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CASE STUDY

Prioritizing pedestrian needs using a multi-criteria decision approach for a sustainable built environment in the Indian context

G. R. Bivina[1] · Manoranjan Parida[1]

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Abstract
Encouraging people to walk and use public transport can be a beneficial approach to tackle social and environmental issues associated with traffic and transportation. To motivate walking as a mode of choice of people, policymakers need to accord importance to pedestrians' needs and expectations. Developing countries like India are lacking proper design guidelines for safer pedestrian infrastructure. With this background, it is essential to understand the concept of pedestrian needs for a safe and comfortable walking environment in Indian cities and provide a framework for planners to develop proper design guidelines for pedestrian infrastructures. The present study enhances the comprehension of decision-making process of pedestrians using Analytical Hierarchy Process to acquire priorities for various criteria that affects pedestrians' choice of walking. A questionnaire survey was conducted in ten zones of Thiruvananthapuram city (Kerala, India) to recognize pedestrian priorities for walking characteristics within four main criteria: 'Safety,' 'Security,' 'Comfort and Convenience' and 'Mobility and Infrastructure' identified based on literature review. The study found that pedestrians perceived 'Safety' as the most important factor than conventionally used pedestrian infrastructure design factor 'Mobility and Infrastructure.' This paper also found a possible approach to quantify the importance of qualitative attributes that are applicable to pedestrian decision process. The findings of this study highlighted the importance of pedestrian-oriented assessment in better understanding of their decision-making process. These results will help urban planners and experts to rank the attributes defining the hierarchy of pedestrian needs and allocating investments into pedestrian facilities based on the needs and expectations of pedestrians.

Keywords Pedestrian · Sidewalks · Walking · Environment · India

✉ G. R. Bivina
biviplna@gmail.com

[1] Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, India

1 Introduction

Walking is the most sustainable urban transport mode available. Walking supports in accessing facilities and opportunities, especially for most vulnerable road users like children, women and aged persons (Borst et al. 2009). Previously, walking was of least priority as a mode and its importance in transportation planning and policy development was ignored, particularly in developing Asian countries. National and local level policies enhancing walking and cycling are formulated only by 68 countries in the world, and thus, there is a continuous decline of walking trips and people mostly depend on private vehicles for their travel (WHO 2013). High motorization in Asian countries led to less walking space for pedestrians. Due to substandard pedestrian infrastructures and the importance given to motorized transport, pedestrians become the victims of the policy neglect. A study conducted by Clean Air Asia, CAI (2011) in thirteen Asian cities it is revealed that if walking environment is not improved, 81% of people would shift from walking to other transportation modes.

For short distance, non-motorized transport trips are very common in Asian cities which are characterized by very high population densities and mixed land use development. Rapid urbanization and motorization have inadvertently affected the sharing of overall non-motorized transport in India. Even though 40–60% of modal share constitutes pedestrians in developing countries (Leather et al. 2011), their needs and expectations are disregarded at local and national levels. This apathy toward pedestrians and their needs is supported by limited funding allocations for pedestrian facilities to enhance provision of good quality pedestrian infrastructures. National Urban Transport Policy (NUTP 2006) has clearly stressed the need to merge infrastructure provisions related to pedestrians and non-motorized modes for the improvement plans of different Indian cities. Total number of accidents reported in India in 2015 was 0.50 million (MoRTH 2013). Pedestrians constituted the highest share of fatalities from road accidents on National Highways in India (MoRTH 2013; Tiwari 2016).

Thiruvananthapuram, the capital city of Kerala, needs an extensive transportation plan that has to be adopted for the wellbeing of pedestrians to ease their movement. A study conducted by the National Transportation and Planning Research Centre (NATPAC 2014) across the city found that out of 1208 road users involved in accidents, 37% were passengers, 33% were pedestrians, and 30% were drivers. Total numbers of fatalities reported in the city were 202 out of 3258 road accidents in 2005 which is one of the highest figures among other million-plus cities of India (MoUD 2008). Therefore, it becomes indispensable to address all issues of pedestrians and their needs (WHO 2013).

In context of developing nations, the Asian countries like India have a different set of problems related to pedestrians, they face many difficulties varying from person to person, but on the whole, they are similar. Problems such as lack of footpaths and crosswalks, cleanliness and security against crime are major problems faced by the pedestrians (Bharucha 2017; Bivina et al. 2018a). Most of the previous studies considering pedestrian needs are in the conext of developed countries, so they cannot be generalized in the Indian context. Difference in economy and geography among developed and developing countries can also vary the pedestrian needs for walking. Therefore, it is essential to provide comprehensive needs of pedestrians within the Indian context (Bivina et al. 2018b). This study attempts to assess the pedestrian needs relevant for the good quality walking environment in the Indian context and prioritizes environmental factors for walking applicable to the people's decision to walk or not to walk. By conducting a personal interview survey in

Thiruvananthapuram city of Kerala, India, the study attempts to define the pedestrian need hierarchy. The results are analyzed using the application of one of the Multi-Crietria Decision Analysis (MCDA) called AHP (Analytical Hierarchy Process). This hierarchy can be useful for understanding the pedestrians' prioritization of various environmental attributes for planning and designing of pedestrian facilities. The rest of the work is organized as follows: the study area is described, and then, Methodology section elaborates the design framework of this research. The last section gives the major findings of the study, conclusions and recommendations that will help in better understanding of pedestrians' needs.

2 Literature review

2.1 Concept of pedestrian needs

Pedestrians' route choice for walking is based on a variety of environmental factors and socio-demographic characteristics are one among them. These characteristics include their age, gender, income, employment status, etc. Moreover, trip characteristics such as walk purpose, trip distance may also impact their decision to walk in a particular route. Two categories of characteristics: socio-demographic and trip characteristics, are fixed variables and hence cannot be altered. At the same time, there is a third group of variables called environmental attributes which can be altered. Taking into account these environmental attributes and magnitude to which these factors satisfy pedestrians' needs, favorable and unfavorable qualities of the route are measured. Pedestrians will decide to walk or not to walk within the walking environment based on those factors. In order to better understand the motivation for walking, clear information about environmental characteristics that positively affect walking is necessary. This motivation originates not only from individual's expectations, but from values, that individual associates with walking. This can affect pedestrians' attitude, and as a result, certain behavioral traits within the sidewalk environment are manifested.

The concept of pedestrians needs developed as a response in generating positive walking environment. In order to understand pedestrian needs concept, two important concepts need to be reviewed such as theory by Maslow (1954) on human needs theory, and Level of service used for the design of sidewalks. According to Maslow (1954), human needs are in a hierarchical order and basic needs such as food, water are found at the bottom of the hierarchy. These needs at the bottom have to be fulfilled first before moving to the other needs at the top. Similarly, pedestrian needs can be arranged in the form of a hierarchical tree concept. Pedestrians would have specific needs and expectations of environment while they walk from one point to another. The presence of these elements contributes towards the fulfillment of pedestrian needs. Nevertheless, pedestrians' needs might change based on the context and they assess their walking environment based on travel experience in that area.

In the context of developing nations, they have a different set of problems related to pedestrians. They face difficulties varying from person to person, but on the whole, they are similar. Problems like the absence of sidewalk and crosswalk, cleanliness and security against crime are major challenges faced by the pedestrians (Bharucha 2017). Previous research on pedestrian needs is around developed countries and hence cannot be generalized for the Indian context. Difference in economy and geography among developed and developing countries is different. In this backdrop, it becomes paramount to provide comprehensive needs of pedestrians in evaluating and designing pedestrian facilities (Marisamynathan and Vedagiri 2017). This study attempts to assess pedestrian needs relevant for a good walking environment in the Indian context and prioritizes environmental factors for walking applicable to the people's decision to walk or not to walk. By conducting a personal interview survey in Thiruvananthapuram city of Kerala, India, the study attempts to define the pedestrian need hierarchy. The results are analyzed using application of one of the Multi-Crietria Decision Analysis (MCDA) techniques, called AHP (Analytical Hierarchy Process). This hierarchy can be useful for understanding the pedestrians' prioritization of various environmental attributes in different layers for planning and designing of pedestrian facilities.

2.2 Critical factors affecting walking

The literature on factors that affects walking has increased over a time. The study conducted by the World Bank (2007) emphasized the importance of sidewalk availability for walking. Southworth (2005) found path quality, connectivity, safety can be the main factors encouraging walking. Mehta (2008) defined the hierarchy of walking needs of the neighborhood street as accessibility, comfort, sense of belonging and pleasure, feasibility and usefulness. Lo (2009) found that walk decision depends on three variable groups such as pedestrians' demographic and social characteristics (Mehta 2008; Wells and Yang 2008), their trip characteristics (Handy 1996; Mehta 2008) and factors of the walking environment (Cervero and Kockelman 1997; Sallis et al. 2004). Said et al. (2016) found that the cleanliness of sidewalks, quality of sidewalks and less blockage of sidewalk have positive effects on walking. Kim et al. (2014) found that microscale street environment factors supporting walking have a significant influence on pedestrian satisfaction on walking. Ariffin and Zahari (2013) stated that the built environment has a great influence on walking frequency and weather conditions, pedestrian facilities, etc., and it can enhance the pedestrians' perceptions of the walking environment. Wang et al. (2016) identified the major environmental barriers that discourage walking that includes safety, opportunity barriers, etc. Mateo-Babiano (2016) developed a pedestrian need concept for Manila, which considered sidewalk environmental attributes like mobility, protection, equity, ease, enjoyment, and identity, but have missed some of the factors relevant in developing countries context like continuity of sidewalks, cleanliness and other traffic factors such as traffic speed and volume. Sidewalk characteristics such as sidewalk width, quality, continuity would be positively influencing walking (Parida et al. 2007; Bivina et al. 2018b).

Despite the difficulty of operationalizing the concept of level of pedestrians' perceptions of various built environment factors for enhancing walk environment, they are still widely used in interpreting the factors mostly influential in bringing more people into walking. Many of the past studies adopted methods like weighted average and regression-based techniques. Landis et al. (2001) and Dowling et al. (2008) used regression analysis for the pedestrian level of service (PLOS) studies of sidewalks, but not for the studies that include qualitative parameters such as security, safety. Weighted average method was adopted by past studies (Parida et al. 2007; Bivina et al. 2019) have also not considered complex decision-making of pedestrians. Thus, none of these methods considered psychological aspects of pedestrian needs and priorities as they lack analytical flexibility. Therefore, they are not advised for establishing a relationship between physical and user characteristics of sidewalks as their results confirm the existing models. In this context, Multi-Crietria Decision Analysis (MCDA) has a good role that better advocates human psychology into the model.

Only MCDA methods can make decisions on people's preference in case where there are conflicting criteria. MCDA is used to assess the weights of various attributes by designating preferred alternatives in small number of classes and rank or weigh them in subjective preference order. MCDA can handle complicated problems into smaller ones. Some of the previous studies such as Sayyadi and Awasthi (2012), Shafabakhsh et al. (2015) adopted one of the MCDA approaches called analytical hierarchical process (AHP) to determine the best pedestrians zones and relation of pedestrians' mental satisfaction with physical characteristics of sidewalks. There are various MCDA techniques such as AHP (analytical hierarchical process), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), ELECTRE (Elimination and Choice Expressing Reality) and Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHUS). AHP is one of them providing an overall ordering of choices, from most preferred to the least preferred. AHP was found to be the most popular technique for solving problems having multiple objectives (Pohekar and Ramachandran 2004). It prioritizes alternatives into quantitative as well as qualitative terms based on common set of criteria. A single problem is decomposed into various levels, and topmost level is considered as the goal to be achieved followed by criteria and alternatives in the second level. The factors at each level are assigned a relative weight. Hence, AHP has been applied in this study since the goal is to assign relative weight to various criterion and alternatives of pedestrian needs.

Also, previous studies have assessed limited number of environmental characteristics potentially affecting walking. Moreover, there are no significant studies available on the pedestrian needs and expectations relevant to the pedestrian planning and policy in the Indian context. Thus, the present study aims at assessing pedestrian needs relevant to the good quality walking environment in the Indian context and prioritizes environmental factors of walking applicable to peoples' decision to walk or not to walk. By conducting a questionnaire survey in Thiruvananthapuram city of Kerala, India, the study attempts to define the pedestrian need hierarchy using analytical hierarchy process. This hierarchy can be useful for understanding the pedestrians' prioritization of various environmental attributes for planning and designing of pedestrian facilities. The rest of the work is organized as follows: The study area is described, and then, Methodology section elaborates the design framework of this research. The last section gives the major findings of the study, conclusions and recommendations helping a better understanding of pedestrians' needs.

3 Study area

Thiruvananthapuram, the capital of Kerala, an Indian state is selected for this study. It is one of the million-plus cities, most populous, and largest cities having a population of about 1.68 million (Census 2011). It has a well-developed and organized transport infrastructure, especially the road and rail networks, and its residents depend on road networks for transport options, and two-wheelers are the favored means of personal transportation (Ashalatha et al. 2012). Like many other million-plus cities in Asia, lack of effective planning and high population growth have induced various transport-related problems in its city center. Moreover, lack of good quality pedestrian facilities had deteriorated walking environment and studies have found that, out of 36 roads selected for the study, 90% of the roads have sidewalks, but their non-utilization makes their quality questionable (NATPAC 2014). From this scenario, it can be understood that ignorance of pedestrian needs and expectations have manifested in

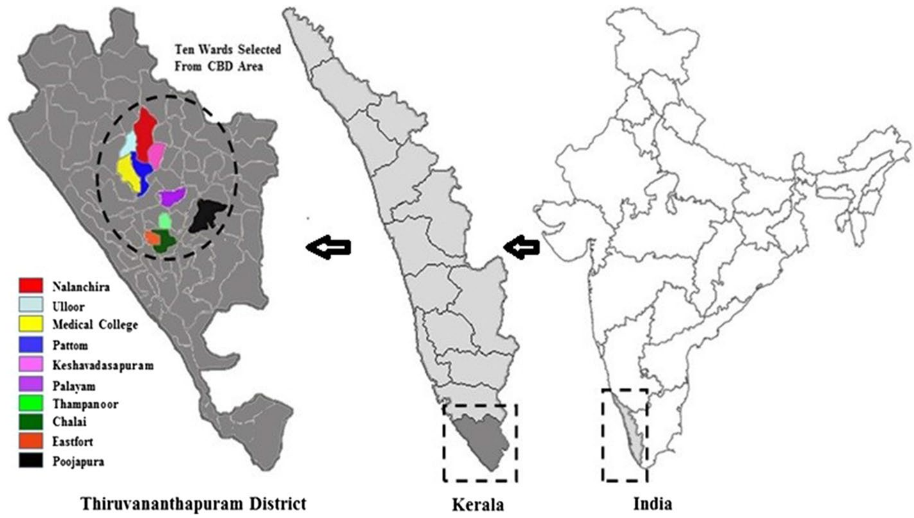


Fig. 1 Map showing study area locations

Table 1 Study area and their land uses

Sl. No.	Zones	Land use type
Area 1	Ulloor	Residential
Area 2	Medical College	Residential + institutional
Area 3	Keshavadasapuram	Residential
Area 4	Nalanchira	Residential
Area 5	Pattom	Residential
Area 6	Palayam	Commercial
Area 7	Thamapanoor	Commercial + terminal
Area 8	Chalai	Commercial
Area 9	Poojapura	Public + semi-public
Area 10	East Fort	Commercial

the non-utilization of pedestrian facilities. Accidents and delays are the most common problems faced by city's commuters.

Ten locations (corporation zones) from different land uses were selected from the CBD area of the city. The selection of zones is done in a way that study locations could represent the entire population of the city. The study locations are displayed in Fig. 1. The land use along the sidewalks is identified by major activities in that locality. As per the master plan of Thiruvananthapuram, the land use is divided into following land use, viz. residential, commercial, institutional, recreational, public and semi-public land use. Table 1 presents the land use patterns of selected zones for the study.

4 Methodology

4.1 Analytical hierarchical process

Analytical hierarchical process (AHP) is a MCDA technique designed by Saaty (1990) to measure pedestrian decision-making process which is difficult to quantify. AHP is used as a qualitative evaluation tool as well as a subjective tool. It has several applications as traffic tool selection, prioritization (Kang and Lee 2007; Oswald Beiler and Phillips 2015) and assessment of transportation alternatives (Jeon et al. 2010). AHP shows more reliability and adaptability with the opinions of decision-makers in urban planning and transport investments. According to Yedla and Shrestha (2003), AHP is stronger than qualitative criteria as it gives results that are more realistic. AHP decision-making process involves the priority of one attribute over another; this ranking of attributes is at least in prioritizing needed to help alternatives. The main assumption is that each criterion can be comprehended for using a set of alternatives. The model calculates the relative weight of alternatives through pairwise comparison. It involves comparing alternatives in a cluster, deriving relative weights for each alternative within a cluster and to the cluster itself. The cluster defined here is referred to the criteria selected for the study. For instance, 'Comfort and Convenience' is a cluster and it consists of various alternatives such as pedestrian amenities, shaded sidewalks and availability of bus shelter. The relative weights of these alternatives within 'Safety' criteria and to the 'Safety' criteria are found out. The 'local' priorities of alternatives in a cluster with respect to their criteria are derived from these comparisons. These relative weights of alternatives in a criterion are defined as local priorities or local weights. The local weights of these alternatives multiplied with weights of their corresponding criteria are defined as global weights or global criteria. The concept of hierarchical structure enables to multiply local weights of elements in a cluster by global weights of parent elements or criteria, thus giving global weights of all elements throughout the hierarchy.

The basic procedure followed for AHP is:

1. Development of the ranking problem to a hierarchical framework with goal, criteria, alternatives.
2. For all criteria and alternatives under each criterion, the pairwise comparison is formed separately. Figure 2 illustrates the decision matrix with values of alternatives (a_{ij}) and criteria weights ($_{Wj}$)
3. A scale of numbers is used to make a comparison showing how much important one element over other elements with respect to which they are compared. Table 2 presents

Fig. 2 Decision matrix

$$\begin{bmatrix} C_1 & C_2 & . & C_m \end{bmatrix} \; Criteria$$

$$\begin{bmatrix} w_1 & w_2 & . & w_m \end{bmatrix} \; Weights$$

$$\begin{bmatrix} A_1 \\ A_2 \\ . \\ A_n \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} & . & a_{1m} \\ a_{21} & a_{22} & . & a_{2m} \\ . & . & . & . \\ a_{n1} & a_{n2} & . & a_{nm} \end{bmatrix} \; Alternatives$$

Table 2 Saaty's scale

Explanation	Option	Value
Both factors are equally important	Equal	1
One factor slightly favors on over another factor	Marginally strong	3
One factor strongly favors on over another factor	Strong	5
One factor very strongly favors on over another factor	Very strong	7
One factor very strongly favors on over another factor	Extremely strong	9
One factor highly gives special importance to one over another time when compromise is needed	Intermediate values	2,4,6,8

the scale called Saaty's scale (Saaty 1990) in the range of 1–9 based on psychological observations. AHP evaluates criteria and its alternatives on this scale. A square matrix represents pairwise comparisons of various criteria with diagonal elements as 1. The comparisons are made for each criterion based on numerical values as per Table 2. A scale of numbers is used to make a comparison showing how much important one element is over the other elements with respect to which they are compared.

4. The next step in the process is the calculation of principal eigenvalue and normalized eigenvector. The weights with respect to their criteria or alternative are termed as the elements of the normalized eigenvector.

For a pairwise matrix

$$\begin{bmatrix} a_{11} & a_{12} & \cdot & a_{1m} \\ a_{21} & a_{22} & \cdot & a_{2m} \\ \cdot & \cdot & \cdot & \cdot \\ a_{n1} & a_{n2} & \cdot & a_{nm} \end{bmatrix}$$

The values in each column are summed up.

$$a_{ij} = \sum_{i=1}^{n} a_{ij} \tag{1}$$

The ratio of the element of the matrix to the sum of its column gives the normalized pairwise matrix.

$$X_{ij} = \frac{a_{ij}}{\sum_{1=1}^{n} a_{ij}} \begin{bmatrix} a_{11} & a_{12} & \cdot & a_{1m} \\ a_{21} & a_{22} & \cdot & a_{2m} \\ \cdot & \cdot & \cdot & \cdot \\ a_{n1} & a_{n2} & \cdot & a_{nm} \end{bmatrix} \tag{2}$$

The sum of the normalized column of matrix divided by the number of criteria (n) gives the weighted matrix.

$$W_{ij} = \frac{\sum_{j=1}^{n} X_{ij}}{n} \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ \cdot \\ W_m \end{bmatrix} \tag{3}$$

This W_{ij} provides weights of parent criteria. Weights of alternatives are calculated similarly by using the same procedure. The global weights of the alternative are obtained by multiplying the local weights of alternative to the weights of parent criteria.

The matrix consistency is evaluated by using two indices such as CI, CR. CI is the consistency index, and CR is the consistency ratio. They are computed when $\lambda_{\max}$ is obtained. Consistency index reflects consistency of one's judgment.

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{4}$$

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{5}$$

RI is the random consistency index whose value is given in Table 3. The matrix is considered to be consistent if $\mathrm{CR} \leq 0.1$ and if $\mathrm{CR} \geq 0$, it should be improved.

4.2 Selection of criteria and alternatives and assigning weights

A multi-level hierarchical tree has been designed for defining a positive sidewalk environment. A list of environmental parameters was identified under each pedestrian need. Each of these parameters represents pedestrian needs and expectations from the walking environment. Based on the extensive literature review, four main attributes were selected as the major pedestrian needs. The factors used in the study were identified by critically reviewing various street design guidelines (IRC:103-2012 2012; UTTIPEC 2010), sidewalk assessment tools (Clifton et al. 2007; Pikora et al. 2002) and pedestrian level of service models (Landis et al. 2001; Gallin 2001; Parida et al. 2007; Asadi-Shekari et al. 2014). Finally, 4 main items were selected based on the review: (1) Safety, (2) Security, (3) Comfort and Convenience and (4) Mobility and Infrastructure. A list of alternatives was defined under each criterion as illustrated in Fig. 3. The brief description of each alternative is provided in Table 4.

5 Data collection

5.1 Sampling design

Simple random sampling was adopted to conduct questionnaire survey where responses were collected from offices, households, public places and others. Responses were collected from their residences, offices and other public places where they were available in groups. A pilot study was conducted among 20 respondents to check the time required to answer the questionnaire and level of complexity of the questions being asked to respondents. Pilot study ensured the validity, effectiveness and reliability of the questionnaire could be ensured. The sample size was calculated from the population of walk trips obtained from the study area using Eq. 6 proposed by Krejcie and Morgan (1970). Sample size was calculated from the population of

Table 3 Values of random index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.46	1.49

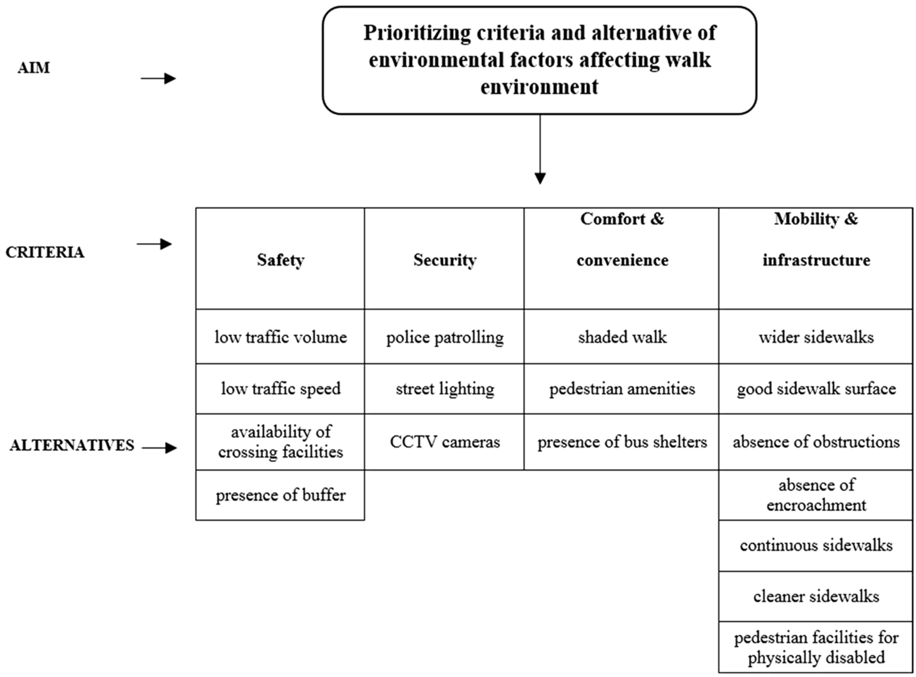


Fig. 3 A framework of criteria and alternatives

walk trips produced in the selected study area at a confidence interval of 95% and 5% margin of error. Walking accounts for 17% of total trips produced in the study area (NATPAC 2014). The minimum number of sample size obtained was 384, and about 502 responses were collected from various households, offices and public places. The responses collected from each zones varied based on the zone's population as more samples were collected from zones with higher populations.

$$S = \frac{\chi^2 NP(P-1)}{d^2(N-1) + \chi^2 P(P-1)} \tag{6}$$

where S, required sample size; χ^2, the table value of Chi-square at anticipated confidence interval (3.8342); N, population size (the number of walk mode trips, i.e., 17% of the total population); P, population proposition of walking trip; and d, the degree of accuracy as a proposition (0.05). The collected questionnaire survey sample in this study is more or equal to the required sample size (S).

5.2 Questionnaire survey

A questionnaire survey was designed to understand the choices and priorities of pedestrians' needs and alternatives. It was designed to have three sections. Section 1 deals with the pedestrian profile, Sect. 2 on walk characteristics, and Sect. 3 the pairwise comparison of alternatives (e.g., sidewalk width and sidewalk surface) on a scale of 1–9 (Saaty 1990). People were asked to give their choice between two alternatives using this scale, where a choice of 1 meant that the respondent is given an equal choice between 'sidewalk

Table 4 Sidewalk environmental attributes

Criteria	Alternatives	Comments
Safety	Traffic volume	High traffic volume especially at residential and commercial areas affects the quality of streets for pedestrians risking pedestrian safety that results in low pedestrian mobility
	Traffic speed	Traffic speed is one of the main factors of pedestrian fatalities. Vehicles plying at high speed make walking uncomfortable and unsafe
	Availability of crossing facilities	Availability of crossing facilities such as zebra crossings, pedestrian foot over bridges, subways makes pedestrians feel safe to walk and ensure that they have a safer place to cross
	Presence of buffer	Buffer is a space between the sidewalk and the lane where vehicles move. It can be provided in the form of grass and trees, or street furniture
Security	Police patrolling	Police patrolling along walkways enhances pedestrians' sense of security against crime or theft
	Street lighting	Street lighting provides good visibility and personal security, especially to pedestrians. It would add personal safety by allowing pedestrians and motor vehicles to see each other and provide security against crimes
	CCTV cameras	Installation of CCTV cameras along streets helps in enhancing the sense of security from crime and theft
Comfort and Convenience	Shaded walk	Pedestrians feel comfortable if there is enough shade along sidewalks while walking. And this is ensured by planting trees or providing weather protection. Also, roadside shops should be encouraged for providing awnings to generate shade, and also provides protection from harsh climate
	Pedestrian amenities	Availability of amenities such as toilets, drinking water provisions enhances the attractiveness of pedestrian environment bringing more people into walking
	Presence of bus shelter	Availability of public transit in the form of bus shelters would positively enhance pedestrians' decision to walk

Table 4 (continued)

Criteria	Alternatives	Comments
Mobility and Infrastructure	Wider sidewalks	Sidewalk width plays a significant role in the quality of pedestrian environment. Narrow sidewalks affect pedestrians' comfort and mobility. Also, wider sidewalks provides pedestrians with sufficient space to move at their pace, socialize and enjoy their surroundings
	Good sidewalk surface	Quality sidewalk surface are important to ensure the better mobility of pedestrians and also ensure persons with physical disability or wheel chair users. The sidewalk texture should be firm, non-slip surface and stable
	Absence of obstructions	Sidewalk obstructions are the objects within pedestrian access that decreases clearance width or limiting the space of a sidewalk by protruding into it. Sidewalk obstructions are in the form of telephone poles, sign boards, electric posts, utilities, etc.
	Absence of encroachment	Street vending has been an integral aspect of Indian cities and towns since olden days. Street vendors are inevitable on urban streets, as they provide affordable services to a majority of the urban population. It also helps pedestrians to cater their day-to-day needs. But sometimes, encroachment extends to such a level that it reduces the clear space of sidewalks for pedestrians making the sidewalks inaccessible or sometimes non-usable
	Continuous sidewalks	Continuity is one of the main factors of sidewalk infrastructure, especially for aged persons and persons with disability. Frequent up and downs of sidewalk affect pedestrians' smooth mobility
	Cleaner sidewalks	Cleaner sidewalks attract more people to walk. The sidewalk should be free from garbage and litter
	Facilities for physically disabled persons	A sidewalk should provide equitable access to all sections of society. It should provide accessibility for people with disability through tactile pavements, ramps

width' and 'sidewalk surface,' while a scale of 9 near to 'sidewalk width' meant that the respondents' choice of preference for 'sidewalk width' is extremely higher than 'sidewalk surface.' There are 17 alternatives defined under 4 criteria to achieve the aim of good walk environment. The relative weight in both global scale and local scale (that is, both global priority and local priority value) has been derived for all alternatives based on the respondents' choice between pairwise comparisons; the default priority of each alternative is same which is summed up to 1.

6 Results and discussion

6.1 Socio-demographic and walk trip characteristics

The demographic profile of the study area has to be viewed carefully viewed for understanding the comparison of variables. These details are presented in Table 5. Females were the majority of survey participants (about 52%). The participants in the age group between 27 and 40 were higher in proportion (33%). The majority of the respondents were students (25%). About 24% and 23% of the respondents were employed in private and public services, respectively. The highest proportion of respondents was having monthly income between Rs 10,000 and Rs 20,000. Responses were taken from people who walk daily either for work or for any other purposes. The purpose of their walking was mainly to keep them fit. The survey sample highly represented the general population of Thiruvananthapuram city.

6.2 Pedestrians choice for the main criterion for walking

The survey results indicate that respondent's accord priority to safe and secure walking environment more than any other needs. 'Safety' secured a global priority value of 0.396. Safety is the most important criterion for pedestrians (Fig. 4). On the other hand, 'Comfort and Convenience' is the least important one. The criterion 'Safety' includes factors such as *traffic volume, traffic speed and presence of buffer and availability of crossing facilities*. Therefore, all these factors of pedestrian safety are relevant for their decision to walk. Study conducted by Evenson et al. (2009) also identified safety as one of the main factors of walking. 'Safety' is followed by the factor 'Security' with a global priority value of 0.36 (Fig. 4). 'Security' factor includes elements ensuring pedestrians' security against crime and theft. This includes factors such as police *patrolling, CCTV cameras and street lighting*. The factor 'Mobility and Infrastructure' received the second least priority among 4 criteria with a global priority of 0.13. 'Mobility and Infrastructure' includes elements that provide ease of mobility for pedestrians such as *wider sidewalks, continuous sidewalks, absence of obstructions, absence of encroachments, cleaner sidewalks and facilities for persons with disability*. 'Comfort and Convenience' criteria gained the least importance, and it includes factors such as *shaded sidewalk, presence of bus shelters and pedestrian amenities*. Rankavat and Tiwari (2016) in her study identified comfort as one of the important factors using pedestrian facilities. In the context of Thiruvananthapuram city, the results found that pedestrians give more importance to 'Safety' and 'Security' factors than 'Mobility and Infrastructure' or 'Comfort and Convenience.' Therefore, it can be inferred that a walking environment should not only be providing factors such as space and mobility, but should also provide qualitative environmental factors for fulfilling the pedestrian

Table 5 Socio-demographic characteristics of respondents

Variables	Categories	Statistics (%)
Gender	Male	48
	Female	52
Age	0–17	10
	18–26	24
	27–40	33
	41–55	22
	56–70	8
	> 70	3
Profession	Student	25
	Public service	23
	Private	24
	Housewife	12
	Retires	6
	Unemployed	3
	Others	10
Income	No income	19
	< 5000	7
	5000–10,000	17
	10,000–20000	32
	20,000–30,000	17
	30,000–50,000	8
	> 50,000	0
Walking time	Not at all	0
	Less than 10 min	48
	11–20 min	43
	21–60 min	9
Walk distance	Less than 100 m	9
	100–200 m	3
	200–300 m	3
	300–400 m	10
	400–500 m	25
	< 500 to 1000 m	24
	< 1000 to 1500 m	14
	> 1500 m	14

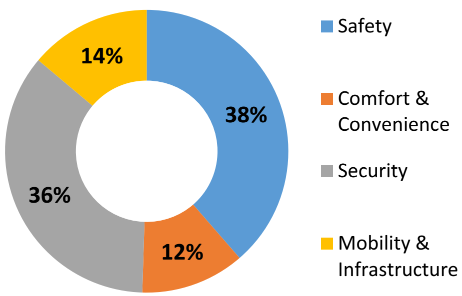


Fig. 4 Composition of pedestrian choice of main criterion of walking

needs such as safety from road traffic and security from anti-social activities, crime and theft.

In order to test gender differences in priority of pedestrians' needs, a nonparametric test has been conducted. Mann–Whitney tests have been conducted to assess whether there is a significant gender differences in the importance rating given to 'Safety' over 'Mobility.' Data have been checked for its non-normality before conducting the test. Results found a significant difference between males and females for their priority for 'Safety' over 'Mobility' (significant at 95% confidence interval, $p < 0.05$). Females tend to give more priority to 'Safety' than 'Mobility' when compared to males.

Kruskal–Wallis tests have been conducted to assess ratings of 'Safety' over 'Mobility' by different age groups. Results showed that ratings given by different age groups are different and statistically significant ($p < 0.05$). The Kruskal–Wallis procedure tests the null hypothesis that the groups are not different from each other by testing whether rank sums are significantly different based on a Chi-square distribution. The test is applicable when data are either ranked or quantitative, samples are independent, populations are not normally distributed, and the measurement scale is at least ordinal (Washington et al. 2010).

6.3 Pedestrians choice for alternatives for walking

The global level priority scale can be used to rank alternatives on a global scale while considering each alternative in all four criteria, whereas local priority scale can be used

Table 6 Global and local priority value for attributes

Attributes	Global priority	Local priority
Goal	1.000	1.000
Safety	0.390	0.390
Comfort and Convenience	0.116	0.116
Security	0.359	0.359
Mobility	0.135	0.135
Low traffic volume	0.097	0.247
Low traffic speed	0.080	0.204
Availability of crossing facilities	0.146	0.375
Presence of buffer	0.068	0.174
Shaded walk	0.057	0.489
Pedestrian amenities	0.028	0.243
Presence of bus shelters	0.031	0.268
Police patrolling	0.155	0.431
Street lighting	0.101	0.282
CCTV cameras	0.103	0.287
Wider sidewalks	0.015	0.110
Good sidewalk surface	0.013	0.098
Absence of obstructions	0.014	0.105
Absence of encroachment	0.015	0.114
Continuous sidewalks	0.026	0.192
Cleaner sidewalks	0.032	0.240
Facilities for people with disability	0.019	0.141

Fig. 5 Alternatives under safety

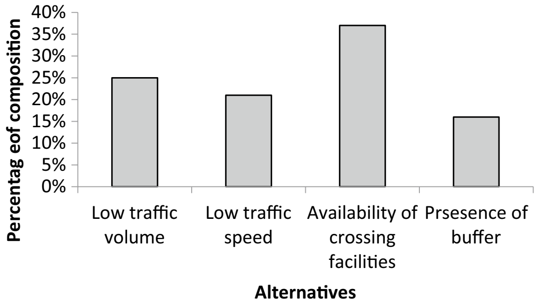


Fig. 6 Alternatives under security

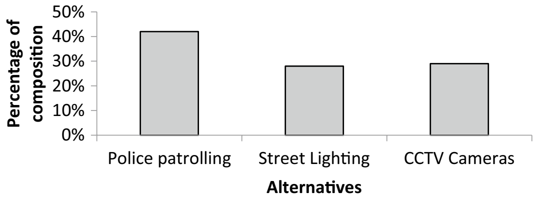


Fig. 7 Alternatives under Comfort and Convenience

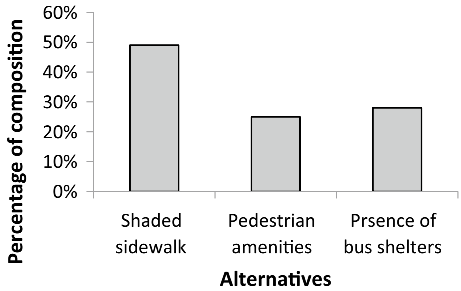
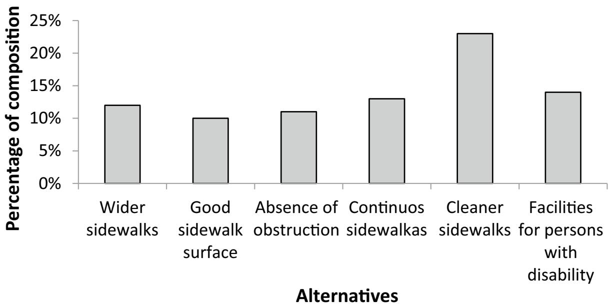


Fig. 8 Alternatives under Mobility and Infrastructure



to elicit relative choice of importance within a criterion. The local weights are relative weights of alternatives within a group of factors with respect to their criteria. They are derived from each set of pairwise comparison in each level of hierarchy. The global weights are obtained by multiplying local priorities of alternatives by the relative weight of criterion (Table 6). The local priority value signifies ranking of an alternative within that

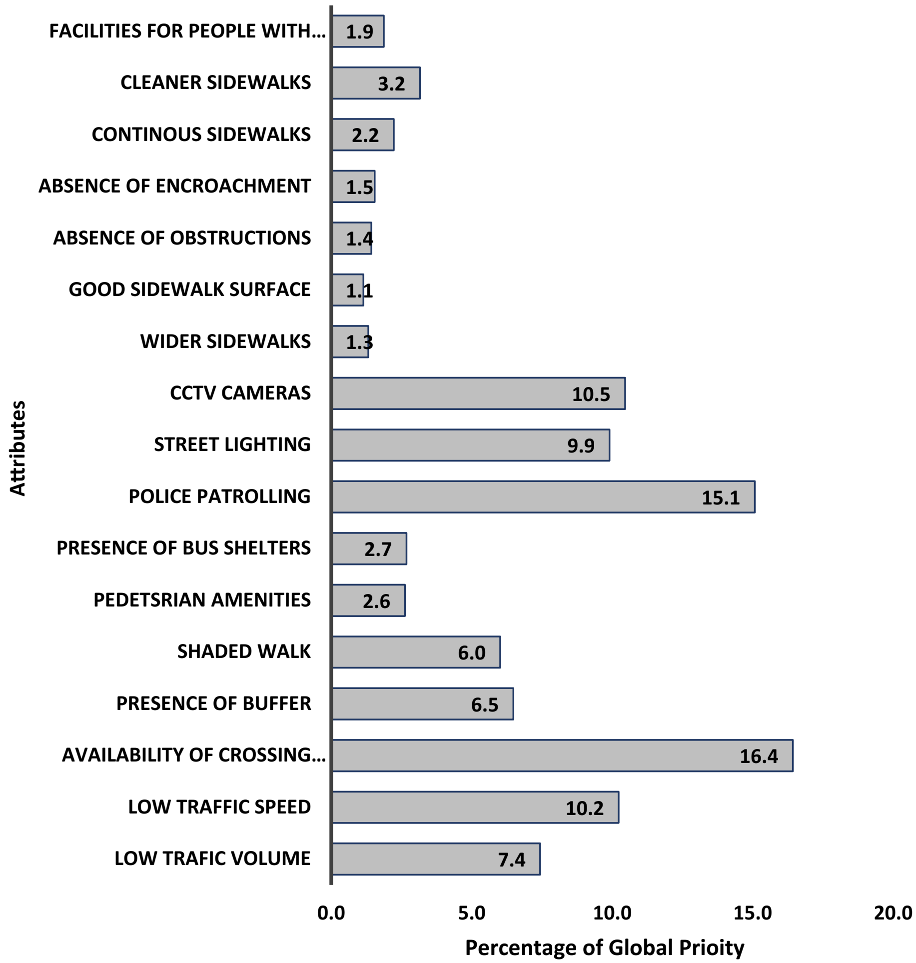


Fig. 9 Compositions of global priority values

criterion. So these values can be used if sidewalk attribute evaluation is done at criteria level. Table 6 presents attributes with global value and local priority value. The alternative '*Availability of Crossing Facilities*' (local priority: 0.375) gained the topmost priority under the criterion 'Safety' followed by '*Traffic Volume*' (local priority: 0.247) (Fig. 5). CR computed using CI and RI was found to be less than 0.10, which illustrated consistency as satisfactory and results are valid and significant. On the other hand, the criterion 'Security' has '*Police Patrolling*' as the topmost criterion (Fig. 6). Under the criterion of 'Comfort and Convenience,' the alternative '*Shaded Walk*' acquired the highest local priority value. The consistency ratio was measured as 3.2×10^{-3}, which is less than 0.10, and hence, the results are consistent. Survey results indicate that under criterion 'Comfort and Convenience,' the topmost priority is for 'S*haded sidewalk*' followed by 'P*edestrian Amenities.*' (Figure 7) While considering 'Mobility and Infrastructure' criteria, 'C*leaner Sidewalks*' received the highest importance, followed by the factor 'C*ontinuous Sidewalks*' with local priority value 0.24 and 0.192, respectively (Fig. 8). Figure 9 illustrates the percentage of

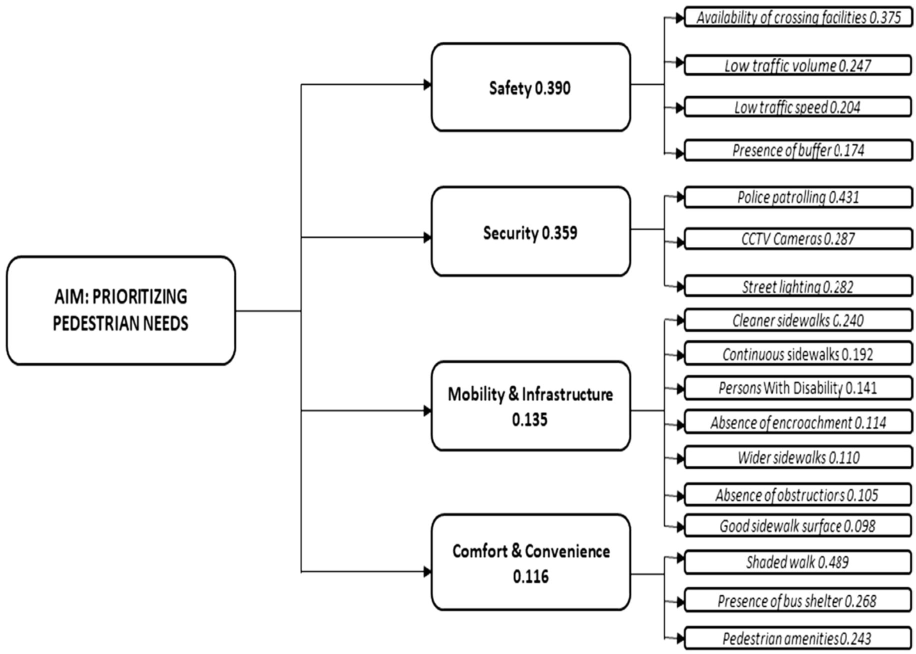


Fig. 10 Hierarchical lists of pedestrian needs

global priority value for each alternative defined under 4 criteria. The alternative '*Police patrolling*' received the highest global priority percentage composition followed by '*Availability of Crossing Facilities.*' A consistency ratio signifies that the results are significant, valid and consistent. The hierarchical list of pedestrian's choices of criteria with global weights and alternatives with local priority weights is illustrated in Fig. 10. These results provide pedestrian preference, prioritization of environmental attributes and ranking criteria in creating a favorable walking environment in Thiruvananthapuram city, Kerala, India.

6.4 Policy interventions for enhancing sidewalk usage and walking

The findings drawn from this study can be used for formulating policies for improving pedestrian facilities which might result in shifting of motorized users to walk or use public transport. Since 'Safety' factor received the highest priority among pedestrians for walking, improving safety in terms of increasing the number of crossing facilities, installing speed control signs for reducing traffic speed and enforcing one-way traffic in residential streets would help in improving walkability. 'Security' from crime is the second most important factor after 'Safety.' Since alternative *police patrolling* under security has received the highest local priority, deployment of police along streets could improve pedestrians' willingness to walk. As Kerala is known for the highest crime reported state in India as per the records of NCRB (National Crimes Record Bureau 2015), it is imperative to create a safe and secure walking environment for people through police patrolling, especially at night. This would enhance people's perception of safety and security from crime or theft, which would further encourage them to walk. Similarly, improvement of other alternatives such as providing *street lighting* and installing *CCTV cameras* along the streets also supports walking. But it is always better to frame policy interventions based on their feasibility of installation and cost. Providing streetlights along the streets would be rather easier and cost-effective than installing CCTV cameras. A case reported by the police of Thiruvananthapuram city, most of the street lights in crime-prone areas are not working. This may be one of the main factors that make people reluctant to walk in the city. Therefore, it is necessary to maintain and repair the existing street lights and install more along the sidewalks. Under the parent criterion 'Mobility and Infrastructure,' sub-criteria *cleaner sidewalk, continuous sidewalk, 'facilities for people with disabilities,'* received the highest local priorities. Among these variables, improving sidewalk cleanliness would be an easier task and can yield better results with lower costs. This can be achieved by regular supervision of municipal staffs on private waste management companies who are responsible for cleaning the streets of city.

7 Summary and conclusion

The degraded quality of pedestrian facilities and walking environment has resulted in an overall negative pedestrian perception. These negative perceptions among pedestrians on the environmental attributes discourage them from using pedestrian facilities. There are only limited studies of pedestrian needs related to environmental attributes. Pedestrian needs have to be considered while framing policies, strategies and design guidelines to improve pedestrian facilities.

The study was designed to recognize the pedestrian's preference for walking characteristics through a pairwise weighing technique called Analytical Hierarchical Process (AHP) to analyze the data collected from questionnaire survey. The study defined a hierarchy structure of pedestrians' needs according to the choice of importance given for each environmental attribute that enhances walking. Relative weights obtained by AHP helped to derive the relative importance of each alternative on both global and local levels according to the pedestrians' opinion.

The results of the study provided two key insights. First, there is significant difference in the priority for various needs on built environment measures of walking based on gender and age group. Second, pedestrians perceived safety and security more critical than mobility. The results of the study are discussed below.

Mann–Whitney and Kruskal–Wallis tests have been conducted to assess the importance of safety over mobility by gender and age groups, respectively. The results proved that priority of safety over mobility differs within the age group and gender. Mann–Whitney tests for gender-based analysis proved that there is significant difference between the priority given to safety over mobility by males and females. Females give more priority to safety than males. Results showed that ratings given by different age groups are different and statistically significant ($p < 0.05$). This proves that pedestrian priorities change with person to person. Policy makers and planners should also take these factors into consideration while preparing strategies for the design of pedestrian facilities considering the needs of all sections of pedestrians.

Important findings derived from this study are that 'Safety' and 'Security' are more critical than other factors. Also, 'Comfort and Convenience' is identified as an important factor after 'Mobility and Infrastructure' which concludes that 'needs of pedestrians' not only gets limited to safer sidewalks but also for other requirements like shaded sidewalks, the presence of amenities like drinking water and seating areas. Most of the respondents ascertained 'Safety' as their first priority that affects the decision to walk or not to walk. The study endorses many earlier works (Parida et al. 2007; Dowling et al. 2008; Christopoulou and Pitsiava-Latinopoulou 2012) that recognized safety and security as main factors of walking. One of the interesting results of the study as compared to other studies on pedestrian needs is that 'Mobility and Infrastructure' received less importance. HCM considers the parameter 'Mobility' by ignoring a number of other qualitative factors for the design of pedestrian facilities. But, the present study proves that in Indian context, there are other relatively important factors for pedestrians. 'Safety' and 'Security' are crucial in making pedestrian environment conducive for walking. This result has a counter effect on the current design practices of pedestrian facilities where they mainly focus on 'Mobility' factor. This result may be due to the fact that pedestrians of Thiruvananthapuram city are more prone to accidents and crime while walking. The present study is a demonstration of application of AHP on pedestrians' perception to quantify their built environment factors affecting walking. Thus, conducting an empirical case study of Thiruvananthapuram city, the study also contributes to the current literature through exploring pedestrians' decision-making process whether to walk or not. Moreover, these results provide fresh insights on pedestrians' satisfaction of walking that will be helpful for urban planners, engineers and government for developing guidelines and formulating new set of strategies to encourage people to walk.

With regard to the limitations, the present study has been limited geographically to Thiruvananthapuram city. The results of the study can be applied to other developing cities of Asia that are similar to Thiruvananthapuram city, where there are transport-related problems due to lack of effective planning and high population growth. Related studies in other cities can initially adopt these factors for the design of pedestrian facilities; these factors are required to be validated based on the study area context to strengthen the generalizability of the study results.

In spite of the limitations, the study provides a useful demonstration of application of AHP on pedestrians' perception of their needs on various built environment factors affecting walking. Thus, conducting an empirical case study of Thiruvananthapuram city, the paper also contributes to the current literature by exploring pedestrians' decision-making process whether to walk or not. Moreover, these results also provide new insights into pedestrians' satisfaction of walk accessibility to metro station that will be helpful for urban planners, engineers and government for proposing guidelines and formulating new strategies encouraging people to walk more.

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