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EVALUATION OF PEDESTRIAN SAFETY IN FAST DEVELOPING NAGPUR CITY, INDIA

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Abstract: Pedestrian safety has become a major issue in most of the developing countries. Thousands of pedestrians are killed each year but still pedestrian safety remains the most ignored parameter in road design. Even after several studies, pedestrian behavior, which is a complex phenomenon remains poorly understood. Interaction and pedestrian response, especially at the intersections, is a serious concern in road safety. The primary objective of the study is to develop a Pedestrian Safety Index (PSI) by identifying the parameters on which pedestrian safety depends. These parameters have been classified as dependent parameters like pedestrian behavior, street infrastructure, and surrounding environment; and independent parameters like a signal break, crossing location, crossing type and crossing time. Pearson's correlation coefficient and ANOVA Analysis are performed to find the relationship between independent and dependent parameters. Analytical Hierarchy Process (AHP) and Multiple Linear Regression (MLR) techniques have been used to prepare the PSI model. The model depicts safety indices at different intersections along the Ring Road which is the major transportation corridor of the city. The data for the analysis was extracted from actual video footages of CCTV installed at the intersections and high-resolution satellite images. The study concludes that the PSI is found to be less at all the intersections along Ring Road and very less in the western segments of the Ring Road Corridor. The values of Pedestrian safety indices are helpful in designing the infrastructure facility at the intersection considering pedestrian safety.

Keywords: Pedestrian Behaviour; Pedestrian Movement; Pedestrian Safety Index; Built-Up Density; GIS; Analytical Hierarchy Process

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INTRODUCTION

The commuters and the motor vehicles share common road space for their movement. In the present scenario, the safety of the road users is at high risk in the developing countries. Pedestrians are the most vulnerable road users as they are unprotected. Traffic accidents involving pedestrians have been a major safety issue in developing countries due to rapid urbanization, high population density and lack of adherence to traffic regulations by the road user i.e., both the drivers and the pedestrians. There are five steps in systematic road crossing strategy i.e., stop before the road kerb or road edge, look for moving traffic, listen to the traffic direction, think to find the right crossing time and then cross the road when clear (Sucha, 2018). It may not be a fact always that the pedestrians are unaware about these strategies, but this strategy would work well when supported by planned complimentary infrastructure. The transportation planning and design mainly concentrates on the vehicular and geometric aspect of parameters, mostly focusing on operating speed and safety of vehicles, giving little importance to the road infrastructure (Thomson *et al.*, 2006).

At the design stage in the developing countries, the pedestrian safety, pedestrian comfort and pedestrian convenience are not taken into account, thereby safety of the pedestrians is at risk. The pedestrian safety is generally taken for granted during the design stage. The importance given to pedestrian safety is almost negligible, which has resulted in less usage of public transportation (Singh, 2005). As per WHO report, about one-fifth of the people killed in road accidents are pedestrian and one pedestrian dies every 115 seconds in a road accident (WHO, 2013). Hence, in fast-developing countries like India, the pedestrian safety is at stake.

The pedestrian interaction with the traffic is predictable and preventable. The causes of pedestrian injuries are vehicular speed, the behaviour of driver and pedestrian, the inadequacy of infrastructure and low visibility. The pedestrian problems are more serious where infrastructure is absent or poorly maintained. The pedestrian in the developed countries feel more secure while using the road, as the awareness among the road users is high, good infrastructure and law enforcement in place (Peden, 2004). The safety of the pedestrian mainly depends on the surrounding environment and the availability of street infrastructure (Handy, 2005).

In recent studies, many researchers have observed that the pedestrians involved in fatal road collisions are increasing every year (WHO, 2013) and number of pedestrian fatalities on road are higher of all the road commuters (Mohan *et al.*, 2009). While crossing the road in an urban area, the pedestrian is at high risk (Lassarre *et al.*, 2007). Dravitzki *et al.* (2003) found that if pedestrian safety is given importance in street design than commuters are encouraged to walk. During the planning stage of the street infrastructure, the pedestrian attitude needs to be given more importance along with road geometric parameters (Holland & Hill, 2007). To encourage the commuters for walking and cycling, availability of infrastructure is an important parameter (Moeinaddini *et al.*, 2015).

In planning and designing of infrastructure in the urban region, the pedestrian behaviour is of great importance (Laxman *et al.*, 2010). Previously, many research studies have been carried to find the pedestrian behaviour, evaluation of street infrastructure facilities and pedestrian safety. Van der Molen (1981) shows the importance of finalizing the objective by considering the children exposure, accident and behavior and provides a conceptual framework about the exposure and behavior. Hamed (2001) studies the pedestrian behavior at divided and undivided street by considering the waiting time and number of attempts required for successfully crossing the road based on maximum likelihood estimates. Zegeer (1998) provided the safety guideline for the design and safety of pedestrian facilities near streets and highway. Davies (1999) gave an overview of different types of pedestrian facility implementation in accordance with education and enforcement. Sarkar (2002) quantified the comfort level of the pedestrian along the walkway for major activity center for walking and bicycling transport mode and the comfort level was quantified both at the macro level (service level) and micro level (quality level). Sisiopiku (2003) studied the pedestrian behaviour at various urban crosswalk for both signalized and unsignalized intersection in relation with the street infrastructure like road marking, midblock crossing, physical barriers, midblock crosswalk, shelters, paving and median, curbs and pedestrian warning signs. Muraleetharan *et al.*, (2005) assessed the pedestrian facility by measure of LOS which depends on safety, comfort, continuity, security and attractiveness. LOS for pedestrian was modelled using urban arterials (Petritsch *et al.*, 2006) and the results showed traffic volume and density of the adjacent road as primary factors. Tan *et al.*, (2007) has assessed the pedestrian LOS in relation to the pedestrian perception and the quality of road facilities in accordance with the traffic flow. Asadi-Shekari *et al.*, (2014) conceptualized the Bicycle Safety Index (BSI) at the micro level by comparing the safety of different facility and defined some standards for calculation of BSI.

Tarawneh, (2001) evaluated the pedestrian crossing speed in accordance to gender, age, crossing distance and group size using the statistical approach and the results provided a concrete evidence that gender, age and group size are significant parameters which must be considered while studying behavior. Carter *et al.* (2006) developed a safety index for pedestrians and bicycles to prioritize the intersection and crosswalk for implementation of safety guidelines. In the development of prioritization model, all the parameters related to pedestrian, bicycle, vehicular traffic and street infrastructure were considered. Diogenes and Lindau (2010) evaluated the pedestrian risk at midblock crossing using regression models. The results showed that pedestrian risk is influenced by factors like busways, bus stops, traffic lanes, road width, pedestrian traffic and vehicular traffic.

The studies have revealed that age and gender significantly affect the pedestrian behaviour (Oxley *et al.*, 2005; Das *et al.*, 2005; Fitzpatrick *et al.*, 2006; Lobjois & Cavallo, 2006; Shahin, 2006; Tiwari *et al.*, 2007). The pedestrian behavior has also been analyzed at signalized intersection (Pei, 2007; Wang, 2008). Zhang *et al.*, (2013) have found the effect of pedestrian signal, crossing length and direction on walking speed at the signalized intersection. Rostogic *et al.*, (2011) has analyzed the pedestrian gap acceptance with land use in highly commercial, educational and recreational land use. The patience level of the pedestrian reduces at median and gap acceptance increases with lag in acceptance (Kadali & Vedagiri, 2013). In case of low volume pedestrian crossing, the pedestrian pays more attention towards traffic before crossing (Lars, 2002).

Based on the above observation it has been established that pedestrian safety depends on many parameters which can be grouped as Commuter related parameters and Infrastructure related parameters. There is a need to carry out study using all the contributing parameters in an integrated fashion to generate information on spatial pattern of pedestrian safety. These parameters must be studied in relation to the change in land use pattern. The aim of the present paper is to provide a visual scenario of pedestrian safety along the fast-developing regions of the city. The paper focuses on developing a Pedestrian Safety Index (PSI) for the fast-developing region in a developing city by considering commuter as well as infrastructure related parameters.

STUDY AREA AND DATA

Study Area

The Nagpur city is located in Maharashtra state in central India. It is the third largest city in Maharashtra with a total area of 218km^2, road length of 1907 km and a population of 2,398,165 as per 2011 census. The study area ranges from 79°0'05"E to 79°11'09"E longitude and 21°3'18"N to 21°13'51"N latitude (**Fig. 1**). The topography of the study area is flat with an elevation of 310m with 67m deviation.

The Nagpur city is one of the fastest developing city in the country. In this study, the urbanized area of the city was selected for study; more precisely the 2.5km corridor along the Nagpur Inner Ring Road (NIRR). The major reason for choosing this study area is the traffic infrastructure, pedestrian behaviour in the newly urbanized region, street infrastructure and pedestrian flow in the region. The inner ring road and the major intersection which were considered for modelling purpose are shown in **Fig. 2**.

Built Up Density Data

The Land Use/Land Cover maps for the region were developed for two-decade time period by using high-resolution satellite data of Nagpur city for the years 1997, 2007 and 2017. The Land Use/Land Cover map was generated by considering only two classes; one built up the region and other non-built up region, known as the built-up density map. The built-up density map for the years 1997, 2007 and 2017 are shown in Fig.3. Spatial change in the built-up area was determined during the period 1997-2017 for all the major intersections along the NIRR for a radius of about 2km by considering a pedestrian crumbling speed of 1.2m/s (IRC 1985) and 30min walking time. Based on the pattern in the built-up density, the study intersection was selected.

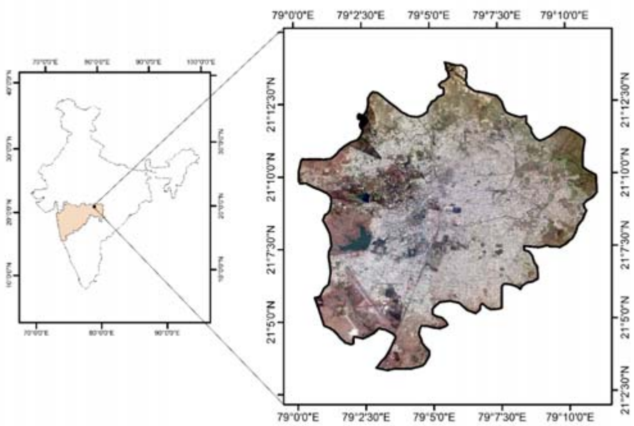


Fig 1: Location of the study area within municipality boundary.

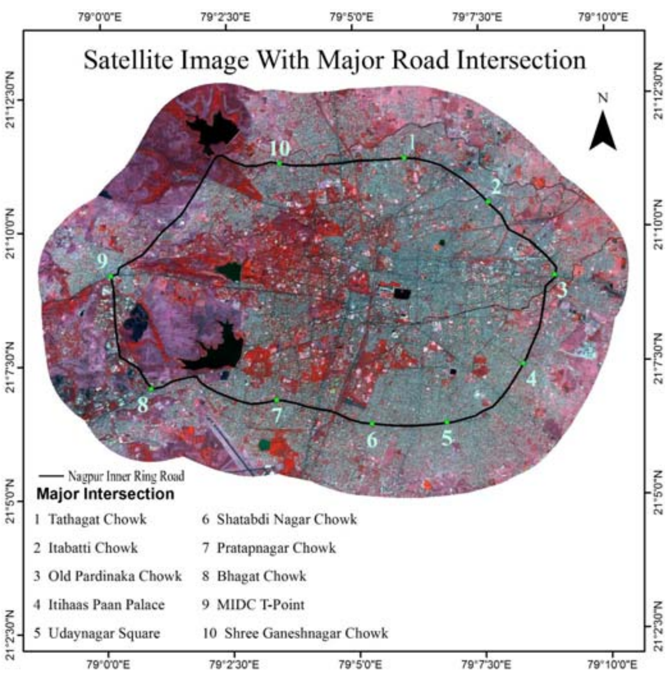


Fig 2. Map showing Major intersection along NIRR over the high-resolution satellite image.

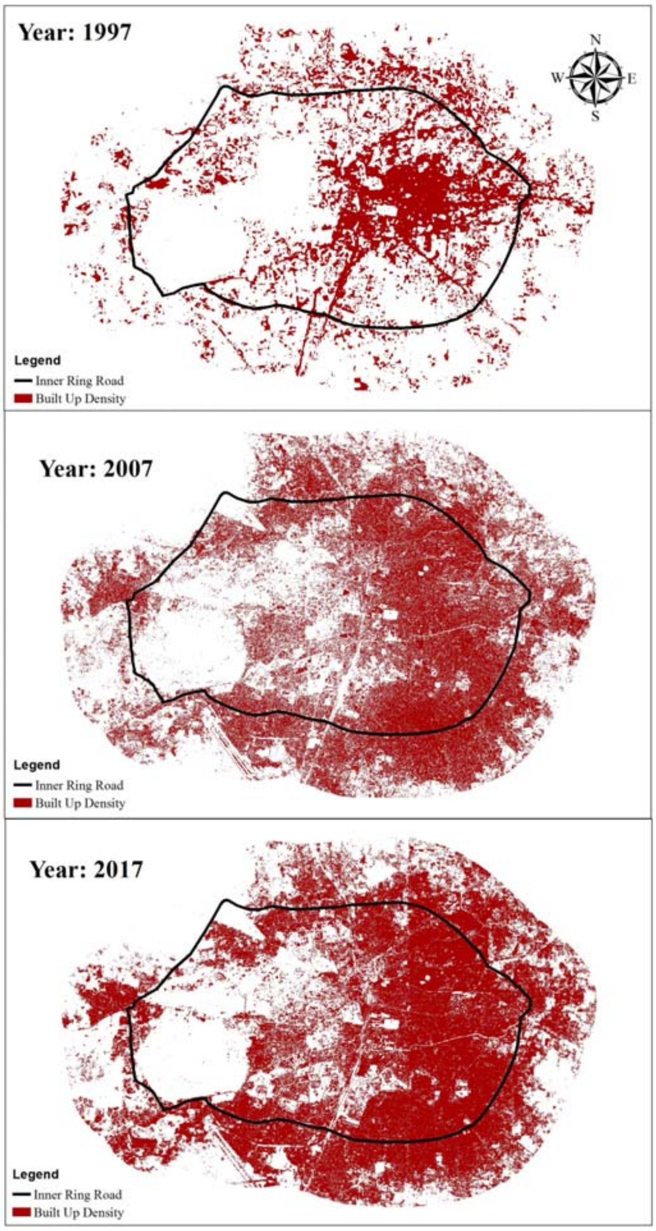


Fig 3. Built up Class in Nagpur city in the year 1997, 2007 and 2017.

Street Infrastructure Data

Street infrastructure is most essential part for providing service to the suburbs in an urban landscape. The street infrastructure needs to be designed at the planning stage i.e., at the land use planning stage. The street infrastructure should not interfere with the vehicular and the pedestrian flow. The safety of the pedestrian depends on the availability and efficiency of the street infrastructure. The street infrastructure at the intersection refers to the availability of waiting lane, road marking, road delineators, signboards, street lighting, operational traffic signals, road condition and the condition of a pedestrian pathway. The data regarding the street infrastructure was collected for major intersections located along the NIRR (Fig.2) by field survey for a region of about 50m at the major road intersection. Each parameter indicated above has been assigned weighed in the scale of 1-10 and cumulative weight at an intersection has been presented as street infrastructure percentage in **Table 1**.

Pedestrian Behaviour Data

Human psychology is the most unpredictable and varying parameter which plays an important role in transportation studies. This psychological character of commuting human being is expressed as their behaviour. Human movement is mostly influenced by the physical environment and operational environment. While crossing the road, the pedestrian behaviour is influenced by factors like age, location, illegal road use, engaging in distracting smart phone talk, mobile phone activity, risk perception and impairment by alcohol (Austroads Research Report, 2016). In the study, data regarding the pedestrian behaviour parameters like a signal break, crossing location, crossing time and crossing type are considered. Data regarding the behavioral parameters were obtained by video footages of CCTV installed at the intersections (**Table 2** and **Fig. 4**). The pedestrian movement and behaviour were extracted using video snapshot wizard software 2 second accuracy for each forward click.

Table 1. Street infrastructure availability at intersection along NIRR

Location	Street Infrastructure %
Tathagat Chowk	62.00
Itabatti Chowk	52.00
Old Pardinaka Chowk	55.00
Itihaas Paan Palace	50.00
Udaynagar Square	55.00
Shatabdinagar Chowk	63.00
Pratapnagar Chowk	68.00
Bhagat Chowk	50.00
MIDC T-Point	68.00
Ganeshnagar Chowk	55.00

Table 2. Different parameters and its classes used in data extraction

Parameters	Description	Quantitative (%)
Gender	Male - 0 Female - 1	Male - 72.64 Female - 27.36
Age	Young -1 Medium - 2 Old - 3	Young - 28.14 Medium -50.95 Old - 20.91
Group Size	Single - 0 More than one - 1	Single - 85.96 More than one - 14.02
Signal break	Yes - 0 No - 1	Yes - 67.96 No - 32.02
Crossing type	Risk Averse - 0 Risky crossing -1	Risk Averse - 52.39 Risky crossing - 47.61
Crossing Time	Less - 1 Normal - 2 More - 3	Less - 19.47 Normal - 47.97 More - 32.59
Crossing Location	Proper - 0 Improper -1	Proper - 51.50 Improper - 48.50

Fig 4. (a) Shows the snip of the video recording of the CC camera. (b) Location of CC camera at the intersection.

METHODOLOGY

Parameter extraction for the analysis

High definition video data was collected from NMC (Nagpur Municipal Corporation) for 6 signalized intersections located along the NIRR corridor. For the purpose of data collection and analysis, only those video footages were considered which were oriented towards the main ring road and data from the intersecting road was not considered as the volume of vehicle movement and accidents on those roads were very less in comparison to the mainstream flow. Pedestrian movement at the intersection was examined by a direct observer. From the video recording, the data regarding the parameters like pedestrian signal break, crossing type, crossing time and crossing location was available with respect to gender, age, and group size. Crossing type was classified into risk-averse and risk-taking. The usage of mobile phone while crossing, haphazard movement and negligence towards vehicular movement were considered under risk-taking factors. The crossing time was classified into slow, normal and fast movers in respect to IRC 1985 standards of a pedestrian normal cruising speed of 1.2m/s and was compared. The crossing locations have been differentiated into the proper crossing and improper crossing.

Pedestrian Movement Behaviour

Pedestrian movement at the intersection is mostly uncertain as it is influenced by the operational and the physical environment. The pedestrian behavioural parameters like signal break, crossing time, crossing type and crossing location were analysed for independent parameters like gender, age and group size. The statistical test was carried at 95% confidence interval by ANOVA and Pearson's correlation coefficient. The dependence of the factors is discussed in results.

In case of ANOVA test, the normal linear model was considered with randomized experiment. In the study mean model was considered to find the correlation coefficient.

$$y_{i,j} = \mu_j + \varepsilon_{i,j}$$

Where,
i= 1,2..., I index for experimental units,
j= 1,2..., J index for the treatment group,
Following matrix represents the data format to be used for analysis.

	I1	I2	I3	….	Ij
1	y11	y12	y13		y1j
2	y21	y22	y23		y1j
3	y31	y32	y33		y1j
:					:
i	yi1	yi2	yi3	….	yij

The mean square for the treatment of variation and the errors are given by

$$MS_{Treatment,Error} = \frac{SS_{Treatment,Error}}{DF_{Treatment,Error}}$$

Where,
SS is the sum of square and DF is a degree of freedom, which is given by

$$SS_{Treatment} = \sum \frac{(\Sigma_i y_{ij})^2}{I_j} - \frac{(\Sigma_j \Sigma_i y_{ij})^2}{I} \quad (1)$$

$$DF_{Treatment} = J - 1, \quad (2)$$

$$SS_{Error} = \sum_j \sum_i y_{ij}^2 - \sum_j \frac{(\Sigma_i y_{ij})2}{I} \quad (3)$$

$$DF_{Error} = I - J \quad (4)$$

The f ratio is calculated by

$$f = \frac{SS_{Treatment}}{SS_{Error}} \quad (5)$$

The Pearson's correlation coefficient value for n number of the sample with x_n and y_n number of pair is calculated using the formula.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\ \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (6)$$

Pedestrian Safety Index

Pedestrian safety index (PSI) depicts the safety of the pedestrian along the NIRR Corridor. The PSI depends on Human Behaviour, Environmental Behaviour and

Street Infrastructure availability. The PSI was calculated for a region of about 2.0km along the NIRR on both the sides. The PSI has been developed using Analytical Hierarchy Process (AHP) wherein the parameters have been assigned rating based on the expert opinions from the people from this field and was analyzed for its consistency. The relative importance to the parameters was given range on a scale of 1-7 and was ranked in ascending order of their importance.

The pair-wise comparison matrix is expressed with [A] = (aij)n×n:

$$[A]=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (7)$$

where, n=total number of criteria being considered. From pair wise matrix [A2] was obtained and sum of each row for [A2] was calculated as follows:

$$\sum Row\ Sum = \sum_{i=1}^{n} RS_i \quad (8)$$

where, RSi is the sum of ith row:

$$RS_i = \sum_{j=1}^{n} a_{ij} \quad (9)$$

The finally normalized values or coefficients corresponding to each row is

$$NV_i = \frac{RS_i}{\sum Row\ Sum} \quad (10)$$

And the final index for the sample layout is

$$Index = \sum_{i=1}^{n} w_i c_i$$

where, w_i is the weight and ci is the normalized value for the corresponding ith criterion (with i=1…..n).

The independent parameters weight was determined by AHP but were not used in modeling due to the error it may possess due to non-interdependency. The PSI was modeled by using Multiple Regression Model (MLR) by considering the variables like the signal break, crossing type, crossing time and crossing location. The PSI was modeled by using multiple linear regression model as:

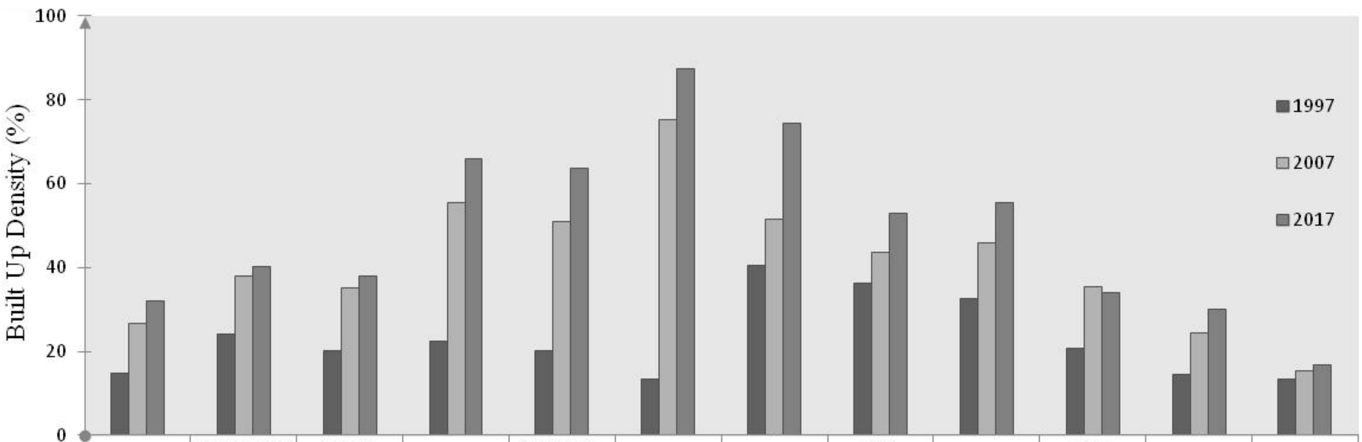
$$Y_i = B_0 + B_1X_{i1} + B_1X_{i2} + . . . + E \quad (9)$$

where, Yi is the dependent variable, Bo is the y-intercept at time zero, B1, B2, Bn are the regression coefficient for the independent variables Xi1, Xi2, Xin, respectively and E is the random error in the prediction. During modelling, the independent parameters like pedestrian age, street infrastructure and built up density was considered.

RESULTS

Selection of intersections for modelling

The variation in built-up density for major intersection located along the NIRR is shown in Fig.5. From the data, it is evident that there are mainly two types of built-up patterns viz., location having a gradual increase in built-up density and location with sudden rise in built up with saturation. The pedestrian data were collected for locations having a sudden rise in built-up density at road intersections at Udaynagar Square, Orange City Hospital Chowk and MIDC T-Point. The locations having a gradual rise in built-up density are represented by Tathagata chowk, Old Pardi Naka Chowk, Ganeshnagar Chowk.



	MIDC T Point	Orange City Hospital Square	Padole Hospital Square	Itihaas Paan Palace	Shatabdi Nagar Chowk	Udaynagar Square	Itabatti Chowk	Old Pardinaka Chowk	Tathagat Chowk	Shree Ganesh Chowk	Mangamurti Square	Bhagat Chowk
1997	14.74	24.23	20.1	22.57	20.28	13.38	40.52	36.29	32.59	20.87	14.54	13.31
2007	26.61	38.06	35.26	55.36	51.04	75.28	51.51	43.54	45.95	35.41	24.38	15.47
2017	31.97	40.23	37.96	66.00	63.61	87.42	74.29	53.03	55.47	34.06	30.11	16.81

Fig 5. Percentage built up density at intersection for different years.

Human movement behaviour

The pedestrian behaviour results obtained from ANOVA and Pearson's coefficient correlation are shown in Table 3-5. From the statistical analysis, it can be observed that for the location having a gradual rise in built-up density, with increase in age of pedestrian the risk-taking nature while crossing road reduces and crossing time increases. In case of gender, the male has a tendency to cross in the stipulated path than female. As the pedestrian group size increases, the time required to cross the road also increases. The parameter signal break has no dependency on age, gender and group size.

The statistical results for location with sudden rise in built up density are shown in Table.4. It may be observed from the results that with increase in pedestrian age, the risk-taking attitude reduces while crossing and crossing time increases. For pedestrian group size, the crossing time increases with increase in the number of pedestrians crossing. The parameter gender is not significant as it does not influence any of the dependent parameter.

The results from the combined data set show almost the same trend in pedestrian behaviour for commuter related parameters (Table 5) as that of two different location type. This suggests that the pedestrian behaviour in the study area is same irrespective of the land use/land cover characteristics. With the availability of the street infrastructure at the intersection, the pedestrian signal break increases, crossing time decreases and improper crossing locations increases. It may be observed from the results (Table 5) that with increase in built up density there will be proper pedestrian crossing at the intersections. During the modelling of pedestrian safety index, the dataset from the entire study area is taken into account. The statistical results indicate that pedestrian age and street infrastructure are more dominant parameters than that the built-up density.

Table 3. Statistical results for factors affecting pedestrian movement for location having gradual rise in built up density

Factors		ANOVA Analysis		Pearson's correlation		Remark
		F Value	Significance	Coefficient	Significance	
Gender	Signal Break	1.882	.171	-.065	.171	Not Significant
	Crossing Time	.005	.945	-.003	.945	Not Significant
	Crossing Type	.085	.770	.014	.770	Not Significant
	Crossing Location	5.483	.020	.111	.020	Significant
Age	Signal Break	14.154	.000	.037	.445	Not Significant
	Crossing Time	33.804	.000	.336	.000	Significant
	Crossing Type	7.245	.001	-.102	.032	Significant
	Crossing Location	6.897	.001	.031	.521	Not Significant
Group Size	Signal Break	2.160	.142	-.070	.142	Not Significant
	Crossing Time	.3804	.050	.093	.050	Significant
	Crossing Type	.351	.554	-.028	.554	Not Significant
	Crossing Location	1.805	.180	-.064	.180	Not Significant

*test performed at 95% confidence interval.

Table 4. Statistical results for factors affecting pedestrian movement for location having sudden rise in built up density

Factors		ANOVA Analysis		Pearson's correlation		Remark
		F Value	Significance	Coefficient	Significance	
Gender	Signal Break	.554	.463	-.087	.463	Not Significant
	Crossing Time	.197	.658	.027	.658	Not Significant
	Crossing Type	2.971	.086	.105	.086	Not Significant
	Crossing Location	.985	.329	.060	.329	Not Significant
Age	Signal Break	.776	.464	.053	.648	Not Significant
	Crossing Time	10.097	.000	.266	.000	Significant
	Crossing Type	5.183	.006	-.189	.002	Significant
	Crossing Location	1.097	.337	-.090	.142	Not Significant
Group Size	Signal Break	.168	.683	-.048	.683	Not Significant
	Crossing Time	3.521	.042	.165	.042	Significant
	Crossing Type	.587	.444	-.047	.444	Not Significant
	Crossing Location	.013	.908	.007	.908	Not Significant

*test performed at 95% confidence interval.

Table 5. Correlation results for behavioural characteristics with dependent parameters

Factors		Pearson's correlation		ANOVA Analysis		Remark
		Coefficient	Significance	Coefficient	Significance	
Age	Signal Break	.073	.041	.077	.041	Significant
	Crossing Type	-.112	.000	-.118	.000	Significant
	Crossing Time	.254	.000	.279	.000	Significant
	Crossing Location	-.031	.336	-.032	.336	Not Significant
Infrastructure (Inf)	Signal Break	.197	.000	.197	.000	Significant
	Crossing Type	-.088	.008	-.088	.008	Significant
	Crossing Time	.002	.958	.002	.959	Not Significant
	Crossing Location	-.205	.000	-.205	.000	Significant
Built Up Density (BUp)	Signal Break	.003	.929	.003	.929	Not Significant
	Crossing Type	.004	.910	.004	.910	Not Significant
	Crossing Time	.019	.558	.020	.558	Not Significant
	Crossing Location	.129	.000	.129	.000	Significant

*test performed at 95% confidence interval.

Pedestrian safety index

The weight to the variables was assigned through index dependency parameters. The relative importance of parameters with respect to other was decided on a scale of 1 to 7. While 1 represents equal importance and 7 denotes the highest importance of parameter with respect to another parameter. The pairwise comparison matrix and the eigenvector is shown below.

$$A = \begin{array}{c} \\ Ag \\ Inf \\ BUp \end{array} \begin{array}{c} \begin{array}{ccc} Ag & Inf & BUp \end{array} \\ \begin{bmatrix} 1 & 0.5 & 5 \\ 2 & 1 & 5 \\ 0.2 & 0.2 & 1 \end{bmatrix} \end{array} \qquad \begin{array}{c} Ag \\ Inf \\ BUp \end{array} \begin{array}{c} \text{Weights} \\ \begin{bmatrix} 0.354 \\ 0.556 \\ 0.090 \end{bmatrix} \end{array}$$

where, Ag is the age parameter of a person, Inf is percentage of street infrastructure available, and BUp is percentage of built-up density around the road intersection for a region of 2 km. In the AHP, the consistency ratio of 0.046473 (<0.1) was observed for the following pairwise matrix. The normalized weight of 35.32% for age parameter, 55.59% for pedestrian parameters and 9.04% for the built-up density were obtained. The PSI model for a scale of 10 is as shown below:

$$PSI = 3.532 * Ag + 5.559 * Inf + 0.904 * BUp$$

The Pedestrian Safety Index (PSI) is calculated along the NIRR Corridor by considering the behavioural characteristics, street infrastructure characteristics and urban set up (Land use) characteristics. The PSI for the NIRR region is:

$$\begin{aligned} PSI = 4.097 - SB * (0.002 + 0.214 * 10^{-3} Inf) + CTy \\ * (0.007 + 0.0170 * 10^{-3} Inf) \\ + 0.021 CTi - CL * (0.004 + 0.1787 \\ * 10^{-3} Inf + 0.227 * 10^{-3} * BUp) \end{aligned}$$

where, SB is percentage of Signal break during peak hours, CTy is percentage of risk crossing by the pedestrian, CTi is percentage of normal speed walking

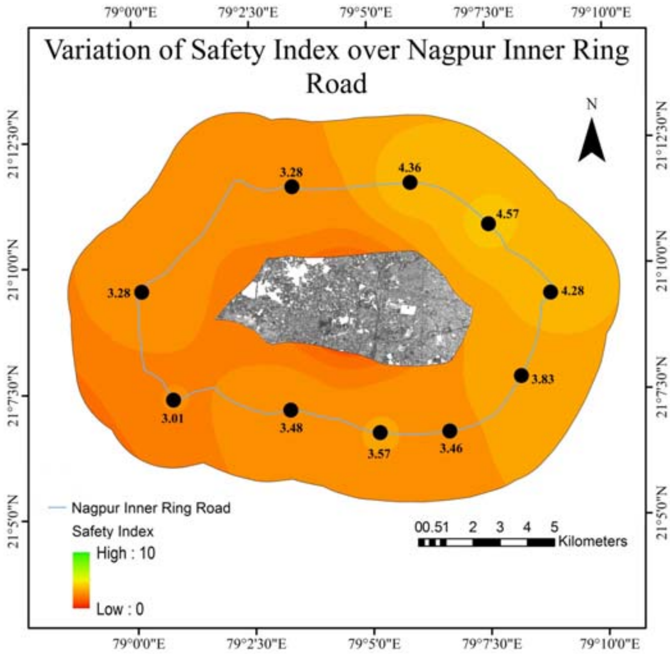


Fig 6. Map showing Major intersection along NIRR.

pedestrian and CL is percentage of improper crossing location by the pedestrian. The PSI was found to have an accuracy of 82% model fit with r- square value of 0.82 in the MLR model. From the model, the PSI values were determined for the remaining major road intersections located along NIRR Corridor (**Fig. 6**).

CONCLUSIONS

The study was conducted for understanding the pedestrian safety along the major intersections in the fast-developing regions of the Nagpur city. The result suggests that the pedestrians have less awareness towards road safety as there is more number of traffic violation by the pedestrians. The pedestrian behaviour was modelled within Nagpur urban area using MLR model. From the MLR model, it is evident that the pedestrian safety is very low along the most important transport corridor within Nagpur urban area – the NIRR.

The study indicates that the cause for the low PSI may be ascribed both to the pedestrian behaviour and the infrastructure characteristics. The land use characteristics do not have any significant effect on the pedestrian behaviour with respect to built-up class.

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