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Criteria Influencing Pedestrian-Friendliness of First/Last Mile Transit Journey using Analytical Network Process (ANP) Group Judgement

Kriteria Mempengaruhi Kemesra-Pejalankakian Perbatuan Pertama/Terakhir dalam Perjalanan Transit Menggunakan Keputusan Berkumpulan dengan Proses Analisis Berjaringan (ANP)

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ABSTRACT

The pedestrian-friendliness of the first/last mile (FLM) transit journey is one of the keys in influencing the quality of transit services. The demands of transit riders are increasing as they have started to ask for more than just accessibility which includes a good walking environment to access the service. Most local governments are aware of this as many of them have the guidelines in planning for a walkable transit services. However, they need to prioritise the criteria influencing pedestrian-friendliness accordingly. This paper proposes a framework for evaluating the priorities of criteria influencing pedestrian-friendliness by using Analytical Network Process (ANP) which relies on group judgement from experts who have wide knowledge and experience within the scope of the study. It can be conducted in six stages which are (1) determining criteria influencing pedestrian-friendliness (2) developing ANP model of the criteria and their dependencies, (3) obtaining experts judgement, (4) aggregating the criteria's priorities, (5) deriving group judgement of the criteria's priorities, and (6) ranking the criteria accordingly. In the end, this study will suggest the priorities for criteria influencing pedestrian-friendliness which can be used as reference in planning for walking environment to access transit services. This study highlighted nineteen criteria that could be used in representing the pedestrian-friendliness of FLM. Based on the analysis, it is suggested that from the nineteen criteria, the presence of signage showing direction is the most important criterion followed by roofed walkway, convenience in term of walking time, access to public parks and presence of traffic lights.

Keywords: Pedestrian-friendliness; walkability; first/last mile; transit service; analytical network process

ABSTRAK

Kemesra-pejalankakian bagi perbatuan pertama dan terakhir (FLM) untuk satu perjalanan transit boleh dianggap sebagai salah satu kunci yang mempengaruhi kualiti sesebuah servis transit itu. Permintaan dari pengguna transit semakin meningkat dan mereka mula meminta lebih dari sekadar kebolehsampaian termasuklah persekitaran berjalan kaki yang baik untuk mengakses servis itu. Kebanyakan kerajaan tempatan peka akan hal ini dimana banyak antara mereka mempunyai panduan untuk membangunkan sesebuah servis transit yang juga mesra pejalan kaki. Walaubagaimanapun, mereka perlu menentukan kepentingan kriteria yang mempengaruhi kemesra-pejalankakian. Kertas ini akan mencadangkan rangka kerja untuk menganalisis kepentingan kriteria yang mempengaruhi kemesra-pejalankakian dengan menggunakan Proses Analisis Berjaringan (ANP) yang bergantung pada keputusan berkumpulan yang terdiri daripada pakar yang berpengetahuan dan berpengalaman luas dalam sesuatu bidang. Rangka kerja akan dijalankan dalam enam peringkat iaitu (1) menentukan kriteria mempengaruhi pemilihan pengguna untuk berjalan kaki, (2) membangunkan model ANP yang menunjukkan kriteria dan kebergantungan mereka, (3) mendapatkan keputusan daripada pakar, (4) mengira kepentingan setiap kriteria, (5) mengira keputusan berkumpulan bagi setiap kriteria, dan (6) mengatur kriteria mengikut kedudukan mereka. Akhir sekali, kajian ini akan mencadangkan kepentingan kriteria yang mempengaruhi sesuatu perjalanan. Ia boleh digunakan sebagai rujukan untuk perancangan yang lebih baik untuk persekitaran pejalan kaki bagi servis transit. Kajian ini memberi focus kepada sembilan belas kriteria yang boleh digunakan untuk mewakili kemesraan pejalan kaki *bagi FLM. Berdasarkan analisis, daripada sembilan belas kriteria terbabit, adalah dicadangkan bahawa kewujudan papan tanda yang menunjukkan tanda arah ialah kriteria yang terpenting diikuti oleh laluan berbumbung, akses ke taman-taman awam dan kewujudan lampu isyarat.*

Kata kunci: Kemesra-pejalankakian; walkability; perbatuan pertama/terakhir, servis transit; proses analisis berjaringan

INTRODUCTION

Transit services is one of the keys in developing a more sustainable and liveable city. Most cities across the globe have transit systems, and each tries to provide efficient access and mobility. Transit services are not just a mean of transportation to travel from one point to another. Nowadays, people start to demand for more than just travelling between two points which could be completed by using personal vehicles that is still preferable to many.

The reason is simple; convenience. It is not about riding the transit. Most people find the transit coach is comfortable and the travelling time can be faster when comparing with driving that need to cope with the road traffic. The problem lies in the first/last mile (FLM) of the transit journey. People find it a hassle to walk to and from the transit station. Although a pedestrian path is provided, they expect more than just connectivity and accessibility. It is essential to first understand their need for a good first/last mile transit journey before developing the service.

This makes the planning for the walking path around the transit stations a great challenge to most governments. They realise people want more than just connectivity. Thus, they need to plan a walking environment that will attract people, not just bring them to a certain destination. For example, in Singapore, they made use of open spaces around the cities to create parks with many activities. Most European cities create greenways instead of ordinary paved walkways to encourage people to stroll, jog and even cycle.

Each city does guidelines to build pedestrian walkways. The question is how to decide which method will have the most impact on creating a pedestrian-friendly walking environment. How can they decide which method will make the FLM transit journey more pleasant? There are many methodologies proposed for that purpose. To date, a rating-based sample survey is still considered as the best method. However, are the techniques adequate? How can one simply translate the rating from one to five in identifying which is important and which is not? What is the best method to carefully rate each criterion objectively? Given five criteria, how can a person make a comparison between the five and select the best option? It is always better to break the five into smaller comparisons, like into pairs.

Multicriteria Decision Analysis (MCDA) could be a solution for this. It is a decision-making technique that can be used in aggregating the degree of importance of more than one criterion at once. It can be conducted using many techniques including Weightage Linear Combination (WLC), Ideal Points (IP) and Pairwise Comparison (Malczewski & Rinner 2015). It this study, the third technique is implemented as it allows the rating of the criteria to be conducted in a pair instead of altogether. With this, the inconsistencies in making judgement can be reduced as the decision-maker will need to make a choice out of two instead of five, for example.

This method will allow the rating for the preferred criteria to be done in a pair. Let's say there are five criteria; each criterion will be compared to the other in a pair, instead of five at the same time. This technique will improve the precision of the comparison as people will need to choose one in a pair instead of in five. Respondents will need to choose their preferred criteria between a pair and give a score of their choice. After they completed their choice for all comparisons, their ratings will be aggregated to derive a set of priorities which represent their choice.

The pairwise comparison method can be conducted using few techniques including the Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP) which is the most implemented techniques for studies related to pedestrian-friendliness including studies that were conducted previously in Seoul and Taipei (Ha, Joo & Jun 2011; Lee et al. 2013; Sung & Oh 2011; Wey 2014; Wey & Chiu 2013; Wey & Hsu 2014; Wey, Zhang & Chang 2016). The only difference between these two techniques lies in the 'hierarchy' and 'network'. The AHP, like its name, performs the aggregation hierarchically. ANP allows the comparison to be made regardless of the hierarchy criteria. Between the two, ANP is a better technique to assess the public's preferences. This is simply because of people's choices that are often very relatable to each other. AHP focuses on hierarchical structure where the degree of importance for the criteria in lower level solely depends on the criteria in upper level. Walking is not an exception. People's choice to walk can be influenced by more than one criterion, and those factors can be related. For example, people want walking to be safe, but at the same time, they want the journey to be short. The two are related. At traffic lights, for example, their walking journey can be increased due to the waiting time. This enhances their safety, but at the same time affects their travelling time.

This paper will propose a framework for assessing the important criteria of a good FLM transit journey using the ANP decision model. The framework begins by determining the criteria influencing people's choice to walk. The criteria will then be modelled with ANP rules showing the criteria and their dependencies. Then, the experts' judgement on each criterion will be obtained followed by the aggregation of the priorities based on their choice. The group decision is derived by averaging the priorities for each criterion. Finally, the criteria will be ranked accordingly. It is expected that the framework can be applied in decision-making to plan a good walking environment for the FLM transit journey. It can also be improvised to suit the demands of people in different cities.

PEDESTRIAN-FRIENDLY FOR THE FIRST/ LAST MILE OF A TRANSIT JOURNEY

FLM is considered the first impression for the quality of a transit service (Guerra, Cervero & Tischler 2012; Papa & Bertolini 2015). It is included as a part of the transit service as every transit journey begins and ends with walking. People walk or cycle to access the service. Therefore, it needs to be in good condition that will allow a journey to be pleasant. It is no longer about connectivity, but mobility. A well-connected route is useless if it does not promote good mobility for people to reach their destinations.

FLM transit journeys refer to the half mile radius to and from a station. There are many opinions about the exact distance depending on the travel behaviour and environment factors in a certain area (Guerra, Cervero & Tischler 2012). For example, in Malaysia, people will walk up to 380 metres for five minutes in an urban area but 600 metres in rural areas (Diyanah Inani, Hafazah & Mohd Zamreen 2013). However, most of the cities use 400 metres since it will make planning easier.

FACTORS INFLUENCING THE PEDESTRIAN-FRIENDLINESS

The term 'friendliness' defines that the footpath or pedestrian walkway should allow people to reach their destinations comfortably by walking. A pedestrian-friendly environment depends on the 3Ds which are the Design, Density and Diversity (American Association of State Highway and Transportation Officials (AASHTO) 2004; Giles-Corti et al. 2014; Mavoa et al. 2012; Montgomery & Roberts 2008; Peiravian, Derrible & Ijaz 2014; Stockton et al. 2016; Transport For London (TFL) 2017). These 3Ds are fundamental in developing a good walking environment.

The first 'D', Design, refers to the street design. It does not mean that a street should have a futuristic design, rather it should be designed to have good connectivity, continuity and most importantly, is attractive for people to walk on. A walking path should allow people to reach their destination without the hassle to take any detour due to disruptions like dead-ends (Cheng & Chen 2015; Papa & Bertolini 2015; Sarkar et al. 2015; Muhamad Razuhanafi et al. 2018).

For attractiveness, it is relatively new but has been taken into consideration in many cities. Most of the time, it aims to enhance the social benefits for pedestrian (Chen & Chang 2015; Doyle et al. 2006; Giles-Corti et al. 2014; Jun & Hur 2015; Mazlina & Said 2008; Moura, Cambra & Gonçalves 2017; Wan Rabiah, Patterson & Pegg 2011; Katiman et al. 2011). In Stockholm for example, the city council decided to put tables painted with a chess board at some resting point along the walking path (Stockholm City Planning Administration 2010). In Singapore, the donated pianos were placed along the path. At the very least, a walking path should have benches or huts for people to rest on or under. These will make the walking path more attractive (Centre for Liveable Cities Singapore & The Seoul Institute 2016).

The second 'D', Density, refers to the intersection density that needs to be safe for people to walk on (Guo & Loo 2013; Hafazah & Diyanah Inani 2013; Landis et al. 2001; Todd et al. 2016; Vale 2015). It should have traffic aids like traffic lights and crossings that will help people cross the roads safely. The final 'D', Diversity, represents the various land uses that should be accessible by the walking path

(Brown et al. 2009; Sugiyama et al. 2016; Sundquist et al. 2011). This will support the various walking purposes. For example, there are people who will use transit services to go to their workplace, but there are also some who use it for leisure to go for shopping.

CRITERIA FOR GOOD WALKING ENVIRONMENT

It is important to prioritise the criteria that have the most influence in any planning works. Planners can never put everything on the board. Such is impractical. They need to know which and what holds the most priority and will satisfy the end users. Therefore, good decision-making needs to be conducted.

However, there are very few studies that used the experts' decision-making in identifying the most important criteria for a good walking environment. Most studies focus on the public's perceptions instead. They determine the criteria based on the public's point of view (Adkins et al. 2012; Raja Noriza & Rustam Khairi 2013; Noor Iza, Ahmad Kamil & Zahrullaili 2012; David et al. 2014; Leslie et al. 2005; Sutikno & Kurniawan 2013). While this can be very good in understanding their preferences, it may not be useful as a basis for planning the actual development in reality.

Those studies used a rating technique on the sample survey to identify which of the criteria has the most impact. They translated the frequency of the selected criteria as its score and ranked them according to preference. Although it might sound relevant, however, looking at a different perspective, its precision can be questioned. There is no way one can decide an order into a long list of criteria at once. Normal people have a very limited capacity in deciding the best choice even in a pair, what not more than that. This could lead to the issue of inconsistencies in making judgement.

Some studies used a correlation analysis to measure the degree of importance for the criteria. It is better than simply basing on the frequency of choice (Ji & Gao 2010; Zeinab & Norsidah 2013; Juriah & Norsidah 2015). This technique has been used many times in measuring the group judgement on a good walking environment. They identified which of the criteria was the best by testing the correlation of the criteria with each other.

One study conducted in Taipei used the experts' judgements to decide the best site which has a good walking environment to build transit stations (Wey, Zhang & Chang 2016). This study used ANP which is different from the ordinary rating to identify the degree of importance for each criterion. Instead of asking the experts to simply rate or rank the criteria as a whole, it paired the criteria into two and asked the experts to make their choice. This will improve the precision of the decision made by the experts. There is only one problem with this study; it took an average of the rating for each criterion obtained by all experts to derive the group decision made by them. It would have been better if they took the geometric mean instead (Malczewski & Rinner 2015).

GROUP DECISION-MAKING WITH ANALYTICAL NETWORK PROCESS

ANP is generalised from the well-known Analytical Hierarchy Process (AHP) but with much more precise judgement (Malczewski & Rinner 2015; Saaty & Vargas 2006). Unlike the hierarchical solving mechanism practised by AHP, ANP allows the interaction between the elements on different clusters regardless of their hierarchy for solving a problem which reflects the reality of most of the world's problems.

In the example, the decision of buying a car does not always depend on its price, performance, and design. Classic AHP decision-making process will give alternative with the best price, performance, and design cumulatively. However, most of the time, people will look at the three criteria that are interdependent as well as the available alternatives. They might have their favourite car among the alternatives, even when the price is higher, they might still buy it. ANP allows the interdependencies between criteria, between alternatives as well as between alternatives and criteria. All criteria can influence each other, and the alternatives influence the criteria.

As illustrated in FIGURE 1, the structure of ANP does not have the classic top-bottom hierarchy.

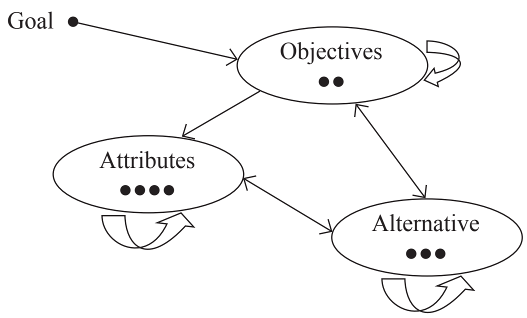

FIGURE 1. Structure of ANP Network

Instead, they are presented as a network with clusters containing nodes and connected by links that signify its dependency. The nodes in the cluster represent either the origin or destination of the influence which is 'Source node' and 'Sink node', respectively. Elements in each cluster can interact with each other as well as elements in another cluster as ANP allows the inner and outer dependency of elements. Like AHP, ANP will derive the scale ratio of priorities for elements and clusters of elements by pairwise comparison methods.

ANP uses supermatrix to synthesise the priorities parallel to the Markov chain process (Malczewski & Rinner 2015; Saaty & Vargas 2006). It calculates the priorities for each of the criteria based on their rating obtained during the pairwise comparison with other criteria. The rating indicates the degree of importance of criteria over the other criteria. The supermatrix in FIGURE 2 consists of several elements where *CN* denotes the *N*-th cluster, *eNn* denotes the *n*-th element in the *N*-th cluster, and W_{ij} block matrix consists of the collection of the priority weight vectors *w* of the influence of the elements in the *i*-th cluster with respect to the *j*-th cluster. If the *i*-th cluster has no influence to the *j*-th cluster, then $W_{ij} = 0$.

The process of aggregating the priorities begins with forming the unweighted supermatrix containing the degree of importance chosen for each of the criteria. This supermatrix will be multiplied with the eigenvectors of their control criteria to form the weighted supermatrix. The values in this supermatrix will then be normalised to derive the priorities for each of the criteria by using the formula in Equation 1.

$$\lim_{k \to \infty} W^k \tag{1}$$

AGGREGATING THE GROUP JUDGEMENT

There are no exact guidelines on the number of respondents required for ANP studies. However, most literature stated that it is better to have a few judgements from people who are familiar with the area of study, i.e. the experts (Malczewski & Rinner 2015; Saaty & Vargas 2006; Sadeghi 2012; Greene et al. 2011). For studies involving public preferences, it is better to have more judgements, but with a good consistency. It is widely known that a high number of judgements can affect the consistency of the decision-making.

However, ANP pairwise comparison controls the consistency of the judgement by allowing the inconsistency under the tolerance of 0.10 (Saaty & Vargas 2006). The inconsistency is based on $\lambda max > n$ for positive reciprocal matrices and $\lambda max = n$ if C is a consistent matrix. It can be calculated using Consistency Ratio (CR) based on the consistency index of judgement made on each of the pair by using Equation 2.

$$CR = \frac{\lambda_{max} - N}{RI(n-1)} \tag{2}$$

A group judgement takes the mean of the priorities aggregated from the experts. However,

$$W = \begin{array}{cc} & \begin{array}{cccc} \begin{array}{c} CN \\ e_{N1}e_{N2}\ldots e_{NnN} \end{array} & \begin{array}{c} CN \\ e_{N1}e_{N2}\ldots e_{NnN} \end{array} & \begin{array}{c} \ldots \\ \ldots \end{array} & \begin{array}{c} CN \\ e_{N1}e_{N2}\ldots e_{NnN} \end{array} \end{array} \\ \begin{array}{cc} C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \square \\ e1n1 \end{array} \\ C_2 & \begin{array}{c} e_{21} \\ e_{22} \\ \square \\ e2n2 \end{array} \\ \square & \square \\ C_N & \begin{array}{c} e_{N1} \\ e_{N2} \\ \square \\ eNnN \end{array} \end{array} & \left[\begin{array}{cccc} W_{11} & W_{12} & \ldots & W_{1N} \\ W_{21} & W_{22} & \ldots & W_{2N} \\ \square & \square & \ldots & \square \\ W_{N1} & W_{N2} & \ldots & W_{N3} \end{array} \right] \end{array}$$

FIGURE 2. Supermatrix of ANP

instead of the simple averaging technique as shown in Equation 3 where the priority of criteria is calculated by the average of the priorities given by the group of experts, geometric mean will be used to maintain the quality of the aggregated priorities in respect to the group of experts.

$$\text{Simple Averaging} = \frac{\lambda Expert_n C_{ij}}{N} \qquad (3)$$

where;

$Expert_n C_{ij}$ = Priority of criterion by an expert
N = Number of Set

The geometric mean uses product of a set of numbers instead of their sum to calculate the average. It is also known as the *n*-th root of the product *n* numbers. It will indicate the central tendency of a set of numbers. It is the best representation of a normalised result. The basic equation of the geometric mean can be improvised to calculate the group judgement for each of the criteria where *n* will indicate the number of experts and *x* will be the aggregated priorities of a criterion for each expert.

$$\left(\prod_{i=1}^{n} x_i\right)^{\frac{n}{1}} = \sqrt[n]{x_1 x_2 \cdots x_n} \qquad (4)$$

where;

n = number of sets
x = value

Thus, the framework of determining the important criteria to measure walkability for the FLM transit services is divided into six steps.

1. Determine the criteria
2. Identify and model the dependencies of each criterion
3. Obtain the expert's judgement on the rate for each criterion using a pairwise comparison technique
4. Aggregate the degree of importance (priorities) for each criterion
5. Derive the geometric mean of each priority obtained from the experts
6. Rank the criteria according to their priorities

DEVELOPMENT OF ANP MODEL TO PRIORITISE THE CRITERIA OF A GOOD WALKING FLM

The process of developing the ANP model began with the identification of criteria and their sub-criteria that will be used in the assessment of the walkability. In this study, there are seven control

TABLE 1 Criteria of Walkability and their Sub-Criteria

<table>
<tr><th colspan="2">Criteria</th><th>Definition</th><th>Sub-Criteria</th></tr>
<tr><td colspan="2">Connectivity</td><td>Provide access to various land uses that ensure the walking path support various walking purposes</td><td>Bus/Taxi Stops
Commercial Area
Residential Area
Industrial / Jobs Area</td></tr>
<tr><td colspan="2">Convenience</td><td>Ensure walking is also convenient as other mode of transportation</td><td>Time
Distance</td></tr>
<tr><td rowspan="3">Comfort</td><td>Traffic Safety</td><td>Ensure the path is safe from any traffic accidents involving pedestrian</td><td rowspan="3">Crossings
Traffic Lights
Abandon Building
Construction Sites
Public Alleys
Row of Roofs
Row of Trees</td></tr>
<tr><td>Perceived Security</td><td>Ensure the walking path is secure from any possible threat from crime to pedestrian</td></tr>
<tr><td>Shelter</td><td>Provide shelter and shade from different climate and weather</td></tr>
<tr><td colspan="2">Conviviality</td><td>Promote an entertaining, enjoyable and pleasant walking experience</td><td>Green Area
Public Parks
Resting Points</td></tr>
<tr><td colspan="2">Conspicuous</td><td>Provide a better navigation and familiarity to pedestrian</td><td>Signage showing Name
Signage showing Direction
Signage showing Distance</td></tr>
</table>

criteria, and at least two sub-criteria are listed to be included in the ANP model. These criteria and sub-criteria are then modelled as a node in their respective cluster using ANP rules in Superdecisions platform. The nodes and clusters are then linked according to their dependencies. Then, their degree of importance will be aggregated by using ANP decision rules. The process will be discussed in detail in this section.

DETERMINING THE CRITERIA AND THEIR SUB-CRITERIA

Based on the 3Ds, five criteria that best represented them were identified as described in Table 1. The five are then represented as at least two measurable parameters. They reflect the built environments along the walking path that need to be assessed. This rendered the five criteria the control criteria whereby their priorities will affect the priorities of their sub-criteria.

MODELLING THE DEPENDENCIES

The criteria and their sub-criteria will be represented as a node in their respective clusters in ANP model as illustrated in Figure 3. The control criteria will be put into a cluster named 'Control Criteria' representing the seven criteria that will be used in assessing walkability. On the other hand, the sub-criteria will be put in their control criteria's clusters respectively. Each of the clusters for the sub-criteria will be named after their control criteria.

Their interdependencies need to be indicated clearly in the ANP model alongside the direct dependencies between the control criteria and their measurable sub-criteria. This can be done by drawing an arrow showing the link between the two dependent nodes or clusters. These links are very important in deriving the priorities of the nodes based on the nodes or clusters on which they depend. Figure 3 shows how dependencies can be drawn in ANP model using Superdecisions platform.

EXPERTS' JUDGEMENT

The process of aggregating the degree of importance for the criteria in this study utilized the expert decision makers' point of view. Even though the public preferences could be the best translation on the level of service of certain facilities, but it can be biased towards an individual point of view. Therefore, the experts' judgement that is based on experiences and facts are very useful here. It is important to find the best possible candidate among the experts that gives truthful judgement on the current walkability environment. Therefore, certain conditions were set in selecting the candidates for the ANP judgement process.

The experts are the academician and industrial experts that have experience in the development planning of a good walking environment. A total of six expert decision makers comprising of three academicians and three industrial experts were selected to provide their judgement on the walkability criteria. The academicians are professors

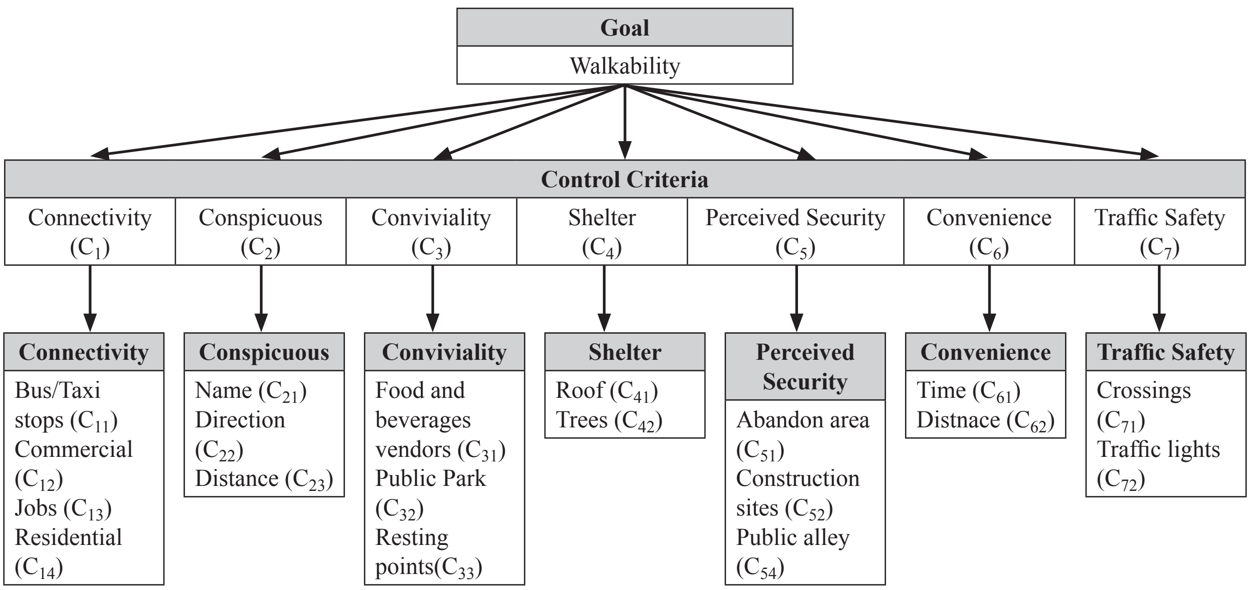

FIGURE 3. ANP Model for the Criteria of Pedestrian-Friendly FLM Transit Journey

or graduate students who are directly involved in researches related to walkability. Likewise, the industrial experts are the town planners currently engaged in the planning and development of good walking environment in the city. The industrial experts were the local authority from Kuala Lumpur City Hall (DBKL), the town planner from the Department of Town and Regional Planning (JPBD) and the public transportation planner from Land Public Transportation Authority (SPAD) involved in the planning of walkable transportation system in KL.

The academicians were selected from local universities that can provide judgement from different perspectives with respect to the experiences in their country. They are two professors from local universities and a graduate student who were actively participating in researches related to walkability in Malaysia. They had published papers related to the walkability criteria and quality of transit services in Malaysia.

The details of the academic and the industrial experts that participated in this study are summarized in Table 2. The data collection for the experts' judgement was conducted by either interviewing them personally or emailing the ANP survey forms for those who prefer this way. Initial contact through email was first made asking for their cooperation and if agreed, an official meeting was scheduled. If not, the ANP survey form was sent to them through email instead so that they can provide their judgement.

Each of the experts will have their set of priorities. Thus, there are six sets of priorities as shown in Table 3. The priorities were aggregated using supermatrix as discussed earlier. The rating given by each expert from the pairwise

TABLE 2 Description of Experts to Provide their Judgement

Experts		Descriptions
Academics	A1	Professor from a local university
	A2	Professor from a local university
	A3	Graduate student from a local university
Industrial Experts	I1	Local council
	I2	Local government's town planners
	I3	Local government's public transport planners

TABLE 3 Aggregated Priorities obtained from each Expert

Criteria	Sub-Criteria	A1	A2	A3	I1	I2	I3
C_1	C_{11}	0.09	0.06	0.04	0.04	0.12	0.12
	C_{12}	0.03	0.54	0.18	0.06	0.26	0.16
	C_{13}	0.26	0.13	0.04	0.24	0.06	0.16
	C_{14}	0.55	0.04	0.57	0.29	0.53	0.48
C_2	C_{21}	0.07	0.05	0.07	0.05	0.06	0.20
	C_{22}	0.65	0.29	0.65	0.66	0.81	0.70
	C_{23}	0.28	0.66	0.28	0.29	0.13	0.10
C_3	C_{31}	0.14	0.35	0.08	0.04	0.05	0.24
	C_{32}	0.56	0.53	0.69	0.07	0.60	0.19
	C_{33}	0.07	0.07	0.10	0.36	0.28	0.24
C_4	C_{41}	0.88	0.10	0.12	0.90	0.90	0.88
	C_{42}	0.13	0.90	0.88	0.10	0.10	0.13
C_5	C_{51}	0.08	0.59	0.05	0.09	0.17	0.29
	C_{52}	0.39	0.14	0.09	0.14	0.51	0.40
	C_{53}	0.43	0.05	0.43	0.23	0.16	0.16
C_6	C_{61}	0.88	0.90	0.50	0.10	0.83	0.17
	C_{62}	0.12	0.10	0.50	0.90	0.17	0.83
C_7	C_{71}	0.14	0.06	0.30	0.13	0.14	0.65
	C_{72}	0.64	0.66	0.08	0.77	0.15	0.21

comparison formed an unweighted supermatrix. Then, the priorities were derived by multiplying the unweighted supermatrix with cluster matrix (priorities of their control criteria)

Equation 5 is applied to the priorities of each criterion as aggregated by each expert to calculate the group judgement made by the experts. The set of group judgement's priorities is calculated by using Equation 5 and described in Table 4.

$$\text{Geometric Mean} = \begin{matrix} \sqrt[6]{A1C_{11}A2C_{11}\ldots I3C_{11}.} \\ \sqrt[6]{A1C_{12}A2C_{12}\ldots I3C_{12}.} \\ \vdots \\ \sqrt[6]{A1C_{72}A2C_{72}\ldots I3C_{72}.} \end{matrix} \quad (5)$$

RESULTS AND DISCUSSION

The degree of importance for each of the criteria are ranked accordingly as shown in TABLE 5. Based on the ranking, the most important criterion in a pedestrian-friendly environment is the presence of the signage showing direction. This is probably due to the fact that it is important to provide good navigation for the pedestrian, especially for people who are not familiar with the area. This will aid in a better walking experience to the pedestrian when they use the route to and from the transit station. People can easily reach the station and their destination by following the direction shown by the signage along the walking route. Therefore, it is important to increase the signage showing directions along the FLM transit routes.

The second most important criterion is the presence of sheltered walkways with a roof. Undoubtedly, the shelter has the greatest impact on people's choice to walk. People want to be sheltered from the rain and protected from the sun. The presence of sheltered walkways will make the FLM transit journey more comfortable and pleasant. In KL, all transit stations have a roofed walkway 100 metres away from the stations. For a

TABLE 4 Calculation of the Group Judgement on each Criterion

Sub-Criteria	Geometric Mean Calculation	Group Judgement
C_{11}	$\sqrt[6]{0.09 \cdot 0.06 \cdot 0.04 \cdot 0.04 \cdot 0.12 \cdot 0.12}$	0.07
C_{12}	$\sqrt[6]{0.03 \cdot 0.54 \cdot 0.18 \cdot 0.06 \cdot 0.26 \cdot 0.16}$	0.14
C_{13}	$\sqrt[6]{0.26 \cdot 0.13 \cdot 0.04 \cdot 0.24 \cdot 0.06 \cdot 0.16}$	0.12
C_{14}	$\sqrt[6]{0.55 \cdot 0.05 \cdot 0.57 \cdot 0.29 \cdot 0.53 \cdot 0.48}$	0.30
C_{21}	$\sqrt[6]{0.07 \cdot 0.29 \cdot 0.07 \cdot 0.05 \cdot 0.06 \cdot 0.20}$	0.08
C_{22}	$\sqrt[6]{0.65 \cdot 0.66 \cdot 0.65 \cdot 0.66 \cdot 0.81 \cdot 0.70}$	0.60
C_{23}	$\sqrt[6]{0.28 \cdot 0.06 \cdot 0.28 \cdot 0.29 \cdot 0.13 \cdot 0.10}$	0.24
C_{31}	$\sqrt[6]{0.14 \cdot 0.35 \cdot 0.08 \cdot 0.04 \cdot 0.05 \cdot 0.24}$	0.11
C_{32}	$\sqrt[6]{0.56 \cdot 0.53 \cdot 0.69 \cdot 0.07 \cdot 0.60 \cdot 0.19}$	0.34
C_{33}	$\sqrt[6]{0.07 \cdot 0.07 \cdot 0.10 \cdot 0.36 \cdot 0.28 \cdot 0.24}$	0.15
C_{41}	$\sqrt[6]{0.88 \cdot 0.10 \cdot 0.12 \cdot 0.90 \cdot 0.90 \cdot 0.88}$	0.45
C_{42}	$\sqrt[6]{0.13 \cdot 0.90 \cdot 0.88 \cdot 0.10 \cdot 0.10 \cdot 0.13}$	0.22
C_{51}	$\sqrt[6]{0.08 \cdot 0.59 \cdot 0.05 \cdot 0.09 \cdot 0.51 \cdot 0.29}$	0.15
C_{52}	$\sqrt[6]{0.39 \cdot 0.14 \cdot 0.09 \cdot 0.14 \cdot 0.16 \cdot 0.40}$	0.23
C_{53}	$\sqrt[6]{0.43 \cdot 0.05 \cdot 0.43 \cdot 0.23 \cdot 0.12 \cdot 0.16}$	0.19
C_{61}	$\sqrt[6]{0.88 \cdot 0.90 \cdot 0.50 \cdot 0.10 \cdot 0.83 \cdot 0.17}$	0.42
C_{62}	$\sqrt[6]{0.12 \cdot 0.10 \cdot 0.50 \cdot 0.90 \cdot 0.17 \cdot 0.83}$	0.30
C_{71}	$\sqrt[6]{0.14 \cdot 0.06 \cdot 0.30 \cdot 0.13 \cdot 0.14 \cdot 0.65}$	0.18
C_{72}	$\sqrt[6]{0.64 \cdot 0.66 \cdot 0.08 \cdot 0.77 \cdot 0.15 \cdot 0.21}$	0.31

TABLE 5 Experts' Choice on the Criteria of the Pedestrian-Friendly Transit Journey

Criteria	Sub-Criteria	Group Judgement	Rank
Connectivity	Bus/Taxi stops	0.07	19
	Commercial area	0.14	15
	Business area	0.12	16
	Residential area	0.30	6
Conspicuous	Signage showing name	0.08	18
	Signage showing direction	0.60	1
	Signage showing distance	0.24	8
Conviviality	Food and beverages vendors	0.11	17
	Public parks	0.34	4
	Resting points	0.15	13
Shelter	Row of Roof	0.45	2
	Row of Trees	0.22	10
Perceived security	Proximity to abandon area	0.15	14
	Proximity to construction sites	0.23	9
	Proximity to public alley	0.19	11
Convenience	Walking time	0.42	3
	Walking distance	0.30	7
Traffic safety	Presence of crossings	0.18	12
	Presence of traffic lights	0.31	5

more pleasant journey, it is better if the walkway is extended to cover at least a half mile radius from the station. Trees scored less than 0.2 than the roof and ranked 10^{th}.

The roofed walkway is then followed closely by convenience in terms of time. After all, people will choose to walk if the walking route can make their journey shorter than another mode of transportation. There is no use if the walking takes longer than driving. If that is the case, people will choose to drive instead since it is more comfortable and less tiring. People care less about the walking distance. They are willing to walk regardless of the distance as long as they can reach their destination conveniently.

The next are a mix of different factors influencing walking. Residential is the most important land used to be connected with the transit services among other land uses, followed by commercial and business areas. However, the connectivity of the walking routes to the bus or taxi stops ranked the second least important criteria for a pedestrian-friendly environment. For conviviality aspects that will enhance the entertaining walking environment, public parks ranked first. This might reflect people's purpose to walk which is for leisure. Food and beverages vendors and resting points scored similarly. This is probably because they are aiming for the same purpose, which is to provide a relaxing walking experience to the pedestrian.

Traffic safety is a highlight of any walkability study. It is considered among the most important aspect of planning for a good walking environment. Although here it ranks lower than the familiarity and convenience, it is still considered among the most important aspects. Experts decided that traffic lights are more important than the presence of road crossings. This might be because traffic lights will control the movement of vehicles. A pedestrian can cross the road more safely with the presence of traffic lights, instead of the crossing on its own.

Perceived security criteria are ranked closely to each other with the construction sites determined as the areas that need to be most avoided. This might be because it will cause more danger to the pedestrian with many construction-related vehicles needing access to the site. Most of the time, it will obstruct the existing walking routes, exposing pedestrians to the danger of being hit by the vehicle. Public alleys and abandoned areas have a similar impact on the pedestrian's safety because they are isolated from activity.

Experts decided that the presence of signage showing only names is the least important criteria for a pedestrian-friendly environment. This is contrasted with the presence of signage with direction. People want to know the direction more than just street sign or building sign when they walk towards a certain point of interest. Signage that includes a distance is also ranked low. This might reflect the people's willingness to walk regardless the distance to reach the destination.

CONCLUSION

This study assesses the criteria influencing the walking environment around the FLM of a transit journey. This is to aid in better planning for good quality transit services. The question is, which of the criteria are the most important in boosting the quality of the FLM transit service. An ANP-based experts' group decision-making was conducted to serve this purpose as summarised in Figure 4. From the final aggregated priorities, signage showing direction is the most important criteria followed by the presence of shelter by a roof. Sub-criteria of safety and security are ranked above average and close to each other. This shows that people are seeking a more convenient and comfortable walking experience rather than just connectivity. This is proved by the mixed score received by the land uses to be connected by the streets.

The recommendations highlighted the suggestions of improvements in future works that share the similar aim and objectives. These recommendations were made based on the limitations by the findings found in this study.

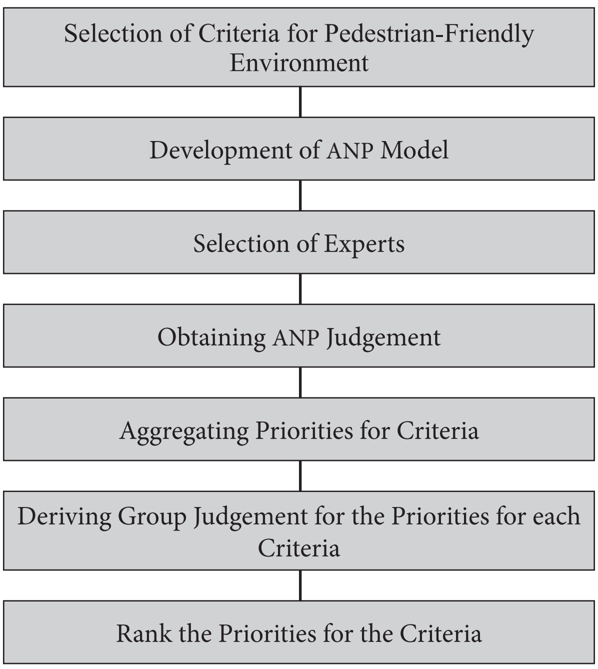

FIGURE 4. Framework for Deriving the Experts' Group Judgements for the Priorities for each Criteria influencing Pedestrian-Friendliness

This includes the differences on academicians and industrial experts' judgements and the limitation in understanding the pedestrian-friendliness solely on facts and experiences from experts. This result might be improved by dividing the priorities by the experts' group which are academics and industrial experts. This is to cluster their perspective and not to mix it since they have different backgrounds and cognitive skills. In the future, it is possible to use this framework to obtain the public's perceptions of the pedestrian environment, but with the application of different multicriteria evaluation techniques that will suit the public's capacity in making judgement such as the rating or ranking technique. The priorities for each can also be incorporated with spatial analysis to measure the pedestrian-friendliness for an existing FLM transit route.

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