

Assessing walkability in Bandar Sunway

Susilawati¹, Meng Kiat Lee¹, Pei-Lee Teh¹, Tan Chee Pin¹, Sekhar Somenahalli², Santha Vaithilingam³

¹Monash University Malaysia, Jalan Lagoon Selatan, Bandar Sunway Malaysia

²University of South Australia, Adelaide, Australia

³Sunway University, Bandar Sunway, Malaysia

Email for correspondence: susilawati@monash.edu

Abstract

Walkability is the degree to which the urban environment is friendly to pedestrians. It has become an important aspect of urban town planning as it could address the quality of pedestrian infrastructure and hence could make walking-related strategies such as the 15-minute city initiative more objective and effective. This work develops a walkability framework for evaluating walkability based on local conditions and assesses the walkability of Bandar Sunway, a township in Kuala Lumpur, Malaysia. The proposed method takes into account different types of land use and pedestrian infrastructure quality and measures walkability in terms of seven key dimensions (7C method) using GIS and street audits. The findings of the walkability analysis are used to measure the readiness of Bandar Sunway to adopt the 15-minute city initiative. The results show apparent differences in walkability scores for different parts of the study area. These mainly are attributed to low connectivity and land use diversity. Thus recommendations to strategise the infrastructure planning and land user diversity to support the 15-minute city initiative are provided.

1. Introduction

It is concerning to know that the transportation sector remains one of the significant contributors to CO₂ emissions. According to Emberger (2017), the transportation sector contributes 20% to 30% of global emissions. Furthermore, according to Allam et al. (2022), it has been shown that more than 60% of the worldwide greenhouse gases have been related to cities. In addition to that, with the growth of the human population, increase in car dependence and therefore increased levels of congestion on our road network, a sustainable measure should be taken towards reducing the environmental impact that the transportation sector brings on cities around the globe. Therefore, there is a growing need to plan modern-day cities to facilitate rapid urban development efficiently.

A 15-minute city built around the core principles of proximity, diversity, density, and digitisation can potentially solve the high carbon emission levels from the transportation sector as its implementation can potentially reduce car dependencies (Allam et al., 2022). The idea of a 15-minute city introduced to the public in 2016 by Carlos Moreno aims to promote the chrono-urbanism concept whereby a city is enhanced by one primary factor, time (Moreno et al., 2021). This is done by enabling more accessible access to critical services and shortening the travel distance of these trips to either a 15-minute walk or cycle.

Thus to make the 15-minute city initiative more objective and effective, it is critical to conduct a walkability analysis. Walkability can be defined as a matrix to measure the degree to which the urban environment is friendly to pedestrians. In the Malaysian context, although walking has several merits in promoting sustainable transport modes, promoting walking among Malaysians has always been difficult for many reasons. One of them is that roads were mainly designed to be used for driving (Sukor, Hatta & Hassan 2017). Wan Omar, Patterson and Pegg (2013) found that residents in Kuala Lumpur disfavour walking due to factors such as unsafe traffic, personal safety, and unsupportive weather, which further substantiate Malaysians' perceptive toward walking.

Therefore, this research paper aims to assess the walkability in the selected study area in Kuala Lumpur, Malaysia, using the 7C method and to evaluate the readiness of this study area to adopt the 15-minute city initiatives. Based on the findings, several recommendations are proposed to strategise the infrastructure planning and land use diversity to support the idea of a 15-minute city. The 7C method has been chosen as the primary tool in walkability analysis because it considers pedestrian infrastructure quality and different types of land use. Hence it comprehensively assesses all elements of walkability.

The study consists of three main parts; the first part is a stakeholder panel discussion to identify the indicators for each 7C dimension and set the questionnaire's structure and questions. The second part is a questionnaire survey to gauge the travellers' perception of the current state of the walking infrastructure available in Sunway City (Kuala Lumpur) and investigate the salient factors that encourage or hinder travellers in Bandar Sunway walk. The third part is to develop a walkability assessment using the existing GIS-based walkability tool. Two types of data (i.e., primary data from the questionnaire survey and data collected from the site-specific physical audits) are fed into the GIS analysis for walkability assessment.

The paper consists of several sections. The literature review encompasses the concept of walkability and various walkability indicators and tools to assess it. Due to varying perspectives, there are extensive studies on indicators on how they affect walkability, but very little has been done on methods to aggregate all the indicators. The third section is the methodology that presents the questionnaire survey development, street auditing and GIS-based walkability assessment development. The results and discussion are presented in section 4. Section 5 is the conclusion and future recommendations.

2. Literature Review

Today, land use planning plays a significant role in shaping a better tomorrow via implementing sustainable city planning measures. Many studies have shown a strong relationship between the built environment characteristics and green mobility and the impact on the emission of CO₂ reduction (Wu et al., 2019, Ashik, Rahman and Kamruzzaman, 2022). These studies suggested that designing cities based on proximity, accessibility, diversity, density, and ubiquity can be achieved by implementing a 15-minute city concept that would promote sustainable mobility and thus aid in reducing vehicle emissions (Moreno et al., 2021).

The 15-minute city promotes sustainable transport mode that includes walking and cycling. Walking is a transport mode used by almost everyone daily as the beginning and end of a journey require walking. Hence walking is an essential aspect of urban planning by shaping urban development and plays a vital role in the first and last mile of connectivity (Rissel et al. 2012).

Over the years, several walkability definitions have been introduced. Owen et al. (2007) considered walking in two contexts – as a means of transport and leisure. He also identified

walkability to behave differently for different social and demographic groups. Lo (2009) stated that the walkability definition is based on the definition of pedestrians. Pedestrians can be defined as simple as “a person travelling on foot”, which can be expanded to include people with a disability based on social equity. To be able to assess and quantify walkability, Forsyth (2015) looked at the different definitions of walkability: some experts focus on the environmental features (walkable path to be compact, attractive); some concentrate on the outcomes spawned by environmental elements (area made lively, promoting a healthy lifestyle through exercising); some define walkability as a multidimensional variable governed by several measurable dimensions. Other researchers considered that built environment, weather conditions, and personal safety correlate to walkability (Abley & Turner 2011; Clark, Scott & Yiannakoulis 2014; Doyle et al. 2006; Owen et al. 2007). These varying perspectives on walkability lead to the development of different methods and tools to measure walkability.

Walkability can be counted as a multidimensional variable using multi-criteria analysis. Multi-criteria analysis (MCA) is a decision-making tool typically applied to complex decision situations. The standard way is to divide each decision problem into smaller parts and analyse them before aggregating all the decisions to generate a solution (Malczewski 1999). There are several methods to do an MCA. For example, the Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP) are two of MCA's most commonly used methods. The Analytical Hierarchy Process (AHP) method developed by (Saaty 1977) is a scaling ratio MCA method. This is done by creating a ratio scale after comparing two elements in a pair. The scales can then transform the decisions into numerical values. However, the AHP method does not consider the criteria to be dependent on one another, which may not be accurate in the real world. Saaty 1997, proposed Analytical Network Process, replacing the hierarchies in the first method with networks. This method can be seen adopted by (Wey & Chiu 2013) combined with the house of quality (HOQ) to assess walkability under a transit-oriented development in Taiwan.

Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) is an MCA application developed by Costa and Vasnick. It is an interactive method that requires only qualitative preference judgement, generating a numerical scale to assist decision-making. The technique itself has been used vastly by the creators. In the creator's work, (Costa & Vansnick 1999), the method was tested to calculate value functions and determine weights between criteria. For simple multi-criteria analysis, de Mello, 2015 included 1000minds in the summarisation of MCA methods. 1000minds is a relatively more straightforward method compared to the methods above. The software works by letting the user choose one alternative from a pair of options for all possible combinations of alternatives (de Mello 2015).

Several walkability tools are proposed. Walk Score is a tool that measures walkability based on walking distances to nearby amenities, including shopping complexes, parks, groceries, etc. (Score 2014). The Path Walkability Index (PAWDEX) is a tool proposed by Lamit et al. (2013) to calculate walkability in the Malaysian urban context. Fifty-six walkability indicators are filtered from the literature review pool of 181 environmental variables. The selected indicators were placed into five different groups based on experts' opinions, as follows: 1) Sense of safety, 2) Sense of security, 3) Comfort, 4) Convenience, and 5) Visual interest. Methorst et al. (2010) proposed an aggregated group with five critical dimensions named “5Cs” for their work at Transport for London that includes “Connected: How well the pedestrian network is linked; Convivial: Walking as an enjoyable activity, in terms of interaction with the surrounding; Conspicuous: Perceivability of the walkways; Comfortable: Extent of walking accommodating

to competences and abilities; Convenient: Extent of the possibility of walking to compete with other transport modes (time, cost)”.

De Cambra (2012) added two more indicators to the existing 5Cs method, forming the “7Cs”. The 7Cs method includes “Coexistence: Extent of pedestrian and other transport modes can coexist at the same time and place without conflict; Commitment: Extent to which there exists engagement, liability and responsibility towards the pedestrian environment” (de Cambra 2012). The 7C indicators are the complete indicators considering almost all aspects affecting walkability. The methodology used in 7C indicators is universal as it considers locals' perception of walkability by conducting a stakeholder survey.

Therefore, 7C's result will reflect more accurately based on the community's perspective. Up to this point, the methods and indicators discussed mainly apply to a sidewalk pedestrian walkway. At the same time, an elevated walkway enclosed with air conditioning may require different assessment methods (Keumala and Mustapha, 2014).

3. Methodology

This project's scope is to assess the walkability of a walking adult in Bandar Sunway, Kuala Lumpur, Malaysia. by acknowledging that walkability is a multi-dimensional variable (de Cambra 2012; Methorst et al. 2010). The 7C method suggested by de Cambra (2012) is adopted. The 7C method consists of 7 dimensions: connectivity, convenience, comfort, conviviality, clarity, coexistence, and commitment that assist transport planners in objectively and effectively planning and designing 15-minute city initiatives by addressing those questions that are tabulated in Table 1.

Table 1. 7Cs dimensions for walkability

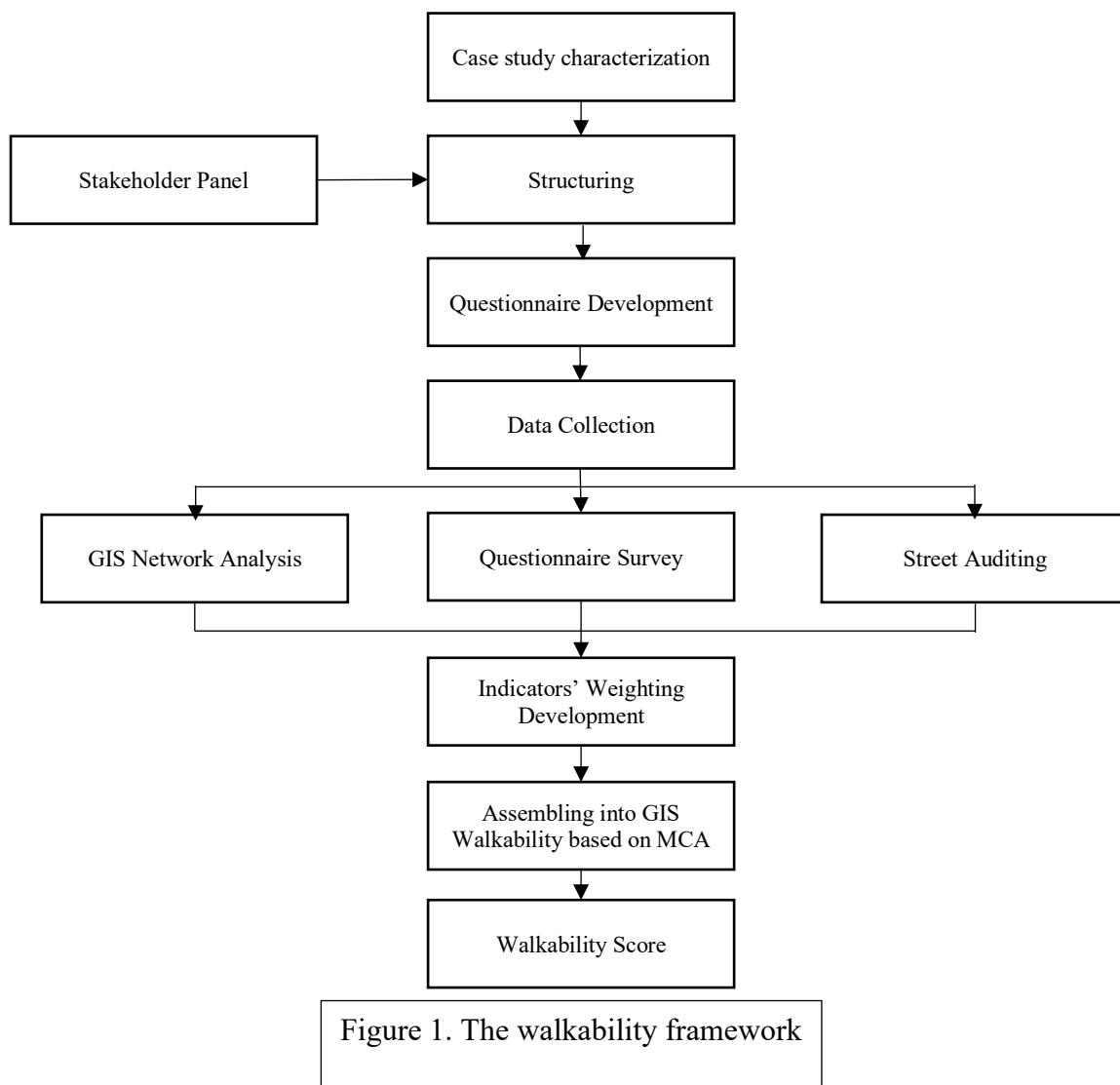
C1	Connectivity	How accessible is the network?
C2	Convenience	How does it compare with other transport modes? (time, cost)
C3	Comfort	How good is the experience?
C4	Conviviality	How attractive is it?
C5	Clarity	How easy to navigate?
C6	Coexistence	Conflict with other transport modes?
C7	Commitment	Concern to do better?

These seven dimensions can be measured using various indicators. For example, connectivity can be measured using street density and path directness, while convenience can be measured using land-use diversity. The comfort and conviviality can be measured using pavement surface quality and the possibility for meeting and sojourning, respectively. Landmarks, wayfinding and pedestrian crossing safety are some indicators that can be used to measure clarity and coexistence. Enforcement and path cleanliness can be used to measure commitment. A complete list of indicators to measure each dimension is tabulated in Appendix 1.

The walkability framework adopted in this study is presented in Figure 1. In general, It has three main parts; the first part is a stakeholder panel discussion to identify and determine the indicators for each seven dimensions and develop the structure of the questionnaire survey. The second part is the questionnaire survey to gauge travellers' opinions about the existing walking infrastructures and their experience using the walking infrastructure around Sunway City. In addition, the questionnaire survey assists in understanding salient factors that encourage or hinder travellers in Bandar Sunway from walking. The outcome of the

questionnaire survey is used to calculate the weights of each 7C indicator that will be used as an input for the third part, a GIS-based walkability assessment using the MCA method.

The proposed framework is started with the case study characterisation to select the study area, followed by the stakeholder panel discussion. After that, the questionnaire is developed. Three types of data collection are conducted, the GIS network data analysis to obtain pedestrian network spatial data from open source map and prepare that spatial data for future research, including data cleaning and updating the spatial data attributes. At the same time, questionnaire surveys and street auditing are also conducted. The input from data collection and analysis are fed into the GIS walkability tool to measure the walkability score. The following section explains in detail each step of the proposed walkability framework.



3.1 Study Area

Located in Subang Jaya, Bandar Sunway is one of the most popular townships in Selangor, known for its higher education hub and diverse amenities. The majority of the significant landmarks were constructed back in the 90s' which marks the beginning of Bandar Sunway. Coinciding with the era of the industrialised nation by the 4th Prime Minister – Tun Mahathir Mohamad, the rose of various car manufacturers further fuels the appetite for Malaysians to own private vehicles (Abdelfatah, Shah & Puan 2015). Several major expressways were

constructed around the same timeframe, such as the New Pantai Expressway (NPE) and Damansara-Puchong Express (see Figure 2). The significant expressways were built, so the township is enclosed within, enabling the township to be highly accessible via automobiles from other major cities. This phenomenon is described as an “edge city” by Hall and Pfeiffer (2000), where a town is built around highway access and has little public transit access. Mass motorisation is responsible for the birth of car-oriented developments. Designed as a car-oriented development, road infrastructure in the township is well established as road infrastructures were believed to equate to economic success throughout Klang Valley (Ariffin & Zahari 2013). However, this poses a problem to other street users, mainly pedestrians and cyclists, as the relatively high volume of automobiles is always given priority on street levels.

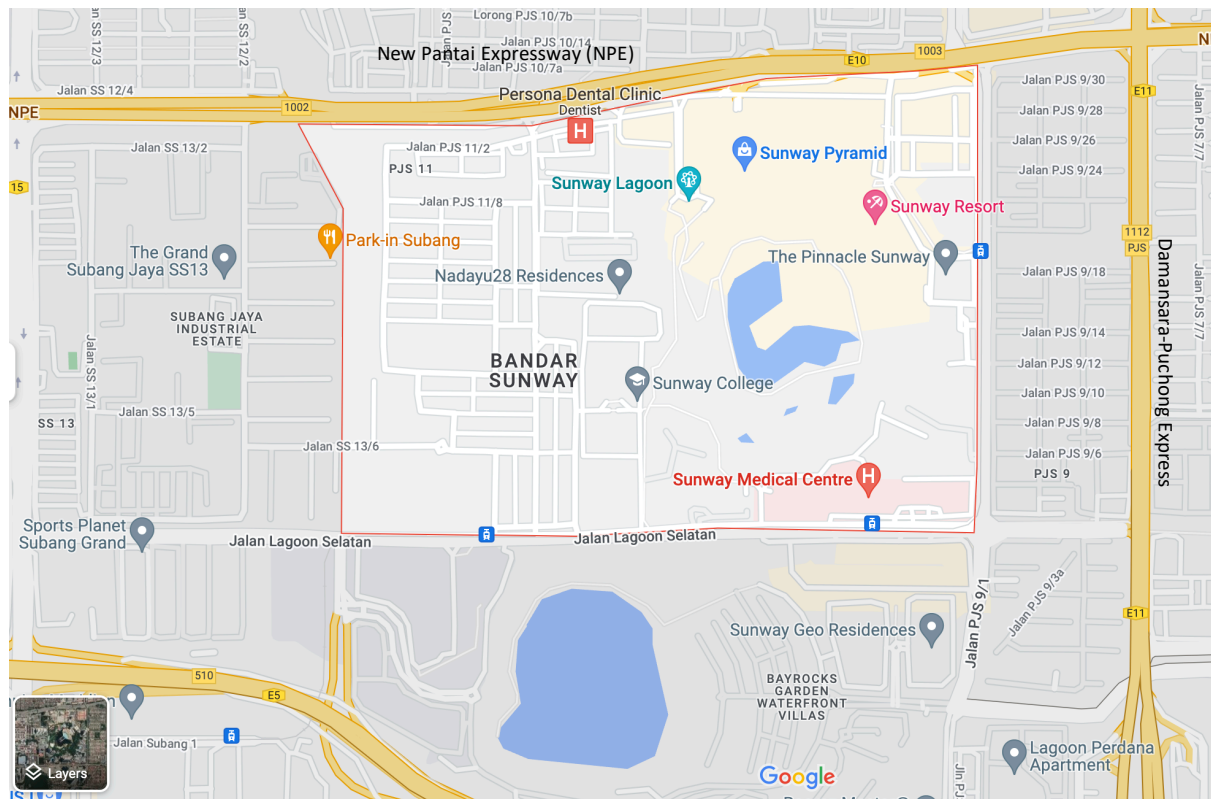


Figure 2. Bandar Sunway

3. 2 Stakeholder panel

As indicated in Appendix 1, multiple indicators are used for each dimension that might constrain the multi-criteria analysis (Baker et al. 2002). Thus a trimming session to determine and identify suitable indicators is conducted. This has been done by inviting a key group of stakeholders in Bandar Sunway. During a focus group discussion, each stakeholder is given a chance to discuss the indicators they think are essential in walkability. With the assistance of stakeholders, the indicator for each dimension is selected. Table 2 shows the trimmed indicators chosen by stakeholders. The stakeholder panel also assists in identifying critical questions for the questionnaire survey.

Table 2 The trimmed indicators chosen by stakeholders

Dimension	Indicator suggested by the stakeholder panel
C1	Continuity of walking path/ sidewalk
C2	Land use diversity
C3	Pavement surface quality
C4	Mixed uses and mixed working hours
C5	Landmarks
C6	Traffic safety (at pedestrian crossings)
C7	Commitment

3.3 Questionnaire development

The questionnaire survey consists of two parts. The first part of the survey collected socio-demographic information. The second part consisted of questions about how the respondents transport themselves to work/study, the distance and frequency of these trips, travellers' opinions about the existing walking infrastructures, and what factors hinder the respondents from walking. The pilot survey was also conducted with 20 individuals before the data collection. As a result of this pilot survey, some questions were updated and rephrased. Respondents are presented with 7C indicators for obtaining indicators' weights, including connectivity, convenience, comfort, conviviality, clarity, coexistence, and commitment. They are asked to state their opinion based on a 5-point Likert scale representing agreement or disagreement, shown in Table 3.

Table 3. Scores and meaning were assigned to the items using a 5-point Likert scale

1	Strongly agree
2	Somewhat agree
3	Neither agree nor disagree
4	Somewhat disagree
5	Strongly disagree

3.4 Questionnaire survey

The questionnaire survey was conducted using face-to-face interviews in May 2018. In total, 210 individuals responded to the survey. Most respondents were students and working adults from Monash University Malaysia, Sunway University, Menara Sunway, Sunway Pyramid, Sunway Geo and Taylor's University. 20% of respondents are Sunway residents who live in Bandar Sunway, and 80% of respondents are non-residents who live outside Bandar Sunway but regularly travel to Bandar Sunway for work or study.

3.5 GIS Network Analysis

The second step is to develop GIS-Network Data. It starts with the preparation of road network data for walkability analysis. The pedestrian network data consisting of Sidewalks and crossings are obtained from Open Source Map (OSM) and are fed into a Geographic Information System (GIS) software –ArcGIS. In addition, the attributes of these features, such as the width of the footpath, are also updated. In total, there are 206 links and 235 nodes, respectively. Links are roadways or pathway segments between two nodes, whereas nodes are

defined as intersections or ends of culdesacs. To ensure the node and links were connected correctly and that the pedestrians flow can traverse between node and through links, the network topology analysis is conducted using the network analyst tool in the ArcMap software.

As indicated in section 3.2. Continuity of walking path/sidewalk, which is indicated by the link ratio is chosen as C1 indicator. In this step, the Continuity of walking path/sidewalk” is also conducted. It is assessed using GIS by incorporating the link-node ratio method on a macro scale. The network with the highest connectivity has a ratio of 2.5 and is described as the perfect grid (Dill 2004). A high link-node ratio indicates more alternative routes to reach a destination. Ewing (1996) suggested that a ratio of 1.4 would be an excellent target for network planning purposes, with at least three cities identified to have adopted the same method with the same target value (Handy, Paterson & Butler 2003). As quantified by de Mello (2015), the scoring of C1 would be a linear relationship with a 0100 score corresponding to a link node ratio of 0 2.5. Apart from the C1, the rest of the indicators require onsite evaluation using street auditing method to assign the scores accurately.

3.6 Street Auditing

To assess the condition of pedestrian infrastructure in the study area, street auditing via on-site evaluation (street auditing) is conducted. It has been done by adopting the street auditing guideline proposed by de Mello (2015), in which every 100m pedestrian path segment is assessed based on each indicator. For example, “C2: Land use diversity” looks at the different land uses found along a 100m segment considering the primary land use types – commercial, residential and services/offices. For each land use spotted, 1 point is awarded to a maximum of 3.

“C3: Pavement surface quality” requires inspecting the pavement quality of each 100m segment. The maximum score of 2 is given to the section if the pavement has very few bumps and cracks instead of 1 if there are some bumps and overgrown vegetation along the pavement. The segment gets zero scores if there is no actual sidewalk. Abley and Turner (2011) consider tripping elements as inputs too. “C4: Mixed uses and mixed working hours” looks at how active a segment will be, primarily affected by the land use mix along the segment. The maximum score of 2 if there is a good land use mix with extended service hours as an indication. A score of 1 if the service hours are only during night/day. A score of 0 if there is little activity on the segment. The maximum score of 2 if landmarks can be seen throughout the whole segment in “C5: Landmarks”. A score of 1 if only visible partially throughout and 0 if no landmarks are visible.

“C6: Traffic safety (at pedestrian crossings)” considers two aspects during crossing that are exposed to traffic and visibility. It is assumed that both aspects are equally weighted. The direction of traffic can aid in scoring this indicator as the left-in the left-out intersection has lower exposure and fewer concerns for incoming traffic from other movements than a cross intersection. Exposure also correlates to traffic speed as high traffic speed will automatically be more dangerous for crossing pedestrians. Hence, a score of 2 if pedestrians will always be given priority and 0 if not perfectly safe.

On the other hand, visibility means no obstruction of sight distance during the crossing. A score of 2 if vehicles and pedestrians can see each other clearly and vice versa for a score of 0. As a crossing is a connection between two or more segments, the connected segment will adopt the average scores of adjacent crossings.

The closest way to quantify “C7: Enforcement of pedestrian regulations” as stated by the Malaysian Public Works Department (Jabatan Kerja Raya 1997), a minimum of 2.0 meters width of a footpath should be provided for sidewalks. A score of 2 is assigned if more than 2 meters of the sidewalk is provided, a score of 1 if 2 meters of the sidewalk is provided and 0 if there is no designated sidewalk presence. Table 4. summarises the scoring method of each indicator.

3.7 GIS-based walkability assessment

The walkability score is calculated by aggregating all seven indicators after standardising the scores generated from the questionnaire survey. The scoring systems are applied to each 100m segment. The description of the scoring system is as follows;

Table 4. Summary of scoring system for each indicator

C1: Continuity of walking path/ sidewalk	Link-node Ratio 2.5 Perfect Grid 0 Base value
C2: Land use diversity	1 Commercial 1 Residential 1 Service/office
C3: Pavement surface quality	0 No Pavement 1 Some bumps or grown vegetation 2 Very few bumps, cracks
C4: Mixed uses and mixed working hours	0 Very little land use mix 1 Good land use mix but service hours during night/day 2 Good land use mix, extended service hours
C5: Landmarks	0 No presence, visibility of reference elements on all arcs 1 No presence, visibility of reference elements on majority of arc 2 Presence, visibility of reference elements in majority of arc
C6: Traffic safety (at pedestrian crossings)	Exposure/ speed of traffic (0 High, 1 Average, 2 Low) Visibility (0 Low, 1 Average, 2 High)
C7: Commitment	Width of the pedestrian sidewalk 0 No sidewalk 1 If 2 meters provided 2 More than 2 meters

The results of street auditing of each 100m pedestrian path segment are inputted into GIS-Data.

3.8 Walkability Score

After assigning scores for each 100m pedestrian path segment indicator, the walkability score can be calculated using equation 1.

$$walkability = a \frac{C1}{max\ score_i} + b \frac{C2}{max\ score_i} + c \frac{C3}{max\ score_i} + d \frac{C4}{max\ score_i} + e \frac{C5}{2\ max\ score_i} + f \frac{C6}{max\ score_i} + g \frac{C7}{max\ score_i} \quad \text{Equation 1}$$

Where a, b, c, d, e, f and g are the weightage of each 7 C dimension and $max\ score_i$ of each 7 C dimension.

4. Result and Discussion

4.1 Questionnaire Survey

Table 5. presents selected sample characteristics. To minimise bias in data collection, the sample characteristics are compared with the country characteristics. The respondents are younger than the average population from which they were drawn. We note that men are overrepresented (58.5%), slightly higher than the national average (51.5%). The level of tertiary education (education level diploma or higher) and the income are relatively higher than the national average. This corresponds to the location of the study area, which is located in the urban setting.

Table 5. sample characteristics

	Pooled sample	Country
Age, years	Respondents range from 19 years to 61 years of age (with a median of 23 years).	Median 29.6 years
Gender	Respondents comprise 58% males and 42% females.	Median 51.5% males Median 48.5 females
Education	All respondents are at least high school graduates, with 48% of them having received tertiary education (diploma or higher).	32% of population having received tertiary
Income	Median income RM 11,000	Median income: RM 7,900

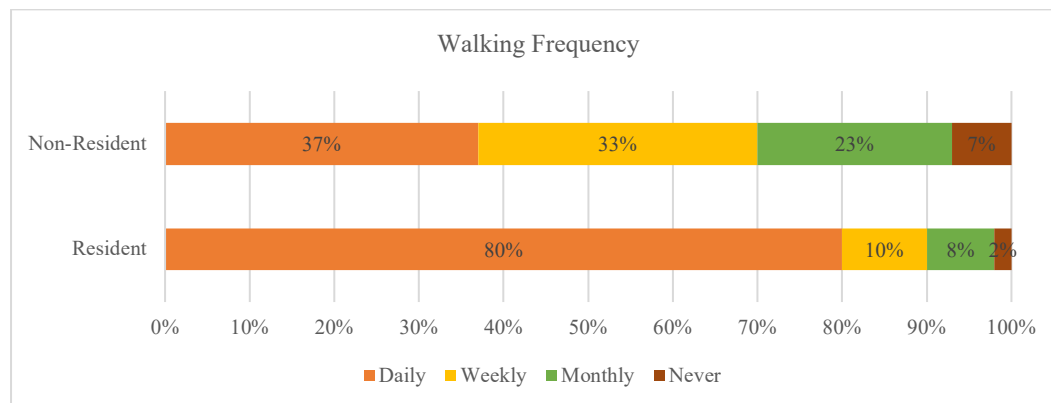


Figure 3. Walking frequency of resident and non-resident

Figure 3 shows the respondent's walking habit. The data shows that about 80% of Sunway residents walk daily. This is a relatively high proportion, which to some extent reflects that the built environment around Sunway support walking. At the same time, only 37% of non-Sunway residents walk daily.

Figure 4. presents survey responses to questions about respondents' perceptions about the availability of the walking infrastructure. Figure 4 shows the percentage of the respondents that strongly agree, agree, neither agree nor disagree, somewhat agree and strongly disagree (on a five-graded Likert scale). As shown in Figure 4. respondents mostly agree with the availability and quality of walking infrastructure.

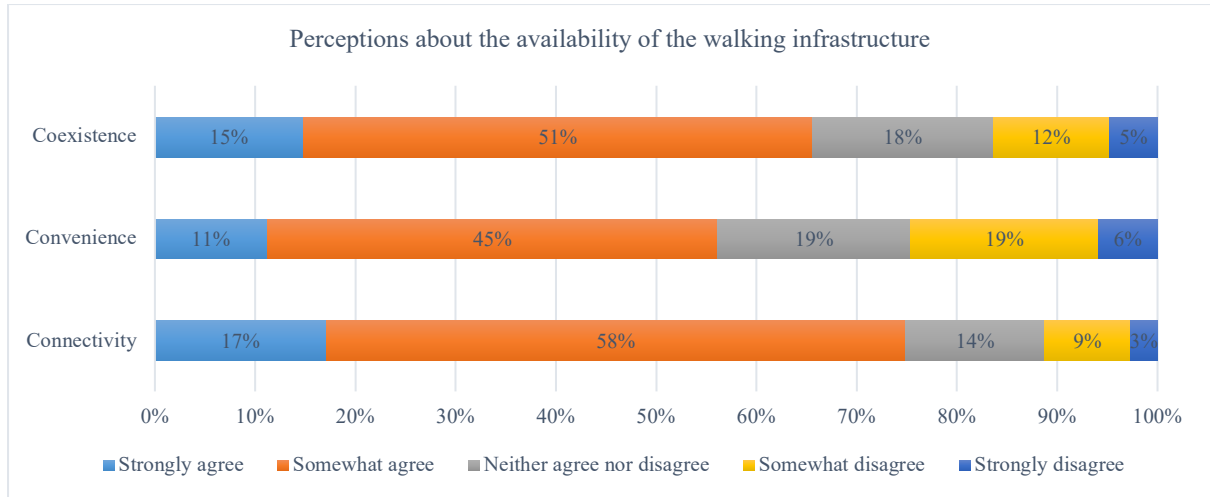


Figure 4. summarise the perception of walking infrastructure

A relative importance evaluation is conducted to obtain the relative importance of each indicator. The Relative Importance Index (RII) is used to determine the relative importance of each indicator. The Likert scale chosen by respondents is multiplied by the number of respondents chosen at that particular point.

The Relative Importance Index (RII) was calculated by equation 2.

$$RII = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{AN} \quad \text{Equation 2}$$

Where n_5 is the number of the respondent of strongly agree, n_4 is the number of the respondent of somewhat agree, n_3 is the number of the respondent of neither agree nor disagree, and n_2 is the number of the respondent of somewhat only disagree, and n_1 is the number of the respondent of strongly disagree. A is the highest weight; in this case, it is 5, and N is the total number of respondents.

The higher the relative importance index (RII) value, the more critical that component is. The result is tabulated in Table 6, which indicates the important indicators affecting walkability in the study area. Connectivity is the top indicator among others (i.e., comfort, clarity, convenience, conviviality, coexistence and commitment). The results of the relative importance are then translated to assess the walkability assessment by assigning a certain weightage to each indicator. This has been done by applying a simple ratio method. For example, C1 has a higher RII than other dimensions. Hence higher weightage is allocated to C1. The result of the relative importance and weightage for each indicator are tabulated in Table 6.

Table 6. The results of the relative importance (RII), weightage and maximum score

Dimension	Indicator	RII	Weightage	Max Score
C1	Connectivity: How accessible is the network?	0.8237	0.17	2.5
C2	Convenience: How does it compare with other transport	0.6722	0.14	3
C3	Comfort: How good is the experience?	0.7224	0.15	2

C4	Conviviality: How attractive is it?	0.6580	0.14	2
C5	Clarity/Conspicuousnes: How easy to navigate?	0.6200	0.13	2
C6	Coexistence: Conflict with other transport modes?	0.6296	0.13	2
C7	Commitment: Concern to do better?	0.6013	0.13	3

4.2 Walkability score

Based on the weightage assigned for each dimension and the allocated maximum score, the walkability score for each 100m pedestrian segment can be calculated using equation 1.

$$walkability = \frac{0.17C1}{2.5} + \frac{0.14C2}{3} + \frac{0.15C3}{2} + \frac{0.14C4}{2} + \frac{0.13C5}{2} + \frac{0.13C6}{2} + \frac{0.13C7}{3}$$

As suggested in section 3.5, the walkability analysis is conducted using Arc-GIS. Each 100 m sidewalk is assessed against the evaluation criteria, and the results are tabulated in Arc-GIS.

Figure 5 shows the walkability of each section in the study area.



Figure 5. Bandar Sunway Walkability

The results indicated that walkways along Jalan Lagoon Selatan and Jalan Lagoon Timur have a high walkability index. These walkways connect all main activities centres in Bandar Sunway and have sufficient width and smooth pavement. In addition, the planting along the walkway separates the walkway from the primary traffic. A border area and landscaping are provided along these roads (see Figure 6a). These provided a buffer space between pedestrians and vehicular traffic that improved the safety and aesthetic of the walkway. Moreover, as seen in Figure 5., the walkability seems to deteriorate near the boundary of the study area, indicating a shift in road hierarchy – moving from secondary arterial roads to primary arterial roads (see Figure 6b). In addition, the walkability index reduces around an area with no or very narrow sidewalks - indicated by red areas (see Figure 6c and Figure 6d), which results in some parts of the township being found to be unwalkable.

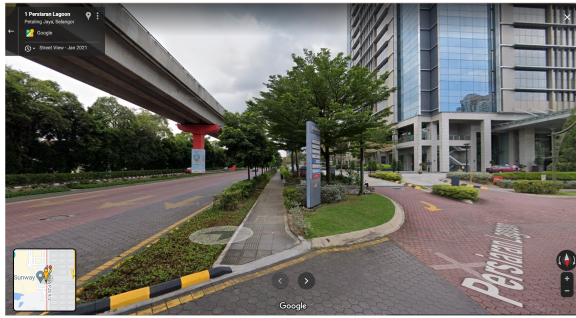


Figure 6a. Landscaping and pavement condition in Location 2



Figure 6c. Area with no sidewalk in location 4



Figure 6b. Walkway along primary arterials in location 3



Figure 6d. Walkway in location 5.

Figure 6. Landscaping and pavement condition in various locations

In addition, Figure 7 illustrates some findings during street auditing, located in location 1 in Figure 5.



Figure 7 Pavement condition in location 1.

Table 7. Walkability scores

Walkability Score (%)	
>80	4%
60-80	30%
40-60	40%
20-40	21%
<20	5%

As shown in Table 7. 70% of the existing pedestrian walkway are good (as illustrated as green and yellow sections on the map). In addition to that, most of the segments fall in 40-60%. Less than 10% for both exceeds a walkability score of 80%. To evaluate the performance of each indicator, the average walkability score is calculated by averaging the score of each 100m segment divided by the total 100m segments.

Table 8. Averaged scores of indicators of all segments

Indicators	Average Score	Maximum Score	Indicator Score
C1	0.88	2.5	35%
C2	1.10	3	37%
C3	1.47	2	74%
C4	0.86	2	43%
C5	1.61	2	80%
C6	0.98	2	49%
C7	0.93	3	31%

Table 8. shows the performance of the individual indicator. The indicator score presents the ratio of the average score and maximum score for each indicator. For example indicator score of C1 is calculated by dividing 0.88 by 2.5, which results in 0.35. Thus C1 indicator score is 35%. This assist in comparing the performance of each indicator among others hence strategic infrastructure planning can be devised.

As shown in Table 8. C5 (Landmarks) has the highest average score of 1.61 out of a possible score of 2. This is true as distinct landmarks throughout the township serve as reference points (i.e. Sunway Pyramid, huge universities block, etc.). C3 (pavement quality) has the second-highest average score of 1.47 out of a possible score of 2, despite C7 (pavement width) scoring the lowest average score. Through street auditing, sidewalks exist on many segments, but failure to provide at least 2.0 meters of minimum width gives C7 a low overall score (see Figure 6a). C6 (crossing safety) is determined based on exposure and visibility. Out of all the crossings evaluated, the exposure is considered high as the average score is 0.82 out of a possible 2.

In contrast, the visibility is higher than average (1.14) - visibility refers to no obstruction of sight distance during the crossing. Since the township was developed to accommodate automotive, it is no surprise that the exposure is very high. Pedestrians are not prioritised at most intersections, and there is a lack of pedestrian crossings with traffic lights (see Figure 8).



Figure 8. Pedestrian crossing in location 1.

C1 (connectivity), C2 (land use mix) and C7 are part of the worst-performing indicators. In the defined study area, the total number of links and nodes are 206 and 235, respectively, producing a link node ratio of 0.88 out of a possible 2.5. A percentage of 1.4 should be met for town planning purposes (Ewing 1996), and Bandar Sunway is far from the target value. To achieve a higher link node ratio, either more links or fewer nodes should be provided. The result of C2 shows that the average score is 1.10 out of a possible score of 3. This indicates only one land use type on an average sidewalk segment (see Figure 6d).

4.3 Discussion n 15-minute city

The 15-minute city idea presented by Carlos Moreno (Moreno et al., 2021) states that two criteria to achieve it are proximity and land-use diversity, represented by a proper mix of neighbourhoods including a mixture of activities and people. A community should offer access to various essential services and has long extended service hours all day. The walkability study in Bandar Sunway somehow assists the transport and urban planner in a preliminary assessment of the 15-minute city initiative. According to the evaluation of the C1, C2 and C4 dimensions of the 7C method that looks into the connectivity that can represent the proximity element of a 15-minute city and land use diversity, most of the areas in Bandar Sunway are not well connected, with an average of only 0.88 link ratio. In addition, the average score of C2 and C4 are only 1.10 out of 3 and 0.86 out of 2, respectively. This low link ratio, C2 and C4 average scores can be attributed to the distribution of the commercial and service/office land use centred around the NPE highway and some parts of Lagoon Selatan and Lagoon Timur. While some residential areas that are located in the south and southwest part of Bandar Sunway are isolated from the main critical land uses.

Though the walkability analysis only focuses on two elements of the 15-minute city initiative, the walkability results suggest how pleasant to walk in Bandar Sunway and how far the Bandar Sunway is from the 15-minute city initiative. As indicated by Moreno et al., (2021), in the 15-minute city initiative, all amenities shall be within walking distance; however, at the current state, the lack of diversity of land use throughout a walking journey significantly affects the scoring of the indicator. Therefore, the walkability results can be used to strategise the infrastructure planning and land use diversification strategy in Bandar Sunway.

5. Conclusion

Walkability has been a complex term over the past decades, but a conclusion can be made that it is a multi-dimensional variable, dependent on many walkability indicators. Very little work has been done on aggregating all the indicators as multicriteria analysis involves many indicators and might prove difficult. 7C method is used in this research to assess Bandar Sunway's walkability. The 7C method is selected as the 7C method that considers the local context by taking into account the results of the pedestrian questionnaire survey. This study only focuses on the walkability of a working adult in Bandar Sunway. A stakeholder focus group discussion and questionnaire survey are conducted to gauge locals' perspectives on walking. These survey results are used to develop local-based accurate indicator weightages, leading to a more precise walkability score.

The results of the walkability analysis suggest that 70% of the existing pedestrian walkway are good. Clarity/Conspicuousness, represented by landmarks assessment around Bandar Sunway, has the highest average score of 1.61. At the same time, comfort (pavement quality) has the second-highest average score. However, most walkways have smooth pavement, and C7 is committed to having a minimum 2-meter pavement width, scoring the lowest average score.

Nonetheless, the recommendation can be made based on the seven indicators to improve the walkability throughout the township of Bandar Sunway. Ways can be looked at to improve the link node ratio by increasing link density. The link node ratio will be higher if the number of links increases or the number of nodes decreases.

Sidewalk widening is still possible, but the cost will be inevitably high. Other indicators involving the land use types in the vicinity can be improved through urban retrofitting. Pedestrian crossings throughout the township can also be enhanced to boost the score of the C6 indicator. As found earlier, exposure to intersections in the township is very high and can be lower by implementing more signalised pedestrian crossings. The proposed research can be extended for future research focusing on walkability analysis for different demographic groups view walkability differently as conditions required to be walkable are different. Also, to make the township inclusive, the walkability analysis can be used as the primary tool to assess the readiness to adopt the 15-minute city concepts and at the same time to strategize the infrastructure planning and land use diversification strategy.

6. Acknowledgement

This research was funded by the Sunway Bhd under the Scientific and technological approach to assess the impact of elevated canopy walkway and bus rapid transit (BRT) on traffic in Bandar Sunway project [Project ID: MRD-000006 and Grant code: 2600006-113-00].

7. References

- Abdelfatah, AS, Shah, MZ & Puan, OC 2015, 'Evaluating the sustainability of traffic growth in Malaysia', *Journal of Traffic and Logistics Engineering*, vol. 3, no. 1.
- Abley, S & Turner, S 2011, *Predicting walkability*, NZ Transport Agency.
- Allam, Z., Nieuwenhuijsen, M., Chabaud, D. & Moreno, C. 2022. The 15-minute city offers a new framework for sustainability, liveability, and health. *The Lancet Planetary Health*, 6, e181-e183.
- Antonini, G, Bierlaire, M & Weber, M 2006, 'Discrete choice models of pedestrian walking behavior.(Report)', *Transportation Research Part B: Methodological*, vol. 40, no. 8, p. 667.
- Ariffin, RNR & Zahari, RK 2013, 'Towards a sustainable urban transport system in the Klang Valley, Malaysia: The key challenges', *Procedia-Social and Behavioral Sciences*, vol. 85, pp. 638-45.
- Ashik, F. R., rahman, M. H. & kamruzzaman, M. 2022. Investigating the impacts of transit-oriented development on transport-related CO2 emissions. *Transportation Research Part D: Transport and Environment*, 105, 103227.
- Baker, D, Bridges, D, Hunter, R, Johnson, G, Krupa, J, Murphy, J & Sorenson, K 2002, 'Guidebook to decision-making methods', *Department of Energy, USA*.
- Clark, AF, Scott, DM & Yiannakoulis, N 2014, 'Examining the relationship between active travel, weather, and the built environment: a multilevel approach using a GPS-enhanced dataset', *Transportation*, vol. 41, no. 2, pp. 325-38.
- Costa, CABE & Vansnick, J-C 1999, 'The MACBETH approach: Basic ideas, software, and an application', in *Advances in decision analysis*, Springer, pp. 131-57.
- Cui, J, Allan, A & Lin, D 2013, 'The development of grade separation pedestrian system: A review', *Tunnelling and Underground Space Technology*, vol. 38, p. 151.
- Cui, J, Allan, A & Lin, D 2015, 'Assessing grade separation pedestrian systems: Planning, design and operation', *Urban design international*, vol. 20, no. 3, pp. 241-52.

- de Cambra, PJM 2012, 'Pedestrian accessibility and attractiveness indicators for walkability assessment', Thesis for the Master Degree (MSc) in Urban Studies and Territorial Management.
- de Mello, LMJ 2015, 'Walkability Assessment for the Urban Environment'.
- Dill, J 2004, 'Measuring network connectivity for bicycling and walking', in *83rd Annual Meeting of the Transportation Research Board, Washington, DC*, pp. 11-5.
- Doyle, S, Kelly-Schwartz, A, Schlossberg, M & Stockard, J 2006, 'Active community environments and health: the relationship of walkable and safe communities to individual health', *Journal of the American Planning Association*, vol. 72, no. 1, pp. 19-31.
- Emberger, G. 2017. Low carbon transport strategy in Europe: A critical review. *International Journal of Sustainable Transportation*, 11, 31-35.
- Ewing, R 1996, *Best development practices: doing the right thing and making money at the same time*, Routledge.
- Forsyth, A 2015, 'What is a walkable place? The walkability debate in urban design', *Urban design international*, vol. 20, no. 4, pp. 274-92.
- Forsyth, A 2015, 'What is a walkable place? The walkability debate in urban design', *Urban Design International*, vol. 20, no. 4, pp. 274-92
- Guthold, R, Ono, T, Strong, KL, Chatterji, S & Morabia, A 2008, 'Worldwide variability in physical inactivity: a 51- country survey', *American journal of preventive medicine*, vol. 34, no. 6, pp. 486-94.
- Hall, P & Pfeiffer, U 2000, *Urban 21: World Report on the Urban Future 21*, Federal Ministry of Transport, Building and Housing.
- Handy, S, Paterson, RG & Butler, KS 2003, 'Planning for street connectivity: getting from here to there', *Apa Planning Advisory Service Reports*, no. 515, pp. 1-75.
- Institute for Transportation and Development Policy 2017, *TOD Standard, 3rd ed.*
- Jabatan Kerja Raya 1997, *A Guide on Geometric Design of Roads*, Jabatan Kerja Raya.
- Keumala, N & Mustapha, TO 2014, 'Innovative Elevated Walkway for a Liveable Kuala Lumpur City'.
- Lamit, H, Shafaghat, A, Majid, M, Keyvanfar, A, Ahmad, MHB & Malik, T 2013, 'The Path Walkability Index (PAWDEX) Model: Measure Built Environment Variables Influencing Residents' Walking Behavior', *Advanced Science Letters*, vol. 19, no. 10, pp. 3017-20.
- Lee, WD, Ectors, W, Bellemans, T, Kochan, B, Janssens, D, Wets, G, Choi, K & Joh, C-H 2018, 'Investigating pedestrian walkability using a multitude of Seoul data sources', *Transportmetrica B: transport dynamics*, vol. 6, no. 1, pp. 54-73.
- Leslie, E, Coffee, N, Frank, L, Owen, N, Bauman, A & Hugo, G 2007, 'Walkability of local communities: using geographic information systems to objectively assess relevant environmental attributes', *Health & place*, vol. 13, no. 1, pp. 111-22.
- Lo, RH 2009, 'Walkability: what is it?', *Journal of Urbanism*, vol. 2, no. 2, pp. 145-66.
- Malczewski, J 1999, *GIS and multicriteria decision analysis*, John Wiley & Sons.
- Methorst, R, Monterde, I, Bort, H, Risser, R, Sauter, D, Tight, M & Walker, J 2010, 'COST 358 pedestrians' quality needs, PQN final report (European Cooperation in Science and Technology)', *Cheltenham: Walk21*.
- Millstein, R, Cain, K, Sallis, J, Conway, T, Geremia, C, Frank, L, Chapman, J, Van Dyck, D, Dipzinski, L, Kerr, J, Glanz, K & Saelens, B 2013, 'Development, scoring, and reliability of the Microscale Audit of Pedestrian Streetscapes (MAPS)', *BMC Public Health*, vol. 13, no. 1, p. 403.
- Moreno, C., Allam, Z., Chabaud, D., Gall, C. & Pratlong, F. 2021. Introducing the “15-Minute City”: Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities. *Smart Cities*, 4.

- Owen, N, Cerin, E, Leslie, E, Coffee, N, Frank, LD, Bauman, AE, Hugo, G, Saelens, BE & Sallis, JF 2007, 'Neighborhood walkability and the walking behavior of Australian adults', *American journal of preventive medicine*, vol. 33, no. 5, pp. 387-95.
- Rissel, C, Curac, N, Greenaway, M & Bauman, A 2012, 'Physical activity associated with public transport use—a review and modelling of potential benefits', *International journal of environmental research and public health*, vol. 9, no. 7, pp. 2454-78.
- Saaty, TL 1977, 'A scaling method for priorities in hierarchical structures', *Journal of mathematical psychology*, vol. 15, no. 3, pp. 234-81.
- Score, W 2014, 'Walk score methodology', *Accessed April*, vol. 24.
- Sukor, NSA, Hatta, NM & Hassan, SA 2017, 'Addressing the Pedestrian Issues in Malaysia: En Route Towards Walking Culture and Sustainable City.
- UN General Assembly 2015, *Transforming our world: the 2030 Agenda for Sustainable Development* 21 October 2015, A/RES/70/1.
- Wan Omar, WR, Patterson, I & Pegg, S 2013, 'Using a Health Belief Model to investigate the walking behaviour of residents living in Kuala Lumpur, Malaysia', *Annals of Leisure Research*, vol. 16, no. 1, pp. 16-38.
- Wey, W-M & Chiu, Y-H 2013, 'Assessing the walkability of pedestrian environment under the transit-oriented development', *Habitat international*, vol. 38, pp. 106-18.
- World Health Organization 2008b, 'Physical Inactivity: A Global Public Health Problem'.
- Wu, X., Tao, T., Cao, J., Fan, Y. & Ramaswami, A. 2019. Examining threshold effects of built environment on travel-related carbon-dioxide emissions. *Transportation Research Part D: Transport and Environment*, 75,

Appendix 1

Dimension	Indicators
C1: Connectivity	C11: Street density (alternative routes)
	C12: Continuity of walking path/sidewalk
	C13: Path directness
	C14: Existence of dedicated pedestrian infrastructure, accessible to all groups
	C15: Network integration in the urban fabric
C2: Convenience	C21: Land use diversity
	C22: Sidewalk available width
	C23: Obstacles (absence of)
	C24: Density of daily uses
	C25: Facilities for accessing steep streets (escalators, elevators, ramps)
C3: Comfort	C31: "Eyes on the street" - windows and facade transparency
	C32: Pavement surface quality
	C33: Amenities (trees, benches, lighting, etc.)
	C34: Climate protection (sun, rain)
	C35: Sensory quality of urban environment
C4: Conviviality	C41: Opportunities for meeting and sojourning (benches, tables, terraces)
	C42: Existence of "anchor sites" - squares, open-air markets, parks, etc.
	C43: Mixed uses and mixed working hours
	C44: "Active edges" - absence of blank walls, empty lots, dull facades
	C45: Population density
C5: Conspicuousness	C51: Landmarks
	C52: Clear sightlines
	C53: Street names, signposting, waymarking
	C54: Architectural complexity
	C55: "Sense of place"
C6: Coexistence	C61: Traffic safety (at pedestrian crossings)
	C62: Pedestrian crossing location
	C63: Appropriate spatial segregation of transport means
	C64: Proportion of pedestrian friendly streets
	C65: Pedestrian space "invasion" - parked cars, running bicycles
C7: Commitment	C71: Enforcement of pedestrian regulations (as the recent disabilities act)
	C72: Street cleanliness
	C73: Means for public participation
	C74: Walking initiatives (walk to school, walk to work, senior walks, etc.)
	C75: Existence of design standards and planned public space interventions