Predicting Road Accidents and Prioritizing Road Safety Improvement Measures in India Using Adapted Traffic Conflict Techniques

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Paper Submitted for presentation at the 2013 TRB 92nd Annual Meeting and publication in Transportation Research Record

Submission Date: August 1, 2012

Word Count: 4,998 + (5 Tables + 5 Figures) * 250 = 7,498

Abstract

Road accidents in developing countries are increasing at an alarming rate. Deaths due to road accidents are becoming the single biggest killer in developing countries. Although there is a pressing need for improving road safety, it has been observed that improvement measures are not taken up systematically. Unless all stakeholders are involved and a systemwide road safety approach is considered, local improvements will not reduce the total number of accidents. Thus, there is an urgent need to identify and undertake prioritized road safety improvement actions across the roadway system. Lack of data on causes of various types of accidents is hindering policy making in planning and implementing road safety improvement measures.

In this research, a mathematical model for predicting road accidents and prioritizing road safety improvement measures is introduced for Indian road conditions. An adapted version of the Traffic Conflict Techniques is used to assess the main causes of accidents on Indian roads. Analysis and results of the conflict data are used to develop a mathematical model to identify and prioritize road safety measures. Recommendations made in this study can be used by agencies with limited resources to prioritize their respective road safety improvement initiatives.

Key-words: road safety, accident prediction model, highway accidents, Indian roads

INTRODUCTION

According to Union Health Ministry and the Ministry of Road Highways and Surface Transport of India (*1*), an estimated 160,000 persons were killed in road accidents in the year 2011. Road accident deaths and injuries in India have been increasing on an average by 15% annually over the last 12 years (2). Therefore, there is a pressing need to take prioritized road safety improvement actions to bring down the number of road accidents. In this research, we explore the reasons behind such huge number of road accidents and introduce a mathematical model to predict road accidents and prioritize safety measures.

Speed combined with ignorance of traffic rules seems to be the primary cause of many road accidents in India. The current average speeds on Indian roads are lower than allowed speeds on similarly built roads of developed countries; however, there is still a need to bring down the upper limits of speeds of vehicles on Indian roads to reduce accidents. Speed limits in India have to be much lower than in the developed countries because of the difference between road safety measures and education levels of road users in developed countries and India.

Road accidents are a socio-economic loss for the families of accident victims and for the country. Lower speed limits and enforcing the same promises to reduce road accidents; however, lower speed limits are also an economic loss to individuals and the country. Lower speeds imply higher road user costs and lower fuel economy. Therefore, there is a need to operate vehicles smoothly rather than at lower speeds alone to improve the safety and economy of the road users and their vehicles.

In order to perform any road accident analysis, reliable road accident data is a prerequisite. In many developing countries, road accident data available from police/court/insurance records is not sufficient to conduct a traffic analysis and ascertain the true cause of the accident. In the absence of reliable road accident data, in an earlier research *(3)*, the authors used an adapted Traffic Conflict Technique (TFT) to quantify the number of conflicts faced by road users in Vizianagaram town, Andhra Pradesh, India and showed that for every 100 km drive in Vizianagaram town at design speed, a driver is likely to encounter 481 right-of-way violations out of which, 161 encounters demand application of brakes to prevent an accident.

In this research, data from the previous study *(3)* is analyzed in more detail to see how the prevailing high number of right-of-way violations can be brought under control so that road user conflicts can be reduced. A mathematical model has been developed to predict the number of accidents based on TFT data. This research brings out an analysis of what agencies and individuals can do to reduce road user conflicts and reduce road accidents. Results of this research are helpful in planning and implementing road safety improvement measures at district (County) levels. Agencies with limited resources can use the recommendations of this study to identify, plan, and prioritize their respective road safety improvement initiatives to reduce accidents.

TRAFFIC CONFLICT TECHNIQUES

Traffic Conflict Techniques (TCTs) have been used by researchers as early as 1960’s in U.S.A. and many countries in the Europe in 1970’s *(4)*. TCTs depend on detection and counting of "near-accidents" or "critical incidents" occurring in real traffic situations. Once recorded, conflict data is analyzed in the same way as accident data in order to identify factors likely to generate future collisions. A Traffic Conflict is defined as an interaction between two road-users (or between one road-user and the road environment) that would shortly lead to a collision unless at least one of the road-users involved performed an evasive action *(4)*.

TCTs have been widely used by researchers in site-oriented diagnostic studies (problems at urban or rural junctions, safety in residential areas, pedestrian safety, etc.) as well as in evaluation studies (new junction facilities, speed reducing measures, etc.) *(4, 5)*. Other adaptations of the original conflict technique were used on board a vehicle in real traffic situation, either to get information on the driver's behavior like assessment of needs or effects or training procedures *(6)*.

In general, behavioral observations in real traffic situations are a basic tool for research on human factors. Impact of such research on safety policies including speed reduction measures is obvious *(7, 8)*. TCTs are best suited for a diagnosis to support action through practical observation studies. In order to design efficient remedial measures, it is necessary to get accurate information on the contributing factors identified in the accident analysis and on their interactions. Because the road-users are at the core of the roadway system, the human factors are particularly at stake *(4)*. In this respect, the observation of driver's behavior with respect to traffic regulations is of particular importance, in order to ascertain whether drivers actually comply and understand the purpose of the regulations *(8, 9)*.

RESULTS OF THE TRAFFIC CONFLICT TECHNIQUE

In order to assess the level of ignorance about traffic regulations, which were presumed to be the main causes of road accidents in India, an adapted version of the TCTs were used *(3)*. In a previous research (*3*), the number of times a horn is used was counted. Small horns (less than 3 seconds duration) were treated as minor threats where drivers wanted their presence known to a possible conflicting pedestrian, vehicle, etc. Longer horns (more than 3 seconds duration) were used by drivers whenever they came across a possible right-of-way violation that could lead to an accident. Two types of horn tests were carried out, a stationary horn test and a dynamic horn test. In a stationary horn test, a surveyor would stand at a location (an intersection or road segment) and count the number of times horns were used by driver. He/she will then classify and note down the reason for using the horn. In dynamic horn test, a trained test driver would drive at a target speed whenever the driver used the horn, he would communicate the reason for using the horn to trained pillion who would then classify and record the use of horn.

Additional data were collected using the same TCTs, which were analyzed in this research to assess the potential for accidents due to conflicts. Table 1 presents a quantitative estimate of risks posed by various types of threats per 100 Km drive in the town of Vizianagaram *(3)*.

Table 1: Road Conflicts Observed Per 100 Km ride in Vizianagaram *(3)*

Type of Obstruction	Minor	Major
Slow vehicles obstructing vehicles going at safe speed (40 kmph)	94.3	37
Pedestrian crossing excluding those using zebra crossing	40.4	16.8
Blind Corners - lack of enough stopping sight distance	33.7	16.8
Joining/merging from left side	20.2	20.2
Street Parking on left side	33.7	3.4
Stopping on left side drop, pickup, soliciting passengers	23.6	6.7
Cycle crossing excluding those not riding while crossing	13.5	10.1
Cyclists who did not drive in extreme left	10.1	10.1
Oncoming vehicles crossing center line	16.8	6.7
Vehicles joining/merging from right	3.4	10.1
Vehicles darting across from right to left	6.7	6.7
Unattended Animal	3.4	6.7
Pedestrian along the road not using footpaths	13.5	0
Vehicles driven in wrong lane	0	6.7
Vehicle darting from left to right (including U-turns)	3.4	3.4
Vehicles waiting in middle of a road to make a right turn	3.4	0
Total	**319.9**	**161.6**

Figures 1 and 2 show the results of TCTs conducted at different average speeds. Trained two-wheeler drivers were asked to drive on two lane divided and undivided urban roads at a target speed of 10, 20, 30 and 40 Kmph, and the type and number of obstacles/conflicts faced by the drivers were communicated to respective trained pillions. Figure 1 shows the number of minor conflicts faced by drivers per 100 Km ride at different speeds. Minor conflicts were, in general, drivers making their presence known to others to avoid a perceived conflict. The Figure also shows that the number of minor conflicts increases exponentially starting from a speed of 20 kmph. In order to ensure the safety of the trained drivers, they were asked not to drive above 40 Kmph. From Figure 1, it can be inferred that driving at about 20-25 Kmph offers a smoother ride on two-lane urban roads.

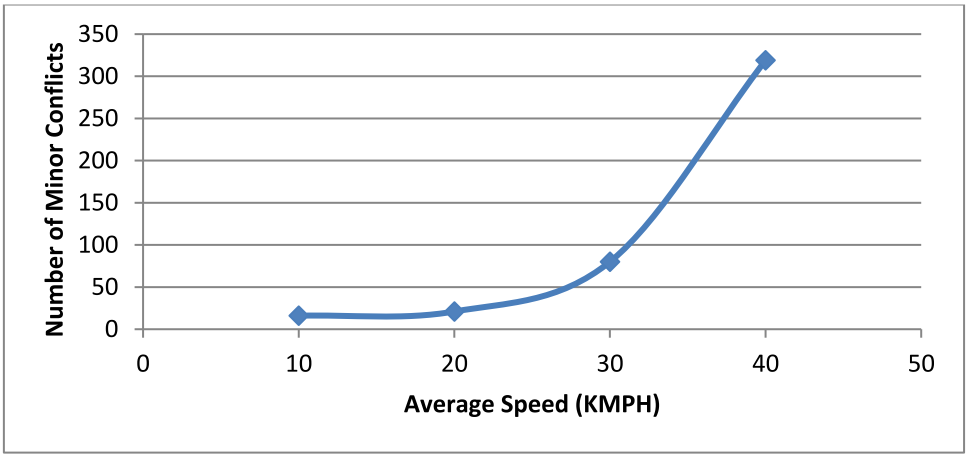

Figure 1: Number of Minor Traffic Conflicts per 100 Km ride on 2-Lane Roads

Figure 2 shows that the number of major traffic conflicts, where applying brakes is necessary to avoid an accident, increases exponentially starting from around 18 Kmph. Although the design speed posted on the 2-lane roads was 40 Kmph, the TCTs showed that it is safer to drive at less than 20 Kmph. Starting from about 24 conflicts at 10 Kmph (Figure 1 plus Figure 2), the number of times a driver has to apply brakes to avoid an accident increases to 161 at 40 Kmph for a 100 Km ride. In addition to being safer, considering increased vehicle wear and tear due to frequent braking, it is also more economical to drive at speeds below 20 Kmph on 2-lane roads.

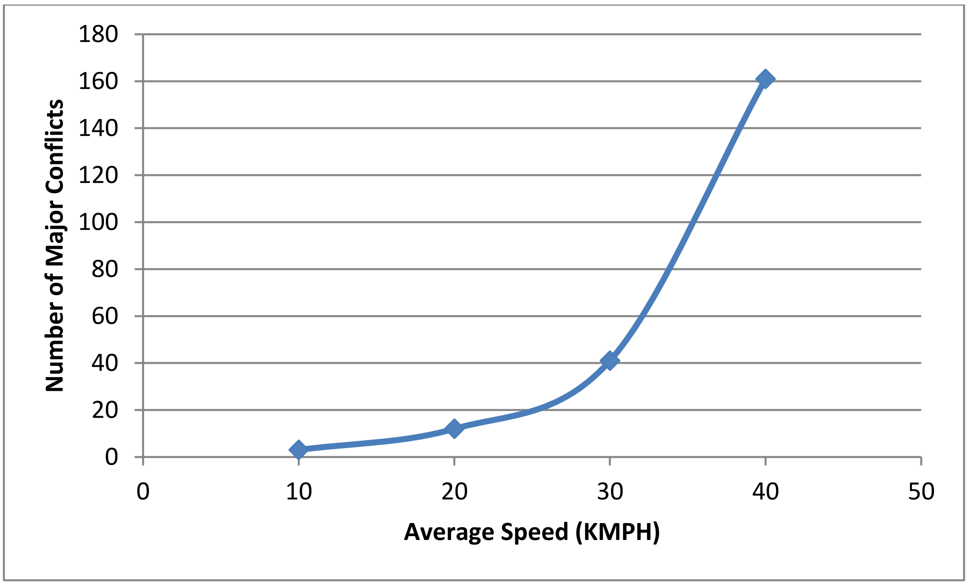

Figure 2: Number of Major Traffic Conflicts per 100 Km ride on 2-lane roads

Different numbers of conflicts were observed on different types of roads. Results of TCTs performed on 2-Lane divided roads are presented in Figure 3 which shows that after about 22 Kmph, the number of major conflicts increases very steeply. Therefore, 20 Kmph should be a safe speed limit for 2-Lane divided roads in small towns.

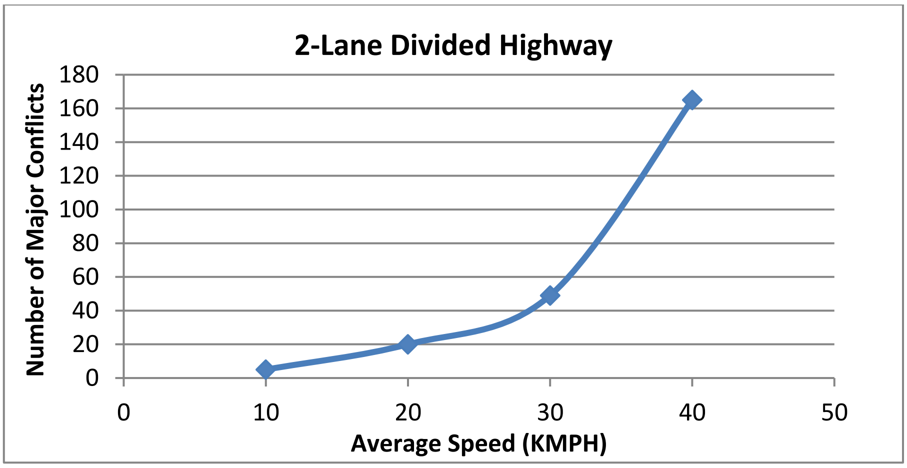

Figure 3: Number of Major Conflicts Per 100 Km Drive on 2-Lane Divided Highway

Figure 4 shows the number of major conflicts observed on 2-Lane undivided roads in urban areas. It can be observed that there is a steep increase in the number of major conflicts from about 28 Kmph average speeds. Therefore, 25 Kmph should be the safe speed limit on 2-Lane undivided roads in urban areas of a small town.

It is interesting to note here that higher conflicts were witnessed on 2-Lane divided roads than on 2-Lane undivided roads. In order to verify this finding, a more in-depth analysis of the conflicts was carried out. It was found that pedestrians crossing 2-lane undivided roads were more careful and waited for longer gaps to cross the road which reduced conflicts. However, when crossing 2-lane divided roads, the median offered protection and pedestrians were taking more risks while crossing 2-lane divided roads which increased the number of conflicts. It was also observed that drivers on 2-lane undivided roads crossed the centre line frequently to avoid conflicts with obstacles on the left side, but drivers did not have that flexibility on 2-lane divided roads. It may be concluded here that, in small towns, if pedestrians and cyclists are not protected on the left side, then it is not safe to build a divided 2-lane roads.

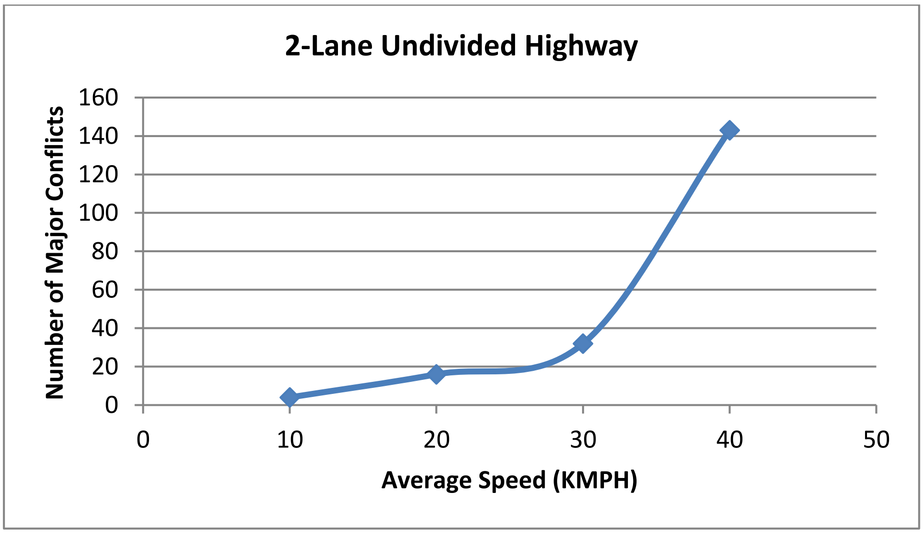

Figure 4: Number of Major Conflicts Per 100 Km Drive on 2-Lane Undivided Highway

One-lane undivided roads are common in small Indian towns. In order to measure accident potential on these roads, TCTs were performed on one-lane roads with typical 3.5 Meter (±0.5 M) carriageway. Figure 5 shows the result of the TCT. The total number of major conflicts per 100 Km ride on such roads increases drastically after about 15 Kmph speed. Figure 5 shows that about 10 Kmph is a safe speed limit on such roads. At a speed of about 25 Kmph on such roads, faster vehicles can expect at least one serious conflict or 'near accident' situation every 1 Km. Ideal speed limit on such roads should be less than 15 Kmph. In order to ensure safety of the data collectors, TCTs were not conducted beyond average speeds of 25 Kmph on 1-lane roads.

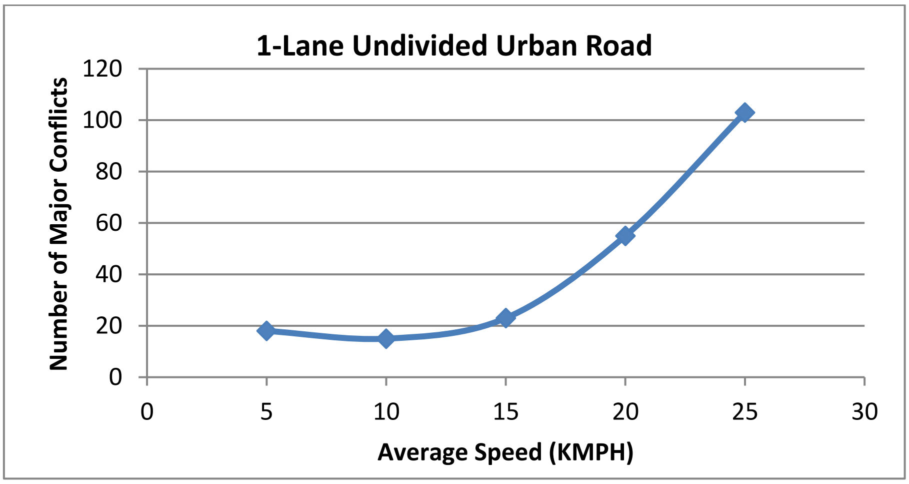

Figure 5: Number of Major Conflicts Per 100 Km Drive on 1-Lane Undivided Urban Road

In order to verify the relation between conflicts and accidents, accident sites were revisited by the research team. TCTs were conducted and survey data for respective accident locations were analyzed. Out of 33 locations studied, at 14 locations, TCT data was either irrelevant or insufficient to have predicted the kinds of accidents that occurred at the locations. A tractor overturning in a warehouse resulting in a fatal accident and a car running off the road and hitting a tree due to tire burst resulting in a fatal accident were some examples where TCT data were either irrelevant or insufficient. At 19 locations, the analyzed TCT data showed a higher number of conflicts which could be used to predict an accident. There are many locations where TCT data showed higher number of conflicts, but no fatal accidents were reported at these locations in the last three years.

In general, TCT data showed that minor conflicts increased with traffic volume and major conflicts increased with traffic speed. Outside city limits and in rural areas, insufficient sight distance was the main cause of major conflicts. Within city limits, right-of-way violations created by pedestrians and vehicles were the main source of major conflicts. Unsignalized intersections in urban areas had high number of both minor and major conflicts. At signalized intersections, number of minor conflicts was nearly same as major conflicts. Minor conflicts are not likely to result in fatal accidents but major conflicts are potential sources of fatal accidents.

A DISCUSSION OF THE RESULTS OF TRAFFIC CONFLICT TECHNIQUE

In the absence of accurate traffic accident data in India, it is difficult to estimate the various causes of accidents . TCTs used in this research are an easy and economical source of valuable statistics on causes of accidents which are essential for planning any safety improvement measures. Without such statistics; identifying, planning, prioritizing and implementing road safety can be fluid and human and economic resource allocation cannot be justified.

Traffic conflicts are precursors to traffic accidents. At this point, there is not enough data to accurately establish an analytical relationship between observed number and type of conflicts and the resulting number or severity of road accidents. However, results of the TCTs provide enough information to start defining the problem areas and work on solutions to address road safety at a district level.

Three disciplines are crucial for ensuring road safety: Engineering, Education and Enforcement. Traffic conflicts have been grouped based on their nature so that roles of each discipline in reducing such conflicts can be identified. Table 2 provides a summary of conflicts and the discipline which should be responsible for taking corrective measures.

Table 2: List of Traffic Conflicts and Recommended Correction Agencies

Type of Traffic Conflict	Engineering	Education	Enforcement
Slow vehicles – Fast Vehicle	√	√	
Pedestrian (crossing) - Vehicle	√	√	√
Blind corners	√		
On-Street Parking	√	√	√
Stopping vehicle – Moving vehicle	√	√	√
Joining/merging/darting Vehicles	√	√	√
Oncoming vehicles			√
Cycle (crossing) – Vehicle		√	√
Pedestrian (along) - Vehicle			√
Unattended animal - Vehicle			√
Right turning vehicles	√	√	√
Vehicles driven in wrong lane			√

Under mixed traffic condition, slow moving vehicles frequently obstruct faster vehicles. Traffic engineers have to take steps to segregate traffic based on speed or find and earmark alternative roads for slow moving vehicles. Drivers of slower vehicles, including cyclists have to be educated to keep as far left as possible in order to avoid conflicts with faster vehicles. If segregation is not possible, traffic engineers should reduce speed limits to reduce conflicts. Traffic engineers should follow volume based warrants and recommend appropriate pedestrian facilities. Pedestrians should be educated on using the infrastructure provided for them and pedestrian regulations must be enforced to reduce vehicle-pedestrian conflicts.

Blind corners are a result of poor traffic engineering practices. Traffic engineers should study the blind corners identified in TCT studies and recommend corrective steps to the Road Transport Authority (RTA). Engineers should also recommend temporary warning signs to be used until RTA takes corrective action to eliminate the blind corners. The TCT studies showed that on-street parking creates conflicts leading to accidents. On-street parking, especially by large trucks and buses, creates temporary blind spots. Engineers should conduct parking demand studies, recommend appropriate parking infrastructure and educate road users about available facilities. Enforcement agencies should ensure appropriate use of parking facilities.

Transport providers, especially private operators, veering and making unexpected stops to solicit passengers were hindering smooth flow of traffic and creating conflicts. Engineers should identify demand and recommend infrastructure for private transport operators. Enforcement agencies should ensure that only designated areas are used for pickups and drop-offs by transport operators, both private and public.

Merging and darting without yielding right-of-way created conflicts. Engineers should identify and recommend educating infrastructure like stop signs and yield signs to increase levels of right-of-way awareness among road users and enforcement should follow up to reduce merging conflicts. Oncoming vehicles crossing centre line were observed during the TCT surveys. Only enforcement can improve proper use of roadways and reduce conflicts. Cyclists crossing the road at will were responsible for a lot of conflicts. Education and enforcement can reduce such motorist-cyclist conflicts.

Pedestrians walking on carriageway instead of sidewalks created conflicts with moving vehicles. It was found in the surveys that pedestrians walked on the carriageway because sidewalks were encroached or unclean. Enforcement in terms of removing encroachment of sidewalks and pedestrians using sidewalks would reduce these conflicts.

Vehicles stopping in the middle of a road to make a right turn created some conflicts. Engineers should do a demand analysis and recommend appropriate infrastructure to allow right turns without blocking the thoroughfare. Conflicts created by vehicles driven on wrong side of the road and unattended animals can be reduced by enforcement.

A MATHEMATICAL MODEL FOR PREDICTING TRAFFIC ACCIDENTS

In order to improve road safety, effect of each element of road transport system has to be examined. Conflicts have a direct relation with number of accidents because every conflict has a potential to become an accident. In the past, many researchers have focused on other roadway elements but not conflicts. Table 3 provides a summary of research available in literature which shows the various roadway elements (independent variables) investigated to find a correlation between the independent variables and the number of accidents. Bauer and Harwood *(19)* have reviewed crash reports at eight urban intersections and concluded that highway variables other than traffic account for only 5 to 14% of the crashes which can be attributed to the geometric features of an intersection. The research report of Vogt and Bared *(17)* attributes only 2% explanatory value to design variables as compared to 27% to Average Daily Traffic.

Vogt *(20)* concludes that there are numerous possibilities with regard to choice of variables. Many factors influence crashes and selection of variables should be influenced by engineering judgment. Because of collinearity of variables exists, it cannot be guaranteed that causation has been established *(20)*. In the literature reviewed so far, accident prediction models have been developed for urban, semi-urban, and rural intersections and rural highway segments. There are no models for predicting crashes on urban segments. In this research, an attempt is made to cover all intersections and urban as well as rural road segments. Data from the TFT surveys conducted (numbers of major and minor conflicts) are used to find the cause of accidents. Table 4 shows the types of models developed by various researchers.

For developing the mathematical model, stationary horn tests *(3)* were conducted at all fatal accident locations in the last 5 years in Vizianagaram town. The number of minor and major conflicts at each location during morning and evening peak hour were recorded for 5 days. The variance of the data was almost the same as the estimated mean of the data. Therefore, it was decided to use Poisson regression models. The proposed model for estimating the number of fatal accidents per year on various types of roads and intersections of Vizianagaram town is as follows:

$$y_i = a_1 * (C_{ni})^{a_2} * (C_{ji})^{a_3} \tag{1}$$

where,

y_i = Expected number of fatal accidents per year at location ‘i’

C_{ni} = Number of Minor conflicts during peak hour at location ‘i’.

C_{ji} = Number of Major conflicts during peak hour at location ‘i’.

a_1, a_2 and a_3 are coefficients of intercept, C_{ni} and C_{ji}.

Majority of the fatal road accidents in Vizianagaram (119 out of 150) in the last five years were on rural roads. SPSS-19 was used to find the relationship between number of minor and major conflicts at a location and the number of accidents. The observations are as follows:

- a_1 = 0.126, Significance = 0.447, Standard Error = 0.1197
- a_2 = 0.113, Significance = 1.000, Standard Error = 0.0031
- a_3 = 0.346, Significance = 1.000, Standard Error = 0.0055

Therefore,

$$y_{rr} = 0.126 * (C_{nrr})^{0.113} * (C_{jrr})^{0.346} \tag{2}$$

where,

y_{rr} = Expected number of fatal accidents per year at a given location on rural roads of Vizianagaram.

C_{nrr} = Number of Minor conflicts during peak hour at the same location on rural roads of Vizianagarm.

C_{jrr} = Number of Major conflicts during peak hour at the same location on rural roads of Vizianagarm.

Table 3: Independent Variables Used by Researchers to Predict Road Accidents

Authors	Rural Intersections	Rural Segments	Urban Intersections	Reference
McDonald J. W.	• Traffic Volumes			*(10)*
Web G. M.	• Traffic Volumes		• Traffic Volumes	*(11)*
David N. A. and J. R. Norman			• Traffic Volumes • Number of U-Turn Restrictions • Number of Right Turn Lanes • Number of Lanes • Signalization • Width of Minor road • Number of Divided streets • Number of left-turn lanes	*(12)*
Hakkert A. S. and D. Mahalel			• Crossing and Merging Traffic Flows	*(13)*
Pickering D., R.D. Hall and M. Grimmer	• Distance from Intersection • Presence of Islands • Channelization • Pairs of traffic flows			*(14)*
Hauer E, J.C.N Ng and J. Lovell			• Number of Flows	*(15)*
Bonneson J. A. and P. T. McCoy	• Traffic Volumes			*(16)*
Vogt A. and J. Bared	• Total number of accidents in the time period • Injury accidents in the time period • Traffic Volumes • Degree of curve for horizontal curves • Crest curve grade rate • Posted speed • Roadside Hazard Rating • Number of driveways (within ± 250 ft) • Channelization • Intersection Angle	• Traffic Volume • Number of non-intersection accidents in the time period • Injury accidents in the time period • Segment Length • Lane width • Shoulder width • Degree of curve for horizontal curves • Weight of Horizontal curve number • Crest curve grade rate • Weight of vertical curve number • Absolute grade for straightway number • Weight of straightway number • Roadside hazard rating • Driveway density • Posted speed • Commercial Vehicle percentage • Location • Exposure • Total width		*(17)*
Oh J, S. Washington, and K. Choi	• Traffic Volumes • Commercial driveways (within ± 250 ft) • Intersection Angle • Roadside Hazard Rating • Degree of curves for horizontal curves • Street Light • Median Type and width • Directional Flows in peak hour • Truck Percentage in peak hour • Right side sight distance on minor road • Average Speeds • Crest curve grade rates			*(18)*

Table 4: Various Crash Prediction Models

Authors	Urban Intersections	Reference
McDonald J. W.	Poisson	*(10)*
Web G. M.	Poisson	*(11)*
David N. A. and J. R. Norman	Linear Regression	*(12)*
Hakkert A. S. and D. Mahalel	Poisson and Traffic Flow Index	*(13)*
Pickering D., R.D. Hall and M. Grimmer	Generalized Linear and Poisson	*(14)*
Hauer E, J.C.N Ng and J. Lovell	Negative Binomial	*(15)*
Bonneson J. A. and P. T. McCoy	Negative Binomial	*(16)*
Vogt A. and J. Bared	Poison and Negative Binomial	*(17)*
Oh J, S. Washington, and K. Choi	Negative Binomial	*(18)*
Miaou et al.	Poison and Negative Binomial	*(21)*
Knuiman et al.	Negative Binomial	*(22)*
Zegeer et al.	Negative Binomial	*(23)*
Fridstrom et al.	Negative Binomial	*(24)*
Poch and Mannering	Negative Binomial	*(25)*
Baur and Harwood	Poison, Negative Binomial and Log Normal	*(19)*
Miaou and Lum	Linier Regression and Poisson	*(26)*
Miaou 1994	Poisson, Negative Binomial and Zero-Inflated Poisson	*(27)*
Lau and May	Classification and Regression Trees	*(28)*

One of the main reasons for researchers (*17, 19, 21, 27*) recommended shifting from Poisson models to Negative binomial is to account for the noise. However, in this research the K Values are very low and hence Poisson models have been used. The models (1, 2, 3 & 4) suggested here are specific to Vizianagaram town. For other cities and towns in India, TFTs used in (*3*) have to be done and models should be recalibrated.

APPLICATIONS OF THE ACCIDENT PREDICTION MODEL

Each road safety improvement measure has a cost and a time element attached to it. Some measures are cheaper to implement than others and some improvement measures are quicker than others to implement. Table 1 provided a list of obstructions on roads that are sources of conflicts in road traffic found while driving in Vizianagaram and Table 2 classified these obstructions and identified agencies responsible for addressing the issues. The mathematical model developed in this research may be useful in identifying and rating the improvement measures so that they can be prioritized.

Table 5 shows results of the model application for rural roads of Vizianagaram. It can be seen that the if 100 minor conflicts and 100 major conflicts are observed at any location on rural roads of Vizianagaram, 1.035 number of fatal accidents can be expected per year at that particular location. If road safety improvement measures are taken up to reduce the major conflicts from 100 to 50, expected number of fatal accidents per year goes down to 0.814. Alternatively, if improvement measures undertaken to reduce minor conflicts from 100 to 50, expected number of annual fatal road accidents goes down to 0.957. If both major and minor conflicts are reduced from 100 to 50, then expected number of accidents goes down to 0.753.

Table 5:Results of the Model Application on Rural Roads of Vizianagaram.

Number of Minor Conflicts in Peak Hour	Number of Major Conflicts in Peak Hour	Expected number of Fatal accidents per Year
100	100	1.035
100	50	0.814
50	100	0.957
50	50	0.753
1	1	0.125

Engineering agencies can work out the cost and time required to define right-of-way and traffic engineers can quantify the effect of providing such or any other road safety improvement measure by conducting the required TCTs. The results of TCTs and use of the proposed model will assist in creating a platform for improving road safety and framing engineering, educational and enforcement policies at state or national level.

Right now, moving traffic violations (especially right-of-way violations) are the biggest sources of conflicts and enforcement of moving violations is near negligible in India. Using the model proposed in this research, if road safety improvement measures can be identified, prioritized and implemented, enforcement will generate more revenue than the investment needed for providing the improvement measures. Although indirect benefits of reducing conflicts which lead to reduction in accidents in terms of socio-economic cost is difficult to quantify, enforcement will generate enough revenue to make road safety sustainable. Because of the lack of a policy framework at state level, providing road safety is being treated as a loss rather than a benefit by respective state governments.

RECOMMENDATIONS

Road Transport Authority (RTA) is a consortium of administrative, political, municipal, engineering, enforcement and citizen representatives, is working in all districts of Andhra Pradesh. All stakeholders of road safety are represented in a District RTA. Therefore, RTA should take complete responsibility for road safety within its district in order to achieve systemwide road safety. RTA should identify, plan, finance and implement road safety measures.

RTA should conduct a road safety meeting on a quarterly basis and take stock of the road safety situation in the district. District Magistrate (DM should chair the quarterly road safety meeting. The DM should ensure that all the road owners are included in every meeting. The DM should take stock of successful implementation of the road safety measures proposed in the previous meetings. If road owners fail to comply with the proceedings of the previous meetings, the DM should be able to issue show-cause notices to the road owners on why action should not be taken on them for compromising road safety.

RTA should have a matrix for measuring improvement in road safety. It should authorize frequent traffic studies to keep track of overall road safety index within its jurisdiction. Such matrix will help in prioritizing road safety improvement measures and assist road owners in allocation of funds for making their respective roads safer.

CONCLUSIONS AND LESSONS LEARNED

Accurate accident data is necessary to understand why road accidents happen and how to prevent future accidents. Unless accurate accident is available it is difficult to design and implement road safety improvement measures. In the absence of accurate accident data, adapted TCTs proposed in this research are an easy and economical method of collecting information on accident hotspots and probable causes of accidents. The mathematical model to predict accidents proposed in this research is an easy and accurate method to predict future accidents based on the TCT data. The model can also be used to identify and prioritize road safety improvement measures based on the benefits offered by various improvement measures and their potential in reducing the number of conflicts.

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