

Research Article

Risk Factors and Magnitude of Human Mortality from Road Traffic Accidents in the North Shewa Zone of the Amhara Regional State in Ethiopia

Afera Mekete Alemu¹, Dagne Tesfaye Mengistie^{2,*} , Dagnew Melake Abebe² , Kasaneh Jigar Alem²

¹Department of Epidemiology and Biostatistics, College of Public Health Science, Gondar University, Gondar, Ethiopia

²Department of Statistics, College of Natural and Computational Science, Jigjiga University, Jigjiga, Ethiopia

Abstract

Introduction: Worldwide, road traffic accidents (RTAs) provide serious risks to public health in both developed and developing nations. For young people between the ages of 15 and 29, they are the seventh most common cause of death and the top source of injury. Overspreading, overtaking, poor road conditions, vehicle condition, driver competence, negligence and behavior, and breaking traffic laws and regulations are some of the many variables that contribute to vehicle collisions. Therefore, the aim objective of this study was to estimate human death per road traffic accident and identify its determinant factors in the North Shewa zone of Amhara regional stat of Ethiopia. **Methods:** A retrospective study was conducted from Insurance Companies in Debre Birehan town from 01 Jan 2018– 31 Dec 2023. All road traffic accident cases from randomly selected districts of the North Shewa zone from 01 Jan 2018– 31 Dec 2023 were included in this study. A total of 894 traffic accident cases were recorded. Data were entered and cleaned using micro soft excels and exported to Stata version 17 for analysis. Zero Inflated Poisson regression was used, and IRR with 95% CI was reported. **Results:** The results showed that from the 100 traffic accident cases 26 individuals getting death which is a few higher than previous studies. Out of a total of 894 road traffic cases were happened, of whomb156 traffic cases results in 234 human deaths. From 100 road traffic accident cases 26 individuals getting death with 95% CI [21/100, 31/100]. ZIP regression model was selected as the best fitted model to analyze the road traffic data since there was inflation zero outcomes with no over/under dispersion in the data set. **Conclusion:** Driving experience in years, education level of drivers, driver-vehicle relationship, seat belt use while driving, speed in km/hr, level of driving license, purpose of the vehicle, and pavement roughness are significantly associated with the number of deaths per road traffic accident at the $\alpha = 0.05$ level of significance. The need for enforcing drivers to obey traffic rules and strong prosecution of speed limits while driving on asphalt roads appear to be the most critical parts of interventions.

Keywords

Road Traffic Accidents (RTAs), Incidence Rate Ratio (IRR), Zero Inflated Poisson (ZIP), Human Death

*Corresponding author: dagne.tesstat1216@gmail.com (Dagne Tesfaye Mengistie)

Received: 11 February 2025; **Accepted:** 28 March 2025; **Published:** 29 April 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Road traffic accidents (RTA) is an accident that happened on a way or street open to public traffic; resulted in one or more persons being exterminated or injured, and at least one moving vehicle was involved [1, 2]. Thus, RTA is collisions between vehicles; between vehicles and pedestrians; between vehicles and animals; or between vehicles and geographical or architectural obstacles [3]. Since the 1960s, the growing traffic concentration has posed a significant task for managing traffic on the roads, both in terms of resolving the enduring congestion issue and addressing concerns linked to road transportation safety [4, 5]. An estimated 1.35 million individuals each year die in automobile accidents *worldwide*. This translates to daily mortality claims from traffic accidents of more than 3,700 persons. Additionally, between 20 and 50 million people suffer nonfatal injuries from road accidents crashes. Not only this, it also reduces the GDP by 3% globally and by as much as 5% in low- and middle-income nations [6].

According to the 2018 Global status report on road safety, the death rates due to RTA is not uniform across regions and income levels of countries of the world. The number of death per RTA is 3 times higher in low income countries than in high income countries. For instance, Nations in Africa and South-East Asia have regional rates of road Traffic deaths higher than the global rate [7]. Like many African countries, Ethiopia is facing enormous road safety crisis. One of its most serious issues with road transportation is road traffic accident. Each year thousands of road users are killed and the majority of them are economically active population [8, 9]. While the Ethiopian government spends a great deal of money on improving and expanding the country's road network, the number, frequency and severity of traffic accidents are still extensive. Factors contributing to the high incidence of RTAs in Ethiopia include rampant reckless driving behaviors, poor road network, substandard road conditions, failure to enforce traffic laws and poor conditions of vehicles [10].

Several RTA prevention measures, including speed limits, seat belt laws, helmet laws, drunken driving laws, mobile phone use while driving laws, and child restraint laws, are being enforced in Ethiopia [11]. Use of restraints, such as seatbelt use, can reduce the number of fatalities and the severity of injuries from RTA. By protecting the occupant from being ejected from the car or hitting the interior components, it lessens injuries. But they continued to be underutilized, particularly in developing countries [9, 12]. Many researchers have studied the RTA determinant variables by employing statistical methods such as descriptive statistics, logistic regression, and time series models to predict accident occurrences in different parts of Ethiopia at various times. Most of these studies had focused on Addis Ababa, Oromia and SNN regions [13]. Even though there are few published research papers in Amhara region about RTA using difference statistical models, the scarcity of studies in Debre Birehan district is high specially those conducted using count regression models [14].

For almost all researches that have been conducted in the country regarding on RTA, the data sources are police stations and health institutions. However, these data sources undercount the total number of deaths and severity levels of road traffic accident due to different reasons [15]. Consequently, this study was attempts to analyze number of human mortality due to road traffic accident in North Shewa zone based on per accident data using appropriate count regression model and retrospectively collecting road traffic data from insurance companies claim charts which have been contained police reports, medical and death certificates in combination. Objectives of the study to estimate rate of human death per road traffic accident and identify its determinant factors in North Shewa zone from 01 Jan 2018-31 Dec 2023.

2. Methods and Materials

2.1. Description of Study Area

North Shewa is a zone located in the Amhara Region of Ethiopia. The name North Shewa is derived from the historical kingdom and former province of Shewa. This Zone is bordered by the Oromia Region to the south and west, by South Wollo to the north, by the Oromia Zone to the north-east, and by the Afar Region to the east. The tallest point in the Zone is Mount Abuye Meda, which reaches 4012 meters, located in the Gish woreda; other notable peaks include Mount Megezez. Notable towns in North Shewa include Ankober, Debre Birhan, and Shewa Robit [16].

The administrative areas within this Zone have undergone numerous renamings, divisions, and boundary adjustments between the 1994 and 2007 national censuses, more so than any other Zone in the Amhara Region. Consequently, the subdivisions can be quite perplexing; while comparing the administrative boundary reports from the Central Statistical Agency (CSA) and the Ethiopian Mapping Authority for this Zone, decided to stop midway through his research, citing a lack of time for field verification [17]. According to the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), this Zone has a total population of 1,837,490, representing a 17.72% increase from the 1994 census, consisting of 928,694 males and 908,796 females. North Shewa covers an area of 15,936.13 square kilometers and has a population density of 115.30. Among the population, 214,227 individuals, or 11.66%, reside in urban areas, while an additional 112, or 0.01%, are classified as pastoralists. The census recorded a total of 429,423 households in this Zone, leading to an average household size of 4.28 persons and 413,235 housing units. The three predominant ethnic groups in North Shewa are the Amhara (90.73%), the Oromo (7.14%), and the Argobba (1.71%), with all other ethnicities comprising 0.42% of the population. Amharic is the first language for 92.97% of the population, while 6.32% speak Oromiffa; the

remaining 0.71% reported a variety of other primary languages. The survey found that 94.71% of the population identifies as practicing Ethiopian Orthodox Christianity, while 4.91% are Muslim. By 2020, the zone was estimated to have a population of 3,550,000 [16].

2.2. Source of Data and Study Design

This study was used secondary data which taken from Insurance Companies in Debre Birehan town A retrospective study from Insurance Companies in Debre Birehan town from 01 Jan 2018– 31 Dec 2023 has been done.

2.3. Source and Study Population

All registered RTAs in North Shewa zone during the study period on registry of all insurance Companies located in Debre Birehan town. Registered RTAs among six randomly selected districts of North Shewa zone during the study period on registry of all Insurance Companies located in Debre Birehan town.

2.4. Inclusion and Exclusion Criteria

2.4.1. Inclusion Criteria

RTAs in randomly selected districts of North Shewa zone by all road motor vehicles during the study period on registry of the all Insurance Companies were included.

2.4.2. Exclusion Criteria

RTA case charts which did not contain complete study variables, accidents which have been occurred on work sites rather than roads, RTA cases which were not timely reported to nearby police stations to have a report were excluded.

2.5. Sampling Techniques

A secondary data from insurance companies in Debre Birehan town has been obtained for analysis. There are 14 districts in North Shewa zone as administrative unit. From these, six districts were randomly selected and traffic accidents at the selected districts during the study period had been completely investigated from insurance companies in Debre Birehan town to infer about the overall study area.

2.6. Variables of the Study

2.6.1. Outcome Variable

The outcome variable of this study was the number of death per road traffic accident.

2.6.2. Independent Variable

The independent variables used in the study were age of

the driver, sex of the driver, education level of the driver, driver-vehicle relationship, experience (in years), ownership of the vehicle,, Seat belt use, alcohol use, speed in km/hr, level of driving license, Mobile use while driving injured persons, Bandit, injured person, Vehicle type, vehicle service (in years) Vehicle movement, Overloading (yes/no), Annual inspection of the vehicle, Accident type, road division, road inclination, road junction, road condition, light condition, air situation, accident time, month in quarter, pavement roughness, overcrowding, Geographical location of the accident, presence of traffic police and/or signals, and urbanization status of the accident location.

2.7. Operational and Term Definitions

Traffic accident: pertain to any vehicle accidents occurred on public high way (i.e. originating on, terminating on, or involving a vehicle partially).

Accident Frequency: is a measure of the relative magnitude of a specific type of accident in relation to all accidents for a specified time period such as one or three years.

Human factors: are factors related to drivers and other road users that may contribute to a collision. Like driver behavior, visual and auditory acuity, decision making ability, and reaction speed.

A motor vehicle: means a mechanically propelled vehicle intended or adapted for use on roads Private Vehicles -A vehicle is classified as private vehicle if it is used solely for social, domestic, pleasure and professional purpose or business calls of the owner.

Commercial vehicles: are vehicles which are constructed or adapted for the carriage of goods and passengers with fee.

Special use vehicles: Ambulances, fire trucks, mobile cranes, ready-mixed concrete carriers, breakdown vehicles, site clearing and leveling plants such as dumpers, excavators, dozers, graders tractor or self-propelled agricultural implement used solely for agricultural or forestry work including carriage of agricultural produce or articles required for agriculture.

Organization use vehicles: An organization is a group of people working together to achieve the specified goal i.e. two or more people work together in a structured way to achieve a specific goal or set of goals. Vehicles used to achieve such objectives are organization use vehicles.

2.8. Data Collection Procedures

The type of accident (death or injury) was critically observed based on structured data extraction techniques that were established. The study's primary variables were all obtained from the insurance companies' claims. In accident situations, all pertinent detail regarding the vehicle, human, environmental, and other elements was meticulously documented. Two weeks before to the actual data collection, certain samples were pre-tested to ensure that the data extraction method was consistent and acceptable.

2.9. Method of Data Analysis

In this study, the variable of interest is a count variable. When the response or dependent variable (number of death due to RTA) is a count which can take on non-negative integer values (0, 1, 2...), it is applicable to use non-linear models based on non-normal distribution to describe the relationship between the dependent variable and a set of predictor variables. For count data, the Poisson and NB regression models are commonly used structures for describing the connection between the result variable and a set of explanatory variables [18]. Poisson distribution is the most common probability model for discrete data with observations assumed to have a constant rate of existence among individual units with the belongings of equal mean and variance. However, in many applications the variance is greater than the mean and over dispersion is said to be present. The application of the Poisson distribution to data exhibiting over dispersion can clue to incorrect inferences and/or inefficient analyses. The most commonly used extension of the Poisson distribution is the NB distribution which allows for unequal mean and variance but may still be inadequate to model datasets with long tails and/or value-inflation [19]. Besides, the response variable can be observed to show excess zero counts, contrary to the expected, on the basis of Poisson or Negative Binomial distribution. This is a consequence that the count data are zero inflated. Zero-inflated models allow for over dispersion as well as modeling zero-inflated count data. The frequent models that will be used for Zero-Inflated count data are zero-inflated Poisson (ZIP) and zero-inflated negative binomial (ZINB). When the sample variance is larger (or smaller) than the sample mean, the data is said to exhibit over dispersion (under dispersion) [20]. In this study, the form of response variable is count data, which is most often characterized as a non-normal distribution. Thus, to deal with the data and methodological issues related to modeling the number of deaths, a varied variety of statistical methods can be used. There are count regression models that have been developed to analyze data with count response variables. In this study, single-level count regression models such as Poisson, negative binomials, ZIP, and ZINB were compared and applied, assuming the occurrence of the number of deaths due to RTA independently occurred. There are four models to be compared in order to select the appropriate fitted model that fits the data well. This was done using Akai information criteria (AIC) and Bayesian information criteria (BIC) [21].

3. Result

3.1. Descriptive Statistics

A total of 894 road traffic accident cases were recorded from randomly selected districts of the study area during the study period. Predictor variables for number of death per road traffic accident in this study are driver related, vehicle related, environment related and road related. The next descriptive tables (Tables 1, 2, 3 and 4) revealed the frequency, percentage, mean (number of death per 100 accidents) and variance of number of human death for each category of predictors.

3.2. Driver Related Predictors for Number of Death per Road Traffic Accident

The average number of human death per accident is inversely related with increasing age of the driver. It was highest (54/100) among driver in the youngest age group of 18-30 years. Considering driving experience of drivers, the highest mean number of human death occurred by the driver who had less than 6 years driving experience (71/100), whilst the smallest mean number of human death was (6/100) reported by the driver who had 16-20 years driving experience. The smallest mean number of human death (11/100) was reported due to the drivers who had completed high school or more than high school level; whereas the highest mean number of human death was (47/100) occurred by elementary and below education level of the driver. Employed drivers had high contribution to the mean number of human death (37/100); on other hand, less contribution was made by owner drivers (7/100). Drivers who use mobile phones, those do not use seat belt while driving and those who are alcohol users have more contribution to mean number of human death whereas smaller mean number of human deaths were resulted by their opponents. The highest mean number of human death per road traffic accident is occurred by drivers who ride by more than 50 km/hr (45/100) when compared with low speed riders in km/hr (9/100). Considering the level of driving license of drivers, the highest mean number of human death occurred among drivers who have one and auto level license (45/100), while the smallest mean number of human death (6/100) was reported among those who have more than three license levels as shown in Table 1 below.

Table 1. Driver related predictors for number of death per road traffic accident and its determinants in north Shewa zone form 01-Jan-2018-31-Dec-2023.

Predictor variables	Categories	Frequency	Percentage	Average number of human death per 100 (%)	Variance
Gender of drivers	Male	875	97.87	26	0.52
	Female	19	2.12	21	0.29

Predictor variables	Categories	Frequency	Percentage	Average number of human death per 100 (%)	Variance
Age of drivers	18-30	371	41.50	54	0.96
	31-50	449	50.22	06	0.08
	50 and above	74	8.28	08	0.24
Driving experience	0-5	241	26.96	71	1.32
	6-10	328	36.69	08	0.09
	11-15	120	13.42	11	0.11
	16-20	96	10.74	06	0.08
	21 & above	109	12.19	15	0.24
Education level of drivers	Elementary	363	40.60	47	0.98
	High school	348	38.93	11	0.15
	Above high school	183	20.47	14	0.17
Driver vehicle relation ship	Employee	565	63.20	37	0.72
	Hired/relative/fried	227	25.39	11	0.16
	Owner	102	11.41	07	0.07
Seat belt use while driving	No	482	53.91	40	0.82
	Yes	412	46.09	10	0.11
Alcohol user	Yes	296	33.11	47	1.03
	No	598	66.89	16	0.23
Speed in km/hr.	0-25	87	9.73	18	0.20
	26-50	397	44.41	09	0.11
	51 & above	410	45.86	45	0.91
Mobile use while driving	Yes	258	28.86	47	0.99
	No	636	71.14	19	0.31
Level of driving license	Level one & auto	401	44.85	45	0.92
	Level two	142	15.88	22	0.17
	Level three	128	14.32	07	0.08
	Level four & five	223	24.94	06	0.14
Type of victim	Passenger & W/c	325	36.35	52	0.98
	Pedestrian	178	19.91	27	0.21
	Animal & others	391	43.74	00	0.17

3.3. Vehicle Related Predictors for Number of Death per Road Traffic Accident

Private vehicles had high contribution to the mean number of human death (28/100) whereas relatively smaller mean number of human deaths were registered on Organization (16/100) and Government (19/100) owned vehicles.

According to body construction, minibus vehicles have high contribution (36/100) while less contribution was made by vehicles constructed for special use such as agricultural and road construction use vehicles (14/100). The finding of this study also revealed that commercial use vehicles had a high contribution on the number of human death per road traffic accident. The expected number of human death due to road traffic accidents for those used as

commercial is 31/100 while those used for private use only is 16/100 and with special use vehicles is 12/100 as shown in the next Table 2.

Table 2. Vehicle related predictors for number of death per road traffic accident and its determinants in north Shewa zone from 01-Jan-2018-31-Dec-2023.

Predictor variables	Categories	Frequency	Percentage	Average number of human death per 100 (%)	Variance
Type of vehicle	Minibus (<=15)	286	31.99	36	0.86
	Bus (>15)	152	17.00	28	0.43
	Cargo (truck/trailer)	299	33.45	19	0.34
	Tricycle/Motorcycle	115	12.86	24	0.33
	Special vehicles	42	4.70	14	0.17
Vehicle owner ship	Private	762	85.23	28	0.56
	Organization	95	10.63	16	0.26
	Government	37	4.14	19	0.21
	Commercial use	614	68.68	31	0.65
Purpose of the vehicle	Private use	211	23.60	16	0.22
	Special use	69	7.72	12	0.16
Presence of comprehensive insurance cover	No	580	64.88	27	0.57
	Yes	314	35.12	25	0.42
Vehicle service in year	0-5 years	131	14.65	28	0.37
	6-10 year	229	25.62	28	0.75
	11-15 years	204	22.82	21	0.29
	16-20 years	183	20.47	24	0.54
	21 & above	147	16.44	32	0.58
	Vehicle-pedestrian	287	32.10	33	0.49
Type of collision	Vehicle to vehicle	275	30.76	30	0.69
	Overturning	160	17.90	28	0.56
	Vehicle to animal or others	172	19.24	06	0.18
Vehicle movement	Direct	619	69.24	24	0.41
	Turn to L/R	220	24.61	34	0.87
	Reverse	55	6.15	23	0.33

3.4. Road Related Predictors for Number of Death per Road Traffic Accident

Road traffic accidents which happened on asphalt roads results in higher mean number of human death (31/100) whereas the smaller death rates are reported by non-asphalt roads as stated in the next Table 3.

Table 3. Road related predictors for number of death per road traffic accident and its determinants in north Shewa zone from 01-Jan-2018-31-Dec-2023.

Predictor variables	Categories	Frequency	Percentage	Average number of human death per 100 (%)	Variance
Road inclination	Slopped (scrap)	536	59.96	29	0.59
	Direct	358	40.04	21	0.41
	Careless driving	310	34.68	29	0.54
	Over speeding	251	28.08	26	0.63
	Overcrowding	87	9.73	25	0.40
Cause of accident	Overloading	52	5.82	29	0.45
	No priority	72	8.05	17	0.20
	Pedestrian error	38	4.25	29	0.32
	Vehicle problem	59	6.60	24	0.84
	Bandit & shifta	25	2.80	16	0.14
Pavement Roughness	Asphalt	630	70.47	31	0.67
	Not Asphalt	264	29.53	15	0.14

3.5. Environment Related Predictors for Number of Death per Road Traffic Accident

The expected number of human death per road traffic accident with not normal whether condition is higher (45/100) whereas relatively smaller mean number of human death were registered on its opponent (23/100). Road traffic accidents are more frequent and results in higher mean number human death on Moring time than other times of a day. It is

also more frequent on the first quarter of the years (S, O, and N) see Table 4.

The predictor Urbanization status of the accident area revealed that semi urban areas such as around towns results in higher mean number of human death per road traffic accident (38/100) when compared with urban (25/100) and rural (17/100) areas. According to this study availability of police and signals is essential to reduce human death since in areas with no availability of police and signals is higher (34/100) while it is 13/100 when there is an access.

Table 4. Environment related predictors for number of death per road traffic accident and its determinants in north Shewa zone from 01-Jan-2018-31-Dec-2023.

Predictor variables	Categories	Frequency	Percentage	Average number of human death per 100 (%)	Variance
Light condition	Dark (no light)	187	20.92	36	0.67
	Night (with light)	99	11.07	26	0.46
	Day (sunlight)	608	68.01	23	0.48
Air situation	Not normal	124	13.87	45	1.14
	Normal	770	86.13	23	0.41
Accident time	Morning	396	44.29	33	0.75
	Evening	198	22.15	22	0.34
	Afternoon	202	22.59	23	0.41

Predictor variables	Categories	Frequency	Percentage	Average number of human death per 100 (%)	Variance
Month in Quarter	Night	70	7.83	20	0.19
	Tsedey (S, O, N)	401	44.85	39	0.79
	Bega (D, J, F)	180	20.13	18	0.28
	Belg (M, A, May)	137	15.32	15	0.19
	Kiremt (J, July, A)	176	19.69	13	0.31
Geographical location of the accident area	Curve	454	50.78	28	0.57
	Not curve	440	49.22	29	0.46
Availability of police and signals	No	577	64.54	34	0.70
	Yes	317	35.46	13	0.16
Urbanization status of the accident Area	Urban	328	36.69	25	0.56
	Semi Urban	283	31.66	38	0.77
	Rural	283	31.66	17	0.20

3.6. Test of Over Dispersion, Zero Inflation and Goodness-of-fit

The Poisson, negative binomial and zero-inflated Poisson, and zero-inflated negative binomial regression models were compared to identify the best fitted model in order to analyze the data. The following Table 5 shows summary statistics for the number of human death due to road Traffic accident during the study period before considering any covariates.

As shown in Table 5 above, the variance (0.52) of human death per road traffic accident was greater than its mean (0.26) with 95% CI [0.21/100, 0.31/100]. This indicated the possibility of over dispersion in the data. From additional

exploration and assessment of the data one can also see the existence of excess number of zeros (82% i.e. 738). Out of 894 had no human deaths per accident) and the shape of the curve is skewed to the right as shown in Figure 1 below.

Table 5. Summary statistics for number of death per road traffic accident in North Shewa zone from 01-Jan-2018-31-Dec-2023.

Mean	Variance	Skewness	Kurtosis
0.26	0.52	4.10	24.21

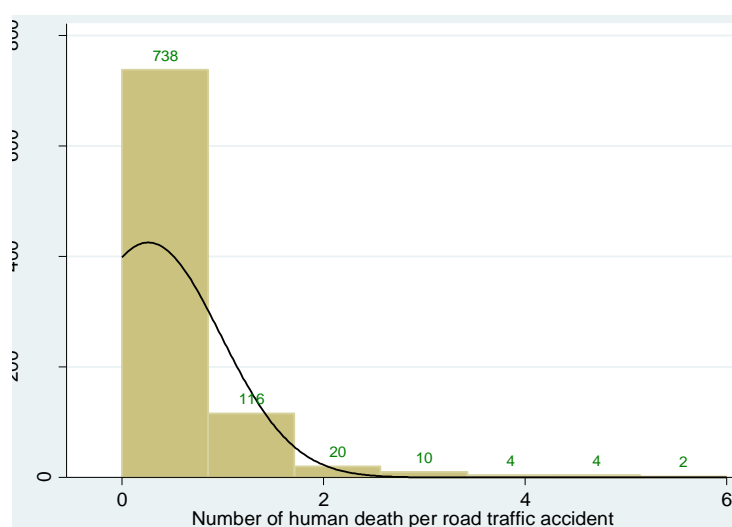


Figure 1. Graphical exploration for number of death per road traffic accident in North Shewa zone from 01-Jan-2018-31-Dec-2023.

Moreover, in Poisson regression analysis, Pearson Chi square goodness of fit statistics can be used to test the presence of over dispersion in the data. If the ratio of Pearson Chi square statistic to the degrees-of freedom is higher than one, there will be an over dispersion in the data set. According to this principle, after multivariable standard Poisson regression analysis has been conducted the Pearson Chi square statistic is 925.07 with its corresponding degrees-of freedom 857. The ratio of these statistical magnitudes is $925.07 / 857 = 1.08$, which is approximately equal to one and indicates absence of over dispersion in the data. But this may not sufficiently enough to assure the absence of over dispersion. The presence or absence of over dispersion must also be checked using the standard negative binomial regression. Commonly used way of checking the presence of over dispersion in NB regression model is a statistical test of the hypothesis: $H_0: \alpha = 0$ Vs $H_1: \alpha > 0$, If P-value of LRT < 0.05 , then there is an over dispersion and the Negative Binomial model is preferred. Where α is an ancillary parameter which is known as Stata's alpha. After multivariable negative binomial regression analysis has been conducted using the road traffic accident data the Stata's alpha (α) value was 0.023 with p value of 0.394 which is not statistically significant and the hypothesis $H_0: \alpha = 0$; was not rejected. This implied absence of over dispersion in the data set.

3.7. Comparison of Models Using AIC and BIC

Table 6. Model selection results based on AIC and BIC for number of death per road traffic accident in North Shewa zone from 01-Jan-2018-31-Dec-2023.

Selection Criteria	Statistical models			
	POISSON	NB	ZIP	ZINB
AIC	842.0248	843.9523	805.2773	807.2773
BIC	1029.466	1026.189	1025.88	1032.676

The above Table 6 shows the model selection criteria used to identify the most preferred model among the candidate models. The model with minimum value of AIC=805.2773 or BIC=1025.88 is preferable to fit the data. These statistical values for Poisson and negative binomial regression models were higher when compared to their corresponding inflated models. The AIC and BIC value for ZIP model is smaller when compared with ZINB model. As one can understand from these realities and Figure 2 above, the road traffic data was consist of non-negative, highly skewed sequence counts with a large proportion of zeros (82%). So zero-inflated models are useful for analyzing such data rather than standard count models. As clearly shown and explained in the

above Tables 1, 2 and 3, the absence of over dispersion but zero inflation was confirmed and it was main characteristics of the road traffic data in the study area. Therefore, the ZIP model is selected as better fitted model to analysis human death per road traffic accident data than did ZINB model since ZINB is considered when data are characterized by both over-dispersion and zero-inflation.

3.8. Multivariate Analysis of ZIP Regression Model

As shown in the log part of Table 7 below: the number of human death per road traffic accident was decreased by 72.4%, 54.8% and 68.5% for drivers whose driving experience was 6-10, 11-15 and 16-20 in years, respectively, as compared to those who have an experience of 0-5 years by allotment all other variables in the model constant. The incidence number of human death per road traffic accident was decreased by 49.6% and 48.3% for drivers whose education level is high school and above high school respectively as compared with these with education level of elementary and below. The incidence number of human death per road traffic accident was decreased by 52.2% and 55.1% for hired/relative/friend possessed and drivers who drive their own vehicles when compared to those employed drivers respectively by holding all the variables in the model constant. Drivers who do not use seat belt were expected to increase incidence of human death by 65.7% when compared with seat belt users. The expected number of human death per road traffic accident for drivers who drive below 25km/hr had decreased by 61% as compared to the expected number of human death per accident for drivers who drive above 51km/hr. holding all other variables in the model constant. Drivers with different level of driving license have also results in significantly different mean number of death per an accident. For instance according to this study those drivers with 4 & 5 license level were expected to decrease mean number of death by 44.4% and those with level three by 61.7% when compared to with lowest level drivers citrus barbs.

The coefficients for different purpose of vehicles are statistically significant. The expected number of human death per road traffic accident by private and special use vehicles is 49.6% and 54.6% decreased as compared to the expected number of human death per road traffic accident for commercial use vehicles respectively by holding all other variables in the model constant. The expected number of human deaths which was caused by overturning of vehicles results in 46.4% higher when compared with deaths caused by direct movement accidents, holding all other variables in the model constant. Urbanization status of the accident area was a significant factor for number of human death per road traffic accident. It was 38.7% higher with semi urban areas when compared with accidents which happened with in towns by holding all other variables in the model constant. When we

consider victim types, collisions with animals/vehicles and/or humans with no death had also decreases the mean number of human death by 42.50% when compared with collision with passengers, holding all other variables in the model constant. The finding of this study also revealed that the expected number of human death per road traffic accident was decreased by 55.11% on own drivers when compared with vehicles derived by employed drivers after holding all variables in the model constant.

The logistic part of Table 7 below also provides estimated coefficients for the factor change in the odds of being in the always zero counts group (no human death per road traffic accident faced) compared to the not always zero counts group (standard count Poisson regression i.e. 0, 1, 2... human death per road traffic accident). In the always zero group, there is no human death per road traffic accident but there are human injuries and property damages. Age of driv-

ers, Level of driving license and Type of victim variables had significant impacts on the probability of being in the always zero counts group. The odds of existence in the always zero counts group was 81.80 and 44.65 times advanced for above 50 years and those between 31-50 age group drivers respectively as compared to those aged 18-30 controlling other variables in the model constant. With regard to level of driving license, the odds of presence in the always zero counts group was 50.24 times higher for level four/five and 21.05 times higher for level three licenses when compared with level one driving licenses holding all other variables in the model constant. Collisions with animals, vehicles and humans with no human death had also increases the odd of being in the always zero group by 8.97 when compared with passengers by holding all other variables in the logistic group hold constant.

Table 7. ZIP regression Parameter Estimation for number of death per road traffic accident in north Shewa zone from 01-Jan-2018-31-Dec-2023.

Predictor variables	Categories of predictors	Coef.	IRR	P>z	[95% CI for IRR)	
Non-zero/log part						
Driving experience in year	0-5 (ref)					
	6-10	-1.286	0.276	0.000*	0.178	0.428
	11-15	-0.794	0.452	0.011*	0.246	0.832
	16-20	-1.156	0.315	0.009*	0.132	0.749
	21 & above	-0.131	0.878	0.682	0.469	1.640
Education level of drivers	Elementary (ref)					
	High school	-0.685	0.504	0.003*	0.323	0.786
	Above high school	-0.660	0.517	0.005*	0.327	0.817
Driver vehicle relation ship	Employee (ref)					
	Hired/relative/friend	-0.738	0.478	0.003*	0.295	0.774
	Owner	-0.801	0.449	0.043*	0.193	1.045
Seat belt use while driving	Yes (ref)					
	No	0.505	1.657	0.017*	1.095	2.508
Alcohol user	Yes (ref)					
	No	-0.059	0.943	0.748	0.659	1.349
Speed in km/hr.	51 & above (ref)					
	26-50	-0.324	0.723	0.285	0.399	1.309
	Below 26	-0.934	0.393	0.000*	0.255	0.606
Mobile use while driving	No (ref)					
	Yes	.046	1.047	0.788	0.748	1.467
Level of driving license	Level 1 & automobile (ref)					

Predictor variables	Categories of predictors	Coef.	IRR	P>z	[95% CI for IRR)	
Non-zero/log part						
Type of victim	Level two	0.032	1.032	0.886	0.669	1.593
	Level three	-0.961	0.382	0.008*	0.188	0.779
	Level four & five	-0.785	0.456	0.006*	0.262	0.794
	Passenger& W/c (ref)					
	Pedestrian	-0.285	0.752	0.267	0.455	1.244
	Animal &others	-0.554	0.575	0.045*	0.326	0.912
	Minibus (<=15) (ref.)					
Type of vehicle	Bus (>15)	0.110	1.116	0.609	0.732	1.703
	Cargo (truck/trailer)	0.068	1.071	0.745	0.709	1.615
	Tricycle/Motorcycle	0.068	1.070	0.790	0.650	1.760
	Special vehicles	0.163	1.177	0.749	0.433	3.199
	Private (Ref)					
Vehicle owner ship	Organization	0.231	1.260	0.464	0.679	2.338
	Government	0.674	1.961	0.148	0.788	4.884
	Commercial use (ref)					
Purpose of the vehicle	Private use	-0.685	0.504	0.001*	0.331	0.767
	Special use	-0.789	0.454	0.043*	0.211	0.976
	Vehicle-pedestrian (ref					
Type of collision	Vehicle to vehicle	0.055	1.057	0.785	0.711	1.570
	Overturning	-0.119	0.887	0.636	0.541	1.456
	Vehicle to animal or others	-0.679	0.507	0.109	0.221	1.162
	Direct (ref)					
Vehicle movement	Turn to L/R	0.381	1.464	0.057	0.924	2.094
	Reverse	-0.053	0.948	0.863	0.515	1.744
Pavement Roughness	Asphalt (ref)					
	Not Asphalt	-0.459	0.631	0.049*	0.438	0.999
Urbanization area of the accident Area	Urban (ref)					
	Semi Urban	0.327	1.387	0.048*	1.003	1.918
	Rural	0.075	1.078	0.726	0.707	1.645
Police & sig	Yes (ref)					
	No	0.205	1.228	0.331	0.812	1.856
Con		0.499	1.648	0.016	1.096	2.477
Inflate/logistic part						
Predictor variables	Categories of predictors	Coef.	OR	P>z	[95% CI for OR)	
Age of drivers	18-30yrs (ref)					
	31-50	3.821	45.65	0.000*	10.447	199.508
	51 &above	4.416	82.80	0.000*	9.278	738.851

Predictor variables	Categories of predictors	Coef.	IRR	P>z	[95% CI for IRR)	
Non-zero/log part						
Alcohol user	No (ref)					
	Yes	-0.577	.562	0.396	0.148	2.126
Level of driving license	Level 1 & automobile (ref)					
	Level two	0.942	2.56	0.346	0.361	18.207
	Level three	3.093	22.05	0.003*	2.879	168.898
	Level four	3.937	51.24	0.000*	5.910	444.311
Type of victim	passenger (ref)					
	pedestrian	-0.883	0.43	0.344	0.066	2.579
	Animal/vehicle	2.299	9.97	0.002*	2.252	44.125
con		-4.667	0.0039	0.000	0.0001	0.074

4. Discussion

This study was conceded out to identify the major factors associated with the number of human death per road traffic accident and estimation its rate based on North Shewa zone road traffic data. The RTAs human death rate (26/100) with 95% CI [21/100, 31/100] found in this study is smaller than the death rate obtained from similar study carried out in North Shewa zone, Ethiopia (41/100) [22]. This may be due to Overcrowding of roads since this study area is found in short distance from Addis Ababa, Ethiopia. Because in Addis Ababa and its surrounding administrative zones, there is high traffic flows per roads when compared with other parts of the country [23].

On the other hand, a retrospective study conducted in Central Ethiopia using relevant police station data had reported 17/100 human deaths as an average which is smaller than this study's output. This may be due to difference in the data source (police stations under count the number of human death per RTAs when compared with insurance companies). When road traffic accident happens human deaths may happened at the accident location, at the time of traveling to health institutions or even they may die within health institutions after a certain treatment [24]. But traffic policy register human deaths which had been occurred at the accident locations only and human deaths other than the accident location would be taken as injuries and reports are written like these. But insurance companies collect death certificates and medical certificates in addition to police reports settle their claims [25]. A study which hand been conducted in china reported number of human death per accident as 19/100 which is smaller than these study's finding. This discrepancy may arise due to difference in quality of cars, road transport rule

enforcements, availability police and traffic signals or it may be raised from difference in mechanical constriction of vehicles or other civilization difference in these regard [26].

Drivers having less than 5 years of driving practice were involved in road traffic accidents with more human death as compared to those who have more than 5 years driving capability. Drivers who have 6-10 year and 11-15 year practice decreases rate of human death by 22% and 45% as compared with drivers who have less than 5 year driving experience respectively. This may arise from the fact that more experienced drivers develop good driving styles, have good emergency handling attitudes, simply adapt the characteristics of their vehicles and matured in age when compared with less experienced ones. These findings are consistent with studies conducted in Addis Ababa, Ethiopia [27, 28]. Education level of drivers is additional significant cause associated with the number of human death per road traffic accident. As education level of driver's rise the number of death per road traffic accident was decreasing. This is may be due to the fact that well-educated drivers can read and understand traffic signals, Obey traffic roads and well understand how accidents will happen and its consequences when compared with less educated once These findings are consistent with studies conducted in Mekelle and Addis Ababa cities [29].

Employed drivers were associated with accidents having higher number of human death per road traffic accident as compared to accidents by divers who drive their own cars and those who drive relatives/friends owned vehicles. The reason for this may be due to absence of responsibly for the vehicles safety in case of non-owner drivers. These findings are congruent with study conducted in Addis Ababa cities [30]. Higher number of human deaths per road traffic accident took place among drivers who do not use seat belt while driving. According to this study finding, they increase incidence of human death by

65.7% when compared with seat belt users. This is due to seat belts preventing drivers and passengers from being ejected during a crash consistent with a study conducted in Finote Selam town, Ethiopia [31].

Over speeding is among common significant predictor variables for the number of human death per accident. Vehicles which derived by more than 50km/hr results in higher incidence of human death when compared with lower speed traveler vehicles consistent with a study conducted in Bahir Dar city, north west Ethiopia [32]. This is due to high speeds make a crash more likely because drivers have less time to react and because it requires a longer distance to stop or slow down. They also make collisions more deadly because modest increases in speed cause large increases in crash energy. Raising speed limits leads to more deaths. Passengers and workmen's on vehicles are highly exposed traffic accident victims. This is because when public transport vehicles have been faced with overturning accident, many individuals may lose their life when compared with pedestrians and other victim types. Severity is among passengers whereas frequency is among pedestrians. This finding is supported by a study conducted in Kenya and China [33, 34].

The number of human death per road traffic accident with respect to main purpose of the vehicles, those which are used for commercial purpose results in high incidence of human death when compared with private and special use vehicles. This may be due to that commercial use vehicles travels many times and long distance per day for different purpose of the owners when compared with private and special use vehicles. This finding is supported by a study conducted in Ghana [35, 36]. Asphalt roads were more significant variable for the inflation of human deaths when compared with non-asphalt roads this may be as asphalt roads enable drivers to ride vehicles with highest speed and this besides lead to occurrence of overturning and collision. Higher number of human death per accident occurred in semi urban areas such as at the gate of towns when compared with accidents occurred at urban areas. Similar study in Sweden showed that higher rate of deaths are occurred with in towns when compared to semi urban areas [37, 38]. This may be due to difference in the study area and study period.

Variables which have significant impact to decrease/increase rate of human death in the standard Poisson regression had resulted in increase/decrease the rate of being in the always zero group in the inflated part of ZIP model respectively. Age of drivers, Level of driving license and Type of victim had significant impacts on the probability of being in the always zero counts group. Drivers with age of 18-30 years rather than higher age groups and those with first level driving license had more significant impact to decrease the always zero group by increasing number of death per road traffic accident [38].

5. Conclusion and Recommendations

5.1. Conclusion

The ZIP model was preferable to Poisson, negative binomial regression, and the ZINB model based on AIC and BIC. This study taken predictor variables that had significant effects on the number of human deaths per road traffic accident. The selected zero-inflated Poisson model fit results indicated that driving practice in the year, education level of drivers, driver-vehicle relationship, seat belt use while driving, speed in km/hr, level of driving license, purpose of the vehicles, pavement roughness, and urbanization status of the accident area were statistically important factors associated with injuries of human death per road traffic accident in the north Shewa zone with different magnitudes of IRR.

5.2. Recommendations

A significant budget should be set aside by the Ethiopian government, relevant organizations, and interested parties for road safety and improvement projects. Amhara area and the office of the transit authority. In order to issue driving licenses, it would be preferable to regulate driving license training facilities for their effectiveness, reinforce regulations, and boost supportive bureaucracy. To lessen the severity and frequency of accidents around district towns, it would also be preferable to increase the number of police officers, install traffic lights, build alternate routes, and keep heavy-duty vehicle roads and public transportation vehicle roads apart. Police stations and personnel in NSZ It would be preferable to enforce traffic laws, vigorously denounce any infractions (such as speeding or driving without a seat belt), and stiffen the penalties for breaking them. It is important to install rumble strip (speed breaker) at a range of minimum stopping site distances from entrances and exit gate in a way that reduce accident frequency. Owners of cars and drivers Vehicle owners must hire drivers according to their age, driving experience, and educational background. Additionally, owners must pay close attention to their vehicles' yearly inspections and third-party insurance coverage. When driving, it is advised that drivers observe and abide by traffic laws and regulations. Every member of the public, including pedestrians, must be aware of and obedient to town traffic regulations, including observing zebra crossings and staying to the left of the sidewalk.

6. Strength and Limitation of the Study

Unlike earlier studies that relied just on police reports with a limited number of factors, road traffic data was gathered from insurance company claim charts, which include police reports along with medical and death certificates. The majority of explanatory variable categorizations were derived from Ethiopian transportation authority and road regulations. The

study's results were presented using suitable statistical techniques. A few significant factors, such as car quality, traffic safety, and driver addiction, are overlooked in the analysis of this study.

Abbreviations

NSZ	North Shewa Zone
GDP	Gross Domestic Product
K-S	Kolmogorov Semirnov
ML	Maximum Likelihood
NB	Negative Binomial
RTAs	Road Traffic Accidents
RTIs	Road Traffic Injuries
WHO	World Health Organization
ZIP	Zero-Inflated Poisson
ZINB	Zero-Inflated Negative Binomial
IRR	Incidence Rate Ratio
WC	Workmen's

Author Contributions

Afera Mekete Alemu: Data curation, Formal Analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft

Dagne Tesfaye Mengistie: Conceptualization, Formal Analysis, Investigation, Software, Validation, Visualization, Writing – original draft, Writing – review & editing

Dagnew Melake Abebe: Data curation, Formal Analysis, Methodology, Supervision, Validation, Visualization

Kasaneh Jigar Alem: Data curation, Methodology, Software, Validation, Visualization

Ethics Approval and Consent to Participate

The Gondar University Institute of Public Health ethical approval committee, under reference number IPH/2509/2023, approved this study. The study was conducted in accordance with relevant guidelines and regulations. Informed consent was obtained from all insurance companies in the north Shewa zone. The data used in the current investigation were secondary, and in the data collection procedures, only the ID number and important variables related to the current investigation were given to researchers.

Consent for Publication

Consent for Publication is “Not applicable”.

Funding

This research did not receive any specific grant from funding

agencies in the public, commercial, or not-from-profit sectors.

Data Availability Statement

All data generated or analyzed during this study are included in this published article.

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Mekonnen, F. H. and S. Teshager, Road traffic accident: the neglected health problem in Amhara National Regional State, Ethiopia. *Ethiopian Journal of Health Development*, 2014. 28(1): p. 3-10.
- [2] Azeze, M., et al., Predictors of Human Death by Road Traffic Crashes in Bahir Dar City, North Western Ethiopia; A Count Data Analysis Regression Model. *Int J Theor Appl Math [Internet]*, 2020. 6(6): p. 95.
- [3] Jindal, A. and S. Mukherji, World report on road traffic injury prevention. *Medical Journal, Armed Forces India*, 2005. 61(1): p. 91.
- [4] Ghaffar, A., A. A. Hyder, and T. I. Masud, The burden of road traffic injuries in developing countries: the 1st national injury survey of Pakistan. *Public health*, 2004. 118(3): p. 211-217.
- [5] Osoro, A., Z. Ng'ang'a, and A. Yitambe, An analysis of the incidence and causes of road traffic accident in Kisii, Central district, Kenya. *IOSR Journal Of Pharmacy*, 2015. 5(9): p. 41-49.
- [6] Deresse, E., et al., Road traffic accident and management outcome among in Adama Hospital Medical College, Central Ethiopia. *Pan African medical journal*, 2021. 38(1).
- [7] Gebremichael, M., et al., Prevalence and determinants of road traffic injuries in Ethiopia: Based on the 2015 STEPS survey findings. *Ethiopian Journal of Health Development*, 2017. 31(1): p. 340-347.
- [8] Demo, D. H. and A. C. Acock, The impact of divorce on children. *Journal of Marriage and the Family*, 1988: p. 619-648.
- [9] Hedström, E. M. and I. Waernbaum, Incidence of fractures among children and adolescents in rural and urban communities-analysis based on 9,965 fracture events. *Injury epidemiology*, 2014. 1: p. 1-5.
- [10] Woldu, A. B., A. A. Desta, and T. W. Woldearegay, Magnitude and determinants of road traffic accidents in Northern Ethiopia: a cross-sectional study. *BMJ open*, 2020. 10(2): p. e034133.
- [11] Geleta, D., et al., Road traffic accidents fatality and associated factors in Southwest Shoa, central Ethiopia. *East African Journal of Health and Biomedical Sciences*, 2020. 4(1): p. 35-46.

- [12] Bifftu, B. B., et al., Depression among people with epilepsy in Northwest Ethiopia: a cross-sectional institution based study. *BMC research notes*, 2015. 8: p. 1-8.
- [13] Getahun, W., T. Belachew, and A. D. Wolide, Burden and associated factors of anemia among pregnant women attending antenatal care in southern Ethiopia: cross sectional study. *BMC research notes*, 2017. 10: p. 1-7.
- [14] Asefa, F., D. Assefa, and G. Tesfaye, Magnitude of, trends in, and associated factors of road traffic collision in central Ethiopia. *BMC public health*, 2014. 14: p. 1-11.
- [15] Oltaye, Z., E. Geja, and A. Tadele, Prevalence of motorcycle accidents and its associated factors among road traffic accident patients in Hawassa University Comprehensive Specialized Hospital, 2019. *Open access emergency medicine*, 2021: p. 213-220.
- [16] Baru, A., A. Azazh, and L. Beza, Injury severity levels and associated factors among road traffic collision victims referred to emergency departments of selected public hospitals in Addis Ababa, Ethiopia: the study based on the Haddon matrix. *BMC emergency medicine*, 2019. 19: p. 1-10.
- [17] Mekonen, E. K., The Economic Effect of Road Traffic Accidents In Ethiopia: Evidences from Addis Ababa City. *ITI-HAS-The Journal of Indian Management*, 2016. 6(2).
- [18] Racioppi, F., et al., Preventing road traffic injury: a public health perspective for Europe. 2004: World Health Organization. Regional Office for Europe.
- [19] Deresse, T., et al., Fatal Road Traffic Accidents and Associated Factors in North Shewa Zone, Central Ethiopia: A Cross-Sectional Study. *Ethiopian Journal of Health Sciences*, 2023. 33(6).
- [20] Fesseha Hailu Mekonnen, F. H. M. and S. T. Sileshi Teshager, Road traffic accident: the neglected health problem in Amhara National Regional State, Ethiopia. 2014.
- [21] Adeoye, P. O., et al., Host, vehicular and environmental factors responsible for road traffic crashes in a Nigerian city: identifiable issues for road traffic injury control. *Pan African Medical Journal*, 2014. 19(1).
- [22] Retallack, A. E. and B. Ostendorf, Current understanding of the effects of congestion on traffic accidents. *International journal of environmental research and public health*, 2019. 16(18): p. 3400.
- [23] Hussain, M. and J. Shi, Predictors of aberrant driving behaviors of Pakistani drivers by using proportional odds (PO) model. *Asian Transport Studies*, 2020. 6: p. 100005.
- [24] Munene, B. K., Motor-cycle Crashes and Socio-economic and Demographic Characteristics of Riders. A Case Study of South Imenti Sub County, Meru County. 2022, University of Nairobi.
- [25] Lankarani, K. B., et al., The impact of environmental factors on traffic accidents in Iran. *Journal of injury and violence research*, 2014. 6(2): p. 64.
- [26] Xu, J., et al., Injury severity and contributing driver actions in passenger vehicle-truck collisions. *International journal of environmental research and public health*, 2019. 16(19): p. 3542.
- [27] Wang, Y. and W. Zhang, Analysis of roadway and environmental factors affecting traffic crash severities. *Transportation research procedia*, 2017. 25: p. 2119-2125.
- [28] Aga, M. A., B. T. Woldeamanuel, and M. Tadesse, Statistical modeling of numbers of human deaths per road traffic accident in the Oromia region, Ethiopia. *PLoS one*, 2021. 16(5): p. e0251492.
- [29] Tadege, M., Determinants of fatal car accident risk in Finote Selam town, Northwest Ethiopia. *BMC public health*, 2020. 20: p. 1-8.
- [30] Aworemi, J. R., I. A. Abdul-Azeez, and S. O. Olabode, Analytical study of the causal factors of road traffic crashes in southwestern Nigeria. *Educational research*, 2010. 1(4): p. 118-124.
- [31] Gheisari, M., Identifying Influencing Factors of Road Accidents in Emerging Road Accident Black spots. 2022.
- [32] Wedajo, T., E. T. Quezon, and M. Mohammed, Analysis of road traffic accident related of geometric design parameters in Alamata-Mehoni-Hewane section. *Int. J. Sci. Eng. Res*, 2017. 8(1): p. 874-881.
- [33] Baru, A., Injury Severity Levels and Associated Factors among Road Traffic Accident Victims Referred to Emergency Departments of Selected Public Hospitals in Addis Ababa, Ethiopia: The Study Based on Haddon Matrix. 2017, Addis Ababa University.
- [34] Qi, M., et al., Analysis of road traffic injuries and casualties in China: a ten-year nationwide longitudinal study. *PeerJ*, 2022. 10: p. e14046.
- [35] Wang, C., et al., Random-Parameter multivariate negative binomial regression for modeling impacts of contributing factors on the crash frequency by crash types. *Discrete Dynamics in Nature and Society*, 2020. 2020: p. 1-13.
- [36] Konlan, K. D., et al., Prevalence and pattern of road traffic accidents among commercial motorcyclists in the Central Tongu District, Ghana. *The Scientific World Journal*, 2020. 2020: p. 1-10.
- [37] Pew, T., et al., Justification for considering zero-inflated models in crash frequency analysis. *Transportation research interdisciplinary perspectives*, 2020. 8: p. 100249.
- [38] Subramaniam, S., et al., Statistical analysis of variability in TnSeq data across conditions using zero-inflated negative binomial regression. *BMC bioinformatics*, 2019. 20: p. 1-15.