Safety, Connectivity, and Comfortability as Improvement Indicators of Walkability to the Bus Stops in Penang Island

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Abstract—This study investigates the determinants of walkability by evaluating assessment indicators by constructing a path model based on on-site data collected in Penang. Based on the path analysis, safety ($β_1=0.559$, $t=8.048$, $p<0.01$) and connectivity ($β_2=0.691$, $t=9.301$, $p<0.01$) have a positive correlation to walkability. Meanwhile, walkability shows a negative correlation with the number of private vehicles. The findings of this study allow the authorities to focus on enhancing the safety of walking facilities that give access to bus stops which will probably increase the likelihood of using the public bus services. The findings from this study also reveal the underlying factors that can boost the public to adopt walking as an active mode of transport and thus reduce the dependency on private vehicles.

Keywords—walkability; Structural Equation Modelling (SEM); factor analysis; sustainable transport; public transport

I. INTRODUCTION

Walkability has many social and environmental benefits. Walking not only decreases the risk of obesity [1-6], but also prevents the incidence of other chronic diseases [7]. Nowadays, there is a decline in the walking behavior of people due to the increasing reliance on the use of private automobiles. Regardless of the negative health consequences that may arise, people still tend to rely on private vehicles instead of practicing active modes of transport. Apart from its negative health consequences, decreased practicing of active modes of transport has adverse consequences to the environment, such as air and noise pollution, while the number of fatal car accidents rises. Statistics from the World Health Organization (WHO) reported that Malaysia was ranked as one of the top three countries in the world with the deadliest roads after Thailand and South Africa [8]. A total of 7,152 deaths related to road accidents were recorded in Malaysia in the year 2016, mainly involving motorcyclists. One of the major factors of these accidents is of course the high reliance on vehicles for transportation. In conjunction with government’s goal to achieve a 40:60 modal split, representing 40% dependency on public transport and 60% on private vehicles by 2030, the current high reliance on private vehicles should be alleviated immediately. In this study, the indicators related to walking facilities at bus stops were investigated for their association with the number of private vehicles. This study can be a future reference for transport engineers and planners to improve the accessibility for walking infrastructure and thus reduce the dependency on private vehicles.

II. RELATED WORK

The most influential factor on encouraging walkability is the accessibility to a good walking environment. Authors in [9] reported a few determinants of walking behavior such as land use mix, street connectivity, distance to transit stops, and destination accessibility. The walking behavior can also be associated with highly urbanized areas [10], destination types [11], and aesthetics factors on choosing a route for walking [12]. Another study reported that connectivity is an important attribute to ensure high-quality public transit [13]. Physical connectivity criteria such as continuously connected sidewalks and place-based barriers do affect the last-mile trip. Also, the origin and destination of the walking trip is one of the built-in environmental factors that affect the willingness to walk [14]. Walkability is also affected by factors such as walking distance, walking time, and the purpose of the trip [15]. In addition to the above factors, gender, age, marital status, shorter travel time and distance, income, education, and vehicle ownership were also claimed as contributing factors to walkability [10, 12, 16, 17]. Safety is another feature that has been prioritized by pedestrians. Most motorcycle-taxi users are reluctant to walk because of safety concerns and most of them are afraid of accidents [18, 19]. A high rate of accidents involving pedestrians also discourages their willingness to walk which increases their dependency on vehicles. In addition, comfort is also associated with walkability; most people would like to walk if the walkway is comfortable [20]. This should be supported by good environmental design, proper space for walking, and good walking surfaces [21]. It is believed that comfortable walkways should be safe, with no obstacles, and smooth for strollers and wheelchair users [22].

The current study focuses on identifying the criteria that improve walkability, especially regarding the accessibility of public bus stations in Penang Island of Malaysia. The most
significant criteria will be selected through path modeling analysis.

III. RESEARCH METHODOLOGY

A. Data Collection

The study was conducted along the proposed Bayan Lepas Light Rail Transit (BLLRT) in Penang Island. The aim of the study is to investigate the readiness of walking facilities to give access to the bus stops as one of the integrated links to the rail stations. Even though the proposed BLLRT alignment is still in the construction stage, this study can still be used as a baseline for further walkability studies. The proposed alignment for the rail network can be seen in [25]. In this study, the alignment was divided into 19 zones based on the location of the proposed train stations. One zone was considered to have 800m radius by considering the maximum distance of willingness to walk to a train station [18, 23, 24]. In total, 123 bus stops located in all zones were identified and grouped as shown in Table I. The data collection involved two types of data: traffic count of private vehicles and a checklist’s inspection results of the 123 bus stops. The private vehicle data were used as input (dependent variable) in the SEM Path Analysis. Meanwhile the scores in the checklists were applied as independent variables. The traffic count in this study was done in the morning and evening peak hours by considering only cars and motorcycles as private vehicles.

| Zone ID | Bus stop ID | No of bus stops |
|---------|-------------|-----------------|
| 1       | Komtar Zone (K) | K1-K24         | 24              |
| 2       | Macallum Zone (M)| M1-M9         | 9               |
| 3       | Bandar Sri Pinang Zone (B)| B1-B8        | 8               |
| 4       | Skybay Zone (S) | S1-S6           | 6               |
| 5       | East Jelutong Zone (E)| E1-E4      | 4               |
| 6       | The Light Zone (TL)| TLI-T17     | 7               |
| 7       | Gelugor Zone (G) | G1-G3           | 3               |
| 8       | USM Zone (USM) | USM1-USM3       | 3               |
| 9       | Kota Bahru Zone (B) | BU1-BU3     | 9               |
| 10      | Pesta Zone (P)  | P1-P9            | 9               |
| 11      | Sg Nibong Zone (SN) | SN1-SN7      | 7               |
| 12      | Bukit Jambul Zone (BJ)| BJ1-BJ8    | 8               |
| 13      | Spiceland Zone (SS) | SS1-SS8      | 8               |
| 14      | Jalan Tengah Zone (JT) | JT1-JT9    | 9               |
| 15      | Fiz North Zone (F) | FN1-FN2      | 2               |
| 16      | Fiz South Zone (FS) | FS1           | 1               |
| 17      | Sg Tiram Zone (ST) | ST1-ST2      | 2               |
| 18      | Penang Airport Zone (PA) | PA1-PA7     | 7               |
| 19      | Permatang Damar Laut Zone (PDL) | PDL1-PDL2 | 2               |

Fig. 1. Location of 123 bus stops at 19 zones.
Auditing tasks were done at the selected bus stops with the use of a checklist. The criteria for the walkability indicators in the checklist were taken from international guidelines, national guidelines, and previous studies shown in Table II. The indicators were audited based on the scores: 0 = the indicator does not exist, 1 = the indicator is available but not following the guidelines, and 2 = the indicator is available and follows the guidelines. The results were inserted into the Statistical Package of Social Science (SPSS) for Factor Analysis. The checklist went through a pilot study and amendments were made to suit the specification of local context at 123 bus stops in Penang Island. Figure 2 shows briefly the way the design of the checklist was developed. A total of 18 indicators were identified.

### TABLE II. WALKABILITY VRIETERA

| Indicator ID | Walkability criteria | Source |
|--------------|----------------------|--------|
| W1           | Connecting pedestrian walkways either paved or unpaved to the nearest main attraction within 400m of a bus stop | [26-30] |
| W2           | The walkway should not be obstructed | [30, 31] |
| W3           | Provision of bollards/shrubs/fences/ditches at the end of the walkway to segregate it from the car lanes | [32] |
| W4           | Provision of bollards at road intersections (if there are intersections) | [28] |
| W5           | Provision of a median refuge island with a minimum of 1m width at crossings for roads that exceed 2 lanes | [33] |
| W6           | Provision of a crosswalk at road intersections | [34] |
| W7           | Well maintained walkways (smooth pavement, not overgrown shrubs, and not fallen trees) | [35] |
| W8           | Signs in good condition (clearly seen/not broken) | [36, 37] |
| W9           | Crosswalk/markings are clearly seen | [38] |
| W10          | Pedestrian signals must be in good condition | [39] |
| W11          | Smooth incline at the end of walkways or towards road intersections which can be used by wheelchair users and strollers | [39, 40] |
| W12          | Seats at bus stops | [41] |
| W13          | Rubbish bins at bus stops | [42] |
| W14          | Sidewalk width must not be less than 1.5m | [43] |
| W15          | Availability of street trees/shrubs/plants | [44] |
| W16          | Provision of signs for the pedestrian walkway | [45] |
| W17          | Provision of street trees/shrubs/plants | [46] |
| W18          | Provision of a divider of minimum 1m width (low shrubs/plants/fence/any safety barriers) between the road and the walkway | [47, 48] |

**B. Data Analysis**

This study aims to investigate the walkability indicators by developing a structural equation path model. SPSS was used for data computation and analysis. Data analysis was conducted in three stages which were: Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and the development of PLS Path-Modelling.

1) **Exploratory Factor Analysis**

The EFA was conducted in order to investigate the relationship between the above mentioned indicators and walkability. EFA identifies the individual constructs and explores the consistency of the proposed latent factors with the actual data. The Principal Component Analysis (PCA) method was used to examine the factor loading among the measurement items for each factor. The value for factor loading of the measurement items should be more than the threshold of 0.5. In this study, the evaluated indicators in the latent variables were extracted based on the output values of Kaiser-Meyer-Olkin (KMO) measures. The components possessing higher factor loading of Kaiser criterion, i.e. more than 0.55 were accepted.

2) **Confirmatory Factor Analysis**

The CFA or reliability test was conducted based on internal consistency that consists of Composite Reliability (CR) and Cronbach’s alpha value and convergent validity that composed of Average Variance Extracted (AVE). The acceptable value for Cronbach’s alpha is 0.7. However, it is suggested to accept lower values (0.6) in the research model [35]. The indicators should adhere the threshold of CR which is not more than 0.6 and AVE above 0.5 to be carried forward for path analysis. Factor loadings for indicator also should be above 0.6.

3) **SEM Path Analysis**

The path model was constructed with a Structural Equation Model (SEM) by using SmartPLS 3.0 software. SEM-PLS was chosen because it can be applied for theoretical confirmation or theory development. Figure 3 shows the conceptual path model for walkability which consists of three latent variables (connectivity, comfort, safety) connecting to the dependent variable, i.e. the number of private vehicles. A total of 18 walkability indicators were constructed as underlying indicators for Independent Variables (IV). Meanwhile, the number of private vehicles collected from the traffic count was considered as the Dependent Variable (DV). This study aims to investigate the hypotheses below:

H1: Connectivity is positively associated with walkability to the bus stop
H2: Safety is positively associated with walkability to the bus stop
H3: Comfort is positively associated with walkability to the bus stop.

Positive association in this context means that the more the provision of evaluated indicators provided at the bus stop, the more the walkability element is promoted at the bus stop which has a tendency to attract people to walk and makes more likely the use of public buses.
C. Path Analysis

As shown in Figure 3, the latent variables safety and connectivity were related to the latent variable walkability, whereas walkability is related to the number of private vehicles. Meanwhile, connectivity and safety were connected to their respective indicators. Bootstrapping was performed on the model to test the significance of the relationships between adjacent constructs [44]. Based on Figure 4, the t-statistic for all independent variables satisfied the threshold value (t ≥ 1.96, p < 0.05) [45]. All the t-statistics are larger than 1.96 which shows that the variables are highly significant. Based on the result run by the PLS-Algorithm, safety shows a path coefficient value of β2 = 0.691 (t = 9.301, p < 0.01) and connectivity β1 = 0.559 (t = 8.048, p < 0.01). The path analysis shows positive results depicting the direct effect on walkability. Safety shows strong correlation due to the higher value, compared to connectivity, of the coefficient β towards walkability. Hence, safety had a huge influence on walkability which is in accordance with the results in [46, 47]. Path analysis also shows a significant negative correlation of walkability towards the number of private vehicles (β = −0.114, t = 1.208, p < 0.05). This means that decreased provision of infrastructure for walkability element at a bus stop will be less likely to reduce the number of private vehicles passed in front of the bus stop. Inadequacy of high quality of public transportation is also argued to give impact on high dependency of private vehicles [48]. The indicators that can improve walkability at the bus stop are presented in Table V.

![Fig. 4. The constructed path model for walkability.](image)

**TABLE V. INDICATORS WITH DESCRIPTION**

| Indicator | Description |
|-----------|-------------|
| W2        | The walkway should not be obstructed |
| W7        | Well maintained walkways (smooth pavement, not overgrown shrubs, and not fallen trees) |
| W14       | Sidewalk width must not be less than 1.5m |
| W6        | Provision of a crosswalk at road intersections |
| W9        | Crosswalk/markings are clearly seen |
| W10       | Pedestrian signals must be in good condition |

B. CFA Results

Table IV shows the reliability and validity results of the constructed model. After CFA assessment, the indicators that surpassed the threshold value of factor loadings (0.7) were only 6, 3 belonging to connectivity (W2, W7, W14) and 3 to safety (W6, W9, W10). Notably, the variable comfort (W) was removed due to the low value of Cronbach's alpha which depicts that this variable is not reliable for further analysis. Connectivity and safety were found to fulfill all requirements by possessing a value of Cronbach’s alpha higher than 0.6 [39, 40]. Meanwhile, values higher than 0.6 are suggested for indicator loadings [41, 42] and for composite reliability [43]. For Average Variance Extracted (AVE), 0.5 is the suggested threshold value [43] and values above this limit are considered acceptable. The results for connectivity and safety in Table IV confirm the convergent validity and good internal consistency of the measurement model.

![Conceptual path model for walkability.](image)

**Fig. 3.** Conceptual path model for walkability. IV: Independent Variable, DV: Dependent Variable.

**IV. RESULTS AND DISCUSSION**

**A. EFA Results**

Before a model is constructed, factor analysis is implied to summarize the data by assessing the structure of variables for further analysis [36]. Theoretically, factor analysis was used to solve the problem by combining variables that are collinear [37]. A PCA was conducted on the 18 walkability indicators with oblique rotation (varimax). Meanwhile, the KMO measure verified the sampling adequacy for the analysis: KMO = 0.733 [38]. Based on Table III, all KMO values for the items were bigger than 0.7, which is well above the limit of 0.50. Bartlett’s test (χ² (153) = 728.586, p < 0.01) indicated that the correlation matrix is significantly different from an identity matrix, in which correlations between items are all zero and which is not random. Out of 18 indicators, 8 indicators were removed and indicators with factor loadings higher than 0.5 were considered highly correlated with the factors extracted and were retained.

**TABLE III. KMO AND BARTLETT’S TEST RESULTS**

| Indicator | Cronbach's Alpha | Loadings | CR | AVE |
|-----------|-----------------|----------|----|-----|
| W2        | 0.766           | 0.844    | 0.864 | 0.680 |
| W7        | 0.766           | 0.859    | 0.680 |
| W14       | 0.864           | 0.768    |
| W6        | 0.819           | 0.864    |
| W9        | 0.902           | 0.680 |
| W10       | 0.803           |

**TABLE IV. ASSESSMENT RESULTS OF THE MODEL**

| Indicator | Connectivity | Safety |
|-----------|--------------|--------|
| W2        | 0.559        |
| W7        | 0.691, *t* = 9.301 |
| W14       | 0.559, *t* = 8.048 |

**TABLE V. INDICATORS WITH DESCRIPTION**

| Indicator | Description |
|-----------|-------------|
| W2        | The walkway should not be obstructed |
| W7        | (smooth pavement, not overgrown shrubs, and not fallen trees) |
| W14       | Sidewalk width must not be less than 1.5m |
| W6        | Provision of a crosswalk at road intersections |
| W9        | Crosswalk/markings are clearly seen |
| W10       | Pedestrian signals must be in good condition |
V. CONCLUSION

In this study, walkability is proven to be negatively significant towards the number of private vehicles. It means that the provision of better walking facilities will reduce the number of private vehicles being used. It is also indicating that the infrastructure at the bus stop should be enhanced. The findings show that safety has the strongest correlation towards walkability depicting that walking facilities should be safe in terms of provision of crosswalk, road markings, and pedestrian signals. This is concurrent with the findings of previous studies which showed that upgrading the walking infrastructure will increase the likelihood to walk [14, 50-51]. However, most of the previous studies were based on the preferences of users [22, 52], whereas this study focuses more on auditing the walking facilities according to the guidelines.

As a conclusion, all the indicators that significantly affecting the likelihood to walk can be suggested to be included in the improvised version of traffic assessment guidelines, especially in Malaysia. This could simultaneously improve the quality to access the bus stops which may reduce the reliance on private vehicles. For countries that practice Traffic Impact Assessment (TIA), these indicators could enhance the traffic study before one development project being endorsed.

ACKNOWLEDGMENT

This study was funded by the Transdisciplinary Research Grant Scheme (TRGS) from the Ministry of Higher Education, MOHE (203/PAWAM/67610002).

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