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Pedestrian Level of Service Model for Evaluating and Improving Sidewalks From Various Land uses

Bivina G.R.[1*], Purnima Parida[2*], MuktiAdvani[3*], ManoranjanParida[4*]

[1] Research Scholar, Department of Civil Engineering, Indian Institute of Technology Roorkee (Corresponding Author)
[2]Senior Principal Scientist, Transportation Planning Division, CSIR- Central Road Research Institute, New Delhi
[3]Scientist, Transportation Planning Division, CSIR- Central Road Research Institute, New Delhi
[4]Professor, Department of Civil Engineering, Indian Institute of Technology Roorkee

Abstract

There are several tools and methods developed for evaluation of sidewalks at street level. But most of the tools have neglected the importance of considering pedestrians' perception in assessing Pedestrian Level of Service (PLOS) of sidewalks. Therefore, in contrast to the earlier research work at the level of service of sidewalks, the present study developed a PLOS model to assess street level sidewalk infrastructure facilities from various land uses considering pedestrians' perceptions**.** This study specifies 10 sidewalk characteristics that cater various pedestrian needs based on the type of land uses where they belong to. The proposed method has been tested in five Indian cities viz; Delhi, Mumbai, Vadodara, Surat and Ahmedabad. The results of the study indicate that PLOS is capable of identifying the main shortcoming of the street network and sidewalk infrastructure in the form of physical and user characteristics. This method allows pedestrians to convey their needs and expectations to city planners and thus demand for improving existing sidewalks.
Keywords: Level of Service, sidewalks, land uses, India

1. Introduction

Walking is the most basic yet an indispensable mode of transportation since the beginning of human civilization. Bullock carts in the ancient times to the modern vehicles in the present generation have eventually discouraged the pedestrian culture. Further, the amenities demanded by roads for faster connectivity and comfort for the automobile users have drastically affected the overall quality of the walking environment. However, the importance of walking in terms of health benefits and necessity cannot be neglected while facilitating modern means of transportation. Hence, it is important to provide comfort conditions for pedestrians during road traffic planning in order to encourage the walking practice. For the execution of this idea, it is vital for the planner to be aware of the current status of satisfaction of pedestrians in using these facilities and factors that are being considered important while walking. Sidewalks at different

[*] Corresponding author: Bivina G R (biviplna@gmail.com)

land use serve different as the pedestrian traffic and behavior varies at each land use. Therefore, the perceptions of pedestrian using sidewalk infrastructures of different land uses can also be different. Pedestrian movement is directly affected by type and purpose of the trip, which further depends on surrounding land use activities. The land use activity of a region defines its pedestrian demand, that further determines the capacity of pedestrian infrastructure. Therefore, it is necessary to develop transportation planning and land use such that it will assist the whole population for their walk trips. This study also assesses the performance of sidewalk from different land uses from pedestrian's perspective.

Level of service is a tool for describing existing conditions and assessing the overall Quality of Service (Asadi-Shekari et al., 2012, 2014). The quality of sidewalks is commonly assessed by Quality of Service (QoS) levels. According to Ona et. al. (2013), transit quality is measured using passenger's perceptions about each factor characterizing the service. So to measure the service of sidewalks, pedestrian perceptions have to be taken into consideration. But the majority of the sidewalk assessment tools for encouraging pedestrian environment rely on auditors or experts' judgment which results in biased outcomes that ultimately results in neglecting pedestrian needs and expectations. And most of the Pedestrian Level of Service (PLOS) standards that have developed so far to assess the service quality of pedestrian facilities have been estimated using experts' opinion and not from pedestrians' perceptions. Thus, the need for an efficient, compatible and applicable method to assess the quality performance of sidewalks at street level. The study introduces a PLOS method to assess the service quality of sidewalks at street level from various land uses using pedestrians' perceptions.

1.2 Review of Existing Methods

Pedestrian Level of Service (PLOS) has been defined as a measure of the performance of pedestrian facilities. PLOS should not only consider the space requirements for a pedestrian to walk, but also the pedestrians' walking experience (Singh K. et. al., 2011). This walking experience includes qualitative factors like comfort, safety, security, convenience, mobility, etc. Qualitative assessment of the pedestrian level of service can also be termed as Quality of Service (QoS). Past studies on PLOS considered quantitative measures such as pedestrian speed, flow, space and density as the main factors of the model that neglected subjective attributes of sidewalks, such as comfort, safety, walking environment, etc. Even though, the pedestrian traffic and behavior changes with the sidewalks at different land uses, many of the PLOS methods have not considered the effect of land use on pedestrian perceptions on sidewalks. Sarkar (1993) proposed PLOS model that suggested six pedestrian service levels from A to F based on the attributes like comfort, convenience, attractiveness, security, continuity, safety and system coherence. However, this method is biased due to the judgment of survey personnel. The point scale developed by Khisty (1994) to assess the level of service was complex to interpret. An elemental question remains that whether these scaling systems really address the pedestrian facilities. Dixon (1996) and Gallin (2001) used a point system that considered only a few parameters that affect mobility, comfort and safety that reflects pedestrian perceptions. Landis et. al. (2001) proposed a six-point PLOS scale that considered factors like presence of buffer between footpath and road, sidewalk width, speed and volume of traffic. Muraleetharan et. al. (2003) used conjoint analysis to estimate the total utility score of sidewalks and crosswalks based on their width, separation from road, obstructions, flow and bicycle events, but study ignored qualitative factors. HCM (2010) considered the factors like volume and speed of the motor vehicle, bicycle lane, shoulder width and presence of buffer, but the study ignored qualitative factors which are also considered to be important for PLOS development. Even though a large number of qualitative PLOS rating

systems have been developed by researchers, none of them can be universally used (Landis, 2001; Dixon, 1996; Gallin, 2001).The PLOS model proposed by Sheikari et.al. (2014) included almost all micro-level infrastructural features along sidewalks that were facilitated for safety, comfort, and convenience of pedestrians. But the assessment model considered too many factors for performance assessment which is tedious for the surveyors and study also ignored pedestrians' perceptions which is one of the major drawbacks of the study. Wibowo et. al. (2015**)** developed walkability measures for city area by finding the walkability index using nine parameters such as pedestrian's conflict with other motorized mode, the presence of walking facilities, availability of crossing, motorist behavior, walking amenities, walking infrastructure for disabled, obstruction and walking security. An analytical point system was proposed by Ghani et. al. (2015) to rate pedestrian facilities using a pedestrian index (P-index) method that considered only four factors like mobility, safety, facility, and accessibility. Table 1 presents a list of different methodological approaches and factors considered by various pedestrian studies in the past.

Most of the qualitative LOS studies used questionnaires and direct observations. Simulation methods, regression analysis, and point systems are the main analytical methods that are used to rate the street's condition. Many of the studies have included quantitative parameters like capacity and width, but neglected qualitative parameters. And the studies that have included qualitative parameters were biased due to the judgment of survey personnel giving limited importance of pedestrian perceptions. However, in India, there is a lack of efficient evaluation tools for assessing the service quality of sidewalks that rely on the perceptions and needs of real users of sidewalks. Furthermore, the studies have considered a number of microscale factors for the performance assessment that would make the study more tedious and time-consuming. A detailed study covering Indian cities that consider the effect of land use has not been done so far. The present study develops a model for the performance assessment of the sidewalks in million-plus developing cities. It also explores the level of importance and satisfaction of pedestrians for sidewalks. This study introduced an analytical point system, which is simple and produced desired outcomes, to evaluate the sidewalks at street level from different land uses.

Table 1:Summary of Previous Qualitative Pedestrian Level of Service (PLOS) studies

Author	***Methods***	***Factors considered***
Sarkar (1993)	Scoring System	Convenience, comfort, safety, security, continuity, system coherence and attractiveness
Khisty (1994)	Scoring System	Comfort, convenience, continuity, attractiveness, system coherence, safety, security
Dixon (1996)	Scoring System	Path conflicts, amenities, motor vehicle LOS, maintenance problems, provision of basic facilities and provision for multiple modes.
Landis et.al. (2001)	Ordinary Least Regression	Lateral separation factors, traffic volume, speed of the vehicle, driveway access frequency and volume
Gallin (2001)	Scoring System	Sidewalk width, sidewalk surface, comfort, walk environment, potential for vehicle conflict, crossing facilities and pedestrian volume,
Muraleetharan et.al. (2005)	Ordinary Least Regression	Sidewalk width & separation, pedestrian volume, flow rate and bicycle events
Jaskiewicz (2005)	Scoring System	Enclosure, Complexity of Path Network, Building Articulation, Complexity of Spaces, Overhangs, Buffer, Shade Trees, Transparency, Physical Components/Condition
Jensen (2007)	CumulativeLogit Model	Sidewalk width, walking environment, pedestrian volume, parked vehicle, bicycle track width, buffer area and landscape

Parida et.al. (2007)	Scoring System	Footpath width, footpath surface, continuity, comfort, safety, encroachment, potential to vehicle conflict, crossing facilities, walking environment and pedestrian volume.
Sheikari et.al. (2014)	Scoring System	Footpath surface, footpath, corner island, width of footpath, tactile pavement (guiding), tactile pavement (warning), signal, seating area, drinking fountain, curb ramp, ramp, grade, signal, bollards, lighting, driveway, traffic speed, buffer, traffic lanes, crossing, facilities, furniture
Garcia & Lara (2015)	Scoring System	Sidewalk width, sidewalk surface, walking distance
Aghaabbasi et. al. (2016)	Scoring System	Sidewalk width, sidewalk surface, ramps, tactile pavements, utilities and landscape

2. Methodology

2.1 Selection of Factors

The initial step of the study was to identify parameters which are to be included in the questionnaire to contemplate the walking environment and aspects of Pedestrian Level of Service of sidewalks. The sidewalk design guidelines and assessment tools are reviewed to identify the important factors to develop the PLOS method to examine the service quality of sidewalks from different land uses. Based on the review of the various literature, 10 sidewalk characteristics are considered among which five are physical characteristics and five are user characteristics. The physical characteristics were sidewalk surface, sidewalk width, obstruction, the potential for vehicular conflict, continuity and user characteristics are encroachment, availability of crossing facilities, security, walk environment, comfort. Brief description about the physical and user factors along with their relevance in PLOS assessment is provided in Table 2.

2.2 Method

This study proposes a method to assess PLOS of sidewalks using pedestrians' perceptions towards their streets and sidewalk infrastructures. A questionnaire was designed to understand the pedestrian perspectives about sidewalks they are using. The first part of the questionnaire included pedestrian profile such as age, gender, income, occupation and about trip characteristics like purpose, trip frequency, trip distance, the reason for not walking, footpath availability, etc. The second part evaluates the importance of each physical and user characteristics of sidewalks from various land uses. A five-point Likert scale was used to rate the sidewalk characteristics according to their importance ranging from 1 (immaterial) to 5 (most important). The results of the questionnaire generate the relative weight for each sidewalk characteristic. This has been done because the sidewalk characteristics will not be having the same impact on the sidewalk's overall condition. Moreover, the perceived importance of certain sidewalk characteristics changes according to age, gender, pedestrians' physical condition. The last part of the questionnaire tries to assess the existing condition of sidewalks through pedestrian perception. Each sidewalk characteristic is evaluated in terms of its quality. A Likert scale is used for this evaluation from 1 (Poor condition) to 5 (Excellent condition).

Table 2: Factors considered for the study and its summary

Factors	*Description*
Sidewalk surface	Sidewalk surface is defined as the floor on which a person walks in the pedestrian environment. Sidewalk surface types often determine how difficult an area is to negotiate. An accessible sidewalk surface should be firm, stable, slip-resistant and free from cracks and bumps.
Sidewalk Width	The sidewalk's width not only affect pedestrian serviceability, but also determines the types of access and other pedestrian elements that can be installed. Pedestrian travel tendencies also affect the width of sidewalks. Sidewalks should be sufficiently wide so that pedestrians can walk and separate themselves from road traffic and avoid street furniture, obstructions and also other pedestrians.
Obstructions	The obstruction can be anything or in any form like garbage bin, hoardings, trees or electric pole present on the sidewalk. The sidewalk should be such that the comfort of pedestrian should not be affected by any obstructions.
Potential for vehicle conflict	Sometimes pedestrians on sidewalks are prone to vehicle conflict if sidewalks are unseparated or not having any guard rails. Grade-separated facilities or raised footpath are facilities that segregate pedestrians from motor vehicles. They can significantly reduce pedestrian-vehicle conflicts and potential collisions.
Continuity	A continuous sidewalks are those sidewalks that don't have any frequent up and downs throughout. Sidewalks should be continuous to provide comfort while walking, especially for disabled pedestrians and old age ones. Discontinuous sidewalks can make them uncomfortable and can drive pedestrians to walk on the carriageway.
Encroachment	Encroachments are the structures, objects or merchandise that comes along the sidewalk. Presence of encroachment can affect the comfort level of pedestrians while using sidewalks. The extent of encroachment should be limited to a certain level that doesn't affect accessibility of pedestrians to footpath.
Availability of crossing facilities	Zebra crossings, pedestrian bridges, underpass, etc. are the common types of crossing facilities. Enough crossings facilities along sidewalks should be available that allow pedestrians and motor vehicles to cross safely.
Security	The feeling of being safe and secure is one of the important factors governing the decision to walk. Pedestrians should feel safe during any time of the day. Safety and security can be ensured by providing adequate street lighting, police patrolling during the night time, etc.
Comfort	Pedestrian needs to be protected from harsh weather and environmental conditions. The trees can act as a protective shield, but they can also act as obstructions if they are planted unplanned. Facilities like chair/benches and rest rooms are other provisions that can add comfort to pedestrians.
Walk Environment	Walking should always be a pleasant experience. Walking environment is governed by the surrounding and the condition of sidewalks. Therefore, sidewalks should be clean and free from garbage.

2.3 PLOS model

The importance of the sidewalk characteristics and their conditions of operation based on pedestrians' perspective is used in this study. The study uses a PLOS based on a point system to rate urban streets for their service quality. Mathematically, the PLOS score can be defined as follows:

$$\text{PLOS} = \sum_{i=1}^{10} A_i \times B_i \qquad (1)$$

where, A_i : Relative importance weight for physical and user characteristics,

B_i : Quality satisfaction score for physical and user characteristics,

i: number of parameters.

The relative importance weight of each sidewalk characteristic (A) gives the effect of each sidewalk factor for the PLOS. The relative weight of each sidewalk is given by following equation:

$$A_i = \frac{\sum_{j=1}^{j=5} I_j \times n_j}{N} \qquad (2)$$

Here, A is relative weight of each sidewalk factor, i is number of parameters, I is importance rating, j is the rating from 1 to 5, n is the number of pedestrians choosing 'j' rating, N is the total number of pedestrians.

PLOS score is obtained when the satisfaction rating of existing conditions of sidewalk characteristics is calculated. Satisfaction score is also calculated by multiplying the corresponding five point scale rating to the number of pedestrians who has been given that rating. In this study, excellent rating gets five points, very good gets four points, good gets three points, satisfactory gets two points while the poor gets one point. The satisfaction assessment score for each factor is given using the following equation:

$$B_i = \frac{\sum_{j=1}^{j=5} S_j \times n_j}{N} \qquad (3)$$

Where B is the satisfaction score obtained for each sidewalk, i is number of parameter, S is the satisfaction score, j is the rating from 1 to 5, n is the number of the pedestrians choosing 'j' rating and N is the total number of pedestrians.

PLOS score classifications; their interpretations and required level of improvements are presented in Table 3. The point system involves rating from A to F. PLOS A indicates that excellent street facilities and sidewalks are excellent condition, B indicates that street facilities and sidewalks are in very good condition, PLOS C indicates that street facilities and sidewalks are in good condition, PLOS D indicates that street facilities and sidewalks are with average quality, but slight issues in safety and comfort , PLOS E indicates poor condition of the street network and pedestrian infrastructures with severe issues on safety and comfort. Finally, PLOS F indicates sidewalks are at worst condition and not at all appropriate for walking.

Table 3: PLOS scores and Level of Improvement needed

PLOS Scores	*PLOS Rating*	*Condition*	*Description*	*Level of improvement*
>125	A	Excellent	Highest quality sidewalk facilities	No improvement needed
≥100-<125	B	Very Good	High quality of sidewalk facilities and light issues of pedestrian comfort.	Very limited improvement needed
≥75-<100	C	Good	Basic quality of sidewalk facilities with considerable issues on pedestrian safety and comfort.	Limited improvement needed
≥49-<75	D	Average	Average facilities for pedestrians with slight issues of safety and comfort.	Some improvement needed
≥25-<50	E	Poor	Low quality facilities for pedestrians with severe issues of safety and comfort.	Many improvements are needed
<25	F	Worst	Worst pedestrian facilities where factors influencing PLOS are below acceptable standards.	So many improvements are needed

2.3 Selection of study area

In this study, five million plus cities of India such as Delhi, Ahmedabad, Surat, Vadodara and Mumbai were selected. Fifty four locations (road stretches) were selected from five cities considering different land uses. The study has collected samples from various types of sidewalk locations like excellent sidewalks, good sidewalks, average sidewalks and bad quality sidewalks. The streets were selected based on various land uses, such as residential, commercial, institutional, terminal and recreational. The land use of sidewalks is identified on the basis of major activities in that locality. Commercial land use represents the area mainly used for commercial activities. The institutional area represents locality having schools and colleges in which mainly pedestrian movement is confined to school going activities. Recreational land use represents the area which is used for the leisure walk, sightseeing, etc. The fifty-four locations selected for the study and their land uses are represented in Table 4.

Table 4: PLOS scores and Level of Improvement needed

City	*No.*	*Location*	*Land Use*
Ahemdabad	1	Lal Darwaja Towards Church	Commercial
	2	Ellisbridge	Recreational
	3	Lal Darwaja Masjid	Commercial
	4	Raikhad Cross Road	Institutional
	5	Near Municipal Corporation	Commercial
	6	Lal Darwaja Towards SBI	Commercial
Mumbai	7	Church Gate On Veer Nariman Road	Commercial
	9	Church Gate on K.C. College	Institutional
	10	Dadar West on N.C. Kelkar Road	Commercial
	11	Powai Area Near Hotel Rodas	Commercial
	12	Powai Area Near Star Bucks Mall	Commercial
	13	Powai Area Near Valencia Apartment	Residential
	14	Powai Area Near Sales Tax Office	Commercial
	15	Ambedkar Road Near C.S.	Terminal
	16	C.S.T Near J.J. College)	Institutional
	17	Bandra Near Railway Station	Terminal
	18	Kalyan Near Kalyan Station	Terminal

	19	Kalyan	Residential
	20	Vile Parle	Residential
Surat	21	Rahul Raj Mall	Recreational
	22	Bhagal	Commercial
	23	V.N.S.G.U	Institutional
	24	Near Ishwar Far	Residential
	25	Satya Nagar (Udhana)	Commercial
Vadodara	26	Sayajibaug (Vadodara)	Recreational
	27	Mandvi	Commercial
	28	M.S.U	Institutional
Delhi	29	Cannaught Place Near Lic Building	Commercial
	30	Cannaught Place Near Regal Building	Commercial
	31	Near Laxmi Nagar Metro StationTowards Preet Vihar	Commercial
	32	Near Laxmi Nagar Metro Station Towards Ito	Commercial
	33	Saket Near Select City Mall Towards Mehrauli	Commercial
	34	Saket Near Select City Mall Towards Chirag Delhi	Commercial
	35	Near Janakpuri District Centre Towards Moti Nagar	Commercial
	36	Near Janakpuri District Centre Towards Uttam Nagar	Commercial
	37	Near Akshardham Metro Stn. Towards Noida	Recreational
	38	I.S.B.T Kashmiri Gate Towards Shahdara	Terminal
	39	Ito Towards PragatiMaidan Near D.D.ABulding	Institutional
	40	Near Dr. Ram Manohar Lohia Hospital Towards Cannaught Place	Institutional
	41	Near Dr. Ram Manohar Lohia Hospital Towards Talkatora Stadium	Institutional
	42	Near Aiims Hospital On Aurobindo Marg Towards India Gate	Institutional
	43	Near Aiims Hospital On Ring Road Towards DhaulaKuan	Institutional
	44	Near Aiims Hospital On AurobindoMargTowards Green Park	Institutional
	45	Near Delhi University On Mall RoadTowards Model Town	Institutional
	46	Near Delhi University On Mall Road Towards I.S.B.T	Institutional
	47	Near Delhi University (On Chatra Marg	Institutional
	48	Near Ashram On C.V. Raman Marg	Residential
	49	Near Ashram On Ring Road	Residential
	50	Near Ashram (On Ring Road) Towards Lajpat Nagar	Residential
	51	Near Ashram On C.V. Raman Marg	Residential
	52	Near Ashram Near Ring Road Towards Lajpat Nagar	Residential
	53	Near Netaji Subhash Place, Pitampura	Residential
	54	Near Netaji Subhash Place, Pitampura	Residential

2.5 Sample Design and data collection

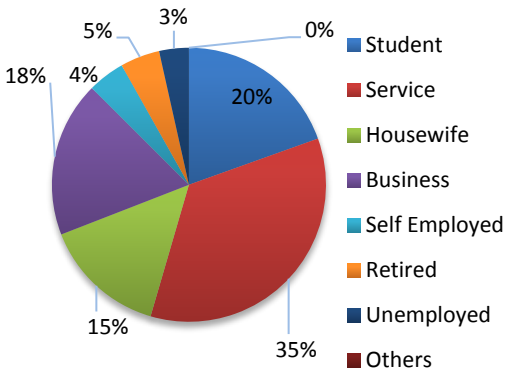
Questionnaires were administered by personnel on both weekends and working days interviewing the pedestrians on sidewalks. The sample size was calculated from the population of walk trips produced in the selected study area (Krejcie, 1970). The minimum sample size was calculated at a confidence interval of 95% and a 5 % margin of error. The responses collected from each zones varied based on zone's population as more samples are collected from zones with high populations. The minimum number of sample size calculated is 384 for each city. The least number of samples were collected from Vadodara (388) with the lowest population and the highest number was from Delhi (864 with the highest population. Samples collected from Mumbai, Surat and Ahmedabad were 765, 395 and 392 respectively. Thus, there were a total of 2804 samples collected for this study. An attempt was made to collect responses from pedestrians across different age groups, sex, income, and profession. The internal consistency of the questionnaire was checked to assess the reliability of the sidewalk characteristics selected in the study. Cronbach's alpha (α) was used to assess the internal

consistency of the questionnaire. The alpha coefficient 0.7 and above indicates that the questionnaire is reliable (Gleim and Gleim, 2003).

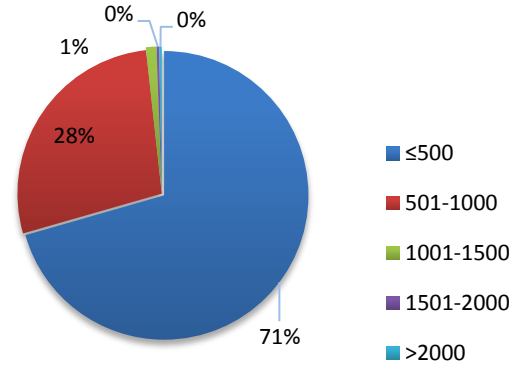
3. Data Analysis , Results and Discussion

3.1 Pedestrian Demographic and Trip Characteristics

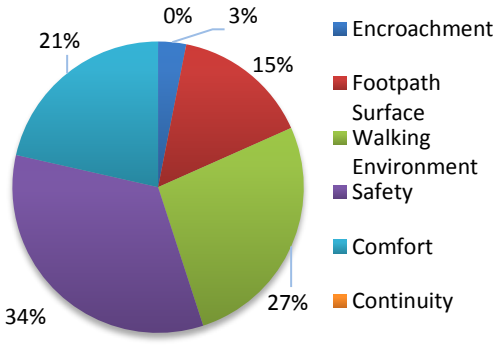
Pedestrian's responses were sorted and combined according to the land uses. Overall, approximately half of the respondents were female and about 67% were between 18 and 45 years old. About 35% reported to be working (see Figure 1 a). Maximum people (71%) prefer to walk for distance of less than 500 metre and none among them prefer to walk for a distance of more than 2000 metre as illustrated in Figure 1 b. It was observed that about 34% of respondents gave 'security' to be the reason behind not walking on footpath even when it was available(see Figure 1 c).Trips of pedestrians are for several reasons such as education shopping, social, medical, change of mode, etc. The frequency of pedestrian trips were also variable such daily, weekly, monthly, occasionally, etc. as presented in Figure 1 d.



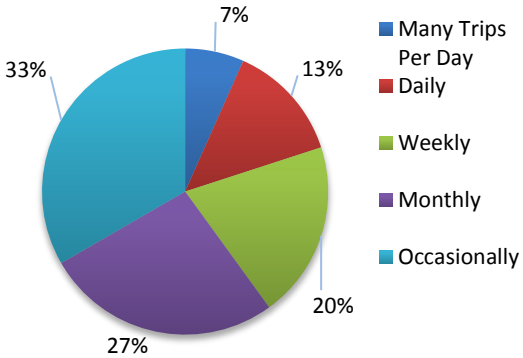
(a)Profession of respondents



(b)Distance of walk trip of Pedestrian



(c)Reason for not walking on sidewalks



(d)Frequency of trip of respondents

Figure 1: Socio Demographic and Walk trip details of survey respondent

3.2 Pedestrian Response Analysis

Service quality evaluation of sidewalks is based on characteristics of sidewalks and its walking environment. The response rates of pedestrians on the level of importance for various attributes are illustrated in Figure 2. Continuity factor has got very least importance among all other factors, that is about 32% people rated it as 1, which signifies that factor 'continuity' is immaterial for them. The footpath surface has got highest importance rating of 5 (23%). 'Footpath surface' is the factor which pedestrians consider most important for walking on sidewalks. Figure 3 illustrates the response rating for the level of satisfaction. Majority of pedestrians rated the attributes as satisfactory. Therefore, obstruction factor has got very least satisfaction rating among all the other factors. It has been noted that satisfaction ratings are comparatively low for those factors that got the highest importance. For example, factors like 'security' and 'encroachment' have got a maximum poor rating, which indicates the absence of security features like lighting, police patrolling etc. along sidewalks. So in order to improve the Quality of Service of sidewalks, satisfaction rating of the most important parameters has to be improved which can be possible only by implementing suitable improvement strategies for that characteristic of sidewalk.There is a possibility that socio-demographic factors like age, gender, income, etc. could influence the perceptions of pedestrians. Future researchers can be conducted to explore potential perception variances resulting from such socio-demographic differences.

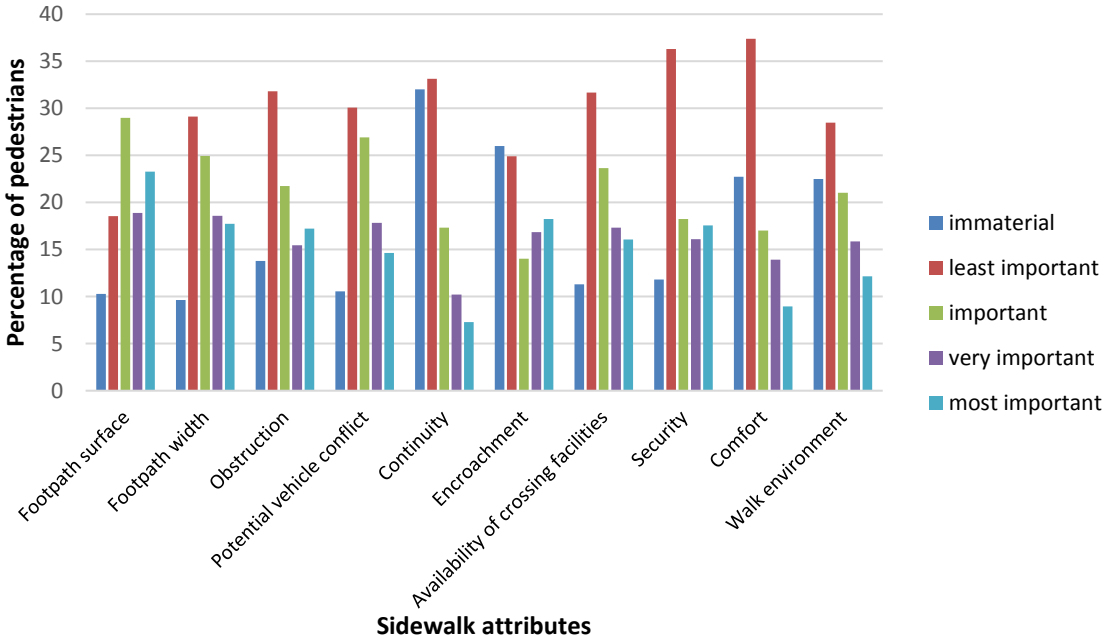


Figure2: Response rating of pedestrians for importance of various sidewalk attributes

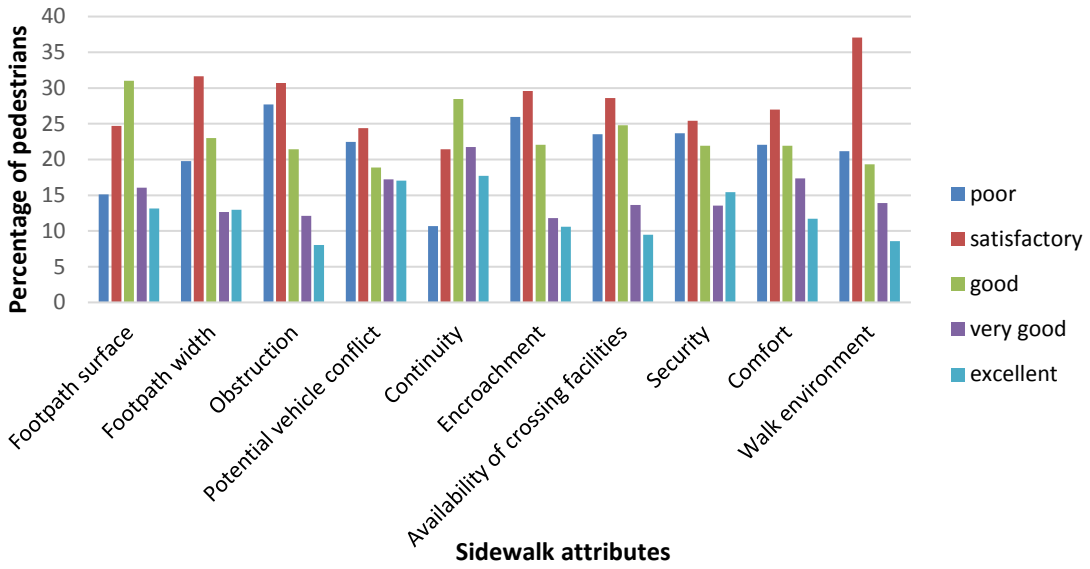


Figure 3: Response rating of pedestrians for satisfaction on various sidewalk attributes

3.3 Internal consistency

The internal consistency of the questionnaire items was checked by reliability tests using Cronbach's alpha value. As mentioned above, the value of alpha should be at least 0.7 to show that the scale is reliable. The study has a Cronbach's alpha of 0.733 indicates that factors in the questionnaire are reliable. Table 5 shows the mean, standard deviation and Cronbach's alpha for the factors being used in the study.

Table 5. Descriptive Statistics

Item Statistics			
Factors	*Mean*	*Std. Deviation*	*N*
Footpath surface	2.83	1.22	2804
Footpath width	2.67	1.27	2804
Obstruction	2.41	1.21	2804
Potential vehicle conflict	2.82	1.38	2804
Continuity	3.120	1.24	2804
Encroachment	2.51	1.27	2804
Availability of crossing facilities	2.57	1.23	2804
Security	2.70	1.35	2804
Comfort	2.69	1.29	2804
Walk environment	2.47	1.17	2804
Cronbach's Alpha	*Cronbach's Alpha Based on Standardized Items*		*N of Items*
0.734	0.734		10

3.3 Assessing Pedestrian Perception and Quantification of Relative Weights

Scaling theory is used to obtain relative weights for each parameter on the basis of importance and satisfaction (Gulliford, 1954). The assumption made in the study is that the distribution of responses to a stimulus is normal on the psychological continuum i. In order to produce scale values for the stimuli, suitable mathematical transformations to the

ratings were done. These scale values indicate perceived values of the stimuli, or more correctly, the relative positions of stimuli on the psychological dimensions being assessed (Brown 1990).The approach used here is to gauge scale values on categorical judgments by determining the central value that represents each category. The principle is to compute mean weights of each attribute using category mean rating with acquired percentage in each category. After this, a linear transformation is applied to means for converting them to a common scale with unit standard deviation. These scale values are used as relative weights for parameters describing physical and user characteristics of sidewalks. The relative weights of parameters based on importance and satisfaction were calculated based on category meaning approach for all five land uses as shown in Table 6 and Table 7 respectively. The importance and satisfaction rating for each parameter is denoted by 'A' and 'B' respectively.

Table 6: Importance rating for various land uses

Characteristics (A_i)	*Land Uses*				
	Residential	*Commercial*	*Institutional*	*Terminal*	*Recreational*
Footpath surface (A1)	3.14	3.17	3.35	2.36	2.40
Footpath width (A2)	2.63	3.53	3.28	1.98	3.04
Obstruction (A3)	2.39	3.30	3.47	1.77	3.31
Potential vehicle conflict(A4)	2.71	3.04	3.51	2.15	3.30
Continuity(A5)	2.22	2.51	2.71	1.71	2.90
Encroachment (A6)	2.46	3.08	3.08	1.55	2.71
Availability of crossing facilities(A7)	2.71	3.23	3.35	1.97	3.33
Security(A8)	2.31	2.72	2.98	1.94	2.78
Comfort(A9)	1.96	2.87	2.34	1.52	3.34
Walk environment (A10)	2.20	2.97	3.09	1.67	2.92

Table 7: Satisfaction rating for various land uses

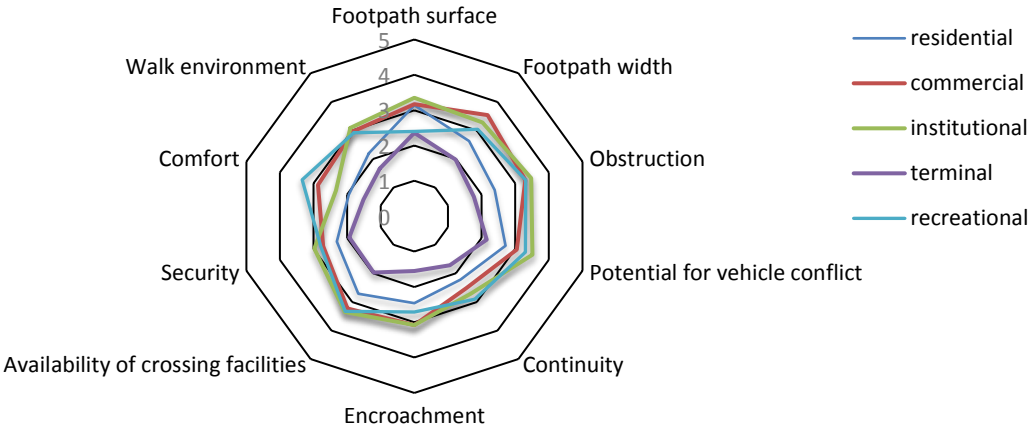
Characteristics (B_i)	*Land Uses*				
	Residential	*Commercial*	*Institutional*	*Terminal*	*Recreational*
Footpath surface (B1)	3.24	2.75	3.11	3.13	3.46
Footpath width (B2)	3.18	2.28	2.93	2.41	3.46
Obstruction (B3)	2.65	2.32	2.36	2.29	3.21
Potential vehicle conflict(B4)	3.61	2.63	2.80	3.25	2.93
Continuity(B5)	3.76	3.02	3.12	3.95	3.35
Encroachment (B6)	2.88	2.50	2.57	2.57	3.30
Availability of crossing facilities(B7)	2.98	2.27	2.79	2.48	3.07
Security(B8)	3.20	2.70	3.24	2.99	3.31
Comfort(B9)	3.28	2.55	2.80	2.99	3.23
Walk environment (B10)	2.59	2.68	3.16	1.67	3.63

To present the scoring of parameters in terms of importance and satisfaction rating at various land uses, spider net graph was drawn as illustrated in Figure 5. The graph explains that how the importance and satisfaction weight at, each land use varies. The mean weight of importance rating for footpath surface is 3.14 which signifies that footpath surface is an important parameter for people who use the sidewalks in residential areas. Hence, the

parameter is important, its timely maintenance is essential. But pedestrians who use the sidewalks from commercial areas, consider the footpath width as the most important factor. The sidewalks along this area demand comparatively larger space requirement than other land use, as people would like to freely walk with their bags enjoying the shopping. It is interesting to note that the satisfaction ratings are low for those parameters of sidewalk facilities whose importance ratings are high.

The institutional area has got a high rating for almost all parameters of the sidewalk. Most of the survey respondents were students and they gave primary importance for the factor 'potential to vehicle conflict' followed by the factor 'crossing facilities'. But the rating for satisfaction is very less for 'potential to vehicle conflict' factor which reveals that sidewalks are not segregated from the carriageway by raised footpath or guard rails. In the recreational area, comfort parameter has got the highest rating 3.34 showing that comfort is the most important among all the factors. 'Comfort' parameter is having satisfaction rating as 3.23 indicating that pedestrians are less comfortable in using sidewalks. 'Obstruction' and availability of 'crossing facilities' are the other factors that are having importance in recreational areas.

The importance rating of almost all parameters is less for sidewalks given by respondents in terminal areas is very low for almost all sidewalk parameters when compared to other land uses. But satisfactory ratings are high for all the parameters in spite of the low importance rating at terminal areas. This is because the people are so busy with their trip and they don't care much for the characteristics of walking facilities offered to them. In terminal areas, 'footpath surface' and 'potential to vehicle conflict' has got the highest rating as these locations were near the railway station and bus stand, thus having a high traffic flow and mode change, there were more chances of pedestrian-vehicle conflict. It is interesting to note that the satisfaction rating is very high for many of the factors with the least importance,



(a) Importance rating

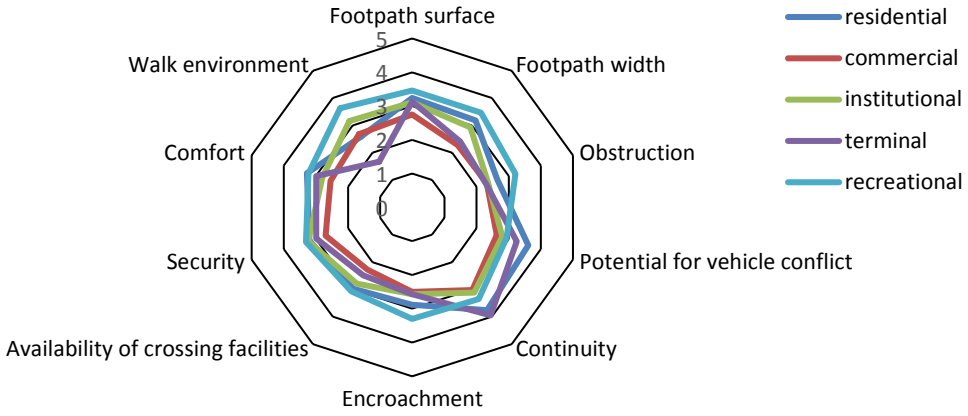


Figure 5: Evaluation of importance and satisfaction rating for different land uses

The data collected from the questionnaire have been analyzed to generate the relative importance weights of sidewalk characteristics according to Eqn 2. An ANOVA was performed to confirm whether the ratings of the parameters were different for different land uses. The test was conducted for importance rating obtained for each land use. The importance ratings of sidewalks characteristics will be similar to all land uses has considered as the null hypothesis for the test. And if F value is greater than the critical F value, the null hypothesis can be rejected, then it is concluded that importance rating for all land uses is significantly different. If the F value is less than the critical F value, then the null hypothesis can be accepted. The test results are presented in Table 8 for various combinations of land uses. From the above ANOVA test results, we found that the $F > F_{critical}$ and therefore null hypothesis can be rejected. This means that there is a significant difference in importance ratings given by pedestrians for various land uses. Thus, it is inferred that pedestrian perceptions of factors affecting sidewalks vary with land uses.

It has been found that there is a statistically significant difference between the pedestrian perceptions on importance ratings given to sidewalks characteristics from different land uses using ANOVA, therefore the next step is to conduct post hoc tests to confirm where the differences occurred between groups. The test results showed that the pedestrian perceptions on the importance ratings in all land use differed significantly. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the various land uses was significantly different from other land uses.

Table 8: ANOVA test results in importance rating

Groups	*Count*	*Sum*	*Average*	*Variance*		
Residential	10	24.73	2.473	0.113023		
Commercial	10	30.42	3.042	0.086596		
Institutional	10	31.16	3.116	0.133827		
Terminal	10	18.62	1.862	0.071707		
Recreational	10	30.03	3.003	0.102334		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11.35599	4	2.838997	27.97115	1.07E-11	2.578739
Within Groups	4.56738	45	0.101497			
Total	15.92337	49				

4. Results

4.1 PLOS Assessment

Streets and sidewalk infrastructure with different characteristics can be evaluated with this PLOS method as it includes the highly important sidewalk factors that are used to evaluate the service quality of sidewalks that can be used in various contexts. PLOS score for five land uses was calculated using Eqn 1. The relative weights are multiplied by the corresponding satisfaction score obtained for each characteristic. Table 7 presents the total weighted score obtained for each land use by adding an individual weighted score for each characteristic. After calculating the PLOS score, grades were assigned based on the score. Table 9 presents the PLOS for the selected street sidewalks from various land uses of different cities and also the improvement to be done to the sidewalk facilities.

Table 9: PLOS each land uses

Characteristics	Land Uses				
	Residential	Commercial	Institutional	Terminal	Recreational
Footpath surface	10.2	8.7	10.4	7.4	8.3
Footpath width	8.4	8.0	9.6	4.8	10.5
Obstruction	6.3	7.7	8.2	4.1	10.6
Potential vehicle conflict	9.8	8.0	9.8	7.0	9.7
Continuity	8.3	7.6	8.5	6.8	9.7
Encroachment	7.1	7.7	7.9	4.0	8.9
Availability of crossing facilities	8.1	7.3	9.3	4.9	10.2
Security	7.4	7.3	9.7	5.8	9.2
Comfort	6.4	7.3	6.6	4.5	10.8
Walk environment	5.7	8.0	9.8	2.8	10.6
PLOS Score	78	78	90	52	100
Grade	C	C	C	D	B

The results of the table indicate that PLOS for land uses like residential, commercial, institutional, terminal and recreational are 78, 78, 90, 52 and 100 respectively; therefore the grades allocated are C, C, C, D and B respectively. Among all land uses, terminal area has got the least grade 'D', which shows that sidewalks are in average condition with acceptable sidewalk infrastructure having slight issues on pedestrian comfort and safety, and these sidewalks in terminal area need improvements because pedestrian infrastructure around terminal facilities plays a good role in improving pedestrian accessibility to public transport. The terminals have got the least score, especially for the factors like walking environment, sidewalk width, and encroachment. PLOS scores of residential, commercial and institutional land uses has achieved same grades 'C', which means the sidewalk is in good condition that measures basic quality of sidewalks with some considerable issues with pedestrian safety and comfort Among the five land uses, the sidewalk characteristics that received average, poor and worst PLOS score needs to be improved by enhancing the quality of each sidewalk characteristics based on the relative weight of those characteristics from each land uses. Recreational area has got the top PLOS grade among all land uses, i.e. 'B', which indicates that sidewalks are in very good condition with the high quality of pedestrian facilities.

5. Conclusions And Discussions

The current study developed a method to assess PLOS of street-level sidewalks from various land uses of five different cities from India. Even though many previous studies have developed PLOS method, neither of the methods has considered pedestrian perceptions. The applicability of many of these standards was questionable to adopt them in various geographical regions context. The importance of pedestrian perceptions towards the assessment of LOS has been admitted by many researchers, but none of them have ever utilized it effectively to build he PLOS index. Earlier studies have neglected the importance of pedestrian perceptions on qualitative factors of sidewalks at street level evaluation. The proposed method considers pedestrians' needs and expectations by selecting a wide range of sidewalk qualitative factors. The pedestrian evaluation of these qualitative factors can be applied to a universal context. Moreover, the method developed is not tedious to use as it contains only main factors that highly influence the PLOS of sidewalks, therefore, this methodology for assessing streets from various land uses is easy to follow. The reliability test was conducted to check the consistency of the factors selected for developing the PLOS method. The Psychometric model was used to ascertain the importance and satisfaction of each parameter for pedestrians and they were combined to a cumulative score to develop the PLOS score. The high relative score of security factors indicates that pedestrians were highly concerned about their security on the sidewalks. Most of the pedestrians were observed to be not using footpath due to lack of safety in the form of street lighting, police patrolling along sidewalks, etc. The attribute "footpath surface" has highest relative weight in all three land uses, except in commercial and recreational area where comfort and footpath width are the highest priority attributes respectively. Thus, timely maintenance of footpath surface is necessary in those land uses where the factor have got highest importance rating. The proposed method was not developed for collecting data for assessing walking behaviour as collected data is not same for community based survey tools. Nevertheless, the results of the assessments were checked to confirm the

consistency of results across the street sidewalks. The results of the assessment factors and their real-world conditions have good consistency across the streets. For example, availability of crossing facilities is not provided in mainly institutional land uses in the selected streets of the study area has obtained very low satisfaction score, which results in low PLOS grade indicating the poor condition of this characteristic in the streets. Terminal area got less PLOS grade among all other land uses. Lack of properly designed sidewalks, obstruction, and encroachments along sidewalks gradually reduces the propensity of using sidewalks for accessing public transport service. Since walk mode is the most suitable mode for accessing feasible distance to the utility such as bus service, rail service, etc., therefore, pedestrian facilities are to be improved around these terminal areas. As the quality of the pedestrian facilities improves, there will be high propensity of walking that can also enhance walk accessibility to the transit stations.

The PLOS model provides a measure of the quality of sidewalk with respect to pedestrians' perception of importance and satisfaction regarding physical and user characteristics of sidewalks. It can also help to evaluate and prioritize the needs of existing sidewalks and to renovate existing constructions. This PLOS tool will be very helpful to the municipal engineers and planners to keep a timely check on the service performance, prioritizing fund allocations and finally improving the pedestrian facilities time to time. The researchers can adopt this methodology in assessing the street and sidewalk infrastructures in all types of land uses.

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