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REVIEW OF RECENT TRENDS IN ROAD ACCIDENT MODELING
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ABSTRACT
Road accident fatalities have been on an increasing trend for the last decade or so. Hence traffic safety management has emerged as a topic of discussion for researchers all over the world. This becomes more important for India, which is a developing country, where its number has increased from over the decades with rise in population and increasing number of vehicles being seen as important factors. Many researchers in India and abroad have tried to quantify different environmental, personal and pavement factors for the cause of accidents by conducting surveys in a particular city and developing different models on it showing the contribution of different factors in accidents. Still much of the efforts are required in this area as the conditions of each and every place differs from another. Our objective is to study various models developed for the accidents and critically review such models. Hence, different accident models over the years have been reviewed here to make a comparative analysis of the accuracy of different models that have been used by the researchers in their studies. Review resulted that male teenagers are the most affected victims of the road crashes. Also various statistical techniques were used to model the road crashes and quantifying the other factors like roadway, geometrical, personal and environmental factors. Gaps in the studies have been found out in this review and further areas of research have been indicated.

1 INTRODUCTION
Road accidents are very common all over the world and annual global road crash statistics (Association for Safe International Road Travel, 2013) states that:

- Nearly 1.3 million people die in road crashes each year, on average 3,287 deaths a day. An additional 20-50 million are injured or disabled.
- More than half of all road traffic deaths occur among young adults ages between 15 to 44.
- Road traffic crashes rank as the 9th leading cause of death and account for 2.2% of all deaths globally.
- Road crashes are the leading cause of death among young people ages between 15 to 29, and the second leading cause of death worldwide among young people ages between 5 to 14.
- Each year nearly 4,00,000 people under the age of 25 die on the world’s roads, on average over 1,000 a day.
- Over 90% of all road fatalities occur in low and middle-income countries, which have less than half of the world’s vehicles.
- Road crashes cost USD $518 billion globally, costing individual countries from 1-2% of their annual GDP. (1 USD = 64 INR).
- Road crashes cost low and middle-income countries USD $65 billion annually, exceeding the total amount received in developmental assistance. (1 USD ≈ 64 INR).
- Unless action is taken, road traffic injuries are predicted to become the fifth leading cause of death by 2030.

During the calendar year 2010, (MORT&H, 2010) number of road accidents in India is around 5 lakhs and number of deaths due to those accidents is 1.3 lakhs. Number of injuries due to those accidents is 5.2 lakhs. The conclusion emerging from data is, 1 accidental death every 4 minutes and 1 road accident every minute.

If the age group and the accident data are compared, it is seen that 55% of road accident victims fall in the age group of 25-65 years while out of rest 45%, 40% of road accident victims come from the age group of 16-24 years. It’s a startling fact that the age gap 16-24 is very small compared to 25-65, but still around 40% victims of road accidents are found in this age group. Hence we can easily come to a conclusion that the adolescents are very much prone to and contribute to most of the accidents in India. (MORT&H, 2010).

Hence, traffic accidents and their safety is a major area of research. So, in this paper, some important models developed for traffic safety along with researches conducted on the topic are studied and are reviewed thoroughly. Also the future scope of the study is discussed in detail.

2 FACTORS RESPONSIBLE FOR ACCIDENTS
Traffic safety and accident studies have been in the research area for last two decades extensively as the rise of accidents have been alarming across the world. From the works done by researchers, it can be said that traffic accidents are caused due to mainly four factors i.e.

1. Personal or human behavioral factors
2. Environmental factors
3. Road geometric factors
4. Traffic factors

Personal or human factors mainly include the age of driver or victim, gender of the victim, was he drunk while driving, etc. Similarly, environmental factors include the general factors of climate and environment, lighting conditions of road, time of accident, i.e. day or night, pavement conditions,

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etc. Road geometric factors include the type of junction or intersection, then horizontal slope, curves, etc. present on the road, due to faults of which, accidents may occur. At the end come traffic factors. This mainly includes the speed, density, traffic flow parameters that may lead to accidents (Mohanty and Gupta, 2014).

3 MODELS FOR TRAFFIC SAFETY
Many models have been devised by the researchers in past for accident safety, causes of accidents safety, accident severity crashes, etc. and also precautionary measures have been stated. Though the most common models used are the regression models, but there are many other techniques that have been used in the modeling by the researchers. Some of them are:
1. Genetic mining approach
2. Logit models, both multinomial and binomial
3. Regression models which includes various types like linear, non-linear, logistic regression techniques
4. Bayesian-cohort model, etc.

Most of the researchers use different regression techniques as it is both simple and also provide a better goodness of fit model with correlation coefficient coming nearly equal to 1. This paper has divided the traffic safety models mainly into two parts under which they will be studied. They are:-
1. Accident study in urban roads
2. Accident study in rural roads

4 ACCIDENT STUDY IN URBAN ROADS
Graham and Glaister (2003) examined the role of urban scale, density and land-use mix on the incidence of road pedestrian casualties. The study concluded that the incidence of pedestrian casualties and Killed and Seriously Injured (KSI) were higher in residential areas than in business areas. In addition, urban density was found to have quadratic relation with high correlation coefficient with pedestrian casualties.

Noland and Quddus (2005) developed a disaggregate spatial analysis based on enumeration district area to examine the effect of congestion on traffic casualties (KSI and slight injuries). Negative binomial models were used to analyze the factors affecting casualties during congested and uncongested periods. The study result showed that traffic casualties are likely to happen on higher speed roads and motorways but not during traffic congestion.

Aguero-Valverede and Jovanis (2006) developed Full Bayesian (FB) and negative binomial models to carry out spatial analysis of fatal and injury crashes in Pennsylvania. The study used counties as the spatial unit. The study concluded that counties with:
1. a higher percentage of the population under poverty level,
2. higher percentage of their population in age groups 0-14, 15-24 and over 64, and
3. increased road mileage and road density have significantly increased crash risk.

H. Al-Madani and A. Al-Janahi (2006) studied the personal background of the pedestrians who were involved in road crashes in the urban highways of Bahrain. The findings revealed that personal characteristics considered in this study have significant influence on pedestrian's involvement in traffic accidents. The results also showed that pedestrians with the following characteristics were probably showing risk to exposure to accidents more than other categories: male, young (0–12 years) and old (50 years and over), non-local, and those with low educational background.

Wedagama and Dissanayake (2010) studied the influence of accident related factors on road fatalities considering Bali province in Indonesia as a case study. The study found that the ratio of fatal accident due to male motorcyclists and motorists at fault were 30 and 40 percent lower than for females respectively. In addition, age was also significant to influence all vehicle fatalities. Age was accounted for about 50% to influence all vehicle fatalities.

Three models were used by author to study the goodness of fit with greater accuracy. They were:
- Cox and Snell Pseudo-R² model
- Nagelkerke Pseudo-R² model
- Hosmer-Lemeshow test

Hauque et al. (2010) performed a detailed study of accidents and severity crashes involving motorcycles as vehicles. They mainly considered the risk-taking behavior and aggression of drivers on the vulnerability of motorcyclists. The main objective of their study was to evaluate how behavioral factors influence the crash risk and to identify the most vulnerable group of motorcyclists. A questionnaire containing 61 items of aggression, and risk-taking behaviors was developed. By clustering the crash risk using the medoid portioning algorithm, a log linear model relating rider behaviors to the crash score/number was developed by him. Aggressive and high risk-taking motorcyclists are more likely to fall under the high vulnerable group. Defining personality types from aggression and risk-taking behaviors, “Extrovert” and “Follower” personality type of motorcyclists are more prone to crashes.

Obaidat and Ramadan (2012) studied the traffic accidents at 28 hazardous locations of urban roads at Amman-Jordan roads. Their study found that the logarithmic and linear models were the most significant and realistic models that can be used to predict the relationship between the accident characteristics as a dependent variable and the other studied variables as independent variables. The developed
models were strong and predictable because the coefficient of multiple determinations was very close to the adjusted coefficient of multiple determinations. The following variables were found to be the most significant contributors to traffic accidents at hazardous locations: average running speed, posted speed, maximum and average degree of horizontal curves, number of vertical curves, median width, type of road surface, lighting (day or night), number of vehicles per hour, number of pedestrian crossing facilities and percentage of trucks.

G. Tiwari et al. (2013), studied the statistical analysis of pedestrian risk taking behavior while crossing the road, before and after the construction of a grade separator at an intersection of Delhi. The results indicate that absence of signals make pedestrians behave independently, leading to increased variability in their risk taking behavior. Variability in the speeds of all categories of vehicles has increased after the construction of grade separators. After the construction of the grade separator, the waiting time of pedestrians at the starting point of crossing has increased and the correlation between waiting times and gaps accepted by pedestrians show that after certain time of waiting, pedestrians become impatient and accepts smaller gap size to cross the road. A Logistic regression model is fitted by assuming that the probability of road crossing by pedestrians depends on the gap size between pedestrian and conflicting vehicles, sex, age, type of pedestrians (single or in a group) and type of conflicting vehicles. The results of Logistic regression explained that before the construction of the grade separator the probability of road crossing by the pedestrian depends on only the gap size parameter; however after the construction of the grade separator, other parameters become significant in determining pedestrian risk taking behavior.

**DISCUSSION**

The various accident models discussed here shows that regression models are most commonly used in the field of traffic safety by the researchers, though it should also be marked that some new models have also been in the study like the Multinomial Logit i.e. MNL, Bayesian method and negative binomial distribution. Almost all the factors have been studied by different authors, which seem to affect the accidents in urban areas. Except Obaidat and Ramadan (2012), others have tried to investigate single factor causing accidents in detail, not taking all factors at a time. After going through all the above mentioned models, it seems that the study by Obaidat and Ramadan (2012) is the most accurate as it has considered almost all factors responsible for accidents. Although it seems to be the most accurate but they could have prepared much better model like logit or logistic regression for more accuracy though. Similarly the study conducted on age and gender factors affecting accidents in Bali province, Indonesia by Wedagama and Dissanayake (2010), was a very narrow model (considered less number of factors) but in terms of analysis it was a model which involved much statistical analysis for a greater accuracy. The study by Hauque et al. (2010) was quite common but the variables taken were new. Overall, it was a good motorcycle accident survey and modeling. Graham and Glaister (2003) did a full-fledged urban study where the urban density of population, land use pattern have been taken into consideration which are believed to be the important factors in urban areas. Negative binomial provides result with good accuracy when the probability of occurring is very less. Noland and Quddus (2005) in their study added a factor of traffic congestion to the above discussed studies which was significantly a fresh addition to their model, but the study only takes a single factor into account. The model is based on that same as previous i.e. the negative binomial distribution. Study of personal/human behavior, road geometry and traffic conditions for occurrence of accidents was done by Aguero-Valverede and Jovanis (2006). It was again a good study with good accuracy considering the methods used for analysis i.e. the negative binomial and Bayesian methods.

**5 ACCIDENT STUDY IN RURAL HIGHWAYS**

Hills et al. (2002) developed a safe and cost-efficient model for rural roads designing in developing countries considering the accidents occurred there. They selected 5 countries for their study and developed separate models for each of them. The countries were Zimbabwe, Botswana, Malawi, Tanzania, India and Nepal. There were three areas of data collection: (i) highway surveys; (ii) accident data collection; and (iii) highway design drawings and detailed breakdowns of construction costs. They used the Generalized Linear Modeling technique (GLIM) for modeling the data collected. For the Nepal/India dataset, it was found that a reasonable model fit could be made for all accident types but that the numbers of individual accident types were too small to produce reliable individual models. As in the Papua New Guinea study, curvature and gradient proved to be significant explanatory variables, both increasing accident rates the sharper the curve or steeper the gradient. According to the model, the presence of a marked edge line in Nepal and India appears to be particularly beneficial in reducing accident rate.

Rengarasu et al. (2007) investigated the road geometry factors and the seasonal factors associated with head-on collisions and single vehicle collisions occurred in Hokkaido, Japan. Head-on collisions represent about 20% of all traffic collisions on
the rural two lane national roads however; head-on collisions were responsible for about 40% of the fatal collisions. They developed a segmented accident database based on Traffic Accident Analysis System (TAAS) produced by Civil Engineering Research Institute for Cold Region Hokkaido. Analysis using Poisson-regression models showed that road geometry factors and seasonal factors were important factors correlated with head-on collisions.

Hagiwara et al. (2010) estimated various factors on number of fatal and injured accidents in highways in Japan outside cities which are usually considered as rural roads by using the data of past 25 years. This study investigated the effects of changes in patterns of age, period and cohort on the number of fatal and injured accidents quantitatively through the use of a wide ranging set of statistical techniques. They used the Bayesian-cohort model for their study.

Mustakim and Fujita (2011) developed an accident predictive model for rural road way based on the data collected at rural roadway, Federal route 50, Malaysia. They carried out black spot study to develop accident predictive models. Multiple non-linear regression method was used to relate the discrete accident data with the road and traffic flow explanatory variable. Their results showed that the existing number of major access points, without traffic light, rise in speed, increasing number of Annual Average Daily Traffic (AADT), growing number of motorcycle and motorcar and reducing the time gap are the potential contributors of increment accident rates on multiple rural roadway.

R.V. Ponnaluri (2012), analysed, interpreted and provided some techniques for prevention of rural road crashes in India taking into account the study of Andhra Pradesh, a state in India. Recommended prevention strategies include: developing a road accident recording system and an access management policy; integrating safety into corridor design and road construction; undertaking capacity building efforts; and expanding emergency response services.

J. W. H. Van Petegem and F. Wegman (2014), analysed the road design risk factors for off-road crashes in the rural roads of Netherland. About 50% of all road traffic fatalities and 30% of all traffic injuries in the Netherlands take place on rural roads with a speed limit of 80 km/h. About 50% of these crashes are Run-Off-Road (ROR) crashes. The results comprise two important outcomes. One is a Crash Prediction Model (CPM) to estimate the relative safety of rural roads with a speed limit of 80 km/h in a network. The other is a small set of estimated effects of traffic volume and road characteristics on ROR crash frequencies.

**DISCUSSION**

The model by Hagiwara et al. (2010) is unique considering the factors taken by them i.e. the age, cohort, and period in Japan but few more factors could have been considered by them for study and the factors like cohort and period are only reliable in case of Japan and they are specific for their conditions which may not be applicable to any other place. Mustakim and Fujita (2011) did a nice full-fledged study on all aspects of traffic factors related to occurrence of accidents. Even the model used gives good results when goodness of fit is considered. Rengarasu et al. (2007) studied road geometric factors in detail in their paper and also regression models were developed with better correlation coefficient values. It’s a good study considering one aspect of traffic safety has been researched deeply. Among the reviewed models, the most accurate study in this field seems to be done by Hills et al. (2002). It’s a good model considering the research was spread over 5 developing countries including India, and comparison of models were also done. Also the factors considered were appropriate considering that the models were developed for different countries. The study by R. V. Ponnaluri (2012) is an eye opener of crashes in India as the results depicts the truth that is usually the roads made in India have defective designs due to which most of the collisions during merging or overtaking occurs at the uncontrolled intersections. In brief it can be said that in rural areas, the most important causative variable affecting road crashes is speed of the vehicle.

**6 COMPARATIVE ANALYSIS OF RURAL VS. URBAN ROAD CRASHES**

National Center for Statistics and Analysis (NCSA) completed a study based on the data from Fatal Accidents Reporting System (FARS) for the period 1975-1993 comparing the rural and urban road crashes. The detailed analysis was provided by J. M. Tessmer (1996). According to the study, 40% more crashes occur on rural roads while number of vehicles travelling on those roads are less. It was noted that rural fatal crashes compared to urban fatal crashes, have a larger proportion of crashes with:

- more than one fatality per crash;
- a truck involved;
- a vehicle rollover;
- severe vehicle damage;
- a head-on collision; and
- ejected persons.

In addition the medical services require more time to reach rural road crash sites. Even crashes in rural areas have a larger proportion involving:

- more than one person per vehicle;
- a single vehicle;
- a truck or van;
- a vehicle rollover;
- striking a fixed object;
- severe vehicle damage; and
- serious injury.
7 CONCLUSIONS
1. It can be concluded easily that much of the study in transportation and traffic engineering have been in the field of traffic safety and planning.
2. Statistical methodologies have been used to model the data and findings obtained from survey for a better and easy understanding. The most common models used are the regression techniques (linear, logistic, multiple) and few authors use regression techniques for finding goodness of fit and then model the equations and coefficients into multinomial logit models.
3. The five leading causes of death among teenagers are Accidents (unintentional injuries), homicide, suicide, cancer, and heart disease. Accidents account for nearly one-half of all teenage deaths.
4. In case of accidents in urban roads, many variables like age of drivers, gender, running speed, road conditions, lighting conditions, etc. are found to be the causative agents of accidents.
5. It can also be seen that researchers usually try to focus on one variable that cause accidents and study it thoroughly rather than considering all factor at a time.
6. In urban road accidents study, some models developed were very accurate considering the used of all forms of regression i.e. linear, nonlinear and multiple linear regressions.
7. In rural road accidents, it is observed that mostly researchers consider speed as a major cause for accidents to occur.
8. Few studies also considered almost every possible factor affecting accidents in rural roads and also a new software based algorithm and approach was used known as the genetic mining approach for modeling the data.
9. Results of the research conducted by few researchers have showed that the major cause of traffic accidents was careless driving (71%) in developing countries.

8 FUTURE SCOPE OF STUDY
1. Though many studies have been done in this traffic safety field, but developing countries like India have not been explored much by the researchers.
2. The regression technologies are good but very old and conventional. New approaches like genetic mining, fuzzy logics have been improving and also are better alternatives to the old approaches as these are more accurate and software oriented so more user friendly. Advances and research on developing more easy techniques with lesser calculations involved with greater accuracy should be looked for.
3. Integration of traffic safety with systems and software should be an area to research on.
4. Better planning strategies with good management system should be employed for averting the risks posing accidents occurrence.