An Approach of Examining Service Condition of Sidewalk Facility in Urban Area

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Abstract: The paper documents a rational approach for prioritizing the intervention areas for conducive improvement of sidewalk facility with reference to an urban area. In this aspect, a set of attributes describing the existing sidewalk facility is ranked as per their current service condition from perspective of pedestrian's perception. The pedestrian's perception on attributes is collected on Likert-scale and is analyzed using a multi-criteria ranking method called Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The work is demonstrated by considering the existing sidewalk facility provided across the geographic area of Bhubaneswar City, India. The work reveals that an immediate intervention must be paid for improvement on attributes such as ramp-facility, sufficient width of sidewalk, sign-board for pedestrians guidance, guard-rail. The work also reveals that the current condition of street-light is the best-performing attribute among all followed by road-surface quality of sidewalk facility.

Keywords: Sidewalk facility, ranking-method, TOPSIS.

1. Introduction

In recent times, importance of walking has gained its prominence in context of urban mobility and policy analysis. With reference to an urban area, walk-mode is considered to be an environmental friendly and also a sustainable option for trip makers. Often, therefore transport policies are shifting to include new objectives, where walking is given preference and urban development is made with a more people-centric vision. Walking has its intrinsic benefits such as improvement of urban mobility and reduction in air and noise pollution. A friendly walking environment in urban area triggers many direct and indirect benefits such as proper access to public transport service, reduction in social cost and prevents many health related problems through active-walk etc. (Frank et al., 2004; Forsyth, 2009).

Walk-mode is found to be one of the most suitable forms of transport in urban India. Over two thirds of all trips in small sized urban area are made by non-motorised transport such as bicycle and walk-mode (Majumdar and Mitra 2015). Walk mode often stands as a viable transport opportunity for low-income urban commuters (Tiwari 2001; Srinivasan and Rogers 2005). Rahul and Verma (2014) indicated that more than 50% of the total trips in Bangalore city,

India have at least one leg with walk-mode. The reason may be attributed to its inherent advantages such as being feasible for shorter distance and dense urban environment (Rastogi, 2011). Walk-mode has gained a prominence in urban mobility studies and policy analysis due to its potential as a worthwhile strategy to deal with urban non-sustainability (Lamíquiz and López-Domínguez, 2015). However, the propensity to undertake walk mode is gradually diminishing. A cursory glance at the plausible reasons for decreasing the attractiveness of walk mode may be attributed to several deficiencies such as poorly designed of pedestrian infrastructure and sidewalk facilities (Wilbur Smith Associates 2008), auto-oriented policies (Rahul and Verma, 2013), absence of designated sidewalk, discontinuous and/or mostly un-segregated side-walk facility (Rastogi, 2011), absence of traffic furniture (Rahul and Verma, 2013) etc. Even with the provision of sidewalk facilities, pedestrian are sometimes forced to share space with the motorized traffic due to encroachment from hawking activities on the sidewalk (Laxman et al., 2010). Many previous studies (Crane, 2000; Ewing and Cervero, 2001; Frank and Engelke, 2001; Handy, 1996) also revealed that these deficiencies of side-walk facilities were having negative influence on its desired usage. Besides, the biased focus on auto-oriented policy and ignorance towards pedestrian-oriented policy creates an unsafe walk-environment. In order to overcome the aforementioned deficiencies, it is important to have a thorough understanding on attributes being perceived by pedestrian and their existing condition. The present work fulfils this research needs by ordering attributes as being perceived by pedestrian.

The guidelines for designing pedestrian facilities given by the Highway Capacity Manual (HCM) 2010 as well as the Indian Roads Congress (IRC 103:2012) suggest the use of concept called Level of Service (LoS) for evaluating its existing service condition in general and sidewalk facility in particular. Both the afore-mentioned guidelines use fundamental characteristics of the pedestrian-flow to measure the LoS, which is primarily quantitative in nature. But, in order to promote a safe and conducive walk-environment, road user's perception on various attributes describing a sidewalk facility must be taken into account. In this regard, a thorough understanding on performance of these attributes is imperative in light of road users' perception. Quite an often lack of proper understanding on such attributes leads to non-uniform and unplanned pedestrian oriented developments (Rahul and Verma, 2013). Therefore, in the present study a scientific approach has been demonstrated to examine the attributes of sidewalk facility by ordering them as per their existing service condition using pedestrian's perceived observations. The ordering of attributes is carried out using a ranking method called TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), which was proposed by Hwang and Yoon (1981). The measure of TOPSIS scores of attributes gives an impression of overall performance of sidewalk facility and helps to prepare a rank-order of attributes as per their improvement need. Though this rank-order of attributes is a relative measure, yet it helps transportation planners and policy makers with a notional guideline for identification of intervention areas. In this work, perceived observations on various attributes are collected on a rating scale, which is ordinal in nature. Likert scale (Likert, 1932) is used to elicit the behavioral datasets. The work is demonstrated by evaluating the existing condition of sidewalk facility in Bhubaneswar city, India.

2. Study Approach

The behavioural response on survey attributes collected using Likert Scale is evaluated by Multi-Criteria Decision Making (MCDM) tool. In evaluation process of the existing condition of

sidewalk, ordering of sidewalk attributes from the worst-performing to the best-performing is prepared. The MCDM is a tool that searches for the best (or the worst) alternative among a set of feasible alternatives. In the context of present study, individual survey attributes are considered as alternative and scores obtained from Likert scale survey is considered as ordering criteria. In this study, an attribute could assume any integer value between scale value 1 and 7, where the scale represents a monotonically increasing level-of-agreement. Numerous ranking methods such as Relative to an Identified Distribution Integral Transformation (RIDIT), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Grey Relation Analysis (GRA) are available in literature of MCDM, where observations collected from Likert scale survey can be used. But, the scope of this study is to consider TOPSIS (Hwang and Yoon, 1981) method only. The basic concept of this method is that the best perceived attribute should have the shortest distance to the positive ideal-solution and the farthest distance from the negative ideal-solution (Triantaphyllou, 2000) in an n-dimensional Euclidean space, where n is the number of attributes. The positive ideal-solution is considered to be the attributes that has the best values possible for all considered criteria; whereas the negative ideal-solution is considered to be the attributes that has the worst values (Sarraf, 2013) attainable for all considered criteria. Here, the TOPSIS method is employed to determine Performance Indexes of attributes describing the sidewalk facility, which act as marker of the performance i.e. their current service condition. The attribute found to be worst in performance is ordered with first rank and thereby requires immediate intervention; and the attribute found to be best in performance is ordered with the last rank and thereby requires not at-all intervention. This ordering could help to prepare a priority order, which may be useful for addressing rational policy for conducive improvement of sidewalk facility. The procedure followed in TOPSIS method is narrated step by step.

Step 1: In TOPSIS method, initially a decision matrix consists of a set of alternatives and a set of criteria needs to be created as following,

$$d = \begin{bmatrix} f_{11} & \cdots & f_{1n} \\ \vdots & \ddots & \vdots \\ f_{m1} & \cdots & f_{mn} \end{bmatrix} \quad (1)$$

for *n* number of alternatives and *m* number of criteria. As already mentioned, survey attributes are considered as alternatives and scores (such as *1, 2,…., 7*) obtained from Likert scale are considered as set of criteria.

Step 2: The elements in the decision matrix are squared and the summation for each scale point are calculated as follows, $\sum_{j=1}^{m} {f_{ij}}^2$ for $j = 1,2,3 \ldots, m$ and then normalized values of all elements of the decision matrix are calculated as follows

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{J} {f_{ij}}^2}} \quad (2)$$

for all *j=1,2,3,…,m and i=1,2,3,…,n*

Step 3: Normally, weights are associated with each attribute denoting their relative importance with respect to each other. The weighted normalized matrix is then calculated with elements x_{ij} as follows

$$x_{ij} = w_{ij} \times r_{ij} \quad (3)$$

In a Likert survey, the weights are equal for all scale points denoting equal probability of being chosen by a respondent.

Step 4: Then it is to be decided, which attributes constitute the positive ideal solution and which attributes constitute the negative ideal solution. Let *J* be the set of benefit criteria, and *J'* be the set of negative attributes. Then the positive ideal solution set is given by

$$A^* = \{V_1^*, \ldots., V_n^*\} \quad (4)$$

$$V_j^* = \{max_i(V_{ij})\ if\ j \epsilon J; min_i(V_{ij}) if\ j \epsilon J'\} \quad (5)$$

and the negative ideal solution set is given by

$$A' = \{V_1', \ldots., V_n'\} \quad (6)$$

$$V_j' = \{min_i(V_{ij})\ if\ j \epsilon J; max_i(V_{ij}) if\ j \epsilon J'\} \quad (7)$$

Step 5: The separation measures from positive and negative ideal solutions are required to be calculated for each attribute as follows,

$$S_j^* = \left[\sum_j (V_j^* - V_{ij})^2\right]^{\frac{1}{2}} \text{ for positive ideal solution} \quad (8)$$

$$S_j' = \left[\sum_j (V_j' - V_{ij})^2\right]^{\frac{1}{2}} \text{ for negative ideal solution} \quad (9)$$

Step 6: The relative closeness C_i^* to ideal solution is then calculated using the following formula,

$$C_i^* = \frac{S_i'}{S_i^* + S_i'} \quad (10)$$

The areas are then prioritized in the ascending order of their C_i^* values. This means that less is the relative closeness of a survey attribute to an ideal solution, the more is the priority for its improvement. The overall approach demonstrated in this work is illustrated using the given schematic diagram.

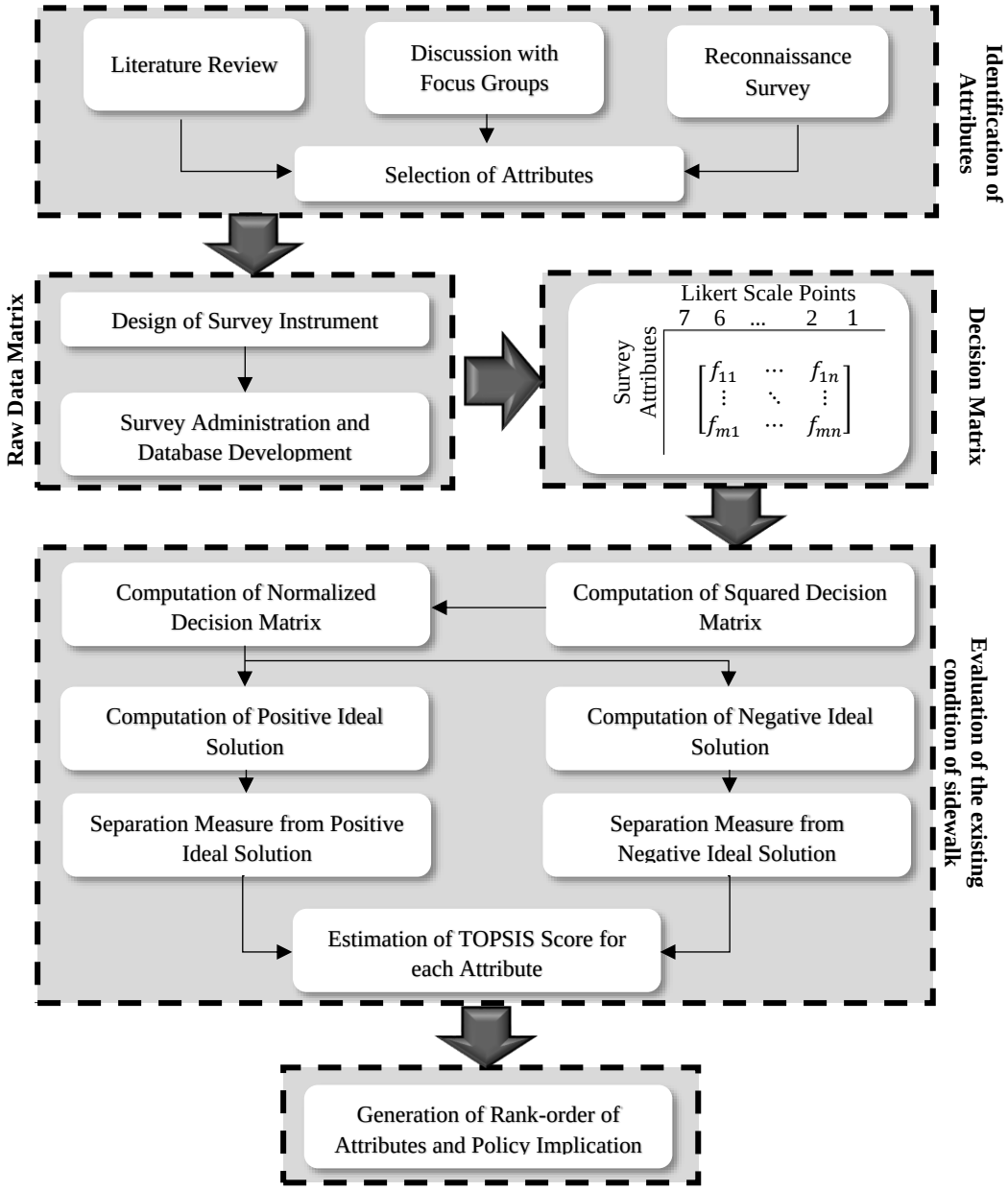

Figure 1. Flowchart of the Study Approach

3. Design of Survey Questionnaire and Datasets Development

As mentioned in Section 1, the present work is demonstrated by examining the existing condition of sidewalk facility in Bhubaneswar City, India. In Bhubaneswar, about 8% of the total area is meant for transportation sector. Within the urban area of the city, about 55% commuters prefer to use personalized vehicles; whereas about 25% commuters prefer to use public (such as city bus) and para-public (such as shared-auto) transportation service. Walk mode is found to be the primary access-mode for public and para-public transportation service, where urban commuters are mostly found to use city's existing sidewalk facility to access those services.

In order to identify relevant survey attributes of the existing condition of sidewalk facility, a thorough literature review was initially carried out. Many studies have identified attributes such as road surface (Rastogi and Rao, 2003), width-of-sidewalk (Parida and Parida, 2007), presence of ramp facilities (Agarwal et al., 2010), sidewalk shelters (Tiwari, 2002) and safety from vehicular traffic (Mohan, 2002) etc., which are appropriate for evaluation of sidewalk facilities in Indian condition. Traffic calming measures such as speed breakers or bollards have also been considered as important attributes in order to account for safety while using the sidewalk facility (Huang et al., 2000; Elvik, 2001; Abdul Ghani et al. 2015). Various other studies (Seattle DoT, 2011; Hawaii DoT, 2013) also highlighted the importance of curb cuts and ramps, seating facilities, guard rails etc. for proper design of sidewalk facility. But none of these studies considered the influence of pedestrian furniture such as seating facility, shelter and information dissemination boards alongside of sidewalk facility. The present study takes an attempt to investigate the current status of such attributes for examining condition of sidewalk facility. The final selection of these attributes was done only after thorough literature review and discussion with some focus groups in Bhubaneswar city. The Table 1 lists an array of attributes considered in this study.

Table 1. Attribute Codes describing Sidewalk Facility and their Statements

Codes of Attributes	Statement
RoW	There is sufficient pedestrian width (i.e. RoW) on the sidewalk
WG	The gradient of the walking-path makes walking experience comfortable
RS	The quality of road-surface is satisfactory for walking
RF	Ramp facility is available in case level change for cross-streets
SB	Sign-board for safe and convenient movement is properly and adequately placed, and they are also clearly visible
TS	Temporal shelter from natural hazard (from Sun rays, rain) are available alongside of sidewalk
SF	Dedicated seating facilities like benches are available alongside of the sidewalk.
GR	Sufficient guard rail is in place alongside of sidewalk.
LF	Adequate street-light facility is available
TC	There are traffic-calming measures such as raised-paving at crossing locations

A survey questionnaire consists of three section is designed to collect responses from pedestrian. The first section records survey respondents' socio-demographic information; whereas the second section records trip related information. In third section, the perception of a survey respondent on sidewalk facility attributes is recorded. In order to record perception response on survey attributes, a Likert scale is found to be suitable. Likert scale is an ordinal

scale, which is used to record qualitative data such as user's perception, satisfaction, and importance. In a Likert scale survey, respondents are required to indicate their levels of agreement or satisfaction towards a series of statements. Each degree of agreement (say satisfaction) or disagreement (say dissatisfaction) is then tagged with a numeric value on a predetermined 7-point scale. This scale is expected to elicit the survey responses with reasonable precision (Wu, 2007). The attributes are described to respondents in such a way that the level-of-agreement to a statement of survey attribute can be recorded. A paper-pencil based face-to-face survey was conducted across various locations of the city of Bhubaneswar between August and November, 2015. The survey was carried out on random sampling basis, where interception of a survey respondent is almost equally likely. Initially, over 700 pedestrians were intercepted to participate in the survey; but a total of 532 complete observations were finally taken into account for analysis.

4. Analysis, Results and Policy Implication

A preliminary observation on the datasets shows that almost 53% of the respondents are between age group of 20 and 35 years indicating that walk mode is well-accepted in this age group. But, it is found to be a less popular (24%) among the age group of 36-55 years. However, the proportion of commuters below age of 20 years and above age of 55 years is found to be significantly as low as 17% and 6% respectively. It is also observed in the datasets that majority (about 83%) of the respondents is captive and they use the existing pedestrian facility for accessing city bus services. Only a minor proportion of respondents (about 17%) are choice rider, who still have option for alternative personalized mode for their reported trips. The datasets also show that average frequency of using walk-facility for accessing city bus services is about 8.46 times per week. This could be explained in a way that on an average walk-mode is used at least once in a day by city commuters. The demographic characteristics of the datasets is tabulated in Table 2.

Table 2. Demographic characteristics of the respondents by various categories

Gender	
Male	65%
Female	35%
Age	
Less than 20	17%
20-35	53%
36-55	24%
Above 56	6%
HH Car Ownership	
1	6%
0	94%
Captive Riders	83%
Choice Riders	17%
Number of trips using walk mode per week	8.46

The responses elicited from Likert scale survey reveal respondent's satisfaction level (as shown in Figure 2) towards various survey attributes considered in the study. For preliminary

purpose, the agreement levels of 5 or more may be considered as gross agreement, and disagreement levels 3 or less may be considered as gross disagreement. The rating scale of 4 signifies neutrality.

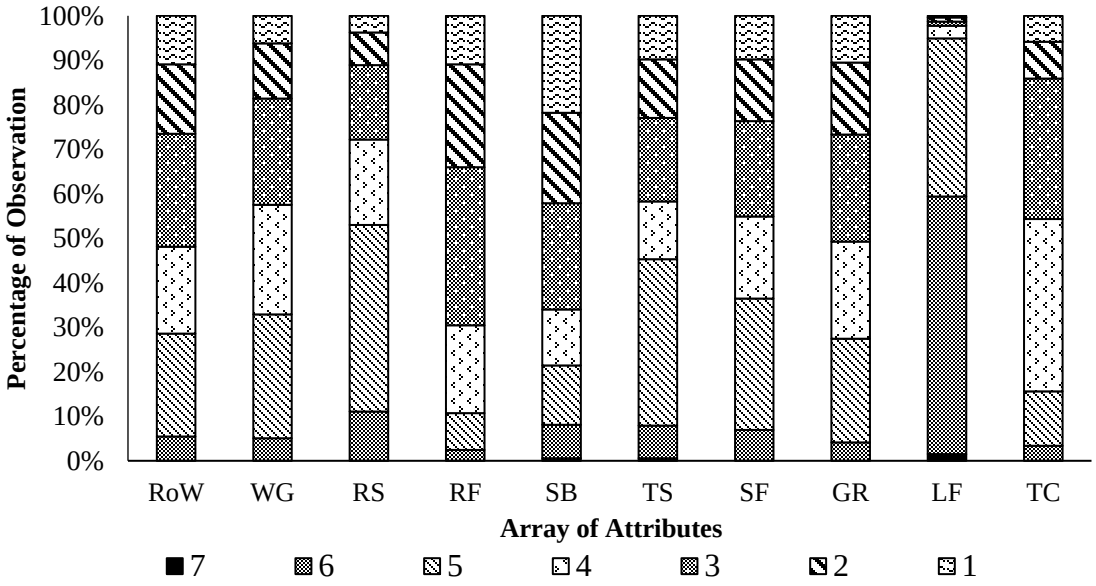

Figure 2. Summary of pedestrians' ratings for various pedestrian facility attributes

The scores of satisfaction is found to vary between 1 and 6 with only 2.63% of the respondents opting for strongly agreeing (rating point 7) with the statements A large proportion of the respondents (57.89%) agreed that lighting facility (LF) is adequately present on the street indicating that condition of the street lights in Bhubaneswar are quite satisfactory. The condition of the road-surface (RS) is also found to be grossly satisfactory to 42% respondents. Ratings on the lower side are observed for ramp facilities (RF). Similar findings are also evident for sign boards (SB). At several locations, the pedestrian pathways are not adequately wide, which is reflected by the fact that 71% respondents showed their disagreement towards the width of sidewalks.

As already mentioned in section 2.0, the attributes under study are treated as alternatives; whereas the different agreement levels of a statement of an attribute are selection criteria. The TOPSIS method is carried out with the objective of maximizing the agreement levels (i.e. 4 to 7) considering them as positive ideal-solutions (*J*) and minimizing the agreement levels (i.e. 1 to 3) considering them as negative ideal-solutions (*J'*). On the basis of these objectives, TOPSIS score (C_i^*) is measured against each of the sidewalk facility attributes. The score values of attributes indicate the actual performance index; but the rank-order of attributes prepared using TOPSIS scores is merely a relative measure. It only helps to prepare an order of attributes from the worst-performing to the best-performing. Table 3 presents the TOPSIS scores of all attributes and their order.

It is observed from Table 3 that pedestrian rate the condition of ramp facility (RF) as poorest among all attributes as it is having the lowest C_i^*measure. Similar type of observation is also found on raw observations (Figure 2) obtained from the Likert Scale survey, where about 69% of the respondents were seen having a gross disagreement towards current condition of the existing

ramp facility. Indeed, it is required to mention that almost no proper ramp facility in sidewalk is observed in Bhubaneswar.

Table 3. Service Condition of Attributes obtained from TOPSIS

Codes of Attributes	*J*	*J'*	*TOPSIS SCORES* (C_i^*)	Order
RoW	1.39905	0.24827	0.26262	3
WG	1.33677	0.46024	0.33665	6
RS	1.23665	0.70752	0.40483	9
RF	1.54377	0.17301	0.21225	1
SB	1.39205	0.16939	0.22819	2
TS	1.16291	0.47995	0.37333	8
SF	1.35112	0.32734	0.29748	5
GR	1.40194	0.27433	0.27199	4
LF	0.54656	2.56578	0.74559	10
TC	1.38291	0.6353	0.36563	7

The only attribute being found as best-performing is street-light, which is having the TOPSIS score closer to unity. The TOPSIS scores of all other attributes are found to be closer to 0, except road surface attribute. TOPSIS scoring closer to zero indicates that attributes such as sign-boards, right-of-way, guard rails, seating facilities, traffic-calming measure etc. are not in good service condition. It may be justified by the fact that sidewalks in Bhubaneswar are often found to be discontinuous with no proper transition from kerb to adjacent road. In some areas, the width of sidewalk is not uniform and many often width is perceived as inadequate. Besides, encroachment to sidewalk by road-side vendors creates obstructions and bottleneck for smooth flow of pedestrian. In many places around the city, absence of guard rails poses a primary concern to pedestrian safety. In Bhubaneswar, dedicated seating facility alongside of sidewalk is rarely found, whose presence might have induced among old-aged fellows to use more sidewalk facility. Lack of similar types of infrastructural facility is also identified in other studies (Sharma et al., 2013; Sadhukhan et al., 2015) in India. It has been highlighted in many previous studies that there is lack or improper planning of pedestrian infrastructure (Rahul and Verma, 2013) in India leading to increased friction with vehicular traffic stream, which in turn increases traffic fatalities (Badami, 2009). Hence, it seems that improvement of traffic furniture like sign boards, guard rails, etc. are vital for creating the walking environment safe. Among all attributes, the TOPSIS score for pedestrians' road-surface condition is measured at 0.4 indicating that the surface quality of sidewalk is not though best, but it is not objectionable from road users' perception.

The observation on measure of TOPSIS scores (C_i^*) of various attributes gives an overall impression on performance of sidewalk facility from pedestrians' perspective. The scores also help to prepare a rank-order of attributes in a scale from the worst-performing to the best-performing attribute. Though this rank-order of attributes is a relative measure, yet it helps transportation planners and policy makers with a notional guideline for improvement of sidewalk facility. Needless to say, the judicious identification of intervention areas must be persuaded only by TOPSIS scores as they represent true measures of their service condition. The work reveals

that due care must be paid almost on all attributes except adequate provision for street-light and road surface quality. But among all attributes deserving due care, an immediate intervention must be paid for improvement of attributes such as ramp-facility, sufficient width of sidewalk, sign-board for pedestrians guidance, guard-rail, as their TOPSIS scores are measured around 0.2. The next intervention areas could be improvement of attributes such as dedicated seating facility alongside of sidewalk, provision for proper traffic-calming measures and temporal shelter alongside of sidewalk from natural hazards, as their TOPSIS scores are measured around 0.3.

5. Conclusion

The present work documents several new findings relating to the service condition of various attributes describing sidewalk facility with reference to an urban area in a developing country. The work is demonstrated by investigating the current service condition of the sidewalk facility provided in Bhubaneswar city, India using pedestrian's perceived observations. The observations are collected on a 7-point Likert Scale to measure the agreement-level towards a statement against an attribute. The observations are analyzed by a ranking method called Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The TOPSIS method relatively orders the attributes from being the poorest service condition to the best service condition based on evaluation of performance index. Though ordering of attributes indicates a relative performance (or say position) of service attributes, the measure of performance index (C_i^*) represents the actual service condition in lieu of pedestrians' perception. In this study, adequate street-light facility is being perceived as the best-performing attribute among all attributes. The performance index measure of all other attributes is closer to 0 indicating that they are not at-all in good service condition. The work reveals that the existing ramp for sidewalk facility is being perceived as the most non-performing. The other attributes such as roadside sign-boards of pedestrians, sidewalk-width, guard rails and seating facility are also perceived as poorly performing.

The work helps transportation planners and policy-makers to prepare a rational guideline for immediate intervention areas for conducive development of a sustainable sidewalk facility with reference to an urban area. It also demonstrates a rational approach for determining a priority-order of intervention areas using end-users (i.e. road users) perceived observations. As a further scope of this study, a heterogeneity study may be conducted in order to understand the difference in perception of the captive and choice riders on existing sidewalk infrastructure.This has important policy implication in terms of understanding preferences of choice riders on sidewalk facility, so appropriate policy tool may be devised in order to attract more choice riders to undertake walk mode.Nevertheless, the work has a vital policy implication on identification of priority intervention areas for needful improvement of sidewalk facility.

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