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Development of comprehensive crash models for four-lane divided highways in heterogeneous traffic condition

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Abstract

Traffic safety is of prime concern worldwide. Highway geometry should be designed for vehicle safety and efficiency. Several researches have been carried out to identify the factors contributing to road crashes and for finding measures to reduce the crash rate. One of the critical gaps in the management of highway safety is the lack of a reliable method for estimating the safety of an existing roadway with, widely varying road geometrics and vehicle mix. The focus of this work is mainly to quantify the relationship between geometric design characteristics and level of safety of intercity highways under heterogeneous traffic conditions. Study was carried out in a four-lane divided rural highway in Tamil Nadu, India and a relationship was established using statistical modeling technique. Crash Prediction Models (CPM) were developed by Poisson regression, Poisson-gamma and negative binomial modeling approach for three categories, namely, current (i^{th}) segment, with preceding (i-1^{th})segment and with succeeding and preceding (i+1&-1^{th}) segments. Results showed the significance of identified variables and the effect of preceding and succeeding segments on the current segment in the case of CPM. Attempts were also made to develop operating speed models for curve and tangent elements. From the developed models, the effect of contiguous element on the operating speed could be understood.

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1. Introduction

Road crashes are complex events and are influenced by many factors such as road geometric design, traffic volume and composition, speed, weather, motivation for travelling, driver's physical and mental conditions

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(*American Association of State Highway Transport Officials, 2004*). For identifying the accident prone location or black spot along a roadway for the purpose of detailed engineering studies and to prioritize the road networks for implementation of safety measures, consistency of the design needs to be examined. Highway geometry should be designed for traffic safety and efficiency. As concerns traffic on Indian roads, it is highly heterogeneous in character and is composed of slow and fast-moving vehicles. As per World Health Organization (WHO) report 2013, India loses more than 100,000 lives due to road traffic crashes every year with a fatality rate of 18.9 deaths per 1,00,000 populations. Approximately half of all deaths on the country's roads are among vulnerable road users - motorcyclists, pedestrians and cyclists (*Global Status Report on Road Safety – Time for Action, 2009*). Recent statistics show that, there were 4,86,476 reported accidents during 2013, out of which 1,37,572 people were killed and 4,94,893 people were injured (*Ministry of Road Transport and Highways, Govt. of India, 2014*). The accident severity viz., persons killed per 100 vehicles is 28.2. According to MoRTH 2012, Tamil Nadu stands at second position with a share of 11.7% in total number killed in road crashes in the year 2012. Road crash statistics in 2013 shows that, 66,238 road accidents were occurred, which resulted in 15,563 fatalities (*Transport department, Government of Tamil Nadu, 2014*).

Several studies were conducted to evaluate the influence of speed on the safety of roadways. According to AASHTO - Geometric Design of Highways and streets, "the safest speed for any highway depends on design features, road conditions, traffic volumes, weather conditions, roadside development, spacing of intersecting roads, cross-traffic volumes, and other factors". Most of the studies considered the operating speed as the 85^{th} percentile speed of those vehicles travelling on the roadway and found speed-related crashes are more likely to occur at mid-block than an intersection (*Solomon, 1964; Lamm et al., 1990; Liu and Chen, 2006; Lu, 2006*). Models were also developed for studying the dependence of crash rates on speed and geometric characteristics, which showed that they are not linearly related (*Garber and Ehrhart, 2000*). Vehicle speed could be related to traffic safety in two ways: (1) greater a vehicle's velocity, the lesser will be the time available for the driver to react to a hazard under the presence of other motorists, bicyclists, or pedestrians. If this relationship exists, it would be expressed in relative incidence of crashes at different speeds and (2) due to the physical relationship of mass and speed to energy, it would be possible to express the relative severity of crashes at different speeds (*Federal Highway Administration, 2000*). Most of the reported studies were carried out on undivided rural highways and only a few on divided highways. Research related to geometric characteristics showed that variables like, radius of the curve and super elevation have a significant effect on the safety of roadways. Radius of curves was identified as one of the significant variables while defining the effect of horizontal and vertical curves on road crashes and also while estimating the speeds on rural highways. Crash rate was found to increase significantly when radii are below 200 m. Super elevation, degree of curve, shoulder width and average daily traffic also contributes to road crashes (*FHWA, 2000; Aram, 2010*). Researchers also concluded that roads with heavier traffic volume, more road lanes and higher speed limits tend to have more severe crashes (*Ma, 2010*). Studies related to divided roadway showed that the presence of raised medians reduces crash rates up to 15 % and also reduces the severity of crashes when modelled accidents using Poisson and negative binomial regression (*Frawley et al., 2005; Sawalha and Sayed, 2003*).

As far as Indian scenario is concerned, data collection and their availability are major issues, as systematic data collection and road crash database are not in place. Few studies were carried out which focused on the development of Accident Prediction Models (APM) for a particular type of road, mainly undivided rural roads. Regression models were found appropriate for evaluating road crashes (*Bhagat, 2008; Robert, 2006; Ramesh and Kumar, 2011; Dinu, 2012*). Studies were carried out to develop APMs with the stepwise introduction of identifying predictor variables based on their magnitude of the coefficient of determination. This resulted in developing multiple linear regression, Poisson, Negative Binomial, exponential and logistic regression models for evaluating total accidents, injuries, fatalities and property damage, casualties and accident rate (*Robert, 2006*). APMs were developed using a Poisson model with random coefficients to predict single vehicle and multi-vehicle crashes for evaluating the safety performance of two-lane undivided rural roads (*Dinu, 2012*). From the literature, it was found that most of the research works are based on the homogeneity and lane disciplined traffic conditions. Hence, the results of the studies may not be directly applicable to the heterogeneous traffic such as the one prevailing in developing countries like India. As discussed earlier, the traffic conditions in India are highly heterogeneous in nature, where the traffic comprises vehicles with diverse static and dynamic characteristics and all such vehicles use the same right-of-way without any physical segregation. Thus, the vehicles of the said heterogeneous traffic, under high-volume conditions, move on Indian roads by sharing the available road space without sufficient lateral as well as longitudinal clearances. The lane-less movement further adds to the complexity of analyzing/modeling mixed traffic.

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