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Systematic Review of Built Environment Attributes of Walkability: Cases of Malaysia

Khair Eddine Demdoum[1,*], Yazid Mohd. Yunos[1], Norsidah Ujang[1], Nangkula Utaberta[2,3,4,5]

[1]Faculty of Design and Architecture, Universiti Putra Malaysia, Malaysia
[2]School of Architecture and Built Environment, UCSI University, Malaysia
[3]Faculty of Engineering, Universitas Sumatera Utara, Indonesia
[4]Faculty of Creative Design and Digital Business, Intitut Teknologi Sepuluh Nopember, Indonesia
[5]Faculty of Vocational Study, Universitas Airlangga, Indonesia

*Corresponding e-mail: gs49946@student.upm.edu.my

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ABSTRACT

Walkability has gained considerable traction in recent years as a key concept for promoting sustainable urban environments and healthier lifestyles. Built environment attributes such as infrastructure, streetscape design, land use mix, and street connectivity were found to have a high impact on walking behavior. However, due to the context-specific nature of walkability, where attributes deemed important in one context may not hold the same significance in another, this study aims to examine walkability attributes and methods within the Malaysian context. The goal is to offer valuable insights for researchers and policymakers operating in similar contexts. This study employed a systematic review following the PRISMA guidelines. A comprehensive search of SCOPUS and Google Scholar identified and assessed studies related to walkability in Malaysia. Rigorous screening and application of inclusion criteria yielded 32 Malaysian articles published between 2011 and 2021 for detailed review. Data extraction focused on specified factors including data source, built environment attributes, unit of analysis, and type of walking. The results identified both similarities and differences in the influence of built environment attributes on walking behavior in Malaysia compared to global patterns. Micro-scale factors, such as the aesthetics and attractiveness of walkways (65%), and safety and security (59%), were found to be leading factors in creating walking-friendly environments. Conversely, macro-level attributes, including density (15%) and mixed land use (18%), did not show a significant impact. This reliance on perceived assessments may struggle to capture the complexity of actual density and diversity, leading to inconsistent results. However, data collection and analysis approaches require further refinement. Future Malaysian research may prioritize the use of GIS-based walkability indexes to comprehensively measure walkability and improve the validity and accuracy of assessments. Additionally, consideration should be given to the regional transferability of these indexes.

Keywords: walkability, built environment, sustainability, walking, pedestrian, systematic reviews, Malaysia

INTRODUCTION

Asian developing countries are currently facing high levels of obesity, declining physical activity, and increasing rates of chronic disease (Mathis et al., 2023). Malaysia, like many Asian countries, is grappling with rising rates of overweight and obesity, associated with a lack of physical activity (Kyaw et al., 2022). According to the National Health and Morbidity Survey (NHMS, 2019), a staggering 50.1% of Malaysian adults are either overweight or obese (Institute for Public Health, 2020), marking the highest rate among adults in South-East Asia (Lobstein et al., 2023). The causes of this health issue are multifaceted, involving various interconnected determinants, including both behavioural and environmental factors. It is essential to recognize that individual-level stressors alone cannot fully explain the surge in overweight and obesity (Townshend & Lake, 2017). Consequently, in recent decade, the focus has shifted from the personal level to community empowerment through the built environment of cities (Kwan et al., 2021).

To combat obesity and promote physical activity, research on "Walkability" focuses on how to design or redesign the built environment to support walking as a mode of active transportation integrated into daily activities. Walkability refers to the measure of how conducive the built environment is for walking, whether for physical activity, active mobility, recreation, or access to services (Battista & Manaugh, 2019). Guidelines from the World Health Organization have shown that moderate physical activity, such as 30 minutes of walking per day, can significantly reduce mortality risk by at least 10% and decrease overweight and obesity levels, along with other associated health benefits, such as reduced diabetes (Booth et al., 2019; Sundquist et al., 2015), cholesterol, and heart disease (Lee & Buchner, 2008). Furthermore, high walkability leads to various environmental and social implications, from reducing automobile dependency and energy expenditure (Lewis & del Valle, 2019) to providing a solution for environmental injustice and social isolation (Forsyth, 2015; Karjalainen & Juhola, 2019). Moreover, a walkable environment contributes to a liveable city (Shamsuddin et al., 2012), providing people with better places to live and improving levels of place satisfaction (Dyck et al., 2011; Lee et al., 2016).

Walkability attributes and their impact on walking behaviour have garnered extensive attention globally in recent years. Systematic reviews have emerged as valuable tools for synthesizing evidence regarding this association. In contrast to narrative reviews, which can be susceptible to subjective bias and have a limited scope (Jahan et al., 2016), systematic reviews employ rigorous search strategies to define built environment attributes that impact walking by utilizing standardized data extraction methods to accurately compare environmental attributes and identify trends (Smith et al., 2017). For instance, Fonseca et al. (2022) conducted a systematic review, analysing 132 documents to assess the influence of built environment attributes on walkability. They identified intersection density, residential density, and land use mix as the most impactful measures on walking behaviour. These findings corroborated earlier systematic reviews, indicating a strong association between walking activities and land use diversity, intersection density, and proximity to non-residential destinations (Ariffin et al., 2021; Day, 2016; Ewing & Cervero, 2010; Saelens & Handy, 2008; Wang & Yang, 2019). Additionally, perceived aspects of the built environment, such as walkway aesthetics, traffic safety, and crime safety, significantly influence both utilitarian and recreational walking behaviour (Ramakreshnan & Aghamohammadi, 2020; Salvo et al., 2018; Smith et al., 2017).

However, the empirical studies previously reviewed predominantly featured settings in developed countries, with a major focus on North America, Europe, and Australia (Ramakreshnan & Aghamohammadi, 2020). As it has long been argued that the relationship between the built environment and walking is context-specific (Liao et al., 2020; Mccormack et al., 2019; Qin et al., 2020; Salvo et al., 2014; Reis et al., 2013), the results of these reviews are not necessarily generalizable to other contexts, such as Malaysia, where the built form and cultural context may differ (Day, 2016; Sallis, 2011). As evidenced by several studies in Asian cities, including cities in China (Qin et al., 2020) and Japan (Inoue et al., 2010), population density, for example, has a reverse impact on walking volume in overpopulated areas due to limited

walking opportunities and pedestrian congestion. Moreover, Salvo et al. (2014) found a negative impact of land use mix entropy (LUM) on overall walking in Cuernavaca, Mexico. Consistent results were found in China (Lu et al., 2018) and Korea (Im & Choi, 2019). In addition, street connectivity, often measured as intersection density, effectively assesses connectivity in areas with grid-pattern street layouts, as found in American and Canadian cities; however, its effectiveness as an indicator is questioned due to the influence of street patterns on its value (Boeing, 2021; Lima et al., 2022; Stangl & Guinn, 2011). Such disparities may stem from differences in data sources, analytical methods, and, crucially, variations in built environment morphologies themselves (Fonseca et al., 2022).

Malaysia's cities and urban areas are generally car-oriented with moderate to high population densities, accommodating approximately 78.21 percent of the total population (O'Neill, 2022). However, according to the NHMS (2019), 27% of urban residents are not physically active.. Encouraging walking in city planning has become a timely issue in Malaysia due to the rapid urbanization associated with changes in the mobility behaviour of city inhabitants (Hidayati et al., 2021). In metropolitan areas like Kuala Lumpur, private motorized vehicles account for 80% of the mode share (Chuen et al., 2014), while non-motorized transport modes like walking and cycling are nearly non-existent, except in tourist areas. This is due to inadequate infrastructure (e.g., discontinuous sidewalks and cycling paths), humid weather, misperceptions about pedestrian safety, and deteriorating street liveability (Mahmoudi et al., 2015; Rahman et al., 2015; Zakaria & Ujang, 2015).

In response to this, the concept of walkability has recently gained prominence in Malaysia, offering contextual insights that are policy-relevant and can be integrated into urban planning and design. Various methods and data sources have been employed to examine the association between walking behaviour and different built environment factors (e.g., Azari et al., 2022; Azmi & Ahmad, 2015; Cheah et al., 2012; Elsawahli et al., 2017; Nordin & Nakamura, 2019; Qureshi et al., 2018;). Recognizing the context-specific nature of walkability, where measures deemed important in one context may not hold the same significance in another, a focused examination within the Malaysian context can significantly contribute to the global body of knowledge, providing valuable insights for researchers operating in similar contexts. This study addresses two key inquiries: How do built environment attributes influence walking behaviour in the Malaysian context compared to global patterns? And what are the specific data collection and analysis approaches adopted? To answer these inquiries, a systematic review approach was adopted to provide robust and context-specific insights that can inform policy and planning efforts toward promoting walkable and healthy urban environments in Malaysia.

METHODOLOGY

To address the preceding questions, a systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Eligibility criteria

A systematic search was conducted to examine English language literature related to the period between 2011 and 2021, investigating the relationship between built environment attributes and walking behaviour in the Malaysian context. Eligible articles encompassed quantitative empirical studies (e.g., natural experiments, prospective, retrospective, experimental, or longitudinal research, including repeated cross-sectional surveys) investigating the correlation between built environment attributes and walking behaviour, physical activity, and/or travel behaviours in children or adults. The included articles are required to be published as full papers (not only as abstracts), include a primary report on methods, analysis, and findings, be conducted in Malaysia, and examine aspects of the built environment and walking behaviour, either by objective or perceived means.

Studies that exclusively examined cultural, social, or economic environments were not included in this study, as the focus is on the association of built environment characteristics with walking. Additionally, qualitative studies and those that did

not measure changes in both the independent and dependent variables were excluded.

Information source

Given the limited availability of indexed publications, Scopus and the Google Scholar research engine were employed in conjunction to identify reliable peer-reviewed documents. Both resources are widely recognized and trusted for conducting systematic reviews and searching scientific publications (Piasecki et al., 2018).

Search strategies

The terms used for abstract and title searches included "walk," "walking," "pedestrian," "travel," "transportation," "exercise," "recreation," "walkability," "built environment," "urban," "urban design," "neighbourhood," and "Malaysia." Several of these search terms were adopted from Saelens and Handy's (2008) review, with additional terms added to narrow the focus to Malaysia. Any unrelated and duplicate studies were excluded, and the remaining articles were reviewed individually in full text.

Study selection

Titles and abstracts of articles were screened for eligibility, and those meeting the criteria were included. Full-text articles were obtained when there was uncertainty about meeting inclusion and exclusion criteria based on the abstract and title alone. Additionally, relevant titles identified through bibliography searches underwent further screening by sourcing and evaluating the respective article abstracts using the same criteria.

For this study, a broad definition of the built environment was employed to identify modifiable factors at the individual, local, neighbourhood, or town scale that could impact walking behaviour. This review selects studies that included objective or perceived measures, encompassing infrastructural or streetscape factors, natural or built aesthetic elements, and other environmental supports for walking. Studies assessing changes in access to public transport were also eligible.

Regarding walking behaviour, studies encompassed self-reported or objectively assessed activities, such as pedometers and accelerometers, to assess any type of walking activities, including recreational or utilitarian walking.

Data extraction

Based on the objectives of this review, data were extracted for all included articles across seven categories: study region, sample size, data source for the built environment, built environment factors, geographic unit, type of walking, and key findings (see Table A1 in the appendix). Regarding the built environment data source, 'interview' or 'survey' indicates that respondents were questioned about their perceptions and awareness of surrounding built environment factors. In contrast, 'objective environmental data' indicates that data were obtained from non-respondent sources, including GIS land use data, street network data, Census data, or professional raters.

Depending on the data source, the 'built environment factors' section lists attributes that influence walking behaviour. These attributes can range from objective environmental factors, such as the number of intersections or land use entropy, to perceived built environment factors, like comfort and safety. Table A1 also highlights the type of walking that was assessed (utilitarian, recreational, or general). Finally, the 'key findings' section discusses the built environment features that were found to impact walking behaviour, as well as any differences observed compared to the overall trend.

Level two of data extraction categorizes environmental characteristics based on the type of assessment (objective or perceived). The selected attributes were acquired from the Neighbourhood Environment Walkability Scale (NEWS). This tool was developed by Saelens et al. (2003) as a valid tool to assess built environment attributes; moreover, it has been utilized in numerous studies (Leslie et al., 2005; Nichani et al., 2019). This enables a comprehensive cross-comparison of the six built environment attributes, namely: (1) density of population and urbanization, (2) street connectivity, (3) accessibility and proximity to

facilities, (4) land use including 7 categories (Mix land use, Commercial, Education, Public transit park and open spaces/ recreational facilities, Government/finical services and Other destination), (5) infrastructure and streetscape characteristics (including; Walk-friendly infrastructure, Sidewalk quality, Street lighting, Greenery, Aesthetic), (6) safety including safety from crime and traffic (Table 1).

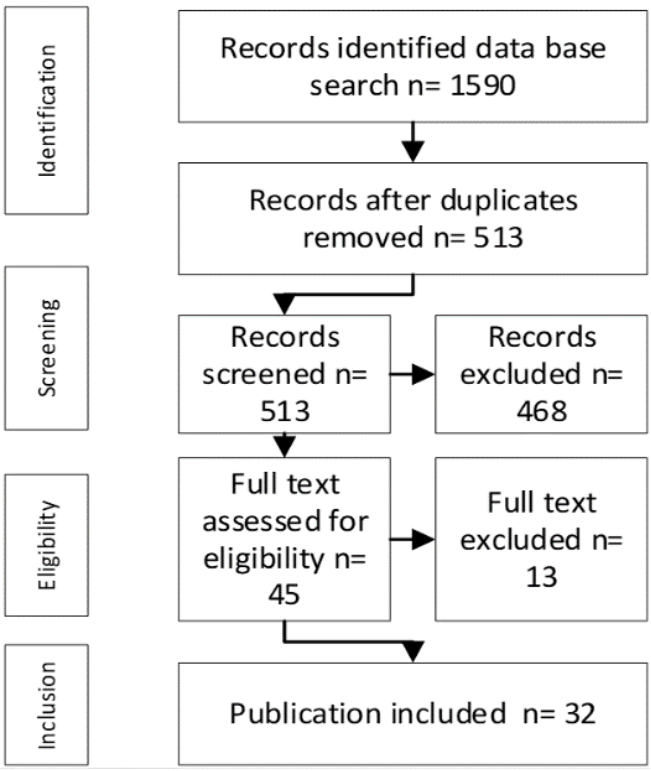
Table 2 is designed to conclude the results regarding the divergence and convergence between Malaysian studies and global findings. A critical comparison is made between environmental characteristics that influence walkability, as identified by the Neighbourhood Environment Walkability Scale (NEWS), across studies conducted globally and those specific to Malaysia. This table is structured with the following headings: 'Environmental Characteristic,' 'Global Research Findings,' 'Malaysian Research Findings,' 'Consistent Arguments,' 'Different Arguments,' 'Development Over Time,' and 'Knowledge Gaps. 'Key attributes of the built environment, ranging from Infrastructure and Streetscape Design to Density, which affect walkability, are examined. Through this approach, the current state of walkability research is elucidated, and the discussion of environmental characteristics is aligned with the content of data analysis, ensuring a cohesive exploration of their impacts on urban walkability. This table provides a crucial tool for understanding the differences and similarities in walkability research, guiding future investigations towards filling the identified gaps and enhancing the global comprehension of walkable environments.

RESULTS

A systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, resulting in a four-phase diagram depicted in Figure 1. This review identified a total of 32 published studies in Malaysia on walking and the built environment, comprising 23 journal papers and 9 conference proceedings.

Figure 1

Literature Selection Process



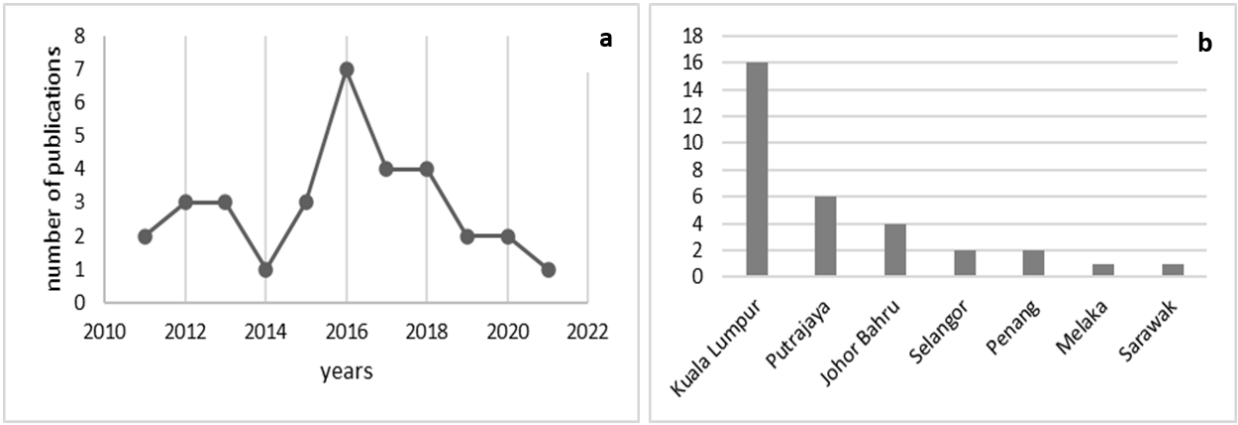
In general, the number of publications over the last decade is regarded as an important indicator for determining the significance of this research. As shown in Figure 2a, the year 2016 marked the highest number of publications on walkability in Malaysia, with seven studies, followed by a noticeable decline over the next five years. In contrast, the number of global publications on walkability has recently increased at a 362 percent annual growth rate, indicating a rapid growth in global interest in this field (Ramakreshnan & Aghamohammadi, 2020). However, high-income countries have shown greater interest in walkability research than middle and low-income countries (Mateo-Babiano, 2016; Reis et al., 2013), resulting in limited funding for such research and, thus, a low number of publications.

In terms of disciplines, urban planning-related affiliations (including architecture, urban design, etc) accounted for the majority of walkability publications in Malaysia, with 26 papers, followed by only 6 studies from health-related disciplines (including public health, medicine, and others) (see Table A1 in the appendix). In comparison to the global body of literature, occupational health has dominated walkability research since 2001 (Ramakreshnan & Aghamohammadi, 2020), with accumulating evidence highlighting a strong association between walkability and health outcomes, specifically physical activity, obesity prevalence, and noncommunicable diseases. More research, however, is required to determine how Malaysian urban built environments affect general health and physical activity (Kwan et al., 2021; Majid et al., 2021).

In terms of study regions, Figure 2b depicted that samples were drawn from Malaysia's most urbanized areas, with 50 percent of walkability studies conducted in Kuala Lumpur alone, followed by Putrajaya and Johor Bahru with 30 percent of the studies, the high rate of studies in these areas being attributed to the level of urbanization. Since 2010, the federal territories of Kuala Lumpur and Putrajaya have been completely urbanized, according to Hasan and Nair (2014). Selangor and Penang, on the other hand, have historically been Malaysia's most densely populated states (Azari et al., 2022), but they received little attention, with only four studies (Figure 2b). In terms of samples, Table A shows that the majority of studies included both male and female participants, with the exception of Harumain et al. (2017) study, which only included females. Most studies' samples are adults (see Table A1 in the appendix), while a small number of studies have examined seniors aged 65 and older (Elsawahli et al., 2017; Nordin & Nakamura, 2019) as well as children and adolescents aged 18 and younger (Cheah et al., 2012; Tung et al., 2016). Few studies have stratified samples based on specific demographic, environmental, and socioeconomic characteristics, despite the importance of these factors as a control variable in the relationship to walking (Day, 2016; Wang & Yang, 2019).

Figure 2

Annual Publication Output Between 2011 and 2021 (a), Number of Publications by Regions (b).



Regarding data sources, most of the studies included in this review used self-reported walking data (Table A1). Measurements based on perceived walking have low reliability when predicting actual walking since they produce measurement errors and biases in the results (Hajna et al., 2015; Moudon et al., 2006; Wang & Yang, 2019). To improve the validity and accuracy of walkability measurement, future research may consider the application of GIS, accelerometers, pedometers, or cell phone applications for assessing walking activity (Hinckson et al., 2017; Wang & Yang, 2019). On the other hand, data on the built environment were typically collected through perceived-based methods such as questionnaire surveys (Table A1); fewer studies used audits, observation, or GIS (Geographic Information System) as a source of objective data on the built environment. Several studies used NEWS (Neighbourhood Environment Walkability Scale) (Saelens et al., 2003) or modified versions to assess neighbourhood walkability, while others developed different survey or interview protocols often tailored for the study itself (Table A1).

Attributes of built environment and methods

This review summarizes the built environment characteristics found in the reviewed documents based on the NEWS (Neighbourhood Environment Walkability Scale) classification. All built environment attributes were aggregated into six (6) measures: Infrastructure and streetscape, Safety and security, Accessibility, Land use diversity, Street connectivity, and Density. For example, measures such as "traffic volume," "speed limit," or “fear of crime” were classified as safety and security, while distance to commerce or recreation was classified as accessibility (Table 1). Several conclusions from prior studies were supported by this review. When considering the overall number of built environment attributes that were included, the most consistent set of conclusions is related to infrastructure aesthetics, safety (traffic and crime), and destinations' accessibility. The discussion below summarizes the main findings of this review regarding the respective attributes of walkability.

Table 1

Classification of Environmental Characteristics Based on the Type of Assessment (Objectively or Perceived)

Environmental attributes	Number of studies	Objective environment assessment (GIS or observation audits) method	Number of studies	Perceived environment assessment (questionnaire, interview, or self- report) method
I-Density (population/ urbanization) ***(25%)***	15%	(Maleki & Zain, 2011) (Nordin & Nakamura, 2019) (Qureshi et al., 2018) (Yi et al., 2017) (Azmi & Ahmad, 2015)	15%	(Cheah et al., 2012) (Nordin & Nakamura, 2019) (Abdulah et al., 2016) (Qureshi et al., 2018) (Tung et al., 2016)
Ⅱ- Street connectivity ***(50%)***	21%	(Maleki & Zain, 2011) (Mansouri & Ujang, 2017) (Nordin & Nakamura, 2019) (Omar et al., 2016) (Qureshi et al., 2018) (Yi et al., 2017a) (Azmi & Ahmad, 2015)	40%	(Abdulah et al., 2016) (Cheah et al., 2012) (Harun & Nashar, 2017) (Mansouri & Ujang, 2016) (Mokhlas et al., 2015) (Nordin & Nakamura, 2019) (Cheah et al., 2012) (Omar et al., 2016)

Table 1 (Continued)

Environmental attributes	Number of studies	Objective environment assessment (GIS or observation audits) method	Number of studies	Perceived environment assessment (questionnaire, interview, or self- report) method
Ⅱ- Street connectivity (50%) **(Continued)**				(Qureshi et al., 2018) (Tung et al., 2016) (Ujang & Muslim, 2014) (Zakaria & Ujang, 2015) (Ramakreshnan et al., 2020)
Ⅲ- Land use diversity (34%)	15%	(Maleki & Zain, 2011) (Nordin & Nakamura, 2019) (Qureshi et al., 2018) (Yi et al., 2017) (Azmi & Ahmad, 2015)	21%	(Arshad et al., 2016) (Cheah et al., 2012) (Nordin & Nakamura, 2019) (Abdulah et al., 2016) (Qureshi et al., 2018) (Tung et al., 2016), (Ramakreshnan et al., 2020)
Ⅳ- Destination accessibility (53%)				
1. Commercial	21%	(Maleki & Zain, 2011) (Mansouri & Ujang, 2017) (Nordin & Nakamura, 2019) (Qureshi et al., 2018) (Shamsuddin et al., 2012) (Yi et al., 2017) (Azmi & Ahmad, 2015)	21%	(Cheah et al., 2012) (Ja'afar & Harun, 2018) (Nordin & Nakamura, 2019) (Abdulah et al., 2016) (Nasrudin et al., 2018) (Qureshi et al., 2018) (Tung et al., 2016)
2. Education	15%	(Maleki & Zain, 2011) (Nordin & Nakamura, 2019) (Qureshi et al., 2018) (Yi et al., 2017) (Azmi & Ahmad, 2015)	15%	(Cheah et al., 2012) (Mahmoud et al., 2016) (Nordin & Nakamura, 2019) (Qureshi et al., 2018) (Tung et al., 2016)
3. Public transit	15%	(Maleki & Zain, 2011) (Mansouri & Ujang, 2017) (Qureshi et al., 2018) (Yi et al., 2017) (Azmi & Ahmad, 2015)	25%	(Mahmoud et al., 2016) (Mokhlas et al., 2015) (Nordin & Nakamura, 2019) (Abdulah et al., 2016) (Cheah et al., 2012) (Qureshi et al., 2018) (Tung et al., 2016) (Ujang & Muslim, 2014)
4. Park and open spaces/ recreational facilities	15%	(Maleki & Zain, 2011) (Nordin & Nakamura, 2019) (Qureshi et al., 2018) (Yi et al., 2017) (Azmi & Ahmad, 2015)	18%	(Abdulah et al., 2016) (Mahmoud et al., 2016) (Nordin & Nakamura, 2019) (Cheah et al., 2012) (Qureshi et al., 2018) (Tung et al., 2016)(Ramakreshnan et al., 2020)

Table 1 (Continued)

Environmental attributes	Number of studies	Objective environment assessment (GIS or observation audits) method	Number of studies	Perceived environment assessment (questionnaire, interview, or self- report) method
5. Government/ finical services	6%	(Nordin & Nakamura, 2019) (Azmi & Ahmad, 2015)		
6. Other destination	3%	(Maleki & Zain, 2011)	9%	(Nordin & Nakamura, 2019) (Qureshi et al., 2018) (Tung et al., 2016)
V-Infrastructure and street scape (65%)				
1. Walk-friendly infrastructure	15%	(Keat et al., 2016) (Keyvanfar et al., 2018) (Mahmoud et al., 2016) (Nasrudin et al., 2018) (Shamsuddin et al., 2012)	43%	(Asadi-shekari et al., 2019) (Cheah et al., 2012) (Elsawahli et al., 2017) (Keat et al., 2016) (Mahmoud et al., 2016) (Nordin & Nakamura, 2019) (Nasrudin et al., 2018) (Qureshi et al., 2018) (Shojaei, 2012) (Shamsuddin et al., 2012) (Tung et al., 2016) (Ujang & Muslim, 2014) (Zakaria & Ujang, 2015) (Karim & Azmi, 2013)
2. Sidewalk quality	15%	(Asadi-shekari et al., 2019) (Keat et al., 2016) (Keyvanfar et al., 2018) (Nasrudin et al., 2018) (Shamsuddin et al., 2012)	46%	(Abdulah et al., 2016) (Arshad et al., 2016) (Asadi-shekari et al., 2019) (Harun & Nashar, 2017) (Keat et al., 2016) (Mahmoud et al., 2016) (Nordin & Nakamura, 2019) (Nasrudin et al., 2018) (Qureshi et al., 2018) (Shojaei, 2012) (Shamsuddin et al., 2012) (Tung et al., 2016) (Ujang & Muslim, 2014) (Zakaria & Ujang, 2015) (Karim & Azmi, 2013)
3. Street lighting	9%	(Asadi-shekari et al., 2019) (Keat et al., 2016) (Keyvanfar et al., 2018)	34%	(Arshad et al., 2016) (Asadi-shekari et al., 2019) (Ariffin & Zahari, 2013) (Harun & Nashar, 2017) (Keat et al., 2016) (Mahmoud et al., 2016) (Nordin & Nakamura, 2019) (Qureshi et al., 2018) (Tung et al., 2016) (Ujang & Muslim, 2014) (Zakaria & Ujang, 2015)

Table 1 (Continued)

Environmental attributes	Number of studies	Objective environment assessment (GIS or observation audits) method	Number of studies	Perceived environment assessment (questionnaire, interview, or self- report) method
4. Greenery	9%	(Asadi-shekari et al., 2019) (Keat et al., 2016) (Keyvanfar et al., 2018)	37%	(Abdulah et al., 2016) (Asadi-shekari et al., 2019) (Harun & Nashar, 2017) (Keat et al., 2016) (Mahmoud et al., 2016) (Nordin & Nakamura, 2019) (Qureshi et al., 2018) (Shojaei, 2012) (Tung et al., 2016) (Ujang & Muslim, 2014) (Zakaria & Ujang, 2015) (Karim & Azmi, 2013)
5. Aesthetic	15%	(Asadi-shekari et al., 2019) (Keat et al., 2016) (Keyvanfar et al., 2018) (Mahmoud et al., 2016) (Nasrudin et al., 2018)	50%	(Abdulah et al., 2016) (Arshad et al., 2016) (Asadi-shekari et al., 2019) (Cheah et al., 2012) (Harun & Nashar, 2017) (Ja'afar & Harun, 2018) (Keat et al., 2016) (Mahmoud et al., 2016) (Nordin & Nakamura, 2019) (Nasrudin et al., 2018) (Qureshi et al., 2018) (Shamsuddin et al., 2012) (Tung et al., 2016) (Ujang & Muslim, 2014) (Zakaria & Ujang, 2015) (Karim & Azmi, 2013)
VI- Safety and security (59%)				
1. Traffic/ pedestrian safety	15%	(Asadi-shekari et al., 2019) (Keat et al., 2016) (Keyvanfar et al., 2018) (Mahmoud et al., 2016) (Nasrudin et al., 2018)	56%	(Abdulah et al., 2016) (Asadi-shekari et al., 2019) (Ariffin & Zahari, 2013) (Cheah et al., 2012) (Elsawahli et al., 2017) (Harumain et al., 2017) (Harun & Nashar, 2017) (Mahmoud et al., 2016) (Mokhlas et al., 2015) (Nordin & Nakamura, 2019) (Nasrudin et al., 2018) (Qureshi et al., 2018) (Shojaei, 2012) (Shamsuddin et al., 2012) (Tung et al., 2016) (Ujang & Muslim, 2014) (Zakaria & Ujang, 2015) (Karim & Azmi, 2013)

Table 1 (Continued)

Environmental attributes	Number of studies	Objective environment assessment (GIS or observation audits) method	Number of studies	Perceived environment assessment (questionnaire, interview, or self- report) method
2. Crime/ personal safety	9%	(Keyvanfar et al., 2018) (Mahmoud et al., 2016) (Nasrudin et al., 2018)	53%	(Abdulah et al., 2016) (Arshad et al., 2016) (Cheah et al., 2012) (Elsawahli et al., 2017) (Harumain et al., 2017) (Harun & Nashar, 2017) (Mahmoud et al., 2016) (Mokhlas et al., 2015) (Nordin & Nakamura, 2019) (Nasrudin et al., 2018) (Qureshi et al., 2018) (Shojaei, 2012) (Shamsuddin et al., 2012) (Tung et al., 2016) (Ujang & Muslim, 2014) (Zakaria & Ujang, 2015) (Karim & Azmi, 2013)

Infrastructure and streetscape

The presence of walking infrastructure and its qualities, such as greenery, lighting, and neighbourhood aesthetics, has been extensively investigated in Malaysian walkability studies. These attributes were consistently presented in 65% of the total research outcomes (Table 1). In comparison to global research, streetscape attributes accounted for less than 5% of the measured walkability attributes (Fonseca et al., 2022). In this review, walking infrastructure characteristics such as the qualities of walkways (46%), greenery (37%), and lighting (34%) (Table 1) were found to be leading factors for walkable areas. Overall, the findings indicate that the presence of sidewalks with sufficient width, free of obstacles, good aesthetics, and providing the desired level of pedestrian services are major factors encouraging people to walk (Asadi-shekari et al., 2019; Harun & Nashar, 2017; Nasrudin et al., 2018; Shamsuddin et al., 2012; Zakaria & Ujang, 2015).

Furthermore, despite receiving less attention globally (Lu et al., 2018), street greenery and the level of tree shading have been extensively examined in Malaysian studies, as they influence pedestrian comfort in a tropical context (Asadi-shekari et al., 2019; Karim & Azmi, 2013; Keat et al., 2016; Ramakreshnan et al., 2020; Tung et al., 2016). Generally, these findings align with the global body of literature; the density of sidewalks was consistently associated with more walking (Vargo et al., 2012), whereas narrow sidewalks with unappealing aesthetics were regarded as barriers to walking (Larranaga et al., 2018; Tsiompras & Photis, 2017). Street trees were also found to be associated with increased walking and physical activity (Lu et al., 2018; Tamura et al., 2019).

However, due to a lack of streetscape data (microscale attributes), the majority of the studies included in this review used perception-based methods to assess the quality of walking infrastructures, while a smaller number of studies used objective assessment approaches such as audit tools or checklists (e.g., Pedestrian Level Of Service, Asadi-shekari et al., 2019). Nevertheless, more objective-based evaluation is still needed to provide additional evidence on the impact of streetscape design attributes on walking behaviour in the Malaysian context.

Safety and security

In 59% of the studies, safety and security were identified as major factors influencing walking behaviour (Table 1). A total of 40% of the studies found a strong association, concluding that both types of safety (crime and traffic) were linked to increased walking in the Malaysian context (Table 1). For instance, Nasrudin et al. (2018) and Arshad et al. (2016) found a strong association between safety, security, and walkability in commercial areas, while Karim and Azmi (2013) and Mahmoud et al. (2016) found this association in residential areas. Furthermore, safety of both types seems to be more closely associated with women's walking than men's walking, as suggested by Harumain et al.(2017), and Abdullah et al.(2016) studies. Additionally, Cheah asserted that safety from crime is one of the main factors influencing the walking behaviour of both genders (Cheah et al., 2012).

These results align with global quantitative findings regarding traffic safety (Suarez-balcazar et al., 2020), crime safety (Foster et al., 2016; Sugiyama et al., 2014), and overall safety (Oyeyemi et al., 2012). However, the evidence of the relationship between overall safety (crime and traffic) and walking was stronger for perception-based measures than objective measures (56% and 15%, respectively) (Table 2). Safety is considered a perceived construct of the built environment that is primarily assessed through questionnaires or interviews. However, its assessment in different contexts can be challenging, as participants rate their neighbourhoods relative to their own experiences, which can vary from place to place (Kerr et al., 2016). Nevertheless, some researchers adopted observational audits to objectively assess safety (Table A1), for example, examining pedestrian crossings and traffic lights at a micro-scale level (Keyvanfar et al., 2018). Incorporating objective measures of safety can provide a more accurate representation (Cho et al., 2009; Foster & Giles-Corti, 2008).

Accessibility

As shown in Table 1, accessibility measures were found in more than half of the studies included in this review (53%). Accessibility reflects the distance/proximity to key amenities and public transport (Cervero et al., 2009). According to the findings of this study, walking was associated with a shorter perceived distance to specific destinations such as public transportation (25%), commercial areas (21%), and recreational facilities such as parks and open spaces (18%) (Azmi & Ahmad, 2015; Ja'afar & Harun, 2018; Maleki & Zain, 2011; Qureshi et al., 2018; Ramakreshnan et al., 2020; Ujang & Muslim, 2014). Consistent with the global body of literature, perceived proximity to certain facilities such as parks and open spaces (Cauwenberg et al., 2015; Kaczynski & Henderson, 2007; Sugiyama et al., 2014; Volker et al., 2018), local stores and services (Jia et al., 2014; Sugiyama et al., 2012), transit stops (Malambo et al., 2017), schools (Kim & Heinrich, 2016), and the workplace (Marquet et al., 2018) was associated with more walking activity.

The measure of perceived proximity, on the other hand, has been criticized for interfering with various socioeconomic and individual variables, such as income and age, resulting in mismatched estimations when compared to actual distances (Koohsari et al., 2014a). The included studies in this review were generally limited by their use of self-report and questionnaire measures of accessibility and proximity. In contrast, objective assessment of distances based on GIS can be more representative than a perceived-based approach (Lin & Moudon, 2010).

On another point, studies have defined 200m (Azmi & Karim, 2011) and 240m (Qureshi, 2016) as the average distance that Malaysians are willing to walk before driving, which is less than the five- to ten-minute (400-800m) average adopted by general walkability studies (Moudon et al., 2006). This is primarily due to extreme weather conditions (Ramakreshnan et al., 2020). Accurate distance representation is especially important in tropical environments because the definition of the unit area for walkability assessment, in which the calculation is to be performed, must be aligned with the distance that can be walked. In this sense, more objective methods for measuring both the built

environment and walking behaviour to define the walking threshold should be investigated in future research.

Street connectivity

Street connectivity is essentially a measure of the "relatedness" of the built environment (Peponis et al., 2008). As shown in Table 1, half of the studies (50%) investigated street connectivity as an indicator of walkability in Malaysia, mostly using self-reported assessments of street connectivity (e.g., NEWS), where respondents were asked to rate the connectivity of their built environment (e.g., Mansouri & Ujang, 2016; Ramakreshnan et al., 2020; Tung et al., 2016; Zakaria & Ujang, 2015; e.g., Ujang & Muslim, 2014). Fewer studies, on the other hand, used objective assessments of connectivity such as intersection density, block length, or link-to-node ratio (e.g., Azmi & Ahmad, 2015; Yi et al., 2017b). Although perceived connectivity was argued to be related to overall walking (Dyck et al., 2011; Kerr et al., 2016), its interaction with personal factors such as income or education may result in misperceiving high connectivity as low or vice versa; for example, (Gebel et al., 2009) found that those without university education were 47% more likely to perceive actual street connectivity as low.

On the other hand, besides being faster and easier to apply, measures such as intersection density offer a highly accurate description of connectivity in relation to walking (Ellis et al., 2015). Evidenced by several studies, intersection density was found to be strongly associated with walking for transportation (Kamruzzaman et al., 2016; Koohsari et al., 2014b, recreation (Hayley et al., 2017), and overall walking (Carlson et al., 2018; Sugiyama et al., 2014). Moreover, as a proxy for network connectivity, some researchers shifted their focus to investigating the topological properties of the street network, such as integration. This method, which is based on a space syntax framework (Hillier & Hanson, 1984), demonstrated a significant ability to measure the connectivity of urban form in relation to walking behaviour (Baran et al., 2008; Koohsari et al., 2016; Lee et al., 2020, Mccormack et al., 2019). Although this approach was introduced to Malaysian walkability literature by Mansouri and Ujang (2016), it is still unfamiliar. Examining the syntactic properties of a street network can help advance research on the street characteristics and walking behaviour.

Land use diversity

Diversity of land use appears in a relatively small number of Malaysian walkability studies; only 34% have assessed it, either objectively (18%) or perceived (21%). Land use mix is known to be a strong indicator of walkability (Hajna et al., 2013). Mixed land use implies greater proximity to destinations (Azmi et al., 2013). Only five studies have concluded that mixed land use was associated with more walking, while other studies found no relationship (e.g., Cheah et al., 2012). This can be attributed to the limitations of perceived-based assessments of land use in detecting actual diversity. Although some studies indicated that perceived high diversity in land uses within an area is associated with more walking (Kerr et al., 2016; van Holle et al., 2012), diversity is often operationalized using objective measures such as entropies and ratios to calculate the prevalence of various land uses (Fonseca et al., 2022). For instance, the entropy index, encompassing residential, commercial, recreational, educational, and office land uses (Frank et al., 2010), correlates with pedestrian-friendly environments and increased walking activity (Brown et al., 2009; Carlson et al., 2018; Clark et al., 2014; Fan et al., 2018). To enhance validity, future Malaysian walkability studies should explore existing GIS-based land use mix indexes or adapt and develop new indexes tailored to Malaysian cities, streamlining evaluation processes and reducing costs.

Density

Only 25% of the studies included density attributes for assessing walkability (Table 1). Density refers to the concentration of land uses within an area, which is mostly operationalized objectively as residential or population densities through density ratios (Fonseca et al., 2022). A large body of research has found a strong link between overall walking and various types of objective density, such as population density (Clark et al., 2014; Huang et al., 2019; Sugiyama

et al., 2014), residential density (Cerin et al., 2018), employment density (Huang et al., 2019), and retail density (Neatt et al., 2017).

However, objective population and residential density have received the least attention in walkability research in Malaysia, with only 15% of the reviewed documents. This can be attributed primarily to the lack of block-level data on population density. However, to address this issue, residential unit density can be used as a proxy for population density. Neighbourhoods with denser residential units imply denser commercial land use and more recreational sites, as there are adequate populations to support them (Frank et al., 2010). Future studies may also need to take into account contextual differences when adapting density indexes for walkability research (Fan et al., 2018). However, Table 2 concludes the results regarding the divergence and convergence between Malaysian studies and global findings and aims to guide future studies for enhanced comprehension of walkable environments.

Table 1

Comparative Analysis of Environmental Characteristics Influencing Walkability: Insights from Global and Malaysian Research

Environmental Characteristic	Walkability attributes, focus, and impact	Global Research Findings	Malaysian Research Findings	Consistent Arguments	Different Arguments	Development Over Time	Knowledge Gaps
Infrastructure and Streetscape design	**Attribute Importance**	Lower focus (~5% of studies) (Fonseca et al., 2022).	High focus (~65% of studies) (Table 2)	Importance of sidewalks, greenery, and lighting.	Mostly based on subjective evaluations .	Extensive examination of street greenery and tree shading in Malaysian studies.	Need for more objective-based evaluation of streetscape design in Malaysia
	Focus Areas	Pedestrian facility and comfort attributes.	Sidewalks, greenery, lighting.				
	Influence on Walking	Density of sidewalks, sidewalk characteristics, slopes at the street level (Ramakreshnan & Aghamohammadi, 2020)	Well-designed sidewalks with ample width, obstacle-free, aesthetically pleasing, and offering desired pedestrian services.				
Safety and Security	**Attribute Importance**	Security: 70% South America, 55% Asia, 53% USA, 50% Africa; Europe & Canada focus on traffic safety (70%) (Fonseca et al., 2022).	56% studies associate both crime & traffic safety with increased walking (Table 2)	Perception-based safety measures are stronger than objective measures in assessing overall safety and its impact on walking.	Safety is more closely linked to women's walking than men's walking in Malaysia.	Need for objective safety data to enhance accuracy, such as: -Incidence of crime in the area - Pedestrian accident rates - Traffic speed and volume	Limited discussion on the potential barrier effect of roads and community severance in Malaysian studies.
	Focus Areas	Safety Prevalent in South America, Africa, and USA; Inconsistent emphasis on crime & traffic safety	Crime and traffic safety.				
	Influence on Walking	Global inconsistency: Traffic safety not related in Africa, negative impact in Canada & USA; Crime safety deters in South America & Africa, variable in Canada & Australia	Both crime and traffic safety are major factors influencing walking behaviour in Malaysia.				

Table 2 (Continued)

Environmental Characteristic	Walkability attributes, focus, and impact	Global Research Findings	Malaysian Research Findings	Consistent Arguments	Different Arguments	Development Over Time	Knowledge Gaps
Accessibility	**Attribute Importance**	41% of global walkability publications (Fonseca et al., 2022)	Found in more than half (53%) of Malaysian studies (Table 2).	Access to amenities and public transport are significant in both, but emphasis on specific aspects may vary.	Global research emphasizes physical distances, including Euclidean and network metric distances, while Malaysian research centres on perceived proximity.	Future research should explore more objective methods for measuring distance/proximity to define the walking threshold.	Studies in Malaysia limited by self-report and questionnaire measures, calling for more objective GIS-based assessments.
	Focus Areas	Distance/proximity to key amenities (Europe, Australia) and public transport (South America, USA)	Perceived proximity to specific destinations (public transport, commercial areas, recreational facilities). Walking associated with shorter perceived distance to public transportation (25%), commercial areas (21%), and recreational facilities (18%).				
	Influence on Walking	Distance to amenities and public transport significantly impact walking behaviour and walkability.					
Street Connectivity	**Attribute Importance**	84% of global walkability publications. (Fonseca et al., 2022)	50% of studies in Malaysia (Table 2).	Generally consistent with global findings on importance of connectivity for walking.	Global research uses both perceived and objective measures.	Reliance on perceived measures in Malaysian research raises potential bias concerns	Shift towards space syntax method to assess topological connectivity in relation to walking. potentially accounting for context-specific factors.
	Focus Areas	Road-based network systems (intersection density, route directness, cul-de-sac, street density). European and Asian studies focus on footpath networks.	Perceived-based connectivity.				
	Influence on Walking	Strongly associated with walking for transportation, recreation, and overall walking.	Moderate impact on walking behaviour.				

Table 2 (Continued)

Environmental Characteristic	Walkability attributes, focus, and impact	Global Research Findings	Malaysian Research Findings	Consistent Arguments	Different Arguments	Development Over Time	Knowledge Gaps
Land Use Diversity	**Attribute Importance**	>53% of global publications (Fonseca et al., 2022)	Less attention than global research (34% of studies); both objective (18%) and perceived (21%) approaches used.	Importance of land use mix as a walkability index.	Global research utilizes objective entropy indexes for land use mix (Frank et al., 2010).	In a Malaysian context, the reliance on perceived assessments may struggle to accurately capture actual diversity, leading to inconsistent results.	Explore existing GIS-based indexes or develop new ones tailored to a Malaysian urban context, streamlining evaluation and reducing costs.
	Focus Areas	Objective entropy indexes for land use mix (Frank et al., 2010).	Perceived-based assessments of land use.				
	Influence on Walking	Mixed land use associated with walkability due to greater proximity to destinations. Objective measures like entropy index link with higher walking.	Mixed findings on association between land use diversity and walking in Malaysia.				
Density	**Attribute Importance**	81% of studies globally	Only 15% of studies in Malaysia addressed density (Table 2).	Strong link between overall walking and various objective density measures globally.	Need for contextual adaptation of density indexes in Malaysian research.	Investigate using residential unit density as a proxy, explore potential for other measures (employment, retail density).	Lack of block-level population density data hindered its use in Malaysian studies.
	Focus Areas	Population/residential densities (mostly adopted in Australia 95%), amenity density, (USA and Europe allocate around 30%).	Perceived-based residential density.				
	Influence on Walking	Strong association between different types of objective density (population, residential, employment, retail) and walking.	Population density is insignificant measure to walking behaviour.				

DISCUSSION

The systematic review of Malaysian walkability literature between (2011-2021) presented in this paper yielded several findings. First, it highlighted the importance of perceived-based attributes of the built environment in encouraging walking behaviour. The qualities of walking infrastructure, including attributes such as the aesthetics of walkways, greenery, and lighting, emerged as crucial factors in promoting walkable areas. Compared to research predominantly conducted in temperate regions, Malaysian studies place a greater emphasis on greenery and shading elements as key built environment attributes that enhance pedestrian comfort, particularly considering the unique thermal challenges of the tropical climate. This emphasis aligns with similar contexts, such as Thailand, where a significant portion of pedestrians identified thermal comfort as a major concern (Janpathompong & Murakami, 2021). By incorporating strategies like strategically placed trees, pergolas, and reflective materials into sidewalk design, tropical cities can create more inviting and comfortable walking environments (Asadi-shekari et al., 2019; Nasrudin et al., 2018; Zakaria & Ujang, 2015).

Moreover, both crime and traffic safety were strongly associated with walking behaviour, affecting both commercial and residential areas. Notably, safety concerns in Malaysia appeared to have a more substantial impact on women's walking than on men's. Research echoes global trends, indicating that women have a stronger association between perceived safety and recreational walking (Ghani et al., 2016; Kramer et al., 2013; Li & Misnan, 2022). To bridge this gender gap, a two-pronged approach is crucial: well-lit streets, designated pedestrian zones, and strategic CCTV deter crime, while fostering community spirit through neighbourhood watch programs and public awareness campaigns create a safer, more inclusive environment for all (Golan, 2017; Sun et al., 2021).

The findings also support the association between walking activity and proximity to non-residential locations. However, the predetermined walkable threshold identified in the Malaysian context (200-240m) (Azmi & Karim, 2011; Qureshi, 2016), similar to Thailand (211.66m) (Janpathompong et al., 2022), falls short of the commonly applied 400-600m range in walkability studies (Tobin et al., 2022). This mismatch can be attributed mainly to the objective and perceived disparity in measurement. As evidence, Demdoum et al. (2023) found that the association between walking and several objectively measured built environment attributes peaked at a 600m buffer in Putrajaya City (Malaysia). This highlights the need for an accurate representation of the walkable distance threshold, as it plays a critical role in determining the unit of data aggregation; therefore, it impacts the association with walking behaviour (Mavoa et al., 2019). Moreover, the findings introduce ambiguity in the relationship between walking activity and factors such as mixed land use and residential density.

Secondly, regarding the method of data collection on the built environment, information was primarily gathered through a questionnaire survey about participants' neighbourhoods (see results section). Using solely perceived-based measures was argued to have low reliability when predicting actual walkability. Qualities of the built environment, respondents' sociodemographic characteristics, as well as their level of walking activity, may interfere with walkability perception. For example, perceived safety, represented by the fear of crime or perceived risk of crime, was found to be crucial for walking, rather than the actual occurrence of crime incidents. This result demonstrates the significance of actual physical attributes and how they are perceived, judged, and processed by pedestrians.

Although perceived-based data can provide valuable insights into how people experience and interact with the built environment, it presents limitations in terms of comparability and generalizability, which results in a limited number of suggestions for designing and planning the physical environment. However, objective measures of the built environment are especially important as they offer the advantage of quickly translating research results into interventions. Therefore, more objective research is required to provide an appropriate level of detail to inform practitioners in designing and planning interventions for a walkable environment.

Thirdly, several limitations in Malaysian walkability studies must be mentioned. Firstly, few studies have stratified samples based on specific factors such as demographics,

environment, and socioeconomics, despite their established impact on walking behaviour. Additionally, there is a lack of standardization in terms of the methods and indicators used to assess walkability. This can make it difficult to compare results across different studies and locations. Furthermore, there is a lack of adequate and precise data on walking activity; the majority of studies rely on self-reported walking data from respondents, which may contain measurement errors and biases in the results. In addition, research has primarily focused on large urban areas, which may limit understanding of the impact of the suburban built environment on walking behaviour. Lastly, the investigation into walkability and physical activity in Malaysia is still in its early stages, and more research is needed to support existing findings. This is particularly important as the impact of the built environment on health appears to vary across countries (Wang & Yang, 2019).

Future Malaysian research may prioritize the use of GIS-based walkability indexes to comprehensively measure walkability and improve assessment validity and accuracy (e.g, Duncan et al., 2014; Frank et al., 2010; Frank et al., 2005; Grasser et al., 2017; Habibian & Hosseinzadeh, 2018; Marshall et al., 2009). The application of these indexes has enhanced the measurement of the built environment due to the ability of GIS to represent spatial data by linking location and attributes (Sallis, 2010). However, combinations and weights of the constructs must take into account the morphological differences of the assessed built environment, as they have a significant impact on the outcomes (Fonseca et al., 2022).

For example, the land use mix index (LUM), which is commonly used in North American and Australian walkability research, has shown inconsistent associations with walking across Asian and European cities, primarily due to the fact that urban areas in North America and Australia have a lower degree of land use mix than Asian and European cities (Liao et al., 2020). Therefore, replicating land use mix formulas may not be appropriate for the Malaysian built environment. Furthermore, the application of GIS-based measures must be associated with accurate geographical definition, where the correlation between the built environment and walking is most consistently detected.

Additionally, as there are fewer walkability studies in suburban areas, researchers may need to validate the existing results drawn from urban areas in their future work; cross-comparison studies between urban and suburban areas are recommended. In terms of data, future studies may consider incorporating a broader range of objective-built environment data, such as land uses, which are mostly available through free official resources, such as the Integrated Land Use Planning Information System (I-Plan), provided by the Department of Town and Country Planning of Malaysia. However, gathering data on participants' walking remains a challenge. To overcome this barrier, the use of modern technology, such as auxiliary data installed in cell phones and smartwatches, can provide large amounts of information on participants' number of steps, travelled distance, and time spent walking. Moreover, to improve data quality on walking, future research may consider the purpose of walking, such as for daily errands, leisure, or commuting to work, and other sociodemographic factors, such as SES, age, and car ownership.

CONCLUSION

This review has identified both similarities and differences in the influence of built environment attributes on walking behaviour in Malaysia compared to global patterns, underscoring the impact of the unique Malaysian context. While perceived attributes like safety, aesthetics, and greenery align with global findings, the emphasis on thermal comfort due to the tropical climate distinguishes Malaysia. However, data collection and analysis approaches require further refinement. The current prevalence of perception-based measures offers valuable insights into subjective experiences, but their limitations underscore the need for increased integration with objective measures for a more comprehensive understanding. Future research should prioritize spatially accurate and context-specific assessments through GIS-based walkability indexes, explore the nuances of suburban environments, leverage technological advancements for precise data collection, and

incorporate sociodemographic factors for a deeper analysis. By addressing these key areas, Malaysian research can not only inform locally appropriate design strategies but also contribute significantly to the global body of knowledge on built environments and walking behaviour, ultimately guiding the development of more walkable and sustainable cities for all.

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APPENDIX A

Table A2

Characterization of studies by region, sample, environmental factors, and data source, unite of analysis, walking type, and key findings

Reference	Region	Sample	Environment factors data source	Environment factors examined	Analyse geographic unit	Walking type	Key Findings
1. (Abdulah et al., 2016)	(Penang)	A total of 200 USM student (University Saint Malaysia) young (under 24 years)	Questionnaire survey "Neighbourhood Environment Walkability Scale-Youth (NEWS-Y)"	• Residential density • Land-use mix diversity • Land-use mix access • Street connectivity • Infrastructure for walking • Aesthetics • Traffic safety • Safety from crime • Neighbourhood satisfaction	Neighbourhood	General (not specified)	The level of walking among youth was not affected by traffic safety, but by personal safety. The main factors encouraging young people to walk were recreation facilities, roadside trees, and green spaces.
2. (Arshad et al., 2016)	(Kuala Lumpur)	A total of 317 participants within three locations (Jalan Tuanku Abdul Rahman, Petaling Street and Bukit Bintang)	Questionnaire survey	• Land Use • Accessibility • Safety • Path Facilities • Amenities • Aesthetic	Nods of pedestrianized areas	General (not specified)	The safety of the pathways is the most important factor in walking for both genders. The aesthetics and convenience of the path have a significant impact on the overall travel experience.
3. (Asadi-shekari et al., 2019)	(Johor Bahru)	A total of 599 participants Within Setia Tropika residents	Questionnaire survey Sidewalk audits tool	• Features of pedestrian facilities (e.g., Ramp, Surface material, Width of the sidewalk, • Lighting, Landscape, and tree).	Neighbourhood	General (not specified)	The developed PLOS (Pedestrian Level Of Service) model indicated that the 'main facilities' within pedestrian path (such as ramp and quality of sidewalk) have the highest association with inclusive pedestrian-friendly streets, followed by 'convenience

Table A1 (Continued)

Reference	Region	Sample	Environment factors data source	Environment factors examined	Analyse geographic unit	Walking type	Key Findings
4. (Azmi et al., 2013)	(Putrajaya)	381 respondents (72 samples for Precinct8 & 307 samples for Precinct 9).	Questionnaire survey	• Accessibility of community facilities within catchment area	Neighbourhood	Utilitarian & recreation	Perceived accessibility to community services can influence the level of walkability in the neighbourhood.
5. (Azmi & Ahmad, 2015)	(Putrajaya)	Two Precincts (Precinct 8& 9).	Geographical Information System (GIS)	• Residential density • Road Intersection • Non-residential • land use • Residential Mixed Land use	Neighbourhood 400 meters of walking radius	General (not specified)	Residential density, street connectivity and non-residential component of mixed land uses do influence the resident's walkability pattern in Putrajaya neighbourhood area; Precinct 8 and Precinct 9.
6. (Azmi & Karim, 2011)	(Shah Alam Selangor)	A total of 86 samples (56 samples from the low-cost housing/ 30 from medium cost housing)	Observation survey Questionnaire survey	• Land use Pattern • Walking Distance & Time taken • Accessibility • Safety and Security • Convenience & Attractiveness	Neighbourhood		Low-cost housing area has a better proximity to facilities than medium cost housing area. Factors of distance, catchment area radius, accessibility, density and land use pattern, highly affects walking behaviour.
7. (Ariffin & Zahari, 2013)	(Petaling Jaya, Kuala Lumpur and Putrajaya)	A total of 126 respondents.	Questionnaire survey Assessment audit	• Safety • Accessibility • Comfort • Convenience of the walking environment	Neighbourhood	General (not specified)	The perception of a walkable environment is greatly influenced by the proximity of the destination, the weather, and the design of the walkways.

Table A1 (Continued)

Reference	Region	Sample	Environment factors data source	Environment factors examined	Analyse geographic unit	Walking type	Key Findings
8. (Cheah et al., 2012)	(Sarawak)	A total of 316 respondents (adolescent students aged 14 – 16 years) within seven residential zones (Kuching South City)	Questionnaire survey "Neighbourhood Environment Walkability Scale-Youth (NEWS-Y)"	• Residential density • Land-use mix diversity • Land-use mix access • Street connectivity • Infrastructure for walking • Aesthetics • Traffic safety • Safety from crime • Neighbourhood satisfaction	Neighbourhood	Recreation	Only three factors; (residential density, safety from crime and presence of walking and fitness infrastructure) had a significant relationship with BMI (Body Mass Index). Residential density, land-use diversity, land-use mix access and connectivity were perceived to favour low walkability neighbourhoods.
9. (Elsawahli et al., 2017)	(Kuala Lumpur)	385 older adults aged 60+ years within Taman Meru, Ipoh and Taman Tun Dr Ismail (TTDI) neighborhoods.	Questionnaire survey	• Walking facilities • Walking barriers • Convenience • Accessibility • Permeability • Maintenance • Safety	Neighbourhood	Recreation	Desire to walk could arise from the availability of accessible facilities, well-connected streets, and well-maintained walkways. Improved pedestrian connectivity and connectivity to community services, leisure, exhibited a high level of social interaction and higher levels of physical activity.
10. (Harumain et al., 2017)	(Kuala Lumpur)	A total of 562 respondents (women) within LRT stations.	Questionnaire survey	• Safety and Security • Perceived distance	LRT station location	Utilitarian	Personal safety is associated with willingness to walk for women.

Table A1 (Continued)

Reference	Region	Sample	Environment factors data source	Environment factors examined	Analyse geographic unit	Walking type	Key Findings
11. **(Harun & Nashar, 2017**	(Kuala Lumpur)	A total of 150 of International Islamic University Malaysia (IIUM) students	Questionnaire survey	• Perceived streetscape physical elements (e.g., Sidewalk, Trees, Lighting) in response to four walkability criteria (Comfort, Connectivity, Safety and Accessibility)	University campus (IIUM)	General (not specified)	One of the fundamentals of achieving street walkability is comfort. It must be supported by other aspects of safety, connectivity, and accessibility.
12. **(Ja'afar & Harun, 2018)**	(Melaka Historic City)	A total of 335 respondents	Observation survey Questionnaire survey	• Building openings • Street aesthetic & urban Character.	Nods of pedestrianized areas	General (not specified)	The design of ground-level building openings that correspond to building function is critical in contributing to the street's character, and thus its walkability.
13. **(Keat et al., 2016)**	(Kuala Lumpur)	A total of 224 First Year students living in eleven residential colleges within Universiti Malaya campus.	Survey observation	• Pedestrian network quality	University campus	General (not specified)	Perceived 'walking distance' and quality of street design between the students' hostels and faculties was crucial to encourage/discourage walking .

Table A1 (Continued)

Reference	Region	Sample	Environment factors data source	Environment factors examined	Analyse geographic unit	Walking type	Key Findings
14. (Keyvanfar et al., 2018)	(Johor Bahru, Skudai)	A total of 120 respondents within Taman Universiti neighbourhood	Self-report questionnaire Path audit tool	• Safety • Connectivity • Comfort • Convenience • Attractiveness • Aesthetic	Neighbourhood pedestrian-oriented distances (400–900 m) within shopping centres (A, B, C)	General (not specified)	The new Path Walkability Assessment (PAW) grading index demonstrates the superiority of pedestrian crossings (safety features) as well as Street-Facing Entrances (connectivity features) as they have the greatest significant impact on neighbourhood walkability.
15. (Karim & Azmi, 2013)	(Putrajaya)	A total of 30 respondents from 17 to 60 years. (Precinct 9 & 14)	Questionnaire survey	• safety • convenience • attractiveness	Neighbourhood	General (not specified)	The attributes of safety and security, as well as convenience and attractiveness, are critical in developing a walkable neighbourhood.
16. (Mahmoud et al., 2016)	(Putrajaya) precinct 14, precinct 16,	A total of 60 questionnaire (30 for each precinct) &6 routes audited and 6 interviewees	Questionnaire Road auditing Interview	• Mixed physical features (e.g., • Safety • walkway quality, Surroundings, walking • distance)	Neighbourhood	General (not specified)	Walking distance to the facilities of the neighbourhood, safety from crime and safety from traffic were ranked as the most important walking promoters.
17. (Majid et al., 2021)	(Johor Bahru)	A total of (n= 256)	Questionnaires survey; Perceived Neighbourhood Built Environment (PNBE),	• land use mix access • safety • street connectivity	Neighbourhood	General (not specified)	Proximity to Food shops location found to be facilitate BMI, and walking.

Table A1 (Continued)

Reference	Region	Sample	Environment factors data source	Environment factors examined	Analyse geographic unit	Walking type	Key Findings
18. (Maleki & Zain, 2011)	(Kuala Lumpur)	155 neighbourhoods within Subang Jaya Township.	GIS map of municipal of Subang Jaya, Kuala Lumpur, Malaysia.	• Density • Land diversity (entropy) • Mixed used • Non-residential land • Employment density	City	General (not specified)	Density, land diversity, non-residential land use, and employment influence the walkable distance to facilities.
19. (Mansouri & Ujang, 2016)	(Kuala Lumpur historical district)	A total of 330 respondents (tourists)	Questionnaire survey	• Accessibility • Connectivity • Continuity	Nods of pedestrianized areas	Recreation	Tourists' expectations on the spatial characteristics of walkways in terms of accessibility, connectivity and continuity were greater than their satisfaction.
20. (Mansouri & Ujang, 2017)	(Kuala Lumpur's historic district)		Observation Space syntax	• Street networks' connectivity and integration	Streets layout within historic district	Recreation	Location of attractions is strongly influenced (at both local and global scales) by the grid configuration. Pedestrian movement in Kuala Lumpur is oriented more to the diversity of land use and attractors than to the connectivity of walkways.
21. (Mokhlas et al., 2015)	(Kuala Lumpur)	35 respondents within (Sri Petaling, Batu Kantomen and Pantai Dalam) rail stations	Questionnaire survey	• Distance to station • connectivity, • Safety (crime& incidences)	400 meters within rail transit stations	Utilitarian	Physical environment and weather are positively correlated with walkability, but only to a minor extent. No correlation between safety and rail service level and walkability.

Table A1 (Continued)

Reference	Region	sample	Environment factors data source	Environment factors examined	Analyse geographic unit	Walking type	Key Findings
22. (Nordin & Nakamura, 2019)	(Johor Bahru)	A total of 280 elderly respondents (45 and above)	NEWS-A (Neighbourhood Environment Walkability Scale-abbreviated) Geographical Information System (GIS)	• Residential Density • Land Use Mix • Access to Services • Street Connectedness • Walking Infrastructure • Aesthetics • Traffic Hazard • Crime	Neighbourhood	General (not specified)	Strong correlations were found between Objective neighbourhood environment and Perceived environment, this association however, does not necessary reflect on total physical activity of residents.
23. (Nasrudin et al., 2018)	(Kuala Lumpur)	A total of 120 respondents (Jalan Tuanku Abdul Rahman)	Questionnaire survey Observation (checklist, zonal mapping and photographs)	• safety, traffic, • comfort • walkways condition)	Commercial area	General (not specified)	Strong association between safety, security, and walkability of the area. Aesthetic criteria for walkways (for example, street art, street furniture landscaping, tree canopy, and signage) can influence perceived comfort and experience while walking.
24. (Omar et al., 2016)	(Kuala Lumpur)	400 samples youth (age15-25 years) within Lembah Pantai district	Questionnaire survey Observation	• accessibility • availability • comfortability • connectivity • maintenance	Urban public housing environment Public Park.	Recreation	More waking and outdoor activities for youth require walkways connectivity.

Table A1 (Continued)

Reference	Region	Sample	Environment factors data source	Environment factors examined	Analyse geographic unit	Walking type	Key Findings
25. (Qureshi et al., 2018)	(Putrajaya)	A total of 402 Precincts (8,9 and18)	NEWS-A (Neighbourhood Environment Walkability Scale-abbreviated) Geographical Information System (GIS)	• Residential Density • Land Use Mix • Access to Services • Street Connectedness • Aesthetics • Safety	Neighbourhood	General (not specified)	For all three study sites, perceived built environmental attributes were strongly related to objectively assessed built environmental attributes.
26. (Ramakreshnan et al., 2020)	(Kuala Lumpur)	A total of 380 participants (campus community)	Questionnaire survey	• Street connectivity • Accessibility • Traffic safety • Pedestrian infrastructure • Land use	University campus	General (not specified)	Street connectivity and accessibility was described as the most opted built environment factor, followed by land use, pedestrian infrastructure, traffic safety and campus neighbourhood.
27. (Shojaei & M.S, 2012)	(Kuala Lumpur)	A total of 70 participants (44 residents and 26 professionals)	Photo-questionnaires Interview	• Perceived characteristics of walkways	Residential development	General (not specified)	People prefer a permeable view of the walkway. Semi-structured covered walkways, are preferred for walkable neighbourhood.
28. (Shamsuddin et al., 2012)	(Kuala Lumpur)	A total of 400 respondents in five zones (Bukit Bintang, Tuanku Abdul Rahman Road, Raja Laut Road, Kampung Baru)	Questionnaire survey Field observation (photography recording and zonal mapping)	• Pedestrian walkaways design • Destination • Safety • Pedestrian facilities • Enjoyable elements	Nods of pedestrianized areas	General (not specified)	The design of pedestrian walkways. encourage walking activities The use of destination land is also important in developing a walkable environment. Walking is also encouraged by safety, pedestrian facilities, and enjoyable elements.

Table A1 (Continued)

Reference	Region	sample	Environment factors data source	Environment factors examined	Analyse geographic unit	Walking type	Key Findings
29. (Tung et al., 2016)	(Klang, Selangor)	A total of 250 children (9–12 years of age) and their parents.	NEWS (neighbourhood Environment Walkability Scale)	• Residential density • Land-use mix (diversity/ access) • Street connectivity • Facilities for walking/cycling aesthetics • Traffic hazards & Crime	Neighbourhood	General (not specified)	More allocation of stores, places and transit stops within walking distance was positively correlated with higher levels of walking activity among children. Negative correlation was found between traffic hazards and safety with children's physical activity.
30. (Ujang & Muslim, 2014)	(Kuala Lumpur city centre)	Not mentioned	Questionnaire survey	• Connectivity • Comfort • Feeling while walking • Safety • Attractiveness • Pleasantness	Deferent Attraction points within city centre	Recreation	The pleasantness of walking and accessibility influence visitors' engagement with activities and functional attachment to places.
31. (Yi et al., 2017)	(Penang and Kota Bharu)	A total of 490 Participants (20 to 65).	Geographical Information System (GIS)	• Mixed land use • Intersection density • Residential density	Neighbourhood	General (not specified)	Physical activity levels differ significantly between participants living in high and low walkable neighbourhoods, indicating the importance of environmental factors (density, connectivity, and land use) in influencing total physical activity.
32. (Zakaria & Ujang, 2015)	(Kuala Lumpur)	450 (150 at Merdeka Square, 150 at (KLCC) area ,150 at Jalan Bukit Bintang) Only 400 were used in the study.	Questionnaire survey	• Proximity • Quality of streetscape, • Connectivity. • Accessibility • Safety	Nods of pedestrianized areas	General (not specified)	Proximity, connectivity, safety, and the appearance of the environment are important factors for pedestrian comfort.