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Pedestrian Accident Prediction Modeling

A Review of Recent Studies

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Abstract

Over 1.2 million people die each year on roads, and between 20 and 50 million suffer non-fatal injuries. In most of the developing countries this epidemic of road accident injuries is still increasing. Road traffic accidents are a major but ignored worldwide problem, requiring intensive efforts for effective prevention. Of all the systems that people have to deal with on a daily basis, road transport is the most complex and the most dangerous. A broad approach is required for improving road safety and reducing the death toll on their roads. In the similar course in this study an attempt has been made to figure out frequent elements which are accountable for accident study in India to develop methods which would provide solution for the same, based on the earlier literature. The studies conducted and stated in the past ten years along with their outcomes and approaches adopted have been reported in this paper. The researchers have also tried to tabulate important explanatory variables and significant.

Although researchers are assuming new methods and many independent variables are being tried into accident prediction modelling but still the outcomes are not decisive.There is a scarcity of studies, which has so far tried to predict accidents by injury severity in India. Comparative influence of variables and effectiveness of different

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modelling techniques also needs to be tested for different data sets.

Keywords: *Road Accidents, Pedestrian Safety, Accident Prediction Model.*

INTRODUCTION

National Highways (NH) and State Highways (SH) comprises of more than 70% of the entire traffic. Pedestrian Safety has become a foremost concern on these highways. The problem is particularly grave when NH and SH pass through rural areas and small cities. The traffic and activities of local people about the highway is the main source of congestion at daytime and turn into a bottleneck for fast moving through traffic. At night when the traffic volume is low, these roads become a safety threat for pedestrian as well as road user. Traffic Calming practices has arisen mainly as a society's reaction to concern for pedestrian road safety. It is well recognized by the researchers that variations in the speed, direction, and size of the vehicles generally govern the severity of road accidents. There is much less variation in direction and vehicle mass. Traffic Calming Practices have played a significant role in attaining safety by ensuring little driving speeds between different road users. The total information from different countries indicates that speed limit, signs and other visual measures alone are not always adequate to aware the drivers about an suitable speed. But when combines with other physical speed calming measures, noteworthy effects can be witnessed. Though, this is not for India as we have a much more diverse fusion of road traffic.

ROAD SAFETY SCENARIO

Daily number of people met with fatal and serious accidents on our roads. Lots of people every year will spend long time in hospitals after severe accidents and several people will never be capable to live their normal life again. Road accidents constitute a main public health crisis, and are forecast to upsurge if road safety is not addressed effectively.

Over 1.2 million people met with fatal accidents every year on roads, and about 50 million suffer injuries. A broad attitude in improving road safety and dropping the death rate on the roads is essential. Developing and under developing countries have higher road traffic fatality rates than developed countries. More than 90% of the fatalities on the roads occur in underdeveloped countries containing only 48% of the total registered vehicles in the world.

The financial cost of road traffic accidents is huge. It is estimated that about US$ 500 billion is consumed on road traffic accidents with under developed and developing countries. For every person killed, injured or disabled by a road accident there are numerous others deeply affected by these accidents. Numerous families are driven into poverty by the expenditures of continued medical care or the loss of a family lone bread-earner.

LITERATURE REVIEW

Road safety is a problem all over the world. Each year millions of people die or get severely injured in traffic accidents. The majority of accidents occur in urban areas. The reason for this is the constant interaction between vehicles and pedestrian. Accidents come with a great cost for the victim and for the society. Speed plays a central role in traffic safety, more and more traffic researchers come to that conclusions. The reason for strong influence of speed on traffic safety is the many negative effect that speed produces. The present

section presents the past studies related to the study.

Liyanage and Rengarasu[1] mentioned that as per WHO report more than 1.3 million people die each year in traffic accidents and disable millions of people annually worldwide. According to traffic offenses details for the first six months of year 2010, there were around 270,000 traffic accidents in Sri Lanka. In recent years, increased attention has been directed at traffic based accident severity prediction. This problem needs a greater attention than what it is getting now. There are very few researches and studies have been done to arrange a proper planning and analysis system in this case. Thus the requirement for proper planning and prediction system for accident analysis has risen up. The main aim of this study is to work out accident prediction models based on traffic police report data. These models correlate accidents, as a dependent variable, with probable reasons of accidents that are associated to accident occurrence such as: time, day, road geometry, light condition, year of driver license provision and vehicle type as independent categorical variables.

Count data models Poisson and Negative-Binomial models along with a non-parametric decision-tree model were developed. Out of those models, the best models were chosen. Considering the results of Negative Binomial model, the important variables causes the accidents are experience of the driver (year of driver license issue), vehicle type, light condition and time of the accident. Moreover, decision tree results show that, road geometry with straight roads contributing to the highest number of accidents. This could be due to the possibility that, when road is straight, drivers would tend to ride at high speeds.

As per (Kibar, Celik et al., 2013) accidents in Turkey have been growing every year. The main objective for their study is to explore the issues cause accidents and to develop an accident prediction model which contains relationships between these factors causing accidents. The probable number of accidents at divided highways can be predicted and appropriate actions can be defined to prevent accidents. The method of generalized linear models was applied to the collected accident data. This model shows that the vehicle kilometres of travel, number of pedestrian crossing the road and average speed of vehicles are noteworthy variables for road accidents.

Singh and Suman (2012) found that rapid growth of population and economy has favored in incredible increase of vehicles on Indian roads. This is one of the prime reasons accountable for accidents. Few works have been carried out on statistical investigation of accidents predominantly on National Highways. Accidental data collected from the Police Stations from 2000-2010 was used for analysis. The collected data was investigated to assess the influencing factors on accident rate. Heavy vehicles were involved in maximum number of accidents on the particular stretches under study. It is assessed that heavy vehicles contributed to almost 48% accidents followed by 2-wheelers 16%, cars 12% and buses 10%. There is no definite trend for monthly variation in accident but the accidents in month of January and July are usually higher. Accident rates increases with traffic volume. The developed model for accident prediction represents that the number of accidents enhances with AADT and there is a decreases in accidents with enhancement in road condition.

Pei, Wong et al. (2012) studied the outcome of exposure and speed on accidents in Hong

Kong. Results showed a positive correlation between speed and accident risk.

Mustakim, Yusof et al. (2008) established accident predictive models based on the data collected on at rural roads. The result confirmed that the current number of major accesses, with no traffic light, speed, AADT, growth rate of car and are the possible contributors of increased accident rates on rural roads.

Lord and Mannering (2010) predicted that due to increase in automobile transportation around the world, bicyclists, pedestrians, and motorcyclists would become more vulnerable to accidents, especially in countries where traffic laws are not enforced properly. The research discussed the potential countermeasures for refining pedestrian safety on roads.

Odeleye (2002) from his study very firmly established that the massive restoration of zebra crossing on all important roads in Lagos recently is appropriate and advisable. It was, however, perceived that the vulnerable road users are unaware of the need for safety measure on the roads.

Fabian, Gota et al. (2010) acclaimed that in the age of rapid motorization, the pedestrian left far behind. Huge investments are directed towards building infrastructure for motorized modes, while little or no planning is provided to non-motorized modes of travel such as walking and cycling, which have been the traditional modes of travel. Increased urban sprawl, improved economic conditions and neglect of pedestrian facilities have all led to increase in the number of motorized vehicles, which have resulted in our cities with high levels of pollution, congestion, road accidents, social inequality, poor mobility, and deterioration of quality of life. Asian cities are set to explode with over 55% of population projected to live in them by 2030. This poses a huge challenge to the concept of sustainability and livability.

Mitesh, Girija et al. (2010) studied the road traffic accidents on selected highways and town/village roads of Sabarkantha district, Gujarat was conducted for the period of one year (from January 2002 to December 2002), during this period, total 512 event of road traffic accidents were recorded in the district, It is observed that the Pedestrian accident (37.78%) dominates overall the other types of accidents. Among the 193 events of Pedestrian accident, 158 (81.87%) were non-fatal and 35 (18.13%) fatal. The maximum number of events (62.69%) took place during daytime and 37.31% of events took place during dark hours. Analysis also shows that highest number of events (35.23%) took place on town/village roads.

Sharma and Iyer (2011) used Head Injury Criteria (HIC) prediction for pedestrian impact analyses during early stages of vehicle development is a challenge for designers and Computer Aided Engineering (CAE) analysts because of minimal geometry information for the hood. This research proposes a HIC prediction tool based on statistical analysis of simulation data from an initial CAE simulation. The HIC prediction tool will be used for pedestrian head impacts on hoods to aid in hood design and under hood components packaging which comprehends pedestrian protection variables. Pedestrian impact HIC performance is a function of various contributing factors like hood thickness, material, deformation space, and also proximity to attachment locations. These parameters have been studied separately and then checked for their combined sensitivity to HIC. With shortened development time,

said tools may enable more robust analytical prediction.

Mohan (2011) discussed that WHO released a global status report on road safety: time for action in July 2009. He analyzed the data reported by Asian countries. The report demonstrates that a few high income countries have unreliable statistics, and on the other hand a few low income countries are able set up good data collection systems. Therefore, all countries should be able to set up reasonable data reporting systems given the right policies. Overall and road user specific fatality rates do not have a high correlation with country income levels. The reasons for this are not known. In the absence of more reliable data and identification of risk factors for each country, it is not possible to give very specific country based countermeasures for road safety. It would be adequate at present to focus on measures that have international validity and are known not to have negative side-effects.

Ott, Wiechel et al. (2012) examined of head injuries in the Pedestrian Crash Data Study (PCDS) indicates that many pedestrian head injuries are induced by a combination of head translation and rotation. The Simulated Injury Monitor (SIMon) is a computer algorithm that calculates both translational and rotational motion parameters relatable head injury. The objective of this study was to examine how effectively HIC and three SIMon correlates predict the presence of either their associated head injury or any serious head injury in pedestrian collisions.

Kawabe, Asai et al. (2012) studied the Pedestrian crashes are the most frequent cause of traffic-related fatalities worldwide. The high number of pedestrian accidents justifies more active research work on passive and active safety technology intended to mitigate pedestrian injuries. Post-impact pedestrian kinematics is complex and depends on various factors such as impact speed, height of the pedestrian, front-end profile of the striking vehicle and pedestrian posture, among others.

Jayalakshmi, Sangakavi et al. studied an active safety systems hold great potential for reducing accident frequency and severity by warning the driver and/or exerting automatic vehicle control ahead of crashes. The research presents a novel active pedestrian safety system that combines sensing, situation analysis, decision making, and vehicle control. The sensing component is based on stereo vision, and it fuses the following two complementary approaches for added robustness: (1) motion-based object detection, and (2) pedestrian recognition. The highlight of the system is its ability to decide, within a split second, whether it will perform automatic braking or evasive steering and reliably execute this maneuver at relatively high vehicle speed (up to 50 km/h). The researchers obtained a significant benefit in detection performance and improved lateral velocity estimation by the fusion of motion-based object detection and pedestrian recognition.

Sharma and Landge (2012) studied that pedestrians are one of the Vulnerable Road User, have become more susceptible to traffic crashes with the rapid growth of motor vehicles in India. In terms of pedestrian crashes on a worldwide scale over 4, 00,000 pedestrians are killed every year and over 10,000 pedestrians are killed on Indian roads. To date, only limited research has been undertaken to develop the accident prediction model for pedestrian accidents. The research focuses on pedestrian crash prediction model on Indian Rural Highway (NH-6). Accident data collected between 2005-09 over a stretch of

100 km of road length are used for modeling. The Negative Binomial method was used to model the frequency of accident occurrence. The Akaike Information Criterion (AIC) is used to measure the relative goodness of fit. The candidate set of explanatory variables are: Total Traffic volume (AADT), Lane width (LW), Shoulder width (SW), and access density (AD). It is observed that access density, Shoulder width and Lane width have significant impact on pedestrian safety.

Singh and Suman (2012) selected a stretch of NH-77 from Hajipur to Muzaffarpur. The accidental data was collected for last eleven years, 2000-2010 from the Police Stations where FIR was lodged. The collected data were analyzed to evaluate the effect of influencing parameters on accident rate. Heavy vehicles like truck are involved in maximum number of accidents on the selected stretch. It was estimated that a heavy vehicles is involved in almost 48% accidents followed by two-wheelers 16%, car 12% and bus10%. There was no definite trend for monthly variation in accident on a study section but the accidents in month of July and January are generally higher. Accident rate in terms of number of accidents per km-year increases with traffic volume. But the accidents rate in terms of number of accident per million-vehicle kilometer-year (MVKY) decreases with increase in traffic volume. Accident rate per MVKY increases during the study year, whereas both injury and fatality rate per MVKY show a declining trend over the study period. The developed model for accident prediction represents that the number of accidents per-km-year increases with AADT and decreases with improvement in road condition.

Milton and Mannering (1996) from their study the use of accident severities in safety programming has been often limited to the locational assessment of accident fatalities, with little or no emphasis being placed on the full severity distribution of accidents. Using accident data from Washington State, a Logit model is projected. In this model volume related variables such as ADT per lane, truck percentage, interchanges per mile and weather effects were best modeled as random-parameters—while roadway characteristics such as the number of horizontal curves, number of grade per mile and pavement friction are best modeled as fixed parameters. The study showed mixed Logit model as a practical tool in highway safety program.

Abdel-Aty and Wang (2006) established that accident prediction models (APMs) have been widely used in ranking of accident sites with the aim of recognizing accident black spots. Before this study black spots had been achieved by using a univariate count data or a multivariate count data model for modeling the number of accidents at different severity levels concurrently. Therefore, the two-stage mixed multivariate model is an encouraging tool in predicting accident frequency according to their severity levels.

McComas, MacKay et al. (2002) confirmed that about Sixty percent of pedestrian accidents involved children under the age of 10 years and mainly due to the children not crossing intersections properly. The reason of this research study was to evaluate a virtual reality (VR) program that was intended to educate children about how to cross intersections safely.

In India safety strategies must emphasis on issue regarding safety of VRUs, especially Pedestrians, constitutes to about 40% of total road users and their interaction with traffic is highly inevitable due to mixed

traffic situation in India. The situation even deteriorates due to more technically advanced vehicle introduced day by day and drivers have little or no traffic training to handle these vehicles, using comparatively very less roadways and enforcement administration structures. Developed nations such as the U.S., Canada, and Australia, etc., have done

Table 1: Choice of Explanatory Variable and the Key Findings in the Literature

Sr. No.	*Explanatory Variable*	*Reported Studies*	*Key Findings*
1	Traffic Vol. (AADT)	Chikkakrishna, Parida et al. (2013)	Accidents/km-year increases with AADT
		Chikkakrishna, Parida et al. (2013)	Occurrence of crashes increases with traffic volume
		Prajapati and Tiwari (2013)	The mid-blocks with heavy traffic have highest traffic crash risk
		Dinu and Veeraragavan (2011); Desai, Minesh et al. (2010)	Captures daily variability in traffic vol. and significantly affects accident rates.
2	Percentage of Trucks	Singh and Dhattarwal (2004); Singh and Suman (2012)	Heavy vehicles were found involved in 38.9% to 48% accidents respectively.
		Sharma and Iyer (2011)	Every 2% rise in heavy veh. traffic may increase motorcycle accidents by 28%.
			Percentage of heavy vehicles in traffic have significant impact on safety of motorcyclists
		Chennaiah, Dinu et al. (2007)	Fatal and major accidents have positive association with heavy commercial vehicles.
		Dinu and Veeraragavan (2011)	Proportion of trucks was found major cause of accidents during night-time.
	% of cars	Srinivas et al. (2007)	Fatal and major accidents have negative relationship with % of non-motorized vehicles and cars
	% of 2-wheelers	Dinu and Veeraragavan (2011)	Increase in motorized two-wheelers resulted in more day time accidents.
3	Road Length	Dinu and Veeraragavan (2011)	Increase in length of highway segment resulted in an increase in accidents.
4	Speed and its variance	Landge et al. (2006)	Identified positive relationships between speed and fatality rate.
		Landge (2013); Sharma et al. (2014)	Speed variance is significant for safety of motorcyclists and high speed cars.
		Landge (2013);	Positive correlation between accidents and speed
		Robert et al. (2007); Rokade et al. (2010)	Observed a negative correlation between number of accidents and speed.
5	Road/lane width	Sharma and Landge (2013, 2012)	Addition of 1 m lane width may reduce the pedestrian accidents by 50% and heavy vehicle accidents by 30%.
		Jacob and Anjaneyulu (2013)	Increased carriageway width beyond certain limit, results in higher speeds and higher unsafe overtaking manoeuvre resulting accidents.
		Srinivas et al. (2007)	Presence of wider lane increases the likelihood for accident

Sr. No.	*Explanatory Variable*	*Reported Studies*	*Key Findings*
		Prajapati and Tiwari (2013)	Roads with broader road width and more number of lanes enhances the risk of fatal accidents for pedestrians and bicyclists
6	Shoulder width and type	Jacob and Anjaneyulu (2013)	Influence of shoulder width on accidents is twice as that of carriageway width and reduction in shoulder width produces more injury crashes than fatal crashes
		Sharma et al. (2013); Sharma and Landge (2012, 2013); Sharma et al. (2014)	1 m extra shoulder may reduce pedestrian accidents by 50% and motorcycle accidents by 24% and additional 0.25 m shoulder on either side of road reduce heavy vehicle accidents by 25%. Shoulder width deficiency has significant influence on accidents of high speed cars.
		Fletcher et al. (2006)	Shoulder width up to 1.5 m reduces the accidents by 28% but a further increase reduces the rate of reduction, but a marked decrease in accidents was indicated at 3 m or more width.
		Padmanaban et al. (2010)	24% occurred due to insufficient shoulder width.
7	Road with median	Jayachandran and Anantharajan (1994)	% of road with median was negatively correlated with number of accidents.
		Prajapati and Tiwari (2013)	Urban road Segments with medians have higher risk compared to those without medians.
8	Drive way density/ minor access/ median openings	Rajaraman (2009)	U-turns close to services were black spots for accidents involving trucks
		Sharma and Landge, (2013, 2012); Sharma et al. (2014)	Access density has significant influence on accidents of high speed cars. Each added access point/km of road length may enhance heavy vehicle accidents by about 60% and pedestrian accidents by 80%.
		Chikkakrishna et al. (2013)	Probability of occurrence of crashes increases with Access Roads and Median opening
		Prajapati and Tiwari (2013)	On urban mid blocks risk reduces as number of junctions increase
		Padmanaban et al. (2010)	34% of front-rear collisions occurred at gaps in medians/ junctions
9	Road marking	Fletcher et al. (2006)	Sections with good road marking have a lower accident rate than those with fair and poor markings.
10	Road Side friction	Fletcher et al. (2006)	Accidents were less at low or medium side friction but a large jump in accidents was observed for high side friction.
11	Road and shoulder condition	Fletcher et al. (2006)	An increase of 65% in fatal and 28% in severe injury accidents on pavements with poor condition.
		Singh and Suman (2012)	Number of accidents per-km-year decreases with improvement in road condition.
		Jacob and Anjaneyulu (2013)	Shoulder condition is positively correlated with accidents.
13	No. of curves and gradients	Jacob and Anjaneyulu (2013)	23% increase in Accident rate for each additional curve but increase after certain number reduces accidents.
		Hills et al. (2002)	Accident rates increase on steeper gradients.

Table 2: Summary of Existing Models Applied to Indian Conditions

Sr. No.	*Model Type*	*References*	*Strength vs Limitation*
1	Models based on Smeed's Formula	Valli 2005 Ponnaluri 2012 and Vijya, 2013	Macro-models, correlate number of accidents in a road network with the population of the area and number of vehicles. But these models provide no cause-effect relationship for various accident related factors and therefore suggest no guideline for safety improvements on a particular road. Therefore, very limited applications.
2	Multiple Linear Regression Models	Desai and Patel, 2011; Rokade et al., 2010; Singh and Suman, 2012	Model development and interpretation is very simple. But the assumption of normal distribution of accidents is not correct.
3	Baseline Models	Fletcher et al., 2006	Simple Models, use only one-two explanatory variables, effect of other variables incorporated through AMFs, flexibility in defining baseline conditions. The problem with this model is that a small sample size can affect the robustness and statistical power of the model. Model may become biased, when the sample mean value is very low
4	Poisson model	Fletcher et al., 2006; Hills et al., 2002; Jacob and Anjaneyulu, 2013;	Basic prediction model; easy to predict, better represents the actual process of accident occurrence. Poisson Model can not manage over and under-dispersion as it assumes mean is equal to variance
5	Negative binomial model	Landge et al., 2006; Robert et al., 2007; Sharma and Landge, 2012; Lord, 2006	Probably most widely used model, Easy estimation, can handle over dispersion of data, but cannot handle under-dispersion; influenced by low sample mean and small sample size
6	Zero-inflated Poisson and negative binomial	Sharma et al., 2013; Sharma and Landge, 2013; Jacob and Anjaneyulu, 2013	Manages data having a great number of zero-accident observations. Can create theoretical discrepancies; can be influenced small sample size,
7	Poisson-Weibull Bayesian models	Chikkakrishna et al., 2013	Can be used for different kinds of data, can handle over dispersion of data, reported inferior than NB models.
8	Random-parameters models	Dinu and Veeraragavan, 2011	More effectively handle fixed parameter models in accounting for undetected heterogeneity Complex procedure; not always improve predictive competence
9	Hierarchical/ Multilevel Models	Fletcher et al., 2006, Lord and Mannering, 2010	Simple, sound, non-parametric method and assumptions based on distributions of the accident data are not required. Can manage temporal, spatial and other correlations Poorly estimated coefficients and wrong inferences if the possible classified structure of the data is not considered, correlation outcomes can be hard to understand
10	Back Propagation Neural Network Model	Sikka 2014, Xie 2007	Non parametric approach; better statistical fit than traditional models Complex approximation procedure; may not be transferable to other datasets; may not have interpretable parameters

advancement in the area of pedestrian safety in recent years. India is undergoing growth in terms of motorization and now the time has come to begin addressing pedestrian's safety necessities to a larger magnitude.

FURTHER STUDY IN THE LINE OF RESEARCH

From the literature review it can be very clearly seen that it's very important to study and find out the contributing factors and further remove them so that Road accidents fall. The basic factors which are extracted from the review of literature, that cause pedestrian accidents are driver condition, vehicle condition, road condition, road users other than the motorist such as bicyclist, rickshaw, and stray animals, etc. The basic purpose of study is to reduce the pedestrians' accidents on Indian Roads. There is a dire need to study non-urban sections of highways in India to identify the significant factors of pedestrian accidents on Indian roads and to develop a predictive model for the same. The study would also assess the traffic safety of Indian roads and recommend suitable improvement.

The data used for this study will be collected over a number of non-urban sections of roads in Haryana. Further a detailed data Collection of accident along with causes from record of traffic police, FIRs, NHAI, PWDs, toll booths and other concerned agencies will be rigorously collected. This data will be categorised and analyzed to determine the various significant factors leading to pedestrian accidents on Indian roads. Using Factor analysis the most critical factors leading to pedestrian accidents would be derived. Further multiple linear regressions would be used to develop quantitative relationship between the various significant variables. Suitable suggestions can be suggested on the bases of prediction model to reduce the high number of pedestrian accidents in the study area.

SOURCE OF DATA FOR THE STUDY

Three different data collection techniques were applied during this project.

For traffic volume data on roads NHAI and State agencies will be contacted and their traffic count registers were obtained. Though the traffic volume data is collected in every 6 months on various counting points but the registers supplied were not updated and there are Gaps which need to be supplemented by traffic volume counts on the identified sections. The FIR data of vehicle accidents was collected from various police headquarters and police stations. This will be a significant source of data. The data of spot speeds will be collected by using radar gun. Road Geometrics will be checked for roads under study (Table 2).

CONCLUSION

The research paper presents an exhaustive review on pedestrian safety while delineating critical factors why this study is necessary. This study also offers the blueprint of an empirical study based on statistical tools and technique and multi vitiate analysis to figure out the most important factors with their factor loading which will help the researcher to exactly know the important factors leading to accidents and devise scientific methods to prevent them.

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