How to Cite:
Pandey, S., & Bura, G. S. (2022). Identification of risk factors associated with road traffic accident in hilly road segment using accident severity model. *International Journal of Health Sciences*, *6*(S3), 5864–5873. https://doi.org/10.53730/ijhs.v6nS3.7285

Identification of risk factors associated with road traffic accident in hilly road segment using accident severity model

Shubham Pandey
Research Scholar. Department of Statistics, BanasthaliVidyapith, Rajasthan, India
*Corresponding author email: shubhambiostat@gmail.com

Gulab Singh Bura
Assistant Professor, Department of Statistics, BanasthaliVidyapith, Rajasthan, India
Email: burastats@gmail.com

***Abstract*---**Every year, 1.2 million people die as a result of road traffic accidents (RTA). Following ischemic heart disease and depression as the leading causes of death, RTA will become the third leading cause of death worldwide. The first RTA instance was documented in 1896 [1]. The term "black spot location" refers to an area where the number of traffic accidents is higher. The most prevalent assumption for a black spot site is that there should be any environmental or physical concerns on the road that are causing accidents to occur repeatedly. Our study was conducted in two districts of the Northern Region of India (Uttarakhand). The data were collected on various factors such as weather, accident type, severity levels, road geometry such as the number of curves, segment length, Annual Average Daily Traffic etc. The present study was an attempt to find out the risk factor for road traffic accident in the identified blackspots in the areas of Dehradun and Haridwar. Roadside features were found to significantly affect the severity of run-off-roadway accidents including the presence of bridges, cut-type slopes, ditches and culverts, fences, tree groups, sign supports, utility poles, and isolated trees, and guardrails.

***Keywords*---**road traffic accidents, black spots, hilly road segment, severity analysis.

Introduction

Many countries are experiencing significant economic losses as a result of vehicle accidents. India is one of these countries. The nature of transportation behaviour

Manuscript submitted: 9 March 2022, Manuscript revised: 18 April 2022, Accepted for publication: 1 May 2022

in our nation is varied, resulting in a greater risk of road accidents. According to a study from the Ministry of Road Transport and Highways (MoRTH), India has the greatest number of accidents in the world. In India, the severity of accidents has been growing year after year. Due to population expansion and technological advancements, the number of motor vehicles on the road today is rapidly increasing. In contrast to rich countries, developing countries have financial challenges in enhancing road safety. [2] The first step in improving road safety is identifying black spots, which is the first stage in black spot treatment. "A road accident black spot on National Highways is a road stretch of about 500m in length where either 5 road accidents (involving fatalities/grievous injuries) occurred during the last three calendar years or 10 fatalities occurred during the last three calendar years," according to the Ministry of Road Transport and Highways (MoRTH), Government of India[3]. Road traffic injuries and deaths are a serious public health concern in developing nations, accounting for more than 85 percent of all deaths and 90 percent of disability-adjusted life years [4].

The basic elements in traffic accidents are road users, vehicles, road condition, road geometry, environmental factors etc. There have been a number of recent examples in the literature [5, 6, 7] of panel data analyses using accident data. For example, the National Safety Council [8] devised a scheme for injury classification-no injury, possible injury, non-incapacitating injury, incapacitating injury, and fatal injury. Road features such as road width, deficit in super elevation, deficiency in site distance, radius of horizontal curve, and others are the primary cause of road accidents. Although road accidents cannot be completely avoided, the accident rate can be decreased by implementing appropriate traffic engineering safety plans and management procedures. Even after an accident, ordinary city roads confront several challenges, such as traffic bottlenecks, which waste important time. As a result, the precision with which black spots are identified has a significant impact on the efficacy of black spot analysis and therapy (Elvik, 2006) [9]

The identification of black spots in Dehradun and Haridwar City is described in this research. The discovery of black spots can aid in the better planning of road safety strategies. The black spot detection approach has also been proved in previous studies and practises to be an effective and reactive method of dealing with the incidence of accidents [10]. According to a research, black spots were identified using techniques such as the Accident Rate Way, Quality Control Method, Accident Density Method, Number of Accidents Method, Combined Method, and the method of severity Index [11].

Nguyen et al. [16] suggested a safety-potential-based black spot management approach for finding true black spots, which relies on a projected number of accidents as an extra criterion in identifying actual black spots. That is, the safety-potential-based approach uses three metrics to identify black spots: the number of accidents that have occurred, the predicted number of accidents, and the critical value. [17] A study by Shankar, Mannering and Barfield (1996) employed a statistical model to provide a broad range of variables, including roadway geometry and weather-related conditions, as well as driver characteristics. Their estimation results provided valuable evidence on the effects that environmental conditions, highway design, accident type, driver characteristics, and vehicle attributes have on accident severity. [18]. Several run-off-roadway accident studies have examined particular roadside features. Council and Stewart (1996) attempted to develop severity indexes for various fixed objects that are struck when vehicles leave the roadway. [19]

Numerous accident severity studies have attempted to determine the impacts of risk factors. In terms of empirical perspectives, many studies have focused on relationships between alcohol and crash risk. [20-23]. For each discovered blackspot in both districts, various factors were investigated using a nested logit technique. The estimated coefficient and t-statistics were determined for variables such as Night, winter, High Traffic, Shoulder width, Lane width, Curve indicator, Guardrail indicator, Bridge, and tree groups.

Methodology

The methodology used in this study aimed to study the effect of roadside characteristics and roadway geometry on run-off-roadway accident severity. A nested logit model was used for this purpose. Among various level of severity, the correlation was captured considerably by all the possible nested structures. The three nested logit models – Total, Urban and Rural sections were estimated with standard maximum likelihood methods for the run-off-roadway accident severity. Road accident data for a one year (January 2019 to December 2019) was collected through respective police station limits of Dehradun and Haridwar city. Based on the data collected, the Accident Severity Index (ASI) value was calculated.. The concept of this method is that the number of fatal or injury accidents at a location is given a greater weight than property damage-only accidents.

Severity of Accidents

Severity of accidents can be expressed in terms Accident Severity Index which measures the seriousness of an accident. It is defined as the number of person killed per 100 accidents. (MORTH, 2012).

Accident Severity Model

A conditional model of accident severity could be developed by assuming discrete outcome data. The Multinomial Logit (MNL) model could be derived to determine the probability of a run-off-roadway accident having a specific severity level by starting with the following probability statement:

$$P_n(i) = P\ (S_{in}\ \geq S_{In}) \qquad \forall\ I \neq i$$

Where,
P = probability
S_{in} = function provided by severity
i = accident
$P_n\ (i)$ = the probability that a discrete outcome i occurs in run-off-roadway accident n.
This function is linearly formed:

$$S_{in} = \beta_i X_n + \in_{in} \qquad \text{............................eq. 1}$$

Where,
β_i is a vector of statistically estimable coefficients, and
X_n is a vector of measurable characteristics that determine severity (ex: roadway geometric factors, socioeconomic factor , type of vehicle, and so on.)
$\in_{in}$ is independent in each of the severity categories and is unobserved error term influencing run-off-roadway accident severity.

$$P_n(i) = P\,(\beta_i X_n + \in_{In} \geq \beta_I X_n + \in_{in}) \qquad \forall I \neq i \qquad \text{............................eq. 3.2}$$

By assuming that the unobserved terms ($\in_{in}$'s) are generalized extreme value (GEV) distributed, a multinomial logit (MNL) model can be derived to estimate the probability of run-off-roadway accident severity [13],

$$P_n(i) = \sum_I \exp[\beta_i X_n]^{-1} \exp[\beta_i X_n] \qquad \text{............................ eq. 3}$$

Where all variables are as previously defined, and the coefficient vector β_i is estimable by standard maximum likelihood techniques [14, 15].
The model has the following form:

$$P_n(i) = \exp[\beta_i X_n + \Theta_i L_{in}]/\sum_I \exp[\beta_i X_n + \Theta_i L_{in}] \qquad \text{............................ eq. 4}$$

$$P_n(k|i) = \exp\left[\beta_{(k|i)} X_n\right] / \sum_k \beta_{(k|i)} X_n \qquad \text{............................ eq. 5}$$

$$L_{in} = I_n \left[\sum_k \exp(\beta_{(k|i)} X_n)\right] \qquad \text{............................ eq. 6}$$

where $P_n(i)$ is the unconditional probability of run-off-roadway accident n having severity i,
X_n is a vector of measurable characteristics that determine accident severity, $P_n(k \mid i)$ is the probability of run-off-roadway accident n having severity k conditioned on the severity being in severity category i,
k is the conditional set of severity categories (conditioned on i), and
I is the unconditional set of severity categories .
L_{in} is the inclusive value (log sum), and θ_i is an estimable coefficient with a value between 0 and 1 to be consistent with the model derivation [13].

Study area and data collection

Study Area

In Uttarakhand, 132 black spots are identified by Transport Research Wing, Government of Uttarakhand. According to Ministry of Road Transport & Highways (MoRTH), Government of India, road accident black spot on National Highways is a road stretch of about 500m in length in which either 5 road accidents (involving fatalities/grievous injuries) took place during last three calendar years or 10 fatalities took place during last three calendar years. The black spots were identified in Dehradun and Haridwar comprising of 81 black spots. Out of which there were 49 black spots which were identified in Dehradun followed by 32 black spots in Haridwar.

Data Collection

The information on road accidents was gathered from city police records during the last three years (2016-2018). Weather (rainfall/fog/cloudy/sunny/storm), accident type (single-vehicle, head-on, rear-end, side), severity levels (fatal/major injury/minor injury/slight), and road geometry (number of curves, etc.) were all taken into account.

Result and Discussion

The sequential estimation approach was employed to estimate the model. To compute the inclusive value (Lin), we first used the multinomial logit (MNL) model to estimate the lower conditional level, and then we used the calculated coefficients of each severity level. Finally, the top level was estimated using a multinomial logit (MNL) model using the inclusive value (Lin; logsum) as an independent variable. Total section run-off-roadway accidents were estimated for both regions, as shown in Tables 1 and 2. The results of the maximum likelihood estimation for the lower level (property damage only (PDO) and probable injury) are shown in Table 1. At night, contributing variables such as weariness and reduced vision increase the risk of injury and property damage. Driving becomes more difficult during the winter months due to bad weather conditions such as snowfall and severe windstorms, which cause loss of visibility and other problems.

Table 1
Estimation of damage to the property as well as possible injury risks in the event of a total run-off-roadway accident with no major/severe injuries

Variable	Estimated coefficient	t-statistics (P-Value)
Constant	2.142	4.894 (<0.001)
Temporal characteristics		
Night Time(1 if accident occurred at Night time, 0 otherwise)	0.581	1.864 (0.081)
Winter Time (1 if october to February, 0 otherwise)	0.443	1.621 (0.320)
Traffic Characteristics		
High traffic (1 if AADT per lane is over 5000 vehicles, 0 otherwise)	0.752	3.154 (<0.001)
Roadway Characteristics		
Shoulder width (1 if more than 3 meter, 0 otherwise)	-0.164	-2.761 (<0.05)
Lane width (1 if more than 3.75 meter single lane, 0 otherwise)	-0.562	-3.48 (<0.001)
Curve indicator (1 if accident occure on horizontal/ vertical curve, 0 otherwise)	-0.521	-2.413 (<0.001)
Roadside Characteristics		
Bridge (1 if presence, 0 otherwise)	0.574	1.112 (0.068)
Cut side slope(1 if presence, 0 otherwise)	0.845	1.152 (0.541)
Guardrail indicator(1 if presence, 0 otherwise)	1.113	2.32 (<0.005)
tree groups(1 if presence, 0 otherwise)		

ρ^2	0.45	
Restricted Log-likelihood	-225.96	
Log-likelihood at Convergence	-154.36	

The "overall nested logit model estimation of run-off-roadway accident severity probabilities for Total sections" is shown in Table 2. According to our data, "run-off-roadway accidents with higher posted speed limits at accident crash locations were more likely to result in obvious harm and debilitating injury/fatality." A smaller shoulder breadth was linked to a lower risk of visible injuries. It's possible that the narrow shoulder contributes to the likelihood of an accident. According to the statistics provided in Table 2, the presence of bridges increases the likelihood of a serious collision.

Table 2
Estimation of overall nested logit model of Total run-off-roadway accident severity probabilities

Variable	Estimated coefficient	t-statistics (P-Value)
Constant (Specific to property damage/Minor injury)	-3.147	-2.651 (<0.001)
Constant(Specific to Major/Severe injury)	-2.906	-2.546 (<0.001)
Temporal characteristics		
Night Time(1 if accident occurred at Night time, 0 otherwise)	-0.624	-2.852 (<0.001)
Winter Time (1 if October to February, 0 otherwise)	-1.065	-2.904 (<0.001)
Traffic Characteristics		
High traffic (1 if AADT per lane is over 5000 vehicles, 0 otherwise)	-0.709	-2.396 (<0.001)
Roadway Characteristics		
Shoulder width (1 if more than 3 meter, 0 otherwise)	0.437	1.216 (0.541)
Speed indicator (1 if speed limit was 60km/h, 0 otherwise)	1.472	1.339 (0.611)
Curve indicator (1 if accident occur on horizontal/ vertical curve, 0 otherwise)	0.663	1.364 (0.211)
Roadside Characteristics		
Bridge (1 if presence, 0 otherwise)	1.113	1.754 (0.441)
Cut side slope(1 if presence, 0 otherwise)	0.521	1.223 (0.522)
Intersection indicator(1 if presence, 0 otherwise)	-0.632	-1.612 (0.081)
tree groups(1 if presence, 0 otherwise)	-1.003	-1.186 (0.603)
ρ^2	0.48	
Restricted Log-likelihood	-498.21	
Log-likelihood at Convergence	-256.46	

Tables 3 and 4 illustrate the "estimation of total Urban and Rural section run-off-roadway accident severity models." All of the variable coefficients were statistically significant and of plausible sign in both the urban and rural sections. For both the Urban and Rural portions, the "accident severity models" produced good statistical fits by the log-likelihood at convergence. Furthermore, the presence of sign supports was associated with a lower risk of damage." Run-off-roadway accidents resulting from loss of control and loss of visibility were more likely to be severe in rainy weather. It seems plausible that, during a rainfall, drivers do not pay attention to the roadside surroundings because much of their attention 89 is directed toward headways to maintain appropriate reaction times. This may explain severe crash rates for Urban sections in rainy weather.

Table 3
Estimation of overall nested logit model of Urban section run-off-roadway accident severity probabilities

Variable	Estimated coefficient	t-statistics (P-Value)
Constant (Specific to property damage/Minor injury)	-4.023	-4.118 (<0.001)
Constant(Specific to Major/Severe injury)	-4.112	-4.034 (<0.001)
Temporary characteristics		
Night Time(1 if accident occurred at Night time, 0 otherwise)	1.781	2.163 (<0.05)
Winter Time (1 if October to February, 0 otherwise)	0.651	1.669 (0.062)
Traffic Characteristics		
High traffic (1 if AADT per lane is over 5000 vehicles, 0 otherwise)	-0.773	-2.286 (0.05)
Roadway Characteristics		
Shoulder width (1 if more than 3 meter, 0 otherwise)	0.458	1.896 (0.091)
Speed indicator (1 if speed limit was 60km/h, 0 otherwise)	-0.562	-1.824 (0.093)
Curve indicator (1 if accident occur on horizontal/ vertical curve, 0 otherwise)	-1.622	-1.521 (0.881)
Roadside Characteristics		
Bridge (1 if presence, 0 otherwise)	1.564	1.662 (0.451)
Sign support indicator (1 if presence, 0 otherwise)	-1.135	-1.621 (0.521)
Intersection indicator(1 if presence, 0 otherwise)		
ρ^2	0.55	
Restricted Log-likelihood	-284.62	
Log-likelihood at Convergence	-153.18	

Table 4
Estimation of overall nested logit model of rural section run-off-roadway accident severity probabilities

Variable	Estimated coefficient	t-statistics (P-Value)
Constant (Specific to property damage/Minor injury)	-2.887	-1.663 (0.411)
Constant(Specific to Major/Severe injury)	-2.132	-1.448 (0.524)
Temporl characteristics		
Night Time(1 if accident occurred at Night time, 0 otherwise)	1.882	2.664 (<0.05)
Winter Time (1 if october to February, 0 otherwise)	0.671	1.659 (0.078)
Traffic Characteristics		
High traffic (1 if AADT per lane is over 5000 vehicles, 0 otherwise)	-0.683	-2.256 (<0.01)

Roadway Characteristics		
Shoulder width (1 if more than 3 meter, 0 otherwise)	0.497	1.676 (0.441)
Speed indicator (1 if speed limit was 60km/h, 0 otherwise)	-0.584	-1.452 (0.721)
Roadside Characteristics		
Guardrail indicator (1 if prresence, 0 otherwise)	1.477	1.116 (0.478)
Presence of any road side fixed object slope(1 if prresence, 0 otherwise)	1.323	1.224 (0.331)
tree groups(1 if prresence, 0 otherwise)	-1.488	-2.869 (<0.05)
P2	0.48	
Restricted Log-likelihood	-268.12	
Log-likelihood at Convergence	-168.32	

Conclusion

To capture the correlation between various severity levels, all feasible layered structures were investigated. The null hypotheses were rejected with 95% confidence by the model comparisons. As a result, statistically significant differences between the urban and rural portions of the country were observed. The goal of this research is to figure out what factors contribute to road segments becoming blackspots in Dehradun and Haridwar's hilly districts. To determine the severity of the blackspots, the rankings were assigned to them.. To rank the discovered blackspots, the classic technique (Accident Severity Model) was utilised (using the nested logit model). Drivers must be able to lower an errant car or regin a vehicle in areas with the intended recovery in order to provide a realistic possibility. The log likelihood at convergence and 2 values produced good statistical fits for total section run-off-roadway accident severity models, and all variable coefficients were 63 of reasonable sign and statistically significant. Loss of visibility and weariness are probable key causes to the increased risk of injury at night compared to PDO. In comparison to PDO, bridges were associated with a higher risk of injury. Because an errant car 70 may go down an embankment and into the river or stream under the crossing, run-off-roadway bridge accidents can be exceedingly serious. The sections of road with cut side slopes are the most dangerous. Desirable roadside recovery spaces are required to offer drivers with a reasonable opportunity to restore control or slow an errant vehicle. Guardrails, on the other hand, may be beneficial in lowering the risk of major harm. Despite the fact that tree groupings may serve as a guide to assist reduce the number of accidents, trees are nevertheless regularly impacted items that result in significant casualties. It is preferable to remove hazardous tree groups, but if this is not possible, safety awareness should be raised, and tree impact absorbing measures should be provided.

References

1. Christopher JL Murray, Alan D Lopez., editors. Boston: Harvard School of Public Health; 1996. The global burden of disease: a comprehensive assessment of mortality and disability from diseases, injuries, and risk factors in 1990 and projectedin2020.

2. S. F. Jafri, "An effective and way forward approach for road safety acquisition of knowledge— Correlative study for pakistan," Engineering Journal, vol. 17, pp. 41–48, 2013. doi:10.4186/ej.2013.17.1.41
3. Kishor R. &Gnanamurthy P B. Identification and Improvements of Blackspots on a Stretch of SH-57 between Hassan and Holenarasipura"- A Case Study, International Journal of Advance Research in Engineering, Science & Technology (IJAREST) Volume 4, Issue 9 September 2017, e-ISSN: 2393-9877, print-ISSN:2394-2444.
4. Nantulya VM, Reich MR. The neglected epidemic: Road traffic injuries in developing countries. [Last cited 2011 June 27];*BMJ.* 2002 324:1139–4.
5. Saffer, H., and M. Grossman. Beer Taxes, the Legal Drinking Age, and Youth Motor Vehicle Fatalities. Journal of Legal Studies, Vol. 16, 1987, pp. 351-374.
6. Chaloupka, F., et al. Alcohol Control Policies and Motor Vehicle Fatalities. Working Paper 3831, National Bureau of Economic Research, Inc., 1991.
7. McCarthy, P. The Effect of Higher Rural Interstate Speed Limits on Alcohol-Related Accidents. Journal of Health Economics, Vol. 11, 1993, pp. 281-299
8. National Safety Council. Manual of Classification of Motor Vehicle Traffic Accidents. 5th edition, 1989.
9. 9.R. Elvik, "New approach to accident analysis for hazardous road locations," Transportation Research Record: Journal of the Transportation Research Board, no. 1953, pp.50–55,2006
10. Sorensen, M.; Elvik, R. Black Spot Management and Safety Analysis of Road Networks; Institute of Transport Economics: Washington DC, USA, 2007.
11. Kowtanapanich W.Black Spot Identification Methods in Thailand. Faculty of Civil Engineering, Mahasarakam University 2006:126-134.
12. H. H. Nguyen, P. Taneerananon, C. Koren, and P. Iamtrakul, "Safety-potential-based black spot safety management approach: A case study in Ho Chi Minh City," Journal of the Eastern Asia Society for Transportation Studies, vol. 10, pp.1991–2009,2013.
13. H. H. Nguyen, P. Taneerananon, C. Koren, and P. Iamtrakul. Safety-potential-based black spot .fety management approach: A case study in Ho Chi Minh City. Journal of the Eastern Asia Society for Transportation Studies, vol. 10, 2013; 1991–2009.
14. Bobade SU, Patil JR, Sorate RR.Identification of Accidental Black Spots on National Highways and Expressways. International Journal of Research in Advent Technology February 2015:82-85.
15. D. R. D. Mcguigan, "The use of relationship between road accidents and traffic flow in 'black-spot' identification," Traffic Engineering and Control, pp. 448–453,1981.
16. D. R. D. Mcguigan, "Non-junction accident rates and their use in 'black-spot' identification," Traffic Engineering and Control, pp.60–65,1982.
17. Hauer E (1992) Empirical Bayes approach to the estimation of "unsafety": the multivariate regression method. Accid Anal Prev 24(5):457–477
18. Evans, Leonard (1990) The fraction of traffic fatalities attributable to alcohol, Accident Analysis and Prevention, Vol. 22, No. 6, 587-602.
19. Lloyd, Chris J. (1992) Alcohol and fatal road accidents: Estimates of risk in Australia 1983, Accident Analysis and Prevention, Vol. 24, No. 4, 339-348.

20. Holubowycz, Oksana T., Craig N. Kloeden and A. Jack McLean (1994) Age, sex, and blood alcohol concentration of killed and injured drivers, riders, and passengers, Accident Analysis and Prevention, Vol. 26, No. 4, 483-492.
21. Kim, Karl, Lawrence Nitz, James Richardson and Lei Li (1995) Analyzing the relationship between crash types and injuries in motor vehicle collisions in Hawaii, Transportation Research Record 1467, 9-13.
22. Council, Forrest M. and J. Richard Stewart (1996) Severity indexes for roadside objects, Transportation Research Record 1528, 87-96.
23. Shankar, Venkataraman, Fred L. Mannering and Woodrow Barfield (1996) Statistical analysis of accident severity in rural highways, Accident Analysis and Prevention, Vol. 28, No. 3, 391-401.