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PEDESTRIAN SAFETY INDEX AT A THREE-LEGGED INTERSECTION IN CHANDIGARH USING FHWA MODEL

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Abstract:
Pedestrians are the most vulnerable user of the road without any safety gadgets and measures to protect themselves from any kind of motorized vehicle. The data and reports show that after two-wheelers pedestrians contribute to the most numbers of casualties globally and also on Indian roads. It has been usually observed that fatal accidents involving pedestrians have mostly occurred in places where there are no provisions, markings, refuge islands, or any other facilities and safety measures for pedestrians. The model consists of different variables that describes the safety standards of intersection for plebeians crossing that major and minor street. In numerous researches, many different variables methodologies are adopted for analyzing pedestrian safety and also for model developments. The Federal Highway Administration (FHWA) has also adopted a legit methodology and considered various parameters before giving Pedestrian Safety Index to researchers and engineers so as to provide safety ratings for various intersections using the given Pedestrian Intersection Safety Index [Ped_{ISI}]. So, further work was carried out on this basis and a three-legged intersection was selected for analysis namely the Sector-11 T-intersection along the Vidya path after determining all the variables, the pedestrian safety index is about 4.57 which is designated between Risk to High risk conditions. Thus, the model helps in categorizing the intersections or specifically crosswalks in case of pedestrians in the range of highly safe to highly risky according to the descriptions given in the safety indices which would help practitioners in prioritizing the intersection for providing safety measures accordingly.

KEYWORDS –Pedestrians, Pedestrian Intersection Safety index, FHWA, T-Intersection, Ped_{ISI}

1. Introduction:

Traveling is now a prominent part of human lives and every traveling method adopted will include being on foot at a certain point in time unavoidably. Globally pedestrians contribute to around 22% of road fatalities as 2,70,000 pedestrians lost their lives annually on world roads as per WHO whereas in some countries this number is high as two-third. So, while doing any geometry design importance should also be laid on pedestrians and significant aspects for their safety. In developing countries like India, any form of Non-motorized transport is ignored for its integration in designing and providing appropriate safety due to budget issues in the early stages of any project. Its impact can clearly be seen in later stages when there is loss to human lives as majority of these people are in productive age groups of 18-45 which in economic terms, the cost to the nation is approximate 3% of Gross Domestic Product. India has seen around 12,330 pedestrian fatalities in 2014 and this number rose to 22,656 in 2018. Also, the ministry of road transport stated 23,483 pedestrian deaths out of 1,31,714 road fatalities in the year 2020. These all numbers somehow develop a condition of rethinking about transport infrastructure for traffic planners and designers. In an exceptional country like India where mixed traffic condition is quite conflating and also streets are very dense and crowded there is a need for special specifications and provisions.

Chandigarh- the city beautiful has a rectangular grid pattern of roads having V8 roads connectivity thus making various intersections for pedestrians to cross. Data shows pedestrian fatalities in different locations in Chandigarh shows that on taking average for several years from 2009 to 2020 percentage of death of pedestrians is 32.205 % out of total fatalities occurred according to the numbers in Chandigarh police reports for these years. There is no sign of decline in this number and the exponentially increasing population will however contribute more towards this number if preventive measures are not taken.

Number of models are designed by taking different variables from both the macroscopic and microscopic approaches. Surrogate Safety Measures are of utmost importance to designers, planners, and engineers so as to come up with adequate solutions. WHO 2013 clearly defines that half of the million estimated people of 1.27 million who die on the world's roads are pedestrians.

Some of the many factors that relate to pedestrian safety are environmental conditions and individual pedestrian and driver behavior [16]. Mostly vulnerable class of pedestrians are elderly, disabled, and children [3]. The Bicycle Safety Index ratings (BSIR)

basically consist of two sub-models specifically one for roadway segments and one for intersections [5]. A new index known as Roadway Condition Index (RCI) was found by laying more emphasis on vehicle speeds. Vehicle speed was given more weightage than traffic volumes [8]. The concept of Level of Service was given depending upon seven different parameters for the safety of pedestrians such as the number of conflicts between pedestrians and vehicles, measures of pedestrian environments, comfort, attractiveness, convenience, etc. in which survey responses was used to measure the level of satisfaction of the people from 1 (worst) to 5 (best) [14]. The PLOS model was developed having four primary variables for pedestrian safety which are the outside lane traffic volume, speed of traffic vehicles in the outside lane, and the presence of walking area for pedestrians [3]. Pedestrian level of service (PLOS) was determined in which variables was subcategorized such as driveways, reduced turn conflict, crosswalk length, pedestrian signal delay and median presence [7]. The focus was primarily on significant factors that gives the sense of comfort and safety to pedestrians while walking along roadway segment and while crossing intersections [15]. For maximum numbers of models, multiple linear regression or linear regression has been used for finding out the model outputs in form of indices, etc. it was mentioned that adequate street facilities for e.g. proper design requirements, adequate facilities for pedestrian crossings, pedestrian mid islands, pedestrian waiting area, proper paving surfaces, and traffic calming can enhance pedestrian safety [19]. A point system was used and almost 11 factors were considered regarding the design, location and pedestrian characteristics themselves [10].

Chapter 18 of the Highway Capacity Manual 2000 has defined the pedestrian Level of Service criteria for un-signalized and signalized intersections and these criteria are stated with regard to pedestrian delay [11]. Also, some researchers have gone beyond the typical approach of capacity and volume so as to consider qualitative measures of pedestrian LOS in which nine evaluation measures were considered such as aesthetics, safety, etc. and scored each measure from 1 (very poor) to 5 (excellent) to analyze commercial areas for pedestrians [6].

For several years many researchers have paid attention to developing models to find out the compatibility of roads with walking in which models relate to operational and geometric features such as data on lane widths, presence of markings, traffic volumes, etc. to find out pedestrian compatibility. The pedestrian environment factor model developed in Portland includes four elements such as sidewalks, street and sidewalk connectivity, ease of crossing streets and terrain on a scale of 1 to 3 with equal weightage which helps engineers, and practitioners to find out and score how pedestrian-friendly it is. The Portland Pedestrian Master Plan also gives two tools to prioritize pedestrian projects namely the Pedestrian Potential Index (PPI) and the Deficiency Index (DI). In both the indices, the PPI basically measures the strength of environmental factors, policies and proximity that favors walking while if we consider DI it measures missing sidewalks, difficulties in crossing, lack of connectivity between streets, missing pedestrian waiting areas, etc. [12].

2. STUDY AREA

A detailed study was conducted so as to analyze and understand the different locations which are vulnerable for road users. Road safety report given by Chandigarh Police was studied for various areas in which different locations, intersections and vulnerable areas were mentioned according to the number of conflicts and accidents that have taken place in several different years in that particular areas. Especially in the road safety reports of year 2017-20 the vulnerable locations, where mostly fatal accidents have occurred is mentioned in these reports. Also, for our analysis of model it requires a three-legged intersection. So considering this, the T-intersection of Sector -11 along the Vidya path which lies in the range of medium road fatalities was selected as a site for initial data collection purposes and to find out the Safety index for that particular location.

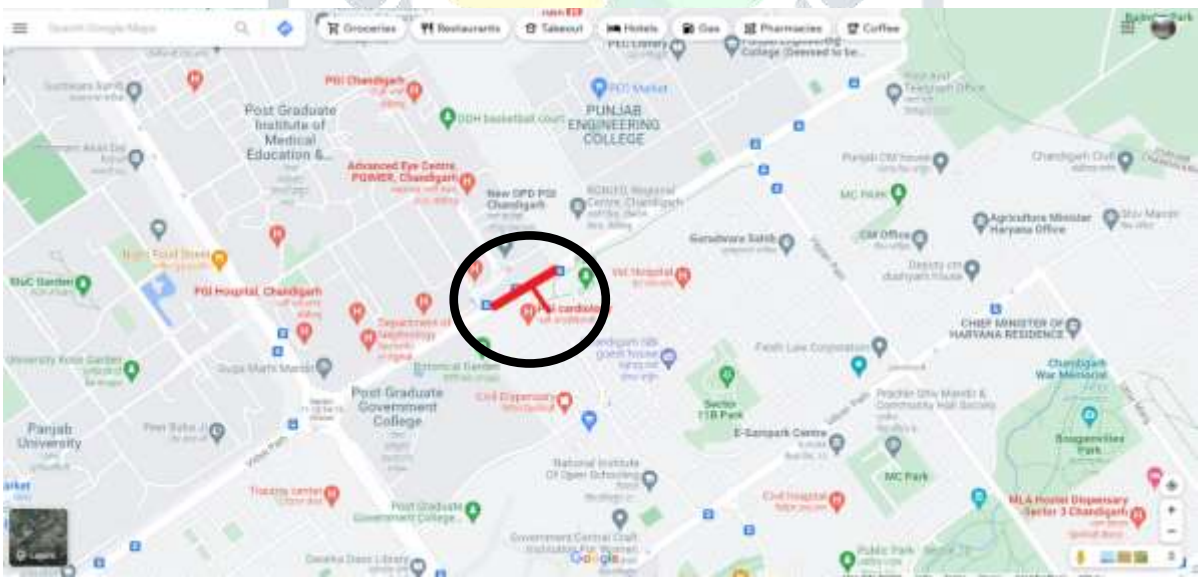
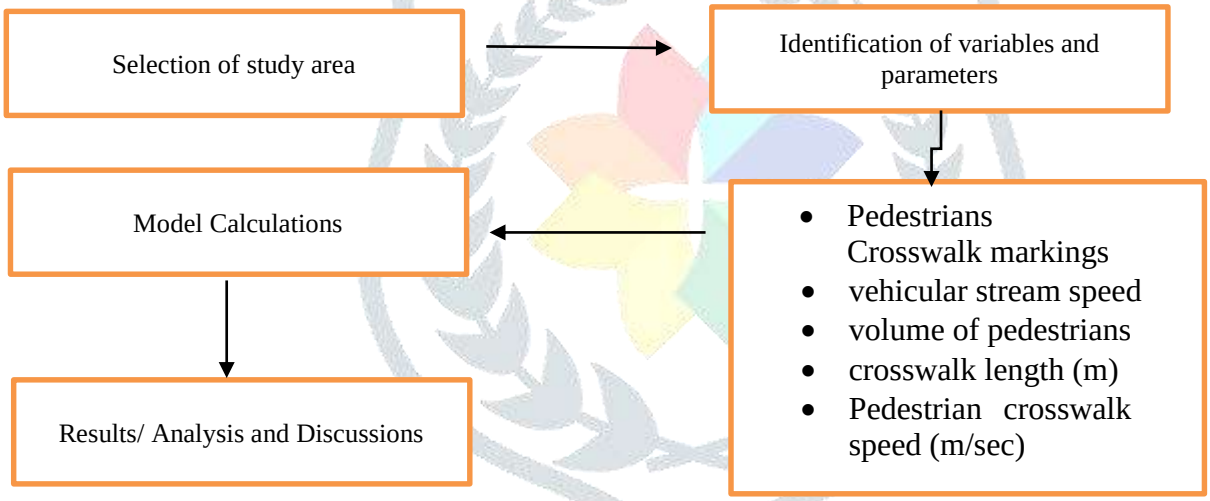


Figure 1: Chandigarh Vidya path Sector-11 T-intersection

Figure 2: T-intersection analysis along different legs (SOURCE: Google Maps)

3. METHODOLOGY

A specific methodology was adopted from the initial stage in which from reconnaissance survey to data collection all steps were taken very sincerely and data is depicted in the best possible way. The first step is to do a complete initial survey and site inspection. To find out the variables various instruments are used for e.g. Speed log and camera setup for video-tapping which significantly helped in getting data values with accuracy and precision. After selection of proper site, the data on characteristics of intersection is find out such as proper markings and street infrastructure facilities for pedestrians. These intersection characteristics is then related to intersection safety which thus helps in achieving the required safety indices.



The Pedestrian ISI is developed by FHWA group of researchers using regression analysis so as to give average rating scores of the intersection and to find out frequencies of conflicts. Number of variables are used which are true to describing about the pedestrian facilities, roadway design geometrics and traffic volumes at that particular crossings. All that variables which are used is defined in the table below.

Description	Values
Main street traffic volume	Average Daily Traffic (ADT) in thousands.
Main Street Speed Limit	30,40,50,60 Km/h
Traffic control on main street	Signal, Stop, None
Total through lanes on main street	1-5
Number of right-turn traffic lanes	0,1
Number of left-turn traffic lanes	0,1
Crossing Width	Width in feet
Median island width	Width in feet
Main street 85th percentile speed	Kilometres per hour
Pedestrian Signal	Yes, No
Crosswalk type	None, parallel lines, Continental, Other
Predominant area type	Commercial, Office, Mixed, Residential

Table 1: Variables used in Pedestrian Analysis (SOURCE: No. FHWA-HRT-06-125).

These variables after outcomes from proper analysis and calibration with ratings of expert is considered for the further statistical approach. After completing all data regarding variables, the required parameters for our model is mentioned below in equation no.1.

4. DATA COLLECTION

The number of variables that are required is extracted through the videography technique. Camera Setup was done on the site in such a way so as to get the data of all different locations and video tapping was also done at different time intervals. Variables such as Pedestrian Crosswalk Marking and Waiting area for pedestrians are marked in binary form as 0 and 1 for their absence and presence respectively in that particular region. Pedestrian Crosswalk Speed observed using video graphic method for all three different locations A, B and C came out to be 1.11 m/s, 1.24 m/s and 0.9 m/s respectively. To carry out the vehicular speed analysis, an instrument called Speed log which works on the principle of the Doppler effect and also logs(collects) the speed of the number of vehicles in a particular site is used to do real-time speed analysis through which speed of total 2,222 vehicles within our site is considered.

LOCATION	Time of survey	Pedestrian volume/flow (ped/hr)	CROSSWALK LENGTH (m)	PCM (Pedestrian Crosswalk Marking)	WAP (Waiting area for Pedestrians)	VSS (km/h)
A	08:00-09:00	229	15.328	1	0	32.2
B	08:00-09:00	425	15.915	1	0	41
C	08:00-09:00	215	14.875	0	1	30.5
A	09:00-10:00	315	15.328	1	0	32.2
B	09:00-10:00	366	15.915	1	0	41
C	09:00-10:00	250	14.875	0	1	30.5
A	10:00-11:00	162	15.328	1	0	32.2
B	10:00-11:00	190	15.915	1	0	41
C	10:00-11:00	159	14.875	0	1	30.5
A	11:00-12:00	130	15.328	1	0	32.2
B	11:00-12:00	175	15.915	1	0	41
C	11:00-12:00	145	14.875	0	1	30.5
A	12:00-13:00	255	15.328	1	0	32.2
B	12:00-13:00	224	15.915	1	0	41
C	12:00-13:00	212	14.875	0	1	30.5
A	13:00-14:00	230	15.328	1	0	32.2
B	13:00-14:00	275	15.915	1	0	41
C	13:00-14:00	185	14.875	0	1	30.5
A	14:00-15:00	280	15.328	1	0	32.2
B	14:00-15:00	305	15.915	1	0	41
C	14:00-15:00	264	14.875	0	1	30.5
A	15:00-16:00	316	15.328	1	0	32.2
B	15:00-16:00	344	15.915	1	0	41
C	15:00-16:00	189	14.875	0	1	30.5
A	16:00-17:00	384	15.328	1	0	32.2
B	16:00-17:00	406	15.915	1	0	41
C	16:00-17:00	170	14.875	0	1	30.5
A	17:00-18:00	150	15.328	1	0	32.2
B	17:00-18:00	178	15.915	1	0	41
C	17:00-18:00	64	14.875	0	1	30.5

Table 2: Data Collection (*PCM-pedestrian crosswalk marking, WAP-Waiting area for pedestrians, VSS-Vehicular stream speed)*

5. RESULTS

The variables used in the equation are described below with the all the values which are determined of our particular location which is considered for our analysis and hence further, values are being implemented in this model.

Statistical approach was adopted and pedestrian behavioural model known as Final Pedestrian Intersection Safety Index was developed. The equation is as shown below.

Variable name	Variable Description	Values	Identified values
ISI	Safety Index Value	Dependent variable	**-(calculated)-**
SIGNAL	Traffic signal-controlled crossing	0=NO 1=YES	**0**
STOP	Stop Sign-controlled Crossing	0=NO 1=YES	**0**
THRULNS	Number of through lanes on street being crossed (both directions)	1,2,3……	**4**
SPEED	85th Percentile Speed of vehicles on street being crossed	Speed in Kmph	**34.56 km/h**
MAINADT	Traffic Volume on street being crossed	ADT in thousands	**29.187**
COMM	Predominant land use on surrounding area is commercial development (i.e. retail, restaurants, etc.)	0 = not predominantly commercial area 1 = predominantly commercial area	**1**

Table 3:Variables in Pedestrian Safety Index (SOURCE: NO. FHWA-HRT 06-125)

$$\text{PED}_{\text{ISI}} = 2.372 - 1.867\mathbf{SIGNAL} - 1.807\mathbf{STOP} + 0.335\mathbf{THRULNS} + 0.018\mathbf{SPEED} + 0.006(\mathbf{MAINADT} * \mathbf{SIGNAL}) + 0.238\mathbf{COMM} \quad \text{---- Eq (1)}$$

The above-mentioned equation is analysed and the required data is calculated so as to make further use of the equation. Thus, this will help us in getting the value of our Pedestrian Intersection Safety Index.

$$\text{PED}_{\text{ISI}} = 2.372 - 1.867 \times \mathbf{0} - 1.807 \times \mathbf{0} + 0.335 \times \mathbf{4} + 0.018 \times \mathbf{34.56} + 0.006(\mathbf{29.187} \times \mathbf{0}) + 0.238 \times \mathbf{1}$$

$$\mathbf{PED_{ISI} = 4.57208}$$

Pedestrian Safety Index Score	Descriptions (at intersections/junctions)
1-2	Highly Safe
2-3	Safe
3-4	Average
4-5	Risky
5 or above	Highly Risky

Table 4: Details of Pedestrian safety level rating

6. CONCLUSION

The selected site is designated as commercial area due to presence of bus stop in location B on both sides of lane and presence of medical market along cross leg namely location C. The pedestrian volume at location B is much higher as compared to other legs of the T-intersection due to presence of bus stop and also due to the entrance through Gate no. 4 of medical facility PGI which is adjoining to this location. Sector -11 medical market is near to the cross leg mentioned as location C, where maximum pedestrians cross coming from location B to attain medicines and other medical facility from nearby hospital PGI. The Pedestrian Safety Index of Sector-11 T- intersection along Vidya path in Chandigarh is 4.57 which lies in the range of risky to highly risky. Thus, the selected site is designated as a risky location for pedestrians to cross at T-intersection. Accordingly, surrogate safety measures should be taken as before as possible to prevent further conflicts and accidents.

It can be suggested that introducing a traffic signal in the crossing will majorly enhance the safety of pedestrians by decreasing the numerical value of the pedestrian safety index also. A safe design and proper waiting area should be made on the site. Also, the proper allocation of bus stops should be done which creates a situation of hustle in the site mostly at peak hours. This makes location overcrowded and unevenly distributed pedestrians cross the major street unmannerly which was observed while doing the field survey. Hence, the Sector -11 T-intersection should be reconsidered and precautionary measures should be suggested by designers, planners and engineers to provide safety for pedestrians.

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