Access Density and Standard Deviation of Speed as Contributing Factors for Accident of High Speed Cars

A.K.Sharma
Associate Professor
Civil Engineering Department
RCOEM, Nagpur, India

V.S.Landge
Associate Professor
Civil Engineering Department
VNIT, Nagpur, India

T.K.Rao
Associate Professor
Civil Engineering Department
RCOEM, Nagpur, India

ABSTRACT
The very high cost of highway accidents paid by societies around the world makes the highway safety improvement an important objective of transportation engineering. The high speed cars are gaining popularity as one of the important means of transportation among the middle and higher income group of the society in India. At the same time the road accident statistics with regard to these high speed vehicles are also alarming. The present research aims at correlation of accident of high speed cars with road geometry and traffic variables. Data collected from National Highway No.6 of India, between Amravati and Nagpur were used for modeling accident. Generalized linear model was used to quantify the effect of various variables in the model. The variables used were lane width (LW), shoulder width deficiency (SWDEF), access density (AD), standard deviation of speed (STDSP) and percentage of heavy vehicles in the traffic (HVPER). Access density, shoulder width deficiency and standard deviation of speed were found to have significant influence on accident frequency of high speed cars.

Keywords
High speed cars, shoulder width deficiency, standard deviation of speed, access density.

1. INTRODUCTION
Growth of transportation has a very unfortunate impact on the society in terms of accidents. Worldwide death and injuries from road accidents have reached epidemic proportions. Over 1.2 million people are killed every year globally and over 20 million are injured or crippled (WHO, 2009). Developing countries accounts for up to 85% of all the fatalities. The problem is particular acute in the Asia-pacific region, which has only 43% of the world's motorized vehicle fleet but accounts for more than 50% of global road death . Around 7, 00,000 people die in road crashes every year in Asian Countries (United Nations ESCAP, 2010).

The accident statistics [1] of 2011 reports that there were 4, 97,686 accidents, out of which 1,21618 were fatal. The number of persons killed in accidents were 1,42,485 i.e one fatality per 3.49 accidents. This suggests that the magnitude of road accidents and fatalities in India is alarming. This is evident from the fact that every hour there are 56 accidents (about one accident every minute).

The National Highway No.6 shares heavy vehicles, cars, two wheelers, auto rickshaw, cycles, cycle rickshaw, animal drawn carts, pedestrians and other non-motorized vehicles. The accident data analysis revealed that high speed cars were involved in 48% of road accidents on the selected stretch.

Many researchers, like Garber and Joshua [2], Miaou[3], Zegeer[4], Paul Griebe[5], Okamoto [6], Landge V.S.[7], Sharma A.K.[8], Vashi and Damodaria[9] ,and Parida[10], studied the occurrence of road crashes and suggested various modeling techniques using linear regression, Poisson regression, Negative binomial regression, neural networks. The accident occurrence was modeled using different road geometry and traffic variables by different researchers.

The aim of this research was to quantify the variables responsible for accidents related with high speed cars.

2. OBJECTIVE
The objective of this research was to

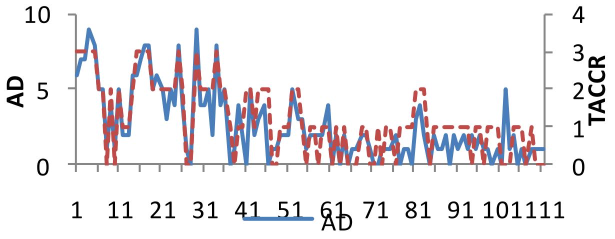
- Develop a correlation between the accident frequency and road geometry and traffic variables.
- Suggest some practical measures to improve safety.

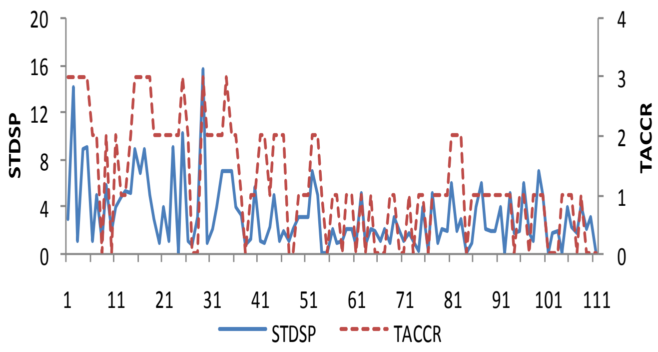
3. STUDY AREA AND SCOPE
The study area chosen was National Highway No.6 commonly refer to as NH-6 or G.E. Road (Great Eastern Road),which is a one of the most busy national highways in India. It's a connecting corridor to major states of India namely Gujarat, Maharashtra, Chhattisgarh, Orissa, Jharkhand and West Bengal. NH-6 is one of the important links of Asian Highway network (AH-46).

The scope of present study is limited to road section passing through central Indian states of Maharashtra. Maharashtra, one of the most advanced states of India, has high traffic accident rate. Most of these accidents occur on the National highways.

4. DATA COLLECTION AND ANALYSIS
Accident data was collected from the police stations and insurance companies. Road geometry and traffic data was collected through field studies and traffic count survey for a road length of 100km between Amravati City and Nagpur City of Maharashtra State in India. For the purpose of collecting road geometry data, the road was divided into segments of similar characteristics 0.7 to 1.6 km for straight portion. Data were collected from 111 segments in a road length of 100 km. The data related to involvement of high speed cars were segregated and used for analysis and modeling.

The preliminary analysis of the data is given in fig.1 and fig 2. Fig.1 shows a positive relation between dependent variable (Total accidents per year per km, TACCR) and access density (AD), which suggest that more number of access points to main highways give rise to more accidents. Fig.2 which gives relation of standard deviation of speed (STDSP) with the dependent variable suggests that accident rate is also a function of standard deviation of speed. Relationships of other variables with the dependent variable were also studied.





5. VARIABLES USED IN MODELING

Lane Width: Traffic flow tends to be restricted when lane width reduces. This is because vehicles have to travel closer together in lateral direction. Lane width available hence is treated as an important parameter. It has been found that accident rates reduce as lane width increases.

Shoulder Width Deficiency: Shoulder provides an area along the highway for vehicle to stop, particularly during emergency. A report by Zegeer et al.[4] indicated that a paved shoulder widening of 2 feet per side reduces accidents by 16%. Shoulder width deficiency from a standard minimum (5m in this study inclusive of both sides) has been a variable with significant influence on safe operations of traffic and hence selected as a variable.

Access Density: The availability of access point is necessary to commercial or residential developments, usually at the expense of traffic operations and the safety of local highway systems. To achieve a good coordination of these two aspects, compromises are often required to be made between accessibility and mobility or capacity and safety. On the study area access density ranging from 0 to as much as 11 per km was observed on the said highway.

Heavy Vehicle Percentage: There are two main traffic related issues associated with commercial vehicles, the first one is ‘delays’ that they may cause to other vehicles and second one is ‘safety’ related impacts. It has been suggested by a number of authors that the presence of a truck in front of any other vehicle may result in the driver being more cautious due to the large size of the vehicle and the diminished sight distances.

Speed Variations: Spot speed is one of the major parameter that is used as an indicator of traffic performance. The data collected shows a wide variation in the spot speed from 25kmph to 60kmph. The data collected showed positive impacts of speed variations on traffic safety. The speed variations of the vehicles are incorporated in terms of standard deviation of speed.

6. TECHNIQUES USED FOR QUANTIFYING VARIABLES

Techniques used for quantifying the effects of variables are, stochastic models and neural networks.

Stochastic Models: Stochastic modeling technique was used by many researchers in the past and it has been shown that the fitness of model may be a function of the data type.

This paper presents models build using Negative Binomial and Zero Inflated Negative binomial Regression.

The model form for the negative binomial regression used in this study is given below:

$$y_i = 0,1,2 \ldots \ldots \textit{with probability}$$

$$\frac{\Gamma\left(\frac{1}{\alpha}+y_i\right)}{\Gamma\left(\frac{1}{\alpha}\right)\ \Gamma(y_i+1)}\left(\frac{1}{1+\alpha*\lambda_i}\right)^{\frac{1}{\alpha}}\left(\frac{\alpha*\lambda_i}{1+\alpha*\lambda_i}\right)^{y_i}$$

$$\lambda_i = e^{\beta_i x_i}\ \textit{where}\ x_i\ \textit{is}\ i^{th}\ \textit{covariate and}$$

$$\beta_i\ \textit{is the regression coefficient}$$

The model form for zero inflated binomial regression model used in this study is given below:

6.1 Base Model

$$y_i = 0\ \textit{with probability}\ \ p_0 + (1-p_0)\left(\frac{1}{1+\alpha*\lambda_i}\right)^{\frac{1}{\alpha}}$$

$$y_i = 1,2 \ldots \ldots \textit{with probability}$$

$$(1-p_0)\frac{\Gamma\left(\frac{1}{\alpha}+y_i\right)}{\Gamma\left(\frac{1}{\alpha}\right)\ \Gamma(y_i+1)}\left(\frac{1}{1+\alpha*\lambda_i}\right)^{\frac{1}{\alpha}}\left(\frac{\alpha*\lambda_i}{1+\alpha*\lambda_i}\right)^{y_i}$$

6.2 Inflate Model

$$p_0 = \frac{e^{r'w_i}}{1+e^{r'w_i}}$$

r’ is the coefficient matrix and wi is the ith covariate, Γ is a Gamma function; and α is the rate of over dispersion.

7. MODEL SELECTION CRITERIA

Maximum likelihood estimation method has been employed widely in estimating Poisson, negative binomial [7] and zero inflated regression models. Akaike Information Criterion (AIC) [12] and Bayesian Information Criteria (BIC) were used to judge the performance of the model. Smaller the AIC and BIC values, the better is the model.

AIC= -2Log L +2K …..

BIC =-2LogL+k Log (n)…..

Where Log L is the log likelihood; K is the number of estimated parameters and n is the number of observations.

8. RESULTS

The regression analysis was done using SPSS.

The best performing model selected on the basis of AIC criteria is frequency is as given below:

$$\lambda = e^{-3.108+0.075*STDSP+0.030*HVPER+1.129*SWDEF+0.268*AD}$$

The negative binomial model for prediction of accident

The zero inflated negative binomial regression model for prediction of accident frequency is as given below:

$$y_i = 0 \; with \; probability \;\; \varepsilon * (p_0 + (1-p_0)(\frac{1}{1+\alpha*\lambda_i})^{\frac{1}{\alpha}})$$

$$y_i = 1,2 \dots \dots with \; probability$$

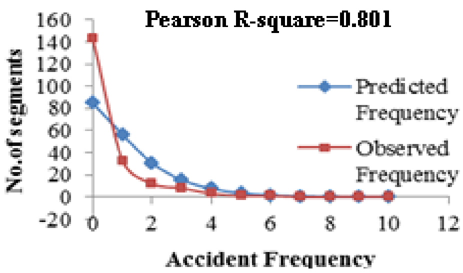
$$\varepsilon * (1-p_0)\frac{\Gamma\left(\frac{1}{\alpha}+y_i\right)}{\Gamma\left(\frac{1}{\alpha}\right)\Gamma(y_i+1)}(\frac{1}{1+\alpha*\lambda_i})^{\frac{1}{\alpha}}(\frac{\alpha*\lambda_i}{1+\alpha*\lambda_i})^{y_i}$$

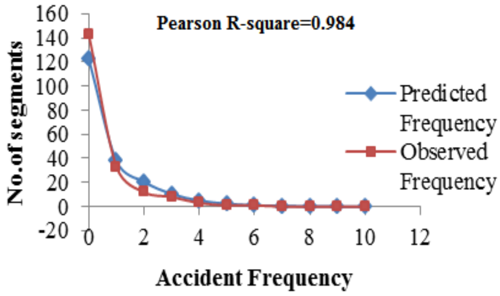
Where p_0 is probability of extra zero given by logit model

$$p_0 = \frac{e^{0.592*AD-0.389*HVPER+0.204*STDSP+2.180*SWDEF}}{1+e^{0.592*AD-0.389*HVPER+0.204*STDSP+2.180*SWDEF}}$$

Where ε is a temporal variable used to give robustness to the model. The total number of segment is used as temporal variable in this study.

The relationships of predicted and observed frequencies are presented in fig.3 and fig.4.





$$\chi^2_{calculated} = 60.12 \; and$$

$$\chi^2_{tabulated} = 16.909 \; at \; 0.05 \; significance \; level$$

Chi-Square test

Negative Binomial Regression

$$\chi^2_{calculated} = 60.12 \; and$$

$$\chi^2_{tabulated} = 16.909 \; at \; 0.05 \; significance \; level$$

Zero Inflated Negative Binomial Regression

$$\chi^2_{calculated} = 9.71 \; and$$

$$\chi^2_{tabulated} = 16.909 \; at \; 0.05 \; significance \; level$$

acceptable.

9. CONCLUSIONS

In this study Zero Inflated Negative Binomial Regression was found to be appropriate choice to predict the accident frequency.

The models that have been developed can be used in the field to predict the probability of certain number of accidents under different geometric and traffic conditions.

Variables like, 'shoulder width deficiency', 'access density, and 'standard deviation of speed' used in this study were found to have significant impact on traffic safety.

10. SUGGESTION TO IMPROVE SAFETY

Based on the results of this study following suggestions are made:

Shoulder width Deficiency should be eliminated from both sides of the highway.

Shoulder should be maintained in usable condition.

Encroached shoulder should be made free from encroachment.

Speed limit enforcement is not required only for maximum speed but also for the minimum speed. This will keep the value of standard deviation of speed to a minimum.

At the planning stage only, lanes separated from motor-way should be provided for motorcycles, slow moving and non-motorized traffic. This will segregate vehicle with similar dynamic and static characteristics and more uniform flow will follow.

The access points to main highways should be very less in numbers. This can be achieved by providing an auxiliary lane, the extra lane constructed besides the highway, to allow road users a safe way to merge into traffic from a specified location. This will reduce bottlenecks caused by road users at many points while attempting to enter or exit the freeway.

11. REFERENCES

[1] A.K.Sharma, V.S. Landge"Zero Inflated Negative Binomial for Modeling Heavy Vehicle Crash Rate On Indian Rural Highway" International Journal of Advances in Engineering & Technology, Jan. 2013, pp 292-301

[2] Garber, N. & Joshua, S., "Traffic and geometric characteristics affecting the involvement of large trucks in accidents." VDOT Project No.: 9242-062-940, Virginia Transportation Research Council, University Station, Charlottesville, Virginia 1990.

[3] Greibe, P., "Accident prediction model for urban roads", Accident Analysis and Prevention, Vol. 35, issue 2, 2003, pp 273-285.

[4] Landge,V.S.,Jain S.S. & Parida, .(2006),"Modeling traffic accidents on two lane rural highways under mixed traffic conditions", 87th Annual Meeting of Transportation Research Board,(CD- Rom).

[5] Miaou, S., Lum, H., 1993. "Statistical evaluation of the effects of highway geometric design on truck accident involvements", Transportation Research Record 1407, 11-23.

[6] Okamoto (1989), "A Method to cope up with random errors of observed accident rates" Safety literature, Vol.4, page 317-332.

[7] Parida ,M, Jain S.S., NaveenKumar , C., "Road traffic crash prediction on National Highways", Indian Highways volume 40 No 6 June 12 pp 93-103.

[8] Road Accident in India(2011)

[9] SharmaA.K., Landge .S.(2012),"Pedestrian Accident Prediction Model For Rural Road", International Journal of Science and Advanced Technology Volume 2, No 8 .

[10] Vashi B.D. & Damodariya S.M. " A model study of road accidents: A case Study of road accidents of Vadodara city in Gujarat state using simulation and ANN technique" , Journal of the IRC, 64(3), Dec. 2003.

[11] Zegeer, C V., Deen, R. C. & Mayes, J. G. "Effect of lane and shoulder widths on accident reduction on rural two-lane roads". TRR 806 1981.pp 33-43

12. AUTHOR'S PROFILE

First Author: A.K.Sharma ,born on 28-12-64 ,graduated in civil Engineering from NIT Raipur(Chattisgarh,India) in 1987. He completed his post-graduate in Highway and Traffic Engineering from IIT Kharagpur (India) in 1989. Presently working at Shri Ramdeobaba College of Engineering and Management, Nagpur , as Associate professor in Civil Engineering Department. His main field of work has been pavement and traffic engineering.

Second Author: V.S.Landge, born on 02-10-68, graduated from RKNEC, Nagpur (India) in 1991. He completed his post graduate studies in Transportation Engineering from BITS Pillani (Rajasthan, India) in 1993. He completed his Doctoral degree form IIT Roorkee (India) in 2006. Presently working at VNIT, Nagpur as Associate professor in Civil Engineering Department.

Third Author: T. K. Rao born on 12th November, 1960, graduated from JNTU Hyderabad in 1983. He completed his post graduate studies in Transportation Engineering from REC, Trichy (presently NIT Trichy) in 1984. He is working as Associated Professor in Civil Engg. Deptt., Shri Ramdeobaba College of Engineering and Management, Nagpur, India.