A Study on Factors Leading to Road Accidents on East Coast Road

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Abstract

According to road safety reports from multiple agencies, road traffic accidents can shrink a developing country's GDP (Gross Domestic Product by 3%. Considering that India although has only 1% of the world's total vehicles, but contributes to about 10% of the global road traffic accidents is alarming. Specifically, the south Indian state of Tamil Nadu has been listed among the top five states with most road traffic accidents over the past five years. Consequently, in this study, we gathered and analyzed data regarding registered accidents over a 25 km stretch of State Highway 49, also known as East coast road (ECR). We have identified five black-spots on this highway stretch that is prone to accidents. Further, our analysis of the major contributing factors indicated over speeding to be a major cause with the most probable outcome being minor injuries.

Keywords**:** *Road accidents; Black spots; Collision type; Road conditions*

Introduction

The UN General Assembly passed a resolution to reduce the road traffic fatalities by 50% during the period 2011-2020 [1], and this resolution was accepted by most countries around the world including India [2]. However, road safety reports published by the World Health Organization [3] and International Transportation Forum [4] have estimated that the annual number of fatalities caused by road traffic accidents is about 1.2 – 1.4 million, while the annual number of injuries is about 50 million. The WHO report estimates that developing countries lose approximately 3% of their GDP due to the road accidents [3].

A closer look at the accident data across the world reveals that India, a developing country with only 1% of the world's vehicles, accounts for about 10% of the total road traffic accidents around the world [5, 6]. In fact, India's State highways, that constitutes only 3% of the total road network, witnesses about 25% of the total road accidents in the country [7]. The MoRT&H report [7] indicated that the south Indian state of Tamil Nadu has contributed close to 14% of India's accidents during the years 2017 and 2018, and Chennai, the capital city of Tamil Nadu, has reported the most accidents amongst other major cities in India. Consequently, the focus of this paper will be on a 25 km stretch of State Highway 49, also called as east coast road (ECR). This highway connects Chennai to Cuddalore and covers the highway between the toll gate at Akkarai and Manamai village near Mamallapuram. It has to be noted that most of this stretch is a two lane road, and is prone to accidents. In this study, we focus on using registered accident data from online databases, and analyze the accident patterns to identify black-spots. Additionally, we identify factors that affect accident propensity along this highway stretch.

The rest of the paper is structured as follows. Section 2 furnishes the review of literature on identifying black spots and factors that affect accident propensity along the highway. Section 3 presents the methodology employed in our study along with the results from our study, while Section 4 presents the conclusion of our study.

Literature Review

The literature on accident analysis focuses on identifying black-spots where accident propensity is high, and then studies various factors that have an effect on the accident propensity at different locations. This section presents a brief review of literature on accident analysis.

The black-spot represent a stretch (of say 100 meters) on the road network with high accident propensity [8, 9, 10, 11]. McGuigan [8] rank ordered the black-spots using a factor called potential for accident reduction that denotes the change in magnitude between the number of reported road traffic incidents and the number of predicted road traffic incidents. Elvik [9] presents a meta-analysis of 36 different studies on road accident blackspot treatment using the log odds method. The study evaluated the extent of the degree of control of four known compounding factors (change in traffic volume, general trend in the number of accidents, regression to the mean, and accident mitigation). A more comprehensive review of literature on black-spot analysis is presented in Elvik [12].

The earlier models for estimating the black-spots used of accidents counts and rates in a statistical quality control framework [10]. However, this method suffers a drawback due to the bias that may be introduced as a result of the regression-to-the-mean phenomenon. This potentially bias can lead to the choosing a site with a randomly high accident count. Persuad, Lyon and Nguyen [10] refined the empirical Bayes method to estimate the safety of a site, in comparison with its expected safety. Based on this, they rank ordered the sites.

Vistisen [11] proposed a multivariate accident analysis model for Denmark under the assumption that the annual accident counts at a particular location are dependent on prior annual estimates. Accordingly, they disaggregated the accident models into sub-periods of one year. The random variation in accident frequencies was described using a hierarchical Poisson-gamma distribution. The model assessed the deviation in the expected accident frequency at a location when compared to other locations with similar accident propensities. Thus, this model explicitly considers both the general trend in accident counts and the dispersion effects. The model offered better sensitivity than earlier models that were implemented in Denmark. Geurts et al. [13] performed accident analysis to identify and rank black-spots for Flanders in Belgium. At the time of the study, Flanders had approximately 1014 black-spots identified based on prior accident data. They performed a sensitivity analysis by assigning weight measures. The weight was defined as (*a_b_c*), where *a* represents the weight for each light accident, *b* represents the weight for each serious accident and *c* represents the weights for each deadly accident. This analysis investigated the impact of 3 different weight combinations, (1_1_1), (1_1_10) and (1_10_10). The study also used the expected number of accidents that were predicted using the hierarchical Bayesian model instead of actual counts.

Mohan et al. [14] and generated spatial and temporal profiles of road traffic incidents (RTI) on the road network in Vellore. The daily time series counts on RTIs were obtained using the first information reports (FIR) maintained in police stations (between January 2005 and May 2007), and the temporal characteristics were examined with respect to the vehicle, road-type and time of the year. A Poisson regression model was employed to estimate the trend in RTI. The study reported that more than 50% of RTI occurred in national highways, and black-spots were identified at major town junctions. The average RTI was significantly higher over weekends, and the fatality rate was 13%.

Mohan and Langde [15] identified black-spots on the Nagpur-Amaravati Asian highway 46 using data from the police department. They further conducted an on-field survey at these black-spots to bring out the latent details pertaining to the accidents. Other research effort that focused on black-spot analysis include the work of Chen [16].

The studies that analyzed accident propensity broadly considered the two types of factors – road infrastructure and human factors. The road infrastructure factors include road side design [17], road conditions and lighting [18], and lane width [19], while human factors include training level [18], sleepy driver [20], age and driver carelessness [21].

Ossenbruggen, Pendharkar and Ivan [17] employed logistic regression models and concluded that factors like land use, road side design, traffic exposure and traffic control devices played an important role in prediction of accidents through statistical models. The study also assessed that the rural areas were less prone to accidents than the urban centers.

Laha, Pravida and Ghosh [18] used data from the national bureau of crime records to identify the factors affecting accident propensity. The data revealed that the distribution of accident times was bimodal, and several combinations of bimodal distributions were considered in the modeling approach. The significant factors identified in the study included *bad condition of roads, traffic density, untrained drivers, slack in enforcement of rules, poor road conditions and sufficient road lighting in all areas*. Additionally, by employing circular flow analysis, the study identified *times* during the day when accident propensity increased.

Mussone, Ferrari and Oneta [22] built a traffic model for Milan in Italy by employing an artificial neural network model. The study concurred that non-signalized intersections resulted in most of the accidents during the study. Fridstrøm et al. [23] developed a generalized Poisson regression model to study accident data from Denmark, Finland, Norway and Sweden. The study considered the variations of accident counts into parts attributable to randomness, weather, daylight and speed limit. The study concluded that 80-90% of the variation was accounted by randomness and exposure (or traffic volume).

Noland and Quddus [24] performed a disaggregate spatial analysis using data from London to study the effect of congestion on traffic safety. A negative binomial count model was used to test whether factor affecting serious accidents differ during congested and uncongested time periods. The study concluded that congestion can mitigate crash severity in urban conditions, while the same may not necessarily hold on highways and motorways.

Jha et al. [25] considered factors such as wet road conditions, driver without license, lack of protective gear and alcohol consumption, and analyzed the data collected from accident reports.

The data was classified based on age group, gender and educational level. The study inferred that the common modes of accident were being knocked down, falling off vehicles, collision between vehicles, being run over, overturning and vehicles hitting stationary objects. With the same dataset, Jha et al. [26] analyzed the injury pattern among accident victims, and found that head, neck, chest, abdomen, pelvis, upper and lower limbs and back were the most common areas injured. The study also inferred that head injuries were common among bicycle riders, pedestrians and motorized two wheeler riders as they failed to wear protective gear like helmet.

Cantillo, Garces and Marquez [27] explored the relationship between the urban road accidents and factors of road infrastructure, traffic volumes, and traffic control. A total of 69 accident prone areas in the city of Cartagena in Columbia were identified using Bayesian models based on GIS. The paper concluded that more accidents occur in commercial areas due to high pedestrian density. Golob and Recker [28] applied linear and non-linear multi-variable statistical analysis to investigate the relationship between contributing various factors and the type of accidents in southern California. The study concluded that the type of collision is strongly correlated to the traffic speed and the temporal speed variation in the left an interior lanes. Additionally, collisions involving multiple vehicles was found to be more prevalent on wet roads, and rear-end collisions occur on dry roads during daylight.

Ahsan [29] reviewed the process of accident reporting and recording system and the present status of the database. Further, the study also discussed the potential sources of error in accident data collection. It was observed that the sources of accident data are biased as a result of under-reporting, especially in the case of minor accidents.

The literature review alludes to the fact that factors affecting road accidents depends on the local road and weather conditions as well as other driver-related factors. As a result, given the large number of road traffic incidents in ECR, we see that there is a need to analyze the factors that affect traffic accident propensity in the highway.

Methodology and Results

In this study, we restrict ourselves to a 25 km stretch between the toll booth in Akkarai and Manamai village near the coastal town of Mamallapuram. This stretch is mostly characterized by only two lanes. We collected data regarding 100 registered road accidents over a period between 20-08-2018 to 26-05-2019. The variable used in our model can be broadly included into human variables and environmental factors including road conditions. The individual factors and their corresponding codes are listed in Table 1.

Table 1: Levels of each factor

Factor	Code	Description
Age	-	-
Sex	2	1 (male) and 2 (female)
# of lanes	2	1 and 2
Presence of footpath	2	1 (yes) and 0 (no)
Presence of shoulder	2	1 (yes) and 0 (no)
Shoulder type	2	1 (paved) and 0 (unpaved)

Junction type	2	1 (cross junction) and 0 (not a junction)
Presence of central divider	2	1 (yes) and 0 (no)
Severity of injury	3	1 (vehicle damage), 2 (minor injury) and 3 (fatal injury)
# of drivers involved	2	1 and 2
# of vehicles involved	2	1 and 2
# of passengers involved	5	0, 1, 2, 3, and 4
# of pedestrians	2	0 and 1
Collision type	4	1 (head on), 2 (hit from rear), 3 (hit pedestrian), 4 (skidding)
Speed Limit	1	40
Accident cause	3	1 (inebriated driver), 2 (driver fault), 3 (over speed)
Light conditions	4	1 (day light), 2 (twilight), 3 (darkness with poor street light), 4 (darkness with no street lights)

The data was then analyzed using R software to identify various factors that affect road traffic propensity.

3.1 Effect of each factor on Accident Propensity

Some of the key findings of our study are presented as follows.

1. The analysis on the effect of driver age on accident propensity shows that most of the accidents (37 out of the 54 records with age information, 68%) are caused by young drivers between the age of 18 and 35 as shown in Figure 1.
2. The gender-based analysis indicated that a male was involved in 94% (80 out of 85 scenarios) of accidents.
3. 99 of the 100 accidents occurred in two lane roads.
4. 98 out of 100 accidents occurred at highway locations that has a shoulder. Of these, 75.5% (74 out of 98) of the accidents happened in the presence of unpaved shoulders.
5. Only 7% of the accidents occurred at junctions. This means that most of the accidents happen in straight road segments, where the cause could be inebriated drivers, over speeding or other driver faults. A careful evaluation shows that 98 out of 100 accidents considered in the study occurred due to over speeding, while one accident was attributed to inebriated driver.
6. 91 % of the accidents happen at locations with no central dividers. This could mean that some of the accidents occur when an over speeding driver is trying to overtake in a two-lane road.

7. Out of the 100 accidents, 38 were head-on collisions, 34 were hit from rear collisions, 14 were caused by skidding, and the remaining accidents involved pedestrians (see Figure 2). 73 accidents involved two vehicles (drivers). In one of the case where two vehicles were involved, a pedestrian was hit.
8. Out of the 100 accidents, 13 resulted in vehicle damage, 77 resulted in minor injuries, while the remaining 10 were fatal.
9. An analysis based on number of passengers (other than the driver) involved showed that 72 accidents occurred when there were no passengers, 18 occurred when there was one passenger, 9 in the case of two passenger, and 1 in the case of four passengers.
10. Based on the light condition, it was found that 76 accidents occurred during the day time, 12 during twilight and the remaining 12 in darkness. Among the 12 accidents that occurred in darkness, 10 occurred when there were no street lights in the location, and the street lighting was poor in the remaining two cases.

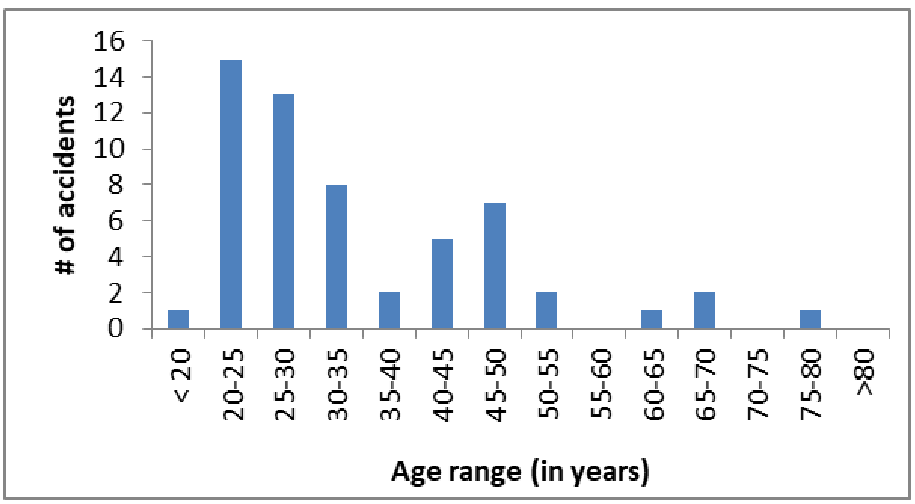

Figure 1: Effect of Driver Age on Accident Propensity

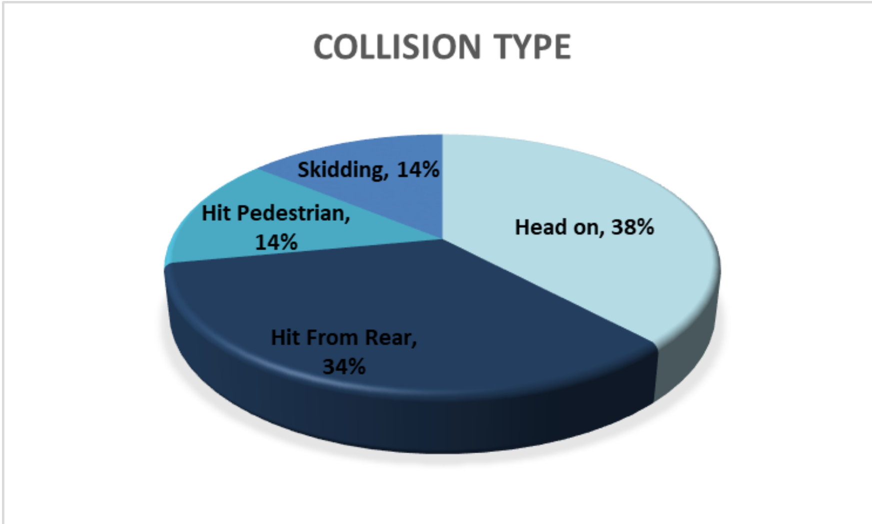

Figure 2: Distribution of Collision Type

3.2 Interaction effect between factors on Accident Propensity

A study of the interaction between the factors led to some interesting findings which are provided as follows.

1. The interaction between junction type and the severity of injury shows that when an accident occurs at a location that in not in a junction, there is a higher possibility that the severity of the injury is minor. Out of the 93 such accidents, 72 resulted in minor injuries (77.4%), 8 resulted in fatal injuries (8.6%) and the remaining 13 resulted in only vehicle damage (14%). However, for the small number of accidents that occur in cross junction (7), the result is either a minor injury (5) or a fatal injury (2). However, a larger data needs to be analyzed before making any solid conclusion on this scenario.
2. In Figure 3, the red, green and yellow dots are used to represent fatal injuries, vehicle damage only cases, and minor injuries, respectively. From the data analysis it can be inferred that no matter the light condition – day light or poor light, if the accident involves pedestrians', chances are that the accident will be fatal. Also when the accident cause is due to high speed and when pedestrians are involved the accident will be fatal.
3. Figure 4 shows that factors such as number of passengers and number of drivers do not have much of an effect on the severity of the accident.
4. Figure 5 depicts the severity of accidents based on the road infrastructure. When the number of lanes is 2 and the roads have cross junction, it can be seen from the analysis

that there is a higher chance of fatal injuries. Similarly, the accidents have been fatal when foot paths are present and the roads have cross junctions. Also, it can be noticed that there are no accident when the junction type is cross junction and central divider is present. However, when central divider is not present at a cross junction, any accident has been fatal.

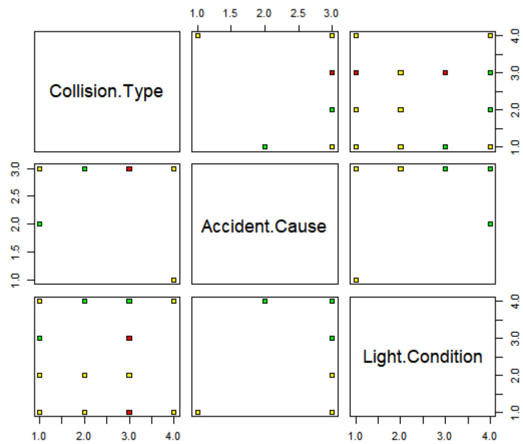

Figure 3: Interaction effect between light conditions, accident cause and collision type

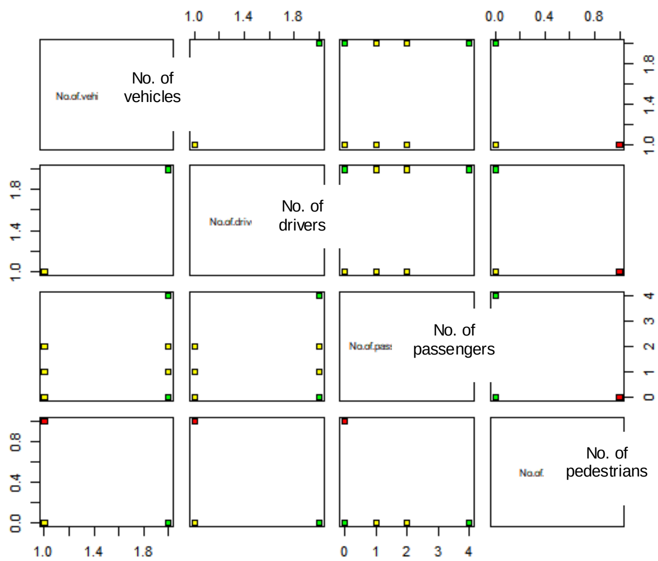

Figure 4: Interactive effect between # of vehicles, drivers, passengers and pedestrians

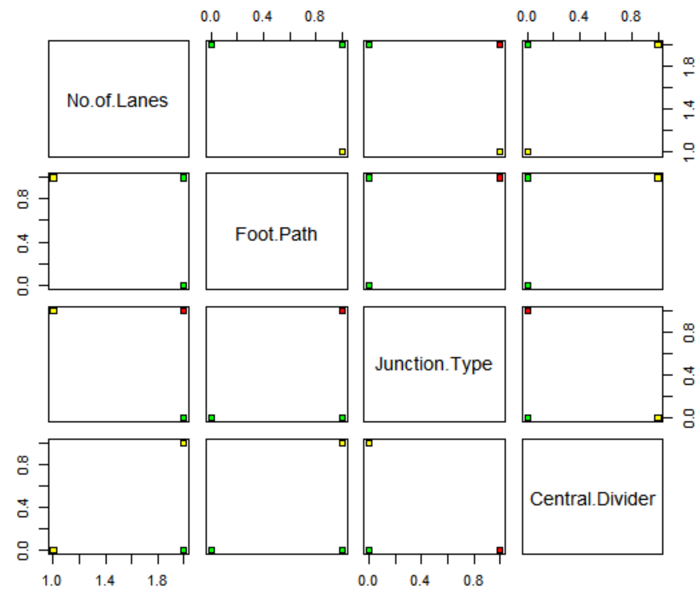

Figure 5: Interaction effect between various road infrastructure factors

3. 3 Location Analysis

The word cloud presented in Figure 6 depicts the accident prone zones in ECR and the size of the text shows the frequency of accidents. The higher the font size, the more the number of accidents in that particular area. The location analysis shows that most of the accidents between 20-08-2018 to 26-05-2019 occurred at Nenmeli and Manamai. The data suggests that Nenmeli accounts for the most accidents (23%) followed by Manamai (18%) and Thiruporur (14%). Together, these three locations account for 55% of the total accidents in the portion of the highway during the duration of the study. Additionally, it was also seen that most of the accidents in Nenmeli happened at a place close to the beach and a religious place. Figure 7 illustrates the bar chart of locations in descending order of the number of accidents.

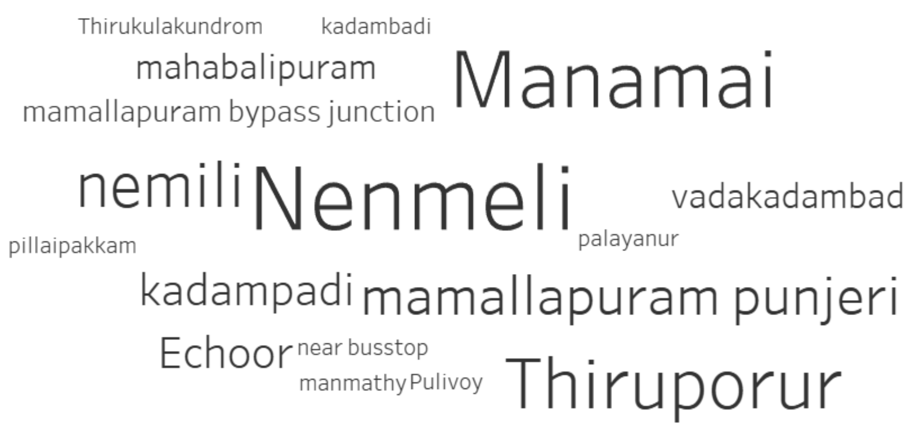

Figure 6: Word cloud showing locations in ECR based on number of accidents

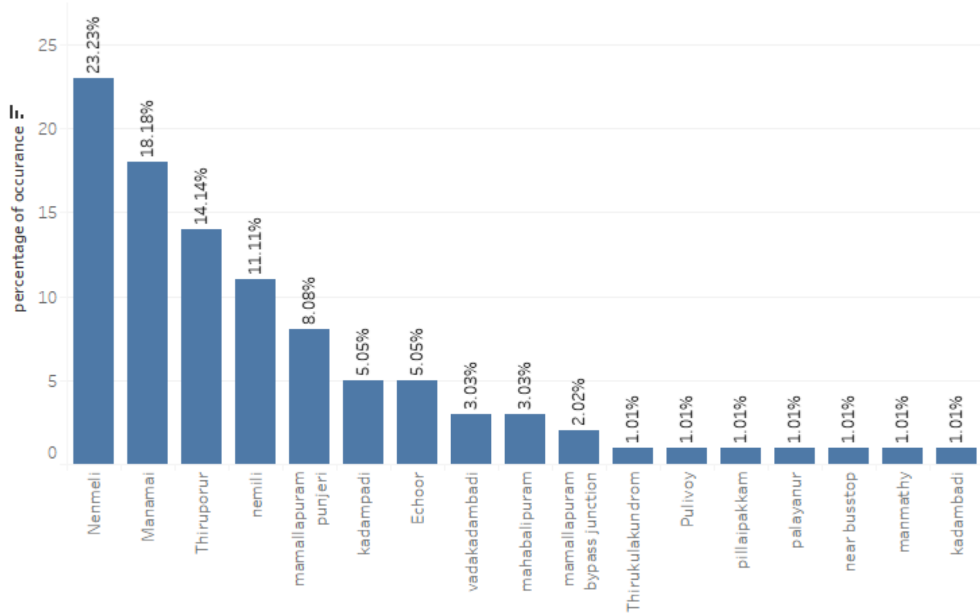

Figure 7: Black-spots in descending order of percentage of accidents

Conclusions

The study analyzes only a small subset of data and presents some useful insights on the accident patterns in a small stretch of SH-49, state highway of Tamil Nadu. At a preliminary level, it helps identify black-spot regions and major contributing factors to accidents in this area of interest. The data on registered accidents was analyzed using R. The study identified that the major cause of accidents on ECR is due to over speeding vehicles. Since ECR is a highway most of the vehicles travel at an average speed of 50km/h to 90km/h. At this speed, accidents could potentially range from serious to fatal. In our analysis, we have noticed minor injuries in most accidents. Further, most of the accidents occurring in different light conditions, especially involving pedestrians led to fatal accidents.

Owing to the small data size, it will be preemptive to make safety recommendations based on the results. However, this work forms the basis for evaluating a larger data set to draw definite conclusions that has the propensity to be modelled for further road accident preventions and recommend much warranted road safety implementations.

References

WHO, Global plan for the decade of action for road safety 2011-2020, World Health Organization, Geneva, Switzerland, 2011.

WHO, Decade of Action for road safety 2011-2020 : Global launch, World Health Organization, Geneva, Switzerland, 2011.

WHO, Global status report on road safety 2018, World Health Organization, Geneva, Switzerland, 2019.

ITF, Road safety annual report 2019, International Tranport Forum, Paris, France, 2019.

P. Mondal, A. Kumar, U. D. Bhangale and D. Tyagi, "A silent tsunami on Indian road: A comprehensive analysis of epidemiological aspects of road traffic accidents," *British Journal of Medicine and Medical Research,* vol. 1, pp. 14-23, 2011.

G. K. Rao, "Road traffic safety management in India – Analysis - Exploring solutions," *International Journal of Application or Innovation in Engineering & Management,* vol. 2, pp. 54-67, 2013.

MoRT&H, Road accidents in India - 2018, Government of India, Ministry of Road Transport & Highways (M0RT&H), New Delhi, India, 2019.

D. R. D. McGuigan, "The use of relationships between road accidents and traffic flow in ``Black-Spot" identification," *Traffic Engineering and Control,* vol. 22, pp. 448-453, 1981.

R. Elvik, "Evaluations of road accident blackspot treatment: A case of the iron law of evaluation studies?," *Accident Analysis & Prevention,* vol. 29, pp. 191-199, 1997.

B. Persaud, C. Lyon and T. Nguyen, "Empirical Bayes procedure for ranking sites for safety investigation by potential for safety improvement," *Transportation Research Record: Journal of the Transportation Research Board,* vol. 1665, pp. 7-12, 1999.

D. Vistisen, "Models and methods for hot spot safety work," Ph.D. dissertation, Department of Informatics and Mathematical Modeling, Technical University of Denmark, Denmark, 2002.

R. Elvik, State-of-the-art approaches to road accident black spot management and safety anlysis of road networks, Report 883, Institute of Transport Economics, Oslo, 2007.

K. Geurts, G. Wets, T. Brijs and K. Vanhoof, "Identification and ranking of black spots: Sensitivity analysis," *Transportation Research Record: Journal of the Transportation Research Board,* vol. 1897, pp. 34-42, 2004.

V. R. Mohan, R. Sarkar, V. J. Abraham, V. Balraj and E. N. Naumova, "Differential patterns, trends and hotspots of road traffic injuries on different road networks in Vellore district, Southern India," *Tropical Medicine & International Health*, vol. 20, pp. 293-303, 2014.

A. Mohan and V. S. Landge, "Identfication of accident black apots on national highway," *International Journal of Civil Engineering and Technology,* vol. 8, pp. 588-596, 2017.

H. Chen, "Black spot determination of traffic accident locations and its spatial association characteristic analysis based on GIS," *Journal of Geographic Information System*, vol. 04, pp. 608-617, 2012.

P. J. Ossenbruggen, J. Pendharkar and J. Ivan, "Roadway safety in rural and small urbanized areas," *Accident Analysis & Prevention,* vol. 33, pp. 485-498, 2001.

A. K. Laha, A. C. R. Pravida and D. K. Ghosh, "Distribution of traffic accident times in India - Some insights using circular data analysis," *International Journal of Business Analytics and Intelligence,* vol. 5, pp. 26-35, 2017.

B. N. Kiran, N. Kumaraswamy and C. Sashidhar, "A review of road crash prediction models for developed countries," *American Journal of Traffic and Transportation Engineering*, vol. 2, pp. 10-25, 2017.

F. Sagberg, "Road accidents caused by drivers falling asleep," *Accident Analysis & Prevention,* vol. 31, pp. 639-649, 1999.

M. Mohanty and A. Gupta, "Factors affecting road crash modeling," *Journal of Transport Literature*, vol. 9, pp. 15-19, 2015.

L. Mussone, A. Ferrari and M. Oneta, "An analysis of urban collisions using an artificial intelligence model," *Accident Analysis & Prevention*, vol. 31, pp. 705-718, 1999.

L. Fridstrøm, J. Ifver, S. Ingebrigtsen, R. Kulmala and L. K. Thomsen, "Measuring the contribution of randomness, exposure, weather, and daylight to the variation in road accident counts," *Accident Analysis & Prevention*, vol. 27, pp. 1-20, 1995.

R. B. Noland and M. A. Quddus, "Congestion and safety: A spatial analysis of London," *Transportation Research Part A: Policy and Practice*, vol. 39, pp. 737-754, 2005.

N. Jha, D. K. Srinivasa, G. Roy and S. Jagdish, "Epidemiological study of road traffic accident cases: A study from south India," *Indian Journal of Community Medicine*, vol. 29, pp. 20-24, 2004.

N. Jha, D. K. Srinivasa, G. Roy and S. Jagdish, "Injury pattern among road traffic accident cases : A study from south India," *Indian Journal of Community Medicine*, vol. 28, pp. 85-90, 2003.

V. Cantillo, P. Garces and L. Marquez, "Factors influencing the occurrence of traffic accidents in urban roads: A combined GIS— empirical Bayesian approach," *DYNA*, vol. 83, pp. 21-28, 2016.

T. F. Golob and W. W. Recker, "Relationships among Urban Freeway Accidents, Traffic Flow, Weather, and Lighting Conditions," *Journal of Transportation Engineering*, vol. 129, pp. 342-353, 2003.

H. M. Ahsan, "Reporting and recording road traffic accidents in Bangladesh," in *4th Annual Paper Meet and 1st Civil Engineering Congress*, 2011.