Neighborhood walkability for older adults and their travel — Shanghai Anshan area case study

Huan Dong
Affiliation:Tongji University
Email:2211335@tongji.edu.cn

Haixiao Pan
Affiliation:Tongji University
Email:hxpank@online.sh.cn

Zizhan Wang
Affiliation:Tongji University,
Email:1810149@tongji.edu.cn

Zhendong Wang
Affiliation: Shandong Urban and Rural Planning Design Institute
Email:www.793162669@qq.com

Kun Li
Affiliation:Arup
Email:Kun.li@arup.com

Abstract
As population ageing accelerates, safeguarding older adults' mobility is vital to promoting their physical health, mental well-being, and social inclusion. Given their reliance on walking within neighbourhoods, walkability is a key factor influencing mobility behaviours. This study refines existing walkability index by incorporating empirical data on older adults' travel characteristics, including walking speeds, gathered via surveys. Using Shanghai's Anshan area—a community with a high proportion of older residents—as a case study, a fine-grained (50 m × 50 m) grid-based analysis was conducted. The modified index reveals spatial disparities in walkability and delineates essential travel patterns within a 15-minute community life circle. Findings inform practical recommendations for age-friendly neighbourhood renewal, offering valuable insights for policy adjustments in the context of rapid demographic ageing.

Keywords: Walkability Index; Older adults; Daily Travel; Community Planning

0. Introduction

The global trend of population ageing is accelerating, with China—owing to its large population—undergoing an especially pronounced demographic shift. As of 2024, individuals aged 60 and above account for 22% of the national population, while those aged 65 and above comprise 15.6% (China National Bureau of Statistics, 2025). In light of the universal reality that "every family has an elder, and everyone will eventually age," the mobility and safety of older adults have emerged as critical societal concerns. As a major global city, Shanghai also faces substantial challenges related to population ageing. Advancing age is often accompanied by a decline in mobility, reduced social engagement, and diminished quality of life among older residents. Therefore, it is essential to investigate the factors influencing the travel frequency and mobility limitations of older people, in order to guide the planning and renewal of age-friendly communities.

Shanghai's "15-minute community life circle" initiative, although instrumental in enhancing residential environments, has yet to fully incorporate design principles tailored to the specific needs of older adults. Common issues such as pedestrian spaces being occupied by parked vehicles and suboptimal configurations of public facilities remain prevalent (Chen et al., 2016; Huang et al., 2022). This underscores an urgent need to optimise neighbourhood environments through an elderly-centred lens. While existing walkability indices serve as important tools for evaluating pedestrian-friendliness, they exhibit notable limitations. These include a failure to distinguish between types of destinations frequently visited by older adults, and a neglect of their subjective experiences and perceptions (Wei et al., 2024; Weng et al., 2019). Most existing studies tend to focus on correlations between the built environment and physical health, with comparatively limited attention paid to mobility challenges as perceived by older adults themselves.

Furthermore, there remains a need to enhance the interpretability of research methodologies. Traditional investigations have predominantly relied on linear regression models to examine direct, linear relationships in travel behaviour. However, the emergence of machine learning techniques has enabled researchers to uncover more complex, non-linear patterns and threshold effects in mobility dynamics (Shi et al.,2022; Wu et al., 2021).

To address these methodological and conceptual gaps, this study proposes an analytical framework for evaluating walkability within community life circles, specifically tailored to the needs of older adults. Drawing upon a comprehensive literature review and empirical fieldwork—centred on the daily living requirements (e.g., shopping, leisure) and travel behaviours of elderly residents—this study refines facility weightings and correction coefficients embedded in conventional walkability indices, thereby formulating an improved, age-friendly walkability assessment system. Older residential neighbourhoods characterised by both a high concentration of ageing populations and mature built environments are selected as case studies. By calculating walkability indices for these areas, the study evaluates the influence of various spatial and environmental factors on accessibility for older adults, offering a theoretical foundation for the regeneration and transformation of urban communities. This study not only provides a robust scientific basis for the development of age-inclusive neighbourhoods but also represents a conceptual advancement in ageing studies—shifting the analytical focus from a singular emphasis on the built environment towards a multi-dimensional, integrated perspective. In doing so, it contributes to the broader societal objective of ensuring that older adults may age with dignity, adequate support, and enhanced quality of life.

2 Methodolody

2.1 Study area and data

The survey area is situated in the Anshan Xincun neighbourhood of Shanghai (Figure 1). Located within Yangpu District and adjacent to Tongji University, Anshan Xincun encompasses an area of approximately 1.51 km². In 1952, four major workers' neighbourhoods were developed to the north of Kongjiang Road, with Anshan Xincun being one of them, forming a large-scale residential community. As a product of Shanghai's transitional period of urban development (Zhigang and Fulong, 2006), Anshan Xincun represents a typical workers' neighbourhood. Its spatial configuration resembles that of traditional alleyways, though it is not entirely open, with service facilities arranged along the main streets. Following the establishment of these residential areas, a substantial number of workers moved in and settled permanently. Today, Anshan Xincun is characterised by high residential density and a deteriorating built environment, serving as a representative example of older urban districts within central Shanghai. The pronounced level of population ageing in the area further renders it a suitable site for investigating the travel behaviours of the elderly.

Figure 1 Location of Anshan Xincun

This study was conducted in three stages, each focusing on the mobility patterns of older people. The first stage comprised semi-structured interviews, each lasting approximately 30 minutes, and aimed at investigating the travel preferences, challenges, and daily mobility needs of older adults. The second stage involved a questionnaire survey, informed by existing literature, to gather data on travel preferences, frequency of travel, and key influencing factors. These data were subsequently used to refine the weighting of facilities within the walkability index. The third stage entailed tracking the travel trajectories of a selected group of older residents in order to determine their average walking speed, thus enabling the definition of a neighbourhood activity radius tailored to their mobility characteristics.

2.2 Walkability index

Empirical research examining the relationship between the built environment and walking behaviour has primarily concentrated on the computation of walkability indices (Cheng et al., 2019; Fonseca et al., 2022; Nagel et al., 2008) with the majority of such studies conducted in Western contexts(Aghaabbasi et al., 2018; Cubukcu et al., 2015). However, many of the indicators employed—such as facility weights and adjustment coefficients—are designed specifically for Western urban settings and may not be well suited to cities such as Shanghai, where the urban morphology differs considerably. Nonetheless, the methodological framework underpinning walkability indices remains a valuable instrument for evaluating walkability at the regional scale, as it encompasses both the spatial distribution of facilities and the pedestrian-friendliness of the built environment. This renders it particularly appropriate for assessing the travel environments of older adults, who are often more vulnerable in terms of mobility.

Mainstream approaches to calculating walkability scores can broadly be classified into environment-based and accessibility-based methods. The former emphasises the physical characteristics of the built environment, while the latter gives greater consideration to pedestrian behaviours and needs (Horak et al., 2022). Accessibility-based walkability indices generally follow a structured logic: based on the travel demands of the target population, relevant facility types are identified and assigned indicator weights. The distances from origin points to surrounding facilities are then computed and adjusted using a distance decay coefficient. The weighted values for each origin point are aggregated to generate a base walkability score, which is subsequently modified using a correction coefficient to produce a final index ranging from 0 to 100 (Horak et al., 2022). Given that older adults are particularly reliant on local facilities and prioritise ease of access, this study adopts an accessibility-based approach to walkability assessment.

The principal framework for adjusting the walkability index in this study is presented in Figure 2.

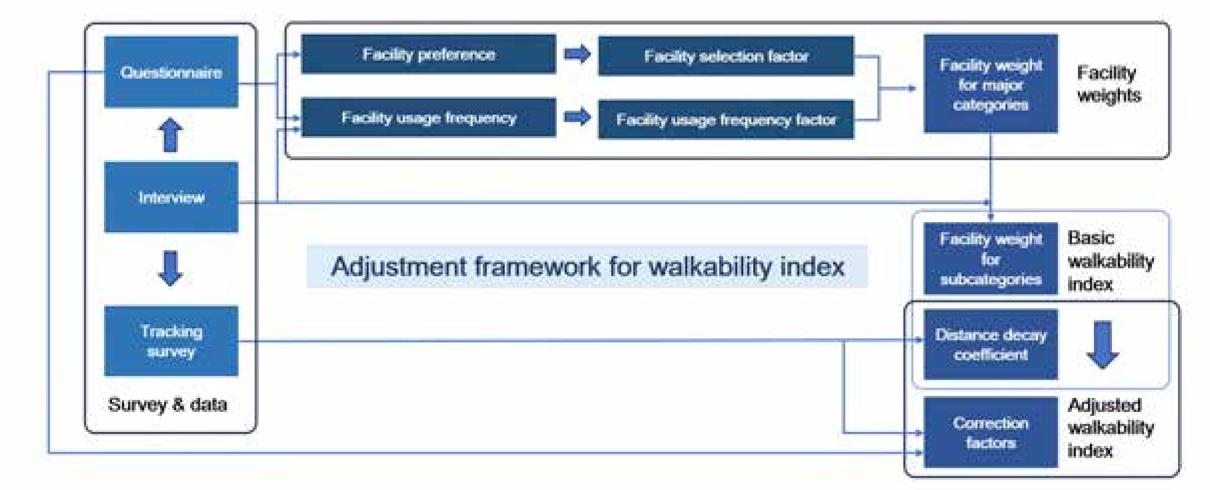

Figure 2 Adjustment framework for walkability index

At present, walkability indices are typically applied at a relatively coarse spatial scale, often using the community centroid as the point of origin. This method tends to neglect intra-community travel distances and spatial variation(Duncan et al., 2013; Hall and Ram, 2018)]. However, owing to the enclosed nature of community design and management in many urban areas, significant spatial heterogeneity may exist even within small-scale neighbourhoods (Li et al., 2024). For example, residents living closer to community entrances may demonstrate stronger travel intentions. Accordingly, this study adopts a fine-grained, grid-based analytical approach, calculating walkability scores at 50-metre intervals to capture localised variations more accurately.

The base walkability index is computed by identifying the types and quantities of facilities surrounding each origin point and aggregating these using the corresponding facility weights, as defined in Equation (1).

$$W_b = \sum_{j=1}^{N}\left[Q_j * \left(\sum_{i=1}^{n_j}(F_{ij} * Y_{ij})\right)\right] \Big/ \sum_{j=1}^{N} Q_j \qquad (1)$$

Where W_b is the basic walkability index, Q_j denotes the original weight value of facility *j*, n_j is the number of decay intervals of facility *j*, F_{ij} is the number of facility *j* in decay interval *i*, and Y_{ij} is the distance decay coefficient corresponding to the i-th facility of facility *j*.

The calculation method of adjusted walkability index is as follows Equation (2):

$$W_a = W_b * (1 - C_i) * (1 - S_i) * (1 - N_{1i}) * (1 - N_{2i}) \qquad (2)$$

Where, W_a is the adjusted walkability index, W_b is the basic walkability index, I_i is the intersection density correction coefficient, L_i is the block length correction coefficient, N_{1i} is the first new correction coefficient, N_{1i} is the second new correction coefficient.

2.3 Model

This study adopts the Gradient Boosting Decision Trees (GBDT) model—a machine learning approach that improves predictive accuracy by iteratively combining multiple weak learners into a single, robust learner. The model approximates true outcomes by minimising the loss function through gradient descent. Compared with conventional linear regression techniques, GBDT offers superior accuracy and is capable of accommodating a diverse range of explanatory variables simultaneously(Ding et al., 2018).

Moreover, GBDT inherently captures interactions between variables without requiring a priori assumptions regarding functional forms, thereby addressing one of the principal limitations of linear models(Wang and Wang, 2021). It is also notably resilient to multicollinearity among independent variables, rendering it especially suitable for models involving a large number of predictors. As a non-linear modelling technique, GBDT is well equipped to detect localised effects and threshold phenomena, demonstrates robustness against outliers, and more accurately reflects empirical patterns. These features collectively enhance its utility in informing planning practices.

Accordingly, this study employs the GBDT model to analyse the influence of various factors on respondents' travel behaviours across different neighbourhoods, thereby effectively mitigating the distorting effects of non-linear variable interactions on overall model performance.

3 Results

3.1 Survey results

3.1.1 Basic Information and Travel Characteristics

The survey findings concerning the respondents' demographic profiles and health conditions are illustrated in Figures 3 and 4.

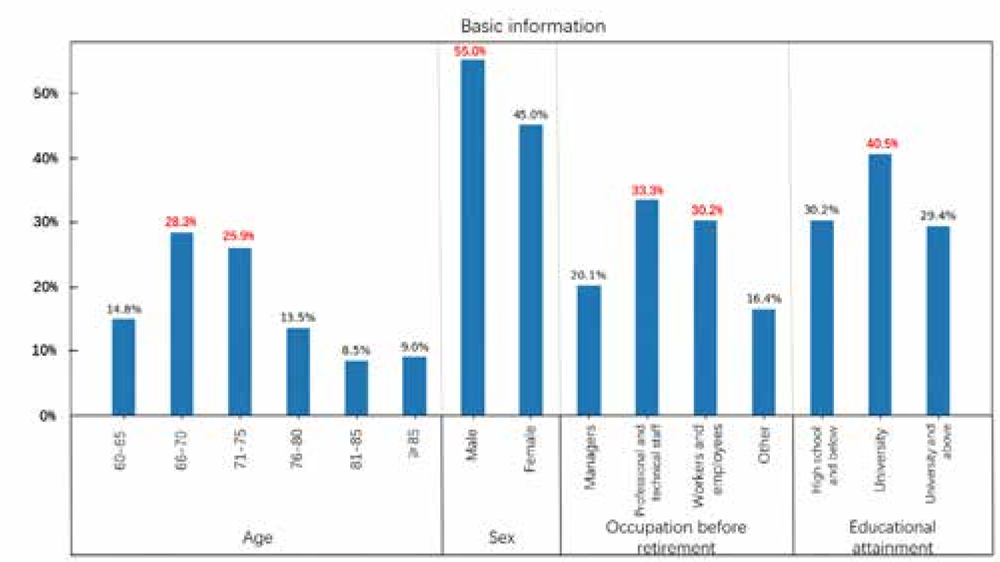

Figure 3 Basic information of the respondents

All respondents are retired residents aged 60 and above, the majority of whom reside either with their spouse or with both spouse and offspring. Approximately 70% are primarily responsible for household shopping. Fewer than 20% of respondents self-assess their health as "good" or "very good". Regarding chronic illnesses, 64.3% report not suffering from any long-term health conditions.

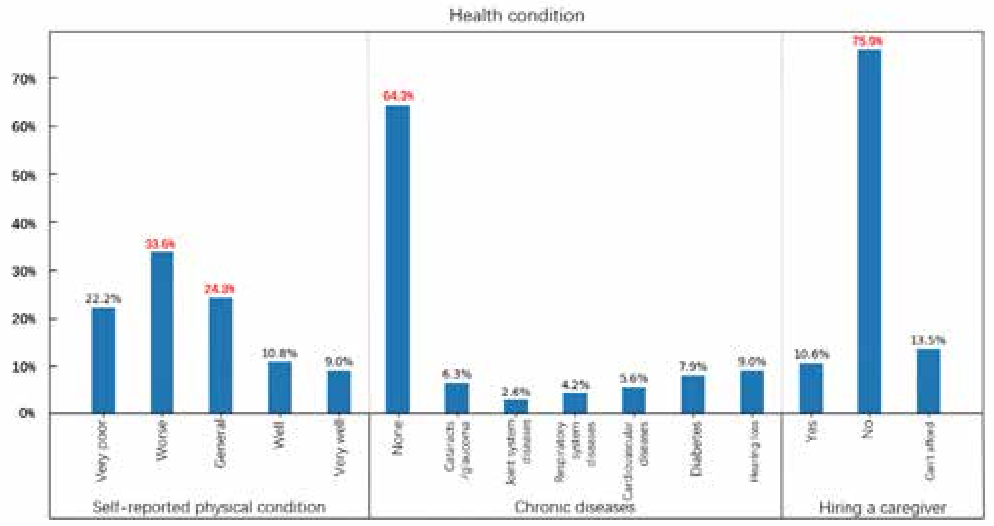

Figure 4 Health condition of the respondents

Respondents typically go out between once and four times per day, with nearly one-third reporting the need to leave their home twice daily. Fewer than 80 respondents are able to travel independently; the remainder rely on mobility aids such as walking sticks or wheelchairs. Furthermore, 42 respondents require the assistance of a companion when travelling, indicating that a significant proportion of the sample population faces mobility-related challenges (Figure 5).

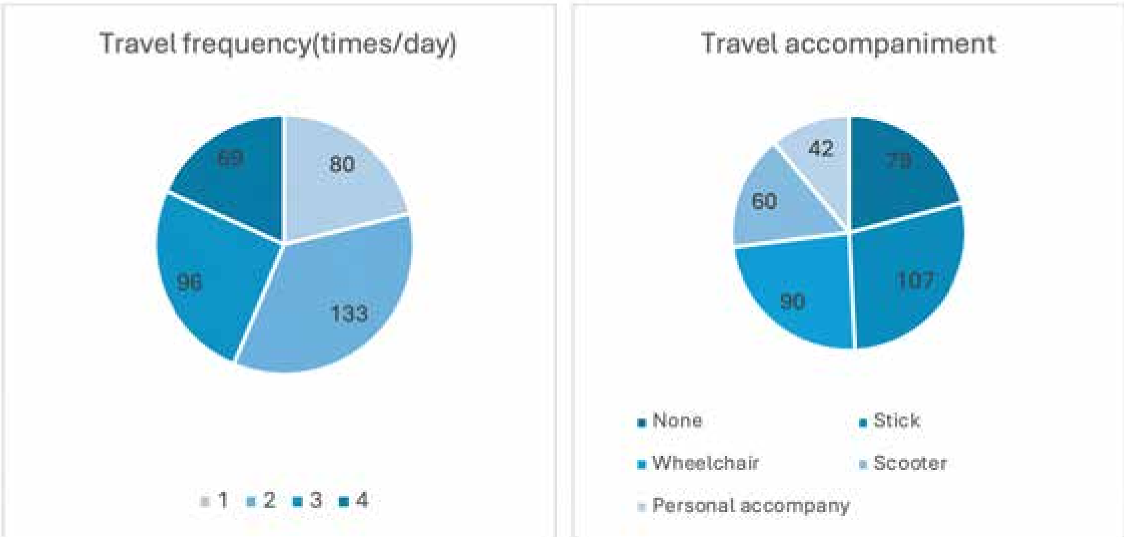

Figure 5 Travel frequency(left) and travel accompaniment(right)

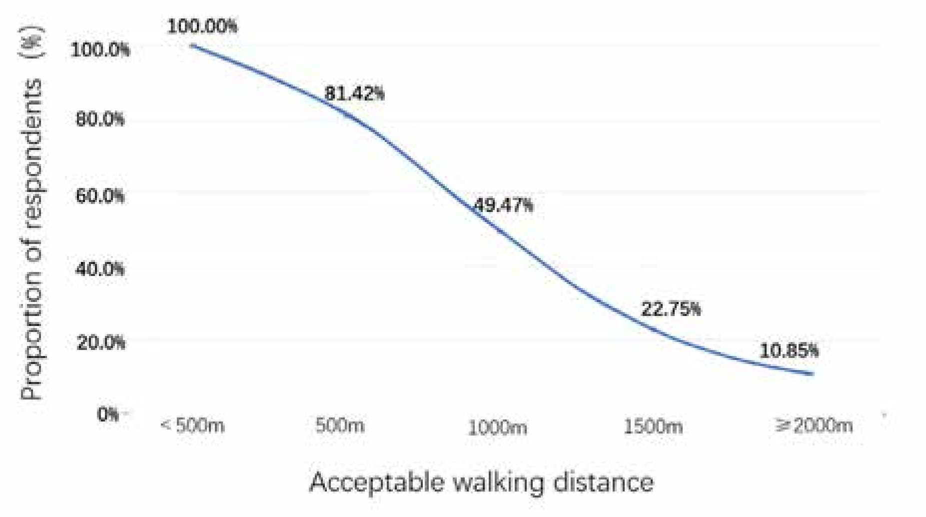

Figure 6 Distribution of acceptable walking distances

The majority of respondents are willing to walk distances of up to 500 metres, while only around 10% are capable of walking 2,000 metres or more (Figure 6). For longer journeys, respondents tend to favour public transport, although a subset uses non-motorised modes such as electric bicycles and mobility scooters designed for older adults. A small number of respondents report using private vehicles or taxis.

3.1.2 Travel problems

When asked about the difficulties encountered during travel, respondents' concerns were classified into four primary categories: inadequacies in facilities, issues related to urban management, challenges in pedestrian flow organisation, and safety risks (Figure 7).

Figure 7 Travel problems of the respondents

Among these, the occupation of pedestrian pathways by private vehicles and insufficient street lighting during night-time—both indicative of shortcomings in public space governance—elicited considerable concern from older adults. These issues are particularly pronounced in historic urban areas such as Shanghai's inner-city neighbourhoods.

Other problems, such as an excessive number of intersections and the absence of lifts in residential buildings, are largely attributable to the period in which these neighbourhoods were developed. While a dense road network may improve overall connectivity, in older neighbourhoods it can simultaneously generate significant mobility challenges for the elderly.

3.2 Walkability index

3.2.1 Facility weights

(1) Facility Selection Coefficient

The initial step involves the calculation of weights assigned to broad categories of facilities. The facility selection coefficient is primarily determined based on the number of respondents who identified each facility type as relevant. The analysis places particular emphasis on those essential services most frequently cited during interviews as critical to the daily lives of older adults. These encompass six principal categories: shopping, dining, medical care, life services, public transport, and educational facilities. Given the prominent role of fresh food markets in meeting the nutritional needs of the elderly, this facility type is separated from the general shopping category and treated as an independent class in subsequent analyses.

The facility category with the lowest selection frequency is designated as the reference, or "equivalent", facility. In this study, public transport facilities were the least frequently selected and thus assigned an equivalence value of 1. Selection coefficients for all other facility types are subsequently derived by calculating the ratio of their respective selection frequencies relative to that of public transport. The core formula is presented in Equation (3):

$$Z = {}^{d_n}/_{d_{min}} \qquad (3)$$

Where Z denotes the selection coefficient for a given facility type, d_n represents the number of respondents selecting that facility, and d_{min} indicates the number selecting the reference facility.

(2) Travel Frequency Adjustment Coefficient

In this study, adjustments to facility weights take into consideration the influence of travel frequency. Based on responses from the questionnaire, the frequency with which different types of facilities were visited as destinations was recorded. Each frequency category was assigned a corresponding score — for instance, visiting once per week was assigned a value of 0.5, while visiting once per day received a score of 1. Scores for other frequency categories were allocated according to a similar rule. As the impact of frequency on the overall score is comparatively limited, a general decay principle was adopted for score assignment.

The travel frequency coefficient was subsequently calculated by multiplying the number of respondents selecting each facility type at a given frequency by the respective score, summing the products, and then dividing by the total number of respondents who reported using that facility. The calculation procedure is expressed in Equation (4):

$$Y = (\sum_{i=1}^{n} p_i f_i)/p_t \qquad (4)$$

Where Y denotes the usage frequency coefficient for a specific facility type, p_i is the number of respondents reporting a given usage frequency, f_i is the assigned score for that frequency, and p_t represents the total number of respondents who reported using the facility.

(3) Coefficient Adjustment Results

Based on the two categories of coefficients described above, the final weight for each major facility type was obtained by combining the facility selection coefficient with the travel frequency adjustment coefficient. The principal calculation formula is provided in Equation (5):

$$X = YZ \quad (5)$$

Where *X* represents the final weight assigned to a given category of facility.

The resulting weight coefficients for each facility type are summarised in Table 1.

Table 1 Facility weights

Type of facility	Selection coefficient	Usage frequency coefficient	Weight
Wet market	4.4	1.1	4.8
Shopping facilities	2.2	1.1	2.4
Dining facilities	2.1	1.1	2.3
Medical facilities	2.1	1.0	2.1
Educational facilities	1.2	1.3	1.6
Service facilities	1.1	1.0	1.1
Public transportation facilities	1.0	1.1	1.1

3.2.2 Distance decay and correction coefficients

(1) Distance Decay Coefficient

The influence of travel distance on facility accessibility is incorporated via a distance decay function. Travel range thresholds are delineated based on the average walking speed of the general population, with distance bands set at 400 m, 1600 m, and 2400 m. Each interval is associated with a decay function to quantify the effect of distance on facility utilisation. Facilities situated beyond the maximum threshold are excluded from the walkability index calculation.

However, both the delineation of travel ranges and the application of decay functions are primarily derived from the mobility patterns of the general population, without sufficient consideration of variations in travel capacities across different demographic groups. In light of the increasing prevalence of ageing, this approach is inadequate for accurately assessing walkability for older adults.

Given the layered structure of 15-minute community life circle planning, this study adopts an interval-based decay function aligned with existing planning frameworks. For instance, Long Ying et al. calculated walking distances based on travel speed and divided decay intervals into five segments informed by literature evidence (Long et al., 2021). Similar methodologies have been employed in other studies (Wu et al., 2014). This study adopts the same approach whilst adapting it to account for the specific characteristics of elderly travel, particularly the need for rest.

Older adults are particularly concerned with whether they can ultimately reach distant destinations, even if the journey requires rest breaks along the way. For those with limited mobility, time is not a primary constraint; instead, reaching a maximal distance usually requires resting breaks. Consequently, elderly residents are generally willing to take multiple pauses to their destination. This behavioural divergence from the general population underpins the adapted methodology for calculating the distance decay coefficient for older adults, as illustrated in Figure 8.

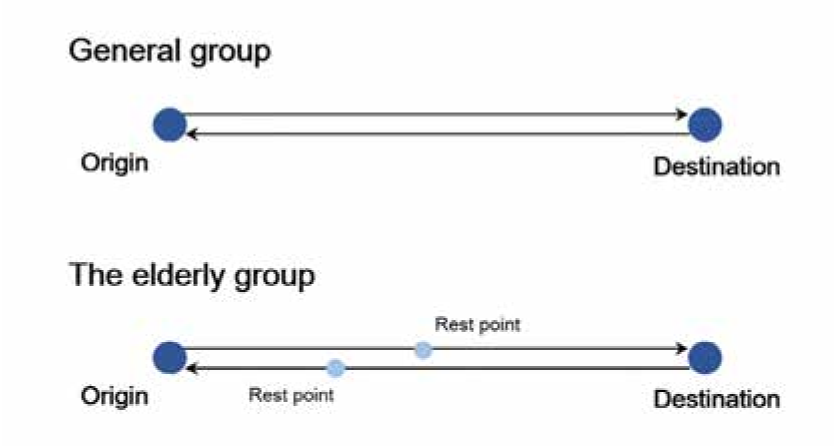

Figure 8 Differences between the elderly group and the general group

Building on the previous discussion of "acceptable walking distances" and the results of the travel tracking survey, the final decay rates are established as follows: no decay is applied within 0–150 m; a 10% decay rate applies between 150–300 m; 20% between 300–500 m; and 30% between 500–700 m. Distances exceeding 700 m are regarded as beyond the acceptable walking range for the majority of older adults, encompassing both those with normal mobility and those with limited mobility. The spatial boundaries of the "5-minute, 10-minute, and 15-minute" community life circles for the elderly are defined according to these distance intervals (Figure 9).

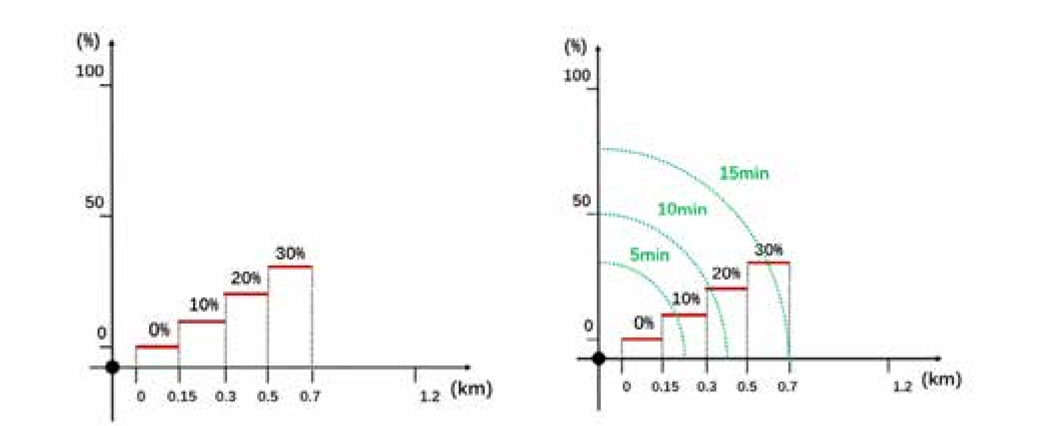

Figure 9 Distance decay coefficient(left) and community life circle radius(right)

(2) Adjustment of Correction Coefficients
The subsequent correction coefficients applied to the walkability index primarily account for two coefficients: the number of street crossings, represented by intersection density, and the scale of community blocks, indicated by block length. Compared with the effect of distance decay, the influence of these correction coefficients is relatively minor. Intersection density reflects the walkability of the street network—a higher intersection density implies a more intricate street grid, which is considered more favourable to pedestrian movement, thereby resulting in a lower decay rate. Similarly, shorter block lengths correspond to lower decay rates, consistent with the design principles of compact blocks and dense networks commonly observed in Chinese urban contexts. Consequently, existing standards for these indicators are maintained.

However, recognising the mobility differences among population groups, particularly older adults, the decay rates associated with these correction coefficients are appropriately adjusted to improve relevance. Drawing on the principal travel barriers identified in previous survey findings and corroborated by existing literature, two additional correction coefficients are introduced: the effective width of pedestrian pathways and the intensity of street lighting at night. Each coefficient is assessed on a scale from 0 to 8 according to actual street conditions.

The adjustment results for all correction coefficients are presented in Table 2.

Table 2 Correction coefficients

Intersection density (1/km2)	Block length (m)	Decay rate (Walk Score®[1])	Adjusted decay rate(%)	Scores (new coefficients)	Decay rate(%)
>77	<120	0	0	8	0
58-77	120-150	1	2	6	1
47-58	150-165	2	3	4	2
35-47	165-180	3	4	2	3
23-35	180-195	4	5	0	4
<23	>195	5	6		

3.2.3 Walkability index

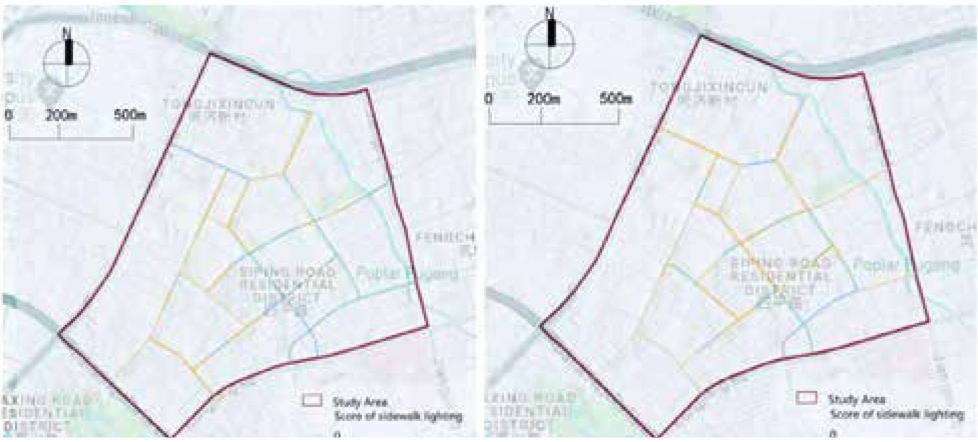

Figure 10 Sidewalk width score (left) and nighttime illumination score (right)

Based on the scores for effective pavement width and night-time lighting (Figure 10), a substantial proportion of roads fall into the lower-quality category (scoring 4 or below) concerning pavement conditions. Narrow pavements increase the risk of elderly pedestrians being compelled to walk in motor vehicle lanes, posing significant safety hazards. This issue underscores challenges in the management and maintenance of community and urban street spaces. The assessment of night-time lighting conditions largely corresponds with pavement width, although certain road segments display notable discrepancies. Inadequate lighting may diminish older adults' willingness to travel during dusk or evening hours(Trop et al., 2023).

1 Walk Score® (www.walkscore.com), a widely used, publicly accessible tool developed by a U.S.-based commercial company

A 50 × 50 m grid was established within the study area, and an origin-destination (OD) cost matrix was constructed from the centroid of each grid cell to various facility types, with the resolution refined to the scale of internal neighbourhood roads. Following the calculation of the basic walkability index, four indicators—intersection density, block length, effective pavement width, and night-time lighting intensity—were employed to adjust the initial walkability scores (Figure 11).

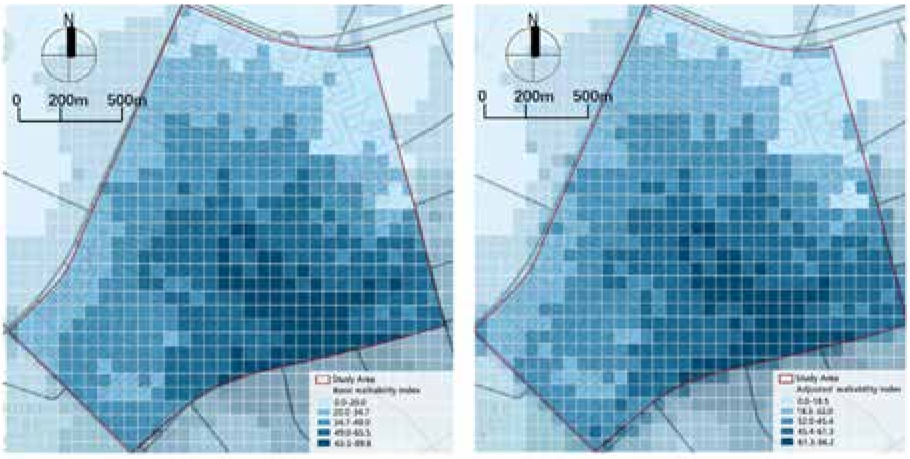

Figure 11 Basic walkability index(left) and adjusted walkability index(right)

The overall walkability index of the Anshan Xincun area is relatively low, a condition that becomes more pronounced following adjustment. Significant spatial heterogeneity in walkability scores was observed within Anshan Xincun, with higher scores concentrated in the southeastern sector and central zones. Conversely, the Tongji Xincun community, particularly in its northwestern corner, emerged as an area of markedly lower walkability. This disparity is preliminarily attributed to coefficients such as the enclosed configuration of large residential communities and the impact of major urban arterials.

The GBDT model was utilised to rank feature importance. Among all independent variables, the adjusted walkability index ranked highest in importance, indicating its substantial influence on the travel frequency of older adults. The normalised feature importance value for the walkability index was approximately 0.40. Other variables, including respondents' demographic attributes, also contributed to the model's predictive performance, albeit to a lesser degree (Figure 12).

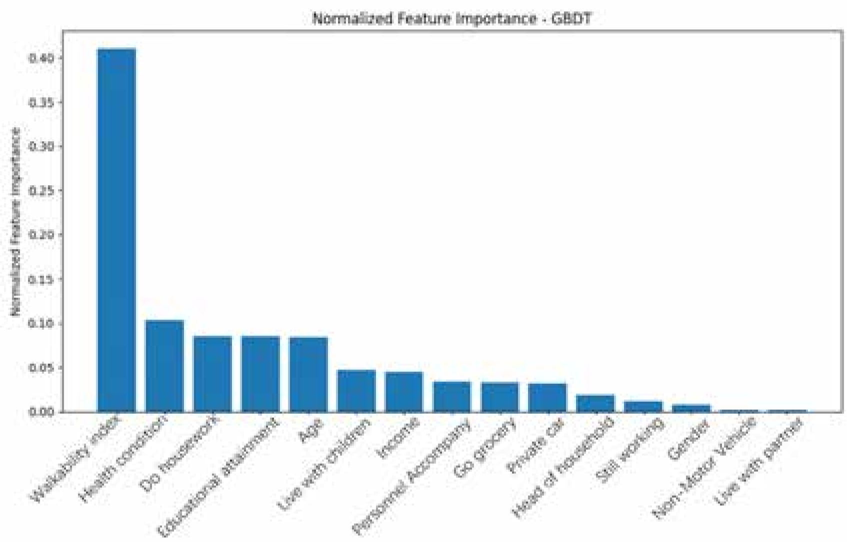

Figure 12 Feature importance of GBDT model

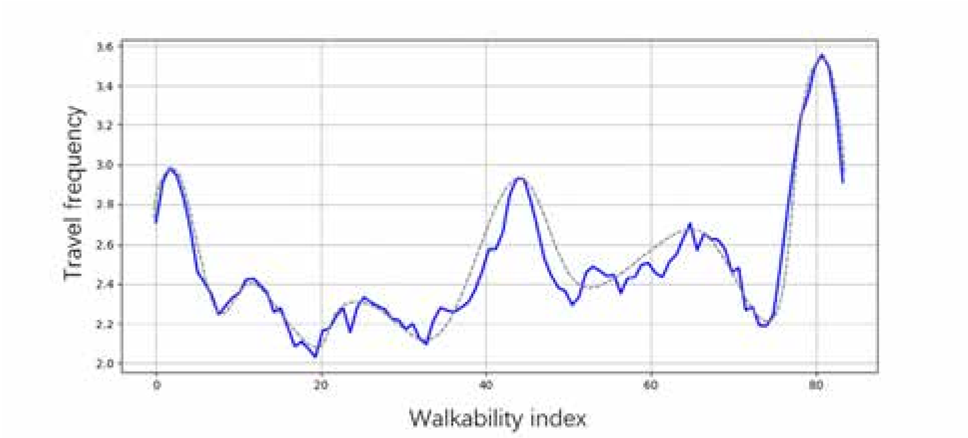

Figure 13 Partial dependence plot of the adjusted walkability index and travel frequency

To further elucidate the non-linear relationship between the walkability index and the travel frequency of older adults, partial dependence plots were generated (Figure 13). These plots indicate that as the walkability index increases, the travel frequency of older adults demonstrates a fluctuating pattern. Generally, areas with higher walkability scores correspond to more frequent travel among the elderly. In poorly walkable areas (scores ranging from 0 to 30), travel frequency tends to decline as scores increase, suggesting that substandard walking environments inhibit mobility intentions. When the walkability score falls within the 30–50 range, a pronounced increase in travel frequency is evident. Although a slight decrease occurs within the 50–60 range, travel frequency remains at two or more trips. A peak in travel frequency is observed when the walkability index attains approximately 80 points.

4. Discussion

A more detailed examination of the findings reveals that the uneven spatial distribution of essential facilities constitutes a key driver behind the marked disparities in walkability index scores across the broader study area, significantly shaping older adults' accessibility experiences. Owing to their generally limited travel range and reliance on a small number of facility clusters to meet daily needs, the absence or poor spatial allocation of critical facilities frequently results in unmet physiological demands, thereby generating pronounced differences in walkability levels between neighbourhoods.

Community scale and the number of access points emerged as principal determinants of detour lengths. This was exemplified in the Tongji Xincun case, where the paucity of entrances—particularly in the northern section—necessitated considerable detours to reach key services. Residents in proximity to the main southern gateway experienced comparatively better accessibility, reflected in higher walkability scores.

In older residential areas, accessibility is further constrained by governance and management-related issues, which often result in public and market-oriented facilities being located outside formal community boundaries. This externalisation gives rise to a dual accessibility challenge. First, in larger compounds, residents living far from main exits or facility-adjacent streets face reduced access, especially acute for elderly residents with limited mobility, for whom even moderate distances can render services effectively inaccessible. Second, the prevalent clustering of facilities often compels older adults to cross vehicular roads, and the lack of suboptimal placement of pedestrian crossings exacerbates these challenges. Those with relatively better mobility typically benefit from a greater number of facilities within 5- and 10-minute walking distances. Internal circulation patterns and intra-community detour lengths also exert a substantial influence on perceived accessibility.

These findings offer a sound empirical foundation for the formulation of targeted strategies for community renewal and retrofitting. Renewal initiatives must be differentiated to address the needs of heterogeneous older adult populations. The study advocates for the potential of open-block planning models in improving accessibility within large, ageing residential areas. Furthermore, it recommends targeted enhancements to the street environment, including sufficient pavement width, improved barrier-free facilities, and the integration of small-scale green spaces such as pocket parks. Critically, the study emphasises the importance of coupling physical facility upgrades with the development of a comprehensive and responsive community service system. Incremental, small-scale interventions may serve as a pragmatic starting point for promoting age-inclusive urban regeneration.

5. Conclusion

As global population ageing accelerates, there is an urgent need for urban environments that better support the mobility, well-being, and social participation of older people. This study set out to assess the impact of the built environment on older adults' mobility by constructing a community life circle walkability index framework specifically attuned to their unique needs. The revised walkability index developed herein exhibited closer alignment with the observed travel behaviours of older adults, suggesting that even well-intentioned and ostensibly advanced urban facilities can, paradoxically, undermine the mobility and safety of this demographic. For existing ageing communities, the implementation of pragmatic and phased renewal strategies—centred on optimising circulation routes and strategically enhancing the distribution and accessibility of key facilities—is imperative. Such measures are vital for increasing travel frequency among older adults, alleviating mobility barriers, and fostering healthy and liveable cities.

Theoretically, this study contributes to the refinement of walkability evaluation frameworks by introducing a multi-dimensional, elderly-oriented perspective. Unlike conventional macro-scale assessments, the present approach incorporates a finer-grained, micro-level analysis that accounts for the nuanced mobility patterns and differentiated needs of older adults. As such, it offers a more precise and contextually relevant evaluative tool for future empirical research.

Nonetheless, several limitations of this study warrant acknowledgment. The sampled population, constrained by practical considerations, may not fully reflect the heterogeneity of the older adult demographic—particularly residents with severe mobility impairments or those requiring continuous assistance. In addition, although the walkability index has been refined, it does not encompass all potentially influential factors, such as detailed pavement conditions, subtle slope gradients, or subjective experiential dimensions of walking. The fragmented nature of the street environment in the study area also posed methodological challenges, particularly with regard to accurately measuring variables such as lighting intensity and effective pavement width. Furthermore, as with any quantitative index, there are inherent constraints in capturing the complex, dynamic interactions between residents and their spatial environments. While the findings offer valuable insights derived from a representative ageing community, the multifaceted interplay between environmental and personal factors remains a topic requiring further exploration.

Building upon these findings, future research would benefit from a more inclusive sampling strategy that captures a broader spectrum of mobility capabilities among older adults. The walkability index could be further enhanced by integrating a wider range of micro-environmental indicators, subjective perceptions, and more sophisticated modelling techniques, including refined service radii and spatial decay functions for facilities. Robust validation efforts—across varied community typologies, employing larger sample sizes and in-depth behavioural surveys—are essential to strengthen the model's generalisability and precision. Moreover, investigating effective governance and spatial management mechanisms will be critical in minimising the potential downsides of open community designs while maximising their benefits. Ultimately, advancing towards a multi-stakeholder, multi-perspective research paradigm is vital for the realisation of truly inclusive and age-friendly community environments.

Acknowledgements
The authors thank Arup for the opportunity of this study and financial support.

References

Aghaabbasi, M., Moeinaddini, M., Zaly Shah, M., Asadi-Shekari, Z., & Arjomand Kermani, M. (2018) Evaluating the capability of walkability audit tools for assessing sidewalks. Sustainable Cities and Society, 37, 475-484.

Chen, T., Hui, E.C.-M., Lang, W., & Tao, L. (2016) People, recreational facility and physical activity: New-type urbanization planning for the healthy communities in China. Habitat International, 58, 12-22.

Cheng, L., De Vos, J., Shi, K., Yang, M., Chen, X., & Witlox, F. (2019) Do residential location effects on travel behavior differ between the elderly and younger adults? Transportation Research Part D: Transport and Environment, 73, 367-380.

China National Bureau of Statistics (2025) The decline in the total population narrowed and the quality of the population continued to improve. [Online] available at: https://www.stats.gov.cn/xxgk/jd/sjjd2020/202501/t20250117_1958337.html

Cubukcu, E., Hepguzel, B., Onder, Z., & Tumer, B. (2015) Active Living for Sustainable Future: A Model to Measure "Walk Scores" via Geographic Information Sciences. Procedia - Social and Behavioral Sciences, 168, 229-237.

Ding, C., Cao, X. (Jason), & Næss, P. (2018) Applying gradient boosting decision trees to examine non-linear effects of the built environment on driving distance in Oslo. Transportation Research Part A: Policy and Practice, 110, 107-117.

Duncan, D.T., Aldstadt, J., Whalen, J., & Melly, S.J. (2013) Validation of Walk Scores and Transit Scores for estimating neighborhood walkability and transit availability: A small-area analysis. GeoJournal, 78, 407-416.

Fonseca, F., Ribeiro, P.J.G., Conticelli, E., Jabbari, M., Papageorgiou, G., Tondelli, S., & Ramos, R.A.R. (2022) Built environment attributes and their influence on walkability. International Journal of Sustainable Transportation, 16, 660-679.

Hall, C.M., & Ram, Y. (2018) Walk score® and its potential contribution to the study of active transport and walkability: A critical and systematic review. Transportation Research Part D: Transport and Environment, 61, 310-324.

Horak, J., Kukuliac, P., Maresova, P., Orlikova, L., & Kolodziej, O. (2022) Spatial Pattern of the Walkability Index, Walk Score and Walk Score Modification for Elderly. ISPRS International Journal of Geo-Information, 11, 279.

Huang, H., Peng, K., & Deng, L. (2022) Research on Micro-Renewal of Old Communities under the Guidance of Life Cycle Concept and Satisfaction Evaluation: A Case Study of Wuhan Zhiyin Dongyuan Community. Modern Urban Research, 37(4), 73-80. (in Chinese)

Li, M., Wang, H., Wang, J., Zhou, H., & Li, D. (2024) Gated or Ungated? A Case Study on Walkability Measurement for Urban Communities. Appl. Spatial Analysis, 17, 1017-1041.

Long, Y., Li, L., Li, S., Chen, L., Pan, Z., Yao, Y., Chen, M., Wang, Y., Quan, J., Zhang, L., Wang, C., & Qian, J. (2021) Measurement of Street Walking Environment Index for Urban Vitality Centers in Chinese Cities. South Architecture, (1), 114-120. (in Chinese)

Nagel, C.L., Carlson, N.E., Bosworth, M., & Michael, Y.L. (2008) The Relation between Neighborhood Built Environment and Walking Activity among Older Adults. Am J Epidemiol, 168, 461-468.

Shi, Z., Liu, Y., He, M., & Liu, Q. (2022) How Does Built Environment Affect Metro Trip Time of Elderly? Evidence from Smart Card Data in Nanjing. Journal of Advanced Transportation, 1-17.

Trop, T., Shoshany Tavory, S., & Portnov, B.A. (2023) Factors Affecting Pedestrians' Perceptions of Safety, Comfort, and Pleasantness Induced by Public Space Lighting: A Systematic Literature Review. Environment and Behavior, 55, 3-46.

Wang, K., & Wang, X. (2021) Generational differences in automobility: Comparing America's Millennials and Gen Xers using gradient boosting decision trees. Cities, 114, 103204.

Wei, Z., Cao, K., Kwan, M.-P., Jiang, Y., & Feng, Q. (2024) Measuring the age-friendliness of streets' walking environment using multi-source big data: A case study in Shanghai, China. Cities, 148, 104829.

Weng, M., Ding, N., Li, J., Jin, X., Xiao, H., He, Z., & Su, S. (2019) The 15-minute walkable neighborhoods: Measurement, social inequalities and implications for building healthy communities in urban China. Journal of Transport & Health, 13, 259-273.

Wu, J., Zhao, C., Li, C., Wang, T., Wang, L., & Zhang, Y. (2021) Non-linear Relationships Between the Built Environment and Walking Frequency Among Older Adults in Zhongshan, China. Front Public Health, 9, 686144.

Wu, J., Qin, W., Peng, J., & Li, W. (2014) The Evaluation of Walkability and Daily Facility Distribution Reasonability of Futian District, Shenzhen Based on Walk Score. Urban Development Studies, 21, 49-56. (in Chinese)

Zhigang, L.I., & Fulong, W.U. (2006) Sociospatial Differentiation in Transitional Shanghai. Acta Geographica Sinica, 61, 199-211.