International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 4 Issue 2, February 2023

Safety Measurement of Urban Uncontrolled Traffic Circle Using Surrogate Safety Measures: A Case Study of Bhopal City

Valmiki Kumar[1], Gaurav Joshi[2], Rahul Sharma[3]
M.Tech Scholar, Radharaman Engineering College, Bhopal (M.P.), India[1]
Assistant Professor, Radharaman Engineering College, Bhopal (M.P.), India[2,3]

Abstract: *Every year, road accidents cost billions of dollars and damage millions of people around the world. With the increased likelihood of fatal crashes resulting from irresponsible driver maneuvers and actions, intersections pose several safety concerns. Noncompliance with priority regulations, poor lane discipline, and non-yielding behavior all have serious safety concerns. As a result, assessing current road safety indications, particularly at uncontrolled T-intersections in mixed traffic, becomes critical.*

Keywords: *Surrogate Safety Measures, PET, Critical Conflict, Severity Level.*

1. Introduction

Road user safety is an important problem for both developed and developing countries, as it has an impact on the people's well-being and economy. Between 2010 and 2019, the total number of registered motor vehicles in India increased at a compound annual growth rate (CAGR) of 9.8%. The rapid growth of motorized cars in India has been fueled by continuous economic growth and rising per capita income. Traffic hazards have expanded dramatically as a result of rising population paired with rapid vehicle growth, particularly in emerging nations like India, where prevailing road infrastructure is inadequate to support the increased traffic. It should be mentioned that states and union territories (UTs) recorded a total of 4, 49,002 traffic accidents in 2019, with 1,51,113 people killed and 4,51,361 people injured. In 2019, there will be 4, 49,002 accidents and 1,51,113 deaths, averaging 1,230 accidents and 414 deaths per day and about 51 accidents and 17 deaths each hour. In terms of accident-related deaths per type of road user, pedestrians accounted for 17 percent, bicycles 3 percent and two-wheelers 37 percent.

1.1 Traffic Conflict Techniques

While working as engineers for General Motors, *Perkins and Harris (1967)* developed the traffic conflict method (TCT). TCT was created in order to discover vehicle construction-related safety hazards. Their research found a link between conflict patterns and accident types, and they came to the conclusion that the prevalence of disputes is a better predictor of risk than the accident rate. Conflicts can be characterized as situations in which two or more road users would collide if neither of them attempted an evasive maneuver, as proposed by *Hydén (1987)*, who used TTC values and speeds to assess the severity of conflicts. Figure 1 illustrates the relationship between severity and frequency of elementary events in traffic with a safety pyramid as proposed by *Hydén (1987).*

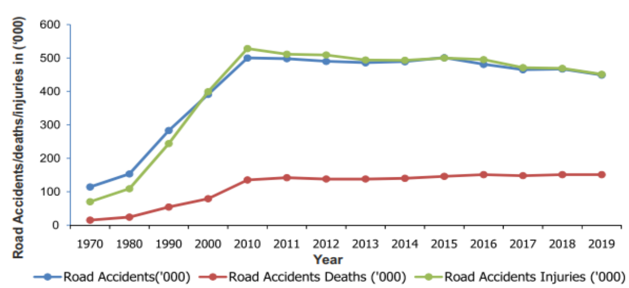


Fig. 1 relationship between severity and frequency of elementary events in traffic with a safety pyramid

2. Methodology

2.1 Introduction

The planned methodology for the research study is described in this chapter. The general technique of the project is depicted in Figure 3.1. The methodology of a research project outlines the complete work process and plan for achieving the research project's goal. We have to go through a long and methodical process to achieve this goal. In our assessment of the literature, we have discovered and studied various surrogate safety measures that have already been utilized and tested. For this study, we picked Post encroachment Time, Velocity of clashing vehicles, Delta V, and Encroachment time. PET is a quantitative method for determining the state of a conflict. Because traffic indicators such as stop and yield signs are frequently absent at uncontrolled intersections, drivers have little control over their approaching speed. Brief methodology adopted for the study:

The methodology consists of various stages. For explaining the complete methodology, the flow chart is shown in Figure 2. These stages are discussed in brief below.

From the past study related to Surrogate safety measures, Crash prediction, proactive safety analysis, and microsimulation the topic of the research work has been finalized. For the research work the study area is selected within the city of Bhopal which is a tier 2 city of India, Madhya Pradesh. Three uncontrolled intersections Ratnagiri Tiraha, 6 No Tiraha, and Neelbad Tiraha are selected which are 3-legged T-intersections. Data is collected on the locations using a video graphic survey for four hours, two hours in the morning from 10 AM to 12 PM, and two hours in the evening from 4 PM to 6 PM. The survey data is taken from the locations on weekdays. The video cameras are set up in such a way that they can catch the trap length for velocity while also providing a clear view of the conflict region, which is the intersection where the grids are positioned. The video data is then analyzed for relevant information for the research project. Kinovea software is used to extract data, which aids in the placement of perspective grids on the video. Grids are used to observe speed before and after entering a conflict area and also to calculate encroachment time. The extracted data is used for analysis from which critical conflicts and clustering were obtained.

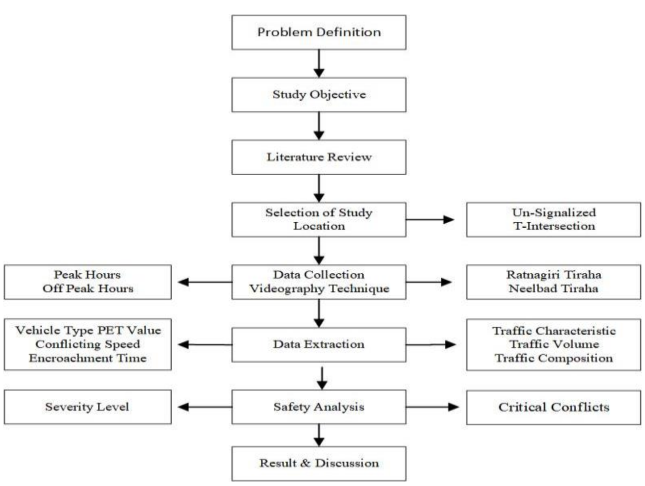


Fig. 2 Flowchart of Proposed methodology

3. Data Collection and Data Extraction

Data collection and data extraction are a primary part of any research work. In this chapter, we will discuss which technique was used to collect the data and how the data was extracted. The study is based on three3-legged intersections in Bhopal city namely, Ratnagiri Tiraha, 6 No. Tiraha,and Neelbad Tiraha.

Selection criteria for study locations

Study locations were chosen to investigate the effectiveness of the SSM for assessing safety performance at an uncontrolled intersection. Three uncontrolled intersections wererecognized on a variety of geometric and traffic characteristics, including the presence of

High-rise buildings near the location capture data effectively,

variable traffic demand at a different site to get more variations in PET,

Vehicles travel at desired speed with less obstruction to flow,

Both commercial and residential land use

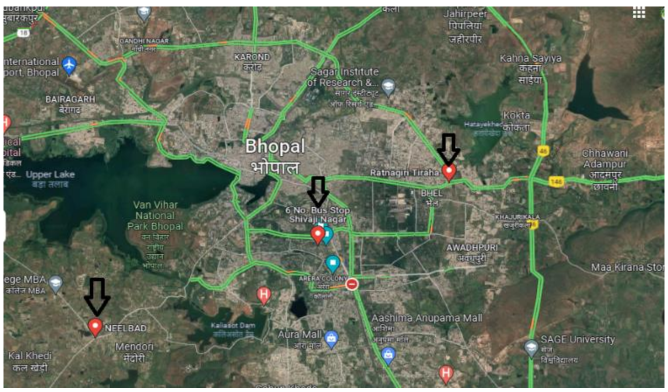
Study Sites

The research was carried out in Bhopal, the state capital of Madhya Pradesh. It's also known as the "City of Lakes" and is one of India's greenest cities. The city of Bhopal is divided into two parts: the historic city and the newly created region, which includes administrative, commercial, industrial, and residential activity. It has been designated as one of the first twenty Indian cities to be developed as a smart city under the Prime Minister's flagship Smart City Mission. In addition, Bhopal has a BRTS route, and a Metro Rail Project is now being built.

Because traffic congestion is a major issue in metropolitan areas, the presence of uncontrolled crossings and mixed traffic makes it even more difficult for drivers to properly move through intersection areas. Based on selection criteria three uncontrolled intersections namely Ratnagiri Tiraha, 6 No. Bus Stop Tiraha, and Neelbad Tirahaare selected for study (shown in Figure 3)

(a)

(b)



(c)

Fig. 3 shows the namely (a) Ratnagiri Tiraha, (b) 6 No. Bus Stop Tiraha, and (c) Neelbad Tirahaare

Location 1: Ratnagiri Tiraha

It is a three-legged, T-type intersection that is one of the Blackspots in Bhopal which connects NH86. The major road connects the Kali MataMandir and the Bagsewaniawhich is the main commercial area of Bhopal city while the minor road connects to Ratnagiri. The intersection constitutes of residential area.

Location 3: Neelbad Tiraha

It is a three-legged uncontrolled intersection that connects theVanvihar, Taj Hotel and Ratibad Road. There is no refugee island on any of the legs of the intersection. The area near the intersection is a commercial as well as residential area.

4. Result & Discussion

This section presents the analysis of the data collected and extracted to assess the safety of selected intersections using surrogate safety indicators namely PET, conflicting speed, DeltaV, and Encroachment Time. PET and conflicting speeds of though traffic are used to find out percentage of critical conflicts between right turning and through traffic conflicts. Further, DeltaV, and Encroachment Time (ET) are taken as surrogate indicators to identify severity levels of through and right turning movements respectively using the clustering technique.

The following Tables.1shows the descriptive statistics of the extracted data at three study locations namely Ratnagiri Tiraha, Neelbad Tiraha, and 6 No. Bus Stop Tiraha. The aggregate mean, standard deviation, variance, skewness, and kurtosis of the SSM indicators evaluated to assess the safety of 3-legged uncontrolled crossings in Bhopal City are shown in the descriptive statistics. The degree and direction of asymmetry is measured by skewness, whereas the weight of a distribution's tails is measured by kurtosis. From the data, it was observed that the mean and standard deviation ranged between 1.03–3.71 and 1.57–3.94, respectively, for three study locations. All of the SSM indicators for the study sites were positive skewed, suggesting that the distribution was skewed to the right, with the mean above the median. Similarly, in the case of kurtosis, all of the components were positive, suggesting that there were more tails than in a normal distribution.

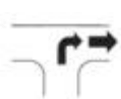
Fig. 4

IJEASM
International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 4 Issue 2, February 2023

Table 1 .Descriptive statistics of SSM parameters at study sites

Parameter	N	Range	Mean	Standard Deviation	Variance	Skewness		Kurtosis	
						Statistic	Stdandard Error	Statistic	Standard Error
Ratnagiri Tiraha									
PET	896	15.899	1.028	1.575	2.482	.755	.082	3.662	.163
Conf. Speed	896	42.038	18.433	6.911	47.758	.727	.082	.395	.163
DeltaV	440	46.471	5.575	5.725	32.778	3.410	.157	18.808	.313
ET	1062	33.050	6.153	3.482	12.123	2.413	.062	9.504	.125
Neelbad Tiraha									
PET	450	24.720	1.558	2.326	5.410	3.014	.115	17.731	.230
Conf. Speed	450	65.872	18.794	8.063	65.013	1.814	.115	6.516	.230
DeltaV	394	40.352	5.982	6.176	38.142	2.227	.175	6.688	.347
ET	365	33.919	4.274	3.355	11.254	3.589	.128	21.492	.255
6 No. Bus Stop Tiraha									
PET	403	23.680	3.710	3.943	15.546	.949	.122	1.155	.243
Conf. Speed	404	39.586	20.329	6.571	43.178	.684	.121	.517	.242
DeltaV	404	23.813	3.785	4.035	16.284	2.117	.121	5.746	.242
ET	396	29.400	4.283	3.521	12.396	3.894	.123	20.653	.245

Table 5.2.Comparison of PET and conflicts in different conflict paths

Conflict Path and its Directions	Intersection	No of Conflicts	Max. PET (sec)	Min. PET (sec)	Avg. PET (sec)	Total Conflicts (%)
	Ratnagiri Tiraha	369	6.75	-3.45	0.99	41.18
	6 No. Bus Stop Tiraha	200	14.88	-2.56	1.53	44.44
	Neelbad Tiraha	221	18.04	-10.24	2.80	54.70
	Ratnagiri Tiraha	317	10.40	-3.65	1.04	35.38
	6 No. Bus Stop Tiraha	168	14.88	-2.00	1.96	37.33
	Neelbad Tiraha	131	16.64	-5.64	5.39	32.43
	Ratnagiri Tiraha	210	9.35	-5.50	0.62	23.44
	6 No. Bus Stop Tiraha	82	5.44	-1.88	0.72	18.22
	Neelbad Tiraha	52	15.08	-2.80	3.32	12.87

Most Unsafe Conflict Path

A total of 896, and 404 conflicts have been observed for two different types of conflicts between right turn and through traffic at Ratnagiri Tiraha, and Neelbad Tiraha respectively. The intersection's overall mean PET readings may not accurately reflect the intersection's safety situation. One of the conflicts may have a large number of incidents, whereas the other may not have even a small number of interactions. As a result, in this study to determine which conflict path is the most severe, so that measures may be implemented to lower the trafficin that route by diverting vehicles to other road or implementing other measures. As shown in Table 5.2, measures such as mean PET can be used to assess a path's safety.

5. Conclusion

This research provided a study that developed a methodology for evaluating a surrogate safety indicator, PET, and conflicting speed to measure traffic safety at three-arm uncontrolled intersections. Further, developed severity levels to assess the safety of through and right turning movement using DeltaV and ET.
PET threshold values are used to determine critical conflicts. However, at intersections with mixed traffic and varying speeds, relying solely on PET to assess safety is insufficient. As a result, conflicts are observed in the current study employing two surrogate indicators PET, and related conflicting vehicle's speed. To determine critical conflicts at intersections, the critical speed is recommended. The braking distance concept is used to find out the critical speed for a certain PET value. There is a substantial percentage of observed conflicts at the intersectionare critical, according to the findings. This demonstrates that right-turning vehicle drivers are willing to take chances and accept short gaps in through traffic paths, which is unsafe. At Ratnagiri Tiraha and 6 No. Bus Stop Tiraha conflicts involving cars are found to be at a higher risk with 64.1% and 58.2% of conflicts involving cars being critical. Whereas, at Neelbad Tiraha LCVs are at higher risk with 24.1% of conflicts involving LCVsbeing critical. This could be owing to the turning vehicle's size. Conflicting through vehicles decelerate down when a car is turning; as a result, TWs conflicts have a lower percentage of critical conflicts. When turning, TWs clears the conflict area faster than Car and LCV, resulting in high PET and a low percentage of critical conflicts.
Further, surrogate safety indicators namely Encroachment Time (ET) and DeltaV are used to define severity levels of right turning and through movements. Three unsafe severity levels were developed namely less unsafe, moderately unsafe, and highly unsafe using the 2-step clustering technique. Among two intersections Ratnagiri Tiraha found it most unsafe for right-turning traffic with 5.65% of vehicles falling under severity Index C, and 6 No. Bus Stop Tiraha found it highly unsafe for through traffic with 6.19% of vehicles falling under severity Index C. The proposed approach provides a dependable method to identify unsafe crossings, unsafe movements, and reducing accidents by executing preventive management measures that exist in developing nations. Several counter measures like providing speed brakers, speed humps, and speed tables can be provided to reduce DeltaV which will eventually reduce ET and results in safer movements. Further, from PET we can find out the unsafe conflict path and unsafe vehicle-vehicle interaction.

References

[1] Allen, B.L., Shin, B.T. and Cooper, P.J., 1978. Analysis of traffic conflicts and collisions (No. HS-025 846).
[2] Alhajyaseen, W.K., 2015. The integration of conflict probability and severity for the safety assessment of intersections. Arabian Journal for Science and Engineering, 40(2), pp.421-430.
[3] Archer, J., 2005. Indicators for traffic safety assessment and prediction and their application in micro-simulation modelling: A study of urban and suburban intersections (Doctoral dissertation, KTH).
[4] Archer, J. and Young, W., 2010, December. The measurement and modelling of proximal safety measures. In Proceedings of the Institution of Civil Engineers-Transport (Vol. 163, No. 4, pp. 191-201). Thomas Telford Ltd.
[5] Amundsen, F. and Hyden, C., 1977. Surrogate safety assessment model and validation. In Proc., Conf. of First Workshop on Traffic Conflicts.
[6] Carlson, W.L., 1979. Crash injury prediction model. Accident Analysis & Prevention, 11(2), pp.137-153.
[7] Gabauer, D.J. and Gabler, H.C., 2006. Comparison of delta-v and occupant impact velocity crash severity metrics using event data recorders. In Annual proceedings/association for the advancement of automotive medicine (Vol. 50, p. 57). Association for the Advancement of Automotive Medicine.
[8] Gettman, D., & Head, L. 2003. Surrogate safety measures from traffic simulation models. FHWA-RD-03050. Washington, DC: Federal Highway Administration.
[9] Gettman, D., Pu, L., Sayed, T., Shelby, S.G. and Energy, S., 2008. Surrogate safety assessment model and validation (No. FHWA-HRT-08-051). Turner-Fairbank Highway Research Center.
[10] Goyani, J., Pawar, N., Gore, N., Jain, M. and Arkatkar, S., 2019. Investigation of traffic conflicts at unsignalized intersection for reckoning crash probability under mixed traffic conditions. Journal of the Eastern Asia Society for Transportation Studies, 13, pp.2091-2110.
[11] Goyani, J., Paul, A.B., Gore, N., Arkatkar, S. and Joshi, G., 2021. Investigation of crossing conflicts by vehicle type at unsignalized t-intersections under

varying roadway and traffic conditions in India. Journal of transportation engineering, Part A: Systems, 147(2), p.05020011.

[12] Huang, F., Liu, P., Yu, H. and Wang, W., 2013. Identifying if VISSIM simulation model and SSAM provide reasonable estimates for field measured traffic conflicts at signalized intersections. Accident Analysis & Prevention, 50, pp.1014-1024.

[13] Hydén, C., 1987. The development of a method for traffic safety evaluation: The Swedish Traffic Conflicts Technique. Bulletin Lund Institute of Technology, Department, (70).

[14] Johnsson, C., Laureshyn, A. and De Ceunynck, T., 2018. In search of surrogate safety indicators for vulnerable road users: a review of surrogate safety indicators. Transport Reviews, 38(6), pp.765-785.

[15] Lu, G., Liu, M., Wang, Y. and Yu, G., 2012. Quantifying the severity of traffic conflict by assuming moving elements as rectangles at intersection. Procedia-Social and Behavioral Sciences, 43, pp.255-264.

[16] Laureshyn, A., Svensson, Å. and Hydén, C., 2010. Evaluation of traffic safety, based on micro-level behavioural data: Theoretical framework and first implementation. Accident Analysis & Prevention, 42(6), pp.1637-1646.

[17] Lloyd, S., 1982. Least squares quantization in PCM. IEEE transactions on information theory, 28(2), pp.129-137.

[18] Mohan, M. and Chandra, S., 2018. Three methods of PCU estimation at unsignalized intersections. Transportation letters, 10(2), pp.68-74.

[19] MoRTH, Road Accidents in India. Ministry of Road Transport & Highways, Transport Research Wing, New Delhi (2019).

[20] Mohanty, M., Panda, B. and Dey, P.P., 2021. Quantification of surrogate safety measure to predict severity of road crashes at median openings. IATSS research, 45(1), pp.153-159.