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Integration of AHP and GIS to Derive a Walkability Index for Women's Access to Rail-Transit Stations

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Abstract

This study utilized Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP) to develop a walkability index for women in accessing rail transit stations. By integrating spatial analysis and multi-criteria decision-making techniques, it addressed key factors such as accessibility, comfort, traffic safety, and attractiveness from a gender-specific perspective. The aim of the research is to identify barriers women face in accessing public transportation and provide actionable insights for urban planning. Expert and public input were gathered to determine the weightage of criteria influencing walkability. Pairwise comparisons through AHP were used to ensure consistent weighting of criteria, while GIS was employed to map and analyze walkability indices. The findings emphasized the need for inclusive urban planning that considers women's unique safety and mobility concerns, offering recommendations for tailored policy interventions. The study demonstrates the effectiveness of GIS and AHP in evaluating walkability, incorporating physical and social dimensions to reflect women's needs in urban environments. Recommendations include integrating real-time data, engaging diverse groups through surveys and focus groups, and expanding the model to other demographic groups. The research highlights the role of enhanced walkability in promoting mobility, increasing public transit use, reducing congestion, and improving public health. Future studies should refine methodologies, incorporate dynamic data, and broaden assessments to ensure equitable and sustainable urban development. This approach underscores the importance of addressing gender-specific needs to create safer, more accessible, and inclusive cities.

1. Introduction

World Health Organization (WHO) adds walkability to be an indicator of how well the design community promotes cycling and walking as alternatives to driving to places like stores, schools, and other destinations. To improve fitness, fight obesity, and support environmental sustainability, several health organizations recommend an increase in community walking activities (WHO, 2023). However, pedestrian fatalities related to road crashes are increasing these days. In US, based on NBC News, the year 2023 recorded the highest number of pedestrian fatalities since 1981, with 7,508 people killed by vehicles, according to a recent report by the Governors Highway Safety Association (Pandey, 2023). Pedestrian deaths have shot up 77% since 2010, according to the report. In addition, about 20 people a day were killed walking in the street. Road safety experts suggested there are several factors behind the trend including pandemic-fueled increase in reckless driving, skyrocketing sales of trucks and larger vehicles and higher rates of people moving to suburbs with roads ill-suited for pedestrians (Pandey, 2023).

The question that often raised is the effect of built environment or the surrounding area in ensuring the road is comfortable and safe for pedestrian (Arshad et al., 2016; Basu et al., 2022). This could be defined as walkability. Walking is a mode of transportation that encourage people to be physically active (Cook et al., 2022; López-Lambas et al., 2021). It is the most typical moderate-intensity activity for adults and has a significant positive impact on health (Schantz et al., 2022) A city's transport sustainability is improved by its walkability in addition to its health benefits. Enhancing active transport options like cycling and walking can help reduce carbon emissions and contribute to a better world (Ahmad & Naharudin, 2022). The term "walkability" describes the degree of comfort a space can offer so that people can walk to their destination, such as a rail transit station (Otsuka et al., 2021). Walkability promotes neighborhood safety, livability, and a reduction in reliance on cars (Ahmad & Naharudin, 2022).

Walkability is important to promote gender equality and enhancing effective public transportation that also depends on the walkability for women to access the services (Bridge, 2025). These days, population of women tend to be more than men in many developing nations. They also are participating in activities outside of their comfy homes to help their family improve their financial situation. There is evidence that said that there are increasing number of women holding executive positions in businesses, working in factories, pursuing higher education, and participating in community events these days (Harumain et al., 2020). Therefore, they need to commute every day to their workplace. Their safety and comfort have been debatable as they are one of the vulnerable groups in a society (Scarponi et al., 2023). The question is, how can the street be safe and walkable for women? Therefore, there is a need to enhance walkability, especially for women in a city (Carpentieri et al., 2023).

Many cities across the globe have guidelines for creating a walkable space for their citizens. Various criteria are included in the guidelines to ensure walkability can be achieved (Gorrini et al., 2021). Accessibility to essential services is one of the important criteria is needed in enhancing walkability. Examples for essential services are toilets, benches and convenience stores. In term of comfort, several pedestrian furniture is needed to enhance walkability especially for women including streetlight and pedestrian bridge. Another criterion is safety and security which is crucial for providing safe environments for women while walking which is regarded as the most important aspect for women's walkability.

There are various methods that could be used to measure walkability including the combination of Analytical Hierarchical Process (AHP) or Analytical Network Process (ANP) and GIS. AHP/ANP method identifies the significance of each land use activity's contribution to walkability (Dasari & Gupta, 2023; Naharudin et al., 2020; Ruslan et al., 2023). The weight of relevance for each component was then calculated using AHP analysis and expert opinion (Dasari & Gupta, 2023; Naharudin et al., 2020; Ruslan et al., 2023). GIS then could be used to measure the walkability (Azlan & Naharudin, 2020). This study attempted to measure the walkability for women to rail-transit stations for Masjid Jamek as it is one of the busiest stations in Kuala Lumpur (KL) (Dzulkifli, 2023). It that has been used by many pedestrians, especially women. The area has a high risk of incidents especially involving women pedestrian. Therefore, the GIS Index Model method was used to study how walkability there can be measured by using GIS. At the end of this study, a map was produced to visualize the walkability that could be used for pedestrian especially women for walking around the station.

Assessing and improving walkability has become priority for cities worldwide as they seek to enhance the quality of life for their residents, promote sustainable transportation, and reduce the environmental impact of car-dependent communities (Bozovic, 2025). One of the most applied methods for assessing walkability is Spatial Multi-Criteria Decision Analysis (Spatial-MCDA) (Malczewski & Rinner, 2015). This GIS-based technique integrates spatial data and decision analysis methods to evaluate complex spatial problems (Elhosni & Faiz, 2021). It is a valuable approach for assessing walkability because it can handle the multifaceted nature of this concept. The concept of walkability is pivotal for creating vibrant, healthy, and sustainable urban environments (Baobeid et al., 2021; Rui & Othengrafen, 2023).

By leveraging the strengths of this systematic approach, Spatial-MCDA provides a powerful way to offer decision-makers a holistic understanding of the urban landscape (Manzolli et al., 2021). By integrating various spatial data, criteria and weights, Spatial-MCDA aids in identifying areas that require attention and helps guide the development of more pedestrian-friendly communities especially women. Given the existing gap and the need for analysis regarding women's access to public transport, this study aims to convey the results of spatial modelling regarding the barriers women face in accessing public transport and provide actionable insights for urban planning.

2. Data and Methods

The methodology used in the research is shown in Figure 1. It started with determining the criteria influencing walkability for women to access the rail-transit station based on review of literature. Then, the data collection for both AHP and GIS part was conducted. The AHP involved conducting experts' interview to obtain Expert's Choice and sample survey to obtain public's preferences by using AHP pairwise comparison method. Next is data processing aiming to calculate AHP weightage and deriving criterion maps that both were used to derive index model for the walkability. The index then was verified by site verification and expert's validation. The final step is creating the map visualizing the walkability index for women to access the rail-transit station.

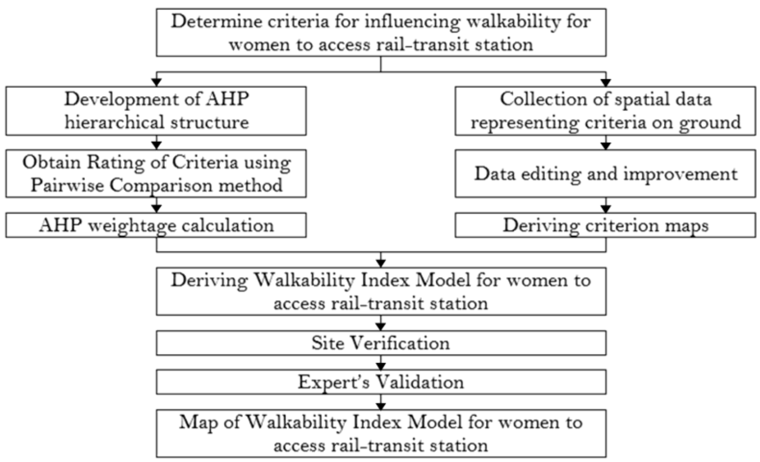

Figure 1. Methodology of the Research

2.1. Method Overview

MCDA techniques include rating, ranking and pairwise comparison (Więckowski et al., 2023). The goal of these methods is to determine the relative importance of the factors affecting the decision-making process. The first technique, ranking, involves placing options in equal groups, starting with the best to worst (Malczewski & Rinner, 2015). Relative weight is allocated to the criteria in the rating procedure. The traits or substitutes hold great importance. For each alternative or choice, the final value can be found by multiplying the weight and value together. In addition, multi attribute utility theories can be easily implemented by using ranking techniques in conjunction with weighted linear averages, which provide a very close approximation to utility functions.

The second technique is the rating technique, which uses a scoring mechanism to quantify weightage and get a more refined conclusion (Malczewski & Rinner, 2015). When it comes to exhibiting harm, some requirements are more crucial than others. In the context of MCDA, greater clarity is needed to establish the weight of the criterion. Swing weighting is a notion that is used to make sure evaluated weights have meaning. Ensuring that the harm units in the various preference scales are equal is the aim of MCDA weightings, which enable the comparison and combining of weighted scores in all dimensions. Weights are essentially scale factors. Likert-scale is one of the rating techniques that may took less time and might potentially reach a larger audience than other techniques like pairwise comparison.

Pairwise comparison is the third technique, where two items are compared to decide which is better or has more quantitative attributes. One of the weighting methods in MCDA is AHP that can be used to resolve complex issues. It depends on expert information in pairs, thus may lead to ambiguity, which could impair the subjective processes of expert comparison cognitively (Malczewski & Rinner, 2015; Saaty, 2004). The decision-making process can be determined through the application of a mathematical model (Saaty, 2004). In a comparative judgement, the choices are compared in terms of smaller, better, more neutral, and less attractive options. The outcomes of these evaluations are displayed on a numerical line. In conjunction, AHP is also a judgement based on comparisons. However, it appears that the impact of the elements that are helpful in the decision-making process is not considered by the first order scaling methods and decision-making strategies.

As mentioned earlier, Spatial-MCDA combines MCDA with GIS analysis. In general, GIS is a method that could be used to capture, analyze and visualize spatial data (Schulze, 2021). It has become an essential asset in assessing and enhancing walkability. It is a technology that combines hardware, software, data, and analysis to manage and utilize spatial information. An innovative tool in the pursuit of walkable cities is GIS (Gaglione et al., 2022; Shields et al., 2023; Telega et al., 2021). It helps with walkability evaluation and improvement in making cities healthier and more livable places. Urban planners and government officials could make decisions that result in a safer, more pedestrian-friendly communities for women by utilizing GIS's capabilities to combine spatial data, perform complex analysis and produce engaging visualizations. GIS is crucial in determining the future of urban living to create cities that put the welfare of their citizens first while minimizing their environmental impact (Naharudin et al., 2020).

Numerous research related to pedestrians have made use of GIS (Azlan & Naharudin, 2020; Naharudin et al., 2020; Syazwany et al., 2024; Oppio et al., 2022; Telega et al., 2021). One of the methods is space syntax that had been used to represent the morphology of building, open spaces and streets (Khotbehsara et al., 2025; Körmeçli, 2023). Space syntax method could help understand the relationship between pedestrian movements and physical space by transforming it into a mathematical model (van Nes & Yamu, 2021). The model evaluates the accessibility of streets in the system by calculating and averaging the changes in direction required to reach from one place to another in urban open spaces. The Space syntax theory and techniques suggest that urban configuration affects human spatial movement patterns in the city, enabling to determine which paths will be used more than others (Atakara & Allahmoradi, 2021). The representation of a connectivity network in space syntax can be used to model the physical configuration of a building or of streets. It tries to investigate how different social, economic, and environmental variables relate to spatial layout and how those things could affect the quality of the services it offers. It had been extensively used to investigate mobility patterns, awareness, and interaction in relation to density, land use and value, urban expansion, societal distinction, safety, and the distribution of crime (Naharudin et al., 2020).

Another method is GIS Index Model which determines each unit area's index value and uses that information to create a ranking map. Both an index model and a binary model rely on overlay operations for data processing and require multicriteria evaluation (Malczewski, 2006). However, an index model generates an index value, not just a yes or no, for every unit area. Selected variables are evaluated at two levels which are relative importance, assigning a weight and observed values are evaluated and given scores (Chang, 2016). The process for calculating the index value is the main factor to consider when creating an index model, whether it is raster- or vector-based. One popular technique for determining the index value is Weighted Linear Combination (WLC) (Malczewski & Rinner, 2015; Saaty, 2004). According to Saaty (2004) AHP and WLC are evaluated at the three levels shown in Figure 2. WLC approach entails evaluation at three levels to construct an index model using the selection criteria. Establish the criterion weights first (Ws for slope, for example). Second, choose the standardized values (s1, s2, and s3 for slope, for example) for each criterion. Third, determine each unit area's index (aggregate) value.

Firstly, each criterion or factor's relative importance is assessed in comparison to other criteria. Expert-derived paired comparison has been employed in numerous research as an evaluation method for criteria (Saaty, 2004). With this approach, ratio estimations are made for every pair of criteria. For example, three is recorded

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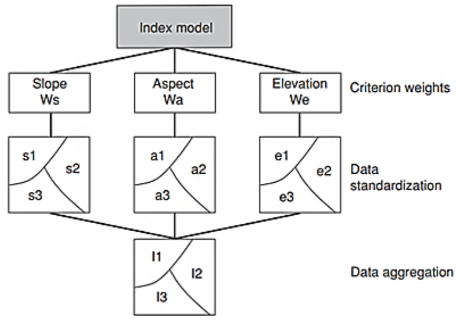
for A/B and one-third is recorded for B/A if criterion A is three times more relevant than criterion B. The paired comparison approach determines a weight for each criterion by taking as its input a criterion matrix consisting of ratio estimates and their reciprocals. The total of the criterion weights, which are stated as percentages, is equal to 100% or 1.0. Commercial software packages (such as Expert Choice and TOPSIS) offer paired comparison.



Source: Chang, 2016

Figure 2. Example of WLC Involves Evaluation at Three Levels

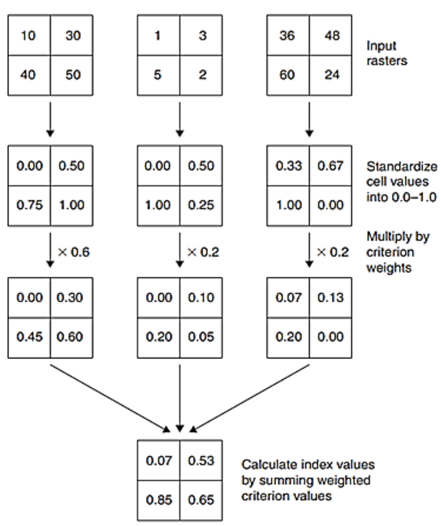
Secondly, every criterion's data is standardized. Linear transformation is a widely used technique for data standardization. For instance, interval or ratio data can be transformed into a standardized scale of 0.0 to 1.0 using the formula in Equation 1.

$$Si = \frac{(X_i - X_{min})}{X_{max} - X_{min}} \text{.................. (Equation 1)}$$

where X_{min} is the lowest original value and X_{max} is the highest original value, and S_i is the standardized value for the original value X_i. Equation 1 cannot be used to original data that are ordinal or nominal in nature. In those circumstances, the data can be transformed into a standardized range, like 0–1, 1–5, or 0–100, using a ranking process based on experience and knowledge. Thirdly, the weighted criteria values are added together and divided by the total weights to determine the index value for each unit area (see Equation 2):

$$I = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \text{.................. (Equation 2)}$$

where n is the number of criteria, I is the index value, w_i is the weight for criterion i, and x_i is the criterion i standardized value.



Source: Chang, 2016

Figure 3. Raster-Based Index Model

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The process for creating a raster-based index model is depicted in Figure 3. Building an index model in a GIS by using the WLC approach is not difficult, provided that the criteria weighting and data standardization are well established. However, there is a need to thoroughly record criterion weights and standardized values. The WLC method has a lot of options. These options primarily address the problems of data aggregation, data standardization, criteria weights, and factor independence. To build a raster-based index model, first, each input raster must have values with a standard range of 0.0 to 1.0. Second, the weight of each criterion will be multiplied by each input raster. Lastly, the weighted criteria values will be summed to determine the index values in the output raster. For example, the index value in the Figure 3 is 0.85 based on calculation of: 0.45 + 0.20 + 0.20.

2.2. Study Area

The research area (see Figure 4) concentrated on the area around the Masjid Jamek LRT Station, located in center of Kuala Lumpur city center, Malaysia. This location was chosen based on the station's significance as a major transit hub in the Kuala Lumpur rail transport network. This station is an significant interchange station linking the Kelana Jaya LRT Line with the Ampang and Sri Petaling LRT Lines.

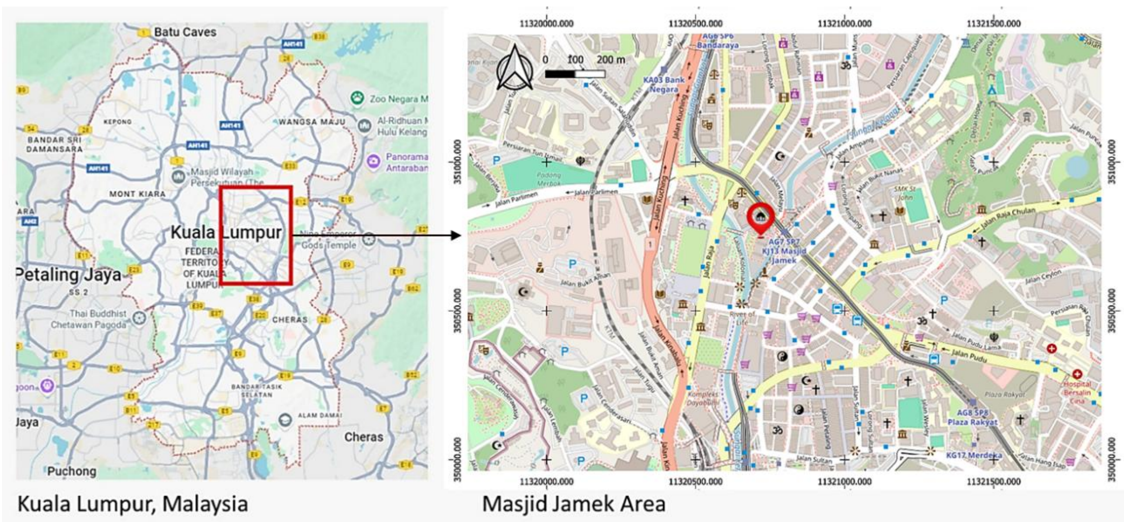

Figure 4. Study Area

Geographically, the area around Masjid Jamek Station is bordered by dense business districts, historic structures, and considerable economic activity. These characteristics make pedestrian traffic in this area very complex. Focusing research on female pedestrians in this location is crucial, given that traffic density and urban infrastructure conditions in the city center often present different safety and accessibility challenges for women compared to men. The study area was defined using a specific radius (buffer) from the station to analyze the extent to which walking accessibility is influenced by the surrounding built environment.

2.3. Determine Criteria

The first step is to identify the criteria through literature review that also assisted in explaining a particular issue and the methodology used in the measurement of walkability study. To quantify walkability in this study, it was necessary to establish the walkability criteria. However, based on literature, there were not many studies focusing on women's walkability (Golan et al., 2019), although there were many studies that had been conducted to measure walkability (Azlan & Naharudin, 2020; Körmeçli, 2023; Naharudin et al., 2020). Therefore, it was quite challenging to come up with the criteria that could be used.

The literature review in this study offered insight into previous research, from which the study's problems were discovered. Numerous research studies on walkability had been conducted. This study was conducted using a review of the literature from journals, articles, websites, and books, with references from those studies. The criteria used in this study is described in Table 1 which also had been validated by expert. The method used to validate the criteria is by interview.

Table 1. Criteria Influencing Walkability for Women to Access Rail-Transit Station

No.	Criteria	Sub-Criteria
1.	Accessibility	Commercial
		Residential
		Educational Institution
		Public Parks
		Transportation Stops
2.	Comfort	Sidewalks
		Open Spaces/Green Areas
		Street Lamps
3.	Traffic Safety	Guard-rail
		Overpass
		Crosswalks
		Traffic Lights
4.	Attractiveness	F&B Shops
		Vending Machine

2.4. *Data Collection*

The next stage is data collection. In this study, there were two (2) types of data that needed to be acquired, which were spatial data and rating of criteria since this study would use the Spatial-MCDA method. The spatial data collection in this study involved collecting data for Land Use, Roads, Sidewalks, Locations of Rail-Transit Stations, F&B Shops, Open Spaces/Green Areas, Street Lamps, Guard-rails, Overpasses, Crosswalks, Traffic Lights, and Vending Machines. Once the preliminary study was finished, the spatial data to represent the criteria and sub-criteria on the ground were determined. These data could be gathered from both primary and secondary data sources.

Since this study combined MCDA with GIS to measure walkability for women, the rating of the criteria and their sub-criteria were needed for their weightage that would be used in GIS analysis. In this study, the criteria rating was obtained from the public and experts by using the pairwise comparison technique, since AHP was a part of the pairwise comparison technique. There were four (4) steps involved in obtaining the rating, which were (i) identifying criteria and their sub-criteria (Table 1), (ii) developing a hierarchical structure (Figure 5), (iii) determining interest groups, and (iv) obtaining criteria rating and sub-criteria.

Based on the hierarchical structure as shown in Figure 5, the pairwise comparisons for the criteria and sub-criteria were conducted. To add a scale rating by Saaty (2004) and provide a pairwise comparison example, the Saaty Scale, which was commonly used in the Analytic Hierarchy Process (AHP), was used. The Saaty Scale assigned numerical values to express the strength of preference between two elements. The scale ranged from 1 to 9, with 1 representing equal importance and 9 indicating extremely strong preference. This approach provided a structured way to integrate both expert opinions and public preferences in decision-making processes. AHP provided a systematic way to handle the complexity of hierarchical decision-making. It ensured that the opinions of both experts and the public were considered and weighted appropriately, leading to more robust and well-informed decisions.

Once the hierarchical structure had been developed, the interest groups to participate in the decision analysis needed to be determined. This study used both the public and experts to provide their ratings on the criteria and sub-criteria. This was to ensure that the decision on the walkability for women later would be as representative as possible. A total of five (5) experts involved in the experts' choice who are from the officers from city council, government agency responsible for road safety, transport consultant, representative from non-government organization related to women and academician. They are all selected due to their expertise in the field which believed to be valuable and could provide comprehensive view on walkability for women. In addition, fifty (50) women using rail-transit station at Masjid Jamek station involved to provide public's preferences. The sample size is sufficient considering the study focus on one station only and on women only.

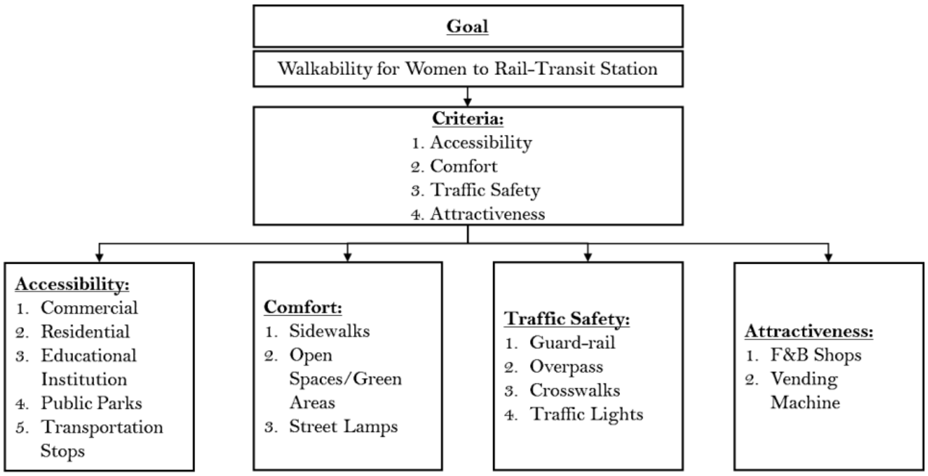

Figure 5. Hierarchical Structure

2.5. Data Processing

The next stage is processing the data. First, the weightage of each criterion and sub criteria were calculated. The ratings that had been obtained during the pairwise comparison technique was used in calculating the weightage of each criterion and their sub criteria. The ratings were first translated into an unweighted matrix. Then, they were used to calculate the weightage using Equation 3. The weightages were then normalized by using Equation 4. Hence, the weightage of criteria can be calculated by using Equation 5.

$$C_w = \lambda_{max} w \quad \text{.................. (Equation 3)}$$

$$c *_{kp} = \frac{c_{kp}}{\sum_{k=1}^{n} c_{kp}} \text{, for all } k = 1, 2, \ldots n \text{.................. (Equation 4)}$$

$$w_k = \frac{\sum_{k=1}^{n} c_{kp}}{n} \text{, for all } k = 1, 2, \ldots n \text{ .... (Equation 5)}$$

The weightage of sub criteria could be calculated using the same equations. However, they only gave weightage of sub criteria in the cluster (among its main criteria). In MCDA, their degree of importance, also known as overall priorities, among all sub criteria was what mattered to solve a spatial problem. Thus, the overall priorities of sub criteria were calculated using Equation 6.

$$V(A_i) = \sum_{k=1}^{n} w_1 w_{k(1)} v(a_{ik}) \quad \text{.................. (Equation 6)}$$

where $V(A_i)$ is a value function, w_1 is a weight of criteria associated to sub criteria, and $w_{k(1)}$ is weight of sub criteria of criteria.

This information could be used in the overall assessment and decision-making process. It was important to note that the pairwise comparison process and the Saaty (2004) Scale helped quantify subjective judgments, providing a structured way to analyze and prioritize criteria based on their relative importance in the context of the decision problem. The results of the AHP survey were sorted, and then they were thoroughly examined. This was to determine whether there was a mistake made when completing the survey. Based on the ratings provided, the respondents' answers were reviewed for consistency. The response would be rejected if it was inconsistent.

To gather the spatial data that represented walkability criteria in a single database, it was crucial to establish a criterion map. In this study, each of the sub criteria had their own criterion map representing them geographically, which would later be used in the index model to derive the walkability index. Since the spatial data representing them on the ground collected from primary and secondary data sources were in vector (discrete) format, they needed to be rasterized.

The reason was that the index model used in this study was a raster-based model; thus, the data to be fed to the model had to be in a raster format. Therefore, in this study, Euclidean Distance was used to rasterize the data as the proximity to each of the sub criteria was generated. The distance ranges in each of the raster of the dataset were then reclassified to standard classes from 1 to 9, representing the same AHP scales. The reclassified raster was called a criterion map.

2.6. Deriving Walkability Index Model

The fourth stage is the process of deriving the walkability index model combined the overall priorities of sub criteria found using AHP with their criterion map in Weighted Overlay Analysis. Each of the criterion maps was assigned a weightage in percentage value, which was the overall priority. The scale value for the classes in the criterion map was also specified to indicate the scale value each class would get from the overall priority. Once the process of assigning the weightage to the criterion map was completed, the walkability index model was derived. The output of this process was a continuous surface of the study area where each cell had its own index value scaling from 1 to 9, from the lowest to highest walkability index.

The fifth stage is Analysis where every area in the research had its Walkability Index examined. There was an identification of the high and low index areas. The presence and weightage of criteria such as safety and security, accessibility to essential services, and comfort of infrastructure significantly influenced the walkability of an area. Walkability referred to the extent to which an environment was conducive to walking, and it played a crucial role in promoting physical activity, health, and community engagement.

The results were then verified by site verification. This involved physically visiting sites with both high and low walkability indices to observe, experience, and analyze the factors contributing to the overall walking environment. In addition to personal site visits, the analysis incorporated expert verification to ensure a comprehensive and objective assessment of walkability. Site verification, combined with expert assessments, formed a robust methodology for evaluating walkability. The firsthand experience gained from walking along roads with varying walkability indices, supplemented by the expertise of urban planners and safety specialists, ensured a comprehensive analysis. This multifaceted approach contributed to the development of informed recommendations for enhancing walkability in urban environments.

2.7. Creating Map Visualizing Walkability Index

The final stage is visualization. The map of walkability for women to the rail transit station was created. In this map, the safety and walkability index were then displayed as a map throughout this phase. Considering this, women pedestrians could utilize the safety and walkability index map as a guide to select their preferred walking path to go to the rail transit station and ultimately their destination. Following normalization, each road had a unique safety index. A safe route plan specifically designed for women pedestrians was created using this safety index. Green was the safest path, yellow was moderate, and red was the least safe. The final map was created to show where women pedestrians may walk to go to a rail transit station.

The visualization aspect of the study, focusing on creating a map of walkability for women to access rail transit stations. The map displays the safety and walkability index, allowing women pedestrians to choose safer routes to their destinations. The use of color-coded paths (green for safest, yellow for moderate, and red for least safe) helps in identifying the level of safety along different routes. This visualization approach not only assists women pedestrians in route selection but also provides valuable data that can be shared with local authorities to improve safety measures around transit stations.

3. Result and Discussion

The analysis began by determining the importance of each walkability criterion through the Analytical Hierarchy Process (AHP). This process involved synthesizing opinions from both experts and the public to ensure a balanced perspective on women's needs. The final calculated weights, which represent the priority of each factor, are summarized in Table 2.

Table 2. AHP Weightage

Criteria	Sub Criteria	AHP Weights (Experts)	AHP Weights (Publics)
Accessibility		**0.14**	**0.24**
	Commercial	0.02	0.12
	Residential	0.02	0.06
	Educational Institution	0.02	0.03
	Public Parks	0.02	0.02
	Transportation Stops	0.04	0.00
Comfort		**0.20**	**0.25**
	Sidewalk	0.11	0.17
	Open Spaces/Green Areas	0.04	0.05
	Street Lamps	0.05	0.01
Traffic Safety		**0.43**	**0.25**
	Guard Rail	0.03	0.14
	Overpass	0.10	0.06
	Crosswalk	0.16	0.03
	Traffic Light	0.12	0.01
Attractiveness		**0.22**	**0.25**
	F&B Shops	0.16	0.21
	Vending Machine	0.06	0.01

Based on the derived AHP weightage, there is slight differences in expert and public perspectives on the criteria which is as expected as public represent the end-users' group while the experts represent the policy-maker, planner or developer. For Accessibility, public assigns a higher priority (0.24) as compared to experts (0.14), reflecting the importance of reaching key destinations such as residential areas, commercial zones, and educational institutions. This reflects the increased necessity for women to commute securely to diverse urban activities (Harumain et al., 2020). Women may prioritize accessibility because they frequently travel for work, shopping, and childcare, making proximity to essential locations crucial. In contrast, experts emphasize transportation stops (0.041) more than the public (0.00), likely considering transit efficiency and network connectivity. This suggests that while planners focus on infrastructure, women value convenience in their daily commutes. To enhance accessibility, integrating pedestrian-friendly pathways and ensuring well-connected mixed-use areas can significantly improve walkability.

Comfort is another factor where the public (0.25) places greater importance than experts (0.20). Sidewalks receive the highest public priority (0.17 vs. 0.11 for experts), reinforcing the need for wide, well-maintained pedestrian pathways that accommodate women, including those pushing strollers or carrying shopping bags. However, street lamps are given much lower weight by the public (0.01) than experts (0.05). This might be due to people commute around Masjid Jamek on daytime to go to their workplace, thus not needing street lamps which is useful during night. However, given that well-lit streets reduce the risk of harassment and accidents may be the reason urban planners emphasize their importance. Additionally, incorporating green spaces and rest areas can further improve walkability by making the journey more comfortable and appealing.

Experts rank Traffic Safety as the most critical factor (0.43), while the public assigns it a lower weight (0.25). Within this category, crosswalks (0.16 for experts vs. 0.03 for the public) and traffic lights (0.12 vs. 0.01) receive significantly more expert emphasis. This indicates that planners prioritize reducing pedestrian risk through infrastructure, while the public may not fully acknowledge the dangers of unsafe crossings. Additionally, the public assigns a higher priority to guard rails (0.14 vs. 0.05 for experts), suggesting that women might be more concerned about physical barriers separating pedestrians from traffic. These findings highlight the need for pedestrian safety campaigns, better-designed crosswalks with visible signals, and barrier installations to protect vulnerable road users.

Both experts (0.22) and the public (0.25) consider Attractiveness important, but women place more emphasis on F&B shops (0.21 vs. 0.16 for experts). This suggests that accessible food and beverage options contribute to a more comfortable and appealing pedestrian environment. Vending machines, however, receive much lower public priority (0.01 vs. 0.06 for experts), indicating a preference for full-service amenities rather than automated options. Walkability improvements should therefore focus on creating vibrant, engaging public spaces with accessible services that encourage foot traffic.

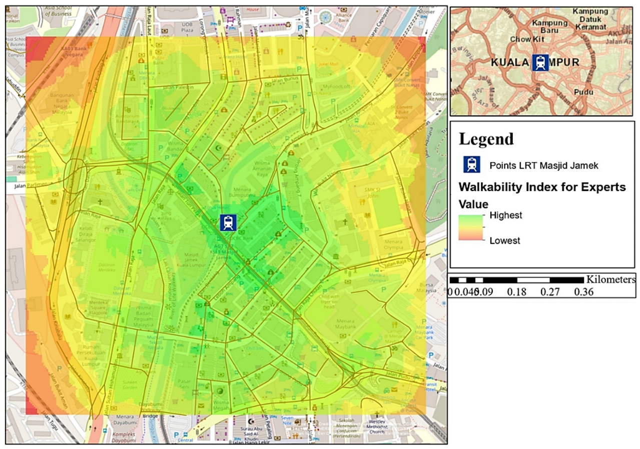

Figure 6. Walkability Index for Women around Masjid Jamek Station based on Experts Choice

Overall, the findings indicate that both the public and experts consider Traffic Safety to be the most important criterion for enhancing walkability. However, there are slight differences in the perspectives of the two groups. First, the experts chose Attractiveness to be the second most important criterion, reflecting their view that appealing environment may contribute significantly to pedestrian satisfaction and walkability. The public on the other hand placed Comfort in the second position, emphasizing the necessity for convenient and comfortable spaces for encouraging walking. This emphasizes that safety and security are crucial for providing safe environments for women, as they are often regarded as a vulnerable group in society (Gorrini et al., 2021; Scarponi et al., 2023). In addition, while the experts assigned the lowest weightage to Accessibility, the public rated it more highly, suggesting greater emphasis on ease of movement and connectivity from their perspective. These differences underscore the varying priorities of stakeholders, with experts focusing more on policy and design factors, and the public placing greater importance on practicality, safety, and overall experience. Nevertheless, both perspectives collectively highlight the importance of developing a pedestrian environment that effectively responds to the needs of all users (Carpentieri et al., 2023).

Based on the weightage derived, two (2) index model for walkability were developed, both representing different perspective from expert's choice and public's preferences. Figure 6 and Figure 7 show the map of walkability index for women around Masjid Jamek rail-transit station. The index was visualized by using shade of red to green signifying lowest to highest walkability index value. Results show that area that is within 200m from the stations has the highest walkability index based on experts' perspective whereas it is within 400m for the public's preferences. However, within 400m, both perspectives have above average walkability index value. The slight difference in the walkability index derived using both perspective is influenced by the weightage of the criteria as discussed earlier. In addition, the index value also decreases as the distance from the station increases. This signifies that the area around Masjid Jamek Station do has a good walkability index for women. This efficiency in walking access is vital for enhancing public transportation services for women (Bridge, 2025). As Masjid Jamek being one of the busiest rail-transit station in KL, with it having a good walking environment, it could enhance the efficiency and overall level of services of the system (Azlan & Naharudin, 2020).

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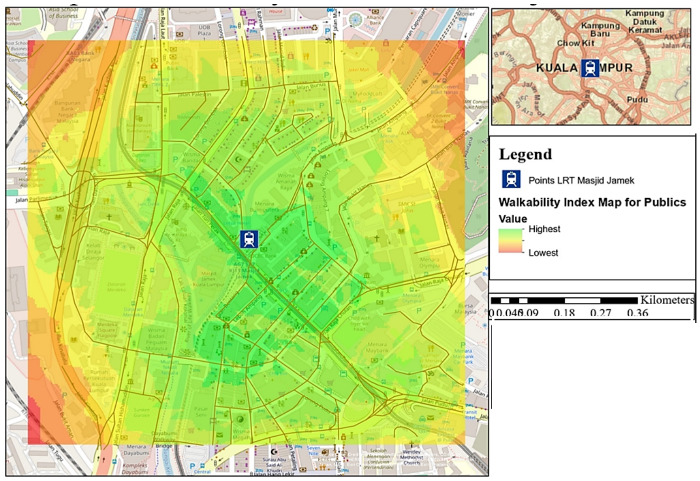

Figure 7. Walkability Index for Women around Masjid Jamek Station based on Public's Preferences

In assessing the value index of the study area using the Saaty scale, variations can emerge due to sub criteria. The following subsections will explain the factors influencing the high walkability index based on perspective of experts and public. Figure 8 shows example of area with high index. As shown in the figure, it can be seen that the area is surrounded by many sub criteria such as crosswalk (17), while the lowest value are residential (2) and public parks (2). Next, for the results that is based on the publics perspective, the index that have the highest value is F&B Shops (21), while the lowest value is transportation stops (1), street lamps (1) and traffic lights (1). Based on experts' perspective, the area in the red boxes not only depends on one sub criteria which is crosswalk (17) but also supported with several sub criteria which are F&B Shops (16), traffic light (13), vending machine (12) and overpass (10).

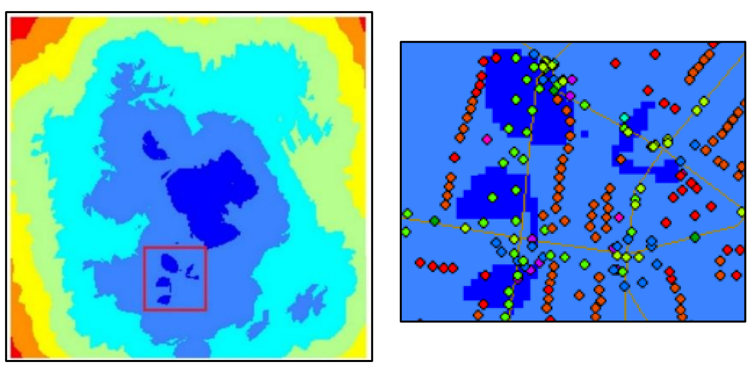

Figure 8. Factors Influencing High Walkability Index

In summary, the integration of AHP and GIS reveals that while experts and the public have slight priority differences, both agree that traffic safety is the most critical factor for women's mobility (Gorrini et al., 2021; Scarponi et al., 2023). The findings underscore that walkability must encompass comfort and access to essential services (Bridge, 2025; Harumain et al., 2020). Although the area within a 200m–400m radius shows a high walkability index, expansion is necessary to enhance overall system efficiency (Azlan & Naharudin, 2020). By addressing these gender-specific needs, urban planners can create more inclusive and secure pedestrian networks for women in Kuala Lumpur (Carpentieri et al., 2023).

4. Conclusion

The application of GIS Index Modelling combined with the AHP has proven to be an effective method for measuring walkability for women accessing rail transit stations. This integrated approach allows for a comprehensive evaluation by considering multiple criteria that influence walkability, such as safety, accessibility, convenience, and environmental quality. By employing GIS, spatial data can be efficiently managed and analyzed, providing detailed insights into the geographic distribution of walkability factors. The use of AHP further enhances this process by offering a structured framework to prioritize these factors based on their relative importance as determined by expert judgment and user preferences.

The study demonstrated that walkability for women is a multi-faceted issue that requires addressing various physical and social dimensions. Factors such as well-lit paths, safe crossings, the presence of surveillance, and the condition of sidewalks are critical. The AHP method enables these factors to be weighted appropriately, reflecting the unique needs and concerns of women in urban settings. The results indicate significant variations in walkability scores across different areas, highlighting specific regions where improvements are necessary to ensure safe and accessible routes for women.

These findings can guide urban planners and policymakers in designing interventions that enhance walkability, promote public transit usage, and ultimately contribute to more inclusive and sustainable urban environments. For future studies, more criteria could be added to enhance the model such as location of main attractions or point of interests in the city and access to other mode of transportation that could support urban mobility.

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