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Prioritizing Attributes for Pedestrian Facility Improvement in a Historically Significant Tier-II Indian City

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Abstract

The paper aims to prioritize attributes for improvement of pedestrian facilities, based on user perceptions, for the City and Ghat (riverside) areas of Varanasi, a historically significant tier-II Indian city. The study areas considered serve different user groups namely commuters and tourists/pilgrims. A paper-pencil based survey instrument was designed to collect importance-performance data, in a five-point Likert-type scale, for attributes related to the existing pedestrian facilities from users. Revised Importance-Performance Analysis (Revised-IPA) with fuzzy C-means clustering was used to identify the factor structure and management schemes for both user groups. The attributes were then prioritized by comparing the obtained factor structure and management schemes. The study was instrumental in understanding and identifying differences in perceptions of commuters and tourists/pilgrims on attributes related to the pedestrian facilities. The results suggest that qualitative aspects (comfort, security and safety) of the pedestrian facility were perceived to be more important than quantitative aspects (pedestrian density) by both the user groups. The priority of attributes for the improvement of existing pedestrian facilities was also determined separately for the City and Ghat areas of the study. Although the methodology presented here is case specific, it can be used to identify differences in user perceptions and priority of attributes while formulating policy measures for the improvement of services in other contexts.

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Keywords: Varanasi; Pedestrian; Ghat; Revised-IPA; Fuzzy C-mean clustering

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1. Introduction

Recent years have witnessed a rapid growth of urban clusters around the globe, particularly in India (The United Nations, 2018) and this trend is likely to increase in the coming years. These urban clusters are centers of higher per capita incomes and higher standards of living (World Bank, 2009). In addition to the growing urban population, the availability of personal motorized vehicles (PMV) at reduced cost and friendly pro-automobile policies of Government, have resulted in an increase in the number of trips made by private vehicles (Ministry of Home Affairs, 2011;Ministry of Road Transport and Highways, 2013). Also, the pedestrian and bicycle facilities have been neglected leading to poor service levels and increased risk of traffic accidents to users of these facilities (Ghate, et al., 2010; Tiwari, et al., 2016). This results in the development of a vicious cycle where commuters are encouraged to own and use PMVs over the Non-Motorized modes of Transport (NMT) such as walking and cycling. Recent studies have indicated a decrease in the share of NMT trips in favour of PMV such as two-wheelers and cars (Tiwari, et al., 2016).

Many urban centers around the world are experiencing high levels of traffic congestion and vehicular emissions. Therefore, the importance of encouraging non-motorized modes, especially for short trips, cannot be over emphasized. Studies indicate that improvement of NMT facilities are likely to result in an increased modal share of NMT leading to lower levels of fuel consumption, CO_2 emissions and improved safety (Tiwari, et al., 2016). Also, good pedestrian facilities are important factors contributing to self-efficacy of a city and thereby encourage heritage tourism (Ginting, 2016). However, with limited resources it is important that facility improvement measures be prioritized. Therefore, the present work aims to prioritize attributes for improvement of pedestrian facilities by assessing their importance and performance with respect to the existing facilities, as perceived by the users. Varanasi, a tier II Indian city where silk weaving and tourism are the main industries, is selected as the study area. The city is considered as the spiritual capital of India and attracts tourists and pilgrims in large numbers. Considering the importance of pedestrian facilities for facilitating modal shift to walking among commuters (Tiwari, et al., 2016) and encouraging heritage tourism (Ginting, 2016), the user perceptions were studied for two distinct parts of the city where pedestrian facilities serve different purposes. The areas are (i) the City area where pedestrian facilities primarily serve commuters and are adjacent to carriageways of high traffic volume, and (ii) the Ghats which are riverfront/ steps leading to the banks of the River Ganges and where pedestrian facilities are primarily used by tourists/pilgrims. The results indicate differences in the users' perception of importance and performance of pedestrian facility attributes for the study areas selected.

The remainder of the paper is organized into four sections. The methodology for prioritizing attributes for pedestrian facility improvement measures is discussed in Section 2. The study area, the city of Varanasi, and details of survey instrument and database development are dealt in Section 3. The results of the analysis followed by a discussion are presented in Section 4. Finally, Section 5 summarizes the conclusion and policy implications of the study along with the scope for future work.

2. Theoretical Background and Methodology

Users' perception on quality of service of pedestrian facilities (environment, security, traffic etc.) is an important aspect which influences their decision to walk (Hodgson, et al., 2004). However, the users' perception on the quality of service is influenced by their satisfaction (Xu, et al., 2007) and it has been established that both importance and performance of certain attributes influence users' satisfaction (Martilla, et al., 1977). Importance-Performance analysis (IPA) is a technique proposed by Martilla and James (1977) to simultaneously analyze both importance and performance of various service attributes and is widely used in the areas of economic planning (Chu, et al., 2000), tourism (Enright, et al., 2004), health care marketing (Hawes, et al., 1985), quality improvement in education (O'Neill, et al., 2004) to mention a few. However, restrictions of the assumptions in IPA were identified by researchers such as Matzler, et al. (2004) and Deng (2007). To overcome the deficiencies associated with the traditional IPA, Deng (2007) proposed a revised version of IPA, which is used in the present study. A brief discussion on Revised-IPA in the context of the present work along with the adopted methodology is described in the subsequent sections.

2.1. Importance-Performance Analysis and shortcomings

Importance-Performance analysis involves the development of a two-dimensional grid with importance and performance of the attributes as the reference axes. The grid is divided into four quadrants using the mean performance and importance. Management schemes for customer satisfaction are prioritized by considering the quadrant to which the respective attributes belong. The management schemes include i) 'concentrate here', (ii) 'low priority', (iii) 'possible overkill', and (iv) 'keep up the good work'. The 'concentrate here' group is the cluster of attributes with high importance but low performance, and therefore, requires immediate attention. The 'low priority' attributes with low performance and importance, also need to be improved, but its priority is lower than 'concentrate here' group of attributes. The attributes falling under 'possible overkill' do not require any improvement rather, it suggests that the users are satisfied with the attributes despite its less importance, and hence, some of the resources may be reallocated to improve other attributes. The management scheme 'keep up the good work' includes the attributes with high importance and satisfactory performance and thus needs to be maintained as it is.

Traditional IPA assumes independence of attribute importance and performance as well as existence of a linear-symmetric relation between attribute-level performance and overall performance of the facility. However, as stated by Matzler, et al., (2004), 'attribute importance can be stated as function of performance'. Also, the 'Three Factor Theory' as proposed by (Kano, et al., 1984) implies nonlinear and asymmetric relation between attribute-level performance and overall satisfaction. Considering these drawbacks of IPA, several revisions for IPA have been suggested (Matzler, et al., (2003); Deng (2007); Caber, et al.,(2012)).

2.2. Revised Importance-Performance Analysis

A Revised IPA which 'integrates three-factor theory and benchmarking' was proposed by Deng (2007). The Three-Factor Theory (Kano, et al., (1984)) classifies the attributes under three categories viz., basic factors, performance factors, and excitement factors. The basic factors are similar to must-be quality elements, and are the minimum requirement to maintain an acceptable level of overall performance. Dissatisfaction in these attributes may have a greater negative impact on the overall performance. The performance factors are similar to one-dimensional quality elements and results in satisfaction when overall performance is high and dissatisfaction when overall performance is low. The excitement factors are similar to attractive quality elements. Deng also proposes the use of natural logarithmic transformation for attribute performance and the subsequent determination of partial correlation with overall customer satisfaction to determine the implicitly derived importance of the attributes. The implicitly derived importance of attributes is then used to determine the factor structure and management scheme of attributes.

2.3. Revised IPA with fuzzy C-means clustering

Typically, the identification of the factor structure and management schemes as described earlier involves the placement of an axis either at the median or mean values of attribute importance and performance. Such placement of axes is a topic of debate over the years. In this regard, Ban, et al. (2016) proposed 'Fuzzy C-means clustering' approach for grouping the attributes in the IPA matrix. This approach generates a membership degree between 0 and 1 to each of the attributes and all the attributes are then clustered based on their highest membership function.

2.4. Prioritization of improvement measures

The present study adopts the rational proposed by Cheranchery, et al. (2018) for prioritizing attributes by comparing the factor structure and management schemes. Therefore, the management schemes shall be considered in the following priority: (1) basic factors clustered as 'concentrate here' (2) basic factors classified as 'least priority' (3) important performance factor under 'concentrate here' (4) excitement factors clustered as 'concentrate here'.

2.5. Methodology

The methodology adopted to perform Revised IPA with fuzzy c-means clustering for prioritizing pedestrian facility improvement measures is discussed below.

Step 1: Transform all performance of attribute (PA) into natural logarithmic form.

$$PA_i \rightarrow ln\,(PA_i) \quad (1)$$

Where,

i : 1, 2, 3,…, n.
PA_i : Performance of i^{th} attribute
n : total number of attributes

Step 2: Perform partial correlation analysis between $ln\,(PA_i)$ and overall performance of the existing pedestrian facility to obtain the derived importance of attributes.

Step 3: Perform fuzzy c-means clustering algorithm proposed by Ban et al. (2016), using users' stated importance of attributes and the implicitly derived importance, to obtain the clusters that indicate the factor structure of pedestrian facility attributes for the users.

Step 4: Perform fuzzy c-means clustering algorithm, using users' implicitly derived importance and performance of attributes, to obtain the clusters indicating management schemes for the attributes of pedestrian facility.

Step 5: Prioritize attributes of pedestrian facility by comparing users' factor structure and management schemes as proposed by Cheranchery et al. (2018).

Figure 1 represents the methodology adopted for the study.

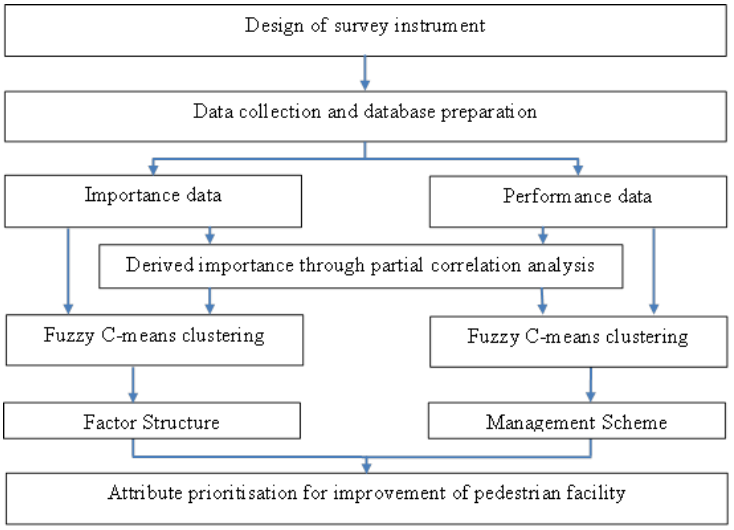

Figure 1 Proposed Methodology: Revised IPA with fuzzy C-means clustering

3. Study Area and Survey Instrument

The present section discusses the particulars of the selected study area, the city of Varanasi and details of the survey instrument and database development adopted for the present study.

3.1. Study area

Varanasi is a tier II Indian city situated on the banks of the River Ganges in the state of Uttar Pradesh, India. The city is considered to be the holiest of the sacred cities by Hindu and Jain pilgrims and attracts a multitude of pilgrims

every year. Considering the type of land use and available transport infrastructure, the city of Varanasi can be demarcated into two distinct zones namely, (i) City area and (ii) Ghat area.

The City area of Varanasi is similar to other Indian cities with its road infrastructure designed to serve the various residential areas, commercial and industrial establishments, recreational areas and institutional areas such as schools, hospitals and government offices. Most parts of the Varanasi City area do not have pedestrian facilities. Where footpaths are existent they may be described as having high pedestrian density, adjacent to heavy vehicular traffic, absence of any barriers, surface condition of moderate quality, narrow width, adequate illumination, insufficient informatory signs, and with poorly located or no crossing facilities.

The Ghat area comprises of the old city of Varanasi with its maze of narrow alleys or 'galis' that wind up to the 'ghats' or ceremonial steps leading to the river Ganges. The alleys being too narrow for cars, can be traversed by foot or are served by cycle rickshaws and auto rickshaws. The Ghats primarily serve the devotees and tourists and host a variety of socio-cultural and religious activities such as festivals, offering rituals, dip in the Ganges, taking a boat ride in the river, selling of silk apparels and brassware, local food stalls, palmistry, and cremation. The walk environment in the Ghat area may be described as having high pedestrian density, poor to moderate surface conditions and cleanliness, insufficient informatory signs, adequate illumination, good interconnectivity between the Ghats, lack of adequate seating and shelter facilities, and presence of stray animals like cows, goats and dogs.

In light of the above aspects, the pedestrian infrastructure of the City and Ghat areas of Varanasi were identified to be distinct and designed to serve different purposes and user categories namely (i) for regular trips by commuters and (ii) for various socio-cultural and religious purposes by tourists/ pilgrims. Therefore, the user perceptions regarding importance and performance of attributes relating to these two pedestrian facilities were likely to be different.

3.2. Survey instrument and database

A paper-pencil based survey instrument was designed to collect responses from pedestrians in City area and Ghat area. While the pedestrian facility in the City area is used for commuting, the facilities in the Ghat area are used for recreational/ socio-cultural purposes. Attributes related to the pedestrian facilities were decided based on literature review (Khisty, (1994); Jaskiewicz, (2000); Gallin, (2001); Sisiopiku, et al., (2007); Kadali, et al., (2016)) and the reconnaissance survey. A few common attributes such as 'security', 'illumination', 'shelter', 'informatory signs', 'surface condition', 'obstruction free walkway', 'pedestrian density', and 'connectivity' were considered for both the facilities. The additional attributes selected for study in the City area comprised of qualitative factors such as quality of crossing facilities, and vehicular speed and volume of adjacent carriageway. These factors are generally adopted in pedestrian level of service analysis (Kadali, et al., 2016). However, the qualitative attributes in the Ghat area were selected considering that the pedestrian facility mainly catered to pilgrims and tourists. Therefore, aspects such as height and tread of steps, interconnectivity of ghats, presence of canteens, toilets, drinking water facilities, stray animals were some of the additional attributes considered for study in the Ghat area.

The list of selected attributes for the City and Ghat areas are presented in Table 1 and Table 2 respectively. A total of 17 attributes were identified for the City area and 18 attributes for the Ghat area.

Table 1 Attributes selected for City Area

No	Attributes	Explanation
A1	Width of Footpath	How wide is the footpath
A2	Surface Condition of Footpath	Condition of the surface on which the pedestrians walk
A3	Barrier between Road and Footpath	Presence of barrier between the pedestrians and the vehicular traffic
A4	Continuity of Footpath	Whether the facility is continuous or discontinuous on a particular route
A5	Obstructions free Footpath	Absence of any obstruction on the existing footpath
A6	Crossing Facility	Availability of safe and proper gaps to cross the road

No	Attributes	Explanation
A7	Frequency of Crossing Facility	How often is the provision given to cross the road
A8	Citywide Coverage of Footpath	Whether the footpath is covered throughout the city
A9	Shelter and Seating at Intermittent Locations	Presence of weather proofing elements and availability of seating arrangements
A10	Illumination on Footpath	Quality of illumination of the streets/ facility after dark
A11	Plants along Footpath	Presence of plants/Greenery along the footpaths
A12	Informatory Signs	Presence of directional signs to inform pedestrians of the routes
A13	Cleanliness and Hygiene	Cleanliness of walking area and effectiveness of drainage system
A14	Security	Presence of Police personnel on or at nearby location
A15	Pedestrian Density	Number of pedestrians per unit time per unit space (level of discomfort experienced based on level of crowding)
A16	Volume of Vehicular Traffic on adjacent road	Number of vehicles passing through carriageway adjacent to the footpath facility
A17	Speed of Vehicular Traffic on adjacent road	Speed of vehicles going past the pedestrians

Table 2 Attributes selected for Ghat Area

No.	Attribute	Explanation
B1	Height of Steps	How high is the step of stair leading to the river
B2	Tread of Steps	How wide is the step of stair leading to the river
B3	Surface Condition of Steps	Condition of the surface on which the pedestrians walk
B4	Handrail	Presence of handrail along stairs to help older citizens, ensure safety etc.
B5	Illumination on Ghats	How illuminated are the streets/ facility after dark
B6	Seating Facility on Ghats	Presence of Benches/ seating facilities
B7	Shelter from Sun and Rain	If facilities are equipped with weather proofing elements or not
B8	Toilet Facility	Presence of toilet
B9	Drinking Water	Presence of drinking water facilities
B10	Canteens/Food Kiosk	Presence of food outlets
B11	Plants on Ghats	Presence of plants/Greenery
B12	Informatory Signs	Presence of directional signs to help users/ visitors
B13	Cleanliness and Hygiene	Presence of clean walking area and good drainage system
B14	Obstructions free Walkway	Absence of any obstructions (vendors, lamp-post, etc.)on the existing walkway
B15	Interconnectivity of Ghats	How connected are the facilities in terms of connections to various riverside destinations (Ghats)
B16	Security	Presence of Police personnel on or at nearby location
B17	Pedestrian Density	Number of pedestrians per unit time per unit space (level of discomfort experienced based on level of crowding)
B18	Stray Animals	Obstruction on the existing footpath by stray animals.

The survey instrument was designed to collect data pertaining to the users' perception towards the importance of attributes (Part A), performance of attributes (Part B), overall performance of the pedestrian facility (Part C), trip

characteristics like trip purpose and travel times (Part D), physical characteristics of the user such as disabilities if any (Part E), and socio-economic characteristics of the individual such as age, gender, education, and income (Part F). The importance and performance of attributes were captured using a five-point Likert-type scale (1 was highly unimportant/ dissatisfying and 5 was highly important/ satisfying). After designing the survey instrument, a pilot study was conducted with 20 users to check for its adequacy. Based on the observations from the pilot study, final modifications were made. After modifying the survey instrument, responses were collected from the pedestrians by trained enumerators using simple random sampling technique. During the survey, responses were collected from 1500 pedestrians (750 each, in Ghat and City areas). They were coded in a digital data base and 1311 refined responses were retained (658 for Ghat and 653 for City area) for the analysis.

4. Prioritizing Attributes for Pedestrian Facility Improvement

The attributes for pedestrian facility improvement were prioritized by considering the factor structure and management schemes obtained using revised-IPA with fuzzy C-means clustering as described in Section 2. The results of the analysis are discussed below.

4.1. Prioritizing attributes for pedestrian facility improvement in City area

The attributes to be prioritized for improvement of pedestrian facility in the City area were identified as explained in the methodology section (Section 2). Initial analysis included a partial correlation analysis of stated importance with the overall performance of facility to compute the derived importance of attributes. Table 3 presents the stated importance, derived importance, stated performance, and their respective normalized values for the attributes. The normalized values of derived importance and performance were then used to determine the factor structure and management schemes for the attributes as discussed in subsequent sections.

Table 3 Importance and performance of attributes for pedestrian facilities in City Area

Sl. No.	Attribute	A	B	C	D	E	F
A1	Width of Footpath	2.873	3.619	0.004	0.039	0.758	0.993
A2	Surface Condition of Footpath	2.309	3.765	0.120	0.943	0.536	0.000
A3	Barrier between Road and Footpath	2.770	3.641	0.009	0.204	0.725	0.949
A4	Continuity of Footpath	2.792	3.491	0.066	0.170	0.955	0.460
A5	Obstructions free Footpath	2.366	3.840	0.012	0.853	0.421	0.921
A6	Proper Crossing Facility	2.801	4.052	0.011	0.155	0.097	0.931
A7	Frequency of Crossing Facility	2.319	3.722	0.083	0.929	0.602	0.314
A8	Citywide Coverage of Footpath	2.299	3.582	0.049	0.961	0.814	0.611
A9	Shelter and Seating at Intermittent Locations	2.274	3.637	0.094	1.000	0.731	0.224
A10	Illumination on Footpath	2.844	4.049	0.078	0.086	0.101	0.362
A11	Plants along Footpath	2.276	3.960	0.081	0.998	0.238	0.331
A12	Informatory Signs	2.752	3.935	0.003	0.233	0.277	1.000
A13	Cleanliness and Hygiene	2.291	4.116	0.102	0.973	0.000	0.157

Sl. No.	Attribute	A	B	C	D	E	F
A14	Security	2.315	3.860	0.048	0.934	0.390	0.613
A15	Pedestrian Density	2.726	3.461	0.020	0.275	1.000	0.858
A16	Volume of Vehicular Traffic on adjacent road	2.897	3.487	0.009	0.000	0.960	0.945
A17	Speed of Vehicular Traffic on adjacent road	2.303	3.619	0.033	0.953	0.758	0.747

A: Stated Performance **B:** Stated Importance **C:** Derived Importance **D:** Normalized Stated Performance **E:** Normalised Stated Importance **F:** Normalized Derived Importance

4.1.1. Factor structure of attributes for pedestrians in City area

The stated importance and implicitly derived importance of various attributes were used to generate the factor structure for the users. The results are summarized in Table 4 showing the membership degrees of each attribute to the four clusters, namely basic factors, important performance factors, excitement factors, and unimportant performance factors (i.e. the attributes with low stated and derived importance as suggested by Tantakasem, et al., (2008). The numbers in bold font in Table 4 indicates the highest value of the membership degree.

Table 4Factor structure with membership degree for attributes of pedestrians in City Area

Attributes	Membership Degree			
	Basic Factors	Important performance Factors	Excitement Factors	Unimportant Performance Factors
Width of Footpath	0.089	0.024	0.038	**0.849**
Surface Condition of Footpath	0.060	0.225	**0.649**	0.066
Barrier between Road and Footpath	0.092	0.023	0.038	**0.847**
Continuity of Footpath	0.088	0.085	**0.491**	0.337
Obstructions free Footpath	**0.844**	0.035	0.032	0.089
Proper Crossing Facility	**0.841**	0.071	0.037	0.051
Frequency of Crossing Facility	0.015	0.034	**0.931**	0.020
Citywide Coverage of Footpath	0.096	0.066	0.258	**0.579**
Shelter and Seating at Intermittent Locations	0.007	0.013	**0.969**	0.011
Illumination on Footpath	0.015	**0.963**	0.016	0.007
Plants along Footpath	0.029	**0.901**	0.054	0.016
Informatory Signs	**0.971**	0.009	0.007	0.014
Cleanliness and Hygiene	0.048	**0.855**	0.071	0.027
Security	**0.376**	0.258	0.208	0.158
Pedestrian Density	0.042	0.021	0.047	**0.890**
Volume of Vehicular Traffic on adjacent road	0.040	0.017	0.034	**0.909**
Speed of Vehicular Traffic on adjacent road	0.066	0.029	0.070	**0.834**

The results provide interesting insights to the factor structure of attributes for pedestrians in the City area. Considering that many initial studies on pedestrian level of service included only quantitative aspects such as pedestrian density, flow rate, and speed in their analysis (Kadali, et al., (2016); Sisiopiku, et al., (2007)), it was interesting to note that 'pedestrian density' was observed as an unimportant performance factor in the present study. This indicates that from a user perspective, quantitative attributes are not the major factors influencing quality of service of the pedestrian facility. This is also supported by studies on pedestrian level of service that consider qualitative factors (safety, security, and comfort) in addition to quantitative factors (Kadali, et al., (2016); Khisty, (1994); Sisiopiku, et al., (2007)). Another interesting observation was that while people perceived presence of police personnel for their security as a basic factor, important aspects related to traffic safety that are considered in most pedestrian level of service studies, such as barrier between footpath and adjacent carriageway, and vehicular speed and volume on adjacent carriageway, were classified as unimportant performance factors by users. This indicates that while pedestrians are probably more careful of their personal safety from delinquents, they are less aware or ignorant of the importance of provision of proper traffic safety measures. Further, it was observed that with regards to provision of crossing facilities, pedestrians perceive provision of suitable and safe gaps more essential than the frequency at which it is provided. It was also observed that absence of obstructions, provision of proper information signs, illumination and a clean walk environment are important attributes for pedestrians. The factor structure is presented in a two dimensional matrix in Figure 2.

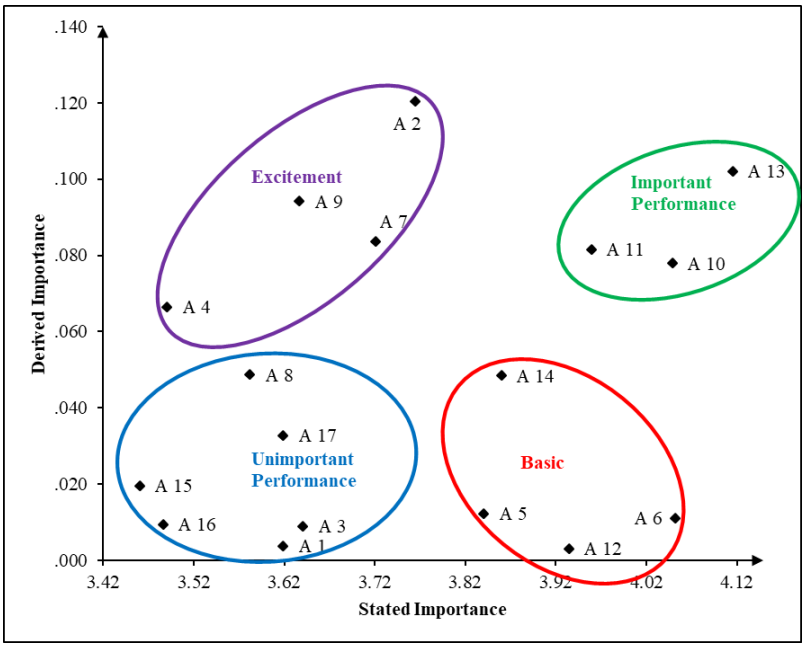

Figure 2 Factor structure of attributes for pedestrians in City Area

4.1.2. Management scheme of attributes for pedestrian facility in City area

The management schemes were identified using fuzzy C-means clustering algorithm as discussed in Section 2. The derived importance of various attributes along with their stated performance was used to identify the management schemes. Table 5 shows the membership degrees of each attribute to the four clusters and the same is also presented in a two dimensional matrix form in Figure 3. The numbers in bold font in Table 5 indicates the highest value of the membership degree.

Table 5 Membership degree of attributes to identify management schemes for City area

Factors	Membership degree			
	Concentrate here	**Keep Up Good Work**	**Possible Overkill**	**Least Priority**
Width of Footpath	0.009	0.040	**0.935**	0.016
Surface Condition of Footpath	**0.855**	0.045	0.025	0.075
Barrier between Road and Footpath	0.002	0.009	**0.984**	0.005
Continuity of Footpath	0.005	**0.975**	0.014	0.005
Obstructions free Footpath	0.078	0.053	0.083	**0.786**
Proper Crossing Facility	0.000	0.001	**0.998**	0.001
Frequency of Crossing Facility	**0.895**	0.018	0.012	0.075
Citywide Coverage of Footpath	0.056	0.013	0.012	**0.919**
Shelter and Seating at Intermittent Locations	**0.993**	0.002	0.001	0.005
Illumination on Footpath	0.006	**0.975**	0.013	0.006
Plants along Footpath	**0.874**	0.018	0.013	0.095
Informatory Signs	0.008	0.025	**0.952**	0.015
Cleanliness and Hygiene	**0.986**	0.003	0.002	0.009
Security	0.050	0.012	0.011	**0.927**
Pedestrian Density	0.022	0.091	**0.844**	0.043
Volume of Vehicular Traffic on adjacent road	0.014	0.070	**0.894**	0.022
Speed of Vehicular Traffic on adjacent road	0.007	0.003	0.003	**0.987**

The management scheme clusters identified for the City area pedestrian facility attributes were studied in light of the presently available pedestrian facilities as discussed in the study area (Section 3.1). The results indicated that users perceived any future intervention for reducing pedestrian density as a possible overkill even though the footpath have high pedestrian densities. This indicates that users, at least in Indian conditions, are not very sensitive to the pedestrian density levels. Another interesting finding was the clustering of important factors related to safety such as provision of barriers, existing vehicular volumes on adjacent carriageways, and provision of proper crossing facilities as ‘possible overkill’ even though the present facilities perform poorly in this regards. However, the qualitative attributes such as provision of plants along sidewalk, cleanliness and hygiene, surface conditions, and provision of intermittent seating and shelter facilities were categorized as ‘concentrate here’ management schemes. These findings indicate that users are more influenced by attributes related to comfort than the more important attributes of safety.

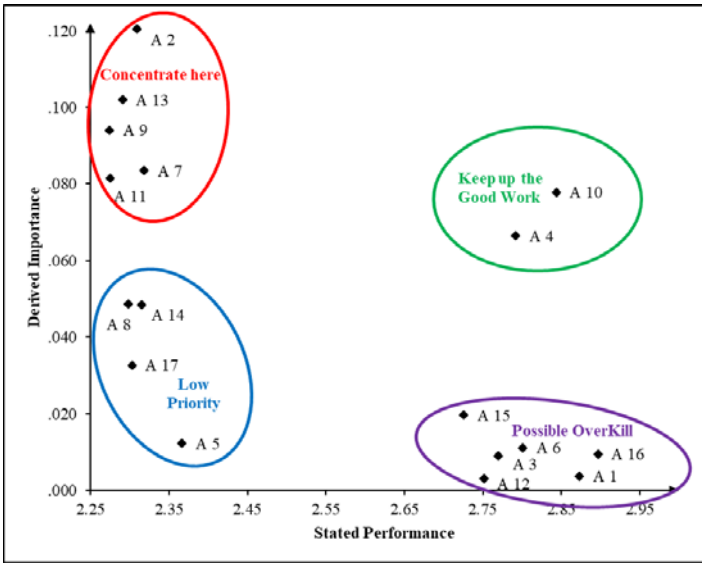

Figure 3Management scheme for attributes of pedestrian facility in City Area

4.1.3. Priority attributes for improvement of pedestrian facility in City area

The priority attributes were identified as described in the subsection 'Prioritization of Improvement Measures' of Section 2. None of the basic factors were clustered under the management scheme 'concentrate here' while two of the basic factors namely, 'obstruction free footpath' and 'security' were identified as 'least priority'. This indicates that the present pedestrian facilities provide satisfactory performance with respect to the basic factors. All the important performance factors other than 'illumination' were classified as 'concentrate here' management scheme. This indicates that most of the performance factors need to be improved to ensure user satisfaction for the existing pedestrian facilities. 'Surface condition of footpath', 'frequency of crossing facility', and 'shelter and seating at intermittent locations' were the excitement factors belonging to cluster 'concentrate here'. Resources may be allocated for the improvement of these attributes, provided the basic and important performance factors are first considered. In summary, the attributes for improvement of pedestrian facility in City area, in order of their priority, were identified as: (1) Obstruction Free Footpath, (2) Security, (3) Cleanliness and Hygiene, (4) Plants along footpath, (5) Frequency of crossing facility, (6) Surface condition of footpath, and (7) Shelter and seating at intermittent locations.

4.2. Prioritizing pedestrian facility improvement measures in Ghat area

The priority attributes for improvement of pedestrian facility in the Ghat area were also identified using revised-IPA with fuzzy C-mean clustering, as discussed for the City area, and the results are presented in this section. The stated importance, derived importance, stated performance and the respective normalized values for the attributes of the Ghat pedestrians facilities are represented in Table 6.

Table 6 Importance and performance of attributes for pedestrian facilities in Ghat Area

Sl. No.	Attribute	A	B	C	D	E	F
B1	Height of Steps	3.578	4.113	0.126	0.049	0.266	0.181
B2	Tread of Steps	3.653	3.313	0.029	0.007	0.946	0.832
B3	Surface Condition of Steps	3.331	4.172	0.153	0.184	0.216	0.000

Sl. No.	Attribute	A	B	C	D	E	F
B4	Handrail	2.494	4.218	0.028	0.645	0.177	0.839
B5	Illumination on Ghats	3.422	4.156	0.137	0.134	0.229	0.107
B6	Seating Facility on Ghats	3.284	4.086	0.017	0.210	0.289	0.913
B7	Shelter from Sun and Rain	2.464	3.434	0.022	0.662	0.843	0.879
B8	Toilet facility	2.006	4.348	0.110	0.914	0.067	0.289
B9	Drinking Water	1.850	4.426	0.004	1.000	0.000	1.000
B10	Canteen/Food Kiosk	2.394	3.586	0.011	0.700	0.714	0.953
B11	Plants on the Ghats	2.195	3.596	0.141	0.810	0.705	0.081
B12	Informatory Signs	2.708	3.395	0.047	0.527	0.876	0.711
B13	Cleanliness and hygiene	2.775	4.368	0.046	0.490	0.050	0.718
B14	Obstructions free Walkway	3.281	3.371	0.053	0.212	0.896	0.671
B15	Interconnectivity of Ghats	3.666	3.393	0.061	0.000	0.878	0.617
B16	Security	2.684	4.208	0.131	0.541	0.185	0.148
B17	Pedestrian Density	3.491	3.249	0.053	0.096	1.000	0.671
B18	Stray Animals	2.388	3.260	0.149	0.704	0.991	0.027

A: Stated Performance **B:** Stated Importance **C:** Derived Importance **D:** Normalized Stated Performance
E: Normalised Stated Importance **F:** Normalized Derived Importance

4.2.1. Factor structure of attributes for pedestrians in Ghat area

The factor structure for pedestrians in the Ghat area was determined using fuzzy C-mean clustering algorithm as described earlier in Section 2. The results are as summarized in Table 7. The numbers in bold font in Table 7 indicates the highest value of the membership degree.

Table 7 Factor structure with membership degree for attributes of pedestrians in Ghat Area

Attributes	Membership Function			
	Basic Factors	Important Performance Factors	Excitement Factors	Unimportant Performance Factors
Height of Steps	0.012	**0.965**	0.016	0.008
Tread of Steps	0.015	0.009	0.016	**0.961**
Surface Condition of Steps	0.024	**0.913**	0.045	0.018
Handrail	**0.988**	0.005	0.002	0.005
Illumination on Ghats	0.003	**0.990**	0.005	0.002
Seating Facility on Ghats	**0.882**	0.038	0.022	0.059
Shelter from Sun and Rain	0.034	0.018	0.025	**0.923**
Toilet facility	0.096	**0.819**	0.048	0.037
Drinking Water	**0.900**	0.042	0.020	0.038
Canteen/Food Kiosk	0.151	0.056	0.063	**0.730**
Plants on the Ghats	0.021	0.077	**0.861**	0.041

Attributes	Membership Function			
	Basic Factors	Important Performance Factors	Excitement Factors	Unimportant Performance Factors
Informatory Signs	0.003	0.002	0.004	**0.991**
Cleanliness and hygiene	**0.868**	0.072	0.024	0.036
Obstructions free Walkway	0.010	0.008	0.017	**0.965**
Interconnectivity of Ghats	0.026	0.024	0.052	**0.898**
Security	0.001	**0.998**	0.001	0.000
Pedestrian Density	0.022	0.019	0.044	**0.915**
Stray Animals	0.012	0.028	**0.926**	0.033

The results indicate that pedestrian density was perceived as unimportant performance factor by pedestrians of Ghat areas, similar to the finding in City area. This reinforces the idea that pedestrian density is not likely to be perceived as an important attribute influencing service quality of pedestrian facilities, irrespective of user segment, in India. Also, the findings indicate that in addition to security, pedestrians also perceive attributes related to comfort such as cleanliness, availability of seating facilities, surface condition of footpath, and presence of toilet and drinking water facilities as important factors influencing the quality of service of pedestrian facilities. The factor structure is presented in a two dimensional matrix in Figure 4.

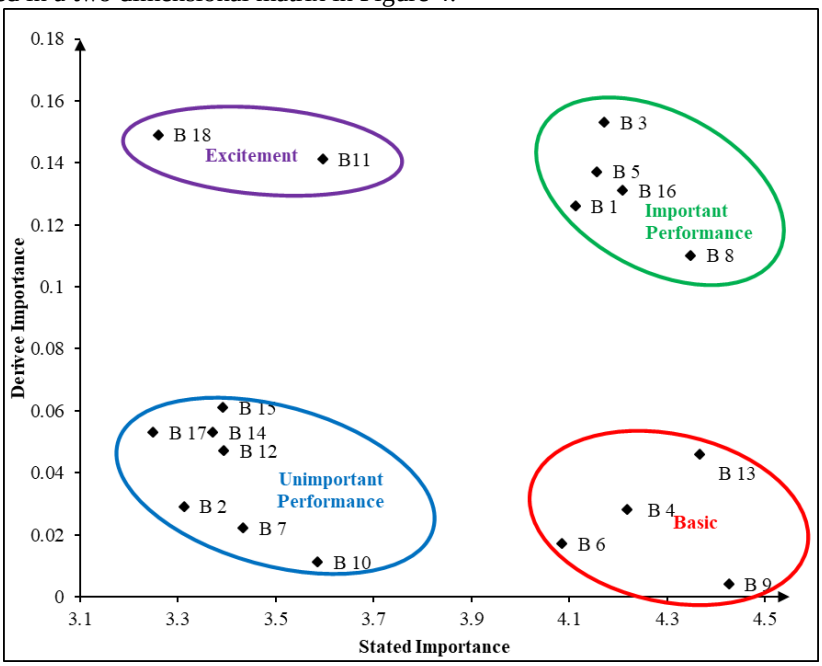

Figure 4 Factor structure of attributes for pedestrians in Ghat Area

4.2.2. Management scheme of attributes for pedestrian facility in Ghat area

Management schemes for the attributes of pedestrian facilities in the Ghat area were also identified. Table 8 shows the membership degrees for each factor to the four clusters. The clustering of various attributes is presented in a two dimensional matrix form in Figure 5. The numbers in bold font in Table 8 indicates the highest value of the membership degree.

Table 8 Membership degree of attributes to identify management schemes for Ghat area

Attribute Name	Membership Function			
	Concentrate Here	Keep up Good Work	Possible Overkill	Least Priority
Height of Steps	0.024	**0.923**	0.040	0.014
Tread of Steps	0.019	0.036	**0.902**	0.044
Surface Condition of Steps	0.036	**0.929**	0.023	0.012
Handrail	0.003	0.002	0.006	**0.989**
Illumination on Ghats	0.000	**1.000**	0.000	0.000
Seating Facility on Ghats	0.036	0.049	**0.767**	0.148
Shelter from Sun and Rain	0.001	0.000	0.001	**0.998**
Toilet facility	**0.785**	0.063	0.048	0.104
Drinking Water	0.109	0.057	0.104	**0.730**
Canteen/Food Kiosk	0.011	0.007	0.020	**0.962**
Plants on the Ghats	**0.976**	0.011	0.006	0.008
Informatory Signs	0.080	0.060	0.183	**0.677**
Cleanliness and hygiene	0.082	0.068	0.242	**0.608**
Obstructions free Walkway	0.020	0.036	**0.897**	0.047
Interconnectivity of Ghats	0.027	0.078	**0.853**	0.042
Security	**0.689**	0.190	0.061	0.060
Pedestrian Density	0.005	0.012	**0.973**	0.010
Stray Animals	**0.935**	0.035	0.014	0.017

The findings indicate that interventions to reduce pedestrian density were clustered as ‘possible overkill’ similar to the observation in the City area. This confirms the inference that quantitative aspects were mostly less important than qualitative aspects such as safety, comfort and convenience for these users. With regards to qualitative attributes, the results indicate the requirement of interventions to improve security, toilet facilities and the walk environment (reduction of stray animals and more plants). The other findings from the study are in agreement with the quality of attributes presently available for pedestrians in the Ghat area.

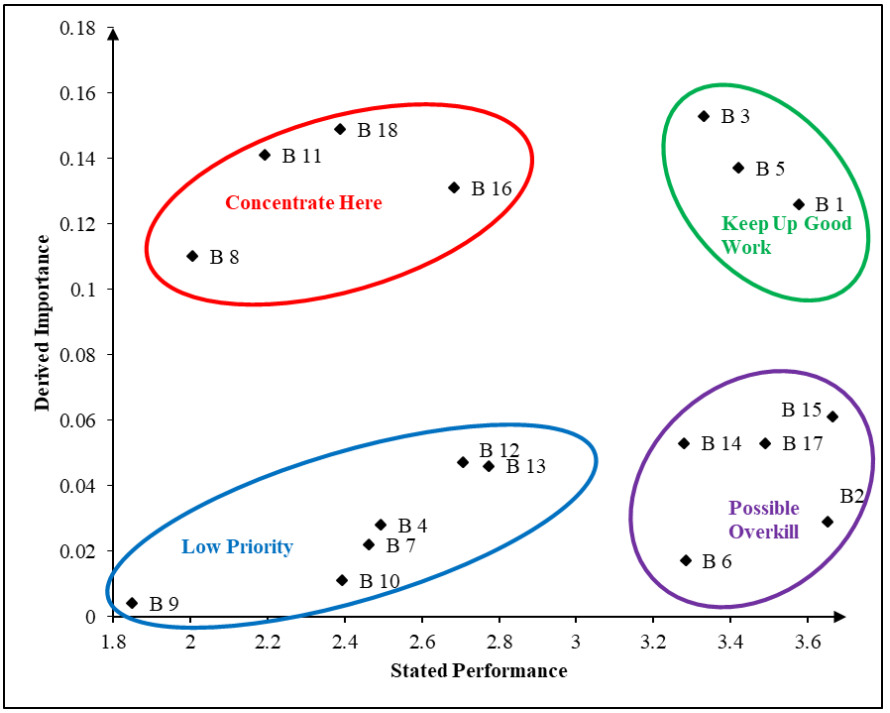

Figure 5 Management scheme for pedestrian facility in Ghat Area

4.2.3. Priority attributes for improvement of pedestrian facility in Ghat area

The priority areas for improvement of pedestrian facility in the Ghat area were identified as explained in the subsection 'Prioritization of Improvement Measures' of Section 2. Among the four attributes constituting the basic factors, no attribute was clustered to the management scheme 'concentrate here', but 'cleanliness and hygiene', 'drinking water', and 'handrails' were basic factors with the 'least priority' management scheme. Since these attributes are basic factors, their absence could result in user dissatisfaction and therefore their present performance needs to be improved. Majority of the performance factors were falling under the scheme 'keep up good work', except for the attributes 'toilet facility' and 'security' which falls under the scheme 'concentrate here'. These attributes need to be improved as the performances of these factors are linearly and symmetrically related to user satisfaction. The excitement factors 'plants on the Ghats' and 'stray animals' were clustered with the scheme 'concentrate here'. These are areas of improvement to be considered after the basic and performance factors have been considered. In summary, areas of intervention for pedestrian facility in Ghat area in the order of priority were identified as: (1) Cleanliness and hygiene, (2) Drinking Water, (3) Handrail, (4) Security, (5) Toilet facility, (6) Plants on the Ghats, and (7) Stray Animals.

4.3. Discussion

The results of analysis indicate differences in the factor structure and management schemes for the common attributes of the two pedestrian facilities considered. Accordingly, the priority attributes for improvement of the two facilities also differed. A comparative study of the obtained results is discussed in this section.

4.3.1. Factor structure of attributes

The factor structure of pedestrians for the common attributes between the City area and the Ghat area is provided in Table 9.

Table 9 Comparison of factor structure

Attributes	City Area	Ghat Area
Surface condition	Excitement	Important Performance
Illumination	Important Performance	Important Performance
Seating facility	Excitement	Basic
Shelter facility	Excitement	Important Performance
Plants	Important Performance	Excitement
Informatory signs	Basic	Unimportant Performance
Cleanliness and hygiene	Important Performance	Basic
Obstruction free walkway	Basic	Unimportant Performance
Interconnectivity	Excitement	Unimportant Performance
Security	Basic	Important Performance
Pedestrian Density	Unimportant Performance	Unimportant Performance

Comparison of the factor structures indicates some interesting observations. Basic factors, performance factors and excitement factors were found to be different for users of both the facilities.

- It was observed that some attributes such as 'illumination', 'cleanliness and hygiene', and 'security' were either basic factors or important performance factors for both user groups. This indicates the importance of these attributes for a pedestrian facility serving either commuters or tourists/pilgrims and the need to ensure their satisfactory performance.
- Attributes such as 'surface condition', 'shelter and seating at intermittent locations' were basic/ important performance factors for pedestrians in Ghat area as opposed to excitement factors for users of city pedestrian facilities. Good surface conditions and intermittent shelter/seating areas are important attributes for pedestrian facilities serving various socio-cultural purposes and where walking distances are likely to be higher.
- 'Informatory signs' and 'obstruction free walkway' were perceived as unimportant factors by users of Ghat pedestrian facility. The same factors were identified as basic factors for City pedestrians, indicating that these are important attributes likely to influence commuter satisfaction.
- 'Plants' on walkway was excitement factor for users of pedestrian facilities in Ghat areas but important performance factors for pedestrians in City area.
- Ghat users considered 'interconnectivity' of walkways as less important performance factors while City users perceived the same as excitement factors. Thus, interconnectivity of walkways is an important attribute for pedestrians in City areas when overall performance of pedestrian facility is satisfactory.
- Lastly, 'pedestrian density' was identified as unimportant performance factor by users of both facilities indicating that they do not perceive crowding as an important attribute. Also considering that the same attribute fell under the 'possible overkill' management scheme for both study areas, it is likely that the users do not perceive pedestrian density as a factor critically influencing walking as their mode choice.

4.3.2. Management scheme for pedestrian facilities

To compare the pedestrian facilities in the City and Ghat area, the identified management schemes for attributes were categorized using their respective factor structure and are presented in Table 10 and Table 11.

A major finding of the present study was that users perceived interventions with regards to qualitative attributes such as comfort, security and safety more necessary when compared to quantitative aspects such as pedestrian density for both facilities. Also, it was observed that attributes categorized under 'concentrate here' management scheme were mostly important performance factors and/or excitement factors. The basic factors were clustered as 'least priority' and/or 'possible overkill'. This indicates that the present pedestrian facilities cater to the basic factors satisfactorily for both the City and Ghat area. However, the satisfaction of users may be improved by reallocating

the resources from the unimportant performance factors under the management scheme 'possible overkill' to the attributes in the scheme 'concentrate here' as stated in the section 4.1.2 & 4.2.2 in the present study.

Table 10 Management schemes with factor structure for pedestrian facilities in City Area

Factor Structure	Attribute	Management Scheme
Basic factors	Obstructions free Footpath	Least Priority
	Proper Crossing Facility	Possible Overkill
	Informatory Signs	Possible Overkill
	Security	Least Priority
Important performance factors	Illumination on Footpath	Keep Up Good Work
	Plants along Footpath	Concentrate here
	Cleanliness and Hygiene	Concentrate here
Excitement factors	Surface Condition of Footpath	Concentrate here
	Continuity of Footpath	Keep Up Good Work
	Frequency of Crossing Facility	Concentrate here
	Shelter and Seating at Intermittent Locations	Concentrate here
Unimportant performance factors	Width of Footpath	Possible Overkill
	Barrier between Road and Footpath	Possible Overkill
	Citywide Coverage of Footpath	Least Priority
	Pedestrian Density	Possible Overkill
	Volume of Vehicular Traffic on adjacent road	Possible Overkill
	Speed of Vehicular Traffic on adjacent road	Least Priority

Table 11 Management schemes with factor structure for pedestrian facilities in Ghat Area

Factor Structure	Attribute	Management Scheme
Basic factors	Handrail	Least Priority
	Seating Facility on Ghats	Possible Overkill
	Drinking Water	Least Priority
	Cleanliness and hygiene	Least Priority
Important performance factors	Height of Steps	Keep Up Good Work
	Surface Condition of Steps	Keep Up Good Work
	Illumination on Ghats	Keep Up Good Work
	Toilet facility	Concentrate here
	Security	Concentrate here

Factor Structure	Attribute	Management Scheme
Excitement factors	Plants on the Ghats	Concentrate here
	Stray Animals	Concentrate here
Unimportant performance factors	Tread of Steps	Possible Overkill
	Shelter from Sun and Rain	Least Priority
	Canteen/Food Kiosk	Least Priority
	Informatory Signs	Least Priority
	Obstructions free Walkway	Possible Overkill
	Interconnectivity of Ghats	Possible Overkill
	Pedestrian Density	Possible Overkill

5. Conclusion

Using revised-IPA with fuzzy C-means clustering the present study prioritizes attributes for improvement of the pedestrian facility in the City and Ghat areas of Varanasi. In addition, the study identified differences in user perceptions on attributes related to pedestrian facilities between commuters and tourists/ pilgrims. This comparative study of factor structures and management schemes suggests that qualitative aspects such as comfort, safety and security are perceived to be more important than quantitative aspects such as pedestrian density by both user groups. Thus the results further reconfirm the importance of considering both quantitative and qualitative aspects of pedestrian facility while determining its level of service.

In terms of case specific findings, it was observed that pedestrians in the City area perceived attributes related to security and comfort (walk environment, surface conditions, and illumination) more important than safety aspects (vehicular volumes and speeds on adjacent carriageway, presence of barrier). The results suggest that commuters lack awareness on concepts of traffic safety and regard walking comfort as a more important attribute. With regards to prioritization of attributes, ‘obstruction free footpath’, ‘security’, and ‘cleanliness’ were identified as top priority attributes for improvement of pedestrian facilities in the City area and ‘cleanliness’, ‘provision of drinking water’, and ‘handrails’ were the attributes identified for the Ghat area. The findings and recommendations from the present work could also help to formulate policy measures for improvement of the overall pedestrian facility in Varanasi. However, further investigation to understand various improvement measures along with the derived benefits and the impact of improvement on the pedestrian facility are required. Although the findings from the present study are case specific, the work is expected to encourage policy makers to apply similar approaches for formulating policy measures for improvement of services in other contexts.

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