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Modeling of Road Accidents Impact of Traffic Parameters

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ABSTRACT:

This paper presents a method for the identification of hazardous situations on the freeways. For this study, about 18 km long section of Eastern Freeway in Melbourne, Australia was selected as a test bed. Three categories of data i.e. traffic, weather and accident record data were used for the analysis and modelling. In developing the crash risk probability model, classification tree based model was developed in this study. In formulating the models, it was found that weather conditions did not have significant impact on accident occurrence so the classification tree was built using two traffic indices; traffic flow and vehicle speed only. The formulated classification tree is able to identify the possible hazard and non-hazard situations on freeway. The outcome of the study will aid the hazard mitigation strategies.

Keywords: road hazard; traffic parameter; classification tree; crash risk model; accident; decision tree

INTRODUCTION:

Road crashes have been in on an increasing trend in the last decade or so. This has led the researchers to think of this problem and find possible causes and precautionary measures to prevent crashes from happening. This field of transportation engineering is more commonly recognized as traffic safety and management. These researches have led to development and discovery of new models predicting road crashes accurately. This paper combines many important models and discusses the theory involving the discovery to that model. It also compares and contradicts the models developed by different researchers. Road accidents are very common all over the world and annual global road crash statistics (Association for Safe International Road Travel, 2013) states that, nearly 1.3 million people die in road crashes each year, on average 3,287 deaths a day with an additional 20-50 million are injured or disabled. More than half of all road traffic deaths occur among young adult ages between 15 to 44 years. Road traffic crashes rank as the 9th leading cause of death and account for 2.2% of all deaths globally. Road crashes are the leading cause of death among young people ages between 15 to 29, and the second leading cause of death worldwide among young people ages between 5 to 14 years. Unless action is taken, road traffic injuries are predicted to become the fifth leading cause of death by 2030. When India is concerned, it is a part of human tragedy. Along with monetary losses it also leads to human sufferings, untimely death, injuries and loss of potential income. During the calendar year 2010, number of road accidents in India is around 5 lakhs and number of deaths due to those accidents is 1.3 lakhs. Number of injuries due to those accidents is 5.2 lakhs. If the age group and the accident data are compared, it is seen that 55% of road accident victims fall in the age group of 25-65 years while out of rest 45%, 40% of road accident victims come from the age group of 16-24 years. It can be concluded that the adolescents are very much prone to and contribute to most of the accidents in India. Traffic performance indicators such as traffic flow and speed which can act as a proxy for the traffic condition may indicate hazardous situations leading to accidents. Weather conditions may also lead to situations which might hamper usual traffic movements and roadway safety. Adverse weather conditions not only reduce drivers' visibility but also make the roads dangerous because of reduced friction between tyres and road surfaces (Goodwin, 2002). Road accident also induces traffic congestion. Due to accident, some or all the lanes of the roadway are blocked and vehicles are stuck in congestion for long durations. This congestion results in increased travel time, vehicle emissions and fuel usage etc. (Golob et al., 2004) This study investigates the relationship among traffic parameters, weather and road hazards. Traffic flow and speed are the two important indices used to quantify the traffic performance while number of accident is used as a performance index for roadway safety. In the study, rainfall intensity is considered as the proxy of adverse weather condition. Statistical analysis method, regression tree, is used to evaluate how traffic parameters and rainfall influence road hazard occurrence.

2. Literature Review

Factors responsible for crashes Traffic safety and accident studies have been in the research area for last two decades extensively as the rise of accidents have been alarming across the world. From the works done by researchers, it can be said that traffic accidents are caused due to mainly 3 factors i.e. • Personal or human behavioural factors • Road and Environmental factors • Vehicle factors Personal or human factors mainly include the age of driver or victim, gender of the victim, was he drunk while driving, etc. Similarly, environmental factors include the general factors of climate and environment, lighting conditions of road, time of accident, i.e. day or night, pavement conditions, etc. Road geometric factors include the type of junction or intersection, then horizontal slope, curves, etc. present on the road, due to faults of which, accidents may occur. At the end come traffic factors. This mainly includes the speed, density, traffic flow parameters that may lead to accidents. 2. Models for traffic safety Many models have been devised by the researchers in past for accident safety, causes of accidents safety, accident severity crashes, etc. and also precautionary measures have been stated. Though the most common models used are the regression models, but there are many other techniques that have been used in the modeling by the researchers. Some of them are: • Genetic mining approach • Logit models, both multinomial and binomial • Regression models which includes various types like linear, non-linear, logistic regression techniques • Bayesian-cohort model, etc. This paper has divided the traffic safety models mainly into two parts under which they will be studied. They are: • Accident study in urban roads • Accident study in rural roads 2.1. Accident study in urban roads Fridstrom et al. (1995) measured the contribution of Randomness, Exposure, Weather and Daylight to the variation in Road Accident counts. Using a generalized Poisson regression model, the variation in accident counts in 4 European countries were calculated into parts attributable to randomness, exposure, weather, daylight, or changing reporting routines and speed limits. A set of specialized goodness-of-fit measures were also developed by them. Pure randomness was seen to "explain" a major part of the variation in smaller accident counts (e.g. fatal accidents per county per month), while exposure was the dominant systematic determinant. The relationship between exposure and injury accidents appears to be almost proportional, while it was less than proportional in the case of fatal accidents or death victims. Together, randomness and exposure accounted for 80% to 90% of the observable variation in their data sets. Graham and Glaister (2003) examined the role of urban scale, density and land- use mix on the incidence of road pedestrian casualties. The study used English census wards as the spatial unit of study and developed negative binomial models to carry out the analysis. The study concluded that the incidence of pedestrian casualties and Killed and Seriously Injured (KSI) were higher in residential areas than in business areas. In addition, the relationship between urban density and pedestrian casualties were found in quadratic form with incidents reduced in highly populated wards. Griebe (2003) described some of the main findings from two separate studies on accident prediction models for urban junctions and urban road links described in (Greibe and Hemdorff, 1995, 1998). They established simple, practicable accident models that can predict the expected number of accidents at urban junctions and road links as accurately as possible.

2.1. Traffic Flow and Road Accidents

A number of studies have been conducted to relate traffic flow with road crash propensity. Jean-Louis (2002) showed that damage-only and injury-involved incident rates are higher in light traffic than in heavy traffic conditions. He also compared the incident rates on the basis of time of the day and found that these rates do not depend on day time or nighttime traffic. Hasan et al. (2011) have found that road accident probability on the freeway depends significantly on the traffic flow. They developed a regression tree by using traffic flow and speed at accident location, nearest upstream and downstream and concluded that road accidents depend more on traffic parameters: traffic flow and vehicle speed rather than weather condition. On the contrary, Lord et al. (2005) showed that the crash risk cannot be predicted perfectly only by traffic flow but adding traffic density so improves the prediction performance. Furthermore, they also described the comparative difference of crashdensity relationship between urban and rural freeways. For the same flow and density, it has been found that crash rates are much higher on urban freeways than the rural ones. Dickerson et al. (1998) revealed significant differences in accident - traffic flow relationship by road class and geography. Their outcomes are based on all types of accidents regardless of severity level. Accident probability also depends on type of vehicles (Ayati and Abbasi, 2011). Non-passenger car vehicles are found to cause more accidents on urban highways than other vehicle types. Interestingly, it was shown that heavy vehicles cause less accident than non-passenger cars including taxis and motorcycles.

2.2. Vehicle Speed and Road Accidents Aarts et al. (2006) reviewed the literature on vehicle speed and road accident relationship and showed that road incidents increase significantly with an increase in speed on minor roads than on major roads. Similarly, Navon (2003) mentioned that excessive speed causes road crashes. He also described that the relationship between average speed and accident is not clear. Elvik (2004) described that mean speed is positively related with frequency and severity of accidents since the number of road accidents increases with increase of speed. In order to develop the relationship between speed and safety, Aljanahi et al. (1999) found significant positive relationship between mean speed and accident rate. Similarly, Hasan et

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al. (2011) also concluded that vehicle speed is a contributing factor to accidents' occurrence on freeway. Also, Taylor et al. (2000) discussed the results of driver based and road based previous studies, and mentioned that higher speed causes more accidents. The outcome of the study showed that approximately 1 km/h decrease in average speed can reduce accident occurrence rate by 2% - 7%. In order to relate the speed limit and fatal crash, Ossaiander and Cummings (2002) found that in Washington (USA) speed limit and fatal crash occurrence have positive relationship, the higher is the speed, more number of fatal accidents occurs. However, the relationship between speed limit and all types of accident rate is not so clear. While aiming to assess the effects of traffic congestion on the frequency of crash rate by using spatial analysis approach, Wang et al. (2009) found that traffic congestion has no impact on the frequency of accident occurrence (either for fatal crash or slight injury crash).

2.3. Accident Prediction Models Mustakim et al. (2008) proposed an accident prediction model based on the dataset of Federal Route 50 in Malaysia. In this study, they considered number of access point per kilometre of the roadway, hourly traffic volume, time gap between vehicle and 85th percentile speed. Multiple linear regression model resulted in good accuracy level. Similarly, Hong et al. (2005) also used multiple regression methods in order to develop a crash prediction model but they focused more on road geometry compared to traffic conditions in choosing the independent variables. Road geometry was also considered as predictors in accident prediction model by Kalokota and Seneviratne (1994) but the selected geometry variables are different. Hong et al. (2005) chose number of intersections, connecting roads, pedestrian traffic signals, existence of median barrier and lanes, whereas Kalokota and Seneviratne (1994) selected degree of curvature, section length, vertical grade, number of lane, right shoulder width and traffic volume as predictors. This may be due to different site locations i.e. urban and rural highways. Eisenberg (2004) has developed a crash risk prediction model based on weather variables such as precipitation and snowfall. Negative binomial regression method was used in this study and accident frequencies were predicted in terms of fatality, injury and property damage only. Similarly, Shankar et al. (1995) made accident frequency prediction model using negative binomial regression. They considered both the road geometry and weather factors to develop the model. Greibe (2003) developed prediction model based on traffic and geometric variables for urban area. Poisson regression model was used in this study. Pham et al. (2010) developed a model using random forest method by disaggregated traffic data in order to identify the rear end crash on motorway. This study is able to differentiate non-crash and pre-crash situations by using this methodology. They concluded that speed within a lane need to be regulated in order to reduce rear end crash. Rujun and Xiuqing (2010) proposed a neural network model for forecasting the road accidents based on eight years' accident data of China. The predictor variables used in this model were population, number of automobiles, road mileage and GDP per capita, and it is found that the rapid growths of these variables influence the rapid growth of accidents. In order to predict the accident risk related to environmental weather conditions, Durduran (2010) formulated decision making system (DMS) with the aid of geographical information systems (GIS). The analysis result has shown that DMS can predict accident with more significant accuracy than that of support vector machine (SVM) and artificial neural network (ANN). Gang and Zhuping (2011) developed a traffic safety model based on the combination of particle swarm optimization and support vector machine (PSO-SVM) by using the dataset of 36 years, from 1970 to 2006. The predictor variables used in the model were railway track in use, mobile car retention quantity, population size, passenger turnover volume and turnover volume of freight. It was found that the formulated model has more accuracy than that by BP neural network.

3. Test Bed The selected site for this study, Eastern Freeway in Melbourne (Australia) is one of the important urban freeways for commuting to city from eastern suburbs of Melbourne. The section for the study is approximately 18 km long, from Hoddle Street to Springvale road, consisting of three to five lanes in each direction. Between entry and exit points of the freeway, there are 7 off-ramps and 8 on-ramps in inbound direction and there are 8 off-ramps and 8 on-ramps in the outbound direction. The total roadway section is equipped with 65 detectors in which 32 detectors are located in outbound direction while the remaining 33 detectors are located in inbound direction.

4. Data Collection and Fusion Three types of data are required in this study. These are: traffic data, accident data and weather data. Traffic flow and vehicle speed are considered as traffic performance indicator in this study. In case of accident data, detailed information for each of the road incidents including location, time, and severity is required for this study. Rainfall intensity data are also needed in this study to investigate the impact of rainfall on accidents. The required data used in this study are collected from two different organisations that provide Traffic data. Namely, VicRoads, which is the road authority of Victoria (Australia), collects data from the loop detectors on the selected roadway. VicRoads also provided detailed road accident information. Bureau of Meteorology (Australia) is responsible for collecting rainfall data from three weather stations near the selected roadway. These three weather stations are View bank (Apsana), Scoresby Research Institute and Melbourne regional office. Traffic, rainfall and accidents data used in this study are from September 2007 till June 2010 which is approximately three years. The minute-by-minute traffic data is aggregated to 5 minutes intervals, rainfall intensity data are being kept as hourly data and categorical crash data with specific crash time and locations are used for the analysis. Categorical crash data are set as a binary variable such as: Accident = ‘yes’, if there was an accident or Accident = ‘no’, if there was no accident at the given time and location. These three data types are used to prepare an aggregated database of 5 minute interval including date, hour, minute, detector location, traffic flow, speed and rainfall intensity during the hour and accident. Data fusion module was developed using programming language Perl.

Conclusion The whole study revolved around the modelling of road crashes and it can be concluded from the literature of various researchers that though there has been ample amount of research in this field of road safety management, still many developing countries have not been able to decrease their share of deaths in road crashes. Hence, much study is needed in the field of traffic safety and planning. Statistical methodologies have been used to model the data and findings obtained from survey for a better and easy understanding. The most common models used are the regression techniques (linear, logistic, multiple) and few authors use regression techniques for finding goodness of fit and then model the equations and coefficients into multinomial logit models. Road crashes account for nearly one-half of all teenage deaths. In case of accidents in urban roads, many variables like age of drivers, gender, running speed, road conditions, lighting conditions, etc. are found to be the causative agents of accidents. It can also be seen that researchers usually try to focus on one variable that cause accidents and study it thoroughly rather than considering all factor at a time. In urban road accidents study, some models developed were very accurate considering the used of all forms of regression i.e. linear, nonlinear and multiple linear regressions. In rural road accidents, it is observed that mostly researchers consider speed as a major cause for accidents to occur. Few studies also considered almost every possible factor affecting accidents in rural roads and also a new software based algorithm and approach was used known as the genetic mining approach for modeling the data. Results of the research conducted by few researchers have showed that the major cause of traffic accidents was careless driving (71%) in developing countries. These are few conclusions that can be noted down from the literatures and discussions mentioned in the article. Many future studies open up in this area of research. Though traffic congestion is a wide spread problem for all developing countries and when we talk about India, it is ranked as top in number of accidents and accidental deaths per year in whole world, still studies of traffic safety have been limited to developed countries mainly. The models mainly used the regression technologies. They are good but very old and conventional. New approaches like genetic mining, fuzzy logics have been improving and also are better alternatives to the old approaches as these are more accurate and software oriented so more user friendly. More research on integration of traffic safety with systems and software should be done. Better planning strategies with good management system should be employed for averting the risks posing accidents occurrence.

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