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Research Article

TRANSVERSE OSCILLATION OF VEHICLES AND ITS RISK ASSESSMENT ON RURAL HIGHWAYS WITH HETEROGENEOUS TRAFFIC

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ABSTRACT

Population from developing country are exposed to high risk of injuries and death from road crashes owing to heterogeneous traffic conditions. The aim of this research includes identifying the factors responsible for the accidents. Data includes six years road accident data, highway geometric characteristics and traffic information like classified traffic volume and speed from a two lane undivided road of India in Maharashtra State near Nagpur City. Stochastic modelling techniques were used so that discrete events that are sporadic in nature can be captured. Some of the variables including lateral sway of vehicles have been identified as important factors contributing to road accident data. Knowing that the lateral sway are very common in everyday traffic, the findings from this study may help prioritize the countermeasures.

INTRODUCTION

The Rural Highways of developing countries accommodate heterogeneous traffic that consists of high speed cars, heavy vehicles, two wheelers and non-motorized vehicles with large speed variation. Populations from developing countries are exposed to high risks of injuries and death from road crashes owing this mixed traffic conditions. Poor conditions of carriageway and shoulders, absence of traffic enforcement measures for parked vehicles on roads, non-motorized vehicles and pedestrians on carriageway are some of the problems faced by road networks in India. The risk of injuries due to high number of road crashes prompted new independent variable like lateral sway of vehicles.

Indian road traffic accident scenario is found to have an increasing trend with varying degree of severity mainly influenced by road network characteristics, road user's behavior and environmental factors, in last three decades. The road accident analysis made in different countries especially in developed countries show work done using recent mathematical techniques. The application of which seems to have delivered results.

Developed countries have successfully experimented with many variables in models. Variable like flow, volume (ADT, AADT), speed oscillation, lane width, shoulder width, socio economic variables like population GDP, education level, illiteracy rate, weather condition and unemployment rate have been used. Ample work is done on both rural and urban arterial roads in developed countries. However not much of work is done to model heterogeneous traffic on rural highways in India.

Research Work Done

Zegeer *et.al.*[1] studied effects of cross-section improvements for rural two lane roads. A data base with 1944 road stretches in seven US states (totalling 7968 km) was used. The study concluded that accident injury rate decreases with increase in, pavement width and paved or unpaved shoulder width. Garber *et al.* [2] related the standard error of the speed distribution and accident occurrence on 36 road segments during 1983 to 1986. The study also concluded that accident rates increase with the speed variance, in all types of road it also concluded that the speed variance, difference between design speed and the legal speed limits are related.

Miaou *et al.*[3], studied the truck accidents on the interstate roads in USA using the accident data of three years (1985 to 1987), to develop model using AADT, AADT of heavy vehicles, lane width, paved shoulder width, degree of horizontal curvature and longitudinal slope as explanatory variables. The study concluded that the accident rate increases

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with increase in deviation from standard shoulder width and decrease in radius of curvature at curves.

Milton *et.al* [4] studied highway injury data for Washington State using mixed (random parameters) logit model. The study concluded that variable like the average daily traffic per lane, average daily truck traffic, truck percentage, interchanges per mile and weather effects such as snowfall are best modelled as random-parameters-while roadway characteristics such as the number of horizontal curves, number of grade breaks per mile and pavement friction is best modelled as fixed parameters.

Zuduo *et.al*. [5] studied the impact of freeway traffic oscillations (deceleration followed by acceleration) on traffic safety in USA. The authors concluded that the standard deviation of speed (thus, oscillations) is a significant variable, with an average odds ratio of about 1.08. This implies that the likelihood of a (rear-end) crash increases by about 8% with an additional unit increase in the standard deviation of speed.

David W. Soole *et.al*.[6]studied the impact of average speed enforcement , which is a relatively new approach gaining popularity throughout Europe and Australia, on road traffic accidents . Authors found evidence to suggest a number of road safety benefits associated with average speed enforcement, including high rates of compliance with speed limits, reductions in average and 85th percentile speeds and reduced speed variability between vehicles. . Reductions in crash rates have also been reported in association with average speed enforcement, particularly in relation to fatal and serious injury crashes.

Chao Wang *et.al*.[7] studied the Impact of traffic congestion on road accidents and concluded that traffic congestion has a mixed effect on road safety: increased traffic congestion has a negative impact on road safety in terms of increased accident frequency; it however has a positive impact on road safety in terms of decreased accident severity.

Kalakota *et.al*.[8] studied the influence of geometric variables on accidents rates on two lane rural highway and suggested safe values for the variables keeping in mind the practical speeds and conditions of two-lane rural roads.

Zegeer *et.al*. [9] studied the effect of lane and shoulder width on accident reduction on two lane rural roads and suggested that the increased lane and shoulder width are advantageous in terms of accident reduction up to a particular limit only.

Sharma *et.al*.[10] studied the influence of deficient shoulder width on crash frequency on rural highways and concluded that deficient shoulders along with speed variations and percentage of heavy vehicles in traffic stream have significant impact on crash occurrence.

METHODOLOGY

This study aims to develop models to quantify the impact of road geometry and traffic variables on crash rate. The study methodology consists of collecting past accident data, highway geometric data and traffic data and statistically analyzing it.
The road chosen for this study was National Highway no.6 in India near Nagpur City, which was a two lane undivided road in Central India during study period of 2012-2015.

Data Collection & Analysis

The data in this study comprise six years of accident data, collected from 160 km of road length on National Highway no.6.from police stations and insurance companies. Road geometry and traffic data was collected through field studies and traffic count survey. For the purpose of collecting road geometry data, the road was divided into segments of similar characteristics. Data were collected from 201 segments. Video camera was installed to measure transverse oscillation of vehicles, and image processing technique was used to measure the magnitude of oscillation of vehicles.

Preliminary analysis of the data showed positive relations of many of the selected independent variable with dependent variable. The analysis suggested that the, crash rate is a function of lateral sway sway), speed variation (sv),access density (ad), volume of heavy vehicles (hvp), and deficiency in shoulder width(sdef) and percentage of non-motorized vehicle (nmv**).** Figures 1 to 6 illustrates relationship of independent variables with crash rates. Fig.1 suggests the variation of accident rates with lateral sway of the vehicles. By observing this graphical representation we can come to a decision that there can be a positive relationship between the two. Similarly the variation of crash rate with other variables are shown from fig.2 to fig.6.

Variables

The total numbers of crashes per year per km (c-rate) was selected as dependent variable, and after the preliminary analysis of the data following highly influential parameters were selected as independent variable.

Transverse Oscillation (tosc): Diverting from the line of movement in lateral direction, during driving is termed as transverse oscillation. Transverse oscillation of 0.4m to 1.55m was observed in different sections of the said highway. This variable is selected for modelling with the name 'tosc'.

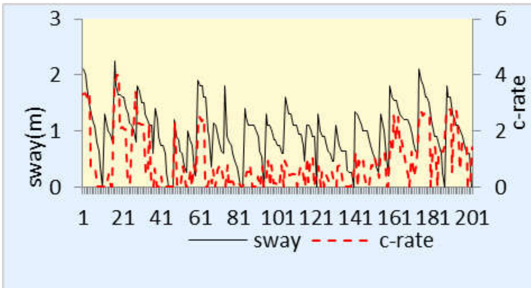

Figure 1 Relationship of crash-rate with lateral sway

Speed variation (sv): Speed is one of the major parameter that is used as an indicator of traffic performance.

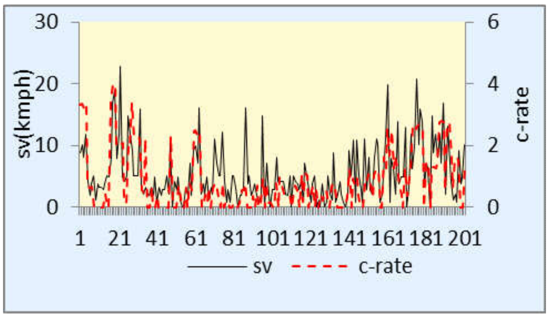

Figure 2 Relationship of crash-rate with speed variation

The variation in the speed of vehicles in a traffic stream is one the factors that can affect road safety. The data collected showed a wide variation in the spot speed from 25kmph to 60kmph. The variation in speed with respect to modal average is taken as speed variation 'sv' in this study.

Access Density (ad): 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. The access density on the study area was recorded and the variation between 0 to 11 access points per km was observed. The variable is included with the name 'ad'.

Deficiency in shoulder width (sdef): Shoulder provides an area along the highway for vehicle to stop during emergency. It is also considered as recovery area for drivers' error. A report by Zegeer *et al*. (1987) 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) can be a factor with significant influence on safe operations of traffic and hence selected as a variable. The variable is included with the name 'sdef'.

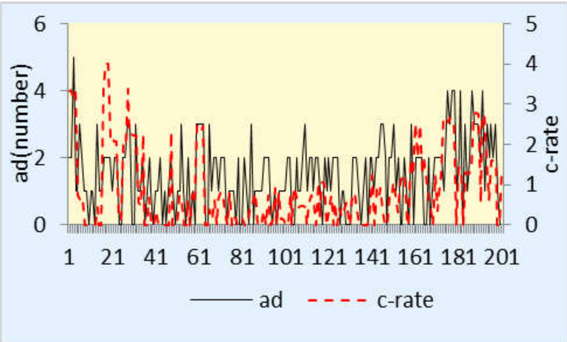

Figure 3 Relationship of crash-rate with access density

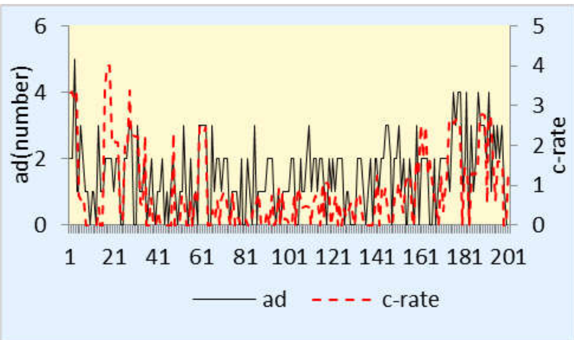

Figure 4 Relationship of crash-rate with shoulder width deficiency

Volume of heavy vehicles: (hvp): There are two main traffic related issues associated with commercial vehicles, namely: delays that they may cause to other vehicles and the 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. The percentage of heavy vehicle is included in the model with the name 'hvp'.

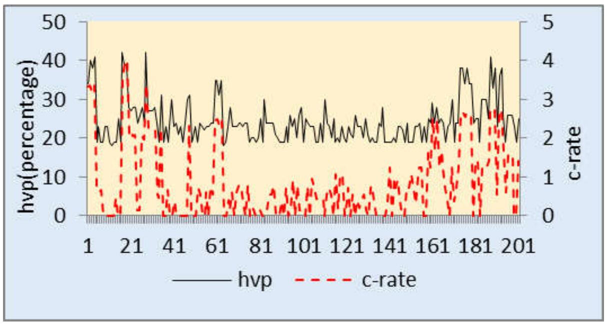

Figure 5 Relationship of crash-rate with percentage of heavy vehicles

Percentage of Non-Motorised Vehicles (nmv): Non-motorized vehicles (NMV) and walking is one of the most exercised modes of transport especially in the developing countries. In a country like India, pedestrians and NMV share same highway which is engineered to carry light motor vehicles and heavy vehicles. The non-motorized vehicles include pedal bicycles, pedal rickshaws (used as a cab for people and for hauling goods) and the animal drawn carts.. High percentages of NMV on the highways pose a threat to the safety of other road users as well as for NMV users themselves. The highway considered for this study has a large population of NMV users. The variable is included with the name 'nmv'.

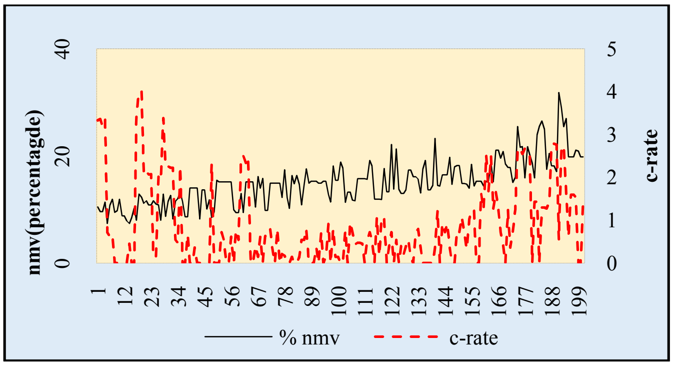

Figure 5 Relationship of crash-rate with percentage of non-motorized vehicles

Quantification of Variables

Stochastic modelling techniques are used for quantifying the effects of variables on crash rate in this study.

Stochastic Models

This paper presents models built using and Poisson regression (PR) and Zero Inflated Poisson Regression (ZIPR)
Modelling form used in this study is

Predicted Frequency = ε *p(y), where ε is exposure term, and p(y) is probability of y no. of accidents.

Mean value of accident rate (λ) is given by

$$\ln(\lambda) = b_0 + b_1 x_{i1} + b_2 x_{i2} + ----b_j x_{ij} \quad \text{------------- (1)}$$

Where b_1, b_2 etc. are the coefficients of independent variables.

$$\lambda = e^{b_0 + b_i x_{i1} + b_2 x_{i2} + ----b_j x_{ij}} \quad \text{-------- (2)}$$

Poisson Regression

The Poisson regression is a suitable model to describe accidents data since they are random, discrete events that are sporadic in nature and non-negative.

$P(y_i) = \frac{\lambda^{y_i} e^{-\lambda}}{y_i!}$ --------------- (3)

Zero-Inflated Poisson Regression

Zero Inflated regression models are two regime models. First probability model governs whether a count number is zero or positive number, called as inflate model. Then the positive part of the distribution is described by suitable stochastic distribution, called as base model.

Inflate Model

$y_i = 0 \ with\ probability,\ p_0 + (1 - p_0)e^{-\lambda}$ -------------- (4)

$y_i = 1,2, \ldots .. with\ probability, (1 - p_0)\frac{\lambda^{y_i} e^{-\lambda}}{y_i!}$ --------- (5)

Model Selection Criteria

Bayesian Information Criteria (BIC) were used to judge the performance of the model. Smaller BIC values suggest that likelihood of getting the desired output is more and model performance will be better.

BIC= -2 In (L) + k ln(n) ----------------(6)

Where ln(L) is the log likelihood;

k is the number of estimated parameters and n is the number of observations.

Crash Models

The analysis of data was done using SPSS software. Twelve models were developed using different combination of variables using 1143 accident data collected from different sections. Data illustrates that 141 segments out of 201 were having zero accidents. Based on statistical significance five best models were selected.

A typical equation for one of PR models is

$$\lambda = e^{-3.740+0.001*nmv+0.026*hvp+0.025*sv+0.703*sdef+0.299*tosc}$$

--------(7)

A typical equation for one of ZIPR models is

$$p_0 = \frac{e^{-0.351*hvp+0.271*sv+2.033*sdef+1.316*tosc}}{1 + e^{-0.351*hvp+0.271*sv+2.033*sdef+1.316*tosc}}$$ -------(8)

λ remains same as in PR regression

The models demonstrated strong relationship between crash rate and transverse oscillation of vehicles along with shoulder width deficiency.
A typical graphical representations of a PR and ZIPR models are shown in fig.7 and fig.8.

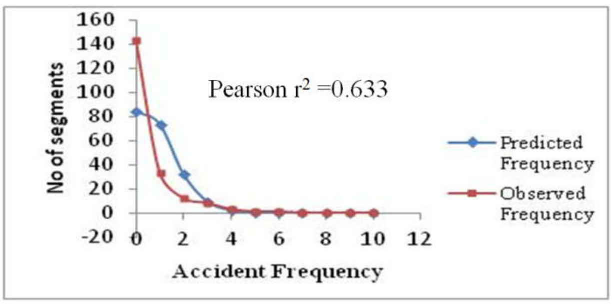

Fig 7 Predicted and Observed for frequencies for a Poisson Model

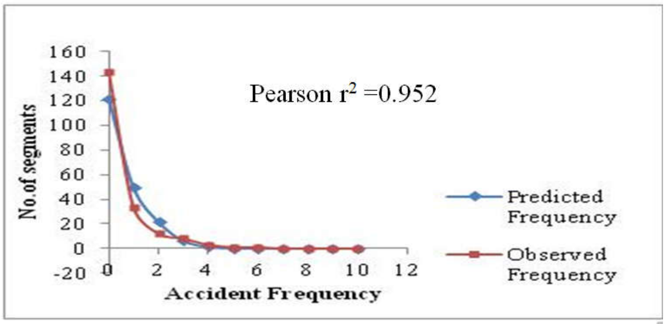

Fig 8 Predicted and Observed for frequencies for a Zero Inflated Poisson Model

Fig.9 and 10 shows the comparison of predicted frequencies and observed frequencies for various models developed using PR and ZIPR.

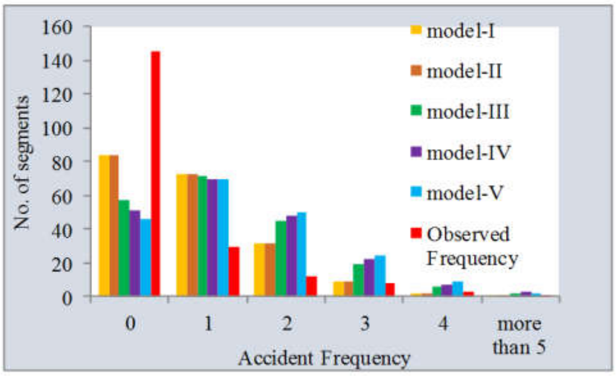

Figure 9 Comparison of Predicted frequencies with Observed frequencies for PR models

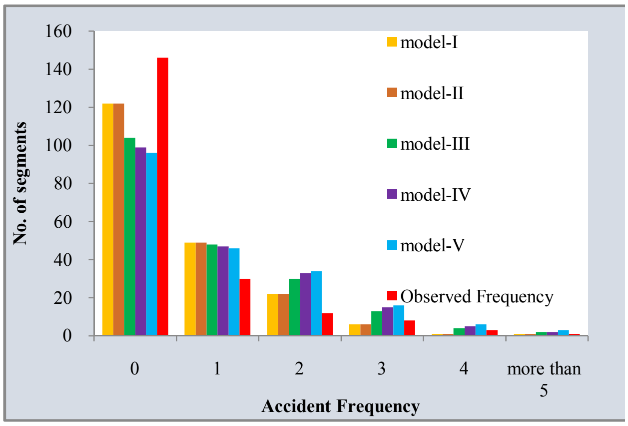

Figure 10 Comparison of Predicted frequencies with Observed frequencies for ZIPR models

From among the various models developed using different combination of dependent variables Model No.2 shown in equation no.7 and 8, was selected as final model for prediction of accident rate. This model was developed using Zero Inflated Poisson Regression analysis. This model qualified the Pearson chi-square test also at 95% confidence level.

CONCLUSION

This study examined the impact of lateral sway on crash occurrence on a two lane undivided rural highway in India. The research employed a study on 160 km stretch of rural highway, which was divided in 201 segments on the basis of similarity of road geometry and other environmental conditions.

Table 1 Pearson R-square and Pearson Chi -square values for different models

Models	First Model		Second Model		Third Model		Fourth Model		Fifth Model	
	R-square	Chi-square	R-square	Chi-square	R-square	Chi-square	R-square	Chi-square	R-square	Chi-square
Poisson	0.633	84.20	0.633	84.20	0.310	196.03	0.230	239.34	0.158	284.29
Zero Inflated Poisson	0.956	21.30	0.952	11.34	0.913	37.43	0.892	46.79	0.883	53.22

Crash data for the study was collected from data base of police stations and insurance agencies. Video camera was installed to measure lateral sway of vehicles.

Models were developed using on Poisson and Zero Inflated Poisson regressions. The results suggest that lateral sway of vehicles and shoulder width deficiencies have very significant impact on crash occurrence. Knowing that the lateral sways are very common in everyday traffic, the findings from this study may help prioritize the countermeasures.

Suggestions to improve safety

Suggestion to improve safety was one of the prime objectives of this study. Accordingly following suggestions are made to improve safety based on the study results.

Pavement Related Issues

1. Shoulder width Deficiency should be eliminated from both sides of the highway.
2. Shoulder should be maintained in usable condition.
3. Encroached shoulder should be made free from encroachment.
4. Surface defects like potholes, ruts, excessive roughness, lack of skid resistance etc. should be corrected immediately to avoid lateral oscillation of vehicles.

Enforcement Issues

1. Strict Enforcement measures for illegal parking on carriage way and shoulders, vehicles moving in wrong direction, stoppages of vehicles on carriageway and shoulders, and roadside petty shops. This will minimize lateral movement of vehicle and also the drivers will be comfortable maintain a particular speed.
2. Speed limit enforcement is not required only for maximum speed but also for minimum speed, so that the variation in speed is minimum.

Planning and Design Issues

1. Vulnerable road users should be separated from motorways at planning stage only. This will protect them against heavy and fast moving vehicles.
2. Provision of lay bays should be there at suitable intervals to avoid illegal stoppage of vehicles.
3. Carriageway should be properly protected from ingress of animals or any other unwanted elements through proper fencing.

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