Bol. Soc. Paran. Mat.
©SPM – E-ISSN-2175-1188
SPM: www.spm.uem.br/bspm

(3s.) **v. 2026 (44) 4** : 1–6.
ISSN-0037-8712
doi:10.5269/bspm.80218

Development of Pedestrian Safety Index Model at Un-Signalized Intersection

Sngewhunshisha Thabah, Kanimozhee Sudalai, Madhu Kundur Anand, Praveena Kumara Kammasandra Munivenkataswamy

ABSTRACT: Pedestrian safety has become a critical issue in developing countries where rapid urbanization and motorization have outpaced the development of pedestrian-friendly infrastructure. Inadequate crossings, limited enforcement, and insufficient pedestrian facilities have increased the frequency of pedestrian–vehicle conflicts, particularly at unsignalized urban intersections. This study focuses on developing a Pedestrian Safety Index (PSI) to quantify pedestrian safety levels by considering human, environmental, and traffic-related parameters. Data were collected through videography over three-hour observation periods, covering the movement of 2,356 pedestrians. Variables such as age, gender, crossing speed, mobile phone usage, vehicle and pedestrian volumes, police presence, road width, number of lanes, and sidewalk conditions were analyzed. Using Multiple Linear Regression (MLR), the model achieved an R^2 value of 0.753, indicating that 75.3 percentage of the variation in pedestrian safety could be explained by the selected parameters. To further enhance predictive accuracy, an Artificial Neural Network (ANN) model was developed, producing Sum of Squares Error (SSE) values of 447.64 (training) and 221.53 (testing), and relative error values close to unity, demonstrating high model reliability and generalization. The study concludes that pedestrian safety is significantly influenced by both behavioral and roadway factors. Integrating these parameters through statistical and machine learning models offers a reliable framework for assessing and improving pedestrian safety. The developed PSI serves as a valuable decision-support tool for urban planners and traffic engineers to design safer, more inclusive intersections and to prioritize safety interventions in rapidly developing urban environments.

Keywords: Pedestrian safety index, multiple linear regression, artificial neural network.

Contents

1. Introduction

Walking forms a key aspects of the sustainable urban mobility, which contribute mostly to the social well-being, economic, and environmental sustainability. It lessens the reliance on motorized transport as well, which helps to minimize the emissions and crash risks and to promotes public health. Despite these advantages, maintaining pedestrian safety-especially at un-signalized intersection which continues to be a major concern in many developing areas. To address this issue, the present study introduces a Pedestrian Safety Index (PSI) aimed to accessing safety conditions in mixed-traffic conditions. The ultimate goal is that to pin point the potential high risk locations and provide a data that support the foundation for the pedestrian urban design, moving beyond the traditional-vehicle focused frameworks.

Previous studies on pedestrian safety in India have largely concentrated on individual aspects such as the built environment [4], road geometry [5], and traffic characteristics [6], primarily to understand risky pedestrian behaviors and crash occurrences. Several proactive methodologies have been adopted, including the examination of pedestrian signal violation behavior [7], risk perception assessment [8],

2020 *Mathematics Subject Classification:* 68T07, 92B20.
Submitted November 18, 2025. Published February 26, 2026

pedestrian–vehicular conflict analysis [9], road safety audits [10], and estimation of walkability indices [11]. Statistical approaches such as linear regression [12] and logit models have been applied to evaluate the influence of multiple contributing factors, the daily activities and built-environment variables, including road width, vehicle speed, and pedestrian volume, affect crash likelihood in Chennai. [13] investigated pedestrian behavior at uncontrolled intersections in Dhaka, revealing a critical absence of pedestrian-focused safety measures. A related study in Chittagong analyzed pedestrian crossings at four-leg un-signalized intersections, emphasizing inadequate pedestrian facilities [14]. Furthermore, recent works have incorporated videographic surveys and behavioral analyses to model pedestrian flow, crossing patterns, and safety indices under mixed-traffic conditions.

Against this backdrop, the present study aims to bridge existing research gaps by combining behavioral, geometric, and traffic parameters into an integrated modeling framework. The study employs both the Multiple Linear Regression (MLR) and Artificial Neural Network (ANN) methods in order to determine the major factors influencing the pedestrian safety and to formulate a predictive framework that will helps to improves the understanding of the pedestrian movement at un-signalized intersection.

2. Data analysis

The study was carried out at two un-unsignalized intersections located in Koramangala, Bengaluru-Thavarekere Main Road (Road A) and Chocolate Factory Road (Road B). a videographic survey was employed to record the pedestrian as well vehicular movements during weekday peak hours (8:00-10:00 a.m. and 5.00-6.00 p.m.). the collected data encompassed the pedestrian volumes, crossing behavior, and walking speeds at the crosswalks. Pedestrian flow on Road Avaried between 313 to 521 pedestrians per hour, while Road B recorded flows ranging from 299 to 465 pedestrians per hour. The mean pedestrian volume was observed to be 424 ped/hr on Road A and 362.3 ped/hr on Road B, with corresponding average walking speeds of 0.8 m/s and 0.975 m/s respectively. The survey also classified pedestrians by age and gender, noting variations in flow and speed across different times of day. A built environment survey recorded details such as carriageway width, number of lanes, and sidewalk conditions, providing insights into the physical and operational aspects influencing pedestrian safety. Traffic characteristics were studied through video analysis to understand vehicular speed, pedestrian behavior, and interaction patterns. Both sites— Thavarekere St. John Cross Road and Chocolate Factory Road intersection—were identified as high-pedestrian areas with mixed traffic and inadequate pedestrian infrastructure, making them critical for assessing pedestrian safety conditions in urban settings.

3. Multiple Linear Regression (MLR)

The modelling was done taking into consideration the Pedestrian Safety Index as the dependent variable and Gender, Age, Cross-speed , Mobile Usage, Crossing Movement, Vehicles Volume, Pedestrian Volume, Police presence, Road width, Number of lanes, Speed breakers, Road lightning, Sidewalk Condition, Traffic Signal and Types of vehicles as the independent variables. Different combinations of the modelling was carried out by considering Pedestrian Safety Index as the dependent variables for all combinations.

The analysis result from MLR using SPSS is represented with p value and Pearson significant coefficient. The determination of Pedestrian Safety Index as a dependent variables on the other independent variables is done.

$$\begin{aligned} \text{PSI} = \beta_0 - \beta_1(\text{Gender}) + \beta_2(\text{Age}) + \beta_3(\text{Vehicle Volume}) \\ +\beta_4(\text{Pedestrian Volume}) + \beta_5(\text{Types of Vehicles}) \end{aligned} \tag{1}$$

The aim of this model is to predict the crossing speed using various variables. The R-square value of the model is 0.759, which can be interpreted as the model of 75.9 percentage good. The MLR analysis using the SPSS shows the different human factors such as age, gender, movement made to cross, the different stages and usage of mobile while crossing has significantly influence the Pedestrian Safety Index because the p value of these is less than 0.05. Model gives Pedestrian Safety Index and Model as:

$$\begin{aligned} \text{PSI} = 3.978 - 0.953(\text{Gender}) - 0.212(\text{Age}) + 0.004(\text{Vehicle Volume}) \\ +0.001(\text{Pedestrian Volume}) + 0.047(\text{Types of Vehicles}) \end{aligned} \tag{2}$$

From the eq 2, the other factors such as movement, crossing have no much influence on Pedestrian safety Index. The values closer to the 0.05 have more influences on the safety index.

4. Artificial Neural Network (ANN)

An Artificial Neural Network (ANN) is a computational framework inspired by the structure and functioning of the human brain, extensively utilized in machine learning and artificial intelligence applications involving complex prediction, classification, and pattern recognition tasks. Unlike conventional statistical techniques such as linear regression, ANNs possess the capability to model non-linear and intricate relationships between input and output variables through adaptive learning mechanisms.

In this study, the dataset was divided into training and testing subsets as presented in the Case Processing Summary. Out of a total of 1,272 cases, 1,269 were valid for analysis, while 3 cases were excluded due to incomplete information. The training set comprised 891 samples (70.2 percentage), and the testing set included 378 samples (29.8 percentage), ensuring adequate representation for both model learning and validation phases.

The Network Information summary delineates the configuration of the developed ANN model. The input layer comprised nine covariates—Gender, Age, Crossing speed, Mobile phone usage, Pedestrian crosswalk length, Vehicle volume, Pedestrian count, Baggage, and Child presence—all of which were standardized prior to training. The network architecture incorporated a single hidden layer consisting of three neurons, employing the hyperbolic tangent activation function to capture non-linear associations effectively. The output layer comprised a single dependent variables, the pedestrian Safety Index (PSI), with the standardization rescaling applied and sum of squares error function used for model optimization.

5. Comparison between MLR and ANN

A comparative assessment was carried out between the Multiple Linear Regression (MLR) and Artificial Neural Network (ANN) models to evaluate their performance in predicting the Pedestrian Safety Index (PSI) at un-signalized intersection. The MLR model defines a linear relationship between a dependent variable and multiple independent variables through a mathematical expression, whereas the ANN model captures complex, non-linear associations between input and output variables using interconnected neuron layers. While the MLR assumes linearity and also it performs effectively with smaller, normally in distributed data sets which makes suitable for the interpretability and simplicity are prioritized, ANN is capable of processing larger datasets and uncovering hidden non-linear patterns, thereby offering superior the precision for the behavioral and environmental interactions.

In this research, pedestrian behavior and crossing patterns were analyzed help to consider variables such as age, gender, crossing speed, mobile phone usage, vehicle volumes, pedestrian volumes, road width, and sidewalk conditions. Data were gathered through videographic surveys which id conducted for three hours daily, hwlps in capturing 2359 pedestrian movement, out of which 48 percentage were male and 41 percentage were female. The average crossing speed ranged between 1.2=1.4 m/s for senior citizens, and below 0.8 percentage m/s for children. Male pedestrians were generally observed to cross faster compared to female and take high risks (p=0.004), while those pedestrians using mobile phones exhibit to slower walking speeds.

The MLR model was developed by using SPSS software, with the Pedestrian Safety Index (PSI) as the dependent variable and behavioral and parameters as predictors or independent variables. The model achieved an R2 value of 0.753, reflecting a good fit of 75.3 percentage . The resulting regression equation expressed as:

$$\begin{aligned}\mathrm{PSI} = 3.978 - 0.953(\mathrm{Gender}) - 0.212(\mathrm{Age}) + 0.004(\mathrm{Vehicle\ Volume})\\ +0.001(\mathrm{Pedestrian\ Volume}) + 0.047(\mathrm{Types\ of\ Vehicles})\end{aligned} \tag{3}$$

While the MLR model provided clear interpretability and quantified as the influence of individuals factors, ANN model demonstrated a stronger capacity to capture non-linear dependencies among multiple parameters, resulting in higher predictive accuracy as well. On the other hand, the ANN approach proved more effective in modeling pedestrian safety within a mixed traffic urban environments.

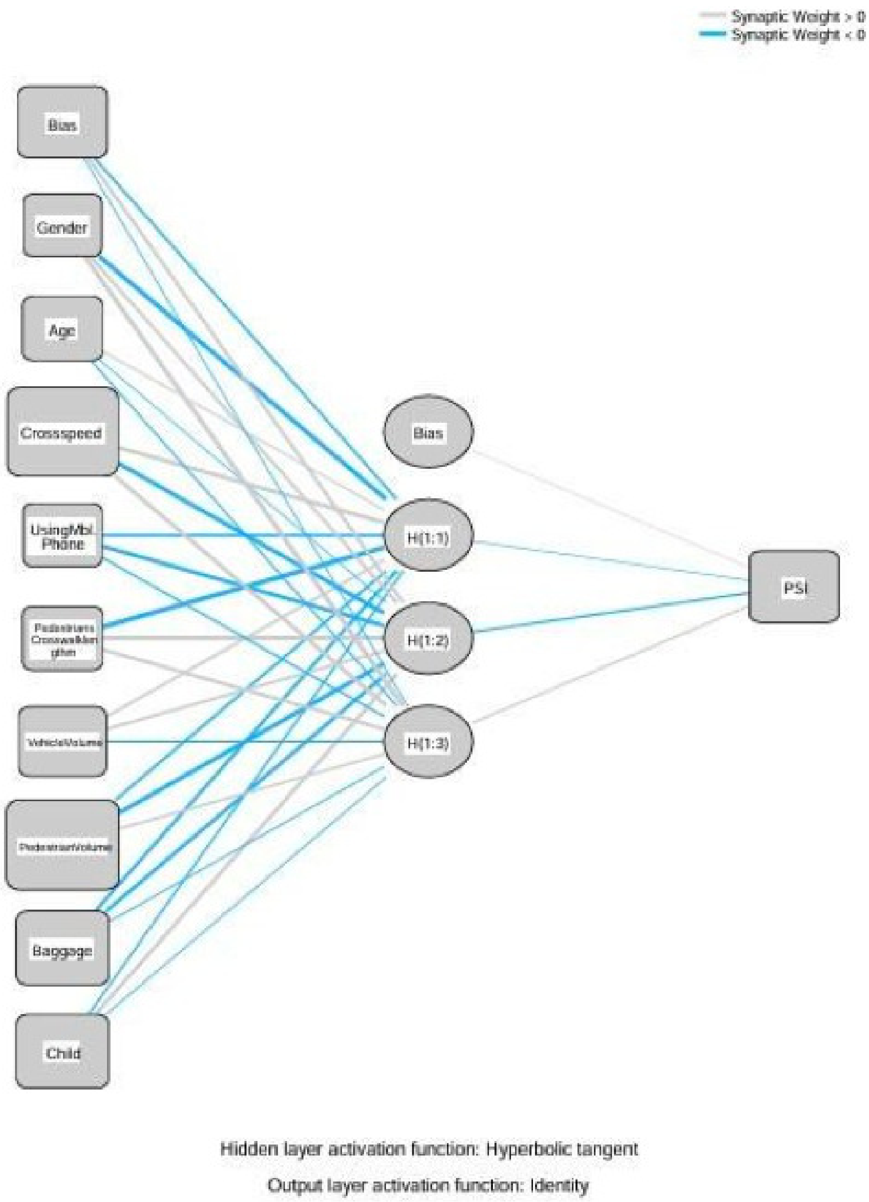

Figure 1: ANN modelling showing the hidden layers and output layers function.

6. Conclusion

The study effectively examined pedestrian safety at un-signalized intersections through the application of both the Multiple Linear Regression (MLR) and Artificial Neural Network (ANN) models. The MLR analysis identified major contributing factors, including gender, age, vehicle volume, pedestrian volume, and vehicle type, achieving an R2 value of 0.753, which reflects a strong linear association between these predictors and the Pedestrian Safety Index (PSI). in contrast, the ANN model demonstrated higher accuracy by capturing intricate, non-linear relationships among behavioral, environmental and as well traffic parameters.

The results indicated that male pedestrian generally crossed at faster speeds and exhibited higher risk-taking behavior, whereas mobile phone usage and group crossings were associated with slower walking speeds. Average crossing speed were observed to be 1.2-1.4 m/s for adults, 1.1 m/s for elderly pedestrians, and below 0.8 m/s for children. Overall, the ANN model provided a more flexible and resilient framework for the evaluation pedestrian safety with the dynamic urban settings, while in the MLR approach offered greater interpretability and insight into all the variables significance. If combining both the methods can strengthen data-driven strategies aimed at enhancing pedestrian facilities and implementing effective safety measure at un-signalized intersection especially in urban areas.

Acknowledgments

The authors would like to thank the referees for their valuable comments and suggestions, which helped improve the

References

1. Vinayaraj, V. S., Arkatkar, S., Joshi, G., Parida, M., Examining pedestrian critical gap analysis at un-signalized midblock crosswalk sections in India. *Transportation Research Procedia* 48, 2230–2250 (2020).

2. Mukesh, M. S., Katpatal, Y. B., Evaluation of pedestrian safety in fast developing Nagpur City, India. *Journal of Urban and Environmental Engineering* 14(1), 52–60 (2020).

3. Comparative study of pedestrian critical gap estimation methods at unsignalized crosswalks. *Transportation Research International Documentation (TRID)* (2022).

4. Safety evaluation of urban roundabouts in India: a safety performance function-based approach. *Traffic Safety Research* (2023).

5. Vasudevan, V., Pedestrian temporal gap acceptance behavior at unsignalized intersections in India under heterogeneous traffic conditions. *Transportation Research Part F* (2020).

6. Anapakula, K. B., Developing an index to evaluate the quality of pedestrian environments in Indian cities. *Sustainable Cities and Society* (2021).

7. Bhaduri, E., Measuring user satisfaction of pedestrian facilities and its implications. *Eastern Asia Society for Transportation Studies* 13, 144–156 (2019).

8. Shaaban, K., Modeling pedestrian gap acceptance behavior at a six-lane unmarked mid-block crossing. *Journal of Advanced Transportation* (2021).

9. Guío-Burgos, F. A., et al., Pedestrian gaps and walking speed at uncontrolled crossings. *Revista de Ingeniería de Transporte* (2023).

10. Bharucha, J. P., An investigation into the walkability problem in Indian cities. *Safer Communities* (2017).

11. Belge, Z. S., et al., Evaluation of pedestrian movement and sustainable urban environments. *Sustainability* 17(18), 8205 (2025).

12. Ros-McDonnell, D., et al., Toward resilient urban design: pedestrians as an important element of city design. *Urban Science* (2024).

13. Tiwari, R., Highlighting pedestrian equity considerations using walkability and space syntax: a case from a suburban area in India. *GLCE Journal*, BonView Press (2024).

14. Jain, B., Baderiya, R., Gupta, A., Modeling pedestrian gap acceptance at mid-block crossings in India. *Proceedings of the Eastern Asia Society for Transportation Studies* 11 (2023).

Sngewhunshisha Thabah,
PG Scholar, School of Civil Engineering,
REVA University,
India.
E-mail address: sngewhunshishat@gmail.com

and

Kanimozhee Sudalai,
Assistant Professor,
School of Civil Engineering,
REVA University,
India.
E-mail address: Kanimozhee.s@reva.edu.in

and

Madhu Kundur Anand,
Assistant Professor,
School of Civil Engineering,
REVA University,
India.
E-mail address: madhu.ka@reva.edu.in

and

Praveena Kumara Kammasandra Munivenkataswamy,
Associate Professor,
Department of Mathematics,
School of Applied Sciences,
REVA University,
India..
E-mail address: praveenkumara.km@reva.edu.in