

ACCIDENT PREDICTION MODELLING FOR AN URBAN ROAD OF BANGALORE

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Abstract

Infrastructure development and/or enhancement of urban areas entail the assessment of safety parameters for the efficient and safe movement of the road users from a transportation engineer's perspective. It has become an essential part of every transportation plan to focus on the road user safety aspects not only in the present traffic condition, but also with the changing scenario of the traffic flow. The major purpose of this study was to develop an accident prediction model that would depict the effect of some of the major factors on accident causation on urban roads. The factors included road characteristics and traffic volume details collected for a selected stretch in Bangalore that is one of the major black spot locations of the city. The selected best fit model had an excellent coefficient of determination ($R^2_{adj} = 0.967$), encompassing the crucial variables such as carriageway width, shoulder type, number of minor crossings, land use, road condition, average speed of traffic stream and composition of trucks. It is envisioned that this study will help recommend the significant safety measures that need to be adopted by the transportation planners in designing a safer road user environment.

Keywords: Accident prediction model, non linear analyses, coefficient of determination

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1. INTRODUCTION

An improvement in socio-economic conditions of the people along with industrial and infrastructural development is bound to create an additional burden on roads by means of an increased number of vehicles and associated modes using the roads. Along with the enormous advantages caused by this magnitude of progress, roadway accidents have also become one of the main causes of concerns due to both individual (persons) and economic losses. Therefore, there is a huge demand for assessing these accidents through identifying and analyzing the various causes that are responsible for their occurrence, and also to recommend the various remedial measures to mitigate the accidents. Generally, road accidents are analyzed by means of precisely defining the event involving damage to the property and/or injury to the road users, which are recorded first-hand by the police and/or emergency services. Accidents are rarely caused by a single factor [1]. Usually, the interaction of the diverse set of factors such as roadway design parameters, road user behaviour, environmental conditions, etc., cause accidents; however, one factor can be more responsible than the rest, and can easily be identified. Most of the metropolitan cities in India are witnessing the phenomenon of escalating growth of vehicular traffic due to population explosion coupled with large scale socio-economic activities. This has resulted in severe traffic problems on roads in terms of safety and deterioration in the

eco-friendly environment due to an increase in noise and air pollution. Causation of accidents can be well understood with the help of analyses of accident statistics, which can provide insight to understanding the many factors of road accidents [2]. Based on the studies [3] it is observed that the highest accident severity rate was recorded in Delhi followed by Bangalore, Mumbai and Chennai. Out of the several influencing factors, such as urbanisation, population growth, increase in the number of vehicles etc., the popularity of mass transit system might be the key reason for a very low accident severity rate in Mumbai. Bangalore is one of the fastest growing metropolitan cities of India (and South East Asia) that has grown exponentially in the past two decades [4]. The population of Bangalore city has reached 9 Million in the year 2011 with a vehicular population of 4 Million; as indicated by the Bangalore traffic police. The boom of software, biotechnology and manufacturing industries have magnified the requirements of fundamental services, which have resulted in an expansive urban sprawl into challenging proportions.

1.1 Background

Generally, prediction of accidents is performed by analyzing the various factors responsible for accidents and quantifying their effect on the accidents using statistical techniques. Several global studies have been carried out in the field of accident prediction modelling from the past few decades,

beginning with the pioneering effort conducted by R. J Smeed [5], popularly known as the Smeed's law developed in the year 1968; this is an empirical equation that relates the vehicle registration and population to the number of fatalities. Later on, the models for the accident prediction developed by Ponnaluri [6] had the Smeed and Andressean's [7] model as the bases. The studies of Ponnaluri analyzed the relationship between accident fatalities, population and vehicle ownership. The stability of the Smeed's model for application to the various states over time was also investigated. The various models developed were compared based on the coefficients of variation (CV) using the Statistical Package for Social Science (SPSS) software. It was found that the original Smeed model overestimated the fatality rate per vehicle when applied to the Indian conditions. The generalized models were found to be efficient enough to understand the fatality rates. Many methods of model development have come to light in the past few years that have made the model development more efficient and effective.

Multiple linear regression analysis was one of the first and simple methods of analysis taken into consideration for the model development, which gave satisfactory performance. This technique is still being used in the development of simple models. Some of the recent studies include the accident prediction modelling conducted by Hashmi et al. [8] which was based on the driver opinion surveys to envisage the accidents. The model helped in identifying the vehicle and driver characteristics that played a vital role in increasing the number of accidents thereby, assisting in formulating effective measures to mitigate the accidents. Mustakim et al. [9] also adopted regression analysis in which road and traffic related factors were considered as independent variables and number of accidents as the dependent variable. The study found that the number of access points to the road stretch; low lighting conditions and the Annual Average Daily Traffic (AADT) are major contributors for the occurrence of accidents. The study conducted by Greibe [10] dealt with the development of simple realistic model for the prediction of accidents in an urban junction and road stretch. The applications of the model were to identify the various factors responsible for the accident occurrence and determine the 'black spots' in the study area. The results of the study shows that the accident frequencies of the road links and junctions considered were related to the various factors causing them by means of generalized linear modelling.

1.2. Objectives and Scope of the Study

The objective of the present study is 1) To identify various factors responsible for the occurrence of the accident in the selected stretch of Bangalore, and 2) To quantify their effects on the causation of accidents 3) To understand the relationship between various factors causing accidents and the accident occurrence. 4) To develop a model between various factors

causing accidents and the accident occurrence, using non-linear regression analysis.

1.3 Study Area

A three-kilometre road section from SRS bus stop to Yeshwanthpur railway station bus stop on the Tumkur road (NH4) was chosen for the study as it is one of the top three major accident prone roads in Bangalore. The study stretch was divided into ten homogeneous sections of 300 meters each for the purpose of analysis. The segments were named as A, B, C and so on up to J for identification.

1.4 Data Collected

The preliminary data collected through road inventory included details on road geometrics, land use pattern and road side facilities. The average peak hour traffic volume per direction was determined through classified volume count surveys for morning and evening peak hours. Secondary data included details on the accidents such as location, vehicles involved and accident severity for the years 2010, 2011, and 2012, with respect to the study stretch, collected from the FIRs of Yeshwanthpur traffic police station.

2. METHOD

For the purpose of analysis the dependent variable was selected as the average of the total accidents that occurred in the past three years, along the study stretch. Road characteristics and traffic volume details formed the independent variables for the analysis and summed up to a total of 19 independent variables. The best trend lines of each predictor variable and the dependent parameter were drawn using MS EXCEL 2007, to understand the relationship between each independent variable and the dependent variable. For further elimination of non essential parameters, a correlation matrix was developed using MS EXCEL 2007. From the correlation matrix, the variables showing high Pearson's correlation ($\rho > 0.5$) with the dependent variables were selected. One out of two dependent variables that had high correlation with each other was also excluded, considering the assumptions made in any type of regression analysis. The individual trends were further used to conduct a mixed type of regression modelling. Statistical Package for Social Sciences (SPSS) software was used to conduct regression analysis.

3. RESULTS

The best trend lines of each predictor variable and the dependent parameter indicates that the variables followed different trends such as linear, polynomial, exponential and power (Table 1).

Table 1: Relationship of each individual parameter with the dependent variable

S. No.	Independent Variable (x)	Expression	Relationship	R2
1	Carriageway width (CW)	$y = 0.7245x^2 - 14.321x + 73.5$	Polynomial	0.604
2	No. of minor crossings/ side roads/ exits (NM)	$y = -0.3533x^2 + 2.5141x + 3.7206$	Polynomial	0.0884
3	Width at approach of minor crossing (WA)	$y = 0.1565x^2 - 0.3571x + 3.3333$	Polynomial	0.237
4	Median width (MW)	$y = -3.9167x^2 + 11.208x + 7$	Polynomial	0.325
5	Shoulder type (ST)	$y = 12.016e-0.636x$	Exponential	0.672
6	Shoulder width (SW)	$y = 1.1111x^2 - 5.4444x + 10.333$	Polynomial	0.274
7	Foot path (FP)	$y = 6.2261e-1.482x$	Exponential	0.467
8	Land use (LU)	$y = 3.8333x^2 - 10.5x + 9.6667$	Polynomial	0.644
9	Average speed of the traffic stream (AS)	$y = 45.421e-0.045x$	Exponential	0.344
10	Service road width (SRW)	$y = -0.4683x^2 + 4.1153x + 3.0621$	Polynomial	0.495
11	Road Condition (RC)	$y = -9.4375x^2 + 17.437x + 8$	Polynomial	0.423
12	No. of junctions (J)	$y = 6.875x + 5.125$	Linear	0.30
13	Total traffic volume (TV)	$y = (-4*10-6)x^2 + 0.0223x - 25.475$	Polynomial	0.128
14	% of 2- wheelers (TW)	$y = 3156.9x^2 - 3472.7x + 957.93$	Polynomial	0.637
15	% of Auto Rickshaws (A)	$y = 170.93e-61.14x$	Exponential	0.538
16	% of Cars/ jeeps/ vans (C)	$y = 10689x^2 - 5328.9x + 665.45$	Polynomial	0.704
17	% of LCVs (LCV)	$y = 179682x^4.1235$	Power	0.253
18	% of Buses (B)	$y = 105.24e-50.92x$	Exponential	0.259
19	% of Trucks (T)	$y = 474.98x - 0.5392$	Linear	0.767

Note: Bold letters indicates the higher influence of those variables with occurrence of accidents.

It could be inferred based on the R2 values (Table 1), that some parameters have a high influence on the total number of accidents. The parameters with higher influence with occurrence of accidents were further filtered keeping in view of practical aspects as well as the correlation matrix to consider those parameters to develop the model. It was found from table 2, that road condition and average speed of traffic stream had a high correlation with each other ($\rho = 0.729$). Consideration of both the parameters for the study was very important as both road condition and average speed of the traffic stream formed crucial factors in any type of accident analysis. To incorporate both these parameters in the model, a new parameter, named 'Speed Component' that was a relationship between the road condition and average speed of traffic stream was generated. This new parameter was also considered as a predictor variable amongst the others for model development. The best fit model was selected based on

the statistical goodness of fit parameters such as "adjusted R2" and "Se/Sy" values shown in Table 3.

Table 2: Correlation matrix

7	CW	NM	WA	MW	ST	SW	FP	AS	J	LU	SRW	RC	TTV	TW	C	AR	LCV	T	B	Y
CW	1																			
NM	0	1																		
WA	0.156	0.703	1																	
MW	0.024	0	0.330	1																
ST	0.489	0	-0.149	0.489	1															
SW	0.304	0	-0.043	0.426	0.592	1														
FP	0.234	0	-0.167	0.234	0.671	-0.195	1													
AS	0.591	0	-0.225	0.179	0.748	0.514	0.396	1												
J	-0.547	0	0.389	0.234	0.671	-0.584	-0.25	-0.704	1											
LU	-0.104	-0.263	-0.111	-0.625	-0.596	-0.649	-0.167	-0.323	0.25	1										
SRW	-0.680	0	-0.064	-0.449	-0.713	-0.441	-0.451	-0.398	0.411	0.630	1									
RC	0.512	0	-0.364	-0.220	0.629	0.548	0.234	0.729	-0.937	-0.104	-0.295	1								
TTV	0.260	0	0.055	0.085	0.160	-0.510	0.667	-0.051	0.177	0.102	-0.437	-0.102	1							
TW	-0.023	0	-0.165	0.369	0.578	0.650	0.124	0.373	-0.450	-0.667	-0.261	0.232	-0.551	1						
C	0.026	0	0.240	-0.318	-0.708	-0.335	-0.565	-0.532	0.452	0.409	0.143	-0.338	0.230	-0.810	1					
AR	-0.012	0	-0.092	0.604	0.745	0.088	0.858	0.400	-0.129	-0.412	-0.370	0.129	0.370	0.408	-0.754	1				
LCV	0.169	0	-0.159	-0.908	-0.480	-0.237	-0.427	-0.056	-0.270	0.587	0.429	0.225	-0.327	-0.248	0.302	-0.734	1			
T	-0.211	0	0.155	-0.488	-0.804	-0.439	-0.598	-0.398	0.434	0.752	0.692	-0.217	-0.081	-0.782	0.741	-0.702	0.508	1		
B	0.096	0	0.021	0.456	0.483	-0.271	0.862	0.14	0.121	-0.146	-0.428	-0.030	0.837	-0.176	-0.233	0.798	-0.684	-0.369	1	
Y	-0.015	0.063	0.473	-0.294	-0.735	-0.486	-0.496	-0.445	0.545	0.727	0.542	-0.387	-0.005	-0.720	0.674	-0.601	0.423	0.876	-0.279	1

Note: Highlighted cells show the maximum correlation values

Table 3: Classification of goodness of fit by statistical parameters [11]

Criteria	adjusted R2	Se/Sy
Excellent	>0.90	<0.35
Good	0.70-0.89	0.36-0.55
Fair	0.40-0.69	0.56-0.75
Poor	0.20-0.39	0.76-0.90
Very Poor	<0.19	>0.90

4. MODEL DEVELOPMENT

The following model was selected as the best fit model, satisfying both statistical ($R^2_{adj} = 0.916$ and $S_e/S_y = 0.390$) as well as practical considerations. Sensitivity studies were conducted to calibrate the model and also study the effect of each variable on the urban road accidents.

$$y = 6.037 + 0.041(CW^2) + 0.471(e^{ST}) + 4.346(T) + 2.170(LU) - 0.338(SC) \dots\dots\dots(1.1)$$

Where, y = average number of accidents per year; SC = Speed Component = $29.904 e^{0.2973(RC)}$;
 RC = Road condition (0- Bad; 1- Average; 2- Good); CW = Carriageway width (m);
 ST = Shoulder type (0- Absent; 1- Paved; 2- Unpaved); T = % of Trucks in the traffic stream
 LU = Land use (1- Residential; 2- Commercial; 3- Industrial);

5. DISCUSSION AND RECOMMENDATIONS

The objective of the study was to identify and analyse the various parameters responsible for accidents. Based on the literature review, the prominent factors responsible for accidents were identified. The study stretch was decided considering some important features such as feasibility for conducting surveys and availability of adequate accident data. Tumkur Road being one of the accident prone roads of Bangalore was selected as the pilot stretch as it fulfilled the aforementioned requirements. Substantial amount of data was collected and segregated for further analyses. Mixed type of non linear regression analysis was adopted and a best fit model was selected which was statistically and practically significant. Although the average speed of traffic stream showed very less R2 value with the dependent variable, it was still considered for the study, as average speed of the traffic stream formed a crucial factor in any type of accident analysis.

The study showed that carriageway width, shoulder type, road condition, land use and composition of trucks in traffic stream were the most significant parameters affecting accidents on urban roads. Some of the recommendations that were drawn from the above results and field observations have been enlisted below:

- Provision of dedicated lanes for the slow moving heavy vehicles and very strict monitoring of the regulation.
- A minimum width of unpaved shoulders to be provided for the road infrastructure which also contributes to the reduction in the rate of the accidents.
- Stringent measures to be taken to restrict the movement of heavy vehicles during the peak hours.
- Restrict the number of minor exits and implement effective design provisions to allow for safe traffic diversion along such exits.

- To allow safe convergence of traffic near the fly over exit, provision of signals (ramp meters) to regulate the inflow of traffic from below the fly over.

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