Conceptual Framework for Walkability Assessment for Pedestrian Access to Rail Transit Services by using Spatial-MCDA

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Abstract. Rail transit services are becoming an important aspect in enhancing mobility in a city. Its level of service is influenced by the journey from the very first to the last mile of using the transit service which refers to walking to access a transit station. Many studies had emerged in an attempt to measure walkability which most of them translated pedestrian’s preferences or perception on walking or used accessibility analysis. There could be drawbacks in these studies which are (a) only few of them had include indoor walking environment in measuring walkability, (b) there could be inconsistencies in making judgement for many criteria simultaneously, and (c) walkability is never a measure of accessibility only. Therefore, this study will attempt to (a) create a spatial model representing indoor walking environment that can be applied in measuring walkability, (b) evaluate the priorities for each of the walkability criteria by using Analytical Network Process (ANP) and (c) measure walkability of pedestrian routes and the existing rail transit stations by using GIS. The main finding of this study will be the walkability index for pedestrian routes to the existing rail transit stations in KL city centre.

1. Introduction
Malaysia is aspired to promote a sustainable living which explains why the national plans always include the Sustainable Development Goal (SDG). The SDG consists of many components such as improving public transportation. The government had been very committed to ensure that by 2030 forty percent of its citizens will have access to the public transportation [1]. This is to reduce the car-reliance and at the same time ensure that the mobility in urban area would not be affected.

Planning for a good public transportation is very complex. It involves many aspects to cater the riders’ satisfaction when using the services. To support the nation’s goal of reducing car-reliance, it is a must for a public transportation to deliver the highest Level of Services (LOS) possible. If not, people might choose to use their own private vehicle instead if the service is poor. Therefore, the LOS for public transportation should be at the highest quality from the very first to the last mile of its journey [2-4]. This means that, LOS of public transportation is not only depends on the frequency of the services and the comfort while riding it only, it should be comfortable and convenient for the rider to access the
services itself and reach their final destination commuters [2,5-7]. This is what the First/Last Mile (FLM) study is all about.

FLM refers to the 400 meters travelling distance by walking or cycling to reach the station [8]. The 400 meters coverage distance is widely used for a planning for a Transit Oriented Development (TOD). With TOD, it is expected that people will only need to travel for 400 meters to reach a transit station, their workplace and even their home. TOD is a concept where a transit station is built prior to other development. Thus, the development of an urban area would surround a transit station. The concept had been widely applied across the world. For example, the Edinburgh Waverly Station which is located at the centre of the Edinburgh. Within the station is shopping area, University of Edinburgh building, a public park just beside the station as well as the Edinburgh Castle [9].

Malaysia had just started to implement TOD concept when the Land Public Transport Agency (APAD) planned for the Mass Rapid Transit (MRT) and the Phase 3 of the Light-Rail Transit (LRT3) [10,11]. Almost all of the newly built stations are all located around an undeveloped area. However, each of the area is under development such as Kwasa Sentral and Kwasa Damansara MRT Station which the area around the two stations is to be developed by the KwasaLand. To support this TOD concept, it is very important to ensure that the area around the stations have a good walkability so that the LOS of a transit services will be at the highest level from the very first to the last mile.

Here comes walkability study where it aims to measure the walkability of pedestrian environment. Walkability referred to the level of comfort of walking a pedestrian experience to travel between two points. It can be influenced by many factors including the travelling time and distance, the safety from traffic, security from any personal risk or threats while walking, accessibility to various land uses, availability of resting area and more [5,12–18].

Various walkability indices had been developed across the globe to analyse and evaluate the walkability of the existing pedestrian environment in urban area [5,14,19,20]. Each index had used different approaches in measuring walkability. One of the most applied methods is by using GIS to analyse the connectivity and continuity of the walking routes. GIS had also being used to measure the accessibility to different landuses which is one of the keys in a good walking environment – to have access to mixed land uses. However, there have been a few drawbacks of the studies.

The first drawback lies on the pedestrian path that had been used in analyzing the walkability. There seems to be a lack of studies that had include the indoor walking environment as a part of their analysis. Most of the studies focus on ground walking path which is parallel to the motorways. This could produce a less accurate result as walking is often include the indoor environment. People do walk inside a building to reach certain destination. Therefore, it is very important to include the indoor walking environment in the analysis to produce a more comprehensive walkability index.

The second drawback lies on the technique used to measure walkability. There were also studies that translated human perception as a measure of walkability [7,16,17]. These studies had different approaches of having public to give their own opinion on the walking environment, and the rating for the pedestrian environment was reflected by their experience of walking on the route. If they were satisfied with the experience, the score will be high and vice versa. There were also some studies that rely on experts to rate the pedestrian environment based on their knowledge on planning for a good walking environment. Although it is statistically good in analysing walkability, they can be very biased towards individual’s preferences and perceptions. Thus, when opinions are used to choose the criteria, for example the best out of two rather than out of five, then the analysis can be inconsistent and inaccurate. The former rating procedure i.e. MCDA will certainly provide more consistent judgement as it has a better structure and techniques in obtaining and translating human judgements into priorities [21].

The third drawback is some of the walkability indices were developed without the spatial analytical assessments though the criteria of walkability can actually be represented in a spatial environment. Although there exists walkability index that use GIS, it is only used for querying purposes instead of spatial analysis i.e. counting the number of road intersections with traffic lights to measure intersection density which is one of the component in calculating walkability index [14]. GIS could be implemented
to identify routes that have a high walkability by including the walkability criteria as parameters in the analysis. Although this combination is possible, but there were very few studies have actually applied it.

Although both studies can be relatively good in measuring walkability, GIS can do more than just conducting a connectivity and accessibility analysis. It can actually be combined with the second technique, which is human perception, in developing a better analysis technique. It is known as Spatial-MCDA. ‘Spatial’ is the spatial analysis or widely known as Geographical Information System (GIS) and ‘MCDA’ is the decision making process that can dealt with multiple criteria at once [21].

In Spatial-MCDA, GIS is used to store, edit and manipulate data for analysis and visualization. MCDA on the other hand is used to determine the degree of importance of criteria involves in a decision-making. Hence, the usage of Spatial-MCDA will integrate the factors influencing walkability and analysed it in the spatial environment to measure the walkability. In short, the MCDA aggregates the degree of importance for the criteria and GIS prioritized the criteria as attributes through spatial analysis.

There are various techniques available in MCDA. One of them, the Analytical Network Process (ANP) could be the most appropriate since it allows the interdependencies between criteria despite their hierarchical position, which is suitable for the walkability criteria that can influence each other [22]. ANP also allows the interdependencies of criteria in different clusters and level. It uses a pairwise comparison rating technique, where the rating for the criteria will be conducted in a pair instead of separately. For that, the aggregated priorities can be more consistent and accurate.

The aggregated priorities of the criteria provide the input parameters for the GIS analysis. The priorities will be considered as attributes for the street network dataset. One of the GIS techniques that can be used to represent the morphology of a street is space syntax. With space syntax, the spatial layout with a range of social, economic and environmental phenomena that could influence the level of services of pedestrian network can be created. Thus, the walkability of the pedestrian network can be measured based on the summation of priorities of the criteria existed along the walking route.

Therefore, the intention of this study is to implement ANP and GIS analysis in measuring the walkability of pedestrian routes in KL City Centre. This study is an extension of the previous study conducted by the same author with some improvements [20]. First, instead of measuring the walkability of pedestrian access to LRT stations only, this study will attempt to measure the walkability for all pedestrian routes in KL City Centre. This study will also include indoor walking environment as a part of the analysis which the last study did not addressed. This study aims to develop a walkability index for pedestrian walking route in Kuala Lumpur City Centre. The objectives for this study are (a) to create a spatial model for indoor walking environment that can be used to measure walkability, (b) to evaluate the criteria influencing walkability using ANP, and (c) to assess the walkability of pedestrian route in KL City Centre using GIS.

2. Review of Literature

2.1. Walkability

Walkability is a measure of the friendliness of an area to walking. It is expected that a walking route to allow people to reach their destination comfortably. Thus, if a walking environment could not do so, it might fail in promoting sustainable lifestyle. Walking path also should have a good connectivity to facilities including shops, schools, parks, etc to support people’s various purposes to walk. In addition, it can be very closely related to the geographic attributes of the particular area. In Kuala Lumpur for example, walking can be influenced by public realms built along the walking path including a roof, a metal rail separated them with road, resting places, food and beverages vendors, and more.

A good walking environment is very beneficial to one particular area in terms of health, environment and socio-economic. Walking is one of the physical activities that can prevent cardiovascular disease, diabetes, hypertension and obesity [23]. Therefore, walking path should have a good walkability to encourage the community to walk more and then can lead them to live a healthier lifestyle.
In terms of environment, walkability can help in decreasing a community’s automobile footprint as walking reduces people’s reliance on motor vehicles [24, 25]. Thus, it helps in reducing the carbon emission which can lead to a better air quality. A cleaner air quality can then lead to healthier environments, healthier lifestyles for the community and will also reduce the contribution to global warming.

The best part of walkability is that it contributes in terms of socioeconomic. This is because it can enhance the livability of an area when more people choose to walk. This later could increase the value of the area [26]. Since recently there is an increase in demand for housing that promotes walkability. People love to live in this kind of housing as they wanted to interact more with their neighbors, have healthier lifestyle and live in a safer community (less crime if more people walk).

With those benefits, many communities started to change from an automobile-oriented community to a walking community as it is believed that this practice could lead to a more sustainable lifestyle. There are many factors that can aid in developing a good walking environment.

2.1.1. Criteria to Measure Walkability

There are currently many practices outlining the criteria to be implemented in assessing walkability. However, the 5Cs are the most implemented as it is the most holistic among all. It is developed by Transport for London (TFL) which is based on five keys of Connectivity, Comfort, Conviviality, and Conspicuous [3]. Each of the criteria will be represented as measurable parameters on ground so that they can be analysed, geographically. In this study, twenty-three parameters are included as shown in Table 1, which is developed by the precedent of this study [18].

| Criteria          | Ground Parameters                                                                 |
|-------------------|-----------------------------------------------------------------------------------|
| Comfort           | Shelter                                                                          |
|                   | Row of roofed walkway                                                             |
|                   | Row of trees                                                                      |
| Perceived Security| Proximity to abandon area                                                         |
|                   | Proximity to construction sites                                                   |
|                   | Proximity to public alleys                                                        |
|                   | Proximity to vacant spaces                                                        |
|                   | Presence of street lights                                                         |
| Traffic Safety    | Presence of crossings                                                             |
|                   | Presence of traffic lights                                                        |
|                   | Presence of separator from motorways                                              |
| Connectivity      | Access to bus/taxi stops                                                          |
|                   | Access to commercial area                                                         |
|                   | Access to jobs/industrial area                                                    |
|                   | Access to residential area                                                        |
|                   | Access to tourist attractions                                                     |
| Convenience       | Walking time                                                                      |
|                   | Walking distance                                                                  |
| Conviviality      | Presence of food and beverages vendors                                            |
|                   | Presence of green area                                                            |
|                   | Presence of public parks                                                          |
|                   | Presence of resting points                                                        |
| Conspicuous       | Presence of signage with name                                                      |
|                   | Presence of signage with direction                                                |
|                   | Presence of signage with distance                                                 |
2.2. Walkability Index

Walkability Index is used in assessing the walkability of an environment. There are many methods designed to develop a walkability index which includes the Pedestrian Environment Review System (PERS) in the United Kingdom (UK), the WalkScore in the United States (US) and the Transit Walkability Index in Melbourne.

The PERS had been used extensively as a walking audit tool a part of the multi-modal Streetaudit assessment tool that had been developed by the Transport Research Laboratory (TRL) with the cooperation with the TFL [3]. It aims to assess the level of service and quality of a pedestrian environment. The scoring method using by PERS is qualitative methods of reviewing the attributes of the pedestrian environments. It uses auditor’s judgement to score the priorities of the attributes.

WalkScore on the other hand uses the distance to different types of amenities as a basis in their measurement [27]. The travelling time to reach amenities from an address determined the walkability of it. The points awarded based on the walking time with the minimum time to reach certain destination will have a maximum points and vice versa. WalkScore however have few weaknesses. First, it only relies on the distance between two points in producing the score which can influence the accuracy of the score as walking is never about travelling time only, there are many other aspects should be included. The second issue is also about accuracy as they treated all amenities similarly when all of them actually served community differently. For example, the role of schools in a community is never at the same level with parks as attending school is compulsory but going to a park is an option, for leisure.

The downside of these indices is that they rely on the quantitative method. But, walkability is very closely related to satisfying people’s needs. Thus, it is always better to incorporate the index with what public actually needs which this study will attempt to do.

2.3. Analytical Network Process

Analytical Network Process (ANP) is a Multi-Criteria Decision Analysis (MCDA) method that can be used in rating the criteria. As it is a part of a technique that allows multiple criteria to be assessed simultaneously, it is suitable for study involving walkability as walking is in fact influenced by many factors. ANP also allows interdependencies between criteria, therefore it is very relevant for walkability study since some of the factors do influence the other for example how the presence of abandon area could increase walking time and distance as pedestrian need to make a detour while walking to avoid the area for their safety purposes.

ANP uses a pairwise comparison technique which means the rating for the criteria will be conducted in a pairwise manner [22]. This means that instead of rating all the criteria involved at once, the decision maker need to only make their choices out of two. This could improve the accuracy and precision in making judgement as human do have a limited brain capacity in making choices when more than two options are available.

ANP uses supermatrix in deriving the priorities or degree of importance for the criteria. First, the rating obtained by each of the criteria in a pairwise comparison will form an unweighted supermatrix. Then, the values will be multiplied with a cluster matrix which is the rating for their control criteria. This procedure will produce a weighted supermatrix. The values in this supermatrix will be normalized to derive relative priorities for each of the criteria [22].

2.4. GIS in Measuring Walkability

GIS is very useful for walkability studies. It had been implemented in many studies either for data collection, analysis or visualizing purposes. Many studies had attempted to use GIS to collect the spatial data for the facilities and furniture available along the walking path [20]. These spatial data is very useful in representing the attractiveness of the walking path. There are few methods that can be used in collecting the spatial data. One of it is the mobile GIS which allows the field data collection to be collected using small and portable devices [29]. This method is widely used as it can reduce the time taken in data collection process. It can be conducted using various portable devices such as smartphones and other handheld devices. In addition, the field data collection can also be conducted with the usage
of mobile terrestrial laser scanner. It will collect the pedestrian routes and the furniture inside a building as point clouds which could be later processed to create a spatial model of the indoor pedestrian environment [30].

GIS is also very useful in analyzing purposes. It had been widely used to measure walkability. Many studies had attempted to measure walkability by using the connectivity and accessibility analysis. There is one more technique in GIS named space syntax which is a methodology that had been used to represent the morphology of building, open spaces and streets [31]. The spatial configuration of a building or streets can be modeled by connectivity graph representation in space syntax. It aims to investigate the relationship between spatial layout with a range of social, economic and environmental phenomena that could influence its level of services. It had been used widely to understand the movement patterns, awareness and interaction in respect to the density, land use and land value, urban growth and societal differentiation as well as safety and crime distribution.

The application of Space Syntax in GIS had been widely used in modelling the spaces as well as analyzing the accessibility of different land uses or public facilities and amenities in urban area. It had been implemented in one study conducted in Seoul to measure the walkability of pedestrian access to two subway stations there [12]. The study developed an axial map with pedestrian facilities attached to the walking route to measure the walkability index of each of the pedestrian access to the subway stations.

3. Conceptual Framework on Measuring SWI

The framework comprises of four (4) phases as described in Figure 1. The first phase is the background study that includes two stages i.e. review of literature and software training. The second phase is the data acquisition stage. The data required for the study are identified, followed by the data collection process. Subsequently, the data processing stage involved building the appropriate decision making model and applying GIS network analysis. The final phase is the data analysis that measures the spatial walkability index (SWI) of the pedestrian access to rail transit stations.

In the background study, the review of literature was aimed to identify the gaps and problems based on previous literature. From this, the aim and objectives of the study was drawn. Furthermore, the literature review provides the understanding on the best criteria and the best methods to measure walkability as adapted by other previous studies. It helps to give the rough idea on how to develop a SWI. Likewise, the background study includes training on the particular software used such as identifying the specific tools and applications relevant to the development of SWI.

In the data acquisition phase, the survey for data availability utilized the web search namely the Malaysian Centre for Geospatial Data Infrastructure (MaCGDI). The portal allows user to find the possible sources of the required data. Consequently, the source for secondary data was collected through the available local agencies. Alternatively, the field data collection was conducted to gather data that cannot be obtained from any local agencies and also the data for the indoor walking route and available public realms along the routes by using mobile GIS technique.

The data processing phase comprises of two sections. The first section covered the development of a Decision-making Model (DM) to aggregate the priorities of the selected criteria. The developed model clustered the criteria accordingly and defines their dependencies. Their priorities were aggregated using suitable rating technique. Second section includes the spatial analysis where the data was prepared in GIS environment. The network dataset that consist the pedestrian path and the walkability criteria signified as ground measurable parameters were built for the network analysis application.

The final phase was the SWI measurement that will be conducted in two parts. First, the walkability for each of the pedestrian routes will be analysed by using space syntax which will identify the measurable parameters of the criteria influencing walkability along the walking route, and their score will be summed up to calculate the walkability index for each of the route. Second, the SWI for each of the rail transit station in KL city centre will be calculated based on the walkability index for the pedestrian routes that connected to them.
4. Expected Outcome
The expected outcomes from this study are the Spatial Walkability Index (SWI) for the pedestrian routes and rail transit stations in KL City Centre. The SWI is expected to aid in a better planning in future for the rail development in KL and other area. It is also expected that the index can be guidance for the rail developer and local authority to improve the current pedestrian environment to ensure their riders experience the highest level of services when using the services.
5. Conclusion

Walkability is one of the keys in ensuring the highest quality of services can be delivered to the rail transit riders when they decide to use the services. It ensures the journey of using the rail transit services is comfortable from the very first to the last mile of their journey. Therefore, it is vital to have the walkability being measured to understand the LOS of the rail transit services. One of the techniques in measuring walkability is by using the walkability index. It has been used in many parts of the world. Many different techniques had been introduced. This study however had decided to use Spatial-MCDA which is a combination of GIS and MCDA. First, a MCDA technique, ANP will be used to derive the priorities of the criteria influencing walkability based on the experts’ decision-making. The derived priorities will be used as attributes for the pedestrian network dataset. By using GIS Space Syntax, the attributes will act as the attractiveness of the pedestrian network, thus lead to a measurement of the walkability index that will be called SWI in this study. The outcomes of this study are the SWI of the pedestrian network and the rail transit stations in KL City Centre. It is expected that it can be useful as a guide for the rail developer and local authority to improve the pedestrian environment wherever needed. It can also be used as a basis of developing new rail transit services in future.

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