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# Identifying individual priorities for walking infrastructure investments: A Best-Worst Scaling approach

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ABSTRACT

The built environment significantly influences individuals' propensity to walk, prompting local authorities to allocate financial resources for its improvement. Organisations overseeing the built environment have developed audit tools as standards to evaluate pathways and highlight developments to facilitate active travel. Using these audit tools as a foundation, this study developed 21 walking investment-relevant factors that were embedded into a preference-based elicitation approach known as Best-Worst Scaling (BWS). We report findings from a UK-wide sample of 364 adults aged 18 years or older. Data were analysed using aggregate (counting) and disaggregated (regression) approaches. Both approaches confirmed that footpath provision, footpath condition, lighting, footpath width, and buffer zone were the top-five priority areas for investment. The instrument is transferable across diverse cultural and country contexts, enabling international comparisons and further refinements by academics as well as policy makers.

## 1. Introduction

Active travel infrastructure plays a crucial role in enhancing quality of life by promoting social interaction and supporting local economic development (Gehl, 2010). Creating age-friendly cities requires safe, accessible, and enjoyable transport options for all, including children and older adults (Sallis et al., 2016). Pedestrian-friendly streets contribute to social equity and inclusivity in transport systems (Garrard et al., 2008) while also strengthening social cohesion and community engagement, as people who walk are more likely to interact with their neighbours and participate in local events (Leyden, 2003).

Despite these benefits, local authorities that are responsible for planning and managing the built environment, operate under recurring budget cuts, making it essential to prioritise active travel infrastructure investments effectively. Decision-makers must carefully determine which interventions will have the greatest impact on promoting walking and enhancing transport networks. Traditionally, audit tools have been used to assess infrastructure quality and identify areas for improvement. Such tools have been developed in the UK (Millington et al., 2009; Welsh Government, 2014), North America (Day et al., 2006; Nabors et al., 2007), Australia (Clifton et al., 2007; Pikora et al., 2002), and China (Cerin et al., 2011; Sun et al., 2017).

However, while audit tools provide an objective evaluation of infrastructure, they do not account for community priorities. Public consultations, such as those conducted in the UK, often lack quantifiable outcomes that can directly inform decision-making. This study proposes using audit tools as a foundation to define specific infrastructure elements that require prioritisation. By engaging the public in ranking these elements based on perceived importance, local authorities can ensure that limited resources are allocated to the most impactful walking infrastructure improvements.

Traditionally, ranking and rating methods of multiple elements (factors) related to the built environment and infrastructure, however, introduce biases and cognitive burdens on respondents (Soutar et al., 2015) and lack evidence-based, citizen-informed decision-making (Adamsen et al., 2013). Additionally, traditional scales are prone to boundary effects (e.g., a tendency to use extreme points on a scale) (Paulhus, 1991) and may not be easily understood by the public, causing potential misinterpretation and misleading findings (Marti, 2012). To address these challenges, this study proposes Best Worst Scaling (BWS)-Case 1 (the object case) as a survey-based preference elicitation method to identify citizen priorities for walking infrastructure. Another two types of BWS experiments are known as Case 2 (the attribute/profile case) and Case 3 (the multi-profile case) (Louviere et al., 2015) (see

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discussion in Section 3).

BWS is theoretically robust, cognitively easier (Heo et al., 2022), and has been empirically shown to perform better than traditional attitudinal scales (Schuster et al., 2024). Furthermore, BWS improves accuracy by mitigating scale-region biases. For example, many studies using traditional scales have shown that some cultures (e.g., China, Philippines, Greece, and Portugal) tend to be more acquiescent, producing higher means than other cultures (e.g. the United States, Australia, the UK, and Germany). Furthermore, some cultures (e.g., the United States, China, Nepal, Philippines, Greece, and Spain) tend to use the extremes of a scale, producing more variance, whereas others (e.g., Australia, Japan, Korea, the UK, and Germany) limit themselves to the middle or one end of a scale (Lee et al., 2007). The developed BWS instrument can serve as a practical tool for local authorities to determine priority areas for infrastructure investment.

The remainder of this paper is organised as follows: Section 2 provides a targeted critical review of the literature on pedestrian needs and audit tools for walking. Section 3 outlines the methodology of this study. Section 4 presents the findings of the BWS data from a preference elicitation exercise in the UK using an array of aggregate and disaggregate analyses related to public priorities for walking infrastructure. Section 5 discusses these findings, and Section 6 concludes with key takeaways and suggestions for future research.

## 2. Pedestrian needs and audit tools for walking

Walking infrastructure plays a crucial role in fostering sustainable, attractive, and accessible cities (Farrell, 2017). With urbanisation accelerating and infrastructure expanding to meet growing demands (Wang et al., 2018), ensuring high-quality pedestrian environments has become a priority (Kuddus et al., 2020). Urban planning now places emphasis on pedestrian safety, infrastructure quality, and active travel promotion (Josephine et al., 2021). To meet this demand, systematic evaluations of pedestrian infrastructure are necessary to assess safety, comfort, and accessibility while identifying areas for improvement (AlKheder et al., 2022).

A high-quality walking environment is defined by safety, convenience, security, continuity, comfort, and attractiveness (Krambeck & Shah, 2006). Safety and security significantly influence decisions to walk while concerns about traffic risks and crime often deter pedestrian activity (HCM, 2000). Convenience is defined as environmental features that make it easier to navigate while walking (Mateo-Babiano, 2016). Well-maintained footpaths, with smooth surfaces, no cracks or obstacles, and proper drainage, enhance the walking experience, promote safety, and encourage pedestrian activity, making them more inviting and functional for users (Nuworsoo & Cooper, 2013).

Traffic management measures such as crosswalks, flashing beacons, zebra crossings, and traffic signals are crucial for regulating pedestrian and vehicular interactions (Patil et al., 2021). They improve safety by managing traffic flow and offering secure crossing options (Guo et al., 2023). Traffic calming measures and 20-mph zones can encourage walking and improve public health by decreasing speed and traffic volume (Jacobsen et al., 2009). However, inconvenient crossing designs, long wait times, and high-speed traffic deter pedestrians, increase unsafe behaviours such as jaywalking (Chandrappa et al., 2021). For example, previous evidence has shown that many pedestrians prefer detours over waiting time in controlled settings, which resulted in many accidents and injuries and decreased their desire for walkability (Zheng et al., 2016).

Beyond safety and security, environmental and infrastructural elements also shape pedestrian behaviours. Features such as pedestrian buffer zones, including pedestrian islands, offer physical separation from vehicular traffic, improving pedestrian safety (Hidayat & Sari, 2020) and walkability (Patil et al., 2021). These exclusive spaces are free from motorised traffic, reduce transit-related burdens, and limit pedestrian exposure to traffic risks (Kim et al., 2023), making walking a more attractive commuting alternative (Lee et al., 2021). Wayfinding signage improves pedestrian safety by guiding and reassuring them of their surroundings, reducing anxiety and increasing confidence to explore walking routes (Ryan & Hill, 2022). Street furniture and amenities such as benches, and shade areas significantly impact walking duration, allowing individuals to walk for extended periods (Mitra et al., 2020). However, inadequate pedestrian infrastructure, such as poor footpath condition, fear of falling, and narrow footpaths, are key contributors to low walking desirability, especially among the elderly (Wojnowska-Heciak et al., 2022). Physical conditions, design, and the local environment limit the practicability of walking in high-traffic environments (Guzman et al., 2022).

To address these issues, several types of evaluation tools for pedestrian infrastructure have been developed over the years to identify inadequate or unsafe areas, understand pedestrian behaviour and experience, and prioritising investments in infrastructure (Lima & Machado, 2019). Such tools support policymakers and urban planners to prioritise investments, allocate resources effectively, and develop more effective policies and interventions. These tools also enhance the pedestrian experience and promote a safer environment for all road users (Nag, Bhaduri, et al., 2020). One way to conduct street assessments is through walking audit tools, which are systematic methods for observing, evaluating, and documenting the physical features and conditions that influence pedestrian activity (Clifton et al., 2007).

Walking audit tools also assist in detecting any possible risks and ensure the effectiveness of risk reduction measures for all users (MTO, 2014). These tools allow planners and designers to locate areas for improvement and make sure that infrastructure fulfils user requirements (Aumann & Arnold, 2017). Audit tools are also important for the ongoing evaluation of transport systems, maintaining performance relative to benchmarks (Vanderschuren et al., 2014), sustaining service quality, pinpointing areas for enhancement, conforming designs to standards, and overseeing facilities for advancement (MTO, 2014). Audit tools facilitate progress monitoring, guarantee infrastructure safety, and uphold efficient transport for users (Aumann & Arnold, 2017).

An example of an audit tools is the Systematic Pedestrian and Cycling Environmental Scan (SPACES) instrument (Pikora et al., 2002), which is designed to measure physical environmental factors that may influence walking and cycling in local neighbourhoods. This tool aims to guide public health, urban planning, and transport policies to promote physical activity. Another audit tool is the Scottish Walkability Assessment Tool (SWAT) (Millington et al., 2009), which was developed to measure and assess the walkability of urban environments in Scotland. The tool is designed to objectively record physical environmental factors believed to influence walkability and walking behaviour. In addition to many other audit tools that were developed to enhance active travel, such as the Walking Route Audit Tool (WRAT) in the UK (Welsh Government, 2014), the Irvine–Minnesota Inventory (IMI) (Day et al., 2006) and the Pedestrian Road Safety Audit (PRSA) both are in the United States (Nabors et al., 2007), the Pedestrian Environmental Data Scan (PEDS) in Australia (Clifton et al., 2007), and the Environment in Asia Scan Tool - Hong Kong (EAST-HK) in China (Cerin et al., 2011).

The developers of the audit tools examined various elements pertaining to the characteristics of the walking environment, including land use, building types and density, path materials, maintenance, obstructions, and amenities. A crucial component of audit tools is safety, including fear of crime, lighting, traffic control devices, crossing aids, and buffers between roadways and pathways. Additionally, lowered curbs, tactile surfaces, gradient, signage, and air and noise pollution. The quantity of items in these audit tools varies significantly. This variation arises because some audit tools assess both walking and cycling elements (e.g., IMI, SPACES, and PEDS), whereas others are exclusively designed for walking. Additionally, certain audit tools incorporate more details regarding a single item. For example, the IMI encompasses information for several classifications of land use, including segments for residential, educational, and public spaces, recreational areas, leisure facilities, fitness centres, civic buildings, institutional sites, commercial enterprises, office services, and industrial and manufacturing zones.

Several common factors appear across the different walking audit tools. For example, various models consistently highlight safety and comfort factors, including perceived safety from crime and accidents (Rahul & Manoj, 2020), footpath width, buffer zone, lighting, footpath quality, and obstructions (Kadali & Vedagiri, 2016; Raad & Burke, 2018). Furthermore, crossings and traffic control measures for pedestrian consider factors such as signal timing, crosswalk design, and the presence of medians or pedestrian refuges (Nagraj & Vedagiri, 2013). Environmental factors, such as the quality of footpath surface and the presence of street furniture, are also critical (Kadali & Vedagiri, 2016; Raad & Burke, 2018; Rahul & Manoj, 2020).

Assessing the quality of walking infrastructure holds significant importance for multiple stakeholders (Benton et al., 2023). Policymakers, urban designers, and transport planners play a crucial role in enhancing city decision-making processes by understanding infrastructure quality (Chowdhury et al., 2018). Evaluation data guides their resource allocation activities, allowing them to either prioritise or reduce allocations (Alipour & Dia, 2023). Such walking audit tools are made for specialist who assess quality of infrastructure. However, in light of limited budgets and the need to develop infrastructure there needs to be a process in which priorities need to be elicited by citizens. Therefore, this study synthesises the common factors across the different walking audit tools and converts them into a preference-based elicitation instrument to identify priorities as they are viewed by citizens.

## 3. Methods

To elicit citizen priorities for walking infrastructure investments, this study adopted a Best-Worst Scaling (BWS) approach. Introduced by Louviere and Woodworth (1990), BWS is an extension of Thurstone's multiple-choice method of paired comparisons. BWS focuses on having survey participants evaluate sets of three or more options, asking them to identify the 'best' and 'worst' options within each set (Louviere et al., 2015). There are three types of BWS, which are defined based on their format. BWS Case 1, also known as the Object case, asks participants to evaluate and rank entire objects or items based on their overall importance or preference. For example, the objects in this study are those listed in Table 1 and stand-alone improvements of walking infrastructure. These improvements such as "footpath width" do not have level structure (e.g. good, fair, poor) (Flynn & Marley, 2014). In BWS Case 2, the Profile or Attribute case, participants concentrate on specific attribute levels within a single profile rather than the overall profile's value. Profiles are descriptions of products, services, or policies that are based on a combination of factors and their related levels (Louviere et al., 2015). Finally, in BWS Case 3, the Multi-profile case, participants evaluate entire profiles based on the attribute levels presented in each profile; this is similar to a stated preference discrete choice experiment (SPDCE). This study used BWS Case 1 (the Object Case) to elicit citizen priorities for walking infrastructure investments.

As shown in Fig. 1, this study involved four main stages: (1) identification of relevant walking-infrastructure factors; (2) survey design including the generation of the BWS choice tasks andsocio-demographic questions of the participants; (3) internal validation of the BWS experiment through cognitive testing via interviews and thematic analysis (Albahlal et al., 2024); and (4) main survey data collection and quantitative analysis of the BWS data to identify investment priorities for walking infrastructure.

### 3.1. Identification and synthesis of related factors

The identification of factors associated with walking infrastructure involved a targeted review of validated audit and scanning tools across the UK (Millington et al., 2009; Welsh Government, 2014), North America (Day et al., 2006; Nabors et al., 2007), Australia (Clifton et al., 2007; Pikora et al., 2002), and China (Cerin et al., 2011; Sun et al., 2017). The number of factors in each tool varied greatly and thus a select number of factors were included in the BWS experiment, with priority to those that were included in more than one audit tool and were related to quality rather than quantity of walking infrastructure. These factors were grouped into five categories: (1) safety, (2) directness, (3) comfort, (4) attractiveness, and (5) coherence. The definition of these factors involved extensive cognitive testing through think-aloud and verbal probing techniques to enhance the face and content validity of the BWS instrument (Beatty & Willis, 2007) as well as to ensure a straightforward and unbiased preference elicitation process (see, Albahlal et al., 2024).

**Table 1**
Walking factors in this study.

| No. | Category | Factor | Description |
|---|---|---|---|
| 1 | Safety | Feel of safety | Footpaths are clear of any signs of crime or vandalism |
| 2 | | Lighting | Availability of lighting along the footpath |
| 3 | | Visibility | Clear lines of sight to all footpath users from all directions |
| 4 | | Buffer zone | Adequate separation between the road and footpaths |
| 5 | | Traffic volume | Low traffic or you can avoid walking near high traffic |
| 6 | | Traffic speed | Low traffic speeds or you can walk away from high-speed areas |
| 7 | Directness | Footpath provision | Provision of continuous footpaths for walking |
| 8 | | Location of crossings | Crossing points are along the footpath of destination |
| 9 | | Gaps in traffic | Only possible to cross the road from controlled crossings |
| 10 | | Crossings waiting times | Short waiting times at controlled crossings |
| 11 | | Green man time | Pedestrians have enough time to cross the road |
| 12 | Comfort | Footpath condition | Well-maintained and level footpaths for walking and pushchairs |
| 13 | | Footpath width | Adequate footpath width to accommodate both walking directions |
| 14 | | Gradient | Flat footpaths with no steep gradients throughout |
| 15 | | Street furniture and amenities | Footpaths with street furniture and amenities |
| 16 | Attractiveness | Footpath materials | Footpaths constructed with top-quality materials |
| 17 | | Walking barriers | Footpaths free of obstructions such as poles and signs |
| 18 | | Traffic control devices | Measures to stop traffic and give priority for pedestrians |
| 19 | Coherence | Air quality | Low levels of air pollution along the footpaths |
| 20 | | Traffic noise | Low levels of noise along the footpaths |
| 21 | | Dropped kerbs and tactile paving | Footpaths with dropped kerbs and tactile paving |

### 3.2. Design of the Best-Worst Scaling Case 1 experiment for walking infrastructure

The BWS Case 1 experiment focused on eliciting investment priorities for walking infrastructure (Albahlal et al., 2024). As shown in Table 1, this study utilised 21walking-related factors to gauge individuals' priorities. The aim was to identify which factors local authorities should prioritise to encourage walking.

The BWS tasks (choice cards) were generated by a balanced incomplete block design (BIBD) using the function 'find.BIB' in the R package

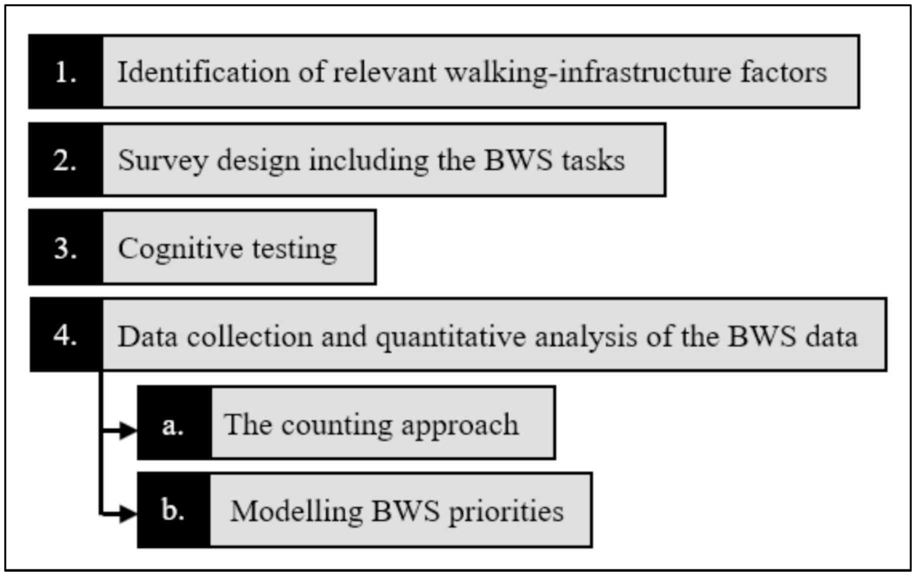
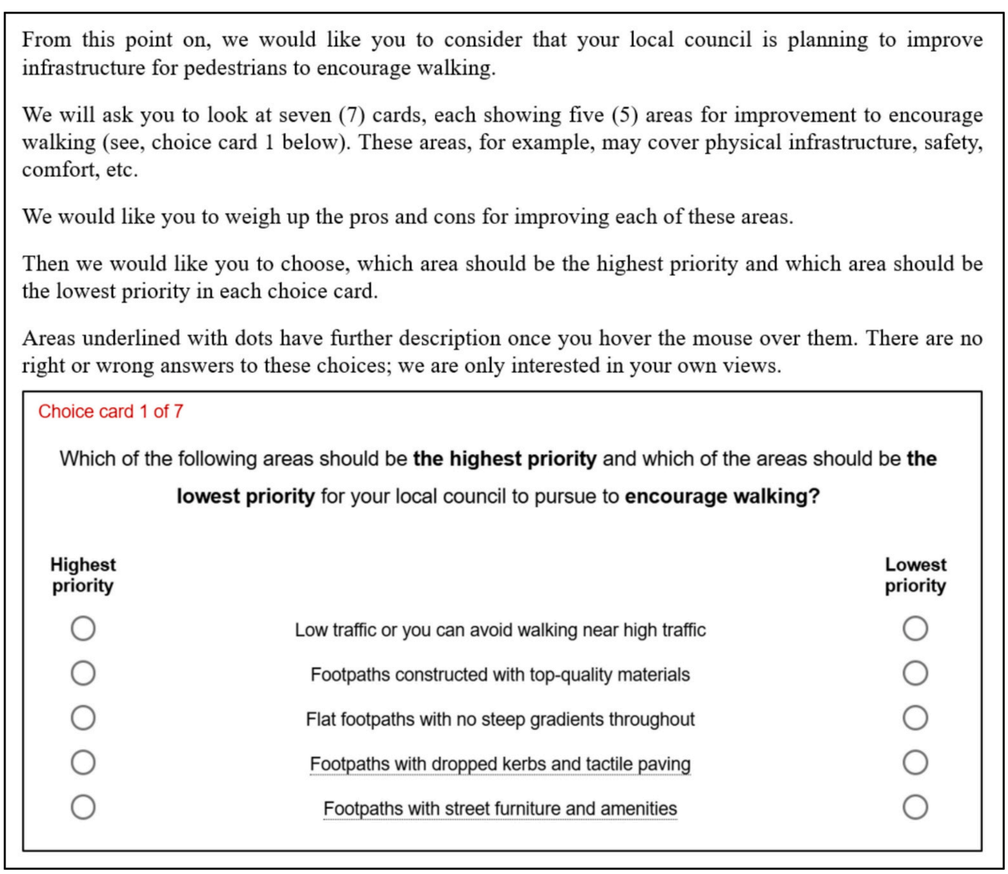



**Fig. 1.** Study design.

"Crossdes" (R Core Team, 2020; Sailer, 2005). BIBDs ensure constant occurrence and co-occurrence of factors, reducing the chance of unintended assumptions (Flynn & Marley, 2014). Each choice card contains a subset of k factors from the full list. The design can be verified as a BIBD by using the function 'isGYD'. In the BWS-Case 1 experiment for walking, $t = 21$ factors, $b = 21$ choice cards, $k = 5$ factors per choice card, each factor was repeated $r = 5$ times, and each pairwise comparison occurred $\lambda = 1$ time (see, Fig. A1 in Appendix A). In presenting the BWS tasks, the order of the factors (objects) was randomised so that they did not appear in the same position multiple times. The design was divided into three blocks, each with seven choice cards, to reduce the number of cards for each participant, and the choice cards were randomly distributed between blocks. These steps ensured a balanced distribution of factors across the complete list of choice cards.


From this point on, we would like you to consider that your local council is planning to improve infrastructure for pedestrians to encourage walking.

We will ask you to look at seven (7) cards, each showing five (5) areas for improvement to encourage walking (see, choice card 1 below). These areas, for example, may cover physical infrastructure, safety, comfort, etc.

We would like you to weigh up the pros and cons for improving each of these areas.

Then we would like you to choose, which area should be the highest priority and which area should be the lowest priority in each choice card.

Areas underlined with dots have further description once you hover the mouse over them. There are no right or wrong answers to these choices; we are only interested in your own views.

Choice card 1 of 7

Which of the following areas should be **the highest priority** and which of the areas should be **the lowest priority** for your local council to pursue to **encourage walking?**

| Highest priority | | Lowest priority |
|---|---|---|
| ○ | Low traffic or you can avoid walking near high traffic | ○ |
| ○ | Footpaths constructed with top-quality materials | ○ |
| ○ | Flat footpaths with no steep gradients throughout | ○ |
| ○ | Footpaths with dropped kerbs and tactile paving | ○ |
| ○ | Footpaths with street furniture and amenities | ○ |

**Fig. 2.** The introduction screen and an example of a BWS task.

### 3.3. Design of the survey questionnaire

The BWS experiment was part of a quantitative survey questionnaire, comprising five distinct sections: (1) screening questions; (2) BWS experiment; (3) demographic questions; (4) travel behaviour questions; and (5) attitudinal questions. Screening questions for age and gender were set to exclude ineligible participants, meet quota sampling requirements, and ensure a representative sample based on specified age and gender strata.

The BWS choice tasks in the survey commenced with an introductory screen that provided instructions regarding what respondents had to do, along with an illustrative example of a BWS task (see, Fig. 2). As mentioned in the previous section, each choice card showed five factors, asking participants to select one factor as the highest priority and another as the lowest. Participants were required to respond to seven choice cards in total. Following the choice cards, three diagnostic questions were presented to determine the participants' understanding of the experiment, namely whether they: (a) understood the descriptions in the tasks; (b) looked at all the items presented in the cards; and (c) were able to make comparisons and largely informed choices. Participants were also asked to indicate additional demographic characteristics. Travel behaviour questions were designed to identify the significance of using active travel in the respondent's daily life. Finally, the attitudinal questions investigated respondents' attitudes on walking infrastructure, safety, environment, beliefs and travel behaviour on five-point of Likert scale.

### 3.4. Sampling and recruitment of respondents and survey implementation

The study's sample consisted adults aged 18 years or older residing in the UK. Mid-year estimates of the UK population for 2019 showed that walking participation was higher among younger adults, but declined with age, with males and females walking at nearly equal rates (ONS, 2021). In this study, it was assumed that those eligible to participate in the survey were 'able to walk' and in 'good general health' according to the ONS mid-year population estimates for 2019. The corresponding percentages in the UK population - according to self-reported health status - were between 71 % and 75 % in 2019 across the UK, which corresponded to 39,389,138 out of a total of 49,004,533 adults (ONS, 2021) (see Fig. B1 in Appendix B).

The sampling of participants aimed to match the corresponding percentages of those 'able to walk' and in 'good health' using a quota sampling technique stratifying the target population by age and gender into seven strata (Taherdoost, 2016), (see Table 2). Individuals aged 18 to 24 were in the first stratum and those 75 years and older were in the last. Male and female proportions were equal within each stratum.

The survey was administered online in June 2021 using Prolific.co, an online platform for participant recruitment for academic research (Palan & Schitter, 2018). Separate projects were launched for each age stratum, and data from all projects were subsequently combined for analysis.

**Table 2**
Age distribution and sample size over the strata.

| | Male | | Female | | Total |
|---|---|---|---|---|---|
| Age group | *n* | (%) | *n* | (%) | (%) |
| 18–24 | 43 | 11.25 | 43 | 11.25 | 22.5 |
| 25–34 | 35 | 9.05 | 35 | 9.05 | 18.1 |
| 35–44 | 30 | 7.80 | 30 | 7.80 | 15.6 |
| 45–54 | 25 | 6.45 | 25 | 6.45 | 12.9 |
| 55–64 | 23 | 6.05 | 23 | 6.05 | 12.1 |
| 65–74 | 18 | 4.60 | 18 | 4.60 | 9.2 |
| 75 + | 18 | 4.80 | 17 | 4.80 | 9.6 |
| Total | 193 | 50 | 192 | 50 | 100 |

### 3.5. Analytical approach

BWS data can be analysed by calculating scores based on how often a factor *i* is selected as the 'best' and 'worst' across all questions for respondents *n*. These scores can be aggregate (total-level) or disaggregate (individual-level) (Finn & Louviere, 1992; Lee et al., 2007; Mueller & Rungie, 2009).

#### 3.5.1. Aggregate analysis of BWS data: the counting approach

The study analysed priorities for the different walking factors using count analysis to determine their ranking (Aizaki et al., 2015). The best-worst frequency score for each walking factor was calculated as the difference between the number of times a factor was selected as the highest and lowest priority (Louviere et al., 2015). Positive values indicate that a factor was chosen more frequently as the highest priority (Cohen, 2009). The Best-Worst (B—W) aggregated score (BWS scores) was calculated by subtracting the frequency of a factor being chosen as lowest from its frequency as highest (Finn & Louviere, 1992).

The aggregate scores represent the overall ranking of factors across all respondents. If *Bi* represents the frequency of a factor selected as 'best' and *Wi* represents the frequency of a factor selected as 'worst', the aggregate BW score, its standardised version, and the square root of the ratio of *Bi* to *Wi* can be calculated (Aizaki et al., 2015).

$$HL_i = H_i - L_i \tag{1}$$

$$std.HL_i = \frac{HL_i}{Nr} \tag{2}$$

$$sqrt.HL_i = \sqrt{\frac{H_i}{L_i}} \tag{3}$$

$$std.sqrt.HL_i = \frac{sqrt.HL_i}{max.sqrt.HL_i} \tag{4}$$

where *N* is the number of respondents, *r* is the number of times factor *i* appears in the choice cards, and max.$sqrt.HL_i$ is the maximum value of *sqrt.HLi*. The frequency with which item *i* is selected as'highest priority' across all the questions is denoted as $H_i$, and as 'lowest priority'as $L_i$. The counting method for BWS scores involves subtracting the number of times a factor was selected as 'lowest priority' from its 'highest priority' across the choice cards, with each factor's score ranging from +5 to −5.

The standardised *sqrt.HLi* (Eq. (3)) is used in analysing factor importance relative to other factors. The standard deviation (Eq. (4)) is used to identify heterogeneity in respondents' priorities regarding these factors. Heterogeneity was examined by plotting the standard deviation on the y-axis against the mean ofindividual BWS score on the x-axis, providing a graphical representation of the heterogeneity (see, Fig. 6).

#### 3.5.2. Disaggregate analysis: individual BWS scores and modelling BWS choices

The mean of the BWS score indicates how often each factor was chosen as the highest or lowest priority. It is obtained by dividing each factor's BWS scores by the sample size (Mueller & Rungie, 2009).

The Conditional Logit Model (CLM) wasused to estimate a complete ranking of walking factors that can be compared to the BWS scores obtained through counting methods. In a BWS experiment with *m* factors, the number of possible pairs where respondents choose factor *i* as the 'highest priority' and factor *j* as the 'lowest priority' is given by the formula $m \times (m - 1)$, where each factor has a utility ($v$) for each respondent. The utility difference between factors reflects the respondent's highest utility difference. The CLM expresses the probability of choosing *i* as the 'highest priority' factor and *j* as the 'lowest priority' factor (Louviere & Woodworth, 1990), can be expressed as follows:

$$Pr(i,j) = \frac{exp(v_i - v_j)}{\sum_{k=1}^{m} \sum_{l=1, l \neq k}^{m} exp(v_k - v_l)} \tag{5}$$

The denominator in Eq. (5) comprises the summation of all the differences in utility across factors *k* and *l*, that is the pairs of factors. In this study, each BWS card contained five (5) factors. The number of BW possible utility pairs among these five factors was 20, requiring the estimation of a multinomial CLM rather that a logistic regression model.

To estimate the CLM, the utility of one factor and thus its coefficient is arbitrarily set to zero (normalised) so that the model can be identified (Louviere et al., 2015). Therefore, all other coefficients are identified as differences from the coefficient of the normalised factor. The estimated utility (coefficient) of all factors, except the normalised one, can be converted into a "share of preference" for factor i (SPi) based on the CLM rule (Kwon et al., 2020), which reflects the relative importance of factors and aligns with the standardised *sqrt.HLi*.

$$SP_i = \frac{exp(v_i)}{\sum_{j=1}^{m} exp(v_i)} \tag{6}$$

The CLM approach also helps to confirm the theoretical assumption underlying BWS that respondents are utility maximisers, and that their choices were driven by this principle (Louviere et al., 2015). Additionally, the CLM verifies whether each coefficient is statistically different from zero, while estimating the ranking order of each factor on a common scale. The quality of the CLM estimates is assessed by model fit criteria such as the pseudo-R-squareand likelihood ratio tests (Ben-Akiva & Lerman, 1985). The CLM was estimated in R using the 'clogit' function of the R package "Survival" (Therneau, 2024).

## 4. Findings

### 4.1. Sample characteristics

Survey data processing involved pre-analysis checks and cleansing, with 399 responses initially recorded. A pre-screening process identified missing or incomplete data resulting in the exclusion of 13 respondents. Reliability of the BWS choice cards was assessed using the remaining 386 responses by evaluating respondents' understanding of the choice cards viathree diagnostic questions. The study excluded participants who did not understand some descriptions in the cards ($n = 2$), did not look at all the factors in the cards ($n = 11$), or were unable to compare options (n = 1). Participants who did not complete the survey ($n = 5$) or the BWS tasks ($n = 6$) within three standard deviations of the mean completion time were also excluded. In total, 22 participants were excluded (after removing duplicates across criteria), representing 5.7 % of the sample. This aligns with similar studies such as Netten et al. (2012), which accept a range between 5 % and 10 %.

The analysis of the data included 184 (50.5 %) male and 180 (49.5 %) female respondents (see, Table 3), with 38.2 % being married or in civil partnership, 18.1 % cohabiting/living together, and 34.3 % being single. Most respondents held a Bachelor's degree (44.2 %) or high school certificate (38.2 %). Over 38 % worked full-time, 11.8 % part-time, 19 % retired, and 4.7 % were unemployed. Most lived in towns or small cities, with 36.5 % in towns, 24.5 % in suburban areas, and 21.7 % in urban areas.

**Table 3**
Sample characteristics ($n = 364$).

| Gender | Number of participants (%) |
|---|---|
| Males | 184 (50.5) |
| Females | 180 (49.5) |

| Age (years) | Total |
|---|---|
| 18–24 | 85 (23.4) |
| 25–34 | 63 (17.3) |
| 35–44 | 56 (15.4) |
| 45–54 | 48 (13.2) |
| 55–64 | 46 (12.6) |
| 65–74 | 35 (9.6) |
| 75 + | 31 (8.5) |
| | |
| Marital status | |
| Single | 125 (34.3) |
| Cohabiting/living together | 66 (18.1) |
| Married or civil partnership | 139 (38.2) |
| Divorced | 24 (6.6) |
| Widowed | 10 (2.8) |
| | |
| Education level | |
| No education qualification | 3 (0.8) |
| Primary school | 1 (0.3) |
| High school | 139 (38.2) |
| Undergraduate | 161 (44.2) |
| Postgraduate | 60 (16.5) |
| | |
| Employment status | |
| Full time | 140 (38.5) |
| Part time | 43 (11.8) |
| Self-employed (own business) | 23 (6.3) |
| Homemaker | 22 (6.0) |
| Student | 50 (13.7) |
| Retired | 69 (19.0) |
| Unemployed | 17 (4.7) |
| | |
| Area | |
| A big city | 79 (21.7) |
| Suburban | 89 (24.5) |
| Town or small city | 133 (36.5) |
| Country village | 52 (14.3) |
| Farm or home in countryside | 11 (3.0) |

### 4.2. Ability to walk and related attitudes

The study sample comprised participants who indicated they could walk independently (98.6 %) and 1.4 % who needed assistance. The survey asked about walking frequency for more than 10 min and walking to work or education places (see Fig. 3). Nearly two-thirds of respondents (62.9 %) walked at least three times a week, and 30.2 % walked daily. Only 3.3 % never walked for more than 10 min. 43 % never walked to work or education places. However, 29.3 % walked three or more times a week, and 16.4 % daily. Among the 256 respondents who worked or studied, 26 % lived between 1 and 3 miles from their workplace or study location, 23 % lived less than one mile and 20 % lived more than ten miles.

Furthermore, the survey investigated respondents' attitudes on walking infrastructure, safety, environment, beliefs and travel behaviour (see Table 4). The majority of respondents (80 %) believed in the importance of allocating more funds for footpath improvement, with 44.2 % stating that there were not enough convenient pedestrian crossings. Nearly two-thirds of respondents prioritised improving footpath connectivity and access to newly developed areas. Most respondents (80.8 %) considered tprotecting the environment important, with 64 % willing to walk more frequently to reduce air pollution and 66.5 % attempting to walk as a means of transport whenever possible. The study also found that 60.7 % of respondents believed cars were easily accessible.

### 4.3. Public priorities for walking infrastructure investment: The counting approach

The counting approach followed the procedure described in Section 3.5.1. As shown in Table 5 (columns 3–5), the highest priority factors were footpath provision, footpath condition and lighting. Footpath provision (BWS score = 236) was selected 272 times as the highest priority and 36 times as the lowest. "Footpath condition" and "lighting" had BWS scores of 234 and 192, respectively. The least important factors

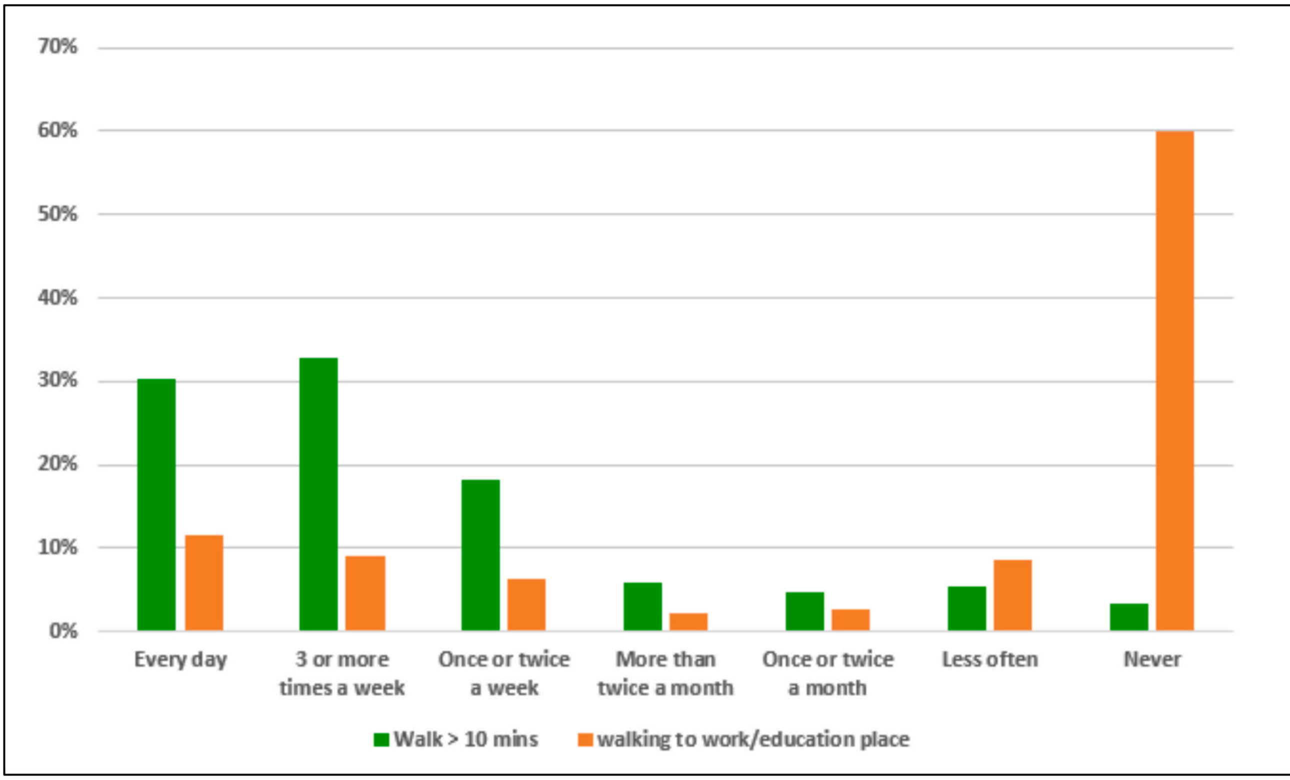



**Fig. 3.** Walking frequency for more than 10 min and walking to work/education.

**Table 4**
Findings from the attitudinal questions.

| | Agree or strongly agree (responses %) |
|---|---|
| Footpath infrastructure | |
| More money should be spent improving footpaths | 80 |
| I would be willing to drive less if there were more footpaths | 32 |
| There are not enough convenient pedestrian road crossings | 44 |
| A top transportation priority should be to improve the connectivity of footpaths | 65 |
| A top transport priority should be to provide improved access to new areas for development | 61 |
| Walking safely | |
| Fears for my personal safety prevent me from walking more often | 36 |
| Adverse weather condition prevents me from walking more often | 66 |
| Environment | |
| Protecting the environment is very important to me | 81 |
| I currently make an effort to walk (as a means of transport) whenever I can | 66 |
| I am willing to walk more frequently to reduce air pollution | 64 |
| Beliefs and travel behaviour | |
| To me, a car is nothing more than a convenient way to get around | 61 |
| I feel that I am wasting time when I have to wait | 57 |
| Traffic congestion is just a way of life and something you learn to live with | 52 |
| Traffic congestion is NOT a major problem for me | 49 |
| For me, car is king! Nothing will replace my car as my main mode of transport | 26 |
| Privacy is important to me when I travel | 51 |
| As long as I am comfortable when traveling, I can tolerate delays | 65 |

were “Gaps in traffic” and “Traffic noise” with BWS scores of −229 and −211, respectively. More participants considered the “Buffer zone” a higher priority (H-L > 0) whereas “Street furniture and amenities” for example was less important (H-L < 0). Factors such as “Air quality”, “Green man time” and “Location of crossings” were in the middle of the scale. These factors were either rarely chosen as highest or lowest priority or were selected as highest and lowest with similar frequency. The BWS scores for the top ten factors ranged between 236 and 18.

Table 5 shows the relative importance of each factor compared to the highest priority factor “Footpath condition” (denoted as 100). The top seven factors were each more than 45 % as likely to be chosen as the highest priority. The relative importance of “Lighting” was 77.7 %, “Traffic speed” 38.5 %, and “Crossings waiting times” only 15.3 %. The probability of choosing “Traffic speed” was about 38.5 % compared to 100% for “Footpath condition” (100 %). The relative importance of “Dropped kerbs and tactile paving”, “Visibility”, “Gradient”, and “Street furniture and amenities” was similar and substantially lower that that of “Footpath condition”. The probabilities of choosing these four factors as important were approximately 25 %.

Fig. 4 plots the square root of the highest-to-lowest priority counts on the y-axis, and the walking factors on the x-axis. As shown in Fig. 4, it is possible not only to observe the order of the factors in terms of their importance but also to compute ‘how many times’ one factor is more (or less) important than another. For example, “Footpath condition” (Sqrt (H/L) = 3.01) is three times more important than “Green man time” (0.98) and approximately 12 times more important than “Gaps in traffic” (0.26). Additionally, “Air quality” (1.09) is twice as important as “Street furniture and amenities” (0.59) and “Walking barriers” (0.49). The top ten factors account for approximately 72.7 % of the variation, whereas the last 11 factors account for only 27.3 %. The range of scores among the last 11 factors differed by only 0.7, suggesting that participants were broadly indifferent to these factors.

The analysis can be extended to investigate priorities for different subgroups within the sample. For example, it is possible to split the sample according to living setting (‘urban/suburban’ vs. ‘town or

**Table 5**
BWS scores for walking factors in the sample.

| Rank | Factors | H | L | H-L | Sqrt (H/L) | Mean of indiv. (H-L) | Stdev. of indiv. (H-L) | Relative importance |
|---|---|---|---|---|---|---|---|---|
| 1 | Footpath provision | 272 | 36 | 236 | 2.75 | 0.65 | 0.129 | 91.4 |
| 2 | Footpath condition | 263 | 29 | 234 | 3.01 | 0.64 | 0.128 | 100.0 |
| 3 | Lighting | 235 | 43 | 192 | 2.34 | 0.53 | 0.105 | 77.7 |
| 4 | Footpath width | 223 | 53 | 170 | 2.05 | 0.47 | 0.093 | 68.1 |
| 5 | Buffer zone | 193 | 34 | 159 | 2.38 | 0.44 | 0.087 | 79.1 |
| 6 | Traffic control devices | 154 | 77 | 77 | 1.41 | 0.21 | 0.042 | 46.8 |
| 7 | Traffic volume | 147 | 78 | 69 | 1.37 | 0.19 | 0.037 | 45.5 |
| 8 | Feel of safety | 126 | 92 | 34 | 1.17 | 0.09 | 0.018 | 38.9 |
| 9 | Traffic speed | 99 | 73 | 26 | 1.16 | 0.07 | 0.014 | 38.5 |
| 10 | Air quality | 112 | 94 | 18 | 1.09 | 0.05 | 0.009 | 36.2 |
| 11 | Green man time | 85 | 89 | −4 | 0.98 | −0.01 | −0.002 | 32.6 |
| 12 | Location of crossings | 83 | 93 | −10 | 0.94 | −0.03 | −0.005 | 31.2 |
| 13 | Dropped kerbs and tactile paving | 69 | 121 | −52 | 0.76 | −0.14 | −0.028 | 25.2 |
| 14 | Visibility | 88 | 147 | −59 | 0.77 | −0.16 | −0.032 | 25.6 |
| 15 | Gradient | 89 | 190 | −101 | 0.68 | −0.28 | −0.055 | 22.6 |
| 16 | Street furniture and amenities | 89 | 195 | −106 | 0.68 | −0.29 | −0.058 | 22.6 |
| 17 | Walking barriers | 64 | 182 | −118 | 0.59 | −0.32 | −0.064 | 19.6 |
| 18 | Footpath materials | 46 | 189 | −143 | 0.49 | −0.39 | −0.078 | 16.3 |
| 19 | Crossings waiting times | 48 | 230 | −182 | 0.46 | −0.50 | −0.100 | 15.3 |
| 20 | Traffic noise | 47 | 258 | −211 | 0.43 | −0.58 | −0.115 | 14.3 |
| 21 | Gaps in traffic | 16 | 245 | −229 | 0.26 | −0.63 | −0.125 | 8.6 |

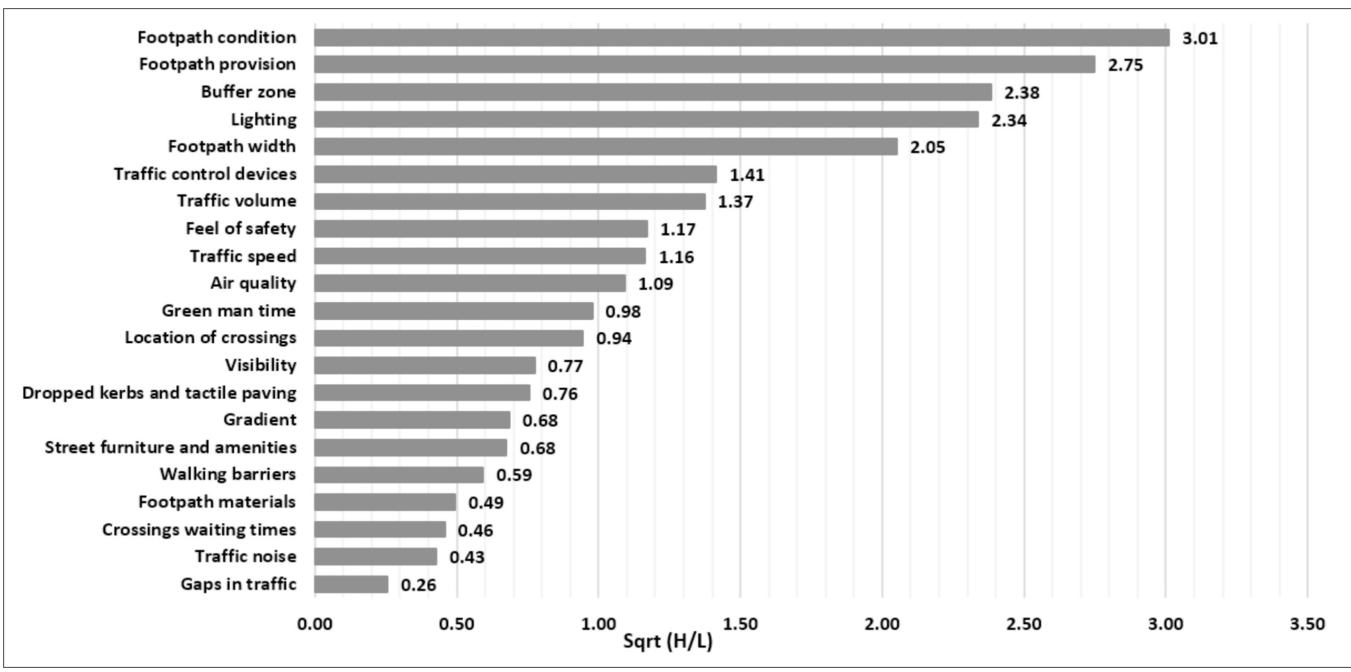



**Fig. 4.** Relative importance of the factors related to walking infrastructure.

smaller') and compute the relative importance of the 21 factors. Appendix C reports the calculation of the relative importance for two groups: those living in an 'urban or suburban' setting and those living in 'towns or smaller areas'. A comparison of the priorities of the whole sample with those of the identified subsamples is shown in Table C3.

### *4.4. Public priorities for walking infrastructure investment: disaggregate analysis*

The mean of the individual BWS scores (Table 5, column 7) was calculated by dividing each BWS score by the sample size (n=364). As shown in Fig. 5, factors more frequently selected as highest rather than lowest appear on the right-hand side with positive BWS scores. The highest priority factor was "Footpath provision" selected 0.75 times as highest and 0.10 times as lowest per respondent, resulting in a net average of 0.65 times. The second highest priority was "Footpath condition", with an average highest priority of 0.64 per respondent.

Additionally, factors more often selected as lowest than highest priority (BWS scores <0) appear on the second half of the vertical axis. The lowest priority factor was "Gaps in traffic", with an average BWS score of −0.63 across its five appearances. Factors in the middle were either rarely selected as highest or lowest, or were chosen as highestand lowest with similar frequency. For example, "Green man time" and "Location of crossings" both had mean BWS scores of −0.01 and −0.03, respectively.

The mean of the individual BWS scores shows that the two most important factors, "Footpath provision" and "Footpath condition", were three times more important than "Traffic control devices". The meanBWS scores for these two factors lie on the right-hand side of the vertical axis (positive side). This means that most participants

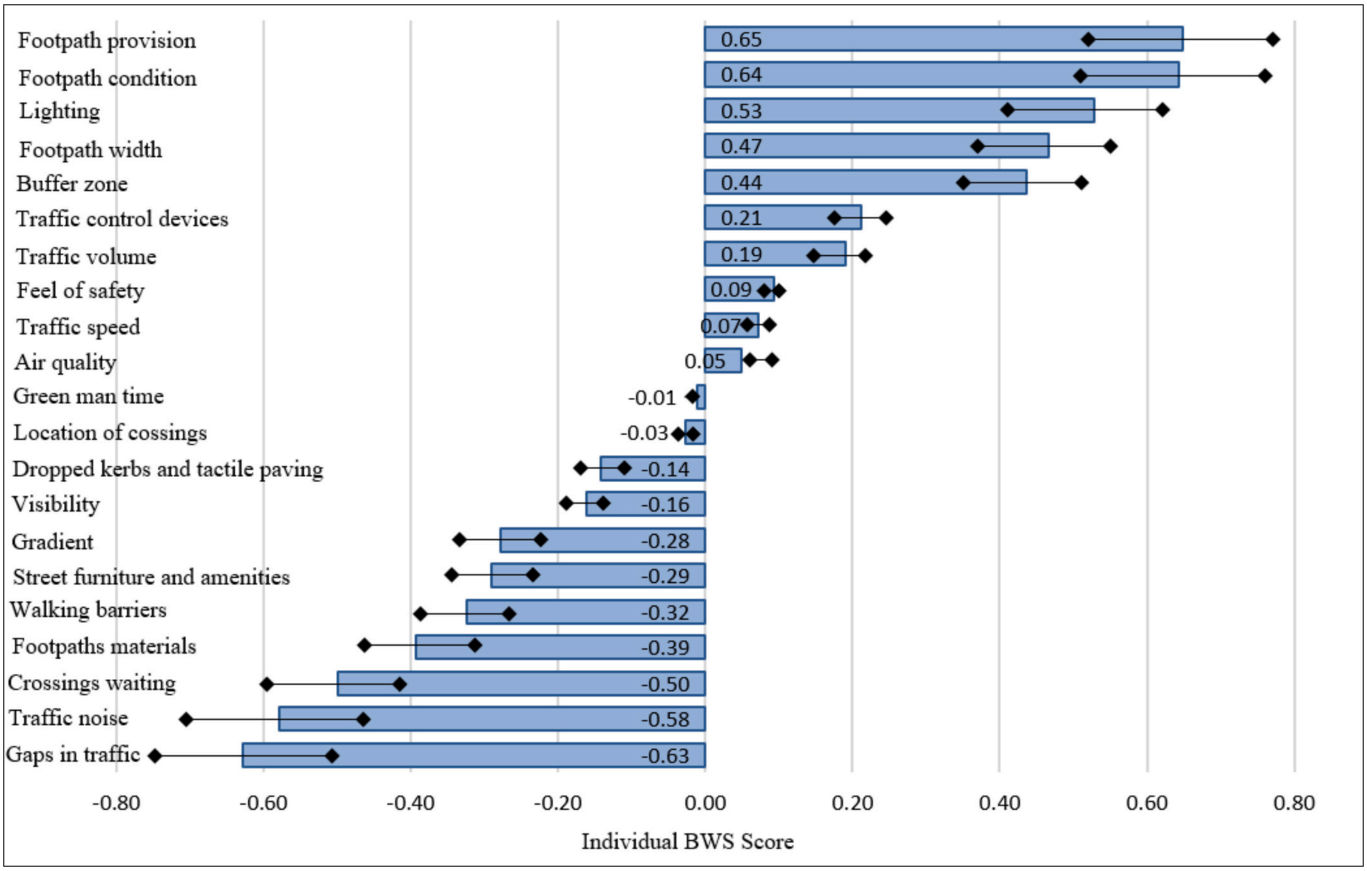



**Fig. 5.** Mean and standard error of the individual BWS scores for each factor.

consistently ranked these two factors as the highest priority whenever they appeared in a choice task. In contrast, most of the mean BWS scores for the lowest- priority factor, “Gaps in traffic”, were on the left side of the vertical axis (negative side), indicating that the majority of participants consistently ranked this factor as the lowest priority whenever it appeared in a choice task. Furthermore, factors with a mean BWS score around zero, such as “Green man time” (−0.01), were almost never chosen as either highest or the lowest priority. In comparison, the heterogeneity in choices of highest and lowest priority for the factor “Air quality” (mean = 0.05) cancelled each other out. The ranking of the factors based on the mean of the individual BWS scores agrees with that of the aggregated ranking.

The mean of the BWS scores shows the ranking of the factors based on their importance to the participants. However, it does not indicate how individual priorities vary in the importance of each factor. For example, the mean of the factors that were in the middle in Fig. 5, such as “Air quality” (mean = 0.05) and “Green man time” (−0.01), could be the consequence of all participants rating them as medium importance or it could be a result of averaging out participants who rated them highly with those who did not, which indicates heterogeneity among the participants (Mueller & Rungie, 2009).

Therefore, the standard deviation was computed to explore the heterogeneity in respondents’ priorities regarding the importance of the factors. Whereas the mean represents the average significance, the standard deviation shows whether the importance of a factor varies across the sample (heterogeneity for the factor) (Mueller & Rungie, 2009). Fig. 5 shows the standard deviation of each factor, represented by a line with two points at each end, indicating one standard deviation around the mean. The line length indicates the proportion of participants with lower or higher individual BWS scores relative to the mean. Factors with a greater standard deviation indicate potential heterogeneity among participants (e.g., traffic noise, and gaps in traffic), with longer lines indicating more variation. A smaller standard deviation suggests greater consensus (e.g., green man time, and location of crossings), while a zero standard deviation indicates total agreement.

The participants’ priorities for the walking factors were also estimated using a CLM. The factor “Gaps in traffic” was normalised to zero (set as a reference factor) as it was the least preferred factor based on the counting analysis and therefore, we would expect all the other factors to have a positive coefficient. As shown in Table 6, most of the factors have statistically significant and positive coefficients.

This means that the twenty factors in the walking experiment, except traffic noise, were significantly more important than ‘Gaps in traffic’, which was the reference factor assigned with a zero coefficient.

The two highest-priority factors, “Footpath provision” (2.170; $p < 0.001$) and “Footpath condition” (2.154, $p < 0.001$), were approximately 9.6 times more important than the lowest priority factor, “Crossing waiting times” (0.224; $p < 0.05$). Furthermore, ’Footpath provision’ and ’Footpath condition’ were about twice as important as the tenth-ranked factor, “Air quality” (1.142 < 0.001). Finally, “Traffic noise” had equal weight to the reference factor because its coefficient did not differ significantly from zero. Overall, the CLM confirms the ranking order of the factors obtained by the counting analysis.

### 4.5. *Exploring heterogeneity*

The relationship between the factors’ mean and the standard deviation can be plotted in a graphical representation (see Fig. 6). Factors such as “Footpath provision”, “Footpath condition”, “Lighting”, and “Footpath width” were of high importance and had low levels of heterogeneity – i.e., higher level agreement across the sample of respondents. Furthermore, factors that exhibited a high degree of

**Table 6**
Conditional logit model estimates for walking-factor priority.

| Rank | Factor | Coef. | Exp (coef.) | Se(coef.) | *p* |
|---|---|---|---|---|---|
| 1 | Footpath provision | 2.170 | 8.756 | 0.101 | *** |
| 2 | Footpath condition | 2.154 | 8.621 | 0.101 | *** |
| 3 | Lighting | 1.974 | 7.203 | 0.101 | *** |
| 4 | Footpath width | 1.833 | 6.254 | 0.100 | *** |
| 5 | Buffer zone | 1.823 | 6.193 | 0.100 | *** |
| 6 | Traffic control devices | 1.408 | 4.089 | 0.098 | *** |
| 7 | Traffic volume | 1.392 | 4.022 | 0.098 | *** |
| 8 | Feel of safety | 1.247 | 3.478 | 0.099 | *** |
| 9 | Traffic speed | 1.203 | 3.332 | 0.098 | *** |
| 10 | Air quality | 1.142 | 3.133 | 0.098 | *** |
| 11 | Green man time | 1.033 | 2.811 | 0.097 | *** |
| 12 | Location of crossings | 1.044 | 2.840 | 0.098 | *** |
| 13 | Dropped kerbs and tactile paving | 0.824 | 2.279 | 0.098 | *** |
| 14 | Visibility | 0.810 | 2.248 | 0.097 | *** |
| 15 | Gradient | 0.597 | 1.817 | 0.096 | *** |
| 16 | Street furniture and amenities | 0.583 | 1.791 | 0.096 | *** |
| 17 | Walking barriers | 0.505 | 1.658 | 0.096 | *** |
| 18 | Footpath materials | 0.403 | 1.497 | 0.096 | *** |
| 19 | Crossings waiting times | 0.224 | 1.251 | 0.096 | ** |
| 20 | Traffic noise | 0.085 | 1.088 | 0.096 | 0.381 |
| 21 | Gaps in Traffic | 0.000 | | Reference | |

Likelihood ratio test vs. null model (df = 20) = 1733, $p < 0.000$, McFadden's-$R^2$ = 0.114.
** $P < 0.05$.
*** $P < 0.001$.

heterogeneity and a reasonable level of importance indicated that they might be essential to a subset of respondents (e.g., vulnerable and older people). In addition, "Air quality" might be important for people with breathing problems and underlying health issues. Factors with low mean BWS scores but with high heterogeneity (standard deviation), such as "Street furniture and amenities" and "Visibility", could be significant in certain places.

## 5. Discussion

The aim of this study was to devise and implement a BWS instrument to elicit public priorities for walking infrastructure investments. The instrument was implemented in the UK. The analysis of the BWS data showed that the highest priority factors for walking infrastructure were: "footpath provision"**,** "footpath condition"**,** "lighting", "footpath width", and "buffer zone". On the other hand, "gaps in traffic", "traffic noise", "crossing waiting time", "walking barriers", and "footpath materials" were the lowest priority relative to the aforementioned factors. The results highlight the importance of safety for pedestrians, as five out of six factors from the safety category were in the top ten priority factors (see, Table 5). In addition, the top ten highest priority factors included two factors from the comfort category (Table 1): "footpath condition" (ranked 2nd) and "footpath width" (ranked 4th). The top ten factors also included one factor from the remaining categories: "footpath provision" (directness category), "traffic control devices" (attractiveness category), and "air quality" (coherence category) ranked first, sixth, and 10th, respectively. The five lowest priority factors were from the directness category ("location of crossings" and "gaps in traffic"), the attractiveness category (walking barriers and footpath materials), and coherence (traffic noise). These findings indicated that priority should be placed on safety and comfort factors for enhancing walking infrastructure.

This study found that pedestrians prioritised safety, namely footpath provision, footpath condition, and lighting as the top priority investments. These findings align with previous studies indicating, for example, that footpath provision fosters a conducive environment for walking, particularly in urban areas (Paudel et al., 2023), and improves access to services, especially for vulnerable people, by offering direct and uninterrupted routes (Rhoads et al., 2023). Also, footpath provision is significantly associated with individuals' walking decisions as they provide a safe and convenient route (Omollo, 2022). Several studies have reported on the significance of footpath provision in promoting walking, such as Nag, Bhaduri, et al. (2020) and Paudel et al. (2023). The second most important factor in this study was well-maintained and level footpaths for walking and pushchairs. Studies have shown that poorly maintained footpaths with uneven surfaces and obstructions do increase accident and injury risks (Advani et al., 2017), particularly for

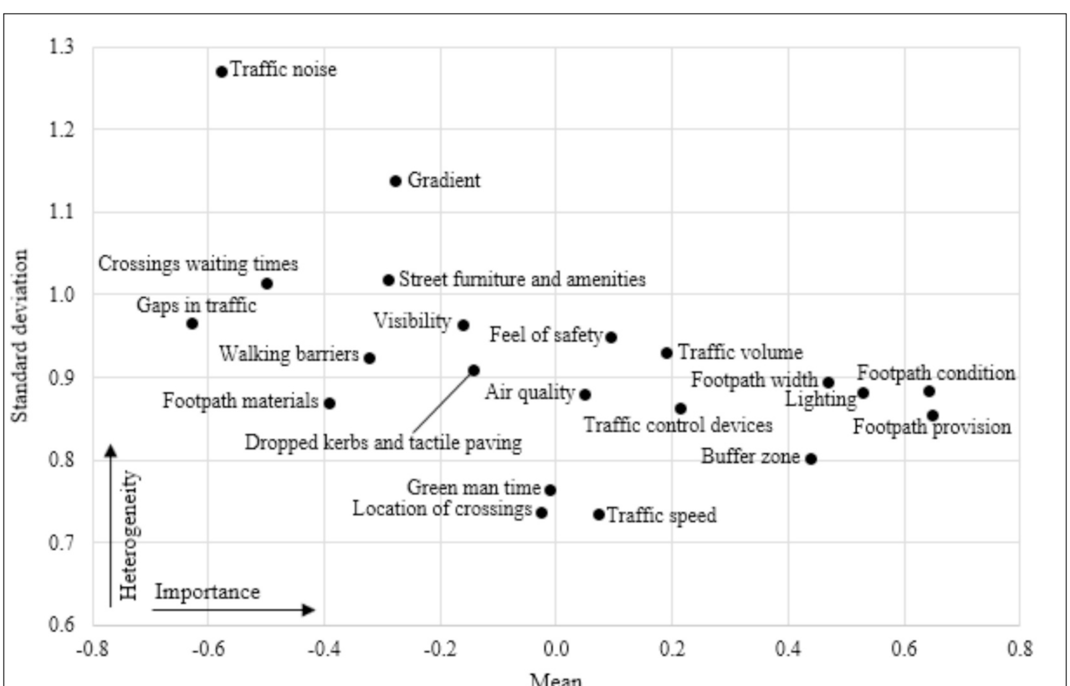



**Fig. 6.** Importance and heterogeneity of walking factors.

the elderly and those with mobility impairments (Cheng, 2014), and negatively impact upon children's active travel to school uptake (Curriero et al., 2013). Finally, footpath conditions significantly encourage walking, as highlighted by various studies, such as Kim et al. (2023), and Das and Maitra (2024).

The availability of lighting along the footpaths was among the top three priorities for pedestrians. This is also in line with Bullough and Skinner (2017) who highlighted the importance of adequate lighting in reducing crime fear and deterring walking (Ferrer et al., 2015), particularly during night-time (Nag, Bhaduri, et al., 2020). Well-lit areas encourage pedestrian activity by making people feeling safe (Das & Maitra, 2024; Kim et al., 2023). Air quality (coherence category) and green man time (directness category) were ranked in the middle of the list, indicating that they were less important relative to most of the safety factors. However, some studies (Chandrappa et al., 2021; Distefano et al., 2023; Tainio et al., 2021; Zheng et al., 2016) have emphasised these factors' importance. These studieseither investigated a single factor or addressed a particular issue (i.e., environment). In addition, some studies indicate that attractiveness factors such as street furniture and amenities, green areas (López-Lambas et al., 2021), signage, and cleanliness (Das & Maitra, 2024) were also key determinants of walking route choice.

The findings indicated that priorities centre on physical infrastructure planning, such as footpath provision, footpath condition, lighting, footpath width, and buffer zones. In contrast, the lowest priorities relate more to subjective perceptions and behaviours, such as crossing waiting times, traffic noise, and gaps in the traffic. These findings suggest that respondents placed greater importance on the construction of walking infrastructure and that councils should adhere to appropriate standards to create walkable environments.

A benefit of using BWS is that the analysis can be extended to examine priorities for different subgroups within the sample. For example, as shown in Table C3 (Appendix C), the sample was split by living setting ('urban/suburban' vs. 'town or smaller'), and the relative importance of the 21 factors was computed for each subgroup. The differences in rankings between the two living settings were minor; however, the overall pattern for the top five and bottom five priorities remained consistent. This suggests that participants from different living environments shared similar perceptions of the walking environment. Similar segmentation can be applied for other subgroups using both counting and modelling methods.

BWS offers a comprehensive and cognitively easier preference elicitation method compared to rating and ranking tasks (Marti, 2012). The advantage of employing BWS experiments is that it requires participants to only choose the extremes - i.e., 'highest priority' and 'lowest priority' from partial sets of a complete list of walking-infrastructure related factors (Louviere et al., 2015), thus achieving exact discrimination of responses. This approach overcomes response biases by requiring respondents to differentiate between items (factors), preventing them from always choosing mid-points, end points, or one end of a scale (Cohen & Markowitz, 2002). Its simplicity and undemanding nature improve data quality (Soutar et al., 2015), overall. For example, if this study had implemented a traditional attitudinal-scale instrument to elicit priorities, it would have been difficult to clearly identify a ranking. Respondents would likely rate almost all 'top-priority' factors with the highest scores (e.g., 10 out of 10) or 'bottom-priority' factors with the lowest scores (e.g., 1 out 10), making it hard to establish a clear priority order. In contrast, by using BWS and its corresponding scores, it has been possible to identify ranking of top-priority factors – namely, footpath provision, footpath condition and lighting – as well as the lowest priority factors, such as crossings waiting times, traffic noise and gaps in traffic. Only a limited number of studies have implemented BWS experiments in the transport literature. This study together with its qualitative validation (Albahlal et al., 2024) provides detailed guidance on how to design and implement a BWS and reports on an instrument that can be adapted for use in other country/contexts.

This study also provides new empirical knowledge on identifying and classifying pedestrian needs such as safety, directness, attractiveness, cohesion, and comfort. Although these factors are used to assess infrastructure quality, few have been converted into a preference-based elicitation instruments to identify priorities as citizens view them. The study developed a survey-based BWS instrument to capture individuals' priorities for walking, using a less cognitively burdensome method. It provides guidance on validating a BWS experiment and implementing this approach to gauge fine-grained evidence from personal interviews (see, also Albahlal et al., 2024).

It is also worth highlight that this study faced some challenges. Firstly, the COVID-19 pandemic heavily impacted the data collection campaign. However, this issue was addressed using an online panel for recruitment, and with the BWS instrument being heavily tested for its internal validity prior to the main fieldwork. To ensure a representative sample, quotas were specified against age groups and gender to match the general population profile in the UK. Moreover, several diagnostic questions were included in survey questionnaires to capture respondents' understanding of the BWS tasks. In addition, the BWS experiment was developed using audit tools to measure infrastructure quality, with the aim of helping local governments prioritise funding with an evidence-based, user-informed instrument. Therefore, this study focused only on tool-related factors; however, other factors, such as seasonal variations, may influence respondents' priorities and perceptions towards walking. Future studies might consider including weather as an attribute or compare responses obtained in the summer vs. winter months.

## 6. Conclusion

This study contributes to knowledge pertaining to the promotion of walking as a mode of transport by identifying priorities for walking-infrastructure investments. In a climate of limited financial resources, this study provides a preference elicitation instrument that allows decision-makers to identify the key pressing areas where funding for walking infrastructure would need to be prioritised in the UK. The findings of this identified public priorities for infrastructure improvements in the UK, highlighting the need for urban planners and policy-makers to prioritise funding allocation for walking uptake. These findings provide evidence-based guidance for local authorities to invest in active travel infrastructure, emphasising the importance of responsiveness to user needs, strengthening democracy, and fostering pedestrian-friendly environments.

In this study, 21 walking investment-relevant factors were developed and embedded into a BWS survey instrument. These factors can also be tested at local and regional levels across the UK (England vs. Scotland vs. Wales) or any other country, including comparisons between urban and town centres, to inform infrastructure investment priorities. Most importantly, the BWS instrument is free from contextual and cultural biases; thus, it can be implemented by local authorities in different countries (Flynn & Marley, 2014). Further, the BWS instrument is not a one-off exercise but rather provides an efficient and useful tool to monitor citizens' priorities for active travel infrastructure development. To the authors' knowledge, this is one of the first studies to implement BWS experiments in active travel research, and provides a robust empirical framework and methodology for developing internally valid, and implementing BWS experiments (see also, Albahlal et al., 2024; Larranaga et al., 2019).

This study developed a framework for assessing priorities for active travel infrastructure investment, based on a thorough review of existing literature, synthesis of audit tools for walking infrastructure, and the development of a robust BWS instrument. The instrument can be used to gather empirical data from the public to elicit priorities for walking infrastructure investments. Moreover, future research may tailor the experiment to a specific road or area, where certain factors may be unrelated or new factors may need to be included in conjunction with local authorities.

## CRediT authorship contribution statement

**Fahad Albahlal:** Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Dimitris Potoglou:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

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## Declaration of competing interest

The authors have declared no conflict of interest.

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## Appendix A

```
> set.seed(123)
> find.BIB(t=21, k=5, b=21)
      [,1] [,2] [,3] [,4] [,5]
 [1,]    1    6   12   16   19
 [2,]    5   15   16   20   21
 [3,]    3    5    6    7   18
 [4,]    4    7   10   11   16
 [5,]    1    2    3   10   20
 [6,]    3    4   13   19   21
 [7,]    4    6    8   17   20
 [8,]    2    7    8   15   19
 [9,]    2    6   11   14   21
[10,]    2   13   16   17   18
[11,]    5   10   14   17   19
[12,]    8   10   12   18   21
[13,]    3   11   12   15   17
[14,]    2    4    5    9   12
[15,]    1    5    8   11   13
[16,]    1    7    9   17   21
[17,]    6    9   10   13   15
[18,]    7   12   13   14   20
[19,]    9   11   18   19   20
[20,]    3    8    9   14   16
[21,]    1    4   14   15   18
> isGYD(bibd)

[1] The design is a balanced incomplete block
 design w.r.t. rows.
```

**Fig. A1.** The balanced incomplete blocked design.

## Appendix B

The required sample size, n, was calculated using a 95 % confidence level and a 5 % margin of error, resulting in 385 participants (Charan & Biswas, 2013):

$$n = \frac{\frac{Z^2 \times \mathrm{P}\ (1-\mathrm{P})}{e^2}}{1+\left(\frac{Z^2 \times \mathrm{P}\ (1-\mathrm{P})}{e^2 N}\right)} = \frac{\frac{1.96^2 \times 0.5\ (1-0.5)}{0.05^2}}{1+\left(\frac{1.96^2 \times 0.5\ (1-0.5)}{0.05^2 39{,}389{,}138}\right)} = \frac{\frac{3.8416 \times 0.25}{0.0025}}{1+\left(\frac{3.8416 \times 0.25}{98{,}472.845}\right)} = \frac{384.16}{1.00} = 384.16$$

where: $Z$ is the z-score, P is the standard of deviation, $e$ the margin of error and N the population size.

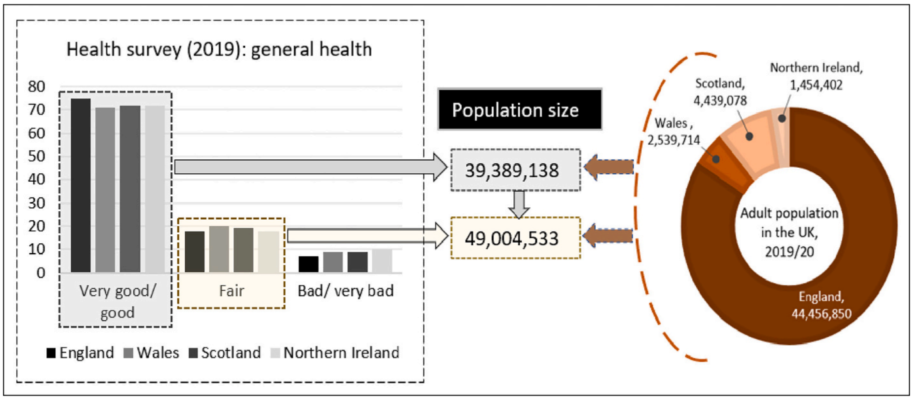


**Fig. B1.** The population size based on general health (Source: ONS, 2021).

## Appendix C

**Table C1**
BWS scores for walking factors based on Living Setting: Urban/Suburban.

| Rank | Factors | H | L | H-L | Sqrt (H/L) | Relative importance |
|---|---|---|---|---|---|---|
| 1 | Footpath provision | 113 | 17 | 96 | 2.58 | 69.5 |
| 2 | Footpath condition | 124 | 9 | 115 | 3.71 | 100 |
| 3 | Lighting | 114 | 22 | 92 | 2.28 | 61.3 |
| 4 | Footpath width | 99 | 24 | 75 | 2.03 | 54.7 |
| 5 | Buffer zone | 85 | 12 | 73 | 2.66 | 71.7 |
| 6 | Traffic control devices | 75 | 36 | 39 | 1.44 | 38.9 |
| 7 | Traffic volume | 70 | 39 | 31 | 1.34 | 36.1 |
| 8 | Feel of safety | 51 | 43 | 8 | 1.09 | 29.3 |
| 9 | Traffic speed | 51 | 35 | 16 | 1.21 | 32.5 |
| 10 | Air quality | 59 | 44 | 15 | 1.16 | 31.2 |
| 11 | Green man time | 32 | 46 | −14 | 0.83 | 22.5 |
| 12 | Location of crossings | 32 | 47 | −15 | 0.83 | 22.2 |
| 13 | Dropped kerbs and tactile paving | 40 | 56 | −16 | 0.85 | 22.8 |
| 14 | Visibility | 42 | 66 | −24 | 0.80 | 21.5 |
| 15 | Gradient | 36 | 82 | −46 | 0.66 | 17.9 |
| 16 | Street furniture and amenities | 45 | 88 | −43 | 0.72 | 19.3 |
| 17 | Walking barriers | 29 | 87 | −58 | 0.58 | 15.6 |
| 18 | Footpath materials | 28 | 85 | −57 | 0.57 | 15.5 |
| 19 | Crossings waiting times | 24 | 105 | −81 | 0.48 | 12.9 |
| 20 | Traffic noise | 22 | 116 | −94 | 0.44 | 11.7 |
| 21 | Gaps in traffic | 5 | 117 | −112 | 0.21 | 5.6 |

**Table C2**
BWS scores for walking factors based on Living Setting: Town or Smaller.

| Rank | Factors | H | L | H-L | Sqrt (H/L) | Relative importance |
|---|---|---|---|---|---|---|
| 1 | Footpath provision | 159 | 19 | 140 | 2.89 | 100 |
| 2 | Footpath condition | 139 | 20 | 119 | 2.64 | 91.1 |
| 3 | Lighting | 121 | 21 | 100 | 2.40 | 83.0 |
| 4 | Footpath width | 124 | 29 | 95 | 2.07 | 71.5 |
| 5 | Buffer zone | 108 | 22 | 86 | 2.22 | 76.6 |
| 6 | Traffic control devices | 79 | 41 | 38 | 1.39 | 48.0 |
| 7 | Traffic volume | 77 | 39 | 38 | 1.41 | 48.6 |
| 8 | Feel of safety | 75 | 49 | 26 | 1.24 | 42.8 |
| 9 | Traffic speed | 48 | 38 | 10 | 1.12 | 38.9 |
| 10 | Air quality | 53 | 50 | 3 | 1.03 | 35.6 |
| 11 | Green man time | 53 | 43 | 10 | 1.11 | 38.4 |
| 12 | Location of crossings | 51 | 46 | 5 | 1.05 | 36.4 |
| 13 | Dropped kerbs and tactile paving | 29 | 65 | −36 | 0.67 | 23.1 |
| 14 | Visibility | 46 | 81 | −35 | 0.75 | 26.1 |
| 15 | Gradient | 53 | 108 | −55 | 0.70 | 24.2 |
| 16 | Street furniture and amenities | 44 | 107 | −63 | 0.64 | 22.2 |

(*continued on next page*)

**Table C2** (*continued*)

| Rank | Factors | H | L | H-L | Sqrt (H/L) | Relative importance |
|---|---|---|---|---|---|---|
| 17 | Walking barriers | 35 | 95 | −60 | 0.61 | 21.0 |
| 18 | Footpath materials | 18 | 104 | −86 | 0.42 | 14.4 |
| 19 | Crossings waiting times | 24 | 125 | −101 | 0.44 | 15.1 |
| 20 | Traffic noise | 25 | 142 | −117 | 0.42 | 14.5 |
| 21 | Gaps in traffic | 11 | 128 | −117 | 0.29 | 10.1 |

**Table C3**
Comparison walking-investment infrastructure priorities by living setting.

| No. | Factors | Relative importance | | | Ranking | | |
|---|---|---|---|---|---|---|---|
| | | Total | Urban /Suburban | Town or smaller | Total | Urban /Suburban | Town or smaller |
| 1 | Footpath condition | 100 | 100 | 91.1 | 1 | 1 | 2 |
| 2 | Footpath provision | 91.4 | 69.5 | 100 | 2 | 3 | 1 |
| 3 | Footpath width | 79.1 | 71.7 | 76.6 | 3 | 2 | 4 |
| 4 | Lighting | 77.7 | 61.3 | 83 | 4 | 4 | 3 |
| 5 | Buffer zone | 68.1 | 54.7 | 71.5 | 5 | 5 | 5 |
| 6 | Traffic volume | 46.8 | 38.9 | 48 | 6 | 6 | 7 |
| 7 | Traffic control devices | 45.5 | 36.1 | 48.6 | 7 | 7 | 6 |
| 8 | Feel of safety | 38.9 | 29.3 | 42.8 | 8 | 10 | 8 |
| 9 | Traffic speed | 38.5 | 32.5 | 38.9 | 9 | 8 | 9 |
| 10 | Location of crossings | 36.2 | 31.2 | 35.6 | 10 | 9 | 12 |
| 11 | Air quality | 32.6 | 22.5 | 38.4 | 11 | 12 | 10 |
| 12 | Green man time | 31.2 | 22.2 | 36.4 | 12 | 13 | 11 |
| 13 | Dropped kerbs and tactile paving | 25.6 | 21.5 | 26.1 | 13 | 14 | 13 |
| 14 | Gradient | 25.2 | 22.8 | 23.1 | 14 | 11 | 15 |
| 15 | Street furniture and amenities | 22.6 | 19.3 | 22.2 | 15 | 15 | 16 |
| 16 | Visibility | 22.6 | 17.9 | 24.2 | 16 | 16 | 14 |
| 17 | Walking barriers | 19.6 | 15.6 | 21 | 17 | 17 | 17 |
| 18 | Traffic noise | 16.3 | 15.5 | 14.4 | 18 | 18 | 20 |
| 19 | Footpath materials | 15.3 | 12.9 | 15.1 | 19 | 19 | 18 |
| 20 | Crossings waiting times | 14.3 | 11.7 | 14.5 | 20 | 20 | 19 |
| 21 | Gaps in traffic | 8.6 | 5.6 | 10.1 | 21 | 21 | 21 |

## Data availability

The authors do not have permission to share data.

## References


Adamsen, J. M., Rundle-Thiele, S., & Whitty, J. A. (2013). Best-worst scaling: Reflections on presentation, analysis, and lessons learnt from case 3 BWS experiments. *Market & Social Research, 21*(1), 9–27.

Advani, M., Parida, P., & Parida, M. (2017). Methodology for evaluating walking facilities based types of obstructions observed on footpath of Indian roads. *Transportation Research Procedia, 25*, 5282–5290. https://doi.org/10.1016/j.trpro.2018.02.054

Aizaki, H., Nakatani, T., & Sato, K. (2015). *Stated preference methods using R.* Taylor & Francis Group.

Albahlal, F., Haggar, P., & Potoglou, D. (2024). Eliciting citizens' priorities for active travel infrastructure investments: A qualitative analysis of best-worst scaling experiments. *Journal of Transport and Health, 36*. https://doi.org/10.1016/j.jth.2024.101795

Alipour, D., & Dia, H. (2023). A systematic review of the role of land use, transport, and energy-environment integration in shaping sustainable cities. *Sustainability (Switzerland), 15*(8). https://doi.org/10.3390/su15086447

AlKheder, S., Alkandriy, F., Alkhames, Z., Habeeb, M., Alenezi, R., & Al Kader, A. (2022). Walkability, risk perception and safety assessment among urban college pedestrians in Kuwait. *Transportation Research Part F: Traffic Psychology and Behaviour, 86*, 10–32. https://doi.org/10.1016/j.trf.2022.02.003

Aumann, P., & Arnold, T. (2017). *Guide to road design: Part 6A, Paths for walking and cycling.* Austroads.

Beatty, P. C., & Willis, G. B. (2007). Research synthesis: The practice of cognitive interviewing. *Public Opinion Quarterly, 71*(2), 287–311. https://doi.org/10.1093/poq/nfm006

Ben-Akiva, M. E., & Lerman, S. R. (1985). *Discrete choice analysis: Theory and application to travel demand.* Cambridge, MA: MIT Press.

Benton, J. S., Jennings, G., Walker, J., & Evans, J. (2023). "Walking is our asset": How to retain walking as a valued mode of transport in African cities. *Cities, 137*, 104297. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0264275123001099.

Bullough, J. D., & Skinner, N. P. (2017). Real-world demonstrations of novel pedestrian crosswalk lighting. *Transportation Research Record, 2661*, 62–68. https://doi.org/10.3141/2661-07

Cerin, E., Chan, K., Macfarlane, D. J., Lee, K., & Lai, P. (2011). Objective assessment of walking environments in ultra-dense cities: Development and reliability of the Environment in Asia Scan Tool — Hong Kong version (EAST-HK). *Health & Place, 17*(4), 937–945. Available at: https://doi.org/10.1016/j.healthplace.2011.04.005.

Chandrappa, A. K., Bhattacharyya, K., & Maitra, B. (2021). Measures for improving pedestrian crossing facilities based on perceptions of urban commuters: An experience in Kolkata. *Case Studies on Transport Policy, 9*(2), 965–973. https://doi.org/10.1016/j.cstp.2021.04.017

Charan, J., & Biswas, T. (2013). How to calculate sample size for different study designs in medical research? *Indian Journal of Psychological Medicine, 35*(2), 121–126. https://doi.org/10.4103/0253-7176.116232

Cheng, T.-J. (2014). *Use of gaze and gait analysis to assess the effect of footway environmental factors on older pedestrians' accessibility*.

Chowdhury, S., Hadas, Y., Gonzalez, V. A., & Schot, B. (2018). Public transport users' and policy makers' perceptions of integrated public transport systems. *Transport Policy, 61*, 75–83. https://doi.org/10.1016/j.tranpol.2017.10.001

Clifton, K. J., Livi, D., & Rodriguez, D. (2007). The development and testing of an audit for the pedestrian environment. *Landscape and Urban Planning, 80*(1–2), 95–110. https://doi.org/10.1016/j.landurbplan.2006.06.008

Cohen, E. (2009). Applying best-worst scaling to wine marketing. *International Journal of Wine Business Research, 21*(1), 8–23. https://doi.org/10.1108/17511060910948008

Cohen, S., & Markowitz, P. (2002). *Renewing market segmentation: Some new tools to correct old problems. Amsterdam* (pp. 595–612).

Curriero, F. C., James, N. T., Shields, T. M., Roman, C. G., Furr-Holden, C. D. M., Cooley-Strickland, M., & Pollack, K. M. (2013). Exploring walking path quality as a factor for urban elementary school children's active transport to school. *Journal of Physical Activity and Health, 10*(3), 323–334. https://doi.org/10.1123/jpah.10.3.323

Das, P., & Maitra, S. (2024). Priority areas of intervention for improving pedestrian infrastructure and facilities at tourist destinations in India. *Transport Policy, 145*, 126–136. https://doi.org/10.1016/j.tranpol.2023.10.018

Day, K., Boarnet, M., Alfonzo, M., & Forsyth, A. (2006). The Irvine-Minnesota inventory to measure built environments: Development. *American Journal of Preventive Medicine, 30*(2), 144–152. https://doi.org/10.1016/j.amepre.2005.09.017

Distefano, N., Leonardi, S., & Liotta, N. G. (2023). Walking for sustainable cities: Factors affecting users' willingness to walk. *Sustainability (Switzerland), 15*(7). https://doi.org/10.3390/su15075684

Farrell, K. (2017). The rapid urban growth triad: A new conceptual framework for examining the urban transition in developing countries. *Sustainability (Switzerland), 9*(8). https://doi.org/10.3390/su9081407

Ferrer, S., Ruiz, T., & Mars, L. (2015). A qualitative study on the role of the built environment for short walking trips. *Transportation Research Part F: Traffic Psychology and Behaviour, 33*, 141–160. https://doi.org/10.1016/j.trf.2015.07.014

Finn, A., & Louviere, J. J. (1992). Determining the appropriate response to evidence of public concern: The case of food safety. *Journal of Public Policy & Marketing, 11*(2), 12–25. https://doi.org/10.1177/074391569201100202

Flynn, T. N., & Marley, A. A. J. (2014). Best- worst scaling: Theory and methods. In S. Hess, & A. Daly (Eds.), *Handbook of choice modelling* (pp. 178–201). Cheltenham, UK: Edward Elgar Publishing Limited.

Garrard, J., Rose, G., & Lo, S. K. (2008). Promoting transportation cycling for women: The role of bicycle infrastructure. *Preventive Medicine, 46*(1), 55–59. https://doi.org/10.1016/j.ypmed.2007.07.010

Gehl, J. (2010). *Cities for people*. Washington, D.C.: Island Press.

Guo, X., Angulo, A., Tavakoli, A., Robartes, E., Chen, T. D., & Heydarian, A. (2023). Rethinking infrastructure design: Evaluating pedestrians and VRUs' psychophysiological and behavioral responses to different roadway designs. *Scientific Reports, 13*(1). https://doi.org/10.1038/s41598-023-31041-9

Guzman, L. A., Arellana, J., & Castro, W. F. (2022). Desirable streets for pedestrians: Using a street-level index to assess walkability. *Transportation Research Part D: Transport and Environment, 111*. https://doi.org/10.1016/j.trd.2022.103462

HCM. (2000). *Highway capacity manual*. Transportation Research Board, National Research Council.

Heo, C. Y., Kim, B., Park, K., & Back, R. M. (2022). A comparison of best-worst scaling and likert scale methods on peer-to-peer accommodation attributes. *Journal of Business Research, 148*, 368–377. https://doi.org/10.1016/j.jbusres.2022.04.064

Hidayat, B., & Sari, N. (2020). Accessibility and connectivity concept between motorcycles and pedestrians at education district. In *IOP conference series: Earth and environmental science*. Institute of Physics Publishing. https://doi.org/10.1088/1755-1315/501/1/012044.

Jacobsen, P. L., Racioppi, F., & Rutter, H. (2009). Who owns the roads? How motorised traffic discourages walking and bicycling. *Injury Prevention, 15*(6), 369–373. https://doi.org/10.1136/ip.2009.022566

Josephine, M., Abiero, G., & Micah, M. (2021). The impact of street layout design on non-motorized activities with Nairobi City, Kenya. *Current Urban Studies, 09*(02), 252–278. https://doi.org/10.4236/cus.2021.92017

Kadali, B. R., & Vedagiri, P. (2016). Review of pedestrian level of service: Perspective in developing countries. *Transportation Research Record, 2581*, 37–47. https://doi.org/10.3141/2581-05

Kim, Y., Choi, B., Choi, M., Ahn, S., & Hwang, S. (2023). Enhancing pedestrian perceived safety through walking environment modification considering traffic and walking infrastructure. *Frontiers in Public Health, 11*. https://doi.org/10.3389/fpubh.2023.1326468

Krambeck, H., & Shah, J. (2006). *The global walkability index: Talk the walk and walk the talk*.

Kuddus, M. A., Tynan, E., & McBryde, E. (2020). Urbanization: A problem for the rich and the poor? *Public Health Reviews, 41*(1). https://doi.org/10.1186/s40985-019-0116-0

Kwon, Y., Kim, S., Kim, H., & Byun, J. (2020). What attributes do passengers value in electrified buses? *Energies, 13*(10). https://doi.org/10.3390/en13102646

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

Lee, J. A., Soutar, G. N., & Louviere, J. (2007). Measuring values using best-worst scaling: The LOV example. *Psychology & Marketing, 24*(12), 1043–1058. https://doi.org/10.1002/mar

Lee, S., Han, M., Rhee, K., & Bae, B. (2021). Identification of factors affecting pedestrian satisfaction toward land use and street type. *Sustainability (Switzerland), 13*(19). https://doi.org/10.3390/su131910725

Leyden, K. M. (2003). Social capital and the built environment: The importance of walkable neighborhoods. *American Journal of Public Health, 93*(9), 1546–1551. https://doi.org/10.2105/AJPH.93.9.1546

Lima, J. P., & Machado, M. H. (2019). Walking accessibility for individuals with reduced mobility: A Brazilian case study. *Case Studies on Transport Policy, 7*(2), 269–279. https://doi.org/10.1016/j.cstp.2019.02.007

López-Lambas, M. E., Sánchez, J. M., & Alonso, A. (2021). The walking health: A route choice model to analyze the street factors enhancing active mobility. *Journal of Transport and Health, 22*. https://doi.org/10.1016/j.jth.2021.101133

Louviere, J. J., Flynn, T. N., & Marley, A. A. J. (2015). *BEST-WORST SCALING: Theory, methods and applications*. Cambridge: Cambridge University Press.

Louviere, J. J., & Woodworth, G. G. (1990). *Best-worst scaling: A model for largest difference judgment*.

Marti, J. (2012). A best-worst scaling survey of adolescents' level of concern for health and non-health consequences of smoking. *Social Science & Medicine, 75*(1), 87–97. Available at: https://doi.org/10.1016/j.socscimed.2012.02.024.

Mateo-Babiano, I. (2016). Pedestrian's needs matters: Examining Manila's walking environment. *Transport Policy, 45*, 107–115. https://doi.org/10.1016/j.tranpol.2015.09.008

Millington, C., Ward Thompson, C., Rowe, D., Aspinall, P., Fitzsimons, C., Nelson, N., & Mutrie, N. (2009). Development of the Scottish walkability assessment tool (SWAT). *Health & Place, 15*(2), 474–481. Available at: https://linkinghub.elsevier.com/retrieve/pii/S1353829208000968.

Mitra, R., et al. (2020). Healthy movement behaviours in children and youth during the COVID-19 pandemic: Exploring the role of the neighbourhood environment. *Health and Place, 65*. https://doi.org/10.1016/j.healthplace.2020.102418

MTO. (2014). *BIKEWAYS DESIGN MANUAL*. Ontario, Canada: Ministry of Transportation.

Mueller, S., & Rungie, C. (2009). Is there more information in best-worst choice data?: Using the attitude heterogeneity structure to identify consumer segments. *International Journal of Wine Business Research, 21*(1), 24–40. https://doi.org/10.1108/17511060910948017

Nabors, D., Gibbs, M., Sandt, L., Rocchi, S., Wilson, E., & Lipinski, M. (2007). Pedestrian road safety audit guidelines and prompt lists. Washington, DC. Available at: https://rosap.ntl.bts.gov/view/dot/42593.

Nag, D., Bhaduri, E., Kumar, G. P., & Goswami, A. K. (2020). Assessment of relationships between user satisfaction, physical environment, and user behaviour in pedestrian infrastructure. *Transportation Research Procedia.*, 2343–2363. https://doi.org/10.1016/j.trpro.2020.08.284. Elsevier B.V.

Nagraj, R., & Vedagiri, P. (2013). Modeling pedestrian delay and level of service at signalized intersection crosswalks under mixed traffic conditions. *Transportation Research Record, 2394*, 70–76. https://doi.org/10.3141/2394-09

Netten, A., et al. (2012). Outcomes of social care for adults: Developing a preference-weighted measure. *Health Technology Assessment, 16*(16).

Nuworsoo, C., & Cooper, E. (2013). Considerations for integrating bicycling and walking facilities into urban infrastructure. *Transportation Research Record, 2393*, 125–133. https://doi.org/10.3141/2393-14

Omollo, W. O. (2022). Planning for non-motorised transport: Provision of footpaths as public spaces in Kisii town, Kenya. *Town and Regional Planning, 80*(1). https://doi.org/10.18820/2415-0495/trp80i1.5

ONS. (2021). Mid-year population estimates. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/latest. (Accessed 19 January 2022).

Palan, S., & Schitter, C. (2018). Prolific.ac — A subject pool for online experiments. *Journal of Behavioral and Experimental Finance, 17*, 22–27. Available at: https://doi.org/10.1016/j.jbef.2017.12.004.

Patil, M., Majumdar, B. B., & Sahu, P. K. (2021). Evaluating pedestrian crash-prone locations to formulate policy interventions for improved safety and walkability at sidewalks and crosswalks. *Transportation Research Record, 2675*(9), 675–689. https://doi.org/10.1177/03611981211004127

Paudel, C., Timperio, A., Loh, V., Deforche, B., Salmon, J., & Veitch, J. (2023). Understanding the relative importance of micro-level design characteristics of walking paths in parks to promote walking among older adults. *Urban Forestry and Urban Greening, 89*. https://doi.org/10.1016/j.ufug.2023.128129

Paulhus, D. L. (1991). Measurement and control of response bias. In *Measures of Personality and Social Psychological Attitudes* (pp. 17–59). Elsevier. https://doi.org/10.1016/B978-0-12-590241-0.50006-X.

Pikora, T. J., Bull, F. C. L., Jamrozik, K., Knuiman, M., Giles-Corti, B., & Donovan, R. J. (2002). Developing a reliable audit instrument to measure the physical environment for physical activity. *American Journal of Preventive Medicine, 23*(3), 187–194. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12350451.

R Core Team. (2020). R: A language and environment for statistical computing. Available at: https://www.r-project.org/. (Accessed 18 May 2020).

Raad, N., & Burke, M. I. (2018). What are the most important factors for pedestrian level-of-service estimation? A systematic review of the literature. *Transportation Research Record, 2672*(35), 101–117. https://doi.org/10.1177/0361198118790623

Rahul, T. M., & Manoj, M. (2020). Categorization of pedestrian level of service perceptions and accounting its response heterogeneity and latent correlation on travel decisions. *Transportation Research Part A: Policy and Practice, 142*, 40–55. https://doi.org/10.1016/j.tra.2020.10.011

Rhoads, D., Solé-Ribalta, A., & Borge-Holthoefer, J. (2023). The inclusive 15-minute city: Walkability analysis with sidewalk networks. *Computers, Environment and Urban Systems, 100*. https://doi.org/10.1016/j.compenvurbsys.2022.101936

Ryan, D. J., & Hill, K. M. (2022). Public perceptions on the role of wayfinding in the promotion of recreational walking routes in greenspace—Cross-sectional survey. *Wellbeing, Space and Society, 3*. https://doi.org/10.1016/j.wss.2022.100111

Sailer, O. (2005). *crossdes A package for design and randomization in crossover studies*. Available at: http://www.

Sallis, J. F., Bull, F., Burdett, R., Frank, L. D., Griffiths, P., Giles-Corti, B., & Stevenson, M. (2016). Use of science to guide city planning policy and practice: How to achieve healthy and sustainable future cities. *The Lancet, 388*(10062), 2936–2947. https://doi.org/10.1016/S0140-6736(16)30068-X

Schuster, A. L. R., Crossnohere, N. L., Campoamor, N. B., Hollin, I. L., & Bridges, J. F. P. (2024). The rise of best-worst scaling for prioritization: A transdisciplinary literature review. *Journal of Choice Modelling, 50*. https://doi.org/10.1016/j.jocm.2023.100466

Soutar, G. N., Sweeney, J. C., & McColl-Kennedy, J. R. (2015). Best-worst scaling: An alternative to ratings data. In J. J. Louviere, T. N. Flynn, & A. A. J. Marley (Eds.), *BEST-WORST SCALING: Theory, methods and applications* (pp. 177–187). Cambridge: Cambridge University Press.

Sun, G., Webster, C., & Chiaradia, A. (2017). Objective assessment of station approach routes: Development and reliability of an audit for walking environments around metro stations in China. *Journal of Transport and Health, 4*, 191–207. https://doi.org/10.1016/j.jth.2017.01.010

Taherdoost, H. (2016). Sampling methods in research methodology; how to choose a sampling technique for research. *International Journal of Academic Research in Management, 5*(2), 18–27.

Tainio, M., et al. (2021). Air pollution, physical activity and health: A mapping review of the evidence. *Environment International, 147*. https://doi.org/10.1016/j.envint.2020.105954

Therneau, T. M. (2024). *A Package for Survival Analysis in R (R package version 3.8-3]*.. Available from: https://cran.r-project.org/web/packages/survival/index.html.

Vanderschuren, M., et al. (2014). *NMT facility guidelines: Policy and legislation planning design and operations*.

Wang, L., Xue, X., Zhao, Z., & Wang, Z. (2018). The impacts of transportation infrastructure on sustainable development: Emerging trends and challenges. *International Journal of Environmental Research and Public Health, 15*(6). https://doi.org/10.3390/ijerph15061172

Welsh Government. (2014). *Design guidance: Active travel (Wales) act 2013. (December)*.

Wojnowska-Heciak, M., Heciak, J., & Kłak, A. (2022). Perceptions of street trees among polish residents with motor disabilities. *Journal of Transport and Health, 27*. https://doi.org/10.1016/j.jth.2022.101490

Zheng, Y., Elefteriadou, L., Chase, T., Schroeder, B., & Sisiopiku, V. (2016). Pedestrian traffic operations in urban networks. *Transportation Research Procedia, 15*, 137–149. Available at: https://doi.org/10.1016/j.trpro.2016.06.012.