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ORIGINAL ARTICLE

Development of Pedestrian Level of Service Assessment Guidelines for Mixed Land Use Areas Considering Quality of Service Parameters

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Abstract
Pedestrian infrastructure facilities form the backbone of an efficient transportation infrastructure. Assessment of Pedestrian Level of Service [PLOS] is important for ensuring safe secure mobility of people. A wide range of literature is available focusing on assessment of PLOS but limited research focusses on integrating qualitative and quantitative parameters for assessment of PLOS for congested mixed land use locations. In this work, initially 31 qualitative and quantitative PLOS assessment factors relevant for old cities having mixed land use were identified from the literature. Importance survey was conducted in 1–5 scale for these factors and Exploratory Factor Analysis was conducted to find 24 important factors clustered in 7 important PLOS assessment parameters. Comparative importance survey of the seven identified PLOS assessment parameters was conducted and PLOS assessment model was proposed using Constant Sum Paired Comparison Method. It can be observed that safety and security offered by the pedestrian facility is the most important parameter for PLOS assessment with the highest weightage among the seven parameters. In addition, encroachments in footpaths and pedestrian convenience offered by the pedestrian facility play an important role in PLOS assessment. It could be observed that there is a wide difference in comparative importance rating for night time condition and traffic on carriageway. The suggested methodology is demonstrated by assessing PLOS of five different locations of Patna using the weightage of the parameters.

Keywords Pedestrian · Mixed land use · Old cities · Perception

Introduction

Pedestrian facilities or sidewalks, which form the backbone of an efficient transportation infrastructure, often get the least priority in vehicle-oriented development. This is more evident in developing countries, where pedestrian infrastructure facilities are often inadequate or in unusable condition. The utilization of pedestrian facilities depend on usability, real or perceived, which in turn depend on comfort, convenience and sense of safety and security offered by the facility. Sometimes people are forced to walk on the carriageway due to encroachments on the sidewalks. In addition, there is a lack of proper designated grade separated pedestrian crossings or signalized pedestrian crossings. This results in large number of pedestrian crashes in the urban areas.

The design of pedestrian infrastructure facilities do not always take into account convenience and comfort factors and proper maintenance of the facility is also not ensured. In addition, for congested old cities, sometimes space constraint forces building of restricted pedestrian facility, which though present becomes unusable. Moreover the signal poles or street lighting facilities at any point of pedestrian facility cause hindrance for pedestrians. Interestingly, encroachments such as roadside vendors, while posing difficulty in walking, may provide a sense of security to the pedestrians. To provide ideal usable pedestrian infrastructure facility, pedestrians' needs are to be assessed carefully. When it comes to the assessment of a road facility, the assessment is based on speed–flow–density relationships only, but for pedestrian ways or footpaths, the assessment is based on various qualitative and quantitative aspects of the pedestrian way. A wide range of literature is available providing assessment guidelines for walkways. Early attempts at developing assessment guidelines for categorization of

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Pedestrian facility Level of Service [PLOS] were based on speed–flow–density relationships [1, 8]. Later, researchers focused on integrating level of service and quality of service parameters in assessing level of service of pedestrian facilities [2, 3]. PLOS assessment guidelines considering adequacy and usability of the available pedestrian infrastructure and quality of service provided by the facility have been developed by researchers for various countries. The demand, perception and needs vary in different geographical regions depending on the land use of the locality. Thus, PLOS guidelines have been developed for different land use areas namely residential, commercial, educational and mixed land use locations. However, limited research focuses on assessment of PLOS for mixed land use areas, i.e., areas having simultaneous residential, educational and commercial land use. Such areas are widely encountered in many old congested cities. Thus, the present work focuses on.

1. Identifying the qualitative and quantitative factors which are perceived to be important by pedestrians for pedestrian infrastructure facilities of old cities having mixed land use.
2. Development of a customized PLOS assessment guideline with the identified important factors for mixed land use areas.

The guidelines were developed with importance survey of residents of Patna, Bihar, India. The city is one of the oldest and densely populated cities in India predominated by mixed land use areas. The trip lengths of the working population of the city are usually small, ranging from 3 to 8 km, and people use walking as an option for access to public transport facilities or sometimes for their complete trips. The developed PLOS assessment tool was used to assess the PLOS of different locations of Patna. This was done to illustrate the methodology of PLOS assessment and to identify areas in which pedestrian facilities need improvement.

The paper, in the next section, gives a brief review of literature, summarizing the available PLOS guidelines. The third section details the methodology of the work. The fourth section details the data collected and used for development of proposed PLOS guidelines. The fifth section briefly describes the analysis and results obtained. The last section summarizes and highlights the conclusions of the work.

Literature Review

A wide range of literature is available focusing on assessment of Pedestrian Level of Service (PLOS) for walking infrastructure facilities [1, 4–7]. The method of Pedestrian Level of Service (PLOS) evaluation has shifted from pedestrian Speed–Flow–Density concept [1, 8] to Safety–Security–Convenience–Mobility–Infrastructure concept [4, 7]. Each of these studies, however, has used different factors and methods to evaluate PLOS. Initially, the traffic engineers tried to assess PLOS in similar scale as that of traffic facilities, i.e., based on pedestrian flow operations and capacity of pedestrian facility [1, 8]. However, equating human and traffic flow, without considering qualitative aspects, may not provide a proper assessment of the facility. Thus, researchers tried to integrate destination accessibility and distance in PLOS assessment framework [9]. Further, researchers have used other quantitative factors for PLOS assessment such as footpath width, shoulder width, buffer zone and on-street parking. Inclusion of qualitative parameters to assess level of service offered by pedestrian facilities for pedestrian movement was an important advancement in the field of PLOS assessment [4, 10, 11].The qualitative factors considered in assessment included quality of footpath surface, convenience of footpath usage in terms of availability of ramps, shading, night time lighting and sense of safety and security perceived by pedestrians. Some recent research work have considered land use type for LOS assessment [6, 12]. Land use type is found to be a variable which significantly affects LOS of pedestrian and bicycle infrastructure facilities. The lack of consensus in PLOS assessment rating is discussed by Karatas and Tuydes-Yaman [13]. The PLOS assessment tools available take into account pedestrian perceptions for some factors such as safety, security, and comfort, but the perceptions are subjective. The research on PLOS assessment so far focused on assessment of PLOS for well-defined pedestrian facilities with proper markings [14, 15]. In most cities of developing countries, footpath is not always available as a well-defined elevated path with proper paver blocks. Sometimes the footpath, though available, may not be in usable condition throughout the stretch due to various reasons such as broken footpath surface, the presence of waste bins, the presence of street vendors or even cars or two-wheelers parked on the footpath [12].

Some researchers determined PLOS considering footpath capacity and pedestrian volume and speed [1, 8]. Some of the researchers developed the 3D's concept layout including Density, Diversity and Design in assessing Pedestrian level of Service [16]. Researchers later expanded this concept to a 5D's arrangement by adding Destination accessibility and Distance to transit for assessing Pedestrian level of service [17]. Researchers also tried to assess the usability of the pedestrian facilities by trying to assess various structural features of pedestrian facilities and their conditions by defining a walkability index [18]. The walkability index considered availability of proper walking and crossing infrastructure, footpath encroachment, and the presence of proper lighting during night time in assessing walking infrastructure conditions of an area. There are significant positive correlations between walking infrastructure assessment score and some measures of the physical environment, either objective measures such as street connectivity, residential density and access to public transit provisions or subjective measures such as safety, comfort and convenience [19]. Duncan et al. [20] suggested that there exists a correlation between walkability in multiple geographic and GIS-based neighborhoods and walkability indicators at multiple spatial scales. Walkability assessment method can be used for various distinct pedestrian groups and trip purposes. It can be used for urban areas with suitable modification for local circumstances with the Indicators of Accessibility and Attractiveness of Pedestrian Environments (IAAPE) for distinct pedestrian groups [2]. Various countries have defined their guidelines for assessing walkability [18, 21–24].

Qualitative urban design parameters of the physical environment measure abstract urban design qualities related to walkability [17]. Khisty C. J. [4] proposed qualitative level of service with seven parameters, viz., attractiveness, comfort, convenience, safety, security, system coherence and system continuity. He categorized built pedestrian environment into anthropogenic and anthropophilic environmental settings. In anthropogenic settings, people and the vehicles they use have to adapt to the built, sterile and nonhuman conditions provided; in anthropophilic settings, the built environment has to be designed to adapt to the needs of human beings. Researchers investigated the relationships between pedestrian satisfaction and a variety of built environment factors, to gain insight into urban design strategies that can improve pedestrian satisfaction [25]. Researchers have further tried to incorporate both quantitative and qualitative aspects of pedestrian infrastructure facility, viz., availability and condition of pedestrian facility, safety, security, comfort, and convenience to assess the level (PLOS) and quality (PQOS) of service of pedestrian infrastructure. Dandan et al. [26] took pedestrian comfort and safety into consideration and proposed a new method of assessing pedestrian level of service (PLOS). They analyzed the relationship between pedestrians' subjective perceptions of PLOS and physical characteristics of road facilities and traffic flow operation. They identified significant factors, viz., bicycle/pedestrian/vehicle flow volumes, driveway access frequency and distance between sidewalk and vehicle lane as primary factors influencing the pedestrian level of service. They developed a PLOS determination guideline—for calculation of PLOS using the identified factors. They also identified the perceived level of importance of the road features for various road and traffic parameters such as the road geometry parameters, the pedestrian flow characteristics, the vehicle and bicycle flow characteristics, the obstructions and the frequency of the driveway access. G R Bivina et al. [27] proposed pedestrian level of service model considering combined qualitative and quantitative parameters. Gehrke et al. [28] reviewed a series of similar alternative PLOS structures, and highlighted the key concerns such as: Accessibility, Pleasantness and Safety from traffic and crime [Irvine–Minnesota Inventory]; Functional, Safety, Aesthetics, Destination and Subjective [Systematic Pedestrian and Cycling Environment Scale—SPACES]; Environment, Pedestrian Facility, Road Attributes and Walking Environment [Pedestrian Environmental Data Scan—PEDS] and Safety, Track, Environment, Population and Purpose [STEPP]. Raad et al. [29] summarized available PLOS models from the existing literature using a systematic literature review. Earlier works adapted approaches used to determine automobile LOS to PLOS. Later approaches use a much wider range of factors but very little consistency could be observed across the studies. These factors were grouped in themes of: comfort, safety, and mobility [29]. The most used factors were footpath width; obstructions to pedestrian flow; motor vehicle speeds and volumes; shoulder widths; and buffers such as on-street parking. He systematically reviewed the literature from 1971 to 2016 to identify the main approaches that have been used to determine PLOS and to identify the most common factors used in assessments. Indo-HCM [24] tried to fill the literature gap by incorporating various features such as safety, security, and convenience for Indian condition. It follows Pedestrian Flow Model which relates density, speed and flow for pedestrian similar to that of vehicular traffic streams. It developed PLOS and PQOS range for different land use such as Commercial, Residential, Institutional, Recreational and Terminal using qualitative and quantitative features both but did not mention any criteria for mixed land use. The current work attempts to fill this gap by identifying factors and developing a framework to assess PLOS for mixed land use areas.

Methodology

Initially, the work aims to identify the factors that the pedestrians perceive to be important for pedestrian infrastructure, for comfortable walking in congested old cities having mixed land use. The important quantitative and qualitative PLOS factors are identified from the literature and importance survey was carried out in 1–5 Likert scale for these PLOS factors. All the important quantitative and qualitative PLOS factors are presented in Table 1. The importance survey is used to group and obtain the key components from the list of initially selected components using exploratory factor analysis.

Then pairwise comparative importance survey is conducted for the identified key parameter groups. The weightage of individual parameters is then obtained from the pairwise importance survey using Constant Sum Paired method [4]. The comparative importance score varies widely and it may be argued that using the average importance score

Table 1 List of important components and their type

Sr. no	Parameters components	Abbreviation	Type
1	Traffic volume and composition of carriageway	TVC	Quantitative
2	Traffic control devices such as marker, signs and signal devices	TCD	Qualitative
3	Buffer zone between sidewalk and carriageway	BZ	Quantitative
4	Traffic speed on carriageway	TS	Quantitative
5	Availability of underpass, foot overbridge, crossing signal for pedestrian	UFC	Qualitative
6	Availability of lighting facility at night	LN	Qualitative
7	Regular police patrolling during night	PPN	Qualitative
8	Availability of CCTV cameras to record crime	CCTV	Qualitative
9	Pedestrian volume at night	PVN	Quantitative
10	Roadside vending shops attracting pedestrians/people at night	RVP	Qualitative
11	Footpath width	FW	Quantitative
12	Footpath height	FH	Quantitative
13	Condition/quality of footpath surface (smooth/broken)	QFS	Qualitative
14	Type of footpath surface (concrete/paver block/colorful/marking)	TFS	Qualitative
15	Frequent change of footpath height	FFH	Quantitative
16	Availability of shades/trees for pedestrian	ST	Qualitative
17	Availability of ramps to access sidewalk by pedestrian	RAS	Qualitative
18	Availability of amenities (public toilet, seating facility, and drinking water facility) for pedestrian	AMN	Qualitative
19	Effect of encroachments due to temporary vendors on sidewalks	ETV	Qualitative
20	Effect of encroachments due to permanent small shops on sidewalks	EPV	Qualitative
21	Effect of illegally parked vehicles on sidewalk	IPV	Qualitative
22	Effect of encroachments due to permanent structures such as electric pole/telephonic pole/trees on sidewalk	EPS	Qualitative
23	Routine sidewalk maintenance for cleanliness	RSM	Qualitative
24	Availability of covered dustbin at regular interval	CD	Qualitative
25	Regular cleaning of public toilet near sidewalk if available	CPT	Qualitative
26	Effect of open stinking waste bin near sidewalk	OSW	Qualitative
27	Presence of regular designated at grade crossing with zebra crossing mark	PZC	Qualitative
28	Presence of unplanned median cut which is used for crossing	UMC	Quantitative
29	Presence of traffic control/traffic police at crossing location	TCL	Qualitative
30	Presence of pedestrian foot overbridges with stairs at regular intervals	PFS	Qualitative
31	Presence of pedestrian foot overbridges with ramps and elevators at regular intervals	PFR	Qualitative

may yield biased weightage results. Thus, while calculating the importance weightage score, the weightage score at mean [μ] and at ($\mu \pm 1\sigma$) are calculated and average of these three weightage scores are taken as the average score. The weightage scores have values between 0 and 1 and sum of all weightage scores equal to 1. The PLOS of any road stretch is defined as in the following equation:

$$\mathrm{PLOS} = \sum_{i=1}^{n} 100 \times \mathrm{W_i} \times \mathrm{P_i}, \tag{1}$$

where W_i is the weightage score for *i*th parameter and P_i is the perception rating of *i*th parameter in 1–5 scale.

The PLOS calculated will have range between 100 and 500. The PLOS can be divided into various level of service groups (LOS) according to the PLOS score obtained. The suggested guidelines for LOS groups are given in Table 2.

Table 2 Pedestrian level of service guideline range

LOS group	PLOS score	Remarks
A	Above 435	Very pleasant
B	434–370	Pleasant
C	369–305	Acceptable
D	304–240	Unpleasant
E	239–175	Very unpleasant
F	Below 175	Unsuitable

The LOS groups are classified based on equal interval classification.

In the second stage, the guidelines for the level of service were used to analyze LOS group of pedestrian infrastructure of all areas of Patna, India. This was done for the purpose of illustration of the proposed method and also for assessing Level of Service of pedestrian infrastructure of the city and prioritizing the locations that need focus on pedestrian infrastructure improvement. The next subsection discusses the Exploratory Factor Analysis and the following subsection describes the constant sum paired method used in the analysis.

Exploratory Factor Analysis

Factor analysis is a statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. It is a method for modeling observed variables, and their covariance structure, in terms of a smaller number of underlying unobservable (latent) "factors". The factors typically are viewed as broad concepts or ideas that may describe an observed phenomenon. For example, a basic desire of obtaining a certain social level might explain most consumption behavior. These unobserved factors are more interesting to the social scientist than the observed quantitative measurements.

Factor analysis is generally an exploratory or descriptive method that requires many subjective judgments. It is a widely used tool and often controversial because the models and methods are so flexible and subjective that debates about interpretations can occur. Factor analysis is an inversion of principal components. In factor analysis, observed variables are modeled as linear functions of the "factors". In principal components, new variables are created that are linear combinations of the observed variables. In both PCA and FA, the dimension of the data is reduced. In PCA, the interpretation of the principal components is often not very clear. A particular variable may, on occasion, contribute significantly to more than one of the components. Ideally, each variables contribute significantly to only one component. A technique called factor rotation is employed towards that goal. Examples of fields where factor analysis is involved include physiology, health, intelligence, sociology and ecology.

Constant Sum Paired Comparison Method

Pairwise comparison is any general process of comparing entities in pairs to judge which entity is preferred, or has a greater amount of some quantitative property, or whether or not the two entities are identical. The method of pairwise comparison is used in the scientific study of preferences, attitudes, voting systems, social choice, public choice, requirements engineering and multi-agent Artificial Intelligence (AI) systems. In psychology literature, it is often referred to as paired comparison. In the present study, the questionnaire contained qualitative and quantitative factors which are important to pedestrians for assessing their perceived level of service of a pedestrian infrastructure facility. The data of the perceived importance of the identified factors were collected from 204 respondents of the congested city of Patna. Primary factor components among the identified factors (qualitative and quantitative) or groups which are identified as important in assessing PLOS is determined by exploratory factor analysis. After that, pairwise importance survey in 11-point scale (0–10) of primary factor components is conducted. For example, in the pairwise survey of components A and B if A is slightly important than B, A/B is given a rating of 6 and B/A is given a rating of 4. Finally, a comparison rating matrix is obtained which assign the weightage of the parameters based on its importance. This is shown in Table 3.

Data

The data used for the study were obtained from primary survey. The survey was conducted in two parts. In the first part, importance survey of 31 important PLOS assessment components, identified from the literature, was conducted. The importance response was taken in 5-point Likert scale, 1 indicating least important and 5 most important. In the second part, comparative importance of primary parameters data which is obtained after exploratory factor analysis and perception rating of primary component for different localities are collected. Detailed description of data collection is given in following subsections. The next subsection describes the study area; the second subsection provides the sample size requirement for surveys and the third subsection describes the importance survey; the fourth subsection describes the comparative importance survey and the last

Table 3 Example weightage calculation (Constant Sum Paired Comparison Method)

	Comparative importance rating				Weightage score calculation	
	A	B	C	D	Total	Weightage score
A	5	6	4	4	6 + 4 + 4 = 14	14/60 = 0.23
B	4	5	4	3	4 + 4 + 3 = 11	11/60 = 0.18
C	6	6	5	6	6 + 6 + 6 = 18	18/60 = 0.30
D	6	7	4	5	6 + 7 + 4 = 17	17/60 = 0.29
					14 + 11 + 18 + 17 = 60	Total = 1

subsection describes the area-wise perception survey for assessing PLOS of different areas.

Study area

The city of Patna in Bihar has been selected as a study area. It is one of the densely populated city of Bihar and it is 15th most populous districts in India out of total 640 districts, with 1823 inhabitants per square kilometer. This city experiences mostly mixed land use. Data have been collected from the five major localities, viz., Bailey Road, Boring Road, Ashok Rajpath, Rajendra Nagar and Kankarbagh of Patna.

Sample Size of Surveys

Average importance of a parameter is considered for PLOS assessment. The sample size for importance survey was decided considering a deviation of 0.2 in importance rating at 99% confidence level. It was observed that the standard deviation of the sample importance survey varied between 0.9 and 1. Thus, a sample of 186–200 importance ratings was found to be sufficient. Thus, 204 importance surveys were conducted for importance survey of 31 parameters and pairwise comparative importance survey of 7 parameters.

Importance Surveys

Factors selected for importance survey for pedestrian infrastructure include both qualitative and quantitative factors (31 components) related to pedestrian infrastructure facility for mixed land use localities. The importance rating survey was conducted in five major localities of Patna viz. Bailey Road, Boring Road, Ashok Rajpath, Rajendra Nagar and Kankarbagh and response was collected from 204 respondents. Respondent were asked to rate all 31 factors on five point Likert scale where 1 represents pleasant condition and 5 represents unsuitable conditions. Respondents are categorized based on age group, gender and locality. Data from four different age groups, viz., below 18 years, 19–45 years, 46–60 years and above 60 years of age were collected from different localities of Patna are taken for analyzing the effect of age on importance and perception rating along with age group variation. Data from 204 respondent from different major localities of Patna are illustrated in Fig. 1.

Comparative Importance Survey

Primary factor components for assessing PLOS, of the identified 31 factors (qualitative and quantitative) are determined by factor analysis. Comparative importance of primary factor component data which are obtained after exploratory factor analysis is collected by pairwise importance survey in 11-point scale (0–10). For example in the pairwise survey of components A and B if A is slightly important than B, A/B is given a rating of 6 and B/A is given a rating of 4. Finally, a comparison rating matrix is prepared as shown in Table 3.

Perception Survey

Perception rating of pedestrian infrastructure describes the usability and accessibility condition of infrastructure. Here, seven parameters, which are obtained from factor analysis,

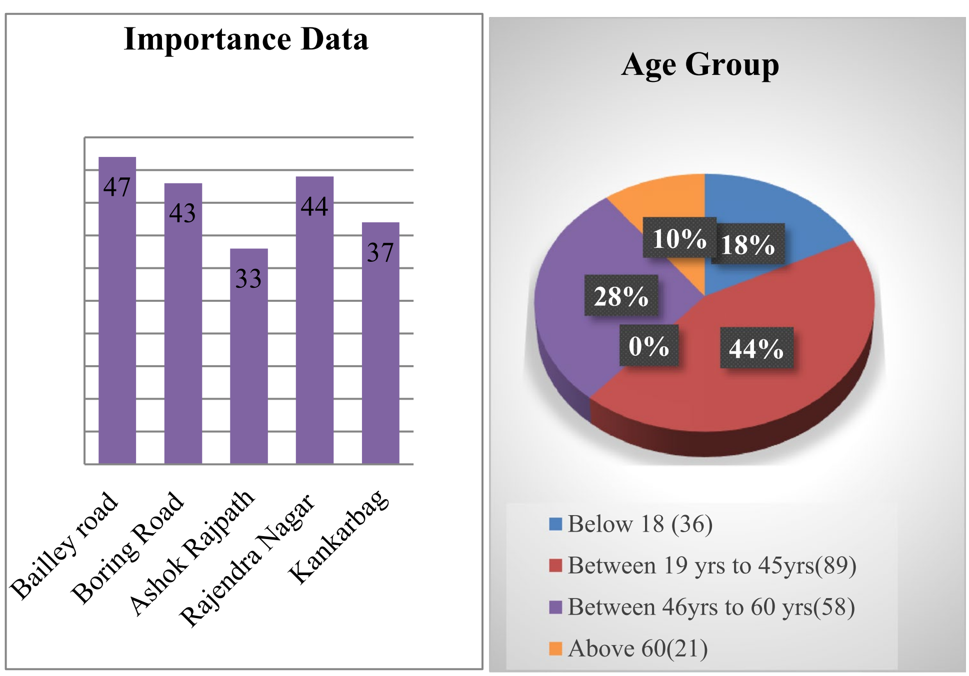

Fig. 1 Importance survey statistics

are taken to describe the usability condition of the pedestrian infrastructure. Perception ratings of primary factor components are collected from the 574 respondent from 5 major localities of Patna on 5 point Likert scale, 1 indicating least serviceability and 5 most serviceability. Average of each primary factor are calculated and used for determining walkability index (Fig. 2).

Analysis Results

The 31 components which are important in assessing PLOS of an area were identified from the literature survey. Importance rating survey of the identified parameters was conducted in 5-point Likert scale forming a structured questionnaire. Scale Reliability for importance rating of 31 components was conducted using Cronbach Alpha value. The Cronbach Alpha value obtained was 0.98 which indicates that the scale is very reliable. Exploratory factor analysis yielded 7 parameters clusters with 24 components as elaborated in Table 4.

Pairwise Importance survey was conducted for the seven identified factor clusters. The weightage of parameters are calculated by Constant Sum Paired Comparison Method at mean (μ) importance score and $m \pm \sigma$ importance scores and is given in Table 5.

It can be observed that safety and security offered by the pedestrian facility is the most important parameter for PLOS assessment. Encroachments in footpaths and pedestrian convenience offered by the pedestrian facility also play an important role in PLOS assessment. It could be observed that a wide difference exists in comparative importance rating for night time condition and traffic on carriageway. The PLOS score for mixed land use is given by the following equation:

$$\begin{aligned} \text{PLOS} = & 14.9 \times P_1 + 16.6 \times P_2 + 14.2 \times P_3 + 15.6 \times P_4 \\ & + 12.6 \times P_5 + 14.9 \times P_6 + 11.2 \times P_7. \end{aligned} \quad (2)$$

Perception rating in 1–5 scale (1 indicating very poor condition and 5 indicating very good condition) for the seven parameters was collected for different areas of Patna, India. Area-wise perception rating of all seven parameters is presented in Table 6.

Comparative study also shows that each area has different priority of parameters which decide the PLOS grade. Area-wise comparative perception rating is represented in Fig. 3.

Based on above Eq. (2), PLOS score and corresponding PLOS grade of selected area of Patna has been determined and presented in Table 7.

It has been noted that PLOS score of an area of Patna is mainly affected by the extent of encroachment. It is observed that areas of Ashok Rajpath, Rajendra Nagar and Kankarbagh are more encroached than Bailey Road and Boring Road. It has been illustrated with the pictorial representation in Fig. 4.

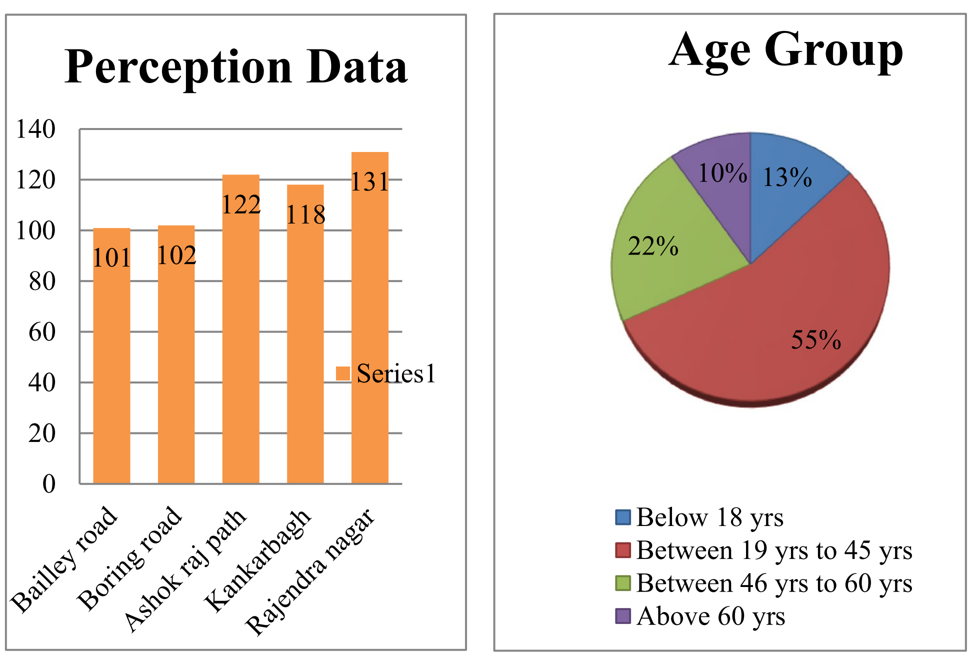

Fig. 2 Perception survey statistics

Table 4 List of parameters and components after exploratory factor analysis

Parameters	Components	Abbreviation
P1. Pedestrian convenience	Availability of shades/trees for pedestrian	ST
	Availability of ramps to access sidewalk by pedestrian	RAS
	Availability of amenities (public toilet, seating facility, and drinking water facility) for pedestrian	AMN
	Routine sidewalk maintenance for cleanliness	RSM
	Availability of covered dustbin at regular interval	CD
	Regular cleaning of public toilet near sidewalk if available	CPT
	Presence of regular designated at grade crossing with zebra crossing mark	PZC
	Presence of traffic control/police at crossing location	TCL
P2. Safety and security	Traffic control devices such as marker, signs and signals	TCD
	Buffer zone between sidewalk and carriageway	BZ
	Availability of lighting facility at night	LN
	Regular police patrolling during night	PPN
	Availability of CCTV cameras to record crime	CCTV
P3. Sidewalk infrastructure	Footpath width	FW
	Footpath height	FH
	Type of footpath surface (concrete/paver block/colorful/marking)	TFS
	Presence of pedestrian foot overbridges with stairs at regular intervals	PFS
	Presence of pedestrian foot overbridges with ramps and elevators at regular intervals	PFR
P4. Heavy encroachments	Effect of encroachments due to temporary vendors on sidewalks	ETV
	Effect of encroachments due to permanent small shops on sidewalks	EPV
P5. Night time condition	Pedestrian volume at night	PVN
	Roadside vending shops attracting pedestrians/people at night	RVP
P6. Partial encroachments on sidewalk	Effect of encroachments due to permanent structures such as electric pole/telephonic pole/trees on sidewalk	EPS
P7. Traffic on carriageway	Traffic volume and composition of carriageway	TVC

Table 5 Weightage score

Parameters	M-1σ	μ	M+1σ	Weightage score
Pedestrian convenience (P_1)	0.15	0.15	0.148	0.149
Safety and security (P_2)	0.21	0.17	0.117	0.166
Sidewalk infrastructure (P_3)	0.17	0.14	0.119	0.142
Heavy encroachments (P_4)	0.14	0.16	0.173	0.156
Night time condition (P_5)	0.16	0.13	0.086	0.126
Partial encroachments (P_6)	0.12	0.15	0.185	0.149
Traffic on carriageway (P_7)	0.05	0.11	0.173	0.112

Conclusions

Assessment of PLOS is important for ensuring safe and secure mobility of people. Sidewalk infrastructure availability and condition plays a vital role in PLOS of a city having mixed land use. A wide range of literature is available focusing on assessment of PLOS but limited research focus on integrating qualitative and quantitative parameters for assessment of PLOS for congested mixed land use locations. This is very important as most old cities are congested and have mixed land use. This work focuses on developing guidelines for PLOS assessment for mixed land use locations integrating both qualitative and quantitative aspects. The guidelines are developed based on the user importance rating

Table 6 Average perception rating

	P1	P2	P3	P4	P5	P6	P7
Bailey Road	3.48	3.59	3.05	3.00	3.19	3.09	2.80
Boring Road	2.91	2.68	2.52	2.41	2.87	2.51	2.80
Kankarbagh	2.55	2.29	2.44	2.35	2.28	2.71	2.76
Ashok Rajpath	2.12	2.14	2.02	2.25	2.12	1.95	2.08
Rajendra Nagar	2.11	2.06	1.98	2.06	2.08	2.09	2.12

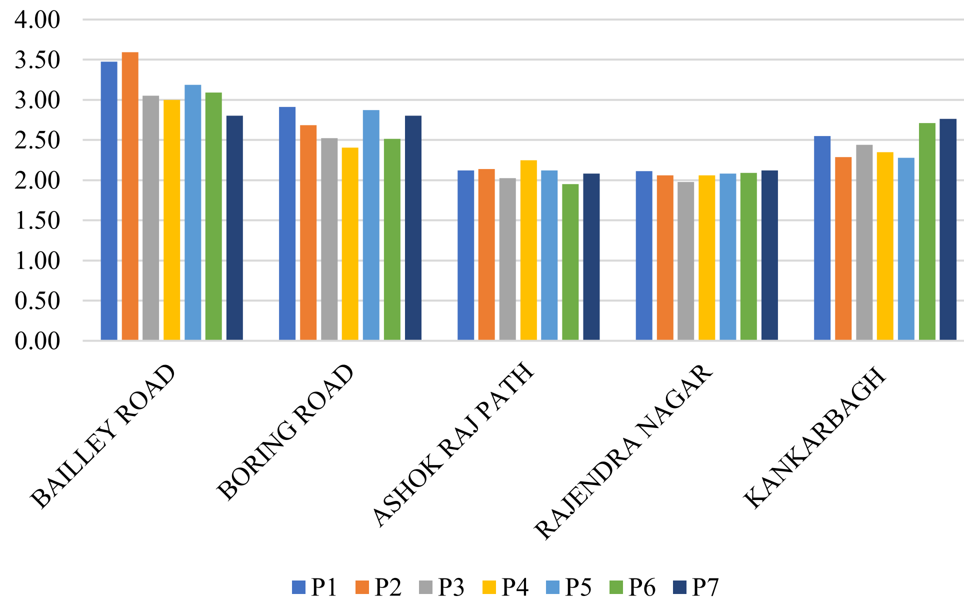

Fig. 3 Area-wise comparative analysis of parameters

Table 7 PLOS score of study areas of Patna

Area	PLOS score	PLOS grade	Remarks
Bailey road	322.5155	C	Acceptable
Boring road	266.3287	D	Unpleasant
Kankarbagh	247.3415	D	Unpleasant
Ashok Rajpath	210.064754	E	Very unpleasant
Rajendra Nagar	207.1487	E	Very unpleasant

on initially identified 31 components which after exploratory factor analysis yielded 7 primary factors with 24 components. Comparative importance survey is then conducted for the seven factors for determination of relative contribution of each factor in determination of PLOS. The PLOS of a pedestrian infrastructure facility can be assessed based on users' perception of the identified qualitative and quantitative pedestrian infrastructure-related parameters. The PLOS grades are segregated based on the user perception as 'A' to 'F' considering 'A' as Very Pleasant and 'F' as Unsuitable condition for pedestrian.

It could be observed that infrastructure conditions and encroachments are most significant factors considered by pedestrians during walking. In addition, safety and security is given high priority by the pedestrians. The relative feedback about traffic condition on carriageway and night time conditions vary widely. The study tries to demonstrate the proposed PLOS assessment methodology by assessing important links of five important areas of Patna which has heavy pedestrian movement. It could be observed that only one area (Bailey Road) out of the five, have acceptable PLOS. Remaining four areas are having unpleasant (Boring Road and Kankarbagh) and very unpleasant (Ashok Rajpath and Rajendra Nagar) PLOS condition. The assessment model is developed with the survey from only one city. For better comparative analysis few more similar cities having similar old settlement and mixed land use may be selected for enriching the model.

Fig. 4 Pictorial analysis of PLOS condition

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