moran et al. (2017) saw few socioeconomic-related differences apart from affluent residents citing better sidewalks and logging longer walks. On the other hand, Buman et al. (2013) and Mitra et al. (2015) showed that concerns varied by housing type: suburban or low-income complexes emphasized sidewalk condition and personal safety more than dense, downtown condominium areas.
(ii) Age within the older adult cohort: Two papers explored intra-cohort variation. Li and Zhang (2024) found participants ≥70 were more sensitive to surface smoothness. Brookfield and Tilley (2016) reported that those ≥75 favored routes with greenery/blue space and high-quality pavements.
(iii) Gender: Evidence is likewise thin. Van Cauwenberg et al. (2012) noted that men emphasized natural features and cleanliness, whereas women valued access to facilities and façade aesthetics. Brookfield and Tilley (2016) added that women’s routes were shorter, more recreational, and more likely to circle through blue space, preferring wide, unobstructed pavements.

3.5.5. *Quantitative models of route-level decision-making*

Only two of the reviewed studies directly compared route alternatives and quantified how specific link features shifted selection. These estimates offer the clearest basis for routing weights. We summarize them here and elaborate on their potential utilization for routing in Section 4. Discussion.

Borst et al. (2009) assigned each street segment a “resistance” score based on how often it was avoided relative to the shortest path; these scores were then regressed on 23 audited features, with coefficients indicating the relative attractiveness or avoidance of each element. Shops had the strongest pull (−0.31), followed by pavements, residential frontage, and front gardens (−0.05 to −0.11). Resistance increased most for parks (+0.43) and stairs or slopes (+0.26), with smaller penalties for blind walls, green strips, and litter (+0.05 to +0.09).

Li and Zhang (2024) estimated a binary logistic regression model in which the likelihood of a walking route being chosen depended on ten route attributes presented in pairwise comparisons. Wide sidewalks (+1.00), high shade (+1.20), and smooth pavement (+0.70) were the strongest attractors, followed by service density, green borders, and active frontages (+0.40 to +0.60). Routes with high traffic or heavy pedestrian flows were penalized (−0.30 to −0.60), and longer durations were mildly discouraged (−0.20).

3.6. *Studies that include older adults within a broader age range*

Three additional papers analyzed mixed-age pedestrian samples in which older adults formed only a minority. Kim and Gong (2024) surveyed 524 pedestrians but had just 11 participants aged 60 +, Gim and Ko (2017) reported 22 % out of 203 respondents aged 50 +, and Kim et al. (2016) gave a mean sample age of 37 years (SD = 14) for 493 participants. All three studies examined mixed-use districts and used discrete-choice models that compared the route respondents walked with a plausible alternative (usually the geometric shortest path).

(i) Gim and Ko (2017) – Asked pedestrians to map the routes they walked to a train station. 80 % of commuters chose the shortest path to a train station; older adults were no more or less distance-sensitive than younger walkers.
(ii) Kim and Gong (2024) – When offered a choice between the shortest path (1.1 km) and a “healthy” path (1.4 km, greener, lower traffic, better sidewalks), older adults and participants motivated by chronic-disease prevention were less likely to pick the longer/healthier option.
(iii) Kim et al. (2016) – Participants generally preferred diagonal over straight crossings because of better sight-lines and visual interest, with no age-related difference in preference.

4. Discussion

This review synthesizes evidence on the environmental and personal factors that influence the route choices older adults make when walking between an origin and destination. While previous review papers, such as Van Cauwenberg et al. (2018), have examined how neighborhood-level features relate to walking in older adults, they largely overlook the micro-scale, turn-by-turn decisions that shape actual routes. Route choice analysis addresses this gap by focusing on the specific paths people select—an approach more relevant to routing systems and pedestrian infrastructure than area-level walkability indices. A prior review of route choice has concentrated on the general population (Basu et al., 2022); this is the first to focus specifically on older adults, whose unique functional constraints warrant dedicated attention.

Our review located 11 empirical studies of pedestrian route choice that include older adults; eight examined this age group exclusively. Despite the small corpus, the evidence converges on three themes familiar from general-population research (Basu et al., 2022)—street infrastructure, environmental quality, and aesthetics—but with a sharper edge: for older adults these attributes often decide whether a trip is possible at all. Benches and transit stops lengthen walking range by providing rest points, while high quality, obstacle-free pavements mitigate fear of falls, making sidewalk condition the most consistent determinant across studies. At the same time, contextual trade-offs emerge. Greenery and quiet streets usually attract walkers yet may feel unsafe if they block sight-lines; slopes discourage utilitarian travel for some but add exercise or scenic value for others. Sensitivity also varies within the cohort: participants aged 70 + showed greater concern for surface smoothness (Li and Zhang, 2024), and gendered patterns appeared in route length and perceived safety cues (Brookfield and Tilley, 2016). Older adults' route choices are also mediated by the use of mobility aids, trip purpose (utilitarian vs. leisure), and neighborhood context (urban grid vs. car-oriented suburb).

Most pedestrian-routing engines still optimize for the shortest distance or travel time—criteria that often mask what matters most to older adults. Translating environmental preferences into routing algorithms requires quantitative estimates of how strongly features affect route choice. Yet such estimates are scarce. Only two studies—Borst et al. (2009) and Li and Zhang (2024)—report coefficients that can be directly converted into routing weights. In Li and Zhang (2024) for instance, a utility weight of $+1.20$ for shade versus -0.20 per additional minute suggests that older adults are willing to walk roughly six extra minutes ($\approx$450 m) to stay on a shaded path. By rescaling these coefficients into "distance equivalents," routing engines could adjust edge weights to reflect comfort and safety, not just length. Borst's resistance scores could be used in the same way. Even so, models built on these limited data cannot yet account for the wide variation in preferences across individuals, trip purposes, or neighborhood contexts.

The empirical base is thin because prevailing methods trade depth for scale. Revealed-preference techniques such as walk-along interviews and photovoice give rich, context-laden insights but yield a limited number of routes—insufficient for statistical weighting across sub-groups or cities. By contrast, mainstream pedestrian research has begun to pair GPS traces with discrete-choice or latent-class models to capture thousands of decisions (Basu et al., 2022); tools rarely applied to older adults. We argue for hybrid designs: a short qualitative phase to reveal locally salient features, followed by large-sample collection, and state of the art choice modelling. Such designs would generate the scalable, high-resolution evidence needed to embed age-responsive cost functions in routing algorithms.

The next four subsections detail the research and data innovations—context-specific attribute lists, scalable preference capture, high-resolution environment mapping, and finer-grained user stratification—that can turn that agenda into practice.

4.1. *Context-specific characteristics of the built environment*

Section 3.4 already illustrated that the reviewed studies split almost evenly between two attribute-selection camps. Top-down audits import items from established tools (e.g., SPACES, IMI, FASTVIEW, NEWS), but those instruments carry normative assumptions—dense land-use mix, façade "attractiveness", etc.—and may omit the micro-features older adults care about, such as benches, kerb cuts, or tactile paving. Validation work with Turkish older adults confirms that omission erodes face validity (Akinci et al., 2022), and even age-adapted versions of NEWS in Australia, the USA, or Austria still miss climate- or culture-specific cues (Cerin et al., 2019; Starnes et al., 2014; Koller et al., 2024).

By contrast, bottom-up elicitation starts with open exploration—walk-along interviews, photovoice, participatory mapping—and lets participants define what helps or hinders them (Mitra et al., 2015; Buman et al., 2013; Moran et al., 2017). We recommend a hybrid protocol:

1. Conduct a brief qualitative scan in the target neighborhood to surface locally salient facilitators and barriers.
2. Translate those findings into a lean, customised attribute list.
3. Deploy that list in a larger quantitative phase.

Such a sequence keeps digitisation workloads manageable while minimizing the risk of omitting small but critical, place-specific factors—an essential step if routing algorithms are to provide trustworthy guidance for diverse ageing populations.

4.2. *Hybrid and scalable methodologies for capturing route preferences*

Identifying relevant environmental attributes is not sufficient unless robust methods exist to observe how older adults trade those attributes off in practice. Traditional revealed-preference (RP) surveys—mailed or online maps on which respondents draw routes—can reach large samples, but they impose cognitive and visual demands that reduce participation among the oldest age groups (Basu et al., 2022). Four of the reviewed studies therefore employed walk-along or narrative interviews (Moran et al., 2017; Van Cauwenberg et al., 2012; Brookfield and Tilley, 2016; Joseph and Zimring, 2007). Although these methods provide rich contextual data, they are labor-intensive and yield relatively few routes.

Passive GPS logging offers greater scale with minimal participant effort and meter-level spatial resolution (Basu et al., 2024).

Privacy and data-security concerns, however, often deter continuous tracking and may prompt researchers to omit demographic variables, limiting age-specific analyses. “Consent-by-design” applications that allow participants to pause tracking, or protocols in which only short, anonymized segments are shared, merit further evaluation.

Interactive web-map or tablet surveys represent another scalable option. Rising digital literacy among older adults in many countries (German Ministry for Family Affairs, 2020) makes such tools feasible, provided the interfaces meet accessibility standards for font size, contrast, and motor precision.

Because RP data cannot test hypothetical conditions, stated-preference (SP) experiments become a possible alternative. Yet pedestrian routes are complex and experiential, making traditional SP tools—like static images or text descriptions—less effective. To address this, researchers have begun exploring immersive SP techniques, including video-based surveys (Rossetti and Hurtubia, 2020) and virtual reality simulations (Farooq et al., 2018). These offer more realistic and engaging environments but require further validation, especially among older adults who may face sensory, motor, or cognitive challenges.

4.3. *Capturing built environment data*

Current approaches to environmental data collection in the reviewed literature present several limitations. Most studies rely on manual audits by experts, which are time-consuming, geographically constrained, and difficult to scale. These methods are challenging to replace because many micro-scale features relevant to older adults (e.g., pavement texture, curb ramps, benches, tactile paving) are not reliably captured through remote sensing or standard GIS datasets. One possible approach to improve scalability is the integration of volunteered geographic information (VGI), such as user edits in OpenStreetMap, to crowdsource updates on environmental features (Barron et al., 2014). Digital audit tools, including FASTVIEW, can also be deployed in “mapathon”-style events, where volunteers annotate street-level imagery to identify features that are absent from publicly available datasets (Gama et al., 2019).

Although manual audits are not entirely subjective, they depend on the assessor’s judgment, which may vary across raters and settings. In situ measurements offer greater precision but are rarely feasible for large-scale studies. Advances in remote sensing and computer vision provide potential solutions. Deep learning models applied to street-level imagery and high resolution aerial photography can identify micro-scale elements that are often absent from GIS databases such as benches (Zhou et al., 2022), street ramps (Olivatto et al., 2022), building facades (Zou and Wang, 2021), and curb conditions ((Cheng et al., 2018)(Cheng et al., 2018)). Nonetheless, the accuracy of such models depends on image resolution, camera orientation, and local urban form (Biljecki and Ito, 2021). Data coverage may also be incomplete in less-surveyed areas, limiting applicability.

Subjective or perceptual environmental characteristics—particularly safety, but also comfort and aesthetics—introduce additional complexity to modelling older adults’ walking behavior. These qualities are difficult to capture through objective measures, but the assumption that they cannot be quantified has been questioned (Janowicz et al., 2022). Supporting this view, recent machine learning approaches and multimodal Large Language Models have shown some ability to predict perceived safety from visual features in street imagery (Li et al., 2015; Malekzadeh et al., 2024), suggesting that certain perceptual dimensions can be approximated through observable proxies.

An integrated approach is therefore recommended. Expert manual audits, supported by volunteered contributions, standard GIS databases, and image analysis, provide complementary information that should be combined to create age-relevant environmental datasets.

4.4. *Towards a stratified view of route choice moderators*

Our inclusive threshold (≥50 years) reflects the range of definitions used in research and policy (see Section 3.2). This scope may blur age-related trends observed in narrowly defined cohorts. Indeed, the few reviewed studies that disaggregate by age show moderation effects, and underscore the need for stratified analyses based on both chronological and functional age. Gerontology commonly distinguishes young-old (65–74), middle-old (75–84), and oldest-old (85+) groups, each with different functional profiles (Neugarten, 1974). Young-old adults generally retain higher physical and cognitive capacity, whereas middle- and oldest-old adults experience greater balance, sensory, and thermoregulation challenges, increasing fall risk and heat stress.

A parallel stratification can be based on functional capability rather than chronological age. Declines in vision, cognition, mobility, cardiopulmonary fitness, and thermal tolerance each influence interaction with the streetscape. These include but are not limited to the following:

(i) Vision impairments like reduced contrast sensitivity—elevate injury risk and complicate navigation, especially on uneven or poorly marked surfaces (Owsley, 2011). Design elements such as tactile paving, accessible signals, and consistent curbs improve safety (Seetharaman et al., 2024).
(ii) Cognitive decline impairs memory and spatial awareness, leading older adults to prefer familiar routes with clear signage, landmarks, and low-stress settings (Salthouse, 2019; Gan et al., 2022).
(iii) Cardiopulmonary conditions limit tolerance for long or polluted walks, making rest opportunities and clean air vital (Tuomola et al., 2024).
(iv) Mobility impairments reduce speed and increase fall risk (Tinetti and Speechley, 1989), prompting preference for even terrain, gentle slopes, minimal stairs, and frequent benches (Portegijs et al., 2017; Simonsick et al., 1999; Van Holle et al., 2015).
(v) Reduced thermoregulation heightens sensitivity to weather extremes, increasing reliance on shade or shelter (Choi and Ailshire, 2025).

Gender also moderates behavior. Although only two reviewed studies examined this directly, wider literature shows that women more often avoid poorly surveilled or male-dominated spaces, preferring amenity-rich, predictable routes—even when longer (Golan et al., 2019; Blöbaum and Hunecke, 2005; Wickramasinghe and Dissanayake, 2015).

Finally, contextual factors modulate all of the above. Although all studies in this review were conducted in high-income countries, those including socioeconomically diverse areas suggest that factors like housing type and income level significantly shape route preferences. Future research should include cross-national and rural–urban comparisons, especially in underrepresented settings in the Global South (Massingue and Oviedo, 2021). Such studies may uncover unique barriers—such as unpaved or poorly lit paths, stray animals, or informal vending—and shift the relative importance of known facilitators. In settings with limited formal infrastructure, older adults may rely more on perceived safety, social familiarity, and tight-knit walkable networks than on conventional indicators like street connectivity or land-use mix. Cultural norms around visibility, safety, and appropriate mobility may also influence how gender and age intersect to shape walking decisions.

4.5. Beyond origin to destination walks - leisure walks

Several studies in this review indicate that a substantial share of older adults' outings are circular "origin-to-origin" loops or loosely linked, multi-stop itineraries undertaken for exercise, social connection, or relaxation (Brookfield and Tilley, 2016; Joseph and Zimring, 2007). Because these trips contribute directly to healthy-ageing goals, understanding the environmental features that encourage or inhibit them is as important as analysing utilitarian travel. Yet current routing engines and walkability metrics, which assume a point-to-point task and optimize for minimum distance or time, cannot represent the logic of recreation-oriented walking or the benefits older adults might derive from it.

Leisure routes differ from errand trips in three respects. First, the walker often starts and ends at the same location, so the notion of a "shortest path" is undefined. Second, the utility of distance is non-linear: moderate length is positively valued for exercise or scenic reward, whereas excessive length incurs fatigue. Third, trips often blend recreation with incidental stops—parks, cafés, pharmacies—blurring the boundary between leisure and utilitarian purposes. These properties violate the linear-distance penalty and single–origin–destination assumptions built into conventional discrete-choice models (Train, 2009).

Several modeling approaches can accommodate these complexities. Quadratic or piecewise distance terms—or flexible machine-learning utilities—capture the hump-shaped valuation of length (Alfonzo, 2005; González et al., 2016). Segmented frameworks and recursive-logit formulations treat a loop as a sequence of dependent decisions, thereby removing the fixed origin-destination constraint (Fosgerau et al., 2013). Latent-class and reinforcement-learning approaches allow for heterogeneous walker types and dynamic factors such as fatigue or spontaneous detours (Walker and Li, 2007; Ziebart et al., 2008). Where routes include several intermediate purposes, activity-based travel models—standard in wider transport analysis—provide a natural extension (Bhat and Koppelman, 1999). Finally, empirical evidence that some older adults rely on simple heuristics such as "stay level" or "follow shade" suggests value in hybrid frameworks that combine utility maximization with rule-based decision making (Tong and Bode, 2022).

The empirical findings point to a new routing paradigm. Recreation-aware navigation must (i) search for looped or multi-stop itineraries instead of a single origin-to-destination path, and (ii) optimize a non-linear, multi-objective cost function that balances preferred distance ranges with scenery, benches, shade, and perceived safety. These costs should be fed by dynamic, user-specific coefficients derived from the models above, not by fixed, one-size-fits-all penalties.

CRediT authorship contribution statement

Nir Fulman: Writing – original draft, Investigation, Conceptualization. **Johannes Huber:** Writing – original draft, Investigation. **Armağan Teke Lloyd:** Writing – original draft, Investigation. **Kathrin Foshag:** Writing – original draft, Investigation. **Yulia Grinblat:** Writing – original draft, Investigation. **Umut Türk:** Writing – original draft, Investigation. **Sven Lautenbach:** Supervision. **Jan Amcoff:** Investigation. **Marina Toger:** Writing – original draft, Investigation. **Johanna Jokinen:** Investigation. **Alexander Zipf:** Supervision.

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.

Acknowledgement

This work was carried out as part of the project "Silver Ways: Integrating a Walkable Routing System with a 15-Minute Neighborhood Index to Enhance Mobility for Older People", which is supported by multiple national funding agencies under the Driving Urban Transitions (DUT) Partnership, co-funded by the European Union. In Türkiye, the project is funded by the Scientific and Technological Research Council of Türkiye (TÜBİTAK 1071, Grant No. 22N052). In Sweden, the project is funded by the Swedish Energy Agency (Energimyndigheten, Project P2024-03186, Organisation No. 202100-2932). In Germany, the project is funded by the Federal Ministry of Education and Research (BMBF) within the framework of the Strategy "Research for Sustainability" (FONA) as part of the Social-Ecological Research funding priority (Funding No. 01UV2559B, www.fona.de/en).

Data availability

No data was used for the research described in the article.

References

Akinci, Z.S., Delclos-Alio, X., Vich, G., Salvo, D., Ibarluzea, J., Miralles-Guasch, C., 2022. How different are objective operationalizations of walkability for older adults compared to the general population? A systematic review. BMC Geriatr. 22 (1), 673.

Alfonzo, M.A., 2005. To walk or not to walk? The hierarchy of walking needs. Environ. Behav. 37 (6), 808–836.

Arksey, H., O'Malley, L., 2005. Scoping studies: towards a methodological framework. Int. J. Soc. Res. Methodol. 8 (1), 19–32.

Arnberger, A., Allex, B., Eder, R., Ebenberger, M., Wanka, A., Kolland, F., Hutter, H.P., 2017. Elderly resident's uses of and preferences for urban green spaces during heat periods. Urban Forestry & Urban Greening 21, 102–115.

Barron, C., Neis, P., Zipf, A., 2014. A comprehensive framework for intrinsic OpenStreetMap quality analysis. Trans. GIS 18 (6), 877–895.

Basu, N., Haque, M.M., King, M., Kamruzzaman, M., Oviedo-Trespalacios, O., 2022. A systematic review of the factors associated with pedestrian route choice. Transp. Rev. 42 (5), 672–694.

Basu, R., Colaninno, N., Alhassan, A., Sevtsuk, A., 2024. Hot and bothered: exploring the effect of heat on pedestrian route choice behavior and accessibility. Cities 155, 105435.

Bhat, C.R., Koppelman, F.S., 1999. Activity-based modeling of travel demand. In: Handbook of Transportation Science. Springer US, Boston, MA, pp. 35–61.

Biljecki, F., Ito, K., 2021. Street view imagery in urban analytics and GIS: a review. Landsc. Urban Plann. 215, 104217.

Blöbaum, Hunecke, M., 2005. Perceived danger in urban public space: the impacts of physical features and personal factors. Environ. Behav. 37 (4), 465–486.

Boarnet, M.G., Day, K., Alfonzo, M., Forsyth, A., Oakes, M., 2006. The Irvine–Minnesota inventory to measure built environments: reliability tests. Am. J. Prev. Med. 30 (2), 153–159.

Bolten, N., Caspi, A., 2019. Accessmap website demonstration: individualized, accessible pedestrian trip planning at scale. In: Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility, pp. 676–678. C.

Borst, H.C., de Vries, S.I., Graham, J.M., van Dongen, J.E., Bakker, I., Miedema, H.M., 2009. Influence of environmental street characteristics on walking route choice of elderly people. J. Environ. Psychol. 29 (4), 477–484.

Bovy, P.H., Stern, E., 2012. Route Choice: Wayfinding in Transport Networks: Wayfinding in Transport Networks, vol. 9. Springer Science & Business Media.

Brookfield, K., Tilley, S., 2016. Using virtual street audits to understand the walkability of older adults' route choices by gender and age. Int. J. Environ. Res. Publ. Health 13 (11), 1061.

Buman, M.P., Winter, S.J., Sheats, J.L., Hekler, E.B., Otten, J.J., Grieco, L.A., King, A.C., 2013. The Stanford Healthy Neighborhood Discovery Tool: a computerized tool to assess active living environments. Am. J. Prev. Med. 44 (4), e41–e47.

Cerin, E., Leslie, E., Sugiyama, T., Owen, N., 2010. Perceived barriers to leisure-time physical activity in adults: an ecological perspective. J. Phys. Activ. Health 7 (4), 451–459.

Cerin, E., Nathan, A., Van Cauwenberg, J., Barnett, D.W., Barnett, A., Council on Environment and Physical Activity (CEPA)–Older Adults working group, 2017. The neighbourhood physical environment and active travel in older adults: a systematic review and meta-analysis. Int. J. Behav. Nutr. Phys. Activ. 14, 1–23.

Carr, L.J., Dunsiger, S.I., Marcus, B.H., 2010. Walk score™ as a global estimate of neighborhood walkability. Am. J. Prevent. Med. 39 (5), 460–463.

Cerin, E., Conway, T.L., Barnett, A., Smith, M., Veitch, J., Cain, K.L., et al., 2019. Development and validation of the neighborhood environment walkability scale for youth across six continents. Int. J. Behav. Nutr. Phys. Activ. 16, 1–16.

Cheng, M., Zhang, Y., Su, Y., Alvarez, J.M., Kong, H., 2018. Curb detection for road and sidewalk detection. IEEE Transactions on Vehicular Technology 67 (11), 10330–10342.

Choi, E.Y., Ailshire, J.A., 2025. Ambient outdoor heat and accelerated epigenetic aging among older adults in the US. Sci. Adv. 11 (9), eadr0616.

European Commission, Eurostat, 2025. Population Structure and Ageing. Statistics Explained (data extracted February 2025).

Farooq, B., Cherchi, E., Sobhani, A., 2018. Virtual immersive reality for stated preference travel behavior experiments: a case study of autonomous vehicles on urban roads. Transp. Res. Rec. 2672 (50), 35–45.

Fosgerau, M., Frejinger, E., Karlstrom, A., 2013. A link-based network route choice model with unrestricted choice set. Transp. Res. Part B Methodol. 56, 70–80.

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. Br. J. Sports Med. 44 (13), 924–933.

Gama, K., Rautenbach, V., Green, C., Gonçalves, B.A., Coetzee, S., Fourie, N., Sastry, N., 2019. Mapathons and hackathons to crowdsource the generation and usage of geographic data. In: Proceedings of the International Conference on Game Jams, Hackathons and Game Creation Events 2019, pp. 1–5.

Gan, D.R., Chaudhury, H., Mann, J., Wister, A.V., 2022. Dementia-friendly neighborhood and the built environment: a scoping review. Gerontol. 62 (6), e340–e356.

German Ministry for Family Affairs, 2020. Older people and digitisation: findings and recommendations from the eighth government report on older people. https://www.bmfsfj.de/resource/blob/159708/ed36ad230d6038b9f0a439fb03ddf35b/achteraltersbericht-kurzfassung-englisch-data.pdf.

Gim, T.H.T., Ko, J., 2017. Maximum likelihood and firth logistic regression of the pedestrian route choice. Int. Reg. Sci. Rev. 40 (6), 616–637.

Golan, Y., Henderson, J., Wilkinson, N.L., Weverka, A., 2019. Gendered walkability. J. Transp. Land Use 12 (1), 501–526.

González, P.A., Weinstein, N., Barros, J., 2016. Testing the limits of optimal foraging theory: the trade-off between travel distance and walking enjoyment in urban pedestrian movement. Environ. Behav. 48 (7), 879–905.

Janowicz, K., Zhu, R., Verstegen, J., McKenzie, G., Martins, B., Cai, L., 2022. Six GIScience ideas that must die. AGILE: GISci. Series 3, 7.

Jarzebski, M.P., Elmqvist, T., Gasparatos, A., Fukushi, K., Eckersten, S., Haase, D., Pu, J., 2021. Ageing and population shrinking: implications for sustainability in the urban century. Npj Urban Sustain. 1 (1), 17.

Joseph, A., Zimring, C., 2007. Where active older adults walk: understanding the factors related to path choice for walking among active retirement community residents. Environ. Behav. 39 (1), 75–105.

Kim, E.J., Gong, Y., 2024. Perceived built environments correlated to route choice for healthy leisure walking. J. Asian Architect. Build Eng. 1–12.

Kim, B., Kim, M., Lee, J., Park, J., 2016. Pedestrian path choice with diagonal streets. J. Asian Architect. Build Eng. 15 (3), 463–470.

Koller, D., Bödeker, M., Dapp, U., Grill, E., Fuchs, J., Maier, W., Strobl, R., 2024. A framework for measuring neighborhood walkability for older adults—a delphi consensus study. J. Urban Health 1–12.

Levac, D., Colquhoun, H., O'brien, K.K., 2010. Scoping studies: advancing the methodology. Implement. Sci. 5, 1–9.

Li, J., Zhang, J., 2024. A study on the impact of street environment on elderly leisure path preferences based on the stated preference method (SP method). Sustainability 16 (17), 7676.

Li, X., Zhang, C., Li, W., 2015. Does the visibility of greenery increase perceived safety in urban areas? Evidence from the place pulse 1.0 dataset. ISPRS Int. J. GeoInf. 4 (3), 1166–1183.

Lloyd-Sherlock, P., McKee, M., Ebrahim, S., Gorman, M., Greengross, S., Prince, M., et al., 2012. Population ageing and health. Lancet 379 (9823), 1295–1296.

Malekzadeh, M., Willberg, E., Torkko, J., Toivonen, T., 2025. Urban attractiveness according to ChatGPT: contrasting AI and human insights. Comput. Environ. Urban Syst. 117, 102243.

Massingue, S.A., Oviedo, D., 2021. Walkability and the Right to the city: a snapshot critique of pedestrian space in Maputo, Mozambique. Res. Transport. Econ. 86, 101049.

Menz, H.B., Lord, S.R., Fitzpatrick, R.C., 2003. Acceleration patterns of the head and pelvis when walking are associated with risk of falling in community-dwelling older people. The Journals of Gerontology Series A: Biol. Sci. Med. Sci. 58 (5), M446–M452.

Mitra, R., Siva, H., Kehler, M., 2015. Walk-friendly suburbs for older adults? Exploring the enablers and barriers to walking in a large suburban municipality in Canada. J. Aging Stud. 35, 10–19.

Moran, M.R., Werner, P., Doron, I., HaGani, N., Benvenisti, Y., King, A.C., et al., 2017. Exploring the objective and perceived environmental attributes of older adults' neighborhood walking routes: a mixed methods analysis. J. Aging Phys. Activ 25 (3), 420–431.

Neugarten, B.L., 1974. Age groups in American society and the rise of the young-old. Ann. Am. Acad. Polit. Soc. Sci. 415 (1), 187–198.

Olivatto, T.F., Inguaggiato, F.F., Melanda, E.A., 2022. Análise exploratória das rampas de ACESSIBILIDADE nas calçadas dos municípios do estado de são paulo. Rev. Geogr. 17 (1), 231–248.

Owsley, C., 2011. Aging and vision. Vis. Res. 51 (13), 1610–1622.

Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K., Donovan, R., 2003. Developing a framework for assessment of the environmental determinants of walking and cycling. Soc. Sci. Med. 56 (8), 1693–1703.

Portegijs, E., Keskinen, K.E., Tsai, L.T., Rantanen, T., Rantakokko, M., 2017. Physical limitations, walkability, perceived environmental facilitators and physical activity of older adults in Finland. Int. J. Environ. Res. Publ. Health 14 (3), 333.

Rădăcină, A.C., et al., 2023. A broad analysis of map routing applications. In: 2023 24th International Conference on Control Systems and Computer Science (CSCS). IEEE, pp. 557–564. C.

Rossetti, T., Hurtubia, R., 2020. An assessment of the ecological validity of immersive videos in stated preference surveys. J. choice model. 34, 100198.

Saelens, B.E., Handy, S.L., 2008. Built environment correlates of walking: a review. Med. Sci. Sports Exerc. 40 (7 Suppl. l), S550.

Saelens, B.E., Sallis, J.F., Black, J.B., Chen, D., 2003. Neighborhood-based differences in physical activity: an environment scale evaluation. Am. J. Publ. Health 93 (9), 1552–1558.

Salthouse, T.A., 2019. Cognitive Aging: A Primer. Psychology Press.

Seetharaman, K., Mahmood, A., Rikhtehgaran, F., Akbarnejad, G., Chishtie, F., Prescott, M., et al., 2024. Influence of the built environment on community mobility of people living with visual disabilities: a scoping review. Urban Plan. Transp. Res. 12 (1), 2296891.

Shigematsu, Ryosuke, et al., 2009. Age differences in the relation of perceived neighborhood environment to walking. Med. Sci. Sports Exerc. 41 (2), 314.

Simonsick, E.M., Guralnik, J.M., Fried, L.P., 1999. Who walks? Factors associated with walking behavior in disabled older women with and without self-reported walking difficulty. J. Am. Geriatr. Soc. 47 (6), 672–680.

Siriaraya, P., Wang, Y., Zhang, Y., Wakamiya, S., Jeszenszky, P., Kawai, Y., Jatowt, A., 2020. Beyond the shortest route: a survey on quality-aware route navigation for pedestrians. IEEE Access 8, 135569–135590 (2020).

Starnes, H.A., McDonough, M.H., Tamura, K., James, P., Laden, F., Troped, P.J., 2014. Factorial validity of an abbreviated neighborhood environment walkability scale for seniors in the nurses' health study. Int. J. Behav. Nutr. Phys. Activ. 11, 1–6.

Thiyagarajan, J.A., Mikton, C., Harwood, R.H., Gichu, M., Gaigbe-Togbe, V., Jhamba, T., et al., 2022. The UN Decade of Healthy Ageing: strengthening measurement for monitoring health and wellbeing of older people. Age Ageing 51 (7), afac147. https://doi.org/10.1093/ageing/afac147.

Tinetti, M.E., Speechley, M., 1989. Prevention of falls among the elderly. N. Engl. J. Med. 320 (16), 1055–1061. https://doi.org/10.1056/NEJM198904203201606.

Tong, J., Bode, M., 2022. Understanding pedestrian route choice heuristics: a systematic review. J. Transp. Behav. 45 (2), 123–137.

Train, K.E., 2009. Discrete Choice Methods with Simulation, second ed. Cambridge University Press.

Tricco, A.C., Lillie, E., Zarin, W., O'Brien, K.K., Colquhoun, H., Levac, D., et al., 2018. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann. Intern. Med. 169 (7), 467–473.

Tuomola, E.M., Keskinen, K.E., Viljanen, A., Rantanen, T., Portegijs, E., 2024. Neighborhood walkability, walking difficulties, and participation in leisure activities among older people: a cross-sectional study and 4-year follow-up of a subsample. J. Aging Health 36 (5–6), 367–378.

United Nations, Department of Economic and Social Affairs, Population Division, 2024. World Population Prospects 2024: Summary of Results. United Nations.

Van Cauwenberg, J., Van Holle, V., Simons, D., Deridder, R., Clarys, P., Goubert, L., et al., 2012. Environmental factors influencing older adults' walking for transportation: a study using walk-along interviews. Int. J. Behav. Nutr. Phys. Activ. 9, 1–11.

Van Cauwenberg, J., Nathan, A., Barnett, A., Barnett, D.W., Cerin, E., Council on Environment and Physical Activity (CEPA)-Older Adults Working Group, 2018. Relationships between neighbourhood physical environmental attributes and older adults' leisure-time physical activity: a systematic review and meta-analysis. Sports Med. 48, 1635–1660.

Van Holle, Veerle, Jelle Van, Cauwenberg, Deforche, Benedicte, Van de Weghe, Nico, De Bourdeaudhuij, Ilse, Van Dyck, Delfien, 2015. Do psychosocial factors moderate the association between objective neighborhood walkability and older adults' physical activity? Health Place 34, 118–125.

Walker, J.L., Li, J., 2007. Latent lifestyle preferences and household location decisions. J. Transport Geogr. 15 (5), 318–331.

Wickramasinghe, V., Dissanayake, S., 2015. Pedestrians' Route Choice Behavior for Intra-cbd Trips in a Developing Country (No. 15-3003).

Zhou, Y., Han, X., Peng, M., Li, H., Yang, B., Dong, Z., Yang, B., 2022. Street-view imagery guided street furniture inventory from mobile laser scanning point clouds. ISPRS J. Photogrammetry Remote Sens. 189, 63–77.

Ziebart, B.D., Maas, A., Bagnell, J.A., Dey, A.K., 2008. Maximum entropy inverse reinforcement learning. In: AAAI Conference on Artificial Intelligence, pp. 1433–1438.

Zou, S., Wang, L., 2021. Detecting individual abandoned houses from google street view: a hierarchical deep learning approach. ISPRS J. Photogrammetry Remote Sens. 175, 298–310.