Expressway Traffic Accidents Involving Human Injuries and Fatalities in Ethiopia: Negative Binomial Regression Model

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Research note

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Abstract

Objective

The purpose of this study is to provide insights and to model significant determinants of accidents involving injuries and fatalities using Ethiopian Toll Roads Enterprise data. Besides, we utilized recent dataset recorded from September, 2014 to December, 2019. We applied the most appropriate but forwent statistical model. Moreover, we examined the significance of the effects of drivers' age and gender that have not been the cases in the literatures.

Results

We found that the number of injuries in accidents were significantly determined by type of vehicles, ownership status of vehicles, accident time weather condition, driver-vehicle relationship, drivers' level of education, and drivers' age. Heavy trucks were more likely to cause more number of injuries than medium or small vehicles. Hot and windy weather conditions were associated with higher probability of the number of injuries. The likelihood of the number of injuries were lower when drivers are owner of the vehicle; drivers level of education is above secondary school; and the age of the driver is between 18 and 23 years old. Moreover, due concern needs to be given for traffic road rules.

Introduction

Road traffic accident (RTA) is a major global concern [1]. Considerable number of people die around the world every year and several millions of people leave with non-fatal injuries as a result of RTA [2]. According to [2], it costs significant amount of annual GDP of countries. Thus, RTA affects public health and economic development in more general terms [1].

The impact and rate of RTA are highly increasing over time in low and middle income countries [1, 2]. Especially, the highest annual rate of RTA fatalities are recorded in Africa [1, 2].

RTA is a major problem in Ethiopia as a country in Afrrica [3, 4]. The road safety record of the Ethiopian expressway is also alarming the severity of the situation [5]. The expressway often called Addis Ababa-Adama Expressway is the first modern road in Ethiopia and East Africa as well which officially opened for traffic in September 2014 [6]. The road has technologically advanced safety management system aiming to reduce traffic accident. However, traffic accidents stil occur frequently [6]. To the best of the researchers' knowledge, no studies have found on the basis of recent datasets of the enterprise. Most importantly, the effects of drivers' age and sex on accidents have not been investigated. We utilized forwent but appropriate statistical method of the arena specifically, the negative binomial regression (NBR) model in order to determine significant factors to traffic accidents in the expressway. Besides, we explored rates of traffic flows and accidents in association with various potential attributes.

Method

The data was obtained from Ethiopian Toll Roads Enterprise. We analyzed a total of 1824 observations of accident data recorded from September, 2014 to December, 2019. The enterprise's real time system recorded 35387231 traffic flow data in this period. We integrated the two datasets to explore the yearly variations and trends of accidents.

The accident dataset contained 13 potential attributes namely, vehicle type, vehicle service years, injury type, accident time, cause of accident, road geometry, weather condition, light condition, driver-vehicle relation, driving experience, drivers' educational level, age and gender. We used descriptive charts to extract insights from the data. Finally, we used the NBR to model significant determinants of the number of injuries. We used the NBR model because it captures the over-dispersion in the data [7]. Moreover, no excess zeros were found in the data. As a result, the NPR model was best fit to the data.

The NBR Model

The NBR model belongs to the family of generalized linear models in which the link function is logarithm of the mean number of total injuries in accident log (μ) [7]. Total number of injuries in an accident was defined to be the number of light, serious, and fatal injuries in an accident. The NBR model based on significant variables is given as (equation 1).

$$\begin{aligned}\log(\mu) = {} & Intercept + \beta_{1i} Vehicle\ Type_i \\ & + \beta_{2i} Vehicle\ Ownership_i + \\ & \beta_{3i} Weather\ Condition_i + \\ & \beta_{4i} Driver\ Vehicle\ Relationship_i \\ & + \beta_{5i} Driver's\ Education\ Level_i \\ & + \beta_{6i} Driver's\ Age_i\end{aligned} \quad (1)$$

Where: the subscript indicates categories of the corresponding variable, the β s' are coefficients which are additive effects on the log of average number of total injuries of categories of the corresponding variable as compared to the reference category, μ is the average total number of injuries in accident.

We also tested for the presence of over-dispersion in the data.

Results And Discussions

Insights from Descriptive Analysis

The percentage of distinct vehicles and flows on the expressway were increasing over time. However, the changes between distinct vehicles and flows differed. The average yearly percentage changes of vehicles was 8% which is approximately double as compared to the average yearly changes in vehicles flow which was found to be 4.2% [Figure S1].

On the other hand, the average yearly changes in accident is approximately 2%. The level of accident began to decrease from 2018 forward [Figure S2]. Although the average absolute changes in accident was increasing, the rate of accidents per 100K flows was decreasing [Figure S3]. From 1824 traffic accidents, 1181(65%) of accidents caused various injuries. Among the casualties, (130)11% were dead and the remaining (324) 27% and (727) 62% suffered respectively from serious and light injuries [Figure S4]. According to [1], the rate of RTA-related injury was 163 (95% CI: 136–195) per 100,000 population. Not only the rates of accidents but also, the rates of injury levels were decreasing [Figure S5]. The rate of accident was higher at night than day times. There was 7 accidents per 100K flows at the early night and 9 at the late night. Lower rate (4 per 100K flows) observed before noon. The after noon takes the third place in which 5 accidents occurred in 100K flows [Figure S6]. However, according to [7, 5, 6], the absolute magnitude of accidents is higher in the afternoon. This study also confirmed the same regarding the absolute number of accidents but different relative to the number of traffic flows. The number of accidents depends on the number of traffic flows [6]. Therefore, regardless of the manner of interpretations, indications of results of the studies coincide.

In 100K flows of heavy vehicles, there were 8 accidents. On the other hand, mini sized buses were less exposed than automobiles [Figure S7]. However, in absolute count automobiles were most frequent in both flow and accidents [5].

Unethical driving/disobeying road traffic rules is another issue which accounted for 41% of accidents. Speed related issue is one of unethical driving. Speed changes also affect the occurrence of accidents [8]. A study also confirmed that major causes of traffic accidents were associated with unethical driving behaviors that caused 59.8% of the total accidents [5]. Another 30% caused from technical problems on vehicles, 4% from fatigue, approximately 1% because of animals, and only small portion 0.2% of the accident was caused from flood. The reasons for the remaining 24% of accidents were unspecified [Figure S8].

Despite the small percentage, the rate of driving without resting enough was increasing [Figure S9]. If animal intrusion, fatigue driving, flood, vehicles' technical problem, and unethical driving were the only factors contributing to the occurrence of accident, avoiding animal intrusion decreases accidents at least by 1% [Figure S10]. It will decrease at most by 25% if all of the 24% unknown causes in [Figure S9] were animals. Similarly, ethical driving, technical assurance, road maintenance, and avoiding restless driving result in (41%-66%), (30%-54%), (0%-24%), and (4%-28%) minimum and maximum decreases in accidents respectively [Figure S10].

Approximately, only 1% were female drivers and 83% were males. The remaining 16% were unspecified [Figure S11]. Although females were small in number, the percentage of females driving unethical was greater than that of males [Figure S12].

Most of the accidents were associated with drivers of young age [Figure S13]. This indicates that traffic accident affected productive man power of the country [1].

Most (34%) of the accidents occurred on sloppy road [Figure S14]. If the only factor contributing to the occurrence of accidents was road geometry, taking the most care at slopes and curves would reduce at least 9%-35% of the accidents [Figure S15].

The longest duration throughout the year is normal in Ethiopia. Thus, our assessment on weather conditions revealed that larger percentage of accidents occurred at normal weather condition [Figure S16].

Estimates of NBR Model Parameters

We tested the presence of over dispersion in the data. The estimate of the dispersion parameter was 3.33238 which clearly greater than the null value 1. The corresponding Z-value was 3.7485 that resulted in a P-value of 0.00008896 which is far lower than the level of significance (0.05) [Table 1]. Thus, we rejected the null hypothesis that states the dispersion is 1 and concluded that there is over-dispersion in the data at 5% level of significance and the NBR model is more appropriate fit to the data than Poisson regression model.

Table 1: Over-dispersion test

Estimate of Dispersion	Z	P-Value
3.33238	3.7485	8.896e-05

We tested all attributes in the dataset for significance. We found that vehicle type, vehicle ownership, weather condition, driver-vehicle relation, drivers' education level, and drivers' age were significant determinants of number of injuries [Table 2].

Table 2: Parameter estimates of NBR model

Factors	Categories	Estimates	SE	Pr(>|z|)
	Intercept	-2.511	1.061104	0.0179
Vehicle Type (Ref: Unspecified)	Big Size Bus & Medium Truck (3Axel)	1.293	1.052125	0.2189
	Heavy Truck Trailer(>=4Axel)	1.386	1.046614	0.1854
	Medium Bus & Small Truck (2 Axel)	2.346	1.037234	0.0237
	Minibus	3.613	1.041141	0.0005
	Small Automobiles &4WD	2.074	1.034441	0.0449
Vehicle Ownership (Ref: Company)	Government	0.009	0.350768	0.9806
	Private	0.499	0.230324	0.0303
	Unspecified	0.242	0.250862	0.3348
Weather Condition (Ref: Cloudy/Misty)	Hot	0.457	0.181940	0.0120
	Normal	0.078	0.137193	0.5676
	Unspecified	-0.365	0.174080	0.0359
	Windy	0.172	0.505791	0.7340
Driver-Vehicle Relation (Ref: Unspecified)	Employee	-0.500	0.180237	0.0056
	Other	-0.285	0.234047	0.2237
	Owner	-0.607	0.209179	0.0037
Drivers' Level of Education (Ref: Unspecified)	Above Secondary	-0.855	0.203963	2.78e-05
	Primary	-0.790	0.252983	0.0018
	Secondary	-0.490	0.176849	0.0056

Driver Age (Ref:Unspecified)	[18-23)	-1.193	0.694820	0.0860
	[23-28)	-0.496	0.200207	0.0133
	[28-33)	-0.149	0.179081	0.4070
	[33-38)	-0.475	0.208279	0.0227
	[38-43)	-0.417	0.219141	0.0571
	>=43	-0.169	0.219206	0.4401

Ref: Reference, Pr: Probability, SE: Standard Error

The number of injuries occurred in association with small automobiles & 4WD, min-buses, and medium sized buses & small trucks (2 axel) were significantly different from that of unspecified vehicle types. On the other hand, injuries as a result of heavy truck trailers (>= 4 axel), and big sized buses & medium trucks (3 axel) were not significantly different from the reference category. Thus, accident on small automobiles & 4WD, min-buses, and medium sized buses & small trucks (2 axel) resulted in significantly different number of injuries from accident on heavy truck trailers (>=4 axel), and big sized buses & medium trucks (3 axel) and it increases the log of average number of injuries by 2.074, 3.613, and 2.346 respectively as compared to accident in unspecified vehicle types holding the effects of other factors constant at 5% level of significance [Table 2]. The significance of vehicle type was confirmed in other study [5].

In the same manner of interpretation, the log of average number of injuries due to accidents on vehicles with private ownership significantly increases by 0.499 as compared to that of vehicles with company ownership. Accidents on vehicles of government and unspecified ownership were not significantly different from vehicles of company ownership. Hot weather condition results in 0.457 increase. The log average number of injuries decrease more (by 0.607) when the driver is owner of the vehicle. Drivers' level of education significantly contributes to the number of injuries in accidents. Drivers' age intervals [23-28) and [33-38) were more likely associated with reduced number of injuries [Table 2].

Conclusions And Recommendations

Stake holders should further work on decreasing accidents [10]. Highest frequency of accidents occurred as a result of unethical/disobeying driving. Thus, awareness need to be created. Besides, traffic road rule enforcement, immediate maintenance of broken roads, and building road side fances for animal prevention are possible lowering measures. More needs to be worked on females' awareness towards road traffic rules and license providing institutions should take further concern. Heavy vehicles were more likely associated to accidents. Thus, truckers should be more conscious since heavy vehicles are more difficult to control. Further, due concern needs to be given for night time traffic movements.

Limitations

We didn't check the significance of more attributes since no further data was recorded for accidents. However, future researchers may find more significant varibles.

Abbreviations

RTA: Road Traffic Accident, NBR: Negative Binomial Regression

Declarations

Ethics Approval and Consent to Participate

Not Applicable.

Consent for Publication

Not Applicable.

Availability of Data and Material

The data analyzed during this study is stored at the database of Ethiopian Toll Roads Enterprise and it will be available on a reasonable request.

Competing Interests

The authors declare that they have no competing interests.

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Not Applicable.

Authors' Contributions

Both authors YAM and AB generated the idea, YAM as a corresponding author analyzed and interpreted the data, AB contributed his part on descriptive analysis of the data under the supervision of YAM. Both authors read and approved the final manuscript.

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