

# Pedestrian Perception of Safety in Areas with Newly Provided Pedestrian Facility: The Case of Bangalore's Tender SURE (Specifications for Urban Utilities and Road Execution Project)



Aditya Saxena, P. S. Reashma, and Basavaraj Kabade

**Abstract** According to India's Ministry of Road Transport and Highways (MORTH), every sixth person killed in a road accident is a pedestrian, making pedestrians vulnerable road users. The general approach to mitigating such an epidemic is to implement corrective infrastructure measures. However, pedestrian perceptions of such changes are often neglected. Although a few studies in the Indian context on pedestrian perceptions of safety have been conducted, the majority of them have been done with the goal of advocating for improvements to existing old infrastructure. This becomes a reactive approach, while the current study aims to examine the safety perceptions of pedestrians in newly pedestrianized zones as a proactive approach by determining the factors that influence pedestrians' perception of safety. The study area under consideration in this study is part of the newly constructed pedestrian zones as a part of the project Tender S.U.R.E. Bangalore. In the present study, principal component analysis (PCA) with a discrete choice model (ordinal logistic regression) was applied to determine the factors affecting the safety perception of pedestrians. Based on the results obtained it was found that pedestrian perceptions of safety were significantly affected by their income level, their frequency of walking, and the three factors derived from principal component analysis. The findings of this study also revealed that pedestrians were most concerned about the approaching speed of vehicles. Referring to the results obtained from the present study, government agencies can plan future interventions pertaining to infrastructural changes.

**Keywords** Pedestrian safety · Perception study · Principal component analysis · Ordinal logistic regression · Income levels · Frequency of walking

---

A. Saxena  
Indian Institute of Technology, Mumbai, India

P. S. Reashma (✉)  
Global Academy of Technology, Bengaluru, India  
e-mail: [psreashma@gmail.com](mailto:psreashma@gmail.com)

B. Kabade  
Bruhat Bengaluru Mahanagara Palike (BBMP), Bengaluru, India

## 1 Introduction

The negative externalities of urban transport cause immense social and economic loss to the nation [1]. According to reports, there are 20–50 million serious injuries each year [2]. According to the World Health Organization (WHO), pedestrian fatalities accounted for 22% of all road-user deaths in 2019, globally [3]. It is imperative that research be conducted to reduce pedestrian crashes [4]. In India, every year almost 1.5 lakh (0.15 million) people lose their lives in road crashes. MORTH categorizes pedestrians and two-wheeler users within the vulnerable road users (VRUs) category [1, 5]. In total, VRUs account for 54% of fatalities. Approximately 55,000 pedestrians were killed in road crashes in just two years (13,400 deaths in 2016 to 22,700 deaths in 2018) [6]. In India, out of the total number of fatalities every year, 17% involve pedestrians, implying that every sixth person who dies in a traffic crash is a pedestrian. Such statistics are indicative of the importance of pedestrian safety studies and inventions in the Indian context. From the start of this century, the Indian government has taken up this matter as a priority. In this regard, amendment in motor vehicle act, approval of Good Samaritan law, allocation of funds for infrastructure improvement, and formation of National Road Safety Committee (NRSC) are some of the clinical measures adopted by the government [7]. MORTH recently initiated grants programs to non-governmental organizations (NGOs) for working on road safety at the advocacy level. In terms of urban design interventions, the Ministry of Housing and Urban Affairs has recently launched its campaign for Pedestrianization of at least three marketplaces in every million-plus city of India [8].

Even after the availability of extensive kinds of literature for pedestrian safety and design guidelines, there exists a gap. In the Indian Context, road safety studies are often worked out from an infrastructure engineering and design point of view, and the perspective of the road user is often left out in such studies. The present study is an attempt to bridge this existing gap by performing a pedestrian perception study and assessing the parameters affecting it. The city of Bangalore is taken up as a case for conducting pedestrian perception study towards road safety. The present study evaluated the influence of 12 parameters selected from the literature review for identifying pedestrian safety perceptions. Cronbach's alpha test was used to assess the reliability and internal consistency of the selected parameters; additionally, the selected parameters were subjected to principal component analysis to derive factors from the selected parameters. The derived factors were then subjected to ordinal logistic regression with perceived safety ratings of pedestrians as dependent and derived factors, other socio-economic variables as independent to establish the relationship.

Bangalore is the fifth largest metropolis in India, with a total population of 8.5 million [9]. Just like most of the metro cities in India, the pedestrian safety scenario in Bangalore is critical. As per the dataset released by the traffic police department of Bengaluru, the city witnessed 7019 fatal crashes which resulted in 7297 losses of lives from 2010 to 2020 [10]. To mitigate pedestrian fatalities and improve pedestrian safety, the government of Karnataka initiated Tender S.U.R.E. (Specifications

for Urban Road Execution) project in Bangalore [11]. As of yet, it has yet to be determined whether such a pedestrian safety initiative would be effective.

## 2 Literature Review

### 2.1 A Subsection Sample

In the context of urban transportation, global, perception studies have been extensively cited [12–[14]. Based on their literature study, Raad [15] highlighted comfort level, footpath width, obstructions to pedestrian flow, motor vehicle speeds and volumes, shoulder widths, and on-street parking as determinants of pedestrian perception towards infrastructure. In another study, it was found pedestrian perception as a powerful tool for evaluating the Quality of Service (QoS) at sidewalks [16]. Another attempted to explore the importance of public perceptions on road safety measures and rules and concluded that in order to build a safe scenario, public participation and their support is pivotal [17]. In a study conducted in Vietnam, the influence of attitudes towards traffic safety, risk perceptions, and pedestrian behaviors was explored [18]. Using regression analysis and structural equation modeling, the author determined that safer attitudes towards traffic safety and higher levels of traffic risk perception are associated with safer pedestrian behaviors.

Ram [19] performed a similar kind of study by applying exploratory factor analysis, followed by confirmatory factor analysis to understand the effect of drivers' risk perception and perception of driving tasks on road safety attitude. His study observed a significant positive correlation between drivers' risk perception and perception of driving tasks and found that both perceptions significantly affect drivers' road safety attitudes. Espinoza [20] also focused on driver's perception of road safety using confirmatory factor analysis and grouped the selected 41 variables into 6 categories (human, vehicle, road infrastructure, regulatory framework and intervention measures, socio-economic and driving precautions). Another study of the same kind was performed by Anapakula [21] for assessing the parameters affecting the quality of the pedestrian environment and later on developing an index for the same. They advocated that such studies will assist governing bodies in progressive decision-making, as well as help them in prioritizing pedestrian-oriented investments. Balasubramanian [22] assessed pedestrians' perception while approaching vehicles crossing towards the road in the nighttime, and concluded that the effect of beam light from vehicles had a direct relation with safe crossing.

There can be multiple parameters and factors affecting pedestrian safety and their perception. Vijayawargiya [23] identified vehicle volume, vehicle speed, carriageway width, pedestrian refugee island, street lights, and road marking and signage as major parameters affecting pedestrian safety perception. In another study, Bendak [24] waiting time before crossing the road, sight distance, speed of approaching vehicle were considered as determining parameters. The world health organization (WHO)

in one of their study found that inadequate visibility, speed of approaching vehicles, and improper road sign and markings were the major reason for pedestrian crashes [25]. Barón [26] determined that properly raising median and curbs, availability of resting places, quality of footpath, cleanliness, and aesthetics are major motivating features for a pedestrian to perceive a secure walking environment.

In India, pedestrian safety research has received considerable attention in recent past years. Both reactive and proactive safety approaches were adopted and tried to quantify both actual as well perceived risk of pedestrian safety. Studies focused on reactive approach, investigated historical crash data, identified the high-intensity crash location (black spot) also the potential risky elements influencing pedestrian safety by correlating the crash data to infrastructure elements, built environment, traffic operational characteristics. One such reactive study was conducted by Rankavata [27], wherein forty-five crash spots were identified using past data, a primary survey was conducted to assess the pedestrians' perceived risk towards safety, and an ordered logit model was further used to evaluate the effect of various demographics on perceived road safety. While proactive safety studies were conducted by Bhaduri [28] and Kumar [29] where the focus was to study the perceived satisfaction of pedestrians towards the present infrastructural services.

Many studies focused on pedestrian behavior aspects and quantified the dynamics of pedestrian-vehicle interaction. Kumar [30] explored the yielding behavior of road users during conflicts and analyze the spontaneous order developed at intersections. The results obtained from their study suggested that vehicle volume, type of vehicle, noncompliance with signals by pedestrians, type of pedestrian-vehicle interaction, and size of intersection are some of the major factors that are significant predictors of the dominance of road users. In order to assess the reasons behind pedestrian-vehicle interaction at un-signalized junctions, a study was conducted by Kathuria [31] where severity levels were proposed under heterogeneous traffic conditions using Import Vector Machine (IVM) approach.

The proactive-based approach is gaining more attention as they promise in-depth safety analysis focusing on nearby pedestrian-vehicle interaction (near-miss collision events) and identifying the degree of severity of collisions by meaningfully relating it to actual crashes. Many researchers have combined both proactive and reactive safety approaches and assessed pedestrian safety. Chatterjee [32] identified several risk factors responsible for road crashes in rural roads using the principles of the road safety audit, developed a risk matrix using available crash data, and concluded that integrating the findings from reactive analysis with proactive safety management is more beneficial than just focusing on only proactive or reactive approaches. Mukherjee [33] proposed a methodology combining both reactive and proactive approaches to assess pedestrian safety at urban intersections using a combination of historical crash data, analysis of pedestrian-vehicle interaction, and pedestrian risk perception towards built environment and traffic characteristics.

For a pedestrian, safety is not limited to being safe but also to the extent of feeling safe. Perception studies are usually deployed to understand how pedestrians feel safe on roads. It also serves as input for decision-makers to improve the safety measures to achieve the safety target. Pedestrian perception safety studies were also

performed in the Indian context, but the nature of these studies and their objectives varied widely. Many research studies Kadali [34] performed perception studies with respect to specific pedestrian facilities and had developed models to evaluate the safety level and determining the respective level of service. Rankavata [27] conducted pedestrian perception studies in Delhi to understand the underutilization of pedestrian facilities like a zebra crossing, underpasses, and overpasses and also assessed the existing safety level of each of these facilities. Mukherjee [33] studied pedestrian perceived satisfaction level at signalized intersections in Kolkata city in the viewpoint of fatal pedestrian crash frequency. Pedestrian perception studies were performed by Banerjee [35] to identify the critical factors influencing the use of pedestrian skywalk facilities in an Indian context. Studies have reported the use of pedestrian perception to identify their impact on future travel decisions Rahul [36].

As noted in the reviewed literature, in the Indian context, it is logit models and structural equation modeling methods are most frequently used for assessing the perception of pedestrians. Contrary to other studies, the present study adopts a proactive approach by assessing the factors influencing pedestrians' perception of road safety by using a combination of principal component analysis and discrete choice model (ordinal logistic model), an approach that has not been previously explored extensively. The advantage of applying such an approach is that it has the ability to analyze pedestrian safety perception at an aggregate level by deriving factors out of the several selected parameters, thus making it easy for the government to implement future infrastructure change easily. The objective of the current study is (i) to identify the various factors that affect the pedestrian perception of road safety and (ii) to assess how satisfied they are with the selected factors.

### 3 Methodology and Data Collection

Based on the discussion with Bruhat Bengaluru Mahanagara Palike (BBMP), Twelve Central Business Districts (CBDs) were selected in Bangalore based on their high utility and footfall. After the selection of the study area, the sample size was determined using Slovin's Formula. All the selected twelve CBDs were considered as one study area and based on the cumulative footfall, a sample size of 384 samples was determined, at 95% confidence level and 5% margin of error. After extraction of the total number of samples to be obtained, the sample size was further distributed based on the footfall proportion of each CBD against the cumulative footfall. With the help of literature review, the present study considers twelve parameters (presence of road sign and marking, lighting at the crossing, presence of refuge island, pedestrian volume, waiting time while crossing the road, visibility and sight distance, cleanliness, and quality of footpaths, continuity of footpaths, obstruction-free footpaths, and speed of approaching vehicles) as the determining parameters for deriving principal component factors. The derived factors and the socio-economic variables of the respondents are then subjected to an ordinal logit model.

A survey questionnaire was designed for the purpose of assessing the impact of selected parameters on perceived satisfaction towards road safety for pedestrians. The samples were collected using the random sampling method. No specific group or class of people was targeted. The survey was conducted by 9 surveyors at the selected locations through Google forms filled by the respondents. A total of 384 samples were collected from selected locations. The data was collected using a 5-point Likert scale. Further, to capture the socio-economic profile of respondents, data regarding their age (0–15, 15–59, and older than 59) in an ordinal scale, gender (male, female) on a nominal scale, household income (0–25, 25–50, 50–100, and above 100k) in ordinal scale, and frequency of walking a week (every day, 3–4 days, 5 days, weekends only, and hardly ever) in ordinal scale were collected.

After the primary data collection, the obtained data were sorted and analyzed using statistical software Jamovi, which is a GUI for the R programming language. For performing statistical analysis, the initial step is to validate the reliability and measure the internal consistency of data. Cronbach's Alpha test was used for this purpose and the standardized value achieved was around 0.8, indicating a very good model fit. Based on the satisfaction rating of twelve selected parameters, collected from the Likert scale, principal component analysis was performed for the purpose of dimension reduction using the varimax rotation method. In our study, varimax rotation was applied since datasets were not correlated [37]. Twelve parameters were reduced into three factors. The three obtained factors were then utilized to understand the relation between them and perceived road safety using an ordinal logistic regression model. For the purpose of regression, respondents were asked to assess the pedestrian road safety condition in the survey area and rate it from "very low" (1) to "very high" (5).

The foremost task was the identification of parameters affecting perception towards safety. The survey questionnaire included questions about the socio-economic profile and travel behavior characteristics of respondents in the first part. In the second part of the survey questionnaire, respondents were asked to rate their satisfaction with the selected parameters. Twelve parameters for principal component analysis were identified from the literature review and were assigned codes for simplicity in analysis. The selected parameters and their respective coding are shown in Table 1.

The survey questionnaire was designed to capture the socio-economic profile and travel behavior of respondents along with their perceived satisfaction on selected parameters and road safety satisfaction level or rating with regard to the area where the survey was conducted. For the purpose of sampling, the total footfall of all the CBDs was considered and Slovin's formula was used to determine the sample size [38]. In Slovin's formula, a 95% confidence level was considered and a 5% margin of error.

Slovin's formula:

$$n = \frac{1}{Ne^2} \quad (1)$$

**Table 1** Identified parameters for principal component analysis

Parameter	Respective infrastructure	Code
Speed of approaching vehicles	Midblock	Q1
Presence of road sign and marking	Midblock	Q2
Waiting time	Midblock	Q3
Lighting at crossing	Midblock	Q4
Presence of refuge island	Midblock	Q5
Visibility/sight distance	Midblock	Q6
Pedestrian volume	Footpath/sidewalk	Q7
Cleanliness of footpath	Footpath/sidewalk	Q8
Availability and quality of street lights	Footpath/sidewalk	Q9
Resting spaces	Footpath/sidewalk	Q10
Continuity of footpath	Footpath/sidewalk	Q11
Presence and quality of kerb height	Footpath/sidewalk	Q12

where,  $n$ -Sample size,  $N$ -Total population/Footfall,  $e$ -Margin of error.

From secondary data, total footfall was found to be around 4,80,000 per day, implying a sample size of 384 when equated in Eq. (1).

## 4 Results

This section details out the results obtained from descriptive and statistical analysis performed from the data collected.

### 4.1 Descriptive Statistics

In terms of socio-economic profile, from the collected data, it was observed that 61% of the respondents were male, while only 39% were female. Within the age category, the working-age group had a very significant share within the respondents with 91% of them between the age group of (15–59), followed by senior citizens with only 8% of them. Within the income category, the lower-income group (0–25 k/month) and the middle-lower income group (25–50 k/month) recorded a significant share with 46% and 27% respectively. Based on the data collected, 73% of the respondents walked every day. The data collected from the primary survey is depicted in Table 2.

**Table 2** Socio-economic profile of respondents

Age	Number	Percentage share
0–15	3	1
15–59	349	91
60 and above	29	8
NA's	3	1
<i>Gender</i>		
Female	148	39
Male	233	61
Other	1	0
NA's	2	1
<i>Monthly household income</i>		
>100k	23	6
0–25k	177	46
25–50k	104	27
50–100k	72	19
NA's	8	2
<i>Frequency of walking in a week (walking as a mode)</i>		
1–3 days	46	12
4–5 days	26	7
Every day	281	73
Hardly ever	1	0
Weekends only	30	8
Total	384	100

## 4.2 Perception Study Details

Results from the perception study depict that overall, people were not satisfied with the current infrastructure provided or present prevailing conditions, as the mean obtained for most of the selected parameters was lower than 3 (which was described as average while conducting surveys). The highest mean was obtained for the twelfth parameter which was “Appropriate Kerb Height.” While the people were most unsatisfied with the first parameter “speed of approaching vehicles.” The selected parameters were coded for the purpose of simplicity in data analysis and representation, as shown in Table 3.



**Table 3** Perception of respondents towards selected parameters

Parameter	Respective infrastructure	Code	Median	Mean
Speed of approaching vehicles	Midblock	Q1	2	2.402
Proper road sign and marking	Midblock	Q2	3	2.825
Waiting time	Midblock	Q3	3	2.517
Lighting at crossing	Midblock	Q4	3	2.836
Presence of refuge island	Midblock	Q5	3	2.559
Visibility/sight distance	Midblock	Q6	3	2.995
Pedestrian volume	Sidewalk	Q7	3	2.671
Cleanliness of footpath	Sidewalk	Q8	3	2.919
Availability and quality of street lights	Sidewalk	Q9	3	2.564
Resting spaces at footpaths	Sidewalk	Q10	3	2.705
Continuity of footpath	Sidewalk	Q11	3	2.817
Appropriate kerb height	Sidewalk	Q12	3	3.201

### 4.3 Statistical Analysis

#### 4.3.1 Principal Component Analysis (PCA)

Principal Component Analysis was performed on all the twelve selected parameters for dimension reduction and extracting factors out of the selected parameters. Principal component analysis (PCA) is a technique for reducing the dimensionality of such datasets, increasing interpretability but at the same time minimizing information loss. The benefit of using PCA is that it removes correlation between different parameters, and improves visualization. Using “Jamovi” as a tool, component variances and component loading was obtained. Component variances refer to estimates of the contributions that different experimental factors make to the overall variability of the data while component loading is the contribution of the particular variable to the principal component [39]. As studied from the literature review, only those factors were retained whose Eigenvalue is above 1 [40]. Three factors were acquired from Component variances, as shown in Table 4. The correlation between factors and parameters was found from component loading and only those parameters were retained whose correlation value was above 0.5 [41], as depicted in Table 5. The following equation was used for computing covariance [42].

$$Cov(X, Y) = \frac{[\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})]}{n - 1} \tag{2}$$

where X, Y are variables.

**Table 4** Eigenvalues for components

Component variances	Eigenvalues	Importance of components (%)
Comp.1	3.79	31.60
Comp.2	1.562	44.60
Comp.3	1.002	53.00

**Table 5** Parameter correlations with obtained factors

Parameters	Component loading			Uniqueness
	1	2	3	
“Q1”	0.691			0.44
“Q2”	0.604			0.57
“Q3”	0.645			0.52
“Q4”	0.539			0.65
“Q5”	0.712			0.47
“Q6”	0.552			0.41
“Q7”	0.597			0.61
“Q8”		0.60		0.37
“Q9”			0.794	0.34
“Q10”		0.643		0.53
“Q11”			0.595	0.39
“Q12”		0.799		0.34

The top three components were only retained. The retained three components explain 53% of the variance which is acceptable [43]. The respective component loading values are depicted in Table 6.

Furthermore, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is used to determine whether the data is sufficient for a stable factors solution. The KMO test considers the variance explanation of the indicators. Bartlett's sphericity test checks the validity of factor analysis by examining the whole correlation matrix, which identifies the correlation between variables. This is a measure of how strongly one variable is correlated with another. A KMO value greater than 0.5 and a significance level of less than 0.05 for Bartlett's test suggest that the data exhibit a strong correlation [44, 45]. Based on the KMO measure and Bartlett's Test of Sphericity, a value of 0.819 was evaluated with a significance level of less than 0.01.

Finally, obtained component values for component loading with respect to the corresponding factor. Factor 1 contains Q1, Q2, Q3, Q4, Q5, Q6, and Q7, Factor 2 comprises Q10 and Q11, while Factor 3 includes Q9 and Q12. Table 6 illustrates the obtained factors and their respective parameters.

**Table 6** Obtained factors and their respective parameters

Parameter	Respective infrastructure	Code
Speed of approaching vehicles	Midblock	PCA 1
Proper road sign and marking	Midblock	
Waiting time	Midblock	
Lighting at crossing	Midblock	
Presence of refuge island	Midblock	
Visibility/sight distance	Midblock	
Pedestrian volume	Sidewalk	
Cleanliness of footpath	Sidewalk	PCA 2
Appropriate kerb height	Sidewalk	
Resting spaces at footpath	Sidewalk	PCA 3
Continuity of footpath	Sidewalk	
Availability of street lights	Sidewalk	

### 4.3.2 Cronbach’s Alpha

To estimate the reliability of data and check its internal consistency of parameters under each factor, Cronbach’s Alpha test was performed. Cronbach’s Alpha measures reliability by comparing the amount of variance shared among the items that make up an instrument to the overall variance of the instrument. For statistical significance, a value of 0.7 is considered acceptable [46]. Majorly, Cronbach’s alpha test is applied to the data collected through the Likert scale. Cronbach’s alpha was performed between the selected parameters for the following purpose. The obtained reliability was around 0.8, which signifies a good fit or good reliability of data. The obtained results are shown in Table 7. Furthermore, to evaluate the multi-collinearity diagnostics, tolerance level and Variance inflation factor (VIF) value was estimated. The range for rejecting multi-collinearity in data was adopted as VIF value < 10 and tolerance value > 0.10 [47]. The dataset was found to be reliable and free from multi-collinearity after performing the tests.

### 4.3.3 Ordinal Logistic Regression

The ordinal logistic model develops the relationship between an ordinal response variable and one or more explanatory variables using ordinal logistic regression. After extracting Factors, ordinal logistic regression analysis was performed for assessing the relationship between the three Factors and the overall city safety rating given by respondents while conducting the survey. The safety ratings were kept as a dependent while the three factors were kept as independent variables. The equation used for performing ordinal logistic regression analysis is as follows [48]:

**Table 7** Results obtained from Cronbach’s alpha test

Parameter	Respective infrastructure	Factor	Mean
Speed of approaching vehicles	Midblock	PCA 1	0.787
Proper road sign and marking	Midblock		
Waiting time	Midblock		
Lighting at crossing	Midblock		
Presence of refuge island	Midblock		
Visibility/sight distance	Midblock		
Pedestrian volume	Sidewalk		
Cleanliness of footpath	Sidewalk	PCA 2	0.732
Appropriate kerb height	Sidewalk		
Resting spaces at footpaths	Sidewalk		
Continuity of footpath	Sidewalk	PCA 3	0.704
Availability of street lights	Sidewalk		

**Table 8** Model fit statistics for ordinal logistic model

Model	Deviance	AIC		R <sup>2</sup> <sub>N</sub>	χ <sup>2</sup>	Overall model test	
			R <sup>2</sup> <sub>McF</sub>			df	p
1	920	950	0.355	0.408	85.9	11	< 0.001

$$y_n = \beta^T x_n + \epsilon_n n = 1, \dots, N \tag{3}$$

where  $y_n$  is given by the combination of variables, parameters, and random residuals that are taken into consideration in the estimated models, being  $n$  as the generic individual and  $N$  as the sample size.  $\epsilon_n$  represents the random residuals. The vector  $x_n$  is a set of covariates, assumed to be independent of  $\epsilon_n$ .  $\beta$  and  $y$  are vectors of estimated parameters.

The results obtained from ordinal logistics regression analysis (keeping safety rating as dependent variable and PCA1, PCA 2, PCA 3, gender, income and frequency of walking as independent variables) are shown in Tables 8 and 9.

From Table 9, it can be observed that while income, frequency of walking, and the three derived factors (PCA1, PCA2, PCA3) had a significant relationship with safety ratings, gender was found to have insignificant relation.

## 5 Discussion and Conclusion

The results indicate that PCA1, PCA 2, and PCA 3 do not support the null hypothesis, as a significant relationship exists between all three derived factors and perceived safety ratings. In addition, income levels and walking behavior (frequency of walking

**Table 9** Results from ordinal logistics regression

Predictor	Estimate	SE	p	Odds ratio	95% confidence interval	
					Lower	Upper
PCA1	0.4232	0.102	<0.001	1.5268	1.25	1.869
PCA2	0.5115	0.101	<0.001	1.6678	1.37	2.037
PCA3	0.5915	0.102	<0.001	1.8066	1.482	2.211
“Monthly household income”						
50–100k – 0–25k	–0.815	0.276	0.003	0.4426	0.257	0.76
>100k – 0–25k	–0.1317	0.426	0.757	0.8766	0.381	2.035
25–50k – 0–25k	–0.4215	0.238	0.077	0.656	0.411	1.045
“Frequency of walking in a week”						
4–5 days–weekends only	–1.2236	0.497	0.14	0.2942	0.11	0.777
Every day–weekends only	–0.9904	0.371	0.008	0.3714	0.178	0.765
1–3 days–weekends only	–0.9522	0.441	0.031	0.3859	0.162	0.914
Hardly ever–weekends only	–4.0273	1.788	0.024	0.0178	4.22E-04	0.724
“Gender”						
Male–Female	–0.0959	0.2	0.631	0.9086	0.614	1.344

in a week) were also significantly related to perceived safety ratings. However, gender did not have a significant relationship. Based on the data analysis results, we can also conclude that all three derived factors had a greater influence on perceived safety than socio-economic variables. In terms of income bracket, respondents earning “50–100 k” per month were 0.44 times less satisfied with perceived safety as compared to those earning “0–25 k” per month. As for walking behavior, Respondents who only walk every day were found to be significantly more satisfied as compared to respondents who walk on weekends only. The results of this study also showed that in general, pedestrians were most anxious about the approaching speed of the vehicles.

The perception of pedestrian safety has been studied from a reactive and a proactive perspective [49–51]. The present study was a proactive approach-based study on the perception of pedestrians regarding the infrastructure changes in Bangalore under the TENDER SURE program. The results of the present study will assist the concerned authorities in identifying the areas on which they need to focus in the future to improve the perceived safety level of roads. The need to improve perceived safety levels has been justified by several studies, in order to enhance the mode share of non-motorized transport and reduce car dependency, safety perception directly influences the choice of mode of transportation [52–54]. According to the results of this study, all the selected parameters (road sign and marking, lighting at crossings,

presence of refuge islands, pedestrian volume, crossing time, visibility and sight distance, continuous footpaths, obstruction-free footpaths, and speed approaching vehicles) except for one (cleanliness on the footpath) had a notable impact on pedestrian safety perception. Furthermore, pedestrians were most concerned about the speed of approaching vehicles, which is consistent with the findings of other studies [22, 55–57]. Moreover, it was also found that people who walk only on weekends are more satisfied with safety levels than people who walk daily, frequently, or rarely. However, this is a distinct observation from the existing literature [58, 59]. The reason for this observation may be that people who walk only on weekends experience fewer safety issues than those who walk daily, frequently. Additionally, these respondents who walk only on weekends do not face the same traffic conditions as those who walk on weekdays.

The conclusion which can be drawn from the present study is that respondents feel unsafe while crossing the road because of the high speed of approaching vehicles while they comparatively seem to be satisfied with the infrastructure provided at side-walk/footpaths. Additionally, the result of the work made under Tender S.U.R.E. can also be related to the project's major purpose, which was primarily about improving pedestrianization with urban design interventions. Based on the responses, it is determined that most respondents complained about difficulty crossing the street, lack of enforcement and policeman to regulate traffic, lack of resting areas on sidewalks, and poor quality of footpaths and streets. On the other hand, most respondents revealed no problems with obstructions on or continuity of the path. Many respondents even expressed a desire for more trees and greenery around the sidewalks. While, with Tender S.U.R.E., city authorities are attempting to meet the infrastructure users' needs, maintaining and ensuring the quality of the services provided are entirely different issues. In addition, respondents repeatedly pointed out the lack of a proper drainage system that causes waterlogging and unhygienic conditions. The issue needs to be addressed quickly so that pedestrians can be safe and secure all year round.

## 6 Research Contribution

Traditionally, pedestrian safety studies have been carried out with a view to suggesting improvements to the old infrastructure. Most studies have used pedestrian perception to examine the root causes of their safety perception and to identify the factors affecting their perception, while in this study, we examine the factors which influence pedestrian perception in areas that have recently been pedestrianized under a government project. The selected areas are under the project of Tender S.U.R.E. The goal of this study is to take a closer look at the areas or parameters that need further attention even after improving road infrastructure specifically for pedestrians. This was determined by selecting 14 parameters that can be directly related to pedestrian safety perception.

Furthermore, the present study employs an approach wherein we combine principal component analysis with the discrete choice model (ordinal logit model). The advantage of using this approach is that often it becomes difficult to interpret the results when several parameters have a significant influence on the dependent variable. By employing this method, we were able to derive 3 factors out of 14 parameters, thus making it easy for the city authorities and implementation agencies to prioritize which factors they need to improve further.

## 7 Future Scope and Limitations

The purpose of this study was to identify the factors that affect pedestrian perceptions of safety. Using principal component analysis and ordinal logistic regression, the current study examined the relationship between perceived safety levels and the contributing factors, as well as the socio-economic profile of respondents. Due to the perception-based nature of the present study, there may be a number of factors that influence pedestrians' perceptions of safety that may not have been taken into account in the current study. It is worth noting that because sampling was random, the socio-economic factor "age" of the respondent was not included in the analysis of the data since the data for age was found to be highly skewed. This is because in India, the category of "15–59" is considered as a working-age group and a vulnerable age group [7]. We kept this category as it is for the purposes of collecting samples in this model. This study is also limited by the fact that nearly 37% of the samples were collected from a specific location, meaning the perception of respondents in that location had a big impact on the overall results. Further, the extracted factors could explain up to 53 percent of the total variance, which is one limitation of using principal component analysis.

### Response to Reviewers

The authors would like to thank the scientific committee for accepting our manuscript and suggesting important changes. The suggested changes have been incorporated. Please find the point-by-point response.

Comments	Revisions
<i>Reviewer 1</i>	
How sample representativeness is checked, how it's representing the population	Based on the discussion with Bruhat Bengaluru Mahanagara Palike (BBMP), Twelve Central Business Districts (CBDs) were selected in Bangalore based on their high utility and footfall. After the selection of the study area, the sample size was determined using Slovin's Formula. All the selected twelve CBDs were considered as one study area and based on the cumulative footfall, a sample size of 384 samples was determined, at 95% confidence level and 5% margin of error After extraction of the total number of samples to be obtained, the sample size was further distributed based on the footfall proportion of each CBD against the cumulative footfall
Is any pilot survey conducted?	Yes, the authors conducted pilot survey to check the adequacy and flow of survey questions. However, we did not include the samples collected from pilot survey for main data analysis
Only traffic safety is considered? What about personal security, i.e., security from crime?	The present study looks into the case of implementation of safety measures adopted under Tender S.U.R.E. project in Bangalore city. The scope of the present study was limited to assess the safety perception of pedestrians towards road crashes. Personal security related to other crimes were not considered in the present study
Mean perception is very low for all variables. What about the standard deviation?	The standard deviation for all the parameters ranged from 0.73 (minimum) to 1.87 (maximum)
Pearson correlation analysis need to conducted to assess the correlation among attributes	In order to account for the effect of collinearity, PCA was employed. The parameters that had high correlation among each other were reduced into a single factor. Table 5 depicts the same Regarding the correlation among the derived factors, PCA as a statistical method itself takes care of it

(continued)



(continued)

Comments	Revisions
What is research contribution and novelty? Similar studies are already conducted in Indian context	Traditionally, pedestrian safety studies have been carried out with a view to suggesting improvements to the old infrastructure. Most studies have used pedestrian perception to examine the root causes of their safety perception and to identify the factors affecting their perception, while in this study, we examine the factors which influence pedestrian perception in areas that have recently been pedestrianized under a government project. The selected areas are under the project of Tender S.U.R.E. The goal of this study is to take a closer look at the areas or parameters that need further attention even after improving road infrastructure specifically for pedestrians. This was determined by selecting 14 parameters that can be directly related to pedestrian safety perception Furthermore, the present study employs an approach wherein we combine principal component analysis with the discrete choice model (ordinal logit model). The advantage of using this approach is that often it becomes difficult to interpret the results when several parameters have a significant influence on the dependent variable. By employing this method, we were able to derive 3 factors out of 14 parameters, thus making it easy for the city authorities and implementation agencies to prioritize which factors they need to improve further
<i>Reviewer 2</i>	
In the Abstract, there are repetitions of sentences in lines from 20 to 28. Please check	Suggested change has been taken care off
Page 3, Line 30, World Health Organisation. W.H.O can be in capital letters	Suggested change has been incorporated
Page 3, line 32 [22]—while citing a reference in the starting of a sentence, parenthesis may be omitted. Please check	Suggested change has been incorporated
Page 3, line 32 [26]—same observation as in 3	Suggested change has been incorporated
Page 4, line 4, line 17, line 31, line 34—same observation as in 3	Suggested change has been incorporated
Page 5, line 3: Research contribution section may be located towards the end of the paper	As suggested by the reviewer we have moved the research contribution section towards the end

(continued)

(continued)

Comments	Revisions
Page 6, line 5, frequency of walking a week, if 4 days, it comes under which category? (3–4 days or 4–5 days?)	Thank you for highlighting this mistake. It will actually come under 3–4 days. To avoid any type of miscommunication we have made the necessary change in manuscript
Page 7, line 7, Slovin’s formula is given as $n = 1/Ne2$ . But it is found to be $n = N/(1 + Ne2)$ . From the following reference. <a href="https://www.statisticshowto.com/probability-and-statistics/how-to-use-slovins-formula/">https://www.statisticshowto.com/probability-and-statistics/how-to-use-slovins-formula/</a> please comment	By mistake, wrong citation was inserted. We have changed the source of information
Page 7, line 23, “Based on the data collected, walked every day (73%).” Please modify the sentence	Suggested change has been incorporated
Page 7, line 15, subsection 5.1, many details in the text (lines 19 to 23) are repeated in Table 2, which can be modified/omitted	Suggested change has been incorporated
Page 7, line 23–24, “The interpretation of data collected from the survey is depicted in Table 2.” This sentence may be modified	Suggested change has been incorporated
Page 9, line 7, punctuation is missing	Suggested change has been incorporated
Page number 12, line 9, please correct the typing error “(frequency of walking in a weak)”	

**Funding** Not available.

**Disclosure Statement** The authors report there are no competing interests to declare.

## References

- Saxena A, Choudhury B (2022) Internalizing the externalities of urban private transport—a case of Gurugram, national capital region, India. *Case Stud Transp Policy*. <https://doi.org/10.1016/j.cstp.2022.08.002>
- Mphela T, Mokoka T, Dithole K (2021) Pedestrian motor vehicle accidents and fatalities in Botswana—an epidemiological study. *Front Sustain Cities*. <https://doi.org/10.3389/frsc.2021.666111>
- The World Bank (2017) The High Toll of Traffic Injuries: Unacceptable and Preventable. <https://openknowledge.worldbank.org/bitstream/handle/10986/29129/HighTollOfTrafficInjuries.pdf?sequence=5&disAllowed=y>
- Zegeer CV, Carter DL, Hunter WW, Richard Stewart J, Huang H, Do A, Sandt L (1982) Index for assessing pedestrian safety at intersections. *Transp Res Rec J Transp Res Board* 1982(1):76–83. <https://doi.org/10.1177/0361198106198200110>
- Saxena A (2022) Is street design and infrastructure perceived differently by persons of different ages, genders, and hierarchy of street? *Innov Infrastruct Solut*. <https://doi.org/10.1007/s41062-022-00880-2>

6. Dash DK (2019) 62 pedestrians die daily in India, up 84% in 4 years. <https://timesofindia.indiatimes.com/india/62-pedestrians-die-daily-in-india-up-84-in-4-years/articleshow/72101003.cms>
7. Transport Research Wing (2019) Road accidents in India—2019. Ministry of Road Transport and Highways, MORTH
8. MOHUA (2020) Pedestrianisation in market places: MoHUA recommends holistic planning for pedestrian friendly market spaces in consultation with stake holders. <https://pib.gov.in/PressReleasePage.aspx?PRID=1630613>
9. Registrar General & Census Commissioner., India (2011) 2011 Census data. <https://censusindia.gov.in/2011-common/censusdata2011.html>
10. Police (2021) Bengaluru traffic. Accident Statistics. <http://www.bangaloretrafficpolice.gov.in/Accidentstats.aspx>
11. Indian Urban space foundation (2012) Government of Karnataka project tender S.U.R.E. Report. Indian Urban space foundation
12. Pietrantonio H, Bornsstein LL (2015) Evaluating road safety audit procedures: some questions and a new method of study. *Transp Plan Technol* 38(8):909–34. <https://doi.org/10.1080/03081060.2015.1079390>
13. Qi Y, Zhao Q (2017) Safety impacts of signalized lane merge control at highway work zones. *Transp Plan Technol* 40(5):577–91. <https://doi.org/10.1080/03081060.2017.1314499>
14. Kim NS, Yoon SS, Yook D (2017) Performance comparison between pedestrian push-button and pre-timed pedestrian crossings at midblock: a Korean case study. *Transp Plan Technol* 40(6):706–21. <https://doi.org/10.1080/03081060.2017.1325146>
15. Raad N, Burke MI (2018) What are the most important factors for pedestrian level-of-service estimation? A systematic review of the literature. *Transp Res Rec J Transp Res Board* 2652(35). <https://doi.org/10.1177/0361198118790623>
16. Rodriguez-Valencia A, Barrero GA, Ortiz-Ramirez HA (2020) Power of user perception on pedestrian quality of service. *Transp Res Rec J Transp Res Board* 2674(5). <https://doi.org/10.1177/0361198120914611>
17. Mikušová M, Hrkút P (2014) Public perception of selected road safety problems. *Proc Soc Behav Sci* 330–339
18. Dinh D, Vũ NH, McIlroy RC (2020) Effect of attitudes towards traffic safety and risk perceptions on pedestrian behaviours in Vietnam. *IATSS Res* 238–247
19. Ram T, Chand K (2016) Effect of drivers' risk perception and perception of driving tasks on road safety attitude. *Transp Res Part F Traf Psychol Behav*
20. Espinoza F, del Valle Arenas Ramirez B, Izquierdo FA (2021) Road safety perception questionnaire (RSPQ) in Latin America: a development and validation study. *International Journal of Environmental Research and Public Health*
21. Anapakula KB, Eranki GA (2021) Developing an index to evaluate the quality of pedestrian environment: case study application in an Indian metro. *Transp Res Interdisc Perspect*
22. Balasubramanian V, Bhardwaj R (2018) Pedestrians' perception and response towards vehicles during road-crossing at nighttime. *Accident Anal Prevent* 128–135
23. Vijayawargiya V, Rokade S (2017) Identification of factors affecting pedestrian level of service of crosswalks at roundabouts. *Int Res J Eng Technol (IRJET)* 342–346
24. Bendak S, Alnaqb AM (2021) Factors affecting pedestrian behaviors at signalized crosswalks: an empirical study. *J Saf Res* 269–275
25. Bartolomeos K, Crof P (2013) Pedestrian safety—a road safety manual for decision makers and practitioners. The World Health Organization (WHO)
26. Barón L, da Costa JO, Soares F (2021) Effect of built environment factors on pedestrian safety in Portuguese urban areas. *Applied System Innovation (Applied System Innovation)*
27. Rankavata S, Tiwari G (2016) Pedestrians risk perception of traffic crash and built environment features—Delhi, India. *Saf Sci* 1–7
28. Bhaduri E, Manoj BS, Sen J (2019) Measuring user satisfaction of pedestrian facilities and its heterogeneity in urban India—a tale of three cities. *J East Asia Soc Transp Stud*

29. Kumar P (2007) The value of design : a study of pedestrian perception in New Delhi, India. *Environment and Planning D-society & Space* D
30. Kumar A, Ghosh I (2020) Analysis of spontaneous order of pedestrian–vehicle conflicts at signalized intersections. *Transp Res Rec J Transp Res Board*
31. Kathuria A, Vedagiri P (2020) Evaluating pedestrian vehicle interaction dynamics at un-signalized intersections: a proactive approach for safety analysis. *Accident Anal Prevent*
32. Chatterjee S, Mitra S (2019) Safety assessment of two-lane highway using a combined proactive and reactive approach: case study from Indian national highways. *Transp Res Rec J Transp Res Board*
33. Mukherjee D, Mitra S (2020) Pedestrian safety analysis of urban intersections in Kolkata, India using a combined proactive and reactive approach. *J Transp Saf Secur*
34. Kadali RB, Nivedan R, Perumal V (2015) Evaluation of pedestrian mid-block road crossing behavior using an artificial neural network (ANN). *J Traf Transp Eng*
35. Banerjee A, Maurya AK (2019) A comparative study of pedestrian movement behavior over foot over bridges under similar land-use type. *Transp Res Proc*. Elsevier
36. Rahula TM, Manoj M (2020) Categorization of pedestrian level of service perceptions and accounting its response heterogeneity and latent correlation on travel decisions. *Transp Res Part A Policy Pract* 40–55
37. Neumann DL, Chan RCK, Boyle GJ (2015) Measures of personality and social psychological constructs. In: Saklofske DH, Gregory GM, Boyle J (eds) *Measures of empathy: self-report, behavioral, and neuroscientific approaches*. Elsevier, pp 257–289. <https://doi.org/10.1016/B978-0-12-386915-9.00010-3>
38. Korkmaz IH, Özceylan A, Özceylan E (2019) Investigating the academic success of industrial engineering students in terms of various variables. *Proc Comput Sci* 158:9–18. <https://doi.org/10.1016/j.procs.2019.09.022>
39. Karamizadeh S, Abdullah SM, Manaf AA (2013) An overview of principal component analysis. *J Signal Inf Process* 173–175. <https://doi.org/10.4236/jsip.2013.43B031>
40. Jolliffe IT, Cadima J (2016) Principal component analysis: a review and recent developments. *Philos Trans R Soc A*
41. Maskey R, Fei J (2018) Use of exploratory factor analysis in maritime research. Use of exploratory factor analysis in maritime research, pp 91–111
42. Dubey A (2018) The mathematics behind principal component analysis. <https://towardsdatascience.com/the-mathematics-behind-principal-component-analysis-fff2d7f4b643>
43. Mishra S, Sarkar U (2017) Principal component analysis. *Int J Livestock Res*
44. Rossoni L, Engelbert R, Bellegard NL (2016) Normal science and its tools: reviewing the effects of factor analysis in management. *Revista de Administração* 51(2):198–211. <https://doi.org/10.5700/rausp1234>
45. Han W, Zhao J (2020) Driver behaviour and traffic accident involvement among professional urban bus drivers in China. *Transp Res Part F Traf Psychol Behav* 74:184–97. <https://doi.org/10.1016/j.trf.2020.08.007>
46. Birren JE (2007) *Encyclopedia of gerontology*. Elsevier
47. Fumagalli LAW, Rezende DA, Guimarães TA (2021) Challenges for public transportation: consequences and possible alternatives for the covid-19 pandemic through strategic digital city application. *J Urban Manage* 10(2):97–109. <https://doi.org/10.1016/j.jum.2021.04.002>
48. Coppola P, Silvestri F (2020) Assessing travelers’ safety and security perception in railway stations. *Case Stud Transp Policy* 8(4):1127–1136
49. Baldwin C, Stafford L (2019) The role of social infrastructure in achieving inclusive liveable communities: voices from regional Australia. *Plan Pract Res* 34(1):18–46. <https://doi.org/10.1080/02697459.2018.1548217>
50. Behrens R (2005) Accommodating walking as a travel mode in south African cities: towards improved neighbourhood movement network design practices. *Plan Pract Res* 20(2):163–82. <https://doi.org/10.1080/026974505000414686>
51. Talen E (2002) Pedestrian access as a measure of urban quality. *Plan Pract Res* 17(3):257–278. <https://doi.org/10.1080/026974502200005634>

52. Guo Y, Yang L, Huang W (2020) Traffic safety perception, attitude, and feeder mode choice of metro commute: evidence from Shenzhen. *Int J Environ Res Publ Health* 17(24)
53. Nordfjærn T, Şimşekoğlu Ö, BrendeLind H (2014) Transport priorities, risk perception and worry associated with mode use and preferences among Norwegian commuters. *Accident Anal Prevent* 72:391–400
54. Nevelsteen K, Steenberghen T, Van Rompaey A (2012) Controlling factors of the parental safety perception on children's travel mode choice. *Accident Anal Prevent* 45:39–49
55. Papić Z, Jović A, Simeunović M, Saulić N (2020) Underestimation tendencies of vehicle speed by pedestrians when crossing unmarked roadway. *Accident Anal Prevent* 143:105586
56. Shi J, Wu C, Qian X (2020) The effects of multiple factors on elderly pedestrians' speed perception and stopping distance estimation of approaching vehicles. *Sustainability* 12(13):5308
57. Butler AA, Lord SR, Fitzpatrick RC (2016) Perceptions of speed and risk: experimental studies of road crossing by older people. *PLoS One* 11(4)
58. Lyu Y, Forsyth A (2021) Attitudes, perceptions, and walking behavior in a Chinese city. *J Transp Health* 21:101047
59. Yoh K, Khaimook S, Doi K, Yamamoto T (2021) Study on influence of walking experience on traffic safety attitudes and values among foreign residents in Japan. *IATSS Res*