



# A Review of Road Crash Prediction Models for Developed Countries

Bangaram Naga Kiran<sup>1</sup>, Nekkanti Kumaraswamy<sup>2</sup>, Chundupalli Sashidhar<sup>3</sup>

<sup>1</sup>Department of Civil Engineering, Rajeev Gandhi Memorial College of Engineering and Technology, Kurnool, India

<sup>2</sup>Department of Civil Engineering, Vasi Reddy Venkataadri Institute of Technology, Guntur, India

<sup>3</sup>Department of Civil Engineering, Jawaharlal Nehru Technological University, Anantapuram, India

## Email address:

2035kiran@gmail.com (B. N. Kiran), Kumaraswamy41@gmail.com (N. Kumaraswamy), sashigunt@gmail.com (C. Sashidhar)

## To cite this article:

Bangaram Naga Kiran, Nekkanti Kumaraswamy, Chundupalli Sashidhar. A Review of Road Crash Prediction Models for Developed Countries. *American Journal of Traffic and Transportation Engineering*. Vol. 2, No. 2, 2017, pp. 10-25. doi: 10.11648/j.ajtte.20170202.11

**Received:** May 17, 2017; **Accepted:** May 31, 2017; **Published:** July 13, 2017

---

**Abstract:** Road Crash losses have been on an growing trend for the preceding decade or so in India. consequently traffic safety organization has emerged as a topic of argument for researchers all over the world. For this reason Crash modeling on different factors causing them has to be conducted. Crash modelling helps to anybody to recognize the real causative agents behind an accident to occur. The effect of one cause can be greater than the other. And those causes can only be known from Crash modelling. In this paper it is tried try to divide this Crash modelling techniques into different categories based on the road geometrics characteristics, traffic characteristics and Environmental factors on urban roads and on rural roads of different developed countries. In both urban and rural road crash studies it can be seen that for the most part regression techniques like linear, multi-linear, logit and poisons regression were used for modelling the road crashes. It was also noticeable that frequently authors have tried to research on one reason and go profound into it to a certain extent considering all factors at a time. From the study of different researches the attention was paid to the safety effects of road environment such as traffic flow, lane width, number of accesses, speed and road connectors. In this paper it is tried to review as much papers as possible and various gaps in research along with future possibility of study in this area has been indicated. Starting from the basic models like Simple/Multiple regression model to the logistic and linear regressions to the new modeling techniques involving Negative Binomial/Zero inflated modelling, genetic mining and fuzzy logics have been discussed in the paper.

**Keywords:** Road Crash, Traffic Flow, Geometric Characteristics, Regression Modelling, Road Safety

---

## 1. Introduction

Road accidents have been occurring on an growing trend in the previous decade or so. This needs headed by the specialists to consider this issue. Furthermore discovery could be allowed on the reasons and precautionary measures which will evade crashes. These researches need prompted change and revelation from claiming new models for foreseeing way crashes faultlessly. This paper combines many important models and discusses on the theory involving the finding to that model.

Road crashes are exceptionally normal everywhere throughout the world and yearly worldwide road crash measurements (Association for Safe International Road Travel, 2013) state that, about 1.3 million citizens die in road crashes every year, overall 3,287 deaths a day with an extra

20-50 million are harmed or impaired. The greater part of all road accident deaths happen among youth ful grown-up ages between 15 to 44 years. Road traffic accidents rank as the 9<sup>th</sup> leading reason for death and record for 2.2% of all deaths internationally. Road accidents are the main source of death among youngsters ages between 15 to 29, and the second driving reason for death worldwide among youngsters ages between 5 to 14 years.

The Central Minister for Road transport, New Delhi said that 4,77,731 road accidents occurred in the year 2014 in India and 1,41,526 deaths happened according to official statistics. Probably, some of the injuries are not reported to the police. The road traffic injuries(RTI) are increasing every year since past 2 decades and the circumstances in India are becoming worst. perhaps it might be partly due to the increase of number of vehicles on the road.7% fatalities are

continuing to increase per year over the past ten years

Therefore, Road traffic accidents and their safety is a main area of research. So, in this paper, a few important models developed for traffic safety along with researches done on the topic are studied and are reviewed carefully. At first the common factors affect that the road traffic crashes and general models developed for predicting road crashes are discussed in brief. It follows the literatures of road crashes in urban and rural roads of different developed countries.

This paper has the subsequent structure. In Section 2, Explained the elements(or) factors which responsible for accidents; in Section 3, Discussed the crash prediction models based on Geometric and Traffic Features In Section 4, Discussed the crash prediction models based on Access Road and Segment length. In Section 5, Discuss the crash prediction models based upon the speed. In Section 6, Discussed the crash prediction models based on Heavy Vehicles. In Section 7, Discussed the crash prediction models based on Econometric & social variables. In Section 8 Discussed the Advantages and Disadvantages of crash models. Finally, gives the Conclusions of the paper.

## 2. Variables Responsible for Road Accidents (or) Crashes

Road Traffic Safety and crash studies have been in the exploration region for most recent two decades broadly as the ascent of crashes have been disturbing over the world. From the works done by scientists, one might say that traffic crashes are brought on because of for the most part 3 components i.e.

- (1) human factors
- (2) Vehicle factors
- (3) Road and Environmental factors

Individual or human variables for the most part incorporate the time of driver or casualty, sexual orientation of the casualty, was he intoxicated while driving, etc. Correspondingly, ecological components incorporate the general variables of atmosphere and condition, lighting conditions of road, time of accident, i.e. day or night, asphalt conditions, and so forth. Road geometric variables incorporate the kind of intersection or crossing point, then level slant, bends, and so forth display out and about, because of deficiencies of which, accidents may happen. Toward the end come traffic variables. This principally incorporates the speed, density, traffic stream parameters that may prompt accidents.

## 3. Crash Prediction Models Based on Geometric and Traffic Features

*Shankar et al [1]* had studied on rural freeway frequency accidents, the effect of environmental and geometric factors. They searched out that horizontal and vertical alignments (road way geometrics), seasonal and weather effects applying negative binomial model. They observed that the positive

role in road accident happenings are the maximum rain fall and its number rainy days.

*Fridstrom et al [2]* said that there are 4 variables called traffic flow, speed limits, weather and lighting conditions are related road accidents. Negative Binomial regression technique was used in their analysis. Based on the fraction of the explained variation when compared to the total variation because good ness-of-fit measures are rather low(or) arguable ( $R^2$ (or) $R^2_D$ ). As explained a new approach comprising variation  $R^2_D$  as compared to the systematic variation  $R^2_D$  rather to total variation was developed. Depending upon the 4 independent variables cited, they could able to explain that the systematic component of variation was between 85 and 95%

*Hadi et al [3]* suggested several accident prediction models pertaining to two lane roads and multilane roads of urban(or) rural. Total crash rate (or) injury crash rate was taken as dependent variables. The significance of these accident indicators were estimated as road environmental factors and a function of AADT. They considered the Poisson and negative binomial models. The outcomes reached out by examining the effect traffic flow on the crash rate were that crash rate increases with increasing AADT on roads where higher levels of traffic and it decreases with AADT on roads having lower traffic volumes. The observations reflected the fact that in the presence of low traffic volumes, free –low conditions remain so that by increasing AADT the users can have more limited freedom for strategy with which a lesser crash risk was combined.

*Vogt and Bared et al [4]* improved accident models using Poisson and negative binomial model for two lane rural segments and intersections. They used data pertaining to Minnesota and wasington. They took segment variables such as road sign hazard rating, driveway, Lane width, shoulder width, driveway density and degree of horizontal curve. They took intersection variables such as average daily traffic (ADT) from main line, minor line and posted speed limit. They opined that these variables made contributions on the main line to the accident rate and right turn lanes, increase the likelihood of accidents.

*Persaud et al [5]* furnished earliest studies for carrying out separate analysis for tangents and curves, albeit limited to two –lane roads. The independent variables were traffic flow and road geometry, while the dependent variable was crash frequency. Regression models were compared the readings with a standard readings of a generalized linear modeling. They used a dummy variable for “undulating(or) flat terrain. Crash frequency for curves was found to increase with AADT, Section length(L) and curvature(1/R). The number of accidents for tangents per year increases with AADT and length. They shown a higher accident number on undulating terrain than on flat one.

*Abdel-Aty and Essam Radwan et al [6]* Used negative binomial distribution to anticipate crash frequency as a function of degree of horizontal curvature, section length, lane, shoulder and median widths, AADT, and urban/rural designation. The power of attracting of this study that the

models were also to account for driver characters including age and Sex. The outcomes shown that crash frequency increases with AADT, Section length and degree of horizontal curvature frequency of accident decreases in comparison with lane, shoulder and median width

*Karlaftis and Golias et al [7]* evaluated the relationship between rural road geometric characteristics, accident rates and their anticipation using hierarchical tree based regression model for rural two lane and multilane lane roads. They observed that geometric variables and pavement condition variables were the two main factors causing accident rates and opined that lane width, pavement type and friction factors were foremost variables have an impact on crash rates for two lane case. Lane width found to increase with higher AADT and pavement condition factors seemed to increase with lower AADT due to higher speeds. They found that access control and median width became more important in reduction of accidents for rural multilane roads.

*Martin [8]* explained the relationship between crash rate and traffic volume per hour (VH) and the influence of traffic on crash severity. They used negative Binomial distribution. To model the possibility of observing one injury crash in a crash, a logistic regression with a binomial distribution was also used. The main point of interest emerged from the study was that relationship between crash rate and VH was shown to be non linear. When VH was forever than 400 vehicles/hour, higher crash rate values, both for damage and injury cases were found. Crash rate also reduced rapidly with enhancing VH, through a minimum 1000 and 1500 vehicles/h for two and three lane carriageways. Later on that crash rate enhanced gradually with an increase of traffic.

*Recker and Golob et al [9]* utilized linear and non linear multivariate statistical analyses to decide how the type of accidents related to traffic flow, weather and lighting conditions. The study was made based on the principal component Analysis(PCA) be cause to identify the most significant variables from a set of original traffic flow variables and authenticated correlation analysis was used pertaining weather and lighting conditions.

*Glaister and Graham et al [10]* tested the role of urban scale, density and land –use mix on the occurrence of road pedestrian casualties. They used English census wards as the spatial unit of study and evolved negative binomial models to carry out the analysis. The study opined that the occurrence of pedestrian casualties, deaths and seriously injured were higher in residential areas than business areas. They found in quadratic form, the relationship between urban density and pedestrian casualition with incidents decreased in highly populated areas.

*Griebe [11]* defined a few of the main findings from 2 different studies on accident prediction models for urban junctions and urban road links. They created simple, practicable accident models that can guess the expected number of accidents at urban junction and road links as correct as possible. These models can be utilized to identify factors causing road safety belonging to “black spot” identifications to undertake network safety analysis by local

road officials. The accident forecast models were taken on the data basis, from 1036 junctions and 142K.m road links in urban places. Generalized linear modeling were taken with reference to accident frequencies to explanatory variables.

*Golob et al [12]* in a later paper described the safety effects of changes in freeway traffic flow. The research was made based on some of the same statistical methods used in the previous study along with the further steps which were needed for forecasting and monitoring purposes. Three crash features were taken in the analysis namely (1) Crash type (2) Crash Location (3) crash severity

*Hauer [13] [14]* evolved statistical road safety modeling by using the Negative binomial distribution. The dependent variable was the number of accident per year while the other were traffic flow and geometric features. The author at the outset suggested guidelines for assigning the functional from to each variable in the model and found that the model equation must have a multiplicative and an additive component. The important innovative aspect of this study was the introduction of an alternative tool for measuring the goodness of fit of the expected models i.e cumulative residuals methods(CURE). In further study in the same year, applied above shown statistical model to estimate crash frequency on undivided 4 lane roads. The findings shown that most important variables were the number of commercial driveways, speed limit and AADT.

*Seunglim Kang et al [15]* promoted a traffic accident analysis method depending upon the accident risk index following the combination of alignment elements and examined applying geographic information system(GIS). From 1996-2000, they studied the crash experiment on curves of 4 lane expressways, in Korea in yeongdong expressway. They studied curve radius, curve length, grade and super elevation which were contradictorily correlated with accident rate. Grade was only with affirmative correlation.

*Quddus and Noland [16]* elaborated a disaggregate spatial analysis depending upon enumeration district area to test the effect of crowd on traffic casualties. Proxy variables controlled spatially congestion. Adverse binomial models were used to analyze the factors making difference on casualties during un congested and congested periods. The result of study shown that traffic casualties are likely occur on higher speed roads and motorways but not during traffic congestion.

*Jovanis and Aguero-valverde [17]* generated Full Bayesian(FB) and Negative binomial models to carryout spatial analysis injury crashes and fatal in pennsylvania. During their study, they used counties as the spatial unit. They opined that the counties with a higher percentage of the population under poverty level in the age group of 0 to 14, 15 to 24 and above 64. The crash risk was increased due to to increased road mileage and road density. They suggested to consider spatial correlation in intersection level accident models and road segment.

*Sayed and Basyonny [18]* prepared comparison of two negative Binomial Regression techniques elaborating

accident prediction model. They identified the difference between the goodness of fit and accident pron location. They took a sample of accident in British, Columbia along with traffic volume and geometric pertaining to 392 segments(58 arterials). They opined that modified NB approach appeared to fit the data between than TNB approach.

*yannis et al [19] [20]* improved multilevel negative binomial models to inquire in to the effects of the strength of the police enforcement on the number of road accidents during 1998-2002 at regional level in Greece and national level. The enforcement of alcohol developed the road safety in Greece as per their findings.

*Wong et al [21]* adopted poisson and negative binomial regression to quantify the power of geometric design, traffic control, road environment, traffic flow on the incidence of killed and severe injury crashed during 2002-2003 in Hongkong. They identified that degree of curve, presence of transports and road environment were main factors for incidence. The traffic volume was having decreasing effect on the crash risk.

*Rengarasu et al [22]* inquired in to the seasonal factors and the road geometry factors involved in head on collision and single vehicle collisions occurred in Japan, Hokkaido. The head on collision were responsible for about 40% of the fatal collisions. They improved a fragmented accident data base depending upon the traffic Accident analysis(TAAS) Created by civil Engineering Research Institute, Hokkaidu. By using analysis poisson regression models they shown that road geometry factors and seasonal factors were significant factors brought relationship with head collisions. In this study the model proposed was capable of recognizing the casual factors of single vehicle collisions.

*Haneen Farah et al [23, 24]* evolved probit regression model stating less time to collision. Model improved based on drivers passing decisions using an interactive driving simulation on two lane rural highways. Finally, they revealed that driver characters, geometric design and traffic had an important contribution to accidents risk

*Nikiforos Stamatiadis et al [25]* aimed on evolving crash prediction models and accident modification factors (AMF) for multilane roads particularly lane widths, type, median width, and shoulder width. They noticed that increasing shoulder width had a affirmative effect on crashes. He opined that shoulder width caused decrease of crashes for divided highways.

*Quddus et al [26]* examined by searching the relationship between the severities of road crashes and the level of traffic difficulties using orderd response models. They collected between 2003-2006 data such as traffic characteristics, crash data and road geometry fro M25 London orbital motorway. They opined that the traffic congestion not affected the severity of road crashes on the M25 motorway.

*Dissanayake and Wedagamma et al [27]* verified the influence of accident related factors on road fatalities taking in to account Bali province in Indonesia as a case study. They improved Logistic regression models for fatal accidents giving importance to motorcycles and all vehicles with data

from Bali in Indonesia. They employed seven predictor variables in the generated models. During their study, they observed the probabilities of accidents pertaining to female motor cyclists and motorized as 79% and 72% than males. Further, they revealed that age was also prominent to influence all vehicle fatalities. It was considered as 50%

*Hauque et al [28]* carried out a detailed study of severity crashes involving motorcycles as vehicles during accidents. The main focus of their study was to apprise how behavioral factors influence the crash risk and to recognize the most vulnerable group of motorcyclists. A questionnaire for 61 items of risk taking behavior was generated. High risk taking motor cyclists are more likely to fall but sensation seeking behavior is not found to be important.

*Chio et al [29]* studied the subscribing factors to crash severity in freeways of Taiwan Which was taken in to account to be rural road. They had taken large number of variables such as occupation and age of driver, travel period, travel purpose, location, vehicle type, action of driver, surface condition, signal control, driver gender, weather, obstacles on road, lighting conditions, collision type, severity, Speed limit, road status, marking, license etc. As per their developed model collision type, purpose of the journey, major cause, and travel period are 4 important factors to the severity of accidents and much need to be given to these 4 factors, for better traffic safety.

*Fujita and Mustakim et al [30]* produced an a accident forecast model for rural roadway depending on the data collected in Malaysia on rural roadway. They had taken black spot study to develop accident predictive models by using multiple non linear regression method. The results shown that major access points such as rise in speed, without traffic light, increasing number of Annual Average Daily Traffic (AADT) are the important contributors of accident rates on multiple rural roads. Hence it is observed that vehicle speed(AS), Annual Average daily traffic(AADT), Motorcycle(MC), motor car(C). Gap (GP) and total length of the Accident section (TL) were the number of access point which contribute to accidents at four lane, two way undivided rural road.

*Niveditha et al [104]* developed four different models with explanatory factors as roadway geometries, traffic data and type of collisions to estimate Crahes. Study suggested that side swipe is more significant for road crashes.

*Naveen Kumar et al [105]* developed two models with explanatory variables as geometric parameters, traffic parameters, temporal parameters, environmental parameters and different land use types on monthly crashes. Study suggested that to rank hazardous crash locations and to develop crash modification factor.

Synopsis: Most of the models were depending on the geometric features considering ADT(Average daily traffic) and opined that ADT was positively related with accidents. But seunglim and Shankar after studying in detail excluded ADT and considered geometric variables, seasonal effects and weather.

#### 4. Crash Prediction Models Based on Access Road and Segment Length

*Sayed et al [31]* studied a method to know accident prone location (APL) Depending on appraisal of factors that subscribed to accidents with the assistance of British Columbia, Ministry of Transportation Highways. They exchanged conflicting views that current methods to Know APL made no difference between accidents resulted from road and non road related factors. They finally said that the fund could be used for safety improvements effectively.

*Walid Abdelwatab and sayed et al [32]* examined accident prone locations using traditional and modified black spots depending on empirical Bayes technique. They revealed that the problem involved with the traditional methods were not correctable by road improvement strategies and modified technique was taken in to account eliminating the locations that may not be rectified from a road authority angle. The opined that traditional program identified locations were not actually hazardous from a road safety authority approach.

*Mannening and Milton et al [33]* identified that an increase in accidents were led by the annual daily traffic and decrease in accidents were observed by the peak percent of this traffic. They tested and understood that more accidents were led by increasing the number of lanes on a given road segment. Accidents frequency was reduced by Washington narrower substandard lane widths i.e less than 3.5m. They opined that horizontal curve not caused by itself to increase accidents but dependent on large straight sections before the curves.

*Saccomanno et al [34]* produced log linear poisson regression and empirical Bayesian (EB) models for recognizing Black spots (BS) on SS 107 Highway at a stretch of 27Kms dividing in to 4 sections( 2 sections of positive and negative grade straight sections and positive and negative grade curve sections in southern Italy. They accepted intersections as independent variables, section length, radius of curvature, lane width reduction, 85<sup>th</sup> percentile operating speed and number of private driveways. The difference between two models in noticing the black spots and made out the cost of taking counter measures for controlling occurrence of accidents. Can an average only 87% of the route length identified as a black spot. can curve section more black spots were identified than on straight section especially for sections negative grade. They identified 17 B. S section by EB Model and 20 B. S sections by the poison model. Finally they revealed that EB Model could produce important savings over poisson model

*Ossenbruggen et al [35]* created logistic regression model to find statistically prominent factors that forecasted the probabilities of crashes and injury crashes. Traffic exposure, road side design, use of traffic control devices and land use activity were explanatory variables. They understood that residential and stopping sites were more dangerous than village sites.

*Ashur [36]* assessed the National strategic plan for traffic safety in the limited Arab Emirates. They understood that

number of fatalities were occurred due to vehicle crashes which increased in the past few years. The author studied and concentrated on appraising traffic safety in the U.A.E. The data shown that number of crashes were decreasing per 100000 populations and were stable in the severity of accidents in the past some years 1995-2000 the pedestrian crashes increased.

*Xiao qin et al [37, 38]* had zero inflated poisson (ZIP) to judge models for prediction of counts for single –vehicle, multi-vehicle same direction, multi vehicle opposite direction for crashes as an action of the dually volume, road way width, speed limit and segment length. They observed that the relationship between the daily volume (AADT) and crashes was non-linear and varies by the types of crashes.

*GirmaBerhanu [39]* utilizedpoisson and negative binomial regression methods to pertain judicious accident data with traffic flow explanatory variables and the road in Ethiopia. He observed that the provision of median was found prominent in both pedestrian accident models and multiple vehicle accident models. The acquired relationship stating that multiple vehicle accidents increased by 30% resulting high on street parking. Multiple vehicle accident risks increased on divided roads with increase of ADT. This findings reflects the fact that accident rates were increased with the density of access to urban divided highways.

*Jutack oh et al [40]* created accident prediction models for rural highway intersections. Poisson and negative binomial regression model were suited to divide crash data from califonia, Geirgia and Michigam. This findings reflects the fact that crash frequency on major and minor roads for 3 divisions and two accident types. The results shown that the turning volume percentages were important for 3 legged (or) T-intersection for injury crashes. Sight distance was an important effect for 4 legged multilane intersections.

*Mohamadreza Banihashemi et al [41]* produced a linear optimization model to know the best combination of improvements for different sections of a case study highway of 4.2Km two lane rural highway given cost problems. Based on this model a 'C' Code program was created to build the test problems. A study was carried out on 4.2Km two –lane rural highway with 3 alternative designs having 5 different types of improvements. The unit costs involved with these improvements were estimated. This findings reflects the fact that for 300000 expenditure crashes were expected to decrease to 10 per year 14.4 crash per year.

*Minwook Kang et al [42]* gathered accident data for 4 years from 1993 to 1996 in the state of Washington on interstate highway number 5 and 90. They evolved Negative binomial model to investigate the impact of length of highway horizontal section on accidents. They noticed that accidents reduced when the curve radius became larger.

Perez (2005) built-up safety impacts of 4 engineering treatments such as traffic signing, pavement surfacing, pavement markings and highway upgrading in Spain by using empirical Bayes method by organizing prior and later studies. This findings reflects the fact that highway upgrading had an important safety impact value of 33%. The

Improvement of traffic signing had an un important safety value of 11%. The repainting of pavement markings were in bad maintenance had an important value of 14%. And the pavement resurfacing on sections with dry –weather accidents had non-significant value of 2% where as with wet –weather accidents had a non-significant value of 36%

*John seok oh et al [43]* made an effort to know traffic conditions that might led to a traffic accident from actual time free way traffic data. They utilized loop detector data in finding out the likelihood of an accident from real time traffic condition. Later. They said that the given traffic measures, explained by spaced variation, the traffic condition leading to an accident was estimated by non parametric Bayesian model.

*Dominique Lord and Bonneson et al [44]* suggested the procedure for estimating accidents per year, connecting two major intersections for a particular highway segments. They took shoulderwidth, segment length and traffic volume as explanatory variables and identified all variables were important.

*Pardillo et al [45]* processed the negative binomial model using random reduction of the sample and stratification of data in the model techniques. In spain they made models using 2500, 2000 and 1500 of 3297 original accident data of two lane rural roads, in random reduction of the sample technique. They observed that in the model fitted with the 1500 sample data effect due to excessive data was very important. There was no significant variation in the measures of goodness of fit subsamples of 2500 and 2000 records. They accepted 4 ranges of stratification of  $AADT < 6000$  and  $AADT > 6000$ ,  $AADT < 8000$  and  $AADT > 8000$ ,  $AADT < 6000$ ,  $6000 < AADT < 8000$ ,  $8000 < AADT < 12000$  and  $AADT > 12000$  in the model stratification. They noticed that value of over estimation (or) under estimation was reasonably reduced by this technique. Variables such as access density, minimum sight distance within one segment elements total traffic flow and minimum design speed of a alignment elements were included in the one K. M segment(Km/Hour), maximum longitudinal grade(%) and reduction speed. Finally, they opined that the random reduction of the original sample resulted in a significant improvement in the fit of the assumed values to the noticed values to the observed data. There was a reasonable decrease in the variation of the residual errors in the stratified model.

*Osman Yildiz and Akgungor et al [46]* done the thoughtful analysis of an accident prediction model by the factorial method. The estimate of perceptive analysis indicated that average daily traffic, width of paved shoulder, lane width, median and their interactions had an important effects on the number of the accidents. They opined that ADT was directly pertaining to the number of accidents.

*Cirocaliendo et al [47]* evolved crash prediction models for multilane roads in Italy. They collected 5 years accident data from 1996 to 2003 for 46.61m four lane median divided motorway. They accepted a total of 1916 accidents, 21of which were fatal and 594 were injuring accidents. As independent variables, they took longitudinal slope, length,

sight distance curvature, AADT and surface condition in to consideration. Separately to tangents and curves, the poisson, binomial and negative multinomial regression models were applied. This findings reflects the fact that with curvature & AADT the number of accidents per year were increased. And he found wet pavement was to be more significant factor in enhancing the number of crashes.

*Haneen Farah et al [48]* built up two crash prediction models depending upon the crash records and the infrastructure coefficients. Infrastructure coefficients that belong to road side environment, sight distance along the highway, road alignment, roadway consistency alignment, presence of guard rails, number of percentage of access points, lane and shoulder width as independent variables. They evolved two infrastructure coefficients and compared with a standard scale of readings by two statistical methods. They proposed that those models could be utilized to develop the safety level of existing highways.

*Yi (Grace) Qi et al [49]* prepared methodically free way accident likely hood prediction using a panel data analysis approach i.e from different individuals groups etc. The observation analysis shown that factors from traffic flow characteristics, geometry and weather had statistically important association with traffic accidents.

*Kay Fitzpatrick et al [51]* Evolved a horizontal curve accident modification factor(AMF) for undivided and four lane divided highways. The variables they took in to consideration were lane width, shoulder width, median width, median type, drive way density, average daily traffic, segment length and degree of curve. 5 years 1997 to 2001 crash data was collected and developed models for curve and tangent. They opined that the driveway density, median width and outside shoulder width along with degree were important when both driveway and non intersection crashes were considered ADT. Further they revealed that the effect of driveway density on segment crashes was similar for horizontal curve and tangent curves.

*Salvatore Caiso et al [52]* buildup comprehensive accident models for two lane rural highways using exposure geometry, consistency and context variables. In Italy over 5 years period they collected 279 accident data with a total of 640 injured persons and 16 fatalities. They evolved 19 models and recommended 3 models. Model-1 Includes only length and traffic volume Model-2 Included drive way density, curvature ratio, the standard deviation of the operating speed profile, length, traffic volume(AADT) Model-3 Included drive way density, road side hazard rating, legth, traffic volume (ADT), Speed differential higher than 10Kmph and curvature ratio. They noticed that accident –AADT was non-linear and concluded that decreased with increasing curvature ratio and with the increasing standard deviation of speed accidents increased.

*Seva et al [53]* studied the motor cycle accidents taking in to consideration of personel and environmental factors. They accepted variables such as traffic movement, road charater, junction type, day, age, lighting conditions, surfaces conditions and driving behaviour. They used Logistic

regression to predict the occurrence of an accident from the variables taken in to consideration and evolved a logit model. As per their study, three variables were identified to be more important predictions of motorcycle accidents. They were junction type, age and driver behaviour. They used Wald's and Hosmer-Lemeshow test as logistic regression for goodness of fit. They opined that the younger drivers are more likely causing accidents.

*Ramadan and oaidet et al [54]* Conducted study on the traffic accident at 28 hazardous at Amman –Jordan urban roads. They noticed that the logarithmic and linear models were most important and realistic models that can be used to predict the relationship between the accident characters and a dependent variables. The following variables were considered to be most important contributors to traffic accident at hazardous places. Number of vertical curves, median width, type of road surface, avg running speed, posted speed, lighting, number of vehicles per hour, number of crossing facilities, maximum and average degree of horizontal curves and percentage of trucks. As per them, the following factors are responsible for causing traffic accidents.-Geometric actors: Types of pedestrian crossings, median width, number of lanes, number of vertical and horizontal curves etc-Drivers behavior factors-Lighting condition of day/Right and surface type-Traffic condition factors-Traffic volume (AADT) and different vehicles percentage.

Anowar et al [55] scrutinized in Dhaka about the accident systems at selected inter sections of an urban arterial. The data revealed that around 40 percent of total accidents are occurring in the Metro Politian city of Dhaka with the intersection accidents. They made an effort to study depending on the data examination to shed some focus on the major causes and types of accidents because to identify the intersection problem. They advised suitable counter-measures to decrease such accidents.

Synopsis: Major studies concentrated using poisson and negative binomial regression models which include traffic flow, segment length and access roads, road environment and segment distance except a study of “sayed et al on accident prone locations using fuzzy pattern which accepted only road environment. “Ciro Caliendo et al “created a model which had additionally taken in to acceptance of sight distance while “Salvatore et al” evolved the comprehensive model considering the curve ratio

## 5. Crash Prediction Models Based on Speed

*Solomon and cirillo et al [56]* had taken interstates as their unit of scrutiny where accidents involved vehicles on two lane and four lane rural highways. They appraised based on their study that incremental duration from the mean speed of the accident involved vehicles speed. They observed that the lowest accident rate occurred with in a speed range of 15 to 20% higher than the mean speed. They opined that as

deviation increased above this range, accident involvement rates increased for vehicles speeds either higher (or) lower than the mean speed.

*Garber Gadiraju et al [57]* studied the relevance between accident experience and speed variance. In Virginia he scrutinized 36 roadway segments. The authors examined and compared design speed, variance of operating speeds and posted speed. Their out-turn compared the geometry on vehicle speeds and the effects of traffic, stating that the accident rates enhanced with increasing speed for all road classes and also speed variance.

*John Collins et al [58]* read the speed variability on rural two lane highways. They found to evaluate geometric design consistency, the speed variance measures can not be used. They further observed that there was low correlation between speed variance and geometric features. They opined that on rural two lane highway the speed variance was not correct measure of design consistency for horizontal curves.

*Kleoden et al [59]* read the risk of crash involvement and the effect of travelling speed on rural roads. The relevance between free travelling speed and the risk of involvement in a causality crash in 80km/H (Or) more in rural south Australia. They observed in his study that the risk of involvement in a causality crash enhanced more than more rapid with increasing free travelling speed above the mean traffic speed. There was a lower risk of being involved casualty crash below the means traffic speed in a crash large potential safety benefits from even small declines in rural travelling speeds.

*Karalaftis and Goliias et al [60]* They read traffic volumes and road geometry on rural road accident rates. The results shown that geometric design variables and pavement condition variables are the two most important factors causing accident rates, through the prominence of isolated variables differs between two lane and multi lane roads. The methodology used for the explicit prediction two lane and multilane roads on of accident rates for given highway sections immediately the profile of a road section is given

*Taylor et al [61]* read the relevance between speed and accidents on single carriageway roads. They had included Accident data for a defined 5 year period i.e vehicle speed data, traffic flow data, Road characteristics and geometric and layout data. Generalised linear modeling procedure was used for study of the data &their correlation. The results of their studies revealed that the accident frequency in all categories increased rapidly with mean speed. Thus showing that a 10% increase in mean speed results in a 26% increase in the frequency of all injury accidents. A 10% enhancement in mean speed would be predicted to result in a 30% raise in the frequency of fatal/serious accidents.

*Hills et al [62]* evolved a safe and cost-efficient model for rural roads designing in developing countries based on the accidents occurred there. They took 5 countries for their study i.e india, Nepal, Zimbabae, Malawi, Botswana and Tanzania and created separate models for each of them. For collected data, they used the Generalized linear modeling technique(GLIM). They found that a reasonable model fit could be made for all types of accidents but number of

individual accident types were too small to create reliable individual models. Based on the model in Nepal and India, the presence of a marked edge line to be mainly beneficial in decreasing accident rate.

*Xuedong et al [63]* took multiple logistic regression model to read the multivehicle rear end accident characteristics by obtaining 2001 accident data base from Florida Department of Highway safety and motor vehicles (DHSMV). They observed that risk of rear end accidents for 2-lane and 4 lane highways were lower than 6-lane highways. They recognized that the accident involvement ratio for night is clearly lower than day time, due to contribution of dry roads surface and wet and slippery road surface to rear end accidents. Further, they opined that if the speed limit increases, the risk of rear end accidents increases when the speed exceeded 65Kmph.

*Letty Aants and Ingrid van schagen et al [64]* enquired in to the impact of driving speed on the risk of road accidents. They observed that crash rate increased with the increase in speed on rural /urban roads. They observed that the speed crash rate relation was lane width, junction density and traffic flow.

*Goldenbeld and Schagen et al [65]* read the possibility of 80Kmph limit for dissimilar rural roads and ascertained the effects of road characteristics and its environment as well as person's characteristics. They investigated with 600Dutch car drivers and Known that major differences between preferred speed and safe speed limit both below and above 80 Kmph. Their outcome was that drivers wanted to drive 4-5 Kmph faster than the speed limit and thought to be safe.

*Jikuang Yang and Chanyukong et al [66]* enquired in to the association between the impact speed and risk of pedestrian casualties in passenger vehicle collision in china based on real world accident data. They improved a multiple logistic regression model accepting impact speed and age and observed that the risk of pedestrian fatality is 26% at 50Kmph, 50% at 58Kmph and 82% at 70Kmph. The pedestrians rarely survived at an impact speed of 80Kmph.

*Survenchen and Fengchen et al [67]* can concentrated on characterizing the transient method of accidents, introducing new variables on ascertaining the accident risk under more dangerous driving conditions and set up more realistic accident criteria. They utilized to define suitable safe driving speed limits for vulnerable vehicles with a risk of vulnerable drivers under normal/extreme conditions.

Synopsis: Majority of these studies with respect to models depending on speed, speed variance, considerable speed drivers and pedestrians age excluding a study which accepted only speed range organized by Solomon and cirillo.

## 6. Crash Prediction Models Based on Heavy Vehicles

*Wael and Bruce et al [68]* evolved prediction models for truck accidents at free way ramps in Washington state using regression and AI techniques. They checked the results with comparison by regression model area, adaptive –networks-

Based Fuzzy Inference system(ANPIS). They decided truck accident frequency and ramp ADT, ramp length, weather condition, surface condition was complex by a regression model. AI techniques were more eligible of explaining such complexity when compared to regression Method.

*Lynn Meuleners [69]* Considered to assess the number of fatalities and serious injuries for heavy vehicle drivers in western Australia involved in a crash from hospitals police records. He used capture and Recapture method to estimate the similarities and differences in the characteristics of heavy vehicle drivers from the sources of police &hospitals. As per the police report each heavy vehicle driver involved in a Crash was tallied against heavy vehicle drivers hospital records with data of crash, age, name vehicle type. The calculated number of fatalities and series injuries to heavy vehicle drivers from 1<sup>st</sup>July 1999 to 31<sup>st</sup> December 2000 was 5 and 59 respectively. It was 25 and 31% more based on the C-R methodology than non-over lapping(aggreated) total official reports of the hospitals &police. For drivers having age between 37 to 40 years was found number of significant age difference ( $P>0.05$ ) in heavy vehicle crash. But female heavy vehicle drivers were over reflected in hospital records when compared to the records of police.

*Landge et al [70]* evolved poisson regression model for traffic accidents on two lane rural highways under traffic mixed conditions. They collected from NH-58 Such as variables spot speed, Percentage of heavy vehicles, shoulder width, traffic volume, intersection density and lane width were collected. They noticed that shoulder width had negative sign and traffic volume had positive sign stating that with more shoulder width, less would be the accidents. They opined that fatality rate decreased as intersection density decreased.

*Joon-Kikim et al [71]* created a microscopic model of freeway rear end crash risk, depending on modified negative binomial regression model and poisson regression using data of Washington. Rear-end crash was accepted to be based on

That a lead vehicle becomes an obstruction

That a back vehicle fails to obtain a collision given to obstruction vehicle.

They took variables such as truck percentage, VMT per lane, AADT, horizontal curve, shoulder width, posted speed limit and nature of area (urban and rural area). The authors noticed that these variables were statistically important at 90% level in the model.

*Janine Duke [72]* made an effort to review age related safety and other factors which contributed to accidents practiced by heavy vehicle drivers. Author used Canadian center for occupational Health and safety. The author found that heavy vehicle drivers below 27 years of age established higher rates of accident and fatality involvement which reduce and plateau until the age of 63 years where higher rates were again noticed. They opined that both age groups in high risk of accidents.

*Sravani Vadlamani et al [73]* recognized high risk sites for large truck crashes in Arizona and tested potential risk factors

belong to the design and high risk site. They identified high risk sites using negative binomial regression and property damage only equivalents methods.

Synopsis: Majority research works on heavy vehicles in model building accepted ADT, Lane width and percentage of heavy vehicles. But the model evolved by "Joon-Kikim" was taken in to account for cross sectional elements and heavy vehicles.

## 7. Crash Prediction Models Based on Econometric and Social Variables

*Fridstrom and ingebriqstem et al [74]* assessed a model using monthly data on traffic accidents for 18 countries in Norway. They observed that improvements and extensions too the national road do not have the desired effect of improving safety. Also they noticed more congested roads led to few casualties. This study revealed many different usual factors contributed to crashes. They Scrutinized the effectiveness of key local area traffic management (LATM), treatment types in decreasing traffic speeds to decline the risk of causality crashes on local roads. Through each treatment type, typical vehicle speed profile were also built up. At the end, a speed based design tool prototype was created to assess operating speed profiles and the desired crash savings for proposed LATM Schemes.

*Ogden [75]* read on Rural Highways in Australia about the safety effects paved shoulders on accidents. The author collected data on two lane way roads on the location, cost and condition of shoulder paving projects. Shoulder was taken between 600 and 200mm, with 600(or) 800mm being most common. The out come of these type of treatment shown that shoulder paving was comprised with statistically important decline in causality accident frequency on two lane way rural highways in Victoria. As per vehicle kilometer basis, manily causality accidents were declined by 41%. The principal accident decline were for accidents connecting rearend, overtaking –out of control, off carriage shoulder left and off carriage way to right in to fixed object. Author assessed by forming relationship between/cost ratio and traffic flow, benefit/cost ratio and shoulder paving as 2.8 times the AADT.

*John Collins et al [76]* read on rural two lane highways about the speed. They noticed that there was speed variance and low correlation between geometric features. Finally, they opined that for horizontal curves on rural two lane highways, the speed variance was not correct measure of design consistency. I t was not beneficial in explaining safety differences between tangents and horizontal curves on two lane highways, while an increase in speed variance might be an indicator of potential safety constraints for some geometric design features (or) traffic situations.

*Ivan et al [77]* assessed poisson regression model for anticipating both multive vehicle and single highway crash rates as a function of traffic density and land use as well as ambient light conditions and time of day. Their study

concentrated on many rural, two lane highway segements, each 11/2 mile(one-half) in length with varying land use patterns. Land use effects were shown by the number of driveways of various types on each segment. For single vehicle crashes as the total vehicle miles travelled and volume/capacity ratio, hourly exposure was represented and for multivehicle crahes, it was the product of the hourly volumes on the roads intersection it along the study segment and the main highway. Variables for multi vehicle crash expect models were, day light conditions from 10:00-15:00 hours and 15:00-19:00 (Positive) number of intersections (negative) and driveways (positive for all types). They observed that traffic intensity explained differences in crash rates even when controlling for time of day and light conditions and that these effects were different for single and multivehicle crashes.

*Hassan et al [78]* built up 3D (mark c Software) operating speed model to develop highway consistency and safety by scrutinizing 8 km segment of highway expected operated speed to the profile of allowable speed depending on 3D Sight distance and vehicle dynamics, the consistency(or) deficiency in highway segment was recognized. The authors noticed that negative values indicated design deficiencies while positive value of the difference indicated a safe design as the drivers travelled faster than the maximum allowable speed. They opined that the difference between 2D and 3D model results were influential(difference +100% to -30%), the 2D investigation was proves to be inadequate for estimation and adopting 3D models in the design guides and commercial computer software would greatly advantage to the highway designer.

*Feiyuan et al [79]* read road safety benfits at 12 sites using empirical Bayesian methods, pertaining to intersection approach realignment on rural two lane highways. They found that multivehicle intersection crashes other than rear on and head on crashes enhanced at site 2012 with traffic signal and average daily traffic of more than 20,000 vehicles entering the intersection. They advised that these factors might decline the effectiveness of treatment for crash reduction. They also noticed that suburban sites tended to have lower crash decreasing factors than did the rural sites. They finally opined that the treatment did not essentially decrease all types of crashes, but instead might have increased some. Run off road crashes and head on and rear end crashes for the curve realignment improvement on the intersection were more greatly decreased than other types of crashes. Run off crashes increased at some sites.

*Hassam et al [80]* evolved artificial neural network models to expect driver injury severity in traffic accidents at signalized intersection, using central Florida 1997 accident data. The relationship between driver and driver injury severity, road way and environment characteristics and vehicle was tested. They concentrated on two vehicle accidents that occurred at signalized intersections. They used fuzzy adaptive resonance(ART) theory neural networks and multilayer percaption(MLP). They understood that rural intersections were more dangerous in terms of driver injury

severity than urban intersections. Further they expressed that female drivers were also more likely to experience severe injury than male drivers. At last, they opined that wearing of seat belt reduced the chance of facing severe injuries and vehicle played a main role in driver injury severity.

*Noland [81]* investigated the relationship between safety across sectional time-series and road infrastructure, using negative binomial fixed effect model and number of models were evolved and number considerable effect was identified for increases in average amount of interstate lanes on fatalities. They opined that changes in highway infrastructure had not decreased traffic fatalities and injuries.

*Jean –Louis Marin and Robert Quincy et al [82]* studied the cross over crashes on a French Motorway network at Median strips equipped with barriers. They noticed out of 44,896 accidents 15943 led to an exit from roadway in to the median barrier. The median barrier was fully crossed in 206 numbers of accidents that is the barrier was crossed the 1.3% of accidents in which vehicles collided with the median barrier. They opined that median barrier crossing the penetration on to the oncoming roadway was a rare event occurring in only 0.5% of all vehicles.

*Christo Bester [83]* read on safety about the effect of road roughness. Author created two regression models for total accident rate and single vehicle accident rate, accepting topography, present serviceability index, shoulder width and total paved width as independent variables. Author noticed that the accident rate increased with improved riding quality on the cross sectional elements, topography (alignment) and riding quality of a road section played an important role in the safety. Author opined that more rugged terrain invariability led to higher accident rates, wider cross section elements usually led to lower accident rates on bad riding quality led to an increase in accident rate.

*Clark and Brad Cushing et al [84]* read carefully in united states of America about the effect of population density on motor vehicle mortality urban and rural areas while controlling for VMT. They collected from Federal Highway Administration for the year 1998-2000, urban data for traffic mortality, vehicle miles (VMT). They obtained traffic mortality data also from National Highway traffic safety Administration. They utilized “linear regression” to calculate the effect of population density, presence of trauma system and VMT Per capita southern location on mortality. They observed that variation in rural mortality rate i.e per 100000 population was proportional to rural VMT per capita. But population anticipators, together accounting for 91% of this variation. The variation in urban mortality rates was not affected by population density but urban rates also higher in south. The variation in rural mortality rate i.e death per 100 million VMT, was inversely proportional to density and explained 41% variation for state to state. The presence of a state trauma system did not cause mortality after controlling VMT and south location where as state population density in rural was moderately strong but not urban traffic mortality.

*Moore et al [85]* collected 84 accident records from

California Highway patrols “First Incident Response service Tracking system to define secondary accidents and evolved methods to know secondary accidents occurrence by traffic queue. They assessed the no of secondary accidents per accident ranges from 0.015 to 0.03 and that the number of accidents per incident ranged from 0.007 to 0.013.

*Casaer Filpeta [86]* enquired in to road traffic accident in Belgium and found that risk of both sexes increased significantly with age. The younger drivers were involved up to 60% in single vehicle crashes and it applied only 20% to the age +65 category. The middle aged road users were the only strongly present within the rear end collisions where as the elderly aged +65 were more involved in lateral (40% of them) and frontal (19% of them) collisions.

*Vivian Robert and Veera Raghavan et al [87]* studied In Karnataka state of India linking Bangalore and Mysore, they organized road safety auditing on state highway-17. They attempted depending upon rural safety audit to produce rating scores showing the safety performance of individual kilometer to a length of 23Km on the highway. They reached at danger ratio to be used for prioritizing the section for safety improvement with in the stretch.

*Filip Vanden Bossche et al [88]* studied In Belgium by using a regression model with ARMA errors (Auto regression Moving Average), they examined the frequency and severity of road traffic accidents. They noticed that introduction of seat belt law resulted in a 6.7% decline in the number of accidents. Also effects were revealed for signalized intersections and 3-legged multi lane intersections.

*Pei Lill and Hsien-Guo young et al [89]* studied During the years 2000 and 2001 in Taiwan, they inquired in to 1593 traffic accidents reported at 62 signalized intersections. The outcome shown that the effect of specific variable on number of intersections proved crashes were not same for various intersections. They noticed that most susceptible characteristics on intersection related crashes were to be number of fast traffic lanes, width of fast traffic lanes, median type between fast and slow traffic lanes, left turn seconds and central median type.

*Kumara and Chin et al [90]* read carefully about the traffic accidents in Asia Pacific countries and observed that population, number of registered vehicles, the size of road network and per capita gross national product were influential factors that enhanced accident occurrences.

*Khaled and Abbas et al [91]* evolved statistical models in Egypt assuming expected number of accidents, injuries, fatalities and casualties on the rural roads. They utilized time series data of traffic and accidents for selected roads over a 10 years period in the comparison of these predictive models. They accepted six important categories leading to accidents namely pedestrian related and driver related causes, out of which, They noticed main reason to be driver related. All these included overspeed, sudden slowing/stoppage, loss of control of driving wheel and vehicle related causes such as tyre burst, vehicle turn over (or) vehicle turn off the road. Total these causes led around 83% of all accident causes on the five roads. Driver related causes contributed around 59-

73%, vehicle related causes contributing 23% road related causes 3.5% and pedestrian related causes contributing around 4%

*Rune Elvik [92]* suggested new approaches to examine the accidents at dangerous locations. Author recorded 8 accidents at dangerous road locations. The results revealed that out of 8 accidents 5 were pedestrian accidents. He observed on binomial trial that normal possibility of a pedestrian accident is 0.125 (possibility of non pedestrian accident is 0.875). Totally, the pedestrian accidents are occurring at night time on a wet road surface. Author opined that wet road and pedestrian combinations, and drunk & drive involved in the occurrence more accidents.

*Karl kim et al [93]* scrutinized the relationship between population size, land use and employment by sector, economic output and motor vehicle accidents. They noticed affirmative statistically important relationships between Jobcounts, populationsize, economic output and accidents. They observed the most of traffic related accidents happened in urban areas. They understood that these were more than ten times the total number of accidents happening in urban areas than to agricultural areas. He found a positive relationship between accidents and population, population revealed nearly 22.30 percentage of total variation in accidents. But, there were 18.80 percentage of the variation in vehicle to vehicle accidents and even less for pedestrian 13.60% and bicycle accidents 9.20%

*Qaderr [94]* built up poisson and binomial road accident regression prediction models for Great Britain to understand important variables for occurrence of accidents. The accident data was used from 1991 to 2002. The variables used were new year, Christmas, day, month, year, holidays, time, population density, population, length of road and police force. Friday and November were found to be most dangerous day and month for accidents. A few accidents occurred on holidays and new-year than other days. Population density, population, length of roads, day of week and police forces were observed to reveal the most of the variation in daily accident happenings.

*Richard Tay et al [95]* used logistic regression model to recognize the factors causing the happenings of hit and run fatal crashes in U.S.A, California. They opined that traffic flow, routes, roadway functional class, types of roadway section, roadway alignment traffic control equipment, speed limit and lighting condition leading to crashes.

*Yuanchang Xie et al [96]* Scrutinized crash injury severity using Bayesian ordered probit models. They noticed that drivers in old vehicles and senior drivers were liable to have slightly more severe injuries. under same crash circumstances, the opportunity for male drivers to suffer the most severe category of injuries was less than female drivers. They opined that drunk and driving was very hazardous and prominently increased the possibility of more severe injuries. Wet surfaces, junctions and adverse climate really led to lower possibility of suffering the most severe category of injuries.

*Lovegrove et al [97]* built up community based, microlevel

collision prediction model (CPM) using with a regional transportation plan. They extracted data from Columbia, Canada, British greater Vancouver including output from the regional transportation model. They observed that volume capacity and VKT were the dominant variables.

*Schultz et al (2010)* enquired in to the relationship between access management, other physical roadway characteristics and safety by linear regression scrutiny. Physical characteristics include road signal spacing, unsignalized access spacing and median openings. They noticed that crash rates were related to signal spacing such that every signal per 1.6 km corresponded to 0.48 crashes per MVKT 0.92 crashes per MVMT Additionally, road segments with adjacent commercial land use had on average 0.77 crashes per MVKT than did segments with adjacent residential land use. Posted speed limit was noticed to be negatively related to crash rate, with 16 kph increase relating to a reduction of less than one(0.44) additional crash per MVKT(0.71 per MVMT)(1.23 CRASHES PER MVMT)

*Yannis et al [98]* had done statistical investigation for using Greek drivers attitude data taken with in the scope of an extensive survey in 23 European countries. The study of analysis usefulness and consideration of new technologies by older drivers was submitted. The evolved ordered logit models provided insight in to the human factors aspect of the introduction of advanced technologies with respect to driver population.

*Clarke [99]* studied the years from 1994-2007, a sample of 2000 crashes involving drivers aged 60 year (Or) was considered from U.K midland police forces. Each case was sum up narratively with a sketch plan and a list of explanatory factors. It was mainly noticed that older drivers had important problems with intersection collisions and failing to give way correctly. These formed the tangent single class of crashes in the sample possible behavioral explanations.

*Domonique Lord and Mannering et al [100]* interacted the key issues combined with crash frequency data as well as the strength and weakness of the various methodological approaches to address these problems by the researchers.

*Deogratis et al [101]* used 2003 to 2007 crash data of Ohio, U.S to enquire in to the odds of a motorcyclist being fatally injured in a crash and the risk factors involved. The fatality rate was found as highest for those who were drug impaired(15.7%), then alcohol use (13.8%) and 4.8% respectively. Night time crashes liable to result in to a higher than average fatality rate of 4.8%. Other factors that shown higher than average fatality rate were bad weather condition (4.1%) weak end crashes (3.7%) and summer season 3.6%

*Xiugang Li et al [102]* Built-up accident modification factor for rural frontage road segments in Texas, using generalized additive models (GAM). They collected in Texas for 123 segments on rural frontage roads and noticed that GAM shown a non linear relationship between crash risk and changes in lane and shoulder widths for frontage roads. They took out crash data for 1997-2001 from texas public safety department and opined that lane and shoulder were observed

to be not fully independent.

Synopsis: Majority of the research work connected with social and economic variables accepted, population and pedestrian, while a study organized by Ashur considered only pedestrians.

## 8. Characteristics of Regression Models Used for Analyze Highway Crash Data

By the end of the literature study, researchers are identified some of the drawbacks of each model. The details of each model mentioned in Table 1

*Table 1. Advantages and Disadvantages of each model.*

Model type	Advantages	Disadvantages
Poisson	Most basic model; simple to estimate	negatively influenced by the low sample-mean and small sample size bias; Cannot handle over- and under-dispersion
Negative binomial/ Poisson-gamma	simple to estimate and can account for over-dispersion	can be adversely influenced by the low sample-mean and small sample size bias; Cannot handle under-dispersion
Poisson-lognormal	More flexible than the Poisson-gamma to handle over-dispersion	can be adversely influenced by the low sample-mean and small sample size bias cannot estimate a varying dispersion parameter; Cannot handle under-dispersion
Zero-inflated Poisson and Zero-inflated negative binomial	handle datasets that have a large number of zero-crash notes	zero-inflated negative binomial can be adversely influenced by the low sample-mean and small sample size bias; Can create theoretical inconsistencies
Conway–Maxwell–Poisson	be able to handle under- and over-dispersion or combination of both using a variable dispersion parameter	No multivariate extensions available to date; Could be negatively influenced by the low sample-mean and small sample size bias
Negative multinomial	Can account for over-dispersion and serial correlation; panel count data	Cannot handle under-dispersion; can be adversely influenced by the low sample-mean and small sample size bias
Zero-inflated Poisson and Zero-inflated negative binomial	handle datasets that have a large number of zero-crash notes	zero-inflated negative binomial can be adversely influenced by the low sample-mean and small sample size bias; Can create theoretical inconsistencies
Poisson – Weibull	It account for over-dispersion	Cannot handle under-dispersion; can be adversely influenced by the low sample-mean and small sample size bias
Gamma	be able to handle under-dispersed statistics	Dual-state model with one state having a long-term mean equal to zero
Generalized estimating equation	be able to handle under-dispersed statistics	Dual-state model with one state having a long-term mean equal to zero
Random-effects	be able to handle temporal relationship	Determine or evaluate the type of temporal correlation a priori; results sensitive to missing values

## 9. Conclusions

*By the end of the literature study, it is observed that*

- (1) Most of the parameters exhibit a non linear relationship with traffic Safety
- (2) Impact of speed limit increasing Injury Severity is Significantly high
- (3) Moreover, various geometric elements and traffic variables have significant influence on crash occurrences
- (4) The Negative binomial model along with log density function was the most appropriate statistical model for collected crash data
- (5) Possibility of rear-end-collision and also, road side accidents increase as access density increase.
- (6) Several International studies indicate an increase in overall crash as speed.
- (7) Further more, passing operation on two-lane roads have important effects on road safety
- (8) Research Indicates that both crash rates and severity of crashes are quick high at horizontal curves
- (9) Several studies Indicate a number of parameters which have significant Impact on road accidents: they are lane and shoulder width, horizontal and vertical alignment, road side condition, traffic control,

exclusive left-and right turn lanes, sight distance and driveway density

- (10) Wider lanes help in lowering crash rates as it provides a buffer against driver mistakes or distraction
- (11) Several models developed in the past have delineated crashes on horizontal curves on the basis of some parameters which include a AADT, length of curve, and degree of curvature.

In brief, it can be said that there had been growing body of literature on crash prediction models. Decades together Multiple Regression, Poisson and Negative Binomial regression models had been widely used to investigate accident count data. The previous researchers mostly had paid attention to the effects road environment such as number of accesses, traffic flow, lane width and road connectors. However, the median openings, number of horizontal curves and sign boards on accidents and causalities were rarely examined.

The entire review spun around the modelling of road crashes and it can be closed from the writing of different analysts that however there has been adequate measure of research in this field of road safety administration, still many creating nations have not possessed the capacity to diminish their offer of deaths in road crashes. Henceforth, much review is required in the field of traffic safety and planning.

Numerous future reviews open up here of research. In spite of

the fact that traffic congestion is an across the board issue for all developing nations and when we discuss India, it is positioned as top in number of accidents and incidental deaths every year in entire world, still investigations of activity wellbeing have been restricted to developed nations predominantly. The models normally utilized the regression innovations. They are great yet extremely old and regular. New methodologies like here genetic mining, fuzzy logics have been enhancing and furthermore are better other options to the old methodologies as these are more exact and programming focused so more easy to understand. More research on reconciliation of traffic safety with frameworks and programming ought to be finished. Better arranging methodologies with great administration framework ought to be utilized for turning away the dangers posturing accidents event.

---

## References

- [1] Shankar, V., Mannering, F. and Woodrow, B. (1994) "Effect of roadway geometrics and environmental factors on rural freeway accident frequencies", *Accident Analysis and Prevention*, Vol. 27, pp. 371-389.
- [2] Fridstrom, L., Ifver, J., Ingebrigtsen, S., Kumala, R., Krogsgard Thomsen, L., (1995). Measuring the contribution of randomness, exposure, Weather, and day light to the Variation in road accident counts. *Accident. Anal. Prev.* 27, 1-20.
- [3] Hadi, M. A., Aruldhar, J., Chow, L., Wattlewort, J. A., (1995). Estimating safety effects of cross section design of cross section design for various highway types using Negative Binomial regression. *Tranp. Res. Rec.*, 1500.
- [4] Vogt, A. and Bared, J., (1998) "Accident models for two-lane rural segment and intersections", *Transport Research Record* 1635, pp. 18-29.
- [5] Persaud, B., Retting, R. A, Lyon, C., (2000) Guidelines for the identification of Hazardous Highway Curves. *Tranp. Res. Rec.* 1717, 14-18.
- [6] Abdel-Aty, M. A., Essam Radwan, E. A., (2000). Modeling traffic accident occurrence and involvement. *Accid. Anal. Prev* 32, 633-642.
- [7] Karlaftis, G. M. and Golias, D. (2002) "Development of comprehensive accident models for two-lane rural highways using exposure, geometry consistency and context variables", *Accident Analysis and Prevention*, Vol. 34, pp. 357-365.
- [8] Martin, J. L, (2002). Relationship crash rate and hourly traffic flow on interurban motorways. *Accid. Anal. Prev.* 34, 619-629.
- [9] Glob, T. F., Recker, W. W., (2003) Relationship among urban freeway accidents, traffic flow, weather, and lighting conditions. *J. Trasp. Eng.* 129, 342-353.
- [10] Graham, D. J., and Glaister, S. (2003) Spatial variation in road pedestrian casualties: the role of urban scale. Density and Land-use Mix. *Urban Studies*, Vol. 48(8), pp. 1591-1607.
- [11] Griebe, P. (2003) Accident prediction models for urban roads. *Accident Analysis and Prevention*, Vol. 35, pp. 273-285.
- [12] Golob, T. F., Recker, W. W., Alvarez, V. M., (2004). Toll to evaluate safety effect of changes in freeway traffic flow. *J. Transp. Engg.* 130 (2).
- [13] Hauer, E., (2004) a. Statistical road safety modeling. In: *Proceedings of the 83<sup>rd</sup> TRB Annual Meeting*, Washington, DC, USA. January 11-15.
- [14] Hauer, E., (2004) b) Safety models for urban four-lane undivided road segments. In: *Proceedings of the 83<sup>rd</sup> TRB Annual Meeting*, Washington, DC, USA. January 11-15.
- [15] Seunglim Kang, Seongkwark, M. L. and Tshnangho, J. K., (2005) "A GIS based traffic accident analysis on highways using alignment related risk Indices", *Transportation Research Board., Annual meeting CDROM*.
- [16] Noland, R. B., Quddus, M. A., (2005). Congestion and safety: a Spatial analysis of London. *Transportation Research Part A: Policy and Practice* 39(7-9) 737-754.
- [17] Aguero-Valverde, J., and Jovanis, P. P. (2006) Spatial analysis of fatal and injury crashes in Pennsylvania. *Accident Analysis and Prevention*, Vol. 38, pp. 618-625.
- [18] Basyonny, E. K. and Sayed, T. (2006) "Collision prediction model using multivariate Poisson log normal regression", *Accident analysis and Prevention.*, Vol. 41, pp. 34-45.
- [19] Yannis, G., Elonora, P. and Constantinor, A., (2007) "Multilevel modeling for the regional effect of enforcement of road accidents", *Accident Analysis and Prevention.*, Vol. 39, pp. 818-825.
- [20] Yannis, G., John, G., and Elonora, P., (2010) "Modeling crossing behavior and accident risk of pedestrians", *Journal of Transportation Engineering*, ASCE., Vol. 133, pp. 634-644.
- [21] Wong, S. C., Sze, N. N. and Li Y. C., (2007) "Contributory factors to traffic crashes at signalized intersections in Hong Kong", *Accident Analysis and Prevention.*, Vol. 39, pp. 1107-1113, 2007.
- [22] Rengarasu, T. M., Hagiwara, T., and Hirasawa, M. (2007) Effects of road geometry and season on head-on and single-vehicle collisions on rural two lane roads in Hokkaido, Japan. *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 7, pp. 2860-2872.
- [23] Haneen Farah, Abishaipolus and Moshi, A., (2007) "Multivariate analysis for infrastructure based crash prediction model for rural highway", *Accident Analysis and Prevention.*, Vol. 41, pp. 887-894.
- [24] Haneen Farah, Shioma, B., and Polus, A., (2009) "Risk evaluation by modeling of passing behavior on two- lane rural highway", *Accident Analysis and Prevention*, Vol.41, pp. 887-894.
- [25] Nikiforos Stamatiadis, Dominique Lord and Jerry, P., (2010) "Safety impact of design element trade-offs for multilane rural highways", *Journal of Transportation Engineering*, ASCE., Vol. 35, pp. 1-24.
- [26] Quddus, A. M., Chao Wang and Stephen, G. I., (2010) "Road traffic congestion and crash severity: Econometric analysis using ordered response models", *Journal of Transportation Engineering*, ASCE., Vol. 136, No.5, pp. 424-435.
- [27] Wedagama, D. M. P., and Dissanayake, D. (2010) The influence of accident related factors on road fatalities considering Bali province in Indonesia as a case study. *Journal of Eastern Asia Society for Transportation studies*, Vol. 8, pp. 1905-1917.

- [28] Haque, Md. M., Chin, H. C., and Lim, B. C. (2010) Effects of impulsive sensation seeking, aggression and risk-taking behaviors on the vulnerability of motorcyclists. *Asian Transport Studies*, Vol. 1, pp. 165-180.
- [29] Chiou, Y., Lan, L. L., and Chen, W. (2010) Contributory factors to crash severity in Taiwan's freeways: genetic mining rule approach. *Journal of the Eastern Asia Society for Transportation Studies*, Vol.8, pp. 1865-1877.
- [30] Mustakim, F., and Fujita, M. (2011) Development of accident predictive model for rural roadway. *World Academy of Science, Engineering and Technology*, Vol. 58, pp. 126-131.
- [31] Sayed, T., Abdelwahab, W. and Navin, F., (1995) 'Identifying accident-prone locations using fuzzy pattern recognition', *ASCE Journal of Transportation Engineering*, Vol-121, No.4, pp.352-358.
- [32] Sayed, T. and Abdelwahab, W., (1997) "Using accident correct ability to identify accident prone locations", *Journal of Transportation Engineering, ASCE*, Vol-123, No.4, pp.107-113.
- [33] Milton and Mannering, (1998) "The relationship among highway geometrics, traffic related elements and motor-vehicle accident frequencies", *Journal of Transportation*, Vol.25, No.4, pp. 395-413.
- [34] Saccomanno, F. F., Grossi, R., Greco, D. and Mehmood, A., (2001) "Identifying black spots along highway SS107 in Southern Italy using two model", *Journal of Transportation Engineering, ASCE*, Vol. 127, No.5, pp. 515-522.
- [35] Ossenbruggen, J. P., Pedharkar, J. and Ivan, N. J., (2001) "Roadway safety in rural and small urbanized areas", *Accident Analysis and Prevention*, Vol. 33, pp. 485-498.
- [36] Ashur, A. S. (2003) "Evaluation of the national strategic plan for the traffic safety in UAE Transportation Research Board., Annual Meeting CDROM.
- [37] Xiao Qin, Ivan, N. J. and Nalini, R., (2003) "Selecting exposure measures in crash rate prediction for two-lane highway segments", *Accidents Analysis and Prevention*, Vol. 36, pp. 183-191.
- [38] Xiao Qin, Ivan, N. J., Ravishankar, N. and Junfeng, Liu, (2005) "Hierarchical Bayesian estimation of safety performance functions for two-lane highways using Markov chain Monte Carlo modeling", *Journal of Transportation Engineering, ASCE*, Vol.131, pp: 345-351.
- [39] Girma Berhanu, (2004) "Models relating traffic safety with road environment and traffic flows on arterial roads in Addis Ababa", *Elsevier*, Vol.36, pp. 697-704.
- [40] Jutaek oh, Simon., W., and Keechoochoi, (2004) "Development of accident prediction models for rural highways intersections", *Transportation Research Board., Annual meeting CD-ROM*.
- [41] Mohamadreza Banihashemi, Dimaiuta and Michael, (2005) "Maximizing safety improvement benefits in crash prediction models with accident modification factors (AMFs)", *Transportation Research Board., Annual Meeting CD-ROM*.
- [42] Minwook, Kang, Taehyungkim and Tceolwoong Doh, (2005) "A new methodology to determine length of highway horizontal curve sections for accident estimation model", *Transportation Research Board., Annual Meeting CD-ROM*.
- [43] Jun-Seok Oh, Cheol Oh and Stephen, (2005) "Real time estimation of accident likelihood for safety enhancement", *Journal of Transportation Engineering, ASCE*, Vol.131, No.5, pp. 358-363.
- [44] Dominique Lord and Bonneson, A. J. (2006) "Role and application of accident modification factors (AMFs) within the highway Design process", *Transportation Research Board., Annual Meeting CD-ROM*.
- [45] Pardillo, M. J., Rafael, B. and Alberto, (2006) "Refinement of accident prediction models for the Spanish national network" *Transportation Research Board., Annual Meeting CD-ROM*.
- [46] Akgungor, P. A., and Osman Yildiz (2007) "Sensitivity analysis of an accident prediction model by the fractional method", *Accident Analysis and Prevention*, Vol.39, pp. 63-68.
- [47] Ciro Caliendo, Maurizio Guida and Alessadra Parisi (2007) "A crash prediction model for multilane route", *Accident Analysis and Prevention*, Vol. 39, pp. 657-670.
- [48] Haneen Farah, Shioma, B., and Polus, A., (2009) "Risk evaluation by modeling of passing behavior on two-lane rural highway", *Accident Analysis and Prevention*, Vol.41, pp. 887-894.
- [49] Yi (Grace) Qi, Smith, L. B. and Jianhan, G., (2007) "Freeway accident likelihood prediction using a panel data analysis approach", *Journal of Transportation Engineering, ASCE*, Vol-133, pp. 149-155.
- [50] Lovegrove, G., Clarklim, M. and Sayed, T., (2010) "Community-based, macro level collision prediction model: use with a regional transportation plan", *Journal of Transportation Engineering, ASCE*, Vol.136, pp. 120-128.
- [51] Kay Fitzpatrick, Dominique Lord and Byung-Jung, P., (2010) "Horizontal curve accident modification factor with consideration of driveway density on rural four-lane highway in Texas", *Journal of Transportation Engineering, ASCE*, Vol-136, No.9, pp. 827-835.
- [52] Salvatore Cafiso, Alessandro, D. G. and Grazia, B.(2010) "Development of comprehensive model for two-lane rural highways using exposure, geometry, consistency and context variables", *Accident Analysis and Prevention*, pp. 1052-10.
- [53] Seva, R. R., Flores, G. M. T., and Gotohio, M. P. T. (2012) Logit model of motorcycle accidents in the Philippines considering personal and environmental factors. *International Journal for Traffic and Transport Engineering*, Vol. 3(2), pp. 173-184.
- [54] Obaidat, M. T., and Ramadan, T. M. (2012) Traffic accidents at hazardous locations of urban roads. *Jordan Journal of Civil Engineering*, Vol.6(4), pp. 436-447.
- [55] Anowar, S., Alam, Md. D., and Raihan, Md. A. (2013) Analysis of accident patterns at selected intersections of an urban arterial. *Proc. of 21stITCT Workshop, Melbourne*.
- [56] Solomon, D. and Cirillo, J. A., (1974) "Accidents on main rural highways related to speed, driver and vehicle", *Federal Highway Administration., Washington, D. C.*
- [57] Garber Gadhiraaju, (1988) "Factors affecting speed variance and its influence on accidents", *Transportation Research Record*, No.1213, pp. 64-71.

- [58] John Collins G. and Helen, S., Tzivelou, (1998) "Aspects of road-accident death analysis", *Journal of Transportation Engineering, ASCE.*, Vol.118, No.2, pp. 299-311.
- [59] Kloeden, C. N., Ponte, G., and McLean A. J. (2001) Travelling speed and the risk of crash involvement on rural roads. Department of Transport and Regional Services Australian Transport Safety Bureau, Report no. CR 204, ISSN 1445-4467.
- [60] Karlaftis, G. M. and Golias, D., (2002) "Development of comprehensive accident models for two-lane rural highways using exposure, geometry consistency and context variables", *Accident Analysis and Prevention*, Vol. 34, pp. 357-365.
- [61] Taylor, M. C., Lynam, D. A., and Baruya, A. (2000) The effects of drivers' speed on the frequency of road accidents. Transport Research Laboratory Report 421, ISSN 0968-4107.
- [62] Hills, B. L., Baguley, C. J., and Kirk, S. J. (2002) Cost and safety efficient design study of rural roads in developing countries. Transport Research Laboratory, Project Report PR/INT/242/02.
- [63] Xuedong Yan, Essam, R., Mohamed, A. A., (2005) "Characteristics of rear-end accidents at signal intersections using multiple logistic regressions Model", *Accident Analysis and Prevention.*, Vol. 37, pp, 983-995.
- [64] Letty, A. and Ingrid Van, S., (2006) "Driving speed and the risk of road crashes", *Accident Analysis and Prevention*, Vol.38, pp. 215-224.
- [65] Goldenbeld, and Ingrid Van Schagen, (2007) "The credibility of speed limit of 80 kmph on rural roads: The effects of road and person (ality) characteristics", *Accident Analysis and Prevention.*, Vol. 39, pp. 1121-1130.
- [66] Chanyu Kong and Jikuang Yang, (2010) "Logistic regression analysis of pedestrian causality risk in passenger vehicle collisions in China", *Accident Analysis and Prevention*, Vol. 42, pp. 987-993.
- [67] Surenchen and Fengchen, (2010) "Simulation-based assessment of vehicle safety behavior under hazardous driving conditions", *Accident Analysis and Prevention*, Vol.136, No.4, pp.304-315.
- [68] Wael, H. A. and Bruce, N. J.(1998) "Prediction models for truck accidents at freeway ramps in Washington State using regression and A Techniques", *Transportation Research Board* 1635., pp. 30-36.
- [69] Lynn Meuleners, (2006) "Estimating crashes involving heavy vehicles in Western Australia", *Accident Analysis and Prevention*, Vol.38, No.1, pp. 170-174.
- [70] Landge, V. S., Parida, M. and Jain, S. S., (2006) "Modeling traffic accidents on two- lane rural highway under mixed traffic conditions", *Transportation Research Board.*, Annual Meeting CD-ROM.
- [71] Joon-Kikim, Yin Hai Wang and Ularsson, F. G., (2007) "Modeling the probability of freeway rear-end crash occurrence", *Journal of Transportation Engineering, ASCE.*, Vol.133, No.1, pp.11-19.
- [72] Janine Duke, (2010) "Age-related safety in professional heavy vehicle drivers", *Accident Analysis and Prevention*, Vol.42, No.2, pp.364-371.
- [73] Sravani Vadlamani, Erdoong Chen, and Washington, S., (2011) "Identifying large truck hot spots using crash counts and PDOE", *Journal of Transportation Engineering, ASCE.*, Vol.137, No.1, pp. 11-20.
- [74] Fridstrom and Ingridgen, (1991) "Multilevel modeling for the regional effect of enforcement of road accidents", *Accident Analysis and Prevention.*, Vol. 39, pp. 818-825.
- [75] Ogden, K. W., (1997) "The effects of paved shoulders on accidents on rural highways", *Accident Analysis and Prevention.*, Vol. 29, pp. 353-362.
- [76] John Collins, Kay Fitzpatrick, Bauer, M. K. and Douglas W. H. (1998), "Speed variability on rural two-lane highways", *Transportation Research Board*, Washington D. C., pp. 1-16.
- [77] Ivan, N. J., Chunyan Wang and Bernardo, R. N., (1999) "Explaining two-lane highway crash rates using land use and hourly exposure", *Accident Analysis and Prevention.*, Vol. 32, pp. 787-795.
- [78] Hassan, Y., Gibreel, G. and Easa, S. M., (2000) "Evaluation of highway consistency and safety practical application", *ASCE Journal of Transportation Engineering.*, Vol-126, pp. 193-200.
- [79] Feiyuan, Xia Quin, Norman, W. G. and Christian, F. D. (2000) "Safety benefits of intersection approach realignment on rural two-lane highways", *Transportation Research Record* 1758, pp. 21-29.
- [80] Hassan, T., Abdel Wahab and Abdel-Aty, A. M., (2001) "Development of artificial neural network models to predict driver injury severity in traffic accidents at signalized intersections", *Transport Research Record* 1746., pp. 6-13.
- [81] Noland, B. R., (2001) "Traffic fatalities and Injuries: Are reductions the result of improvements in highway design?". *Transportation Research Board.*, Annual Meeting, Washington, DC.
- [82] Jean-Louis, M. and Robert, Q., (2001) "Cross over crashes at median strips equipped with barriers on a French motor way network", *Transportation Research Record* 1758, pp.6-12.
- [83] Christo J Bester (2003) "The effect of road roughness on safety", *Transportation Research Board.*, Annual Meeting CD-ROM.
- [84] Clark, E. D. and Cushing, M. B. (2004) "Rural urban traffic fatalities, vehicle miles, and population density", *Accident Analysis and Prevention.*, Vol. 36, pp. 967-972.
- [85] Moore, E. J., Ginliano, G. and Seongkil cho, (2004) "Secondary accident rates on Los Angeles Freeways", *Journal of Transportation Engineering, ASCE.*, Vol-130, pp. 280-285.
- [86] Casaer Filip, Geert Wets and Thomas, I. (2004) "Road traffic accident clustering with categorical attributes", *Transportation Research Board.*, Annual meeting CD-ROM.
- [87] Vivian Robert, R. and Veeraragavan, A., (2004) "Hazard rating scores for prioritization of accident prone sections on highways", *Transportation Research Board.*, Annual Meeting CD-ROM.
- [88] Filip Van Den Bossche, Geert Wets and Tom Brijs (2004) "A regression model with ARMA errors to investigate the frequency and severity of road traffic accidents", *Transportation Research Board.*, Annual Meeting CD-ROM.

- [89] Pei Lin and Hsien-Guo Young, (2004) "A neural network approach on studying the effect of urban signalized intersection characteristics on occurrence of traffic accidents", Transportation Research Board., Annual Meeting CD-ROM.
- [90] Kumara, S. S. P. and Chin, H. C., (2004) "A study of petal traffic accidents in Asia Pacific countries", Transportation Research Board., Annual Meeting CD-ROM.
- [91] Khaled, A. Abbas, (2004) "Traffic safety assessment and development of predictive models for accidents on rural roads in Egypt", Accident Analysis and Prevention., Vol.36, pp. 149-163.
- [92] Rune Elvik, (2006) "A new approach to accident analysis for hazardous road locations", Transportation Research Board., Annual Meeting CD-ROM.
- [93] Karl Kim, Made Brunner and Eric Yamashita, (2006) "The influence of land use, population, employment and economic activity of accidents," Transportation Research Board., Annual Meeting CD-ROM.
- [94] Qadeer, M. A., (2006) "Road accident prediction models developed from a national database; Poisson and negative binomial regressions", Transportation Research Board., Annual Meeting CD-ROM.
- [95] Richard Tay, Upal Barna and Lina Kattan, (2009) "Factors contributing hit and-run in fatal crashes", Accident Analysis and Prevention., Vol.41, pp.227-233.
- [96] Yuanchang Xie, Yunlong, Z., Faming, L., Joon-kikim, Yin Hai, W. and Ullarsson, F. G., (2009) "Modeling the probability of freeway rear-end crash occurrence", Journal of Transportation Engineering, ASCE., Vol.133, No.1, pp.11-19.
- [97] Lovegrove, G., Clarklim, M. and Sayed, T., (2010) "Community-based, macro level collision prediction model: use with a regional transportation plan", Journal of Transportation Engineering, ASCE., Vol.136, pp.120-128.
- [98] Yannis, G., John, G., and Elonora, P., (2010) "Modeling crossing behavior and accident risk of pedestrians", Journal of Transportation Engineering, ASCE., Vol. 133, pp. 634-644.
- [99] Clark, E. D. (2010) "Older driver's perception and acceptance of in-vehicle devices for traffic safety and traffic efficiency", Journal of Transportation Engineering, ASCE., Vol.136, pp. 472-479.
- [100] Dominique Lord and Bonneson, A. J. (2006) "Role and application of accident modification factors (AMFs) within the highway Design process, "Transportation Research Board., Annual Meeting CD-ROM.
- [101] Deogratias, Vamsikrishna and Peter Honey (2010) "Identification of risk factors associated with motorcycle related fatalities in Ohio", Journal of Transportation Engineering, ASCE., Vol.4, pp. 1-13.
- [102] Xiugang Li, Dominique, L., and Yunlong, Z., (2011) "Development of accident modification factors for rural frontage road segments in Texas using Generalized Additive Models", Journal of Transportation Engineering, ASCE., Vol. 137. pp. 74-83.
- [103] Niveditha. v, Ramesh. A, Kumar. M., (2015) "Development of models for crash prediction and collision Estimation-A case study for Hyderabad City", International Journal of Transportation Engineering vol3/No.2/Spring.
- [104] Naveenkumar. C, Manoranjan Parida., Jain S. S., (2016) "Identifying safety factors Associated with crash Frequency and severity on Non urban Four lane Highway Stretch in india,". Journal of Transportation Safety & Security.