Proceedings of IOE Graduate Conference, 2015
pp. 339–343

Dependency of Road Accidents with Volume and Speed (A Case Study of Major Black Spot Location within Kathmandu Valley)

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Abstract

Road Crashes, simply termed accidents; refers to any accident involving at least one road user and resulting in injuries, death and/or loss of property. Approximately 1.24 million annual fatalities occurs as a result of road accident, which rank as eighth overall cause of death, Fifth ranked killer of women and First ranked killer of young people aged 15 – 29. Unpremeditated vehicular growth, over speeding, road condition, vehicular and road user characteristics are the major contributor of increasing accidents frequency in Kathmandu valley, which accounts for more than 5,000 accidents. Speed and volume are often considered as the major contributor of road accidents. Three form of speed, viz. 85^{th} percentile speed, time mean speed and space mean speed; traffic volume, expressed as PCU per hour per lane and percentage of two wheeler are checked for their influence on the number of accidents in this research paper. Model is being developed using major nine black spots locations within Kathmandu valley. Independently each independent variables has less impact on the accident, but the significance of the model gets increases when impact of speed and volume is studied, as R^2 value reach near to 33%. Similarly model comprising all three independent parameter yield even more significant model, with goodness of fit of 50%. Though it was found that road crashes get influenced to quite reasonable extent by speed, traffic volume and percentage of two wheeler at the locality. Just 50% goodness of fit reveals that other independent variables that may include road geometry (radius, grade, sight and setback distance, presence of divider, etc), road pavement condition, vehicular condition and road user characteristics need to be consider for development of more realistic model.

Keywords

Road Crashes – Accidents – Black spot – Volume – Speed – goodness of fit

1. Introduction

Road Crashes (RC) or Road Traffic Injuries (RTI), or simply road accidents refers to any accident involving at least one road user, occurring on a road open to public circulation resulting in injuries, death and/or loss of property. Road crashes leads to both mortality as well as morbidity along with financial loss. Thus, traffic safety is one of the major challenge in today's world. Approximately 1.24 million people die, and another 20 to 50 million sustain nonfatal injuries as a result of road traffic crashes annually. Road crashes is the eighth leading cause of death globally, with an impact similar to that of communicable diseases, such as malaria. It is the Fifth ranked killer of women and First ranked killer of young people aged 15 - 29. Current trends suggest that road traffic injuries will become the fifth leading cause of death by 2030 [1]. UN Secretary General Ban Ki-moon warned the necessity of funding for Decade of Action for Road Safety 2011-2020 to reduce road accidents to 50% for developed countries and 35% for developing countries. [2]

Road accident are the consequence of various factors, such as: road user, vehicular, road and environmental factors. Road user i.e. human factor includes physical, mental, psychological and behavioral aspect of road user, which alone contributes two third and 95 percent combining with other factors. Vehicular factor contributes 8 percent, whereas road and environment factors share 28 percent of total road accident in union form. Among various human factors, reckless driving, immaturity, over-

speeding, unsafe overtaking, driving under influence of alcohol are the major factors that are often on news in most of the road accidents. Road geometry, such as inadequate sight distance, sharp curves, steep gradient; poor road condition are the poor engineering aspect that might cause accident. Vehicular factors contributing to road accidents may includes poorly maintained vehicles, low brake efficiency, overloading of vehicles. [3]

Road fatalities accounts about 1,800 annum fatalities nationwide and more than 5,000 accidents occurs within Kathmandu valley. One of the major cause of accident within Kathmandu valley is supposed to be over speeding and high traffic volume, especially percentage of two wheelers. About 1.6 million motorized vehicles are registered in the country with highest share of motorized two wheelers, which is about 80 percent. [4]

It is utmost necessary to enhance the road safety scenario nationally and globally. Various Road Safety Strategies are summarized as "E", which includes: Education, Engineering, Enforcement and Emergency response. Awareness campaign, Traffic Safety week, Orientation program to drivers, Road safety education from school level are some of the educational measures to change attitude and behavior of road user. Improving horizontal and vertical alignment, provision of cat eye and delineating measures, maintenance of vehicles, road lighting and enhancing pavement surface characteristics are some engineering measures. Medical check, Speed limit and Drug under Influence checking and high enforcement of traffic rules and punishment to violator also helps to increase road safety status [5]. Also statistics reveals that more than half the fatalities occurs not at site, just during transportation from site to hospital or at hospital, and hence fully equipped ambulance service, First aid kit, trauma center helps to improve road safety accident.

2. Objectives of Study

There are various factors that contributes to accident within the urban area, major of these factors includes road user characteristics along with road condition. Traffic volume and speed are regarded as one of the major contributor of accidents and thus the question arises how much impact these factors has on road accident. Thus, the objectives of this research work is to check the dependency of road accident on speed, traffic volume and proportion of two wheeler via development of model based on the selected major black spot areas within Kathmandu valley. Also the models have been checked for their statistical significance before any sort of conclusion is drawn from the model.

3. Methodology

3.1 Study Area

Traffic Police analyze location with frequent accidents and termed them as Black Spots locations, based on statistics. Traffic police are the concerned authority in arranging data on road accidents statistics, but the records are not digitized and even lacks technical evaluation. Even there is not the exact location of major black spots. Last three year statistics of various black spot locations were analyzed and nine highest one are selected as the study area.

Table 1: Selected Major Black spot locations

Location	Number of Accidents at year		
	2068-69	2069-70	2070-71
Koteshwor	527	564	597
SinghaDurbar	160	281	336
Satdobato	285	322	319
New Buspark	264	249	284
Swayambhu	127	192	210
Maharajgunj	149	130	207
Jawalakhel	212	236	203
Gaushala	381	253	162
Gatthaghar	109	122	156

Among the nine locations, Gausala only is found to have decreased accidents/crash rate in each year; whereas Jawalakhel also has decreased accidents compared to first year, whereas all other location have increased accident rate.

3.2 Data Collection and Analysis Methodology:

Classified vehicle count and spot speed measurement are two primary data collection methods. Statistics on accidents are obtained via secondary sources (Traffic Police). There is not precise location of black spot and thus this research is based on the assumption that the volume and speed at the selected stretch can be generalized to be throughout the provided black spot area. The stretch

of road section at each black spot area is selected such that it is straight and unaffected by influence of parking, bus stops and intersection. Geometrical features of the road at these sections were noted down, especially width of road via measuring tape.

Spot speed is the instantaneous speed of a vehicle at a specific location. Speed is maximum during off peak hour and hence spot speed measurement is performed between morning(8:30-10:30) and evening peak (16:30-18:30). Manual method of spot speed measurement is employed for data collection for one hour duration in each direction. Random Sampling techniques, considering every 5th vehicles is adopted for study. Class interval has been determined for each direction and 85th percentile speed, along with time mean speed and space mean speed at each location has been determined.

Classified traffic count, is performed during peak period in either morning (8:30am-10:30am) or evening peak (4:30pm-6:30pm) for an hour and 15 minutes at each location. Vehicles have been categorized into five types viz. two wheeler (bike and scooter), car/jeep, micro/light truck, bus/truck, and tempo [6] and each fifteen minute count has been recorded manually. Fifteen minute count is considered as stable flow [7] and has been employed for this study and this is further used to determine peak hour and peak hour factor, which ultimately helps to determine design Hourly volume (volume/PHF). Each types of vehicles have a certain equivalency factor, called Passenger Car Unit (PCU)and total volume of each category is multiplied by PCU factor and divided by number of lane to obtain PCU per peak hour per lane.

Table 2: Passenger Car Unit (NRS 2070)

Vehicle	Two wheeler	Car/ jeep	Micro	Bus/ Truck	Tempo
PCU	0.5	1	1.5	3	1.5

The percentage of bike in terms of PCU composition is also calculated for each location. Thus, there will be three major independent variables, percentage composition of bike in terms of PCU, different forms of speed (Time mean speed, Space mean speed and 85th percentile speed) and volume expressed as design PCU/hour/lane. As this study just check the dependency of accident on volume and speed, all nine location data have been used to calibrate the model for each independent variables first then in union. And, later goodness of fit for each model have been analyzed and conclusion regarding the dependency of accident with volume and speed is justified based on the model.

The study only assumes linear relationship between the dependent and independent variables[8]. And the goodness of fit is just checked based on R^2 vale and standard error. As crashes are found to have occurred during off peak hour due to speeding and during peak hour due to high traffic volume. Hence it is assumed that peak hour volume and off peak hour speed affect the crash/accidents rate significantly rather than speed and volume both at same time and thus off peak hour speed and peak hour volume is used for modeling purpose.

4. Data Analysis

Time mean speed (TMS) is the average of the speed measurements at one point in space over a period of time. Simply, it is the arithmetic average of a number of spot speed measurements.

$$TMS = \frac{\sum f * x}{\sum f}$$

Space mean speed (SMS) is the average of speed measurements at an instant of time over a space. Simply, it is the harmonic mean of spot speed measurement.

$$SMS = \frac{\sum f}{\sum f/x}$$

where f = frequency and x = mid value

Being arithmetic mean, TMS is always greater than SMS. Both will have same value only when all the vehicles moves at a same speed.

85th percentile speed, also known as upper speed limit, is the speed above which 15% of the vehicles still moves on the roadway segment and is obtained from cumulative frequency distribution curve. Volume is expressed as PCU/hr/lane during peak hour period. The composition of 2-wheeler is expressed in two ways: % of 2-wheeler in total composition (in terms of just number) and % of 2-wheeler expressed as PCU in total PCU considering all vehicles. Bike is used to represent all the two wheeler throughout this paper. All the calculated data[9] have been summarized in the Table 3.

Table 3: Summarized Dependent and Independent variables

Location	Accident	Speed (Kmph)			Lane	Volume (PCU / hr / lane)	% bike in terms of PCU	% bike in total volume
		85%	Time mean	Space Mean				
Gaushala	162	27	22.79	21.45	4	958	36.13	62.78
Gatthaghar	156	28	24.28	22.83	4	1096	47.84	75.52
Swayambhu	210	26	23.45	22.46	3	926	34.54	63.65
Jawalakhel	203	22	18.66	16.79	3	1245	51.33	71.23
Koteshwor	597	31	26.91	24.31	6	1266	39.41	66.27
Maharajgunj	207	31	27.47	26.29	4	829	28.07	55.92
Naya buspark	284	29	25.39	23.42	3	1212	29.42	57.69
Satdobato	319	27	22.99	21.32	3	843	26.52	54.99
Singhadurbar	336	48.5	42.24	40.51	4	853	45.87	70.21

Model have been calibrated to check the dependency of number of accidents/crashes (A) with each independent variables. All the calibrated model have been checked for their goodness of fit and standard error, which shows that none of the independent variable has high impact on road accident alone, with high impact of just 11% of 85th percentile speed, followed by 10.4% of traffic volume. Also, as the impact of bike proportion in total PCU and that in just total composition alone is too low. Among two, bike proportion expressed in terms of total PCU is used in further calibration as both have almost similar value. All the developed model along with R^2 value and standard error have been summarized in Table 4.

Table 4: Model Calibration with just one independent variables

S.N	Calibrated Model	R^2 Value	Std. Error
1	$A = 97.2 + 5.94 \times 85\%$ Speed	0.11	138.6
2	$A = 103.2 + 6.59 \times$ TMS	0.10	138.9
3	$A = 142.9 + 5.41 \times$ SMS	0.07	141.5
4	$A = 24.25 + 0.244 \times$ Volume	0.104	138.7
5	$A = 313.18 - 1.02 \times$ %Bike expressed as PCU	0.0045	146.2
6	$A = 355.94 - 1.26 \times$ %Bike in total composition	0.0044	146.3

Then the models considering two various independent variables are calibrated, which yields comparatively reasonable goodness of fit as illustrated in Table 5. Based on table 5, it is found that volume and any forms of speed in combination has the greater impact on the accident as the impacts is about 33% compared to just 10% when just a single independent variable is considered.

Table 5: Model Calibration with two independent variables

S.N	Calibrated Model	R^2 Value	Std. Error
1	$A = 9.5 \times 85\%$speed $+ 0.4 \times$ volume $- 412.3$	0.335	129.1
2	$A = 10.9 \times$ TMS $+ 0.4 \times$ volume $- 411.9$	0.334	129.2
3	$A = 10.4 \times$ SMS $+ 0.4 \times$ volume $- 397$	0.303	132.1
4	$A = 84.2 - 0.3 \times$ volume $- 3.72 \times$ %bike expressed as PCU	0.154	145.6
5	$A = 153.2 + 6.2 \times 85\%$speed $-1.7 \times$ % bike expressed as PCU	0.117	148.7
6	$A = 156.5 + 6.8 \times$ TMS $- 1.58 \times$ % bike expressed as PCU	0.112	149.0
7	$A = 191.7 + 5.6 \times$ SMS $- 1.42 \times$ % bike expressed as PCU	0.076	152.0

Finally the model is calibrated considering volume, bike proportion and all forms of speed as independent variables and have been summarized in Table 6.

Table 6: Model Calibration incorporating all independent variables

SN	Calibrated Model	R^2 Value	Std. Error
1	$A = 12.58 \times 85\%$speed $+ 0.59 \times$ Volume $- 7.41 \times$ %Bike expressed as PCU $- 433.7$	0.509	121.5
2	$A = 13.94 \times$ TMS $+ 0.59 \times$ Volume $- 7.12 \times$ %Bike expressed as PCU $- 425.06$	0.497	122.96
3	$A = 13.8 \times$ SMS $+ 0.47 \times$ Volume $- 7.16 \times$ %Bike expressed as PCU $- 422.16$	0.467	126.75

Accidents seems to have good correlation with speed, volume and bike proportion expressed as PCU as the goodness of fit reaches about 50 percent. This shows, road sections with high volume per lane and high speed tends to have high number of accidents.

5. Summary and Conclusion

Three form of speed, viz. 85^{th} percentile speed, time mean speed and space mean speed; peak traffic volume and percentage of two wheeler are checked for their influence on the number of accidents within the Kathmandu valley based on data of nine black spot locations. Number of accident is highly influence by speed and volume in combination as goodness of fit reaches 33 percent. When proportion of bike is also incorporated in the model, even it yields more significant model, with goodness of fit of about 50 percent. One interesting fact obtained from the model is that proportion of bike has the negative impact on the accidents number based on calibrated model as the coefficient for percent % bike expressed as PCU in Table 5 and 6 is negative. This shows, all other independent variables remaining constant, accident gets decreases with increase in proportion of bike in that certain locality.

Due to less goodness of fit (R^2) and high standard error, the developed model is not recommended as the most appropriate model for predicting accidents at other location. Yet, conclusion can be drawn that accident is influence to quite reasonable extent by speed, traffic volume at the locality and percentage of two wheeler. Just 50 percent goodness of fit reveals that other independent variables that may include road geometry (radius, grade, sight and setback distance, presence of divider, etc), road pavement condition, vehicular condition and road user characteristics need to be consider for development of more realistic model.

6. Research Area

This paper only covers the relationship of accident with various forms of speed, volume and proportional of certain type of vehicles. This doesn't account for large significance on the developed model and thus, models comprising different independent variables, i.e. road condition (SDI, IRI, etc), geometric features (radius, grade, etc.), road user characteristics, location characteristics, etc. need to be developed for higher level of accuracy. These models with higher accuracy can be used to predict the accidents at various location. One of the conclusion from this study is road accident is negatively impacted by proportion of bike, this finding need to be supported by another research.

Acknowledgments

This paper is based on Project work, conducted as a partial fulfillment of the requirement for Bachelor Degree in Civil Engineering. The author would like to thank National College of Engineering for providing the platform for this sort of research work. The acknowledge will not be complete without appreciating the effort, dedication and contribution of Reetu Bangshi Thakuri, Shanker Kshetri, Smriti Shrestha, Sonalee Chhetri, Bhawana Maharjan and Bidur Pathak for the successful completion of this research work.

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