Development of Safety Performance Measures for Urban Mid-Blocks

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***Abstract*—Traffic crashes are the major public health problem, leading to cause of death, injury and disability around the world. Statistical record states that, despite of insignificant decline in traffic crashes during the year 2011, the issue of traffic safety still remains acute in India. It was observed that there were around 4,98,000 traffic crashes, in which 1,42,485 people were killed and more than 5,00,000 persons were injured in the year 2011. More than 90 per cent of these deaths occur in low-income and middle-income countries, which have less than half of the world's vehicles. This is due to the reason that they lack in effective road safety strategies. Therefore, this study attempts to analyze the factors affecting the crash severity and crash frequency in urban mid-blocks. Safety performance measures are those parameters which influences the traffic crashes that should be constantly maintained and checked for Urban mid-blocks. Severity prediction models can be developed which aids in developing safety performance indicators which work as an effective tool for the evaluation of the effectiveness of potential safety treatments for the roads. Hence, Mixed modelling can handle correlated data and unequal variances. The methodology includes the identification of study area, data collection, preparation of database, modelling, interpretation of results obtained from the modelling and to derive the conclusions. Adequate treatment measures like reduction in speed of the vehicles, imposition of strict lane discipline, incorporation of proper driving skills to the road users were suggested to reduce the traffic crashes at mid-block sections.**

***Keywords*—mid-blocks, crash severity, crash frequency, mixed modelling, negative binomial**

I. INTRODUCTION

The most deleterious side effects of development and expansion of transportation system is the relentless increase in traffic crashes. In recent, despite advancement in technology and scientific progress in traffic safety issues, the prevailing high incidence of traffic crashes leading to injuries and fatalities, becomes a challenging factor to socio-economic well-being and public health, predominantly in the developing countries.As a consequential cause of deaths, injuries, and property loss, traffic crash is a major concern for public health and traffic safety. Conforming to statistics, despite of insignificant decline in traffic crashes during the year 2011, the issue of traffic safety still remains acute in India. During the year 2011, there were around 4,98,000 traffic crashes, in which 1,42,485 people were killed and more than 5,00,000 persons were injured. According to the International Road Federation, every year India suffers a loss of Rs.1 lakh crore (15 billion USD) due to traffic crashes. Further attention due to enormous life and property loss, is implemented in various ways to improve the traffic safety.It has been observed that, the developing countries have still a long way to go in achieving the target for reduction in traffic crashes by the year 2020. Traffic crashes are the utmost public health issue, leading to cause of injury, disability and death around the world. From the study done by United Nations for road traffic safety, it was observed that every year, nearly 1.3 million people die and about 20 to 50 million more are injured due to traffic crashes. More than 90 per cent of these deaths occur in low-income and middle-income countries, which have less than half of the world's vehicles. Traffic crash injuries are one among the three leading causes of death for people between 5 and 44 years of age. This is due to the reason that they lack in effective road safety strategies.

Therefore, this study attempts to analyse the factors affecting the traffic crashes and severity of crashes in urban mid-blocks. The crash prediction models can be developed which aids in developing safety performance indicators. These indicators work as an effective tool for the evaluation of the effectiveness of potential safety treatments for the roads.

The study aims at developing safety performance measures for urban mid-blocks using crash prediction modelling techniques.
The study is performed to accomplish the following objectives:

- To identify the study area based on the analysis of crash data in urban mid-blocks of Bengaluru city.
- To formulate data sheets for surveys like road inventory, traffic count and crash data.
- To collect the data on previous traffic crashes, perform road inventory, traffic volume count and spot speed for the study area.
- To form database and to perform data analysis
- To develop models on the analysed factors affecting traffic crash severity and crash frequency.
- To select the best model out of a set of alternatives
- To infer the results from the selected model and to provide recommendable safety measures

II. LITERATURE REVIEW

Meera et al., (2010),Several research works focused on the relationship between crash occurrences and roadway, traffic, and operational factors. The effect of lane width and number of lanes on safety is inconsistent across several research works. This study identified the risk factors that influence crashes at urban mid-blocks, considering the hierarchical structure of crash data. The study showed that crash frequency is influenced by regional level and site level variables whereas crash severity is influenced by regional level, site level, crash level and driver-vehicle unit level variables. Road length, lane width and road side obstructions have a positive influence on single carriageway crash frequency whereas they have a negative influence on dual carriageway crash frequency. Traffic volume has a positive influence on crash frequency of both single and dual carriageway roads. The crash severity prediction models show that larger lane width causes more severe crashes at single carriageway roads.

RuiGarrido et al., (2014), In the area of crash severity research, continuous efforts have been conducted in order to develop the relationship between the level of severity (dependent variable) and a set of explanatory variables such as driver attributes (age and gender), vehicle features (body type, vehicle age and number of vehicles involved in the crash), road characteristics (number of lanes, road surface conditions, intersection control and types of road), and crash characteristics (cause of crash). The influence of other variables on crash severity like speed limit, day of the week, time of the day, average traffic characteristics (AADT), weather and traffic conditions have also been scrutinized. In this study, the ordered probit model was used to examine the influence of various factors on the injury severity faced by motor-vehicle occupants involved in traffic crashes.

RezaieMoghaddam et al., (2010). This study was found that the factors associated with levels of crash severity were complicated due to various factors like personal characteristics such as age & gender, vehicle characteristics such as type of vehicle, environmental characteristics such as weather condition and road characteristics such as Geometrical Design. This study utilises a series of artificial neural networks to model the simultaneous crash related factors. So, different neural models were trained and finally models illustrating crash-related factors in crash severity such as fatal, injury or property damage were presented

MeysamEffati et al., (2014). This study presents a comprehensive approach to model the severity of motor vehicle crashes on two-lane, two-way roads. They incorporated a broad range of potential factors influencing crash severity, ranging from driver and behavioral factors to vehicle, environmental, and geographic factors. The output of the proposed crash severity estimation approach includes four categories: no crash, property damage only (PDO), crash with injury, and crash with fatality. The results demonstrated that vehicle failure, drivers wearing seat belts, and weather conditions are some of the most significant contributing factors on crash severity.

III. METHODOLOGY

The development of reliable methodologies for crash prevention mitigation is an important concern in road safety research. Some of the factors such as those affecting safety on mid-blocks were studied. The methodology adopted for the study is being illustrated stage by stage. The first stage involves the analysis of study area in which the study area was identified based on the previous statistical records. The second stage of methodology includes the preparation of format sheets for the data collection. The next stage includes the collection of data from the study area required for the database formation and interpretation. From the prepared database, the various factors affecting the traffic crashes were determined. The fourth stage involves the database preparation, in which the collected data is structured in the suitable form (such as in the form of Microsoft Excel) for the later stages of modelling input. Certain modelling concepts were incorporated, such as Crash Severity Prediction modelling. The modelling approach for the crash prediction modelling would be much concentrated on novel concept. The next stage comprises of software modelling. In this stage, the input values are incorporated from the prepared database in the form of MS-Excel and the input variables are selected for the analysis and interpretation in the modelling. The next process includes the presentation of results/inference that is obtained from the modelling. This gives the result of the input factors that predicts the cause for traffic crashes. Based on the results of modelling, the recommendations were made for safety treatment of unsafe road locations. The safety treatments can be evaluated for effectiveness by developing safety performance indicators.

IV. DATA COLLECTION

The study area was chosen for South Bangalore region, namely, Madivala and Electronic city, that is, the starting of Silkboard flyover to Seasons restaurant near Electronic city bus stop. The study area was selected based on the maximum number of traffic crashes for the entire city. This data has been collected from FIR Center for Bangalore region.The total length of the road measures to about 8,850km.The data collection for the Crash Severity and Crash frequency study includes Primary and Secondary Data Sources. The primary data sources comprise of preliminary surveys such as Road Inventory, Traffic Volume studies and Spot Speed studies. The road inventory was done manually using a Rodo meter to measure the width of carriageway, median width, median height and various other parameters were marked such as presence of lane markings, presence of edge markings, presence of bus stop, presence of subways, condition of the pavement surface, presence of street lights, land-use pattern, number of lanes, side-walk details, etc. Peak one hour classified Traffic Volume count of the study sites were collected manually. Simultaneously, the spot speeds were also collected for the same. The secondary data includes archived data sources maintained by State Crime Records Bureau (SCRB) of Karnataka. One major issue with the archived source is that all the crashes were not reported and all the reported crashes were not recorded correctly.

Table 1: Coding of crash severity factors

SL NO.	FACTORS	CODING	MEASURE (Ordinal/Nominal/Scale)
1	Severity	1. Non-fatal 2. Fatal	Ordinal
2	Number of vehicles involved	1. 1 vehicle 2. 2 vehicles 3. 3 vehicles	Ordinal
3	Number of people involved	1. 1 pupil 2. 2 people 3. 3 people	Ordinal
4	Season	1. Winter (December-March) 2. Pre-Monsoon (April-June) 3. Monsoon (July-September) 4. Post-monsoon (October-November)	Ordinal
5	Time	1. Dawn (4.30AM - 6AM) 2. Daylight (6AM - 5PM) 3. Dusk (5PM - 7PM) 4. Dark (7PM-4AM)	Ordinal
6	Accused vehicle type	1. 2-Wheeler 2. 3-Wheeler 3. 4-Wheeler 4. 6-Wheeler 5. 8-Wheeler 6. 10-Wheeler 7. 14-Wheeler	Ordinal
7	Hit and Run	1. No 2. Yes	Ordinal
8	Presence of Median	1. Yes 2. No	Ordinal
9	Presence of Bus-stop	1. No 2. Yes	Ordinal
10	Carriageway width	_	Scale
11	Traffic volume	_	Scale
12	Spot speed	_	Scale

To interpret the factors affecting severity, individual crash case details were taken into consideration. From the archived data collected from SCRB, the available factors that influenced the crashes were considered for the preparation of database in the form of Microsoft-Excel for modelling. Each individual crash was grouped section-wise for both main road and service road. Some of the factors such included were: Severity; Number of vehicles involved in the crash; Number of people involved at the crash; Season; Time; Hit and Run; Accused vehicle type. Season and the time of accident were achieved from the date of the accident. From the primary data collection, factors like Traffic volume count; Spot speed; Carriageway width; Presence of Median; Presence of Bus-stop were collected for all the 30 sections that was grouped for both main roads and service roads. The classification and coding of various factors to be input as variables into the modelling software for analysis is given in Table 1.

The numerous factors responsible for the crash severity were classified and certain numerical coding were assigned for almost all the factors in the increasing order with effect to crash severity. Table 2 represents the summary statistics of various factors influencing the traffic crashes. These values were derived from the collected data for the study at mid-block sections.

Table 2: Summary Statistics

FACTORS	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION
Spot speed	19	50	36.27	8.769
Traffic volume count (in PCU/hour)	2192	9340	4744.18	1702.163
Carriageway width (m)	6	11	9.78	1.652
Median width (m)	1.1	4.67	3.29	0.9
No. of crashes	0	11	3	3

V. MODELLING AND ANALYSIS

A model is defined as a mathematical description of the process that procreates to the observations within a set of data. A statistical model comprises of an equation illustrating the presumed influence of explanatory variables and a description of probability distributions associated with aspects of the process to be characterized by random variation. Models that consists of both fixed and random effects are termed as 'Mixed Models'. Since the factors are distributed under both fixed and random effects, Mixed modelling is used to interpret the result. Strategic decision-making process can be made with the help of the data. Hence, effective analysis can be done later as it is much required to accumulate such data in a warehouse based on the requirement. One such analysis in resolving the factors that influence the crash was identified using a software called SPSS which can work on large amount of data. Hence, SPSS software was used to analyse the data.

1. CRASH SEVERITY PREDICTION

The factors influencing traffic crashes and the level of crash severity have been extensively applied as the indicator for measuring the efficiency of service provision in the road network systems of every country.From the prepared database, the input variables are considered to predict the crash severity for the selected study area. For the purpose of modelling, SPSS software is used to predict the severity of crash so as to obtain accurate results.The factors that influence the traffic crash severity contain both fixed and random effects, thereby choosing 'Mixed Modelling' technique would be appropriate. The variables chosen for fixed effects are the independent variables and it does not depend on the crash details. The factors considered for fixed effects are Presence of median, Presence of Bus-stop, Spot -speed, Traffic volume count in PCU/hour and carriageway width. These are the factors that does not require crash details or it does not depend on the time of crash. All the other remaining factors such as season, time of crash, number of vehicle involved, number of people involved, accused vehicle type, hit & run. These factors depend on the individual crash details. From the model output, it was observed that 80.8% of the time, the model was found to be accurate with the result. Table 3 and Table 4 shows the effect of fixed and random effect variables on crash severity respectively.(i) The general form of the equation of crash severity has been shown below in equation 1.

$$\text{logit}\left[\frac{prob\ (y=j)}{prob\ (y=J)}\right] = X_j\,\beta + Z_j\eta_j \qquad \ldots\ldots (1)$$

For j=1,……,(J-1)

Table 3: Tabular representation on coefficients and significance of fixed effects
Target: Severity
Reference category: FATAL

Model term	Coefficient	t	Significance
Threshold for severity = 1	4.342	0.613	0.542
Spot speed (kmph)	0.123	1.241	0.218
Traffic volume count in PCU/hour	0.093	0.213	0.832
Carriageway width (in m)	-0.066	-0.060	0.952
Median present	-1.751	-0.394	0.694
Median absent	0		
Bus stop absent	0.068	0.077	0.939
Bus stop present	0		

Table 4: Tabular representation on coefficient and significance of random variables

Random Effect Block 2	Estimate	Z	Significance
Var (No. of people injured)	0.716	0.816	0.414
Var (Hit by)	0.098	0.416	0.884
Var (Hit & run)	0.165	0.178	0.859

2. CRASH FREQUENCY PREDICTION

In order to reduce the crashes and to improve traffic safety, it is necessary to identify the key factors that impact crash frequency on urban mid-blocks.

Table 5: Tabular representation of the effect of magnitude on crash frequency
Fixed Coefficients
Target: crashes/year

Model Term	Coefficient	t	Significance
Spot speed	0.001	0.022	0.982
Traffic volume count in PCU/hour	0.000	1.341	0.192
Carriageway width (in m)	0.183	0.746	0.463
Median present	-1.134	-0.648	0.523
Median absent	-1.571	-1.363	0.186
Bus stop absent	0.856	1.541	0.136
Bus stop present	0		

The number of crashes occurring in a geographical region over a specific period of time per year (or per more than one year, such as three years) is termed as crash frequency, which has been widely used as an indicator of the crash occurrence at highways or certain segments of the roads. Modelling highway traffic crash frequency is an important approach to identify prominent crash risk areas that would help the transport agencies to allocate limited resources more efficiently, and find preventive measures. A variety of dependent variables that affects crash frequency such as spot speed, carriageway width, traffic volume(PCU/hour), presence of median and the presence of bus stop are considered for the study at mid-block sections. The general form of the equation for crash frequency is shown in equation 2.

$$y = e^{(a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4)} \qquad \text{..... (2)}$$

where, x_1, x_2… are the variables that influences the crash frequency
and a_0, a_1, a_2… are the co-efficient of the variables x1, x2…

From the previous studies made on crash frequencies, it was observed that negative binomial gave better results as compared to poisson or any other modelling techniques. SPSS software was used to predict the modelling similar to the crash severity.The total number of crashes occurred for the three years considered for the study was taken and the rate of crashes per year were calculated. The fixed variables which influences the crash frequency were identified for the study area and the analysis were modelled with reference to crashes per year. Table 5 illustrates the influence of fixed variables on crash frequency obtained from the model output.

6. RESULTS

The most appropriate modelling technique was identified for both crash severity and crash frequency. The factors influencing the crashes were studied and the results were obtained by the SPSS modelling software in both the cases. It was represented in the form of table so as to clearly understand the effect of various parameters that is responsible for the traffic

crashes. From the crash severity prediction, it was observed that increase in speed of the vehicles increases the severity of crashes. Increase in traffic volume increases the crash severity. Increase in carriageway width decreases the crash severity. Presence of median decreases the severity of crashes. Presence of bus stop reduces crash severity. Similar to crash severity, crash frequency prediction was also performed. The various factors that is responsible for the occurrence of crash was determined. From the model output, it shows that increase in speed of the vehicle increases the crash frequency. Increase in the traffic volume at mid-block increases the crash frequency. The presence of median decreases the frequency of crash. The presence of bus stop decreases the crash frequency.

7. CONCLUSION AND RECOMMENDATIONS

The statistical record collected from archived sources for the study area highlight that, most of the traffic crashes occur due to reckless driving, over-speeding of the vehicles, improper lane discipline, jumping traffic signals and unfollowed safety precautions. Hence, intense actions should be imposed to reduce the speed of vehicles at that region. Speed hump is an important measure to alert their speed and to guide their respective movements. This can be resolved by implementing speed humps/speed breakers to reduce the speed of the vehicles at mid-block sections. It can adversely reduce the fatality of traffic crashes.

Reckless driving is caused due to negligent driving behaviour among the drivers. Proper driving skills should be incorporated to the drivers which is also a vital cause for the traffic crashes. From the road inventory data, it was observed that sufficient signs were not provided at the required sections. Adequate signs and proper markings indicating the speed hump ahead, road and lane markings, bus stop markings should also be provided and made visible to the driver at a distant. Sufficient carriageway width should be provided based on the standard guidelines for different types of roads. This would reduce the occurrence of crashes to a large extent. Strict imposition of safety measures among the drivers should be made by using rider helmets, which is the main cause for fatality leading to loss of life. This can partially reduce the fatality level.

From the study conducted on mid-block sections, various factors influencing the crash frequency and crash severity were identified and suitable measures were found so as to minimise the fatality and the occurrence of crashes in the upcoming years. These results can be applied at mid-blocks for future construction of such roads and their respective parameters that affects the crashes are to be considered.

REFERENCES:

[1] Abdel-Aty, M. A., Radwan, E. Modeling traffic accident occurrence and involvement. *Accident Analysis and Prevention*, 32, 633-642, 2000.

[2] Abdulhafedh, A. (2016). Crash Frequency Analysis. *Journal of Transportation Technologies*, 6, 169-180.

[3] Baruya, A., & Finch D. J. A speed accident relationship for European single carriageway road, *Traffic Engineering and Control*, 40, 135-139, 1994.

[4] Chen W., Jovanis P. P. Method for Identifying Factors Contributing to Driver-Injury Severity In Traffic Crashes, *Transportation Research Record*, 1717, 1-9, 2000.

[5] Deublein, M., Schubert, M., Adey, T., Kohler, J., Faber, H. Prediction of road crashes: A Bayesian hierarchical approach, *Accident Analysis and Prevention*, 51, 274-291, 2012.

[6] Dinesh, M., Geetam, T., Sudipto, M. Urban traffic safety assessment: A case study of six Indian cities, *International Association of Traffic and Safety Sciences*, 35(2), 95-101, 2016.

[7] Domnique, L. The statistical analysis of crash-frequency data: A review and assessment of methodological alternatives, *Transportation Research Part-A:Policy and Practice*, 44(5), 291-305, 2010.

[8] Fang Zong, Hongguo Xu and Huiyong Zhang. Prediction for Traffic Accident Severity: Comparing the Bayesian Network and Regression Models. *Mathematical problems in* engineering, College of Transportation, Jilin University, China, 2013.

[9] Garrido, R., Bastos, A., Almeida, A., Elvas, J. Prediction of road crashes severity using the ordered probit model. 17th Meeting of the EURO Working Group on Transportation, EWGT2014, Spain, 214-223, 2014.

[10] Greibe, P. Accident prediction models for urban roads. Accident Analysis and Prevention, 35, 273-285, 2003.

[11] Harwood, D. W., Bauer, K. M., Richard, K. R., Gilmore. D. K., Graham, J. L., Potts, I. B., Torbic, D. J., &Hauer E. Methodology to predict the safety performance of urban and suburban arterials, NCHRP project report 17-26, Transportation Research Board, 2010.

[12] IRC: SP: 88-2010. Manual on Road Safety Audit.

[13] Jones, A. P., & Jorgensen, S. H. The use of multilevel models for the prediction of road accident outcomes. *Accident Analysis and Prevention*, 35, 59-69, 2003.

[14] Kustra, W., Jamroz, K., Budzynski, M. Safety PL – a support tool for Road Safety Impact Assessment, *Transportation Research Procedia*, 14, 3456 – 3465, 2016.

[15] Meera, J., Anjana, S., Anjaneyulu M.V.L.R. Development of hierarchical safety performance functions for urban mid-blocks, 2nd Conference of Transportation Research Group of India (2nd CTRG), 104, 1078-1087, 2013.

[16] MeysamEffati, Mohammd Ali Rajabi, FarshadHakimpour and ShahinShabani. Prediction of Crash Severity on Two-Lane, Two-Way Roads Based on Fuzzy Classification and Regression Tree Using Geospatial Analysis. *Journal of Computing in civil Engineering*, 29(6), 04014099/1-04014099/14, 2015.

[17] Moghaddam, F., Afandizadeh, Sh., Ziyadi, M. Prediction of crashes severity using artificial neural networks. *International Journal of Civil Engineering*, 9(1), 41-49, 2010.

[18] Neelima, C., KaminiGuptab. Analysis of Driver Behaviour and Crash Characteristics during Adverse Weather Conditions. *2ndConference of Transportation Research Group of India*, 104, 1048-1057, 2013.

[19] Peden, M., Scurfield, R., Sleet, D., Mohan, D., Hyder, A., Jarawan, E., Mathers, C. World Report on Road Traffic Injury Prevention, *World Health Organization Geneva*, 2004.
[20] Prajapati, P., Tiwari, G. Evaluating safety of urban arterial roads of medium sized Indian city. *Proceedings of the Eastern Asia Society for Transportation Studies*, Vol. 9, 2013.
[21] Sitran, A., Delhaye, E., Uccelli, I. Directive 2008/96/EC on road infrastructure safety management: an ex-post assessment 5 years after its adoption, Transportation Research Procedia, 14, 3312-3321, 2016.
[22] Zeng, Q., & Huang, H. Bayesian spatial joint modelling of traffic crashes on an urban road network, *Accident Analysis and Prevention*, 67, 105-112, 2014.

Abbreviations

USD: United States Dollar
FIR: First Information Report
SCRB: State Crime Records Bureau
PCU: Passenger Car Unit
Std: Standard
SPSS: Statistical Package for Social Sciences
Var: Variable