

# A User Perception-Based Prioritization of Determinants of Walkability of Pedestrian Infrastructure Based on Multi-attribute Decision Making (MADM) Approach: An Indian Experience



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**Abstract** To plan the pedestrian infrastructure facilities, it is imperative to understand the pedestrian perception towards key critical attributes influencing sidewalk and crosswalk. However, a review of existing research literature suggests that evaluation of walkability of pedestrian infrastructure remain unexplored in a typical Indian setting. This paper addresses this research gap with respect to pedestrian infrastructure evaluation in Hyderabad, the capital of Telangana, a premier IT hub and a focal point for educational institutions, where a significant proportion of population uses walking for their daily commute needs. This paper demonstrates a user perception-based approach, proposed to identify and analyse the important factors of the urban environment that support or detract pedestrians from walking. In this study, initially, a brief literature review is taken up to identify a key set of parameters influencing the walkability of pedestrian infrastructure in typically Indian context. Then, user perceptions on these attributes are collected in a suitable five-point Likert scale. The collected data are then analysed based on grey relational analysis (GRA), a suitable multi-attribute decision making (MADM) technique to identify and prioritize the most important variables related to pedestrian walkability. Results indicate that safety and security are perceived as the most important parameters influencing pedestrian walkability.

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## 1 Background and Objective

India being one of largest democracies in the world is fast moving towards its vision of being one of the leading economic powers. This has led to an accelerated urbanization. Rapid urbanization of Indian cities has resulted in an increase in the population influx. This increase in the urban population has emanated an increased need for mobility adding to an increased vehicular ownership and alarming growth of traffic on roads. Elevated levels of traffic on roads have contributed to severe traffic congestion on roads and rise in levels of pollution. Automobiles has made commute easier and comfortable for the people but also has made people vulnerable to high toxic levels of emissions from the combustion of fuels in automobiles. However, to deal with the heavy traffic congestion, often the focus has been on expanding the roads and constructing overpasses rather than trying to curb the traffic on roads and improving the sustainable modes of transportation. In regard to the major concerns of increasing traffic and levels of pollution, it is imperative that we promote walking as a prepared mode of transport at least for shorter distances and public transport for longer distances to address these issues to a certain extent. With a country like India, which seems to be bursting at seams in regards to its population, shrinking spaces and mixed land use, it is viable that we encourage walking which could considerably reduce the number of trips being performed by the automobiles.

Walking is one of the basic and sustainable modes of transport. Everyone uses walking in their daily commute to varying extents. However, the comfort and ease of travel offered by motorized mode of transport has made people to rely upon these modes even for a shorter distance travel adding to traffic congestion and pollution. Moreover, pedestrians are the most vulnerable road users who are at greater risk of being prone to accidents. Despite considerable number of trips being performed by foot, there is no adequate pedestrian infrastructure in the country. Often the design of roadways is based on managing the vehicular traffic with very little to no emphasis on the pedestrian facilities. The roads are expanded to deal with the increasing levels of traffic at the cost of pedestrians. The lack of proper pedestrian infrastructure has forced the pedestrian to use the road space intended for vehicles which not only disrupts the traffic but also compromises their safety putting them at higher risk of being involved in accident. This issue has to be addressed by proper design of pedestrian facilities thereby encouraging more people to walk.

In this background, this study assesses the walkability of pedestrian infrastructure in India, by examining the various factors influencing pedestrian's perception to walk. The objective of this study is (1) to conduct a detailed review of pedestrian walkability to understand the gaps in the existing literature and propose appropriate method. (2) To identify the factors influencing the walkability. (3) To prioritize the factors using MADM technique. Findings and inferences from this study would provide necessary

inputs to urban planners. In the following section, a brief review of existing literature is presented for identification of suitable research gaps and demonstration of a suitable methodology.

## 2 Literature Review

A range of methodologies including quantitative as well as qualitative methods have been existing so far. For improved understanding of the research problem, a brief review of existing literature is conducted. In the following section, a summary of previous researches is briefly presented.

A study by Florian Gräßle and Tobias Kretz (210) focused at the understanding the route choice of pedestrian. An observation was made on how the pedestrians would choose the route when they were presented with two similar alternative routes. The study inferred that the pedestrians choose geometry over the shortest path. The pedestrians refrained from using the shortest path giving importance to the geometry. Most of the pedestrian preferred to walk along the long path with paved walk way than walking over the shortest grassy terrain. However, this behaviour of pedestrians is ambiguous and it has been inferred that the route choice of pedestrians varies with the varying situations like flow on the routes, consideration for time etc.

In a study by Kelly et al. (2011) three methods were used to evaluate the walkability of the pedestrian infrastructure and a comparison was made. Stated preference (SP) survey, on-street survey and mobile method were the three methods used for the evaluation of the pedestrian environment. A household survey has been conducted using 47 attributes as checklist to determine how important they are in influencing the walkability of pedestrians. From the survey, the most significant set of nine attributes were identified. These attributes include the speed of the traffic, volume of the traffic, illumination of the streets, width, evenness and cleanliness of the pavement, cyclists on the pavement, detours and road crossings. Around 100 respondents were selected and they are presented with a hypothetical scenario. The respondents were asked to select their preferred route based on the prevailing pedestrian conditions with regard to the nine-identified factors. Using a tool developed in Excel, the given route is evaluated and utility scores were calculated. The study inferred that traffic volume was most detrimental to the pedestrian with cleanliness of the footpath being second most attribute to be deterring the pedestrians. In the on-street survey method, a paper questionnaire was designed to evaluate the user perception towards the 21 attributes identified from literature survey. The results indicated that ease of crossing the road and provision of litter bins and traffic volume were the worst-scored factors.

Another relevant study by Ariffin and Zahari (2013) aimed to assess the factors that would promote walking through the evaluation of people's perception towards identified factors. A survey was conducted to evaluate the user perception towards the attributes influencing their walking. Pedestrian concern with regard to existing pedestrian conditions on the roads was found out by walkability audit. A majority of respondents were found to be stating "places being far away" was the main factors

detering them from walking. Crime issue was addressed to be the next most important attribute preventing the pedestrians from walking more often. Volume and speed of cars, travel with small children were found to be having more or less equal impact in affecting the pedestrian's walkability. Presence of sidewalk and the condition of the sidewalk were found to be having very less influence on pedestrians. Very few pedestrians identified the street light and presence of curb ramps to be that factors preventing them from walking often.

A very interesting study by Cubukcu et al. (2014) developed walkability maps for an area. This study aimed to evaluate the walkability using geographic information systems (GIS). The study which was conducted in the districts of Turkey. The data of 6500 road segments corresponding to nine districts were evaluated. The land use data were digitalized using GIS and analysed using spatial design network analysis. The parameters influencing the walkability were identified and classified into seven categories, namely land use, accessibility, safety from traffic, crime safety, comfort for walking and cycling and environment aesthetics. Walk score a measure of walkability is evaluated by network design and accessibility to amenities. Network designed was analysed based on two scores, namely centrality and betweenness scores. Evaluation of access to amenities is done by network analysis. The walkability maps were developed from the walkability score evaluated.

In their study Zainol et al (2014) evaluated the pedestrian satisfaction towards the facilities available in the study area. The study was based in the Melaka historical city centre. A survey questionnaire was developed to evaluate the user perception towards the attributes on a 9-point Likert scale. The attributes in the survey corresponded to the pathway, aesthetic and amenities, signage and street furniture, personal safety and separation from the traffic flow. The analysis and evaluation of road segments in the study area were done using analytical hierarchy process.

A review study by Kadali and Vedagiri (2016) identified the various factors in influencing the pedestrians level of service pertaining to sidewalk, cross walk at intersection and midblock cross walk. Few studies have developed qualitative method considering the factors like safety, security, continuity, comfort and convenience. Various parameters like surface quality, pedestrian volume and obstructions have been used for the assessment of level of service (LOS) offered by the pedestrian facilities in some of the studies. In few studies, the main focus has been on the safety considered by the adjacency to traffic flow and level of segregation from the traffic. Most of the studies existing have been based on user perception. In regard to crosswalk, signal control, delay at intersections, turning manoeuvres, vehicle stop line behaviour and pedestrian vehicle interactions were identified to be the most significant attributes. From the studies, it has been inferred that the midblock cross is more dangerous than crosswalk despite the absence of turning traffic. Studies have also proved that midblock crosswalk is likely account for more number of accidents or the vehicle pedestrian conflicts.

From the literature review, it can be inferred that there has been very limited existing research work on pedestrian infrastructure in the country. The user perception-based evaluation and prioritization of attributes would help in developing

**Table 1** List of identified attributes

Attributes relevant to sidewalk and crosswalk	Attributes relevant to crosswalk
Presence of sidewalk facility	Traffic speed
Safety from traffic	Traffic volume
Foot path geometry	Presence of crossing facilities
Footpath cleanliness	Complex turning movements of traffic
Aesthetics and amenities	Signal control
Street lighting	Pedestrian vehicle interactions at intersection
Safety and security	Intersection geometry
Other pedestrian characteristics	Pedestrian holding space near junction
Weather condition	Pedestrian delay at intersections
Pollution	Vehicle stop line behaviour at junction

a pedestrian friendly environment. Table 1 lists the most significant attributes identified from literature review. The attributes are further divided into two groups, namely attributes relevant to sidewalk and crosswalk both and specific to crosswalk only.

### 3 Methodology

#### 3.1 Area of Study

This study attempts to understand the pedestrian’s perception towards the factors influencing their level of walkability with regard to the prevailing pedestrian facilities in the city of Hyderabad, the capital of Telangana. Hyderabad, being the capital city, has an interesting mix of population. Not only does it attract many tourists but also draws a lot of trade. It being a premier IT hub and a focal point for educational institutions and coaching centres, it will be safe to say that significant proportion of population uses walking in their daily commute. Despite the considerable amount journey made by foot, there are no proper pedestrian facilities in the city. Most of the existing footpaths are encroached by vendors or obstructed by poles or the vehicles being parked on the sidewalks, which forces the people to use the road space which is laden with high volumes of traffic. An on-street survey of pedestrians is conducted in the pedestrian crowded areas to understand user perception towards various parameters affecting the walkability of pedestrians.

### **3.2 Data Collection**

Initially, a set of most significant factors with regard to typical Indian context were identified from the list of factors obtained from a detailed literature review. The data collection is based on a typical travel behaviour survey questionnaire. A survey questionnaire was designed to evaluate the user's perception towards each of the identified attributes. The responses were collected on suitable five-point Likert scale. Users were provided with five levels of criteria for each of the attribute, namely very less important (-2), less important (-1), neutral (0) important (+1) and very important (+2). Around 120 responses were collected through on-street and off-street survey, out of which eight responses were removed from the data due to incomplete information and the remaining 112 responses were used for the development of data base and further analysis.

## **4 Analysis**

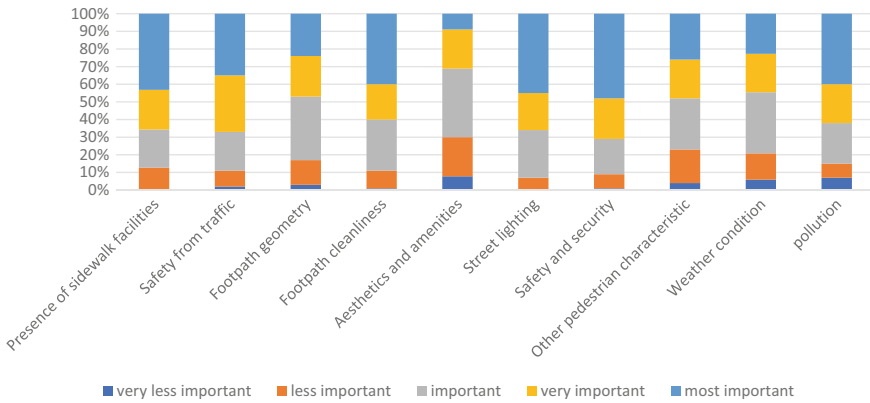
### **4.1 Preliminary Analysis**

This section presents the results of a preliminary analysis of the responses recorded from the respondents. Out of the total respondents, males constitute 53% and females constitute 47% with majority of them being in the age group between 20 and 35 years. From the analysis, it can be inferred that 65% of the people walk every day. The respondents were majorly found to be walking to school or work followed by walking for recreation. The details of descriptive analysis were presented in Table 2.

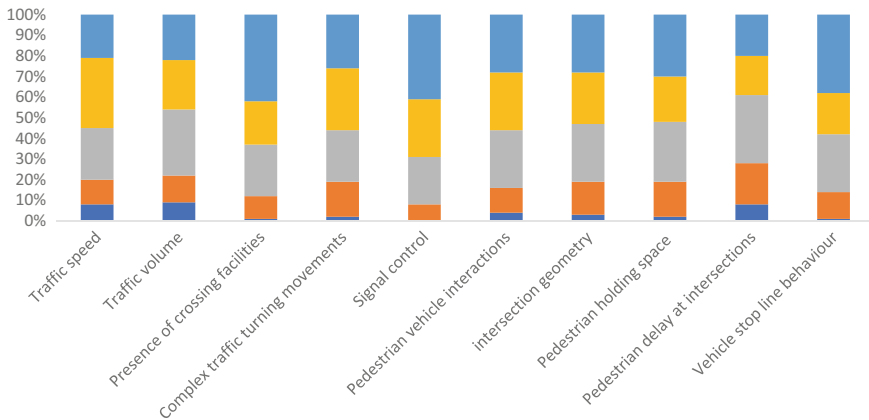
The following charts represent (Figs. 1 and 2) the percentage of respondents corresponding to various levels of importance given to the attributes. A considerable amount of strong or moderate agreement (strongly agree or agree) on an attribute indicates that the particular attribute is perceived to be strongly or moderately influencing (motivating/deterring) pedestrian's walkability. For example, 48% and 23% of the pedestrians have provided very strong and strong agreement with the attribute safety and security. This observation clearly indicates that improper safety and security from the crimes are the most deterring factors as perceived by pedestrians. Secondly, safety from traffic has been perceived by majority of the respondents as the factor deterring the pedestrians from walking. In specific to cross walk, the pedestrians perceived signal control as very important. On the otherhand, it can be noticed that aesthetics and amenities were considered to be less important based on user's perception. In regard to cross walk, pedestrians perceived the delay caused in waiting to cross a road to be very less important.

**Table 2** Preliminary analysis of data

Socio-economic classification	Groups	% of respondents
Age	<20	19
	20–35	57
	35–55	20
	>55	4
Gender	Male	53
	Female	47
Frequency of walking	Once in a week	6
	2–3 times in a week	12
	Sometimes in a week	17
	Everyday	65
Purpose of walking	Walking to school/work	54
	Walking to transport	19
	Walking to run errands	9
	Walking for recreation	18



**Fig. 1** Percentage of level of importance given to various sidewalk attribute



**Fig. 2** Percentage of level of satisfaction given to various crosswalk attributes

## 4.2 *Prioritization of Factors Influencing Pedestrian's Walkability Based on MADM Techniques*

Deng proposed grey relational analysis to investigate a distribution-free discrete data series based on Likert-type scale. GRA combines a range of scores associated with different factors into a single factor and reduces the dimension of the original problem. A number of previous studies used GRA for solving MADM problems. In his paper, Wu (2007) argued that the justifiability of traditional techniques of statistical analysis is based on assumptions made with regard to the distribution of population and variances of samples. The lesser size of sample generally affects the accuracy and solidity of the results produced by such techniques. As Wu (2007) suggested that in some of the real-life situations, making decisions under uncertainty and with insufficient or limited data available for analysis are actually essential. In this regard, J. Deng proposed the grey system theory in 1974. In various fields, for the analysis of data, grey systems theory has been widely applied. The grey relational analysis is an effective approach for data analysed on a Likert scale which analyses the discrete data series using grey system's theory. This technique is especially useful for small or limited data availability. For Likert-type data analysis, GRA is one of the widely adopted approaches. However, as a further extension of this research, a Fuzzy-GRA application would be ideal.

## 4.3 *Theoretical Background of Grey Relational Analysis*

Deng proposed the grey systems theory in 1974 to enhance the decision making under incomplete and uncertain information available. The term grey in grey relational analysis stands for poor, representing insufficient and uncertain information



available. Grey relational analysis (GRA), a subset of the grey systems theory is used for the evaluation of discrete data. Using GRA, the relative importance of an attribute over other attributes can be evaluated. The process of grey relational analysis is discussed in detailed below.

**Step-1:** Generate reference data series  $x_0$

In the above expression,  $m$  is the number of respondents. In general, the  $x_0$  reference data series consists of  $m$  values representing the most favoured responses.

**Step-2:** Generate comparison data series  $x_i$

$$x_i = (d_{i1}, d_{i2}, \dots, d_{in})$$

where  $i = 1, \dots, k$ .  $k$  is the number of scale items. So, there will be  $k$  comparison data series and each comparison data series contains  $m$  values.

**Step-3:** Compute the difference data series  $\Delta_i$

$$\Delta_i = (|d_{01} - d_{i1}|, |d_{02} - d_{i2}|, \dots, |d_{0n} - d_{in}|)$$

**Step-4:** Find the global maximum value  $\Delta_{\max}$  and minimum value  $\Delta_{\min}$  in the difference data series.

$$\Delta_{\max} = \forall i^{\max}(\max \Delta_i)$$

$$\Delta_{\min} = \forall i^{\min}(\min \Delta_i)$$

**Step-5:** Transform each data point in each difference data series to grey relational coefficient.  $\gamma_i(j)$  represents the grey relational coefficient of the  $j$ th data point in the  $i$ th difference data series, and then the coefficient can be estimated from the following form

$$\gamma_i(j) = \frac{\Delta_{\min} + \zeta \Delta_{\max}}{\Delta_i(j) + \zeta \Delta_{\max}}$$

where  $\gamma_i(j)$  is the  $j$ th value in  $\Delta_i$  difference data series.  $\zeta$  is a value between 0 and 1. The coefficient  $\zeta$  is used to compensate the effect of  $\Delta_{\max}$  should  $\Delta_{\max}$  be an extreme value in the data series. In general the value of  $\zeta$  can be set to 0.5.

**Step-6:** Compute grey relational grade for each difference data series. Let  $\Gamma_i$  represent the grey relational grade for the  $i$ th scale item and data points in the series are assumed of the same weights.

$$\Gamma_i = \frac{1}{m} \sum_{n=1}^m \gamma_i(n)$$

The magnitude of  $\Gamma_i$  reflects the overall degree of standardized deviance of the  $i$ th original data series from the reference data series. In general, a scale item with a high value of  $\Gamma$  indicates that the respondents, as a whole, have a high degree of favoured consensus on the particular item.

**Step-7:** Sort  $\Gamma$  values into either descending or ascending order to facilitate the managerial interpretation of the results.

#### 4.4 GRA-Based Prioritization of Factors

Table 3 presents the prioritization of factors based on the average grey score evaluated.

**Table 3** Ranking of attributes based on GRA

Attribute relevant to sidewalk and crosswalk	Average grey score	Rank
Presence of sidewalk facilities	0.8719	4
Safety from traffic	0.8874	2
Footpath geometry	0.8296	7
Footpath cleanliness	0.8709	5
Aesthetics and amenities	0.8014	10
Street lights	0.8858	3
Safety and security	0.8940	1
Other pedestrian characteristics	0.8267	8
Weather	0.8211	9
Pollution	0.8642	6
Attributes specific to crosswalk	Average grey score	Rank
Traffic speed	0.8286	7
Traffic volume	0.8187	8
Complex traffic turning movements at intersections	0.8403	5
Signal control	0.8830	1
Pedestrian vehicle interactions at crosswalk	0.8427	3
Intersection geometry	0.8384	6
Availability of pedestrian holding area near junction	0.8417	4
Pedestrian delay at intersection	0.8018	9
Vehicle stop line behaviour at junction	0.8637	2

## 5 Discussion

A greater value of grey score for an attribute indicates that a particular attribute has been given the top-most priority by the pedestrians. Safety and security was the top prioritized factor with grey score of 0.8940 indicating the pedestrians utmost concern for safety and security from the crimes happening on the roads. The second most consideration of pedestrian as inferred from the result was the safety from the traffic. Street light, presence of sidewalk facilities and footpath cleanliness were the third-, fourth- and fifth-ranked attributes followed by pollution, footpath geometry. Signal control was the first-ranked factor specific to a crosswalk with the vehicle stop line behaviour being the second-ranked attribute. Pedestrian vehicle interaction, holding space at intersection and complex turning movements were the next top-ranked factors. The pedestrians were least concerned about the delay incurred in waiting to cross the road.

## 6 Conclusion

Based on a detailed investigation on user perception towards a set of attributes influencing both sidewalk and crosswalk infrastructure, the following concluding remarks can be made:

- Firstly, safety and security were perceived as the most important attribute. In the present-day scenario of increasing crime rates and possibility of mishaps taking place, the pedestrians gave at most attention to their safety and security on roads.
- Secondly, safety from the on-street traffic is found to be the second most important consideration to the pedestrians. This finding clearly indicates that, adequate buffer distance has to be provided so that it could give adequate space for protecting the pedestrians in situations where the vehicle has gone out of control. However, in typical Indian context, inadequate space and increasing levels of traffic on roads have made the interaction more and simultaneously increased the risk of pedestrians being involved in accidents.
- Thirdly, provision of adequate illumination through street lights was found as an influential variable as perceived by users. Provision of street lights can reduce the fear of crime and encourages the pedestrians to walk even after dark by increasing the safety and security.
- Fourthly, among the crosswalk specific factors, signal control was perceived as the top-most important attribute by the pedestrians. The unsignalized intersections are likely to result in unsafe pedestrian crossing.
- Fifthly, vehicle stop line behaviour was also perceived as an important attribute as it is very essential that vehicles come to a stop at the stop line and do not stand on the roadway ahead of the stop line which would result in less available space for the crossing pedestrians.

- Sixthly, this study is one of the unique efforts towards prioritization of attributes influencing user perception at sidewalks and crosswalks in typical Indian context and shows an application of multi-attribute decision making approaches such as GRA.

Overall, these findings can be used as preliminary guidelines for planners and stake-holders in India. Although, the results are case-specific, the demonstrated methodology can be applied in other cities with similar socio-economic settings.

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