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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Exploring the causes of Traffic Crash and Injury Severity on Addis Ababa - Adama Expressway

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The undersigned have examined the thesis entitled **"Exploring the causes of Traffic Crash and Injury Severity on Addis Ababa - Adama Expressway"** presented by **Bedria Hussien**, a candidate for the Degree of **Master of Science** and hereby certify that it is worthy of acceptance.

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ii

UNDERTAKING

I certify that research work titled **" Exploring the causes of Traffic Crash and Injury Severity on Addis Ababa - Adama Expressway"** is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged or referred.

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ABSTRACT

Road traffic crashes is a serious problem since it increased periodically in alarming rate throughout the globe. It is the eighth leading causes of death for all age groups worldwide, especially in developing countries. According to the global status report on road safety, in Ethiopia, road traffic deaths occurred about 26.7 per 100,000 populations.

The objective of the study was to explore the causes of Traffic Crash and Injury severity on Addis Ababa - Adama Expressway. In the study, eighteen main variables (with sixty two sub variables) are derived from the three major contribution factors of roadway environment, human and vehicle factors. For the analysis, five years (from July 8, 2016 – July 7, 2021) recorded traffic crash data and traffic flow data taken from Ethiopian Toll Roads Enterprise and the as-built drawings of the expressway taken from Ethiopian Roads Authority. During the last five-year study period, a total of 1838 traffic crash occurred on the expressway causing 98 (4.0 %) fatal injuries, 268 cases (10.94 %) serious injuries, 700 cases (28.57 %) slight injuries, and 1384 cases (56.5 %) were property damage only (PDo).

Descriptive Statistics and empirical statistical analysis by ordered logistics regression model was carried for the analysis of traffic crash and severity. Moreover, the operating speed of vehicles and 85^{th} percentile speeds of each type of vehicle category is computed to compare and evaluate the daily number of vehicles exceeded the posted speed limit of the expressway.

The analysis result show that, among the sixty two independent variables, seventeen independent variables are statistically significant with p-value of <0.05 with 95 % Confidence Interval and they have significant influence on accident severity. These influencing variables include; radiuses of horizontal curves in the range of 61m - 120m and 251m – 900m, level grade (0%), downgrade, light vehicles, medium vehicles, vehicle technical problem, speeding, sleep deprivation and fatigue, drivers error, head on crash, rear-end, roll over, sideswipes collisions, weekdays , driver's age from 18 – 30 and 31 - 50 yrs. are statistically significant for the severity of crash on the expressway

Key Words: Accident Severity, Crash Frequency, Geometric Design Parameters, Logistic Regression, Road Traffic Crash, 85^{th} percentile speed.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AADT	Average Annual Daily Traffic
AASHTO	American Association of Highway Transportation Officials
ADT	Average Daily Traffic
AIC	Akaike Information Criterion
ANRS	Amhara National Regional State
APM	Accident Prediction Models
BAC	Blood Alcohol Concentration
BIC	Bayesian Information Criterion
CI	Confidence Interval
DIC	Deviance Information Criterion
EAN	Equivalent Accident Number
ERA	Ethiopian Road Authority
GDP	Gross Domestic Product
GIS	Geographic Information System
GNI	Gross National Income
HGV	Heavy Goods Vehicle
HSM	Highway Safety Manual
ITS	Intelligent Transportation System
MNL	Multinomial Logit
NB	Negative Binomial
NCHRP	National Cooperative Highway Research Program
PDo	Property Damage Only
RIA	Road Safety Impact Assessment
ROC	Receiver Operating Characteristic Curve
RSDP	Road Sector Development Programme
RTAs	Road Traffic Accidents
SPSS	Statistical Package for Social Sciences
SRSM	Statistical Road Safety Modeling
TRB	Transport Research Board
UNECE	United Nations Economic Commission for Europe
WHO	World Health Organization

LIST OF SYMBOLS

km	kilometer
m	meter
sq. km	square kilometers
%	percent
yrs.	years
k	number of parameters in the statistical model
L	maximized value of the likelihood function for the estimated model
N	number of observations, or equivalently or the sample size

CHAPTER ONE

1 INTRODUCTION

1.1 Background of the study

Ethiopia is a landlocked country located in Eastern Africa, bordered by Sudan and South Sudan in the west, Djibouti and Eritrea in the north, Somalia in the east and Kenya in the south (UNECE, 2020). From the point of view of Ethiopia's geographical land scape and scattered & isolated pattern of rural settlement over 1.1million sq. km wide area, road transport plays crucial role in connecting rural areas with urban area. Even though, Road transport has different impacts such as road traffic accidents, it is the most important infrastructure in providing access to rural and urban areas in Ethiopia. Ethiopian Government launched a Road Sector Development Programme (RSDP) since 1997 which focus on upgrading and rehabilitating the existing road network, expanding new road network and constructing expressways, and providing routine and periodic maintenance.

Addis Ababa - Adama Expressway the first expressway which is constructed under expanding the road network for the Road Sector Development Programme. However, the traffic accident has been found to be high after the Expressway becomes operational (Deme and Bari, 2018; Abera, 2019). Despite being an important development issue, road traffic safety is not allocated sufficient funds and institutional arrangements remain inadequate in less developed countries (UNECE, 2020).

Road safety depends into three main factors, human, vehicle, and road environment factors (Abebe, 2019; Kriswardhana et al, 2020). Among them, the human factor is the leading factor causing accidents. These factors influence road safety separately or in combination. Despite these facts, the police report indicated that only a single cause of accident has been reported for a given accident in Ethiopia and the number of accidents that had been caused by road defect accounted around 1% of total accidents per year, which underestimates its contribution to road accidents (Abebe, 2019).

The purpose of this investigation was to review relevant literature and explore the cause of traffic crash and injury severity depending on the effect of eighteen main influencing factors

or independent variables. The independent variables include; accident occurrence place, radius of horizontal curve, cross sectional transversal slope of the road, longitudinal slope (grade), road gradient direction, road surface condition, vehicle travel direction, accident-involved vehicle type, number of vehicles involved, causes of crashes, types of crashes, accident occurrence time, weather condition, day of the week, lighting condition, drivers' gender and age. Descriptive statistics and statistical models were applied to carry out the comprehensive assessment of traffic crash, severity and cause of severity on Addis Ababa–Adama Expressway. In addition, for each of the five segments of the expressway depending on merging or diverging ramps, traffic volume and crash frequency is computed. Finally, the operating speed for each type of vehicle categories, depending on ETRE vehicle classification is analyzed and the 85^{th} percentile speed is computed for light vehicles , medium vehicles and large vehicles and compared with the posted speed limit of the expressway to evaluate the daily number vehicles exceeded the posted speed limits of the expressway.

1.2 Statement of the problem

Road traffic crash data obtained from Ethiopian Federal Police Commission report for 2019/20 and 2020/21 shows the traffic accident severity in terms of total number of fatalities, serious injury and slight injury has been increasing. Whereas, traffic crash result for the property damage only decreases. In 2020/21, fatality from road traffic accidents was increased by 9.6 % while road traffic accidents increased by 3.9 % which is threefold increase.

The cause of this high severity of road traffic accidents in Ethiopia hasn't been fully investigated and documented by empirical research so that series of actions can be taken by relevant institutions to address the problem.

Research focused on identifying potential factors that are contributing to high road traffic accidents and severity can be undertaken based on two approaches. These approaches are at nationwide level using time series traffic accident data collected on all road links and by selecting specific road links on the bases of high traffic accidents and severity (case study). The later approach is preferable than the former as it allows to identify factors related to defects in geometric design that are often different for different road section cases.

Traffic safety data on Addis Ababa - Adama expressway in the last five years shows high occurrence of traffic accidents and severity. Depending on the Ethiopian Federal Police Commission report, the severity of traffic accidents that occurred on the expressway during the same period is 57 % which is high compared with 36.3 % national average. Potential factors contributing to this high severity of traffic accidents have to be identified through empirical research in order to do something to address the problem.

So far, three separate researches have been conducted to identify contributing factors to traffic accident on Addis Ababa - Adama expressway, all have major shortcomings mentioned as follows. The first research conducted by (Deme and Bari, 2018) used one and half year traffic accident data which is insufficient to fully identify potential causes of accidents. Moreover the number of influencing factors independent variables are investigated in the study which are mainly selected from the human and vehicle factors. The other two researches conducted by (Abera, 2019; Mustefa and Belayhun, 2021) though both used five years traffic accident data to fill the gap of the previous research, but both researches were not investigated the contribution of road geometric design elements on causes of traffic accidents and injury severity, rather they studied the general causes and countermeasures of traffic accidents.

Therefore, to bridge the gap in the previous three researches, this research will evaluate the effect of the road geometric design parameters of the expressway on the contribution of the occurrence of traffic crash and injury severity if any. The effect of the horizontal and vertical road geometric design parameters on the cause of traffic accidents and severity of crash is assessed by linking traffic accident data with the actual location where the accident occurred and the geometric design parameters data from the as built documents of the expressway.

Besides this, the research identify factors other than geometric design that are contributing to the occurrence of high traffic accidents and their severity. Moreover the operating speed of the vehicles on the expressway has been evaluated.

1.3 Objectives of the study

1.3.1 General objectives

The general objective of the study is to explore the causes of traffic crash, injury severity and identifying the major influencing factor of crash severity on Addis Ababa - Adama expressway.

1.3.2 Specific objectives

Specific objectives of the study are to:

- Assess the frequency of traffic crash on Addis Ababa- Adama expressway.
- Identify the influencing factors for crash severity.
- Evaluate the daily number of vehicles exceeded the posted speed limit of the expressway.

1.4 Research questions

The main questions to be answered in the study are;

- How frequent is traffic crash on Addis Ababa – Adama expressway?
- What are the major contributing factors to the severity of traffic crash on the expressway?
- How many vehicles per day exceed the posted speed limit of the expressway?

1.5 Scope and limitation of the study

The causes of traffic accident on the expressway are the road environment that includes roadway geometric design parameters, driver's behavior, environmental factors, and vehicle factors. In this research, we assess the causes of traffic crash, and severity of the study area and to propose possible countermeasures in order to reduce the traffic accident severity. In addition, the 85^{th} percentile speed of the vehicles travelling on the expressway was analyzed to evaluate its contribution on the traffic crash and severity on the expressway.

In this study, the influencing factors such as the road cross-sectional width (such as number of lane and width, shoulder width) is not included since the whole stretch have the same

number of lane and width (i.e. 3x3.75 m) in both directions. In addition, the recorded crash data are incomplete on some of the variables on human factors and vehicle factors, such as drivers' driving experience, drivers' educational level, level of driving license, service year of the vehicles, so these variables were not considered for the analysis.

1.6 Organization of the thesis

This research paper has been organized in to five charters and appendixes as follows.

- The first chapter presents an introduction to the study topic which contains background information, statement of the problem, objectives, research questions and scope and limitation of the study.
- The second chapter contains the literature review part that encompasses a review on related previous researches, guidelines and books that used for assessing the causes and severity of traffic accidents and evaluates influencing factors that contributes for the causes of traffic accidents and injuries severity. It includes; traffic crashes in Ethiopia and its law enforcements, relationship between geometric parameters and traffic accidents, traffic safety statistical models.
- The third chapter presents the study methodology and materials used for the analysis.
- The fourth chapter presents the results and discussion part of the research. It includes the analysis of traffic volume and crash frequency on the entire expressway road and the road segments of the expressway, the descriptive analysis and empirical statistical model analysis of the influencing factors and the analysis of the operating speed and 85^{th} percentile speed for each vehicle type.
- Finally, the conclusions, recommendations and for future study area are presented in in chapter five.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Introduction

Vehicle collisions have been described differently by various organizations. According to the economic commission for Europe, Road traffic Accidents (RTAs) are accidents that occur on a way or street open to public traffic; result in one or more person's being killed or injured, and at least one moving vehicle was involved.

Road traffic crashes which is interchangeable used with the term RTAs is based on the prevailing definition used by the Addis Ababa police. Accordingly, it is an accident occurring on a way or street open to public traffic resulting in bodily injury to any person or damage to property caused by, or arising out of, involves at least one moving motor vehicle on a road, and could injure the driver or passengers of a vehicle, or even other road users such as pedestrians, cyclists and motorcyclists. Road traffic crashes can be categorized by in different ways such as location of the vehicle in accident, collision type, and also the type of damage. Accordingly, Ethiopia's road traffic crash classification was depending on type of damage i.e., is based on severity and type of injury (Beshah and Hill, 2010).

Those are:

- Fatal crash or killed: a human casualty who dies within 30 days after an accident.
- Serious injury: a person hospitalized for more than 24 hours due to an accident.
- Slight injury: a person hospitalized for less than 24 hours after an accident.
- Property damage: non-injury crashes (property damage i.e., roadside objects, vehicles)

In this research, Ethiopian classification due to the type of damage was used in order to match current crash analysis consistently with police crash records.

2.2 Road traffic accident Global Status

Traffic accident increased periodically in alarming rate and it was a serious problem throughout the globe particularly in developing countries like Ethiopia (WHO, 2018; Deme, 2019). Road traffic crashes are the worst in low- or middle-income countries which was

responsible for about 5 % loss of GDP in low- or middle-income countries and 3% of GDP globally (WHO, 2018; Abera, 2019). Reported number of road traffic deaths in Ethiopia was 4352, having point estimate of 27,326 and (95 % Confidence Interval (CI): 21,494 - 33,159) have a modeled number of road traffic deaths (WHO, 2018). The report shows that 26.7 per 100,000 populations were occurred by traffic accidents. Among them, the road user's death covers 36.7 % of pedestrians and 63.3 % have other or unspecified users.

Road traffic injury is the eighth leading causes of death for all age groups worldwide (WHO, 2018). The number of annual road traffic deaths has reached 1.35 million per year. The report indicates that, there is no reduction in the number of road traffic deaths were observed in any low-income country, while some reductions were observed in 48 middle- and high-income countries from 2013 to 2016. The number of deaths increased in 104 countries during this period. Figure 2.1 shows rates of death per 100, 000 populations for different regions.

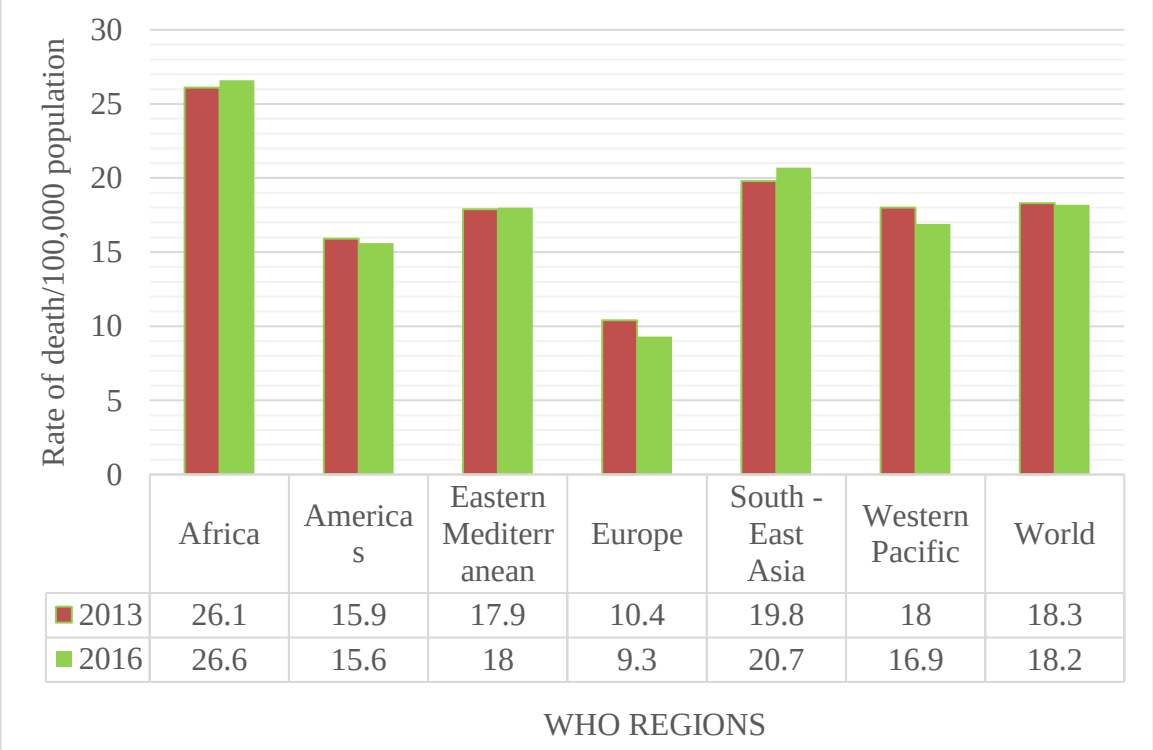


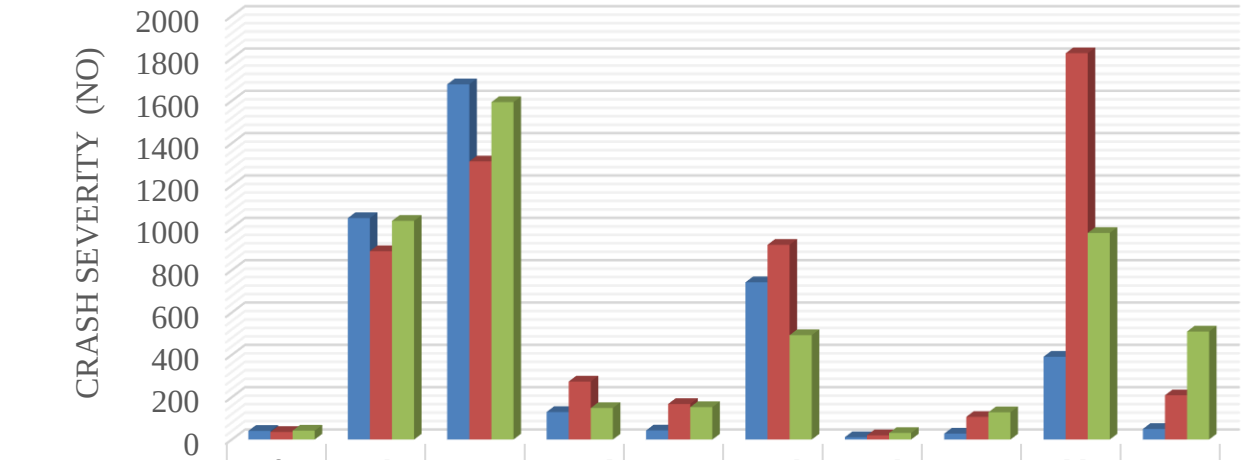
Figure 2.1: Rates of road traffic death per 100,000 populations by regions (WHO, 2018)

2.3 Traffic accident in Ethiopia

Traffic injuries for low - and middle-income countries are commonly under-reported, significantly higher for less severely injured road users (Abegaz et al, 2014). They found that the number of road traffic injuries and deaths collected by both traffic police and hospitality registry are different. In addition, according to the United Nation Economic Commission for Africa and for Europe report the actual fatality figures may in fact be much larger than those reported by the Ethiopian Federal Police Commission as a result of underreporting and misclassification of road traffic fatalities (UNECE, 2020).

Road traffic accident in Ethiopia for 11 years (from 2007/18 - 2017/18) were analyzed using descriptive and inferential statistics approach by (Deme, 2019). He investigates the growth rate of road traffic accident, road network coverage and motorized vehicle, and their relationships. He finds more than 291,577 road traffic accident; 912,956 km road network and 681,000 motorized vehicles were developed within the past 11 years. Average annual growth rate of road traffic accident, road network development and motorized vehicle were 9.16 %, 10.81 % and 13.34 % respectively. Deme (2019) finds that the road traffic accident had no direct or indirect relation with growth of motorized vehicle and road network coverage in Ethiopia. In addition, the trend of traffic crashes shows an increase by about 9 % on average within 8 consecutive years from 2010 to 2018 (UNECE, 2020). Ethiopia loses around 3.3 billion birr due to road traffic accident.

Road traffic accident is a major but neglected public health challenge (Tadege, 2020; Mekonnen and Teshager, 2014). According to Ethiopian annual traffic crash report, the annual traffic crash for 2019/20, 2020/21 was 3,795 and 4,161 cases for fatality with an increase in 366 deaths (9.64 %); 6124 and 5763 cases for serious injury with a decrease in 361 (5.89 %); 4943 and 5110 cases for slight injury with an increase in 167 (3.38 %) respectively. In addition, estimated PDo of annual traffic crash for 2019/20, 2020/21 was 8, 789,091, 027 and 2,285,999,562 birr cases for PDo with a decrease in 6,503,091,465 (73.99 %) respectively. Again, for injury or severity cases, the total severity has 38, 590, 41, 386 injury cases with an increase in 2796 (7.25 %) for 2019/20, 2020/21 respectively.



	Afar	Amhara	Oromia	Somalia	Benishangul Gumuz	Southern region	Gambella	Hareri	Addis Ababa	Dire dawa
Fatal	41	1046	1678	130	43	743	11	28	391	50
Serious Injury	36	890	1314	274	168	920	20	107	1825	209
Slight Injury	42	1033	1594	149	153	493	31	129	976	510

Figure 2.2: Regional traffic crash for fatal, serious, slight injury cases in 2020/21

In Ethiopia, RTAs related causalities are extremely high. Among RTAs causalities; 21.9 % were drivers, 35.0 % were passenger vehicle occupants and 36.0 % were vulnerable road users including: motorcyclists (21.0 %), pedestrian (12.1 %), and cyclists (2.9 %) (Abegaz and Gebremedhin, 2018). In Ethiopia, Eckersley et al. (2010, p. 4), "81% of the total accident was attributed to driver error".

The main causes and consequences of road traffic accidents in Amhara region using secondary data collected from Amhara National Reginal State (ANRS) police commission from 2007 - 2011 were presented by (Mekonnen and Teshager, 2014). The study results that, 83.8 % of all traffic accidents caused by drivers, such as failure to give priority to pedestrians, speeding, failure to stay on the right side of the road, failure to maintain distance between vehicles and failure to yield the right of way for other vehicles.

2.4 Traffic law enforcements in Ethiopia

Highway safety specialists can influence traffic safety in different road rules, law enforcements and others. According to global status report on road safety, Ethiopia has the following law enforcements (WHO, 2018). Ethiopia has national manual type of speedy laws and enforcements. Maximum default speed limits for urban, rural and motorway have 60, 70 and 100 km/h respectively.

Ethiopia has national drink driving law based on BAC having nation maximum legal BAC (g/dl) level have ≤ 0.08 for general population, young drivers and professional or commercial drivers. Testing was carried out for all drives either randomly or in the case of fatal crash. Due to alcohol 4.3 % of road traffic deaths are occurred in Ethiopia. Ethiopia has national motorcycle helmet laws and enforcements which apply to all drivers, adult passengers, all roads, all engines.

Ethiopia has national seat belt law which applies for all drivers', front seat passengers and rear seat passengers. We haven't data for seat belt wearing rates of drivers, only front seat occupants, and rear seat occupants. But, for all occupants there is < 1 % seat belt wearing rate. Ethiopia has national mobile phone law which applies for both hand-held phone use and hands-free phone use for any data on use of mobile phone while driving.

Ethiopia has road safety management, strategy and target. It has lead agency which is funded having functions of coordination, legislation, and monitoring and evaluation. It has road national road safety strategies having partial fund of fatal road safety target. Ethiopia has total number of 708,416 registered vehicles in 2016, having no vehicle standards.

2.5 Contributing Factor of Road traffic crash

The three main factors that contribute to road crashes are: a) human b) vehicle and c) roadway/environment factors (Haddon, 1972). Among the three factors, roadway factors include roadway and roadside design elements. Traffic crashes occurred due to roadway factors contribute only 3 % of road crashes and 34 % of road crashes are occurred due to a combination of roadway and other factors as per AASHTO highway safety manual (2010) report. Figure 2.3 shows the contribution of three factors for vehicular crashes.

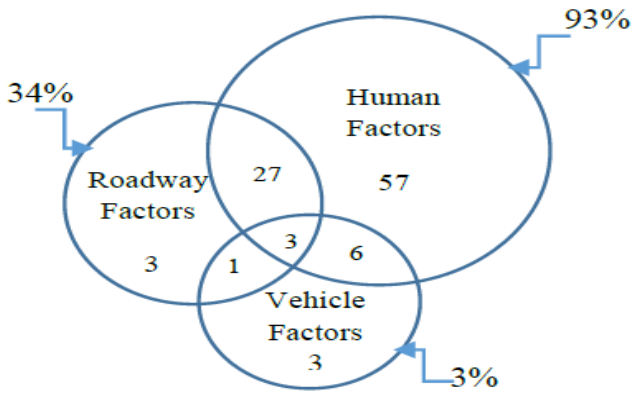


Figure 2.3: Contributing factors to vehicular crashes (AASHTO HSM, 2010)

The road traffic accident using reported data from case diaries and police records for 2009 data were studied by (Goswami and Sonowal, 2009) in Dibrugarh city, India using SPSS software and Ky-plot software for bivariate comparisons. The study result showed that 95.38% of traffic accidents from the total road traffic accidents occurred due to human characteristics (rush and negligence); 60 % and 38.46 % of the accident were recorded during day time (6 AM to 6 PM) and peak time (12 PM to 6 PM) respectively.

The road environment has been identified as a prime cause of accidents, contributing to about 17 to 34 percent of accidents and as the sole contributing factor for 2 to 3 % of accidents (O'Cinnelde, 2004).

(Jalilian, 2019) studied, the environmental factors associated with road traffic accidents using chi - square test and logistic regression model for 2314 traffic accidents. The result shows that frequency of RTAs occurred during daytime and sunrise are 72.3 %, 0.83 % respectively. The result also shows 91.7 % of the road traffic accident RTAs was occurred during day and 3.5 % of RTAs was occurred during cloudy weather. As a result, there is a significant relationship between RTAs and location of accident, accidents place, the climate, lighting of the day.

2.6 Effect of Traffic volume on Traffic Safety

On motorways, congestion is well-known traffic problem (Duivenvoorden, 2010). At certain times of day, roads get congested and the number of interactions between road user's increases. In general, higher traffic volumes and congestion affect road safety.

The relationship between accidents and traffic volume or congestion for 120 intersections in Adelaide, Australia was analyzed by (Retallack and Ostendorf, 2020). Results shows that an approximate linear relationship between traffic volume and accident frequency at lower traffic volumes. While, in higher traffic volumes, Poisson and negative binomial models showed a significant quadratic explanatory term as accident frequency increases at higher rate. Due to this, the researcher recommends good managements avoids or be the most effective in reducing accident frequency.

Crash prediction models were developed for European project RiPCORD-iSEREST by (Eenink et al, 2008). The study shows that the number of crashes increases with an increasing traffic volume. However, this increase is not a proportional one i.e. the crash rate, which is here defined as 'the number of crashes per motor vehicle kilometer', decreases with increasing traffic volume. It is however unknown whether this is due to the higher traffic volumes or to a safer design of roads with higher traffic volumes.

2.7 Effect of road geometric design parameters on traffic safety

Different studies focused on roadway geometric design and safety aim to improve highway design and to eliminate hazardous locations. Accordingly, Mohammed (2013) studied the effects of design elements such as horizontal and vertical curves, lane width, shoulder width, super elevation, median width, curve radius, sight distance, etc. on safety. Due to this, their result shows that an accident was caused by a combination of several factors. As a result, dimension of radii, ratio of consecutive curves, dimension of vertical curve and sight distance conditions are the most influencing factors for traffic safety.

Most of the design parameters that are considered in design of a road are related with road safety either directly or indirectly (Mohammed, 2013). Accordingly, all the geometric design parameters have to be checked in relation to safety. The road defect was one factor for negative

road engineering which directly triggers a crash, where the road defect misleads the road user and thereby creates human errors.

Road geometric design is strictly related to the level of a road traffic accident. Due to this, highway standards are limit standards (Hauer, 2004). Indeed, different countries have their own manuals such as ERA manual in Ethiopia by providing the minimum design standard values for geometric design parameters.

The relationship between road geometric design parameters with accident rate by using a variety of statistical modeling approaches such as linear regression model, multiple linear regression models, Poisson regression models, Poisson-gamma models, negative binomial models, bivariate and multivariate models, generalized estimation regression models, random parameters models was assessed by (Islam et al, 2019). The study relates road geometric design elements such as lane number, sight distance, super-elevation, median width and type, lane and shoulder width, curve radius, gradient, and horizontal and vertical alignments to accident rates. They found some geometric design elements such as short sight distance and small curve radius can significantly increase the road accidents rate and severity.

2.7.1 Radius of horizontal curves

For geometric design of roads, curve radius is a primary element with horizontal curve design and it is related to traffic accidents as the smaller the curve radius, the higher the possibility of accidents to occur on roads (Islam et. al, 2019). Similarly, Zhang (2009) analyzes the relation between road horizontal alignment, especially the horizontal curve and traffic safety. According to Zhang, type of collision such as vehicle steering, and transverse stability such as slippage and overturns depends on the curve radius. Again, Zhang calculates the average radius and curvature degree. He applies regression for all categories of calculated radius against mean of accident rates.

In addition, increase in accident rate becomes significant with roads which have curve radius below 200 m (Simpson and Kerman, 1982). Due to this, researchers suggest that the minimum curve radius value at which the impact on road accident can reduce. In addition, low radius

curves result in much shorter curve lengths and that the overall implications for accidents may not as bad as would appear.

For two-lane highways horizontal curves have high crash rates than straight sections of similar length and traffic composition (Aram, 2010). (Aram, 2010) uses statistical package software for descriptive statistical analysis. The result show, the difference becomes apparent at radius less than 1000 m and the increase in crash rates become particularly significant at radius below 200 m. In addition, on horizontal curves collision were occur in the form of roll-over crashes, opposite direction sideswipe crashes because of centripetal forces, than other road sections. (Glennon, 1987) was also concluded that the road safety would decline when the curve radius is above 400 m . that means, the greater curve radius can increase the accident rates and costs. Based on different researchers and by considering using minimum radius for design purpose, we can conclude that small radius curves are more associated with high accident rates and severity and the reverse.

2.7.2 Road gradients

Road gradient is one of geometric design elements under vertical curve design of road to be considered in association with road accident rates. During gradient design of curves, the association of sight distance with traffic safety are considered. (Glennon et al., 1987) assessed the gradient effect for US roads and concluded that roads which were designed grade sections have a higher road accident rates compared to roads which were designed with level sections. They also observed that higher accident rates were found in steep gradient in comparison with mild gradient roads; while down grade roads have more potential accident rates compared to upgrade roads. In addition, for Swedish roads with 2.5 % grade can increase road accidents by around 10 % whereas roads with 4 % grade can increase the accident rates by 20 % approximately as compared to near horizontal grades (Hedman, 1990).

2.7.3 Super elevation

Super elevation is a transverse slope under horizontal curve elements which is designed for the purpose of acting against centrifugal force that influences the vehicle's running on curves by providing higher on the outer side and lower on the inner side of the curve. It leads that for

stability of vehicles and driver's comfort. It depends on the horizontal alignment, curve radius and natural conditions. Due to this, improper super elevation value or no super elevation all will cause accident (Zhang, 2009).

The super elevation of horizontal curves is used as an input variable in the Highway Safety Manual (HSM) methodology. The HSM methodology considers the difference between the actual super elevation and the super elevation recommended by the AASHTO policy. Super elevation affects safety in the HSM methodology only when this difference exceeds 0.01 (HSM, 2008).

The effects of road geometric elements on accident severity were analyzed by (Sameen and Pradhan, 2016). They use mobile laser scanning method to extract the geometric elements and a logistic regression model is used to establish relationship between road geometric elements and accident severity. Depending on the coefficients calculated by the logistic regression model, the result shows that the average super elevation was the most contributed factor to serious injuries; grade change factor was the most critical factor for minor injuries and the damage only of accident severity levels. Due to this, improving super elevation on horizontal curves should be considered by the safety agencies in Malaysia. Similarly, the maximum super elevation rates of 4, 6, 8, 10, and 12 % was recommended by (Aram, 2010). For each maximum super elevation rates, he develops minimum radius with normal crown. He presents for a 1.5 % normal crown and maximum super elevation rate have minimum radius.

2.8 Effect of Human and Vehicle factor on traffic crash and severity

The main causes of motor vehicle crashes indicate the behavior of driver, which is mainly influenced by his personality, skills, and experience (AASHTO, 2011). In addition, external factors such as weather conditions, road conditions, time of day, or light conditions influence the driver behavior as well. The relation between accidents and road geometry is proved; while having similar geometry are characterized by different accident occurrence it is also a question of the driving behavior.

The role of human factor in incidence and severity of road crashes using descriptive analysis, multinomial logistic regression having target population 347, 285 road crashes due to age,

gender, safety belt, driver license that were occurred in Iran for fatal, injury, and no injury severity level was studied by (Pakgohar et al, 2011). The result shows that 97.5 %, 70.5 %, and 31.5 % accidents were occurred due to human, environmental, and vehicle factors respectively.

The frequency, causes and human impact of motor vehicle-related RTAs in the first semester of the year 2015 for 288 drivers (144 drivers are guilty drivers and 144 are not guilty as per road safety agents) was studied by (Nangana, 2016). Results show that, among 144 causing RTAs were affects 104 people including 93 injury and 11 fatality cases. Their mean age has 33.8±7.4, 35±8.8 for RTA causing drivers and controlled drivers respectively. The majority of drivers (53.4%) didn't attend a driving school, over speeding (32 %) distracted driving (22 %), overtaking (16 %) and careless driving (risky maneuver (15%) and driving under the influence of alcohol (9 %).

Factors associated with risky driving behaviors for road traffic crashes among professional car drivers on institution based cross sectional study for 376 participants using binary logistic regression analysis were carried by (Mekonnen et al, 2019). Results show that average monthly salary, driving experience, distance driven per year, and previous history of involvement in traffic crashes was significantly associated with risky driving behavior.

The effect of driver & vehicle characteristics on speeds at a tangent section was investigated by (Al-Omari.et.al., 2013) in Jordan. To reduce external and vehicular factors, the study was takes place at free flow condition and midblock location which has posted speed limit of 80 KPH. by considering driver characteristics (Gender, Age) and vehicle characteristics (Vehicle type, Vehicle Occupancy and Loaded and un-loaded vehicle). Their Study result showed that, younger drivers have higher speed than older driver and male drivers has also greater speed than female drivers but not significantly large. Small cars (passenger cars) and newest cars had larger speed than largest and oldest vehicles respectively.

2.9 Crash Type

Head on crashes are among the most sever collision types and of great concern to road safety authorities (Hosseinpour et. al, 2014). The study develops different crash prediction models

that relate crash outcomes with set of contributing factors both on frequency and severity of head-on crashes. The model results, the variables horizontal curvature, terrain type, heavy-vehicle traffic, and access points were found to be positively related to the frequency of head-on crashes, while posted speed limit and shoulder width decreases the crash frequency. With regard to the crash severity, the results shows that horizontal curvature, paved shoulder width, terrain type, and side friction were associated with more severe crashes, whereas land use, access points, and presence of median reduced the probability of severe crashes.

The hit-and-run vehicle crashes that happened in thirteen urban road tunnels traversing through binary regression model to identify factors related to the offending drivers, the vehicular and environmental conditions, tunnel characteristics and crash information were employed by (Jiang, 2016). The result founds that five categories and inclusive factors: 1) offending driver (alcohol involvement); 2) vehicle condition (vehicle type, number of vehicles involved); 3) tunnel characteristics (posted speed limit, number of unidirectional lanes, tunnel length); 4) environmental conditions (weather conditions, season of the year, day of the week, time of day); and 5) crash information (occurrence location in the tunnel, crash type, crash injury severity). In addition, the result indicates that accident was higher at night, in the tunnel exit, near to or in short tunnel, when a two-wheeled vehicle or heavy goods vehicle (HGV) was involved and when alcohol was involved.

2.10 Operating Speed and 85th percentile speed

Speed has been identified as a key risk factor in road traffic injuries, influencing both the risk of a road crash as well as the severity of the injuries that result from crashes.

The speed at which drivers are operating their vehicles during free-flow conditions is the operating speed and 85th percentile speeds is the measure of operating speed of most drivers on specific geometric features (AASHTO, 2011). Whereas, posted speed is the maximum lawful vehicle speed for a particular location as displayed on a regulatory sign (AASHTO, 2011). Most researchers and transport agency assured that the posted speed limit is decided based on 85th percentile speed predominantly.

The relation between Operating Speed and Posted Speed are studied by many researchers. According to the investigation on the relation b/n posted speed limit and operating speed on federal arterial road in Malaysia (M.A.Rahim, et al., 2015), found that the operating speed of drivers in most section exceeded the posted speed limit. (S.Wu & T.Xu, 2010) studies the coordination between operating speed and posted speed limit on classified highway, the finding of the study is there exist strong relationship between operating speed and posted speed limit, and operating speed is always larger than posted speed limit. They also studied by vehicle class ; it was found that the operating speed of cars has little change when the posted speed limit increase and for trucks, the posted speed does not affect the operating speed rather geometric parameters of the road or in coordination.

The effect of posted speed limit on drivers speed choice studied by (Rohaizan & Mashros,, 2016) on three different sites having varies posted speed limit from 60km/hr. To 80km/hr. during off-peak period. It was found that driver speed choice is depend on the posted speed limit of the driver irrespective of driver attitude and driving style. Their speed distribution study showed that, both 15 and 85 percentile speed increase with posted speed limit and also the driver speed compliance changes with speed limit implies that driver speed compliance decrease with increase of posted speed limit.

A study on the relationship between Speed Limits and Operating Speed was carried on straight roads of ordinary Provincial Arterial Highways by (Zhang , 2015) in nine sections which have speed limits of 30km/hr., 40km/hr. and 60km/hr. The result of analysis is done for different class of vehicle using SPSS statistical software. The study result reveals that operating speed of car is greater than posted speed limit and the difference between operating speed and posted speed limit decrease, when posted speed limit is increase. But there is little difference between posted speed limit and operating speed of truck and when the posted speed limit increases , the difference between the operating speed and the posted speed limit becomes large incase of truck.

Based on the above literature review, the operating speed of drivers are greater than that posted speed limit. This indicate that, the negligence of driver or bad behavior of driver especially driver of passenger car. Based on different study conducted in different country, the degree of

compliance of posted speed limit is varies with driver behaviors and method of enforcement of speed limit. Some operating speed models showed that posted speed limit is not statically significant variables implies that drivers are recklessness for speed limit or never had awareness for speed limit.

2.11 Statistical road safety models

Statistical road safety modeling (SRSM) is the fitting of a statistical model to data such as past accidents and traits (traffic, geometry, and environment) for a set of road segments, intersections, or other infrastructure elements (Hauer, 2007). SRSM is an equation with the estimate of expected accident frequency on the left and a function of traits on the right. It is used to estimate the expected accident frequency of an infrastructure element based on its traits and to estimate the change in expected accident frequency caused by a change in a trait of an infrastructure element. Hauer suggests few ways to improve SRSM process, and when models produced by different researchers and based on diverse data sets produced similar results, this will be a sign that modeling is on the right track.

According to SRSM, there is no theory to indicate how, for example, accident frequency increase as traffic increase or how it should be related to the radius of horizontal curve. Due to this, different statistical modeling approaches have provided to know the effects that geometric parameters have on the frequency and severity traffic accidents. In traffic safety, due to the interrelationship between geometric design parameters each other and with other road accident factors, leads lack of reliable methodology and different statistical models were employed (Islam et al., 2019).

Different researchers study different alternatives that have been used to analyze vehicular accident severity. Among them, logistic regression model analyses severity data based on car mass, age of the driver, and restraint use (Jones and Whitefield, 1988). They explored the effects of driving without a license, alcohol use, speed, seat belts, and helmet use on accident severity.

Again, the relationship between alcohol and crash risk, seat belts with preventing fatalities, human factors on accident severity such as drivers age was studied by (Tadege, 2020). The

study results, driver characteristics and vehicle service year influence accident severity. A statistical model to provide a statistical range of variables, including roadway geometry, weather related conditions as well as driver characteristics were studied by (Milton et al, 2008). They used a multinomial logit formulation to evaluate single vehicle motorcycle accident severity and estimate a nested logit model to predict vehicle occupancies with standard accident data. The result shows that, accident severity was affected by highway design accident type, driver characteristic, environmental conditions, and vehicle factors.

Logistic regression has also been extensively applied to study the influence factors of all kinds of indexes on traffic safety. It is used to describe data and to explain the relationship between one dependent binary variable and one or more nominal, ordinal, interval or ratio level independent variables. The regression can identify key elements influencing accident severity and their degrees of influence (He et al, 2018; Jiang et al, 2016).

Depending on the basis of logit regression model, multinomial logit (MNL) regression was developed to know the probability that vehicular accident and severity was estimated using the likelihood of discrete choices (several accident categories occurring) by (Milton et al, 2008). Each accident could be assigned one discrete outcome from a set of (1) property damage only, (2) possible injury involved, (3) evident injuries involved and (4) disabling injury or fatality involved.

According to regression problems, the response variable Y is restricted to a set of possible values, called response categories. These response variables are called polytomous or multi-category responses which can be discrete numerical, nominal or ordinal. In accident analysis, the response categories may refer to the different types of injury severity e.g. fatal, serious injuries, slight injuries and property damage only (Tutz, 2012).

Response categories are labels, ordered, and nested or hierarchical. If no order is implied, the response Y is measured on a nominal scale. If there is ordering in the categories and the corresponding numbers may be interpreted but not the distance or spacing between categories, then Y is measured on an ordinal scale. The other type of response category that contains more structure than the nominal case occurs in the form of nested or hierarchical response

categories. In this case, the response category Y, the injury severity of road users which has unordered categories.

Multinomial regression is a simple extension of the binomial distribution in that it allows for more than two possible outcomes. In road accident dataset, road users involved were classified according to their severities of injuries. The number of outcomes depends on the number of mutually and exhaustive injury severity categories (Tutz, 2012).

To select models in statistics, goodness of fit for the model and adjust or penalize for model complexity is important. Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used to compare models.

The Akaike Information Criterion (AIC) is a mathematical method for evaluating how well a model fits the data. In statistics, AIC is used for best model selection (Tutz, 2012). The AIC is named after the Japan statistician Hirotugu Akaike, who formulated it. It is defined by;

$$AIC = -2\log\big(L(\beta)\big) + 2k \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where,

k - is the number of fitted parameters (independent variables) in the statistical model, the default value is 2 and if independent variable is 1 then k is 3, and so on.

L - is the maximized value of the likelihood function for the estimated model.

For AIC criterion, the number of fitted parameters is added to the deviance as a measure for discrepancy between the data the fit. Due to this, increasing the number of parameters (penalty = 2k) discourage overfitting, this lead increasing the number of parameters in the model almost always improves the goodness of fit. Based on the above equation, AIC is specific for the sample size at hand. The AIC is calculated for each model considered, using same data and the general rule is that the model with the lowest AIC is chosen.

Bayesian Information Criterion (BIC) is also a model selection criterion, which is developed by Gideon E. Schwarz and published in 1978. The model is based on the empirical maximum log-likelihood estimation. Due to this, BIC is closely related to AIC. Like AIC, it is appropriate for models fit under the maximum likelihood estimation framework. The

derivation of BIC assumes a true generating model, and independent of sample size (Tutz, 2012). Selection of true model is obtained only asymptotically. The BIC is defined by:

$$BIC = -2\log\big(L(\beta)\big) + k * \log(n) \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where, L = the maximum value of likelihood function of the model

k = number of fitted parameters

n = sample size

The model with the minimum BIC is preferred.

2.12 Summary of Literature reviews

Road Traffic accident is a serious problem throughout the world particularly in developing countries. According to the report of (WHO, 2018), the road traffic injury is the eighth leading causes of death for all age groups worldwide. In Ethiopia, road traffic accidents related causalities are extremely high.

Various studies have been addressed the different aspects of road traffic accidents by focusing on predicting the critical factors influencing injury severity. As per the studies, there are numerous factors which contribute to road traffic accidents and traffic injuries, and these factors can be classified into three categories: namely, the road / environment related factors, human relate factors and vehicle related factors.

Many researchers have done studies on the role of road / environment factors on the causes of the road traffic accident and the relationship between road geometric design parameters with accident rate. These studies relates road geometric design elements, such as horizontal and vertical alignments, which includes horizontal curve radius, super elevation, road gradient, lane number, sight distance, median width and type and shoulder width, to accident rates. Many of the researchers found that some geometric design elements such as small curve radius and steep gradient can significantly increase the road accidents rate and severity. Most of them agreed that the crash rates become significant at radius below 200 m and roads which were designed with steep grade sections have a higher road accident rates as compared to roads which were designed with level sections.

The role of human factor on the causes of road traffic crashes indicate the behavior of driver, which is mainly influenced by his personality, skills, and experience. Research on the effect of drivers' speeds at a tangent section showed that, younger drivers have higher speed than older driver and male drivers has also greater speed than female drivers but not significantly large. Study results on behavior of drivers on driving speeds, the operating speed of drivers are greater than that posted speed limit. This indicate that, the negligence of driver or bad behavior of driver especially driver of passenger car. Based on different study conducted in different country, the degree of compliance of posted speed limit is varies with driver behaviors and method of enforcement of speed limit.

Various research have been done on the effect of traffic volume and accident frequency. Most of them agreed on the results that the accident frequencies increases as the traffic volume increases.

The aim of this study is to explore the causes of the traffic crash and severity on the Addis Ababa – Adama expressway that evaluate the frequency of traffic crash and investigate the causes of crash severity considering all the influencing factors associated with road/ environment, human and vehicles factors. The effect of the horizontal and vertical road geometric design parameters on the cause of traffic accidents and severity of crash will be assessed by linking the traffic accident location with the actual geometric parameters value of the expressway. Moreover the vehicles operating speed on the expressway will be evaluated to see its contribution on the traffic crash and severity.

CHAPTER THREE

3 RESEARCH METHODOLOGY

This chapter deals with the methodology and materials used to explore the cause of traffic crashes and severity on the Addis Ababa -Adama Expressway. Traffic crash Data and Traffic flow data were taken from the Ethiopian Toll Roads Enterprise (ETRE) database to assess the road traffic crash occurrence and severity of crash injury.

It started from data collection from ETRE and ERA, then the data was cleaned, sorted, filtered and recorded in to different variables and groups for the purpose of this study. Descriptive statistics were computed to determine frequencies of different variables and for the better understanding of the variables and their cases which is presented in Chapter 4.

Among the different statistical analysis methods that are presented in the literature review, three statistical analysis models namely; Ordered logistics regression model, Ordered Probit regression model and multinomial logistic regression (MNL) model were selected for comparison and selection of goodness of fit. To select best model, AIC and BIC for each model are computed and compared and finally the model with the smallest AIC and minimum BIC value of less is selected for analysis.

The general procedure of this research was structured after reviewed several literatures. The overall flow chart is presented as follows:

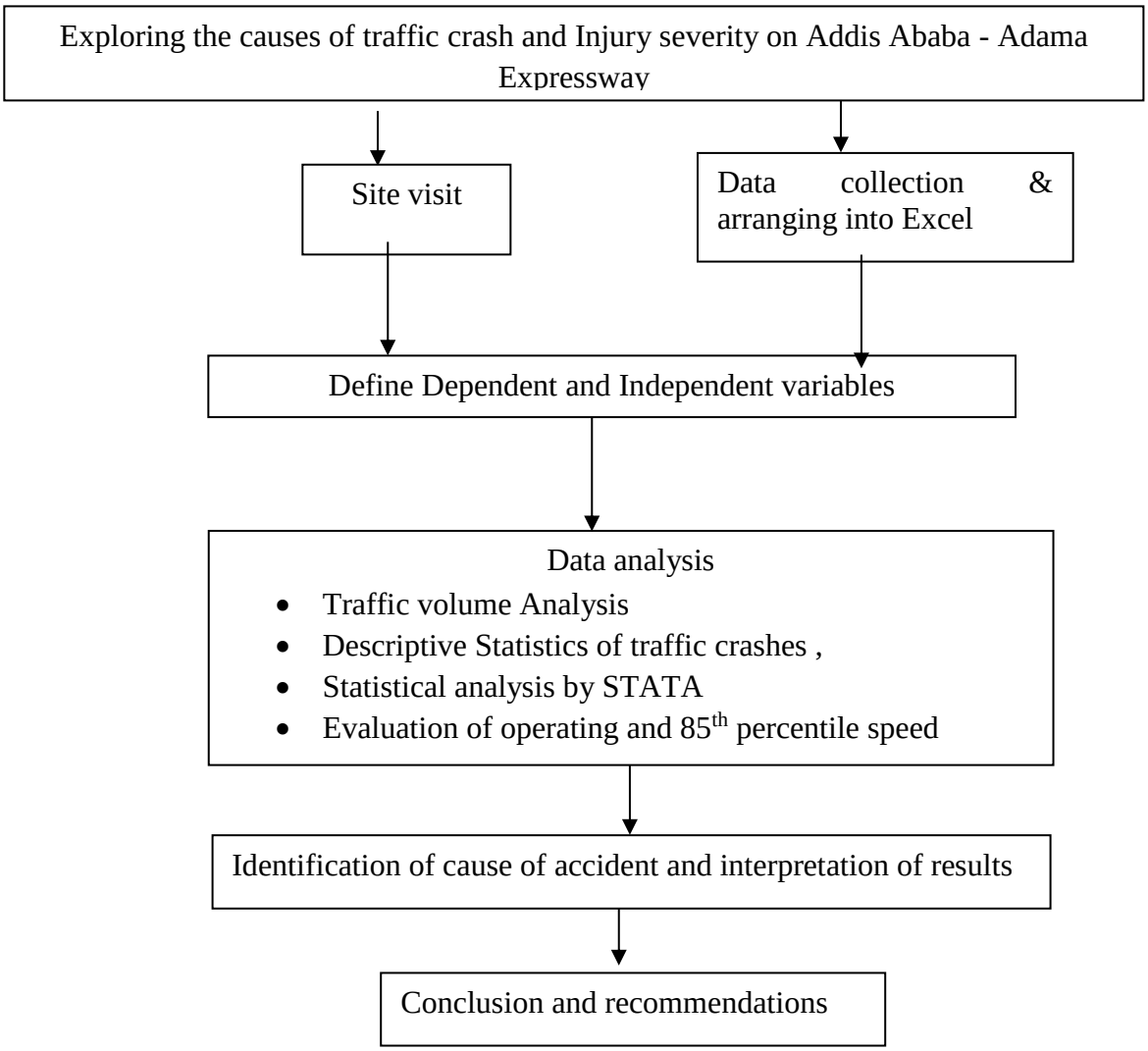


Figure 3.1: Methodology flow chart

The following section deals on approaches of the research, study area description, data collection analysis of data used for traffic accidents severity and road geometric parameters were presented below.

3.1 Description of the study area

Addis Ababa - Adama expressway is located in central part of Ethiopia, Oromia National Regional State. The expressway starts from Tulu Dimtu, 13 kilometers south-east of Addis Ababa city, proceeds in a southeast direction, passing to the east of Dukem, Bishoftu and Modjo towns crossing the old Addis Ababa - Adama road at approximately 62 km to bypass Adama to southern side. The expressway terminates to the east of Adama, connecting with the existing Adama - Awash trunk road. Figure 3.3 shows the location map of Addis Ababa - Adama expressway.

The Addis Ababa -Adama expressway is a controlled-access highway with a total length of 78.7km starting from the Addis Ababa outer ring road in which the toll plaza at Tulu Dimtu is located at km 2.690 (ERA's). The expressway has two main toll gates (i.e. at Tulu Dimtu and Adama) and six interchanges, where the main line of the expressway connected with other roads either by interchange or ramp toll plaza. The following table 3.1 shows the location and type of interchange on the Addis - Adama expressway.

Table 3-1: Location and arrangement of interchanges

No.	Location at	Interchange name	Cross road	Cross style
1	Km16+930	Bishoftu (N)	Addis-Adama road	Trumpet-type
2	Km33+860	Bishoftu (S)	Addis-Adama road	Trumpet-type
3	Km52+180	Modjo	Modjo-Arerti road	Trumpet-type
4	Km60+530	Adama west	Addis-Adama road	Half cloverleaf-type
5	Km67+215	Wonji road	Wonji road	Roundabout-type
6	Km71+700	Asela road	Asela road	Roundabout-type

As per the location of the toll plaza and interchanges, the main line of expressway has five segment sections which have different length and volume of traffic flow expressed in average annual daily traffic (AADT). Table 3.2 shows the segment section with their respective length.

Table 3-2: Section of the expressway by segment

No.	Segment section	From (km)	To (km)	Length (km)
Seg 1	Tulu Dimtu to Bishoftu (N)	2+690	16+930	14.240
Seg 2	Bishoftu (N) to Bishoftu (S)	16+930	33+860	16.930
Seg 3	Bishoftu (S) to Modjo	33+860	52+180	18.320
Seg 4	Modjo to Adama West	52+180	60+530	8.350
Seg 5	Adama West to End	60+530	78+427	17.897

The expressway has three lanes on each direction. The right-hand lane and the middle lane are serving as basic lanes (uninterrupted travel lanes) while the left lane serves as 'over taking lane'. The right lane is seen being used by low moving traffic such heavy trucks and trucks with trailers and buses.

The posted speed limit of expressway has three ranges: right lane: 60 kms/hr. to 80 kms/hr. , middle lane: 80 kms/hr. to 100 kms/hr. and left lane (overtaking lane): 80 kms/hr. to120kms/hr. The lower speeds are on-place for trucks with trailers, heavy trucks and large buses while the higher ones are believed regulate the light to medium vehicles.

Figure 3.2: Posted speed limit of the study area

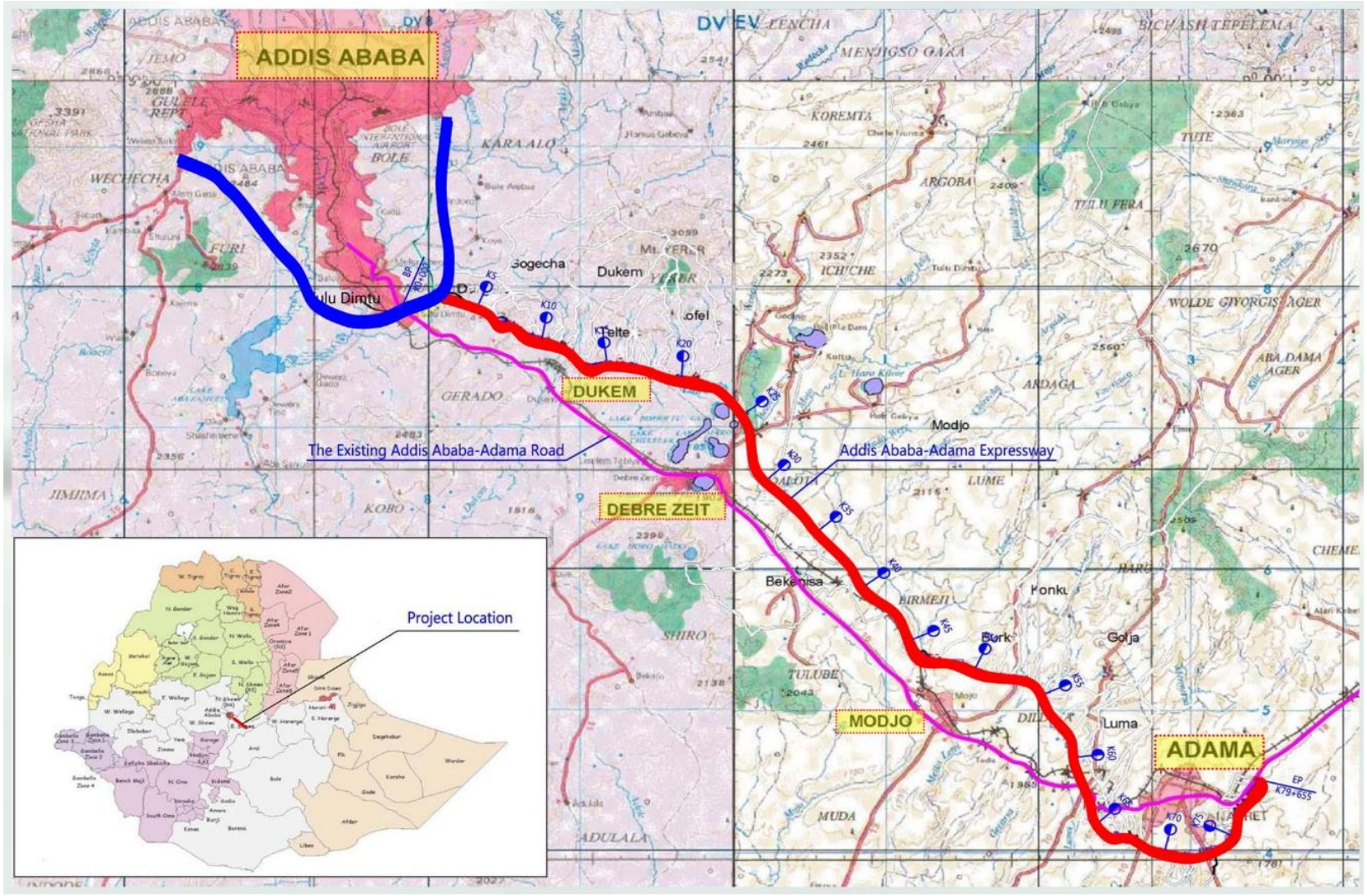


Figure 3.3: Location of the study area (ERA, 2017)

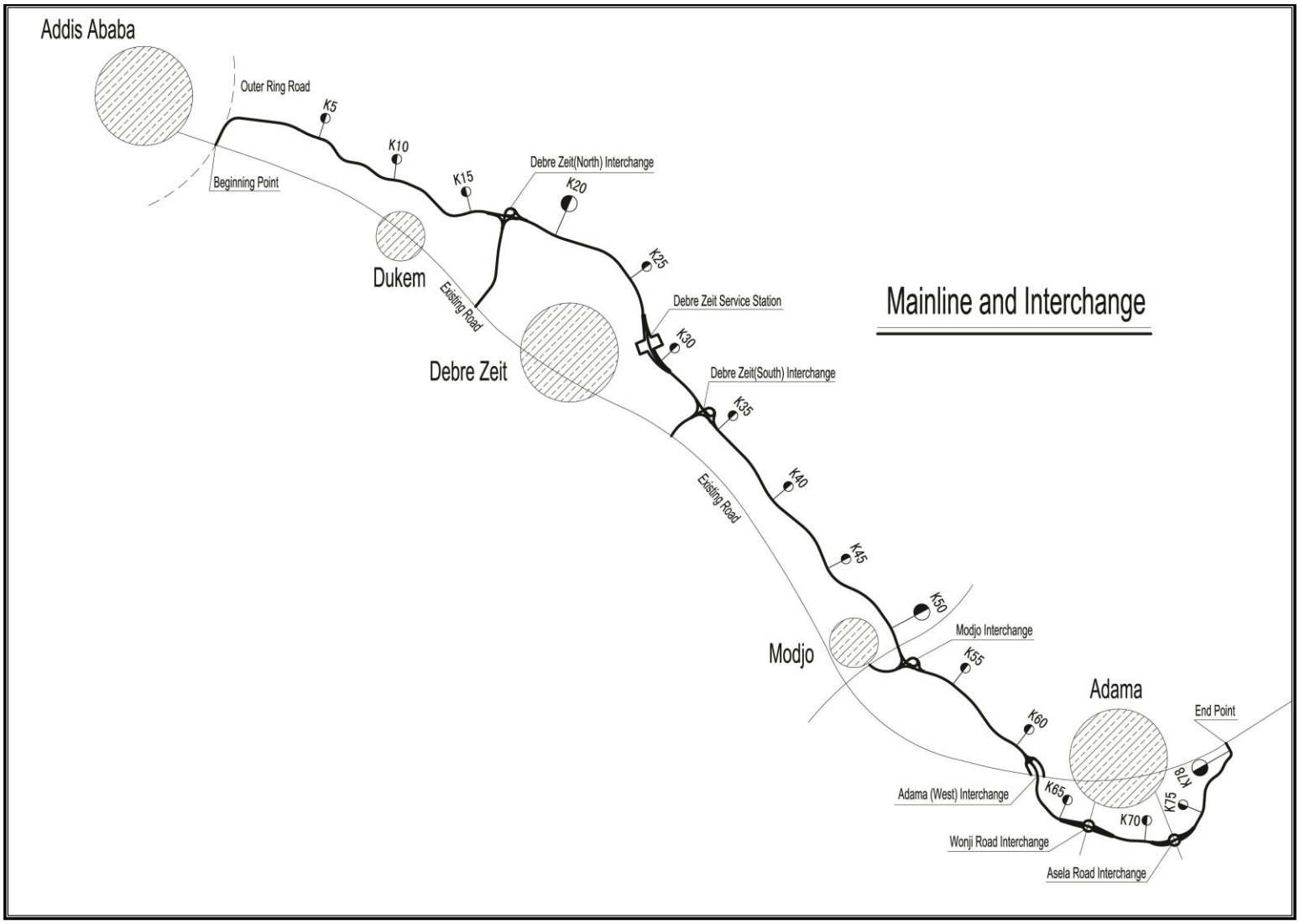


Figure 3.4: Location plan for mainline and interchange of the study area (ERA, 2017)

3.2 Method of data collection

The types of data collected are secondary data comprising of quantitative and qualitative types. The following data were collected and used as input and supporting features to explore the causes of traffic crash and severity on the Expressway.

3.2.1 Traffic crash data

Ethiopia Toll Roads Enterprise (ETRE) has provided the five years (i.e. from July 8, 2016 to July 7 2021) of traffic crash data observed on the Addis Ababa – Adama expressway in softcopy in Excel format. The accident database mainly includes information such as date and time of the accident, accident occurred place / location in km distance, type of accident, cause of accident, and accident-involved vehicle type, accident severity, drivers' gender, age and so on. The km reading of the accident occurrence location is taken from the km station written on the median guard rail at every 100m and the station in between 100m is written on the curbstone of the median at an interval of 20m. The researcher collects the traffic crash data in softcopy in Microsoft Excel format for further analysis. ETRE's traffic crash reporting format is attached in Appendix 2 and Appendix 3.

3.2.2 Traffic flow data

Ethiopian Toll Roads Enterprise (ETRE) collects traffic flow data using automatic traffic recorders operating 24-hours a day throughout the year. The traffic flow database mainly includes the information such as the date, vehicle type, the vehicle entrance and exit plaza ID number, vehicle entry and exit time, and distance travelled and so on. The researcher collects the traffic flow data to compute the Average Annual Daily Traffic (AADT) on each road segment on both sides of the expressway and to evaluate the operating speed of vehicles and the 85^{th} percentile speed for each category of the Vehicle type to evaluate the daily number of vehicles exceed the posted speed limit of the expressway. ETRE classifies the type of vehicles into 7 groups namely V1, V2, V3,….to V7 based on axle configuration for the use of charging road users. The researcher groups the vehicle type in to three categories for the analysis. Accordingly, vehicle types V1 and V2 are grouped in to light vehicles, V3 and V4 are grouped

in to medium vehicles and the remaining V5, V6 and V7 are grouped in to large vehicles. The Vehicle categories descriptions of ETRE is attached in Appendix 1.

3.2.3 Road geometric design parameters

The final As-built drawings and reports of Addis Ababa - Adama Expressway was collected from Ethiopian Road Authority. The following extracted data of geometric design elements classification with their units, used in a study to assess the effect of safety on the expressway are:

- The location of toll plazas, interchanges and the main line of the Addis Ababa – Adama expressway,
- Horizontal Alignment data which includes: straight sections, curved section, radius of curve (m),
- Vertical alignment data which include: gradient of the tangent (%) , direction of gradient (upgrade or down grade), and
- Cross sectional elements: roadway cross slope , Normal crown slope, super elevation slope (%).

3.3 Sample size

The Road traffic accident data was collected from Ethiopian Toll Roads Enterprise from July 8, 2016 to July 7, 2021 for five consecutive years. The total Road traffic accident were 1838 having 98 fatalities, 268 serious injuries, 700 slight injuries, and 1384 Property damage only (PDo). The whole traffic crash and severity data was used for this research; therefore, sampling for traffic accident data is not done for traffic accident and severity data.

Whereas, for the computation of operating speed and 85^{th} percentile speed of each vehicle categories (i.e. for light, medium and large vehicles), a sample data of seven days traffic flow from January 1, 2021 to 7, 2021 is used from the traffic flow database. The total number of vehicles sampled were 199, 315 which consists of 122, 420 light vehicles, 67, 740 medium vehicles and 9, 155 large vehicles.

3.4 Description of the variables

Study variables, dependent and independent (influencing) variables, are derived from the traffic accident data and from the as-built drawings of the expressway. The dependent variables are the severity of the Road Traffic Accident (RTAs) which consist of fatalities, serious injury, slight injuries and PDos on the Expressway. Table 3.3 shows the descriptions of the dependent variable (accident severity level) which are considered in this study.

Table 3-3: Description of dependent variables with their accident severity

No	Code	Variable	Descriptions of variables
1	F	Fatal	Human who dies within 30 days
2	SI	Serious Injury	A person hospitalized for more than 24 hours
3	LI	Slight Injury	A person hospitalized for less than 24 hrs.
4	PDo	Property Damage Only	Property damage comprise damage to the vehicles, any valuable objects on and the scene of accident i.e., only non-injury crashes

The independent variables (influencing factors) also derived from the traffic crash data and the as-built drawings and reports of the expressway. Eighteen main influencing factors or independent variables are selected from the three main causes of traffic accidents namely human factors, vehicle factors, and road and environmental factors. Table 3.4 shows the main independent (influencing) variables considered in the study.

Each main influencing variables has two or more sub variables and consequently the effect of sixty two sub variables on fatality, serious injuries and slight injuries are analyzed. Table 3-4 shows the list of the main independent variables with the number of the sub variable in each of the main variable. The detailed description of the main and sub independent (influencing) variables are presented in Appendix 5.

Table 3-4: Lists of the Main Independent Variables

No.	Main Variables	No. of Sub Variables (for each main Independent variables)
1	Accident Occurrence Place	2
2	Radius of Horizontal Curve (m)	8
3	Cross sectional transverse slope (%)	2
4	Longitudinal Slope (Grade) (%)	3
5	Road Gradient direction	3
6	Radius <200m with grade>4%	1
7	Day of the week	2
8	Accident-involved Vehicle Type	3
9	Accident Occurrence Time	2
10	Causes of Crash	8
11	Number of Vehicles Involved	3
12	Vehicle Travel Direction	2
13	Road Surface Condition	2
14	Weather Condition	3
15	Light Condition	3
16	Type of Crush	8
17	Driver Gender	3
18	Driver Age (Yrs.)	4
	Total Sub independent variables (No.)	62

3.5 Method of data analysis

3.5.1 Traffic Volume Analysis

Annual Average Daily Traffic (AADT) is one of the most important parameters in transportation engineering. Addis Ababa - Adama Expressway having a 78 km length was taken for traffic analysis. The Expressway have five segments (i.e. five merging and diverging ramps) having different traffic volume and segment length. The AADT on each segment are

computed on each direction (i.e. to Adama direction and to Addis Ababa direction) by taking the traffic count data entered in to the expressway at the all-toll gates and exited the expressway at the five toll gates. The AADT of the segments is calculated by adding the total vehicle volume of each segment for a year divided by 365 days.

3.5.2 Analysis of traffic accident and severity

After data collection, the five-year traffic accident data are sorted in to homogenous category and merged in to one excel file as per the dependent variables and influence factors. Then after, the road geometric parameters data, from the as-built drawings has been linked with the traffic accident location for each accident occurrence place to analyze the effect of road geometry on the severity of accident. It was time consuming since this task is done manually.

After arranging the crash date and linked the road geometry parameters data, the descriptive analysis will be done for each influencing variables. The influencing variables has two or more sub variables and consequently the effect of 62 sub variables on fatality, serious injuries and slight injuries are analyzed.

The magnitude of contribution of each of the independent variables disaggregated in to two or more sub variables on human injury is analyzed considering fatalities. serious injuries, and slight injuries each as dependent variable at a time.

For statistical analysis model, STATA software and Excel were used. For the analysis, a significance level of 5% were used. Among the different statistical analysis methods, logistic regression analysis method was used for this study depending on the above variables or factors. Ordered logistics regression model, multinomial logistic regression model and probit ordered logistics regression model were selected for comparison and selection of goodness of fit. The selection criteria depend and presents on Chapter 2 , Section 2.11.

3.5.3 Computation of Vehicles Operating speed and 85th percentile speed

A vehicle operating speed and 85th percentile speed is computed from the traffic flow database collected from ETRE. The database includes the detail information of vehicles entering and leaving the expressway. The data table mainly include the entry and exit plaza ID number,

traveled distance, entry time and exit time, and vehicle type, which provide important database for computing the vehicles operating speed. The format of the traffic flow data is attached in Appendix 4.

The freeway operating speed of the vehicles of each vehicle categories is calculated by dividing the total traveled distance by the time duration to travel the distance. The distance travelled is directly taken from the traffic flow data and the time duration is computed by calculating the time difference between vehicle exit and entrance time.

Then after, to determine the 85^{th} percentile speed, a frequency distribution table is prepared for each type of vehicle category. The cumulative frequency is computed from lower to higher speed and graph of number of vehicles verses speed is plotted to get the 85^{th} percentile speed of each vehicle type. Finally, the number of vehicles exceed the posted speed limit is computed from the frequency distribution table.

Microsoft Excel was used for arranging data for statistical analysis, computation of AADT, computation of operating speed and 85^{th} percentile speed of vehicles and number of vehicles exceed posted speed limits on the expressway.

CHAPTER FOUR

4 RESULT AND DISCUSSIONS

4.1 Traffic flow and Traffic crash analysis on Addis Ababa – Adama Expressway

4.1.1 Traffic crash and severity for the whole section

The Ethiopian Toll Roads Enterprise (ETRE) real time system recorded 24 hrs. traffic flow data throughout the year. For this study, the last five years traffic flow and crash data from July 2016 to June 2021 (from 2009 to 2013 E.C fiscal year of Ethiopia) were taken for analysis. Based on the year, traffic flow for each segments and the yearly variations and trends of crash rates of the expressway was analyzed.

Addis Abeba – Adama road being part of three import – export corridor (Djibouti, Mombasa and Berbera) is the most heavily trafficked road in the country compared with all other trunk roads radiating from Addis Ababa. Addis Ababa – Adama road consists of expressway six lanes separated by median and the old two-lane road both accommodating significant volume of traffic per day.

Traffic volume per day on the expressway has steadily increased from 18,600 in 2016/17 to 24506 in 2020/21. Currently Addis Ababa- Adama expressway alone carries about 25,000 vehicles per day. Table 4.1 shows the last five years AADT in Addis Ababa - Adama expressway.

Table 4-1: Traffic Flow on Addis Ababa- Adama Expressway on the last five year

Year	Total Traffic flow per year	AADT
2016/17	6,788,741	18,600
2017/18	7,810,351	21,399
2018/19	7,796,276	21,360
2019/20	8,347,038	22,869
2020/21	8,944,353	24,506

Depending on the collected vehicle flows from ETRE, the number of traffic flows for the last five years were increase from year to year. The average yearly changes in percentages of vehicle flows was found to be 7.27%.

The traffic crash count data on the expressway shows a total of 1838 crashes has occurred over the period 2016/17- 2020/21. Annual distribution of the traffic crash ranges from 302 in 2016/17 to 444 in 2018/19, with average annual number of crashes being 368. The annual average number of crash shows traffic crash occurred almost every day on the Addis Ababa – Adama Expressway and this could be considered high.

The number of traffic crash has increased from crash count of 302 in the year 2016/17 to 2017/18 and from year 2018/19 to 2020/21 reached maximum crash count of 444 in 2020/21. The crash data shows the crash count in 2018/19 was declined which was registered only 260 crash occurred. However, the crash count rises in 2019/20 and 2020/21. Table 4.2 shows the traffic crash, fatality, serious injury, light injury and property damage only (PDo) data for the last five years in Addis Ababa - Adama expressway.

Table 4-2: Traffic crash count and severity on the study area for last five year.

Year	Total no. of crash	No. of human injury			Property damage
		Fatal injury	Serious injury	Slight injury	
2016/17	302	19	33	75	246
2017/18	390	27	70	140	307
2018/19	260	24	79	178	152
2019/20	442	12	34	143	345
2020/21	444	16	52	164	334
Sum	1838	98	268	700	1384

The relationship between number of traffic per year and number of traffic crash per year on Addis Ababa- Adama expressway is increasing except in the year 2018/19 which is the lowest traffic crash occurred in the last five year.

In theory, the number of traffic crash increases as the number of vehicles on the road increases. In other words, as a greater number of vehicles enter into a road, the probability of occurrence of vehicle crash also increases.

In the case of Addis Ababa – Adama Expressway, the number of traffic per year on the expressway increased from 6,788,741 in 2016/17 to 8,944,353 in 2020/21, representing 7.27% increase over five years period. The number of traffic crash per year on the expressway increased from 302 in 2016/17 to 444 in 2020/21, representing 16.56% increase over five years period which supports the theory. Fig 4.1 shows the relation between traffic flow and number of traffic crash of the last five year of the Addis Ababa- Adama Expressway.

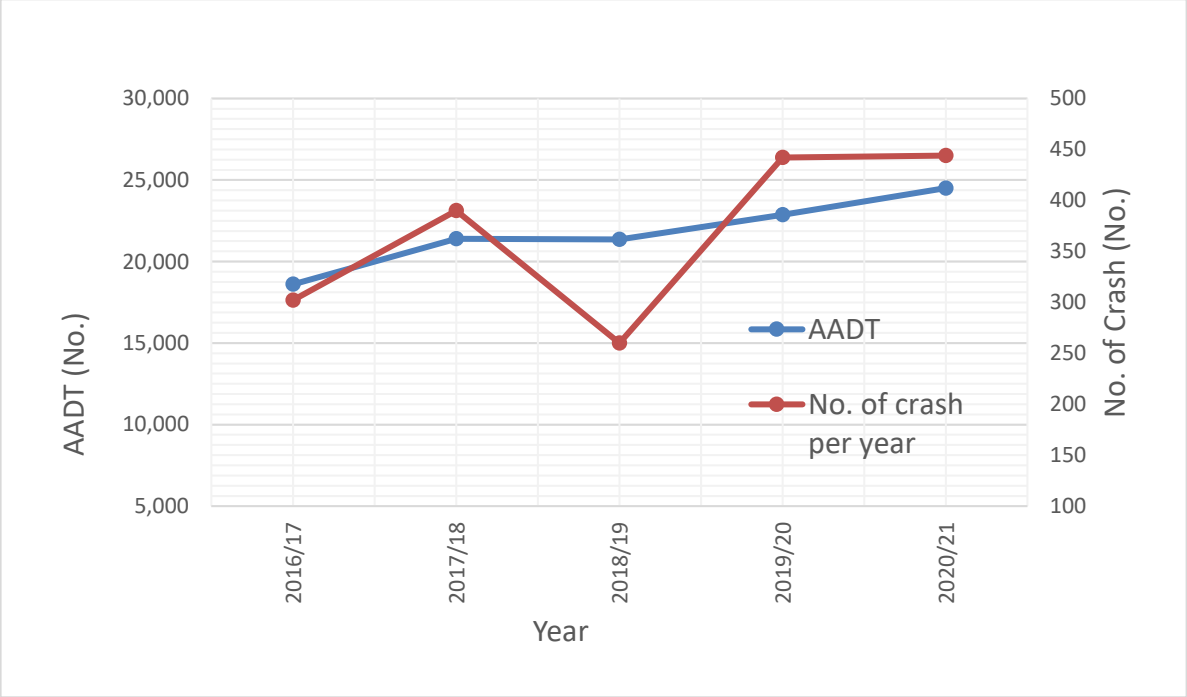


Figure 4.1: Total No. of crashes and AADT of the Expressway for each year

Data collected from ETRE shows that a total of 1838 traffic crash occurred over the period between 2016/17 and 2020/21 that resulted in a total of 1066 human injuries and 1384 property damage only (PDo). From the total of 1066 human injuries, 98 (4.00 %) were fatalities, 268 (10.94 %) were serious injuries and 700 (28.57 %) were slight injuries.

From the total numbers of traffic accidents 43.51% of them caused human injury. The occurrence of human injury from traffic accident is so high that attention has to be given to address the problem. The average human injury was 213 which consist of 20 (9.19%) deaths, 54 (25.14%) serious injuries and 140 (64.67%) slight injuries. Table 4.2 shows fatality, serious injury and slight injury on the expressway from the period 2016/17 to 2020/21.

Analysis of trend of fatalities from traffic accidents was not consistent over the years. Frequent fluctuation in fatalities was recorded each year but the margin of fluctuation was very small. As result of gradual change (i.e. neither significant increase nor significant decrease in number of fatalities) was observed.

Likewise, the trend in serious injury showed fluctuation over the years was still gradual. However, the trend in slight injuries showed frequent fluctuation by significant number over the years. Accordingly, number of slight injuries sharply risen in 2018/19. Then, rapidly decreased in 2019/20. Also, the number of slight injuries rapidly increased in both 2017/18 and 2018/19 then rapidly declined in 2019/20 and then slightly increased in 2020/21. Fig 4.2 shows the trend of severity of traffic crash of the last five year of the Addis Ababa- Adama Expressway.

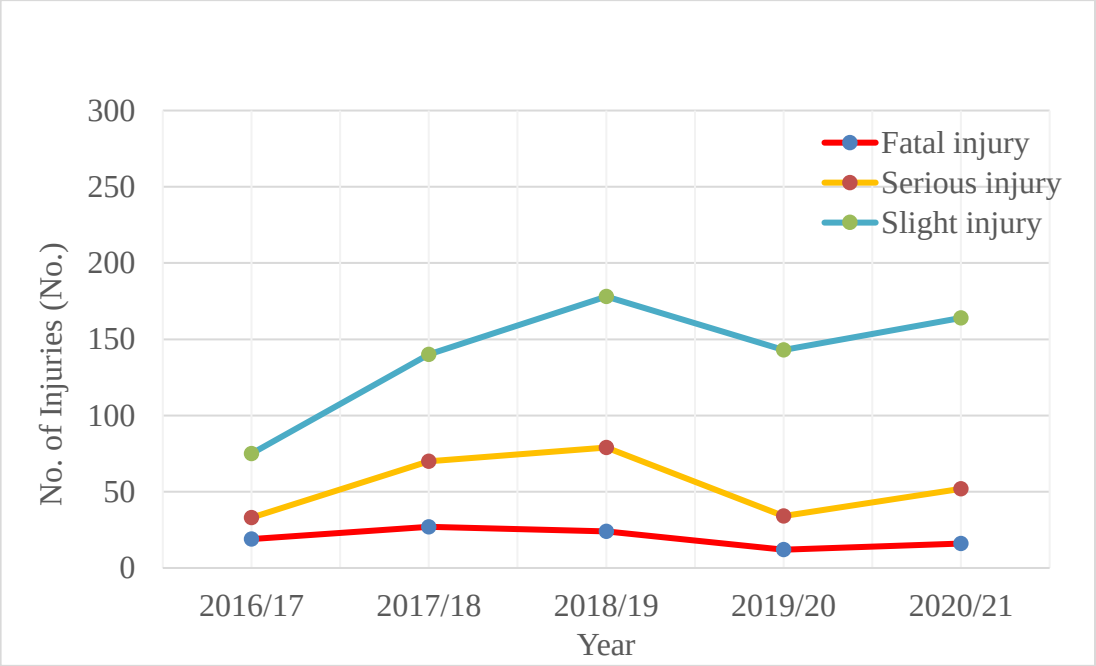


Figure 4.2: No. of Human Injury or severity for each year

4.1.2 Traffic flow and accident on the expressway by segments

The traffic volume on the road expressed as AADT is one of the most important parameters in transportation engineering. To investigate the effect traffic volume on the severity of traffic crash, the AADT of the road segments are computed. Depending on the description of segments presented in chapter 1 section 1.2, the expressway is divided in to 5 segments having different length based on the location of the toll plaza where the vehicles enter/exit the expressway.

The traffic volume on each segment and direction is computed from the traffic flow database collected from ETRE. The AADT is calculated for the last five years by adding the total vehicle volume travelled on each road segment for each year divided by 365 days. Finally, the average AADT is computed for each segment on both directions.

4.1.2.1 Addis Ababa - Adama direction

Tuludimtu - Bishoftu North (14.24 km) is the first segment of the expressway for which vehicles either destined to Adama and towns after Adama (through traffic) or leaves from the expressway at some point to go to Dukem, Bishoftu, Modjo, Hawass and Moyale. The average AADT on the 1st segment in the last five years have been 9072 which is the highest compared with the Bishoftu north - Bishoftu south (16.9 km), Bishoftu south (S) - Modjo (18.3 km), Modjo - Adama west (8.3 km) and Adama west - Adama - Awash junction (end of expressway) (17.8 km) which are the 2nd. 3rd, 4th, and 5th segments of the expressway towards Adama direction.

The size of average AADT on the 2nd, 3rd, 4th and 5th segments of the expressway depends on the balance of number of vehicles leaving the expressway at exit points to go to other towns and the number of vehicles entering in to the expressway at entry points. The size of average AADT on the 2nd segment significantly diminishes to 6330 as compared with the 1st segment as a greater number of vehicles left the expressway at Bishoftu (N) to go to Dukem than number of vehicles entered in to the expressway at Bishoftu (N) entrance.

However, the size of average AADT on the 3rd segment was increased to 6759 as the number of vehicles entered at Bishoftu (S) entry point exceeded the number of vehicles that left the at the same exit point. The size of average AADT on the 4th segment substantially reduced to 5000 as the number of vehicles that left the Expressway at Modjo exceeded the number of vehicles that enters in to the Expressway. Likewise, the size of AADT on the 5th (the last) segment substantially reduced to 3353 for significant number of vehicles left the Expressway at Adama west. Table 4.3 shows the AADT on segments of expressway (Adama direction).

Table 4-3: AADT on segments along Addis Ababa - Adama direction

Road section (from – to)	Segment		AADT by Year					Average AADT
	No.	Length (km)	2016/17	2017/18	2018/19	2019/20	2020/21	
Tuludimtu - Bishoftu N.	1st	14.24	7091	8968	9875	10097	9330	9072
Bishoftu(N) - Bishoftu(S).	2nd	16.93	5542	6102	6708	6833	6461	6330
Bishoftu S.- Modjo	3rd	18.32	5835	6566	7137	7272	6981	6759
Modjo to Adama (W)	4th	8.35	4643	4709	5391	5436	4825	5001
Adama west to End	5th	17.90	2356	3000	3601	3799	4007	3353

Data on traffic crashes recorded from ETRE on the five segments of the expressway for the last five years shows on the average 57 traffic crashes occurred on the 1st and 3rd segments each which is the highest as compared with the 2nd, 4th, and 5th segments. The highest number of traffic accidents that occurred on the 1st and 3rd segments have been related to the highest average AADT recorded on the 1st and 3rd segments as shown on table 4.3 and table 4.4.

Table 4-4: Traffic crash on segments along Addis Ababa - Adama direction

Road section	Seg No.	Year					Average traffic crash
		2016/17	2017/18	2018/19	2019/20	2020/21	
Tuludimtu - Bishoftu N.	1st	49	62	46	61	67	**57**
Bishoftu(N)–Bishoftu(S).	2nd	25	51	33	52	48	42
Bishoftu S.- Modjo	3rd	41	54	43	73	75	**57**
Modjo to Adama (W)	4th	19	24	18	29	27	23
Adama west to End	5th	15	36	15	30	25	24

Traffic accident record also shows, on the average 42 traffic accidents occurred on the 2nd segment which has highest average AADT next to the 1st and 3rd segments. In addition, the 4th and 5th segments have the least number of traffic accidents occurred which have also the lowest average AADT in the last five years. The average traffic accident that occurred on the 4th and 5th segment is 23 and 24 respectively. Despite, the 5th segment having the lowest average AADT (3353) compared with the average AADT of the 4th segment (5000), it has equivalent number of traffic accidents to the 4th segment which shows relatively higher number of traffic accident on the 5th segment is explained by reasons other than the volume of traffic accident.

The descriptive statistics on severity of the traffic accidents shows that accidents that occurred on the 2nd and 3rd segments of the expressway are the most severe. Average annual fatalities, serious injuries and slight injuries that resulted from traffic accidents that occurred on the 2nd and 3rd segments accounted for 68 % and 66 % respectively. Traffic accidents that occurred on the 5th segment is the 2nd most severe. Accordingly, average annual number of deaths, serious injuries and slight injuries accounted for 55 % for the 5th segment of the expressway. Traffic accidents that occurred on the 1st and 4th segments of the expressway resulted in 47 % and 44 % of human causalities (death, serious and light injuries) respectively.

Overall, severity of traffic accidents that happened on all segments of expressway towards Adama direction is 56 % which can be regarded as high and worrying. Hence, the causes of high severity of traffic accidents that occurred on all segments are objectively investigated in this study. Table 4.5 shows the severity of traffic crash by segment in to Adama direction.

Table 4-5: Severity of crash by segments along Addis Ababa - Adama direction

Segment from __ to ___	Seg. No.	Severity					Avg. Crash	% Severity from the total crash
		Fatal	Serious Injury	Light Injury	Total Severity (5Yrs.)	Avg. Severity on each seg.		
Tuludimtu-Bishoftu (N)	1st	17	30	86	133	27	57	47%
Bishoftu(N)–Bishoftu(S)	2nd	14	29	99	142	28	42	68%
Bishoftu S.- Modjo	3rd	23	53	112	188	38	57	66%

Modjo to Adama (W)	4th	3	13	36	52	10	23	44%
Adama west to End	5th	6	17	43	66	13	24	55%
Sub Total		**63**	**142**	**376**	**581**			

4.1.2.2 Adama - Addis Ababa direction

Traffic flow on the five segments of the expressway follow the same pattern as the pattern to Addis Ababa - Adama direction. Accordingly, the average AADT on Tuludimtu - Bishoftu(N), the first segment, is recorded to be 8630, which is the highest of all other segments towards Addis Ababa. Whereas, the average AADT on Tuludimtu - Bishoftu (N) segment towards Addis Ababa is lower than the average AADT on the same segment towards Adama direction.

The average AADT on Bishoftu (N) - Bishoftu (S), the second segment towards Addis Ababa, significantly diminished to 5745 and it is lower than the average AADT on the same segment towards Adama. The third segment on Bishoftu (S) - Modjo have average AADT to be 6148 and it is lower than the average AADT on the same segment towards Adama.

The average AADT of the fourth segment, Modjo - Adama west, and the fifth segment Adama west - end of the expressway successively decline to 4866 and 2992 respectively. The average AADT on the fourth segment towards Addis Ababa is lower than average AADT on the same segment towards Adama. Also, the average AADT on the fifth segment towards Addis Ababa is lower than the average AADT on the same segment towards Adama.

Table 4-6: AADT on segments along Adama - Addis Ababa direction

Road section (from – to)	Segment		AADT by Year					Average AADT
	No.	Length (km)	2016/17	2017/18	2018/19	2019/20	2020/21	
Tuludimtu - Bishoftu N.	1st	14.24	6679	8757	9229	9535	8949	8630
Bishoftu(N)–Bishoftu(S).	2nd	16.93	4968	5844	5962	6166	5784	5745
Bishoftu S.- Modjo	3rd	18.32	5218	6313	6357	6573	6281	6148
Modjo to Adama (W)	4th	8.35	4181	4907	5078	5180	4986	4866
Adama west to End	5th	17.90	1882	2918	3080	3332	3747	2992

The average annual traffic accident on Tuludimtu - Bishoftu (N) towards Addis Ababa is 68 and it is higher than average annual traffic accidents on the same segment towards Adama direction, which is 57. Whereas, the average annual traffic accident on Bishoftu (N) - Bishoftu (S), Bishoftu (S) - Modjo, Modjo - Adama west and Adama west - end towards Addis Ababa is lower than average annual traffic accident on the same segment towards Adama direction of the expressway.

Table 4-7:- Number of traffic crash on segments along Addis Ababa - Adama direction

Road section	Seg No.	Year					Average traffic crash
		2016/17	2017/18	2018/19	2019/20	2020/21	
Tuludimtu - Bishoftu N.	1st	64	78	41	74	81	68
Bishoftu(N)–Bishoftu(S).	2nd	34	46	28	49	36	39
Bishoftu S.- Modjo	3rd	41	26	24	35	44	34
Modjo to Adama (W)	4th	12	8	4	17	14	11
Adama west to End	5th	2	6	8	22	27	13

Traffic accidents that occurred on the 3rd and 5th segments in Addis Ababa direction are the most sever. Average annual fatalities, serious injuries and slight injuries that resulted from traffic accidents that occurred on 5th segment in Addis Ababa direction is the highest accounting for 80 % followed by the 3rd segment which accounts for 78.24 %. The average annual fatalities, serious injuries and slight injury that occurred on the 1st, 2nd and 4th segments in Addis Ababa direction accounts for 52.4 %, 53.4 % and 36.4 % respectively. Table 4.9 shows severity of traffic accidents to Addis Ababa direction.

Table 4-8:- Severity of crash by segments along Adama - Addis Ababa direction

Segment from __ to ___	Seg. No.	Severity					Avg. Crash	% Severity from the total crash
		Fatal	Serious Injury	Light Injury	Total Severity (5Yrs.)	Avg. Severity on each seg.		
Tuludimtu - Bishoftu N.	1st	12	49	116	177	35	68	52.37%
Bishoftu(N)–Bishoftu(S).	2nd	9	32	62	103	21	39	53.37%
Bishoftu S.- Modjo	3rd	10	30	93	133	27	34	78.24%
Modjo to Adama (W)	4th	1	4	15	20	4	11	36.36%
Adama west to End	5th	3	11	38	52	10	13	80.00%
Sub Total		**35**	**126**	**324**	**485**			

Overall, the average traffic accident on the segments towards Addis Ababa is lower than the traffic accident occurred towards Adama direction. Table 4.9 shows the summary of the five years average AADT and average traffic crashes on each segment to Adama direction and to Addis Ababa direction.

Table 4-9:- Summary of Average AADT and average traffic crash to Adama direction and to Addis Ababa direction

No.	Segment	Length (km)	To Adama Direction		To Addis Ababa Direction	
			Average AADT	Average Traffic Crash	Average AADT	Average Traffic Crash
Seg 1	Tuludimtu - Bishoftu N.	14.24	9072	57	8630	68
Seg 2	Bishoftu(N)–Bishoftu(S).	16.93	6329	42	5745	39
Seg 3	Bishoftu S.- Modjo	18.32	6758	57	6148	34
Seg 4	Modjo to Adama (W)	8.35	5001	23	4866	11
Seg 5	Adama west to End	17.9	3353	24	2992	13

From the table 4.9, we can conclude that as the AADT increases, the possibility of the occurrence of the traffic crash is increases.

4.2 Analysis of factors contributing to traffic accident and severity

4.2.1 Descriptive statistics for accident severity and occurrence

Descriptive statistics for 18 independent variables to severity of traffic accidents on Addis Ababa - Adama was evaluated. The severity of traffic accidents on Addis Ababa - Adama expressway in terms of fatalities, serious injuries and slight injuries is high as discussed in earlier sections. The traffic crash data reveals that, a total of 1838 traffic accidents occurred on the expressway in the last five years that have 98 fatalities, 268 serious injuries and 700 slight injuries. In this section, the contribution of the eighteen main variables was examined in order to know and understand the causes high severity of traffic accidents.

Each main variables has two or more sub variables and consequently the effect of 62 sub variables on fatality, serious injuries and slight injuries are analyzed. The magnitude of contribution of each of the eighteen independent variables (main variables) disaggregated in to two or more sub variables on human injury is analyzed considering fatalities. serious injuries, and slight injuries each as dependent variable at a time.

The results of the descriptive statistics of the variables used in the analysis of the traffic crashes is presented in Appendix 6. The descriptive statistics analysis table shows the distribution of crashes during the last five-year depending on independent variables or influence factors with their roadway or environment, vehicle factors and human factors associated places with their accident severity. The percentage of the fatality, serious injuries, slight injuries and property damage only (PDo) crashes observed across each category of the independent variables are also summarized.

The traffic crash frequency and severity of crash with influencing factors are discussed below.

4.2.1.1 Accident occurrence place

Traffic crash severity for the whole section of the expressway (i.e. on the main line and at the toll plaza which includes approaches to toll plaza, the entrance and exit to toll plazas) was assessed by the crash data collected from ETRE and the road geometry data collected from ERA. While looking at the severity level of the crash, majority of the crash occurred on the expressway which results 85.7 % of the fatal, 87.7 % of the serious injuries and 82.9 % of the

slight injuries occurred in the main line of the expressway. While, at the toll plaza, the severity in fatal, serious and slight was 14.3 %, 12.3 % and 17.1 % respectively. Table 4.10 shows the result of the descriptive statistics on the accident occurrence place.

Table 4-10: Crash frequency and Severity of crash on places of the expressway

Independent variables	**Severity**					
	Fatal		**Serious injury**		**Light injury**	
Accident Occurrence Place	No.	%	No.	%	No.	%
• Toll plaza	14	14.3	33	12.3	120	17.1
• Main line	84	85.7	235	87.7	580	82.9
	98	100.0	268	100.0	700	100.0

The traffic accident crashes at the main line of the expressway increased due various reasons such as over speeding, driver's negligence, vehicles technical problem. To summarize, 84 % of the traffic crash and severity is occurred on the mainline of the expressway whereas the remaining 14% occurred at the toll plaza area (Appendix 6). This result is consistent with (Mengyuan Z.,2016) study on Freeway Interchange Crash Characteristics and Influence Areas in which the researcher evaluates the crash frequency on freeway segments, ramps and speed change lanes resulting that the freeway (mainlines) were generated most crashes when compared with ramps. However the result on the accident occurrence place is not consistent with (Deme and Bari, 2018) in their findings, the frequency of crashes was high at the toll gates areas.

4.2.1.2 Radius of horizontal curve

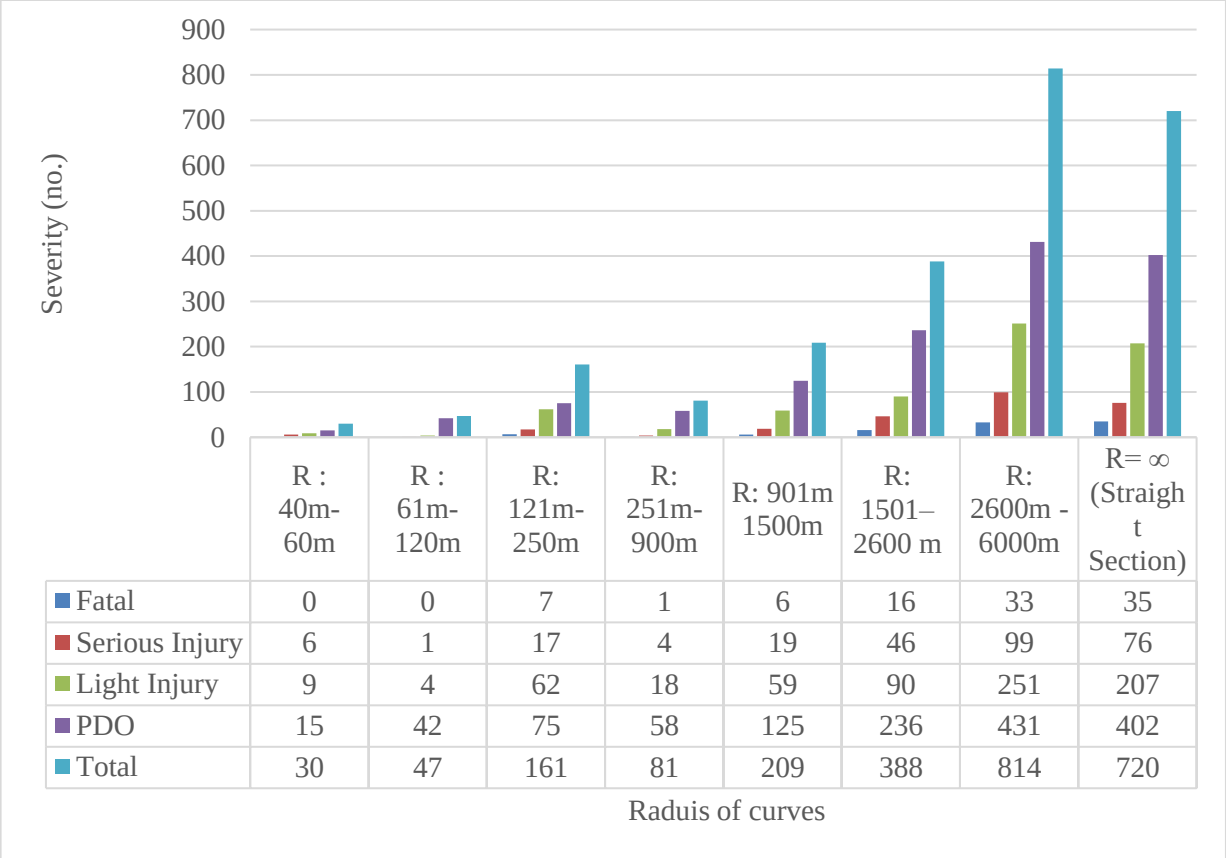
To evaluate the effect of the horizontal geometry on the traffic crash and severity of crash, specially radiuses of horizontal curves of the expressway with the observed severity, the radius of horizontal curves is categorized in to eight groups and used as a sub variable by taking the ranges of radius of horizontal curves.

The results shows the severity of crashes is the highest in straight road sections and on curved sections with large value of radiuses. According to the analysis result, 35.7 % and 33.7 % of

the fatality occurred on straight (tangent) sections (R = ∞) and on flatter curves having horizontal radius in the range of 2600m to 6000m respectively. On sections of the expressway with radius of horizontal curves between 1501 - 2600 m, 901 - 1500 m and 121 - 250 m the fatality decreased to 16.3 %, 6.1 % and 7.1 % respectively. For relatively sharp curves with radius of curves less than 120 m (which is located on the entrance /or exit to the toll plaza) there is no fatality recorded during the study period. The descriptive statistics result presented in Appendix 6.

Likewise, for serious injuries and slight injuries, the crash severities are high on straight sections and gentle curves (radius between 2601 - 6000 m) with a percentage of 28.4 %, 36.9% for serious injuries and 39.6 % and 35.9 % for slight injuries, respectively.

From the recorded traffic accidents, severity increases at the straight (tangent) section or at the larger horizontal curve radiuses. Figure 4.3 shows the severity of traffic crash with respect to the horizontal road geometry of the Addis Ababa - Adama expressway. This result is consistent with (Yoseph A. 2021) a study on Investigation of the Causes of Road Traffic Crashes and Remedial Measures on Debre Markos – Bahirdar Road, in which his findings stated that the crash occurred on straight and level section is 71 percent. Glennon et al. (1985) also pointed out that accident rates can be increased by greater curve radii and they concluded that the safety of road would decline when the radius of road curve is above 400 m. On the other hand, the result is not consistent with other studies. Because, in other studies traffic crashes are high when the radius is small while having large radius the effect is negligible on accidents frequency and severity (Simpson and Kerman, 1982; Glennon, 1987; Aram, 2010; Islam et al, 2019).



	R : 40m-60m	R : 61m-120m	R: 121m-250m	R: 251m-900m	R: 901m 1500m	R: 1501–2600 m	R: 2600m - 6000m	R= ∞ (Straight Section)
Fatal	0	0	7	1	6	16	33	35
Serious Injury	6	1	17	4	19	46	99	76
Light Injury	9	4	62	18	59	90	251	207
PDO	15	42	75	58	125	236	431	402
Total	30	47	161	81	209	388	814	720

Figure 4.3: Severity of crash due to horizontal alignment of the expressway

4.2.1.3 Cross sectional transverse slope

Likewise the radius of curves, the descriptive statistics result on the traffic crash and severity of crash is evaluated on the cross sectional transversal slope of the expressway for normal crown (NC), and super elevated (SE) section. The analysis result shows 71.4 % of fatalities occurred on the normal crown (NC) sections, whereas the remaining 28.6 % of the fatalities occurred on the super elevated (SE) section of with different values of super elevation depending on the radius of horizontal curves. Similarly, for serious injuries and slight injuries, the crash severities are high on normal crown (NC) sections with a percentage of 67.2 %, 67.9%, respectively. From the result, severity is higher at normal crown (NC), transversal slope and this is consistent with the severity of crash on straight sections and curves with large radius discussed above in the radius of curves. Table 4.11 shows the result of the descriptive analyses on the cross sectional transversal slope of the road.

Table 4-11: Severity of traffic crash due to transversal slope of the road

Cross sectional / transverse slope	Severity						PDo	
	Fatal		Serious injury		Light injury			
	No	%	No.	%	No.	%	No.	%
• Super elevated (SE)	28	28.6	88	32.8	225	32.1	506	36.6
• Normal Crown (NC)	70	71.4	180	67.2	475	67.9	878	63.4
	98	100.0	268	100.0	700	100.0	1384	100.0

4.2.1.4 Longitudinal slope (grade)

The severity of the crash on the longitudinal gradient has analyzed to understand the association of the vertical geometry of the expressway with the observed severity. The longitudinal grades are categorized in to three groups and used as a sub variable. The three ranges of grades are from grades 0 - 3 %, 3 - 5 % and grades greater than 5 %.

The descriptive statistics result shows that the severity of crashes on vertical grades in the range of vertical grades from 0 - 3 % and from 3 - 5 % is high percentage with 63.3 %, 29.6 % cases for fatal injury; 67.9 %, 24.6 % cases for serious injury; 73.9 %, 18.7 % cases for slight injury respectively. According to (Glennon et al, 1987; Hedman, 1990) studies results that road having grade section have a higher road accident rates than level sections. As a result, increase in road gradient can increase accident rates which is not consistent with the Addis Ababa – Adama expressway road result. The descriptive statistics result presented in Appendix 6. The figure 4.4 shows the severity of crashes due to the vertical grade of the expressway.

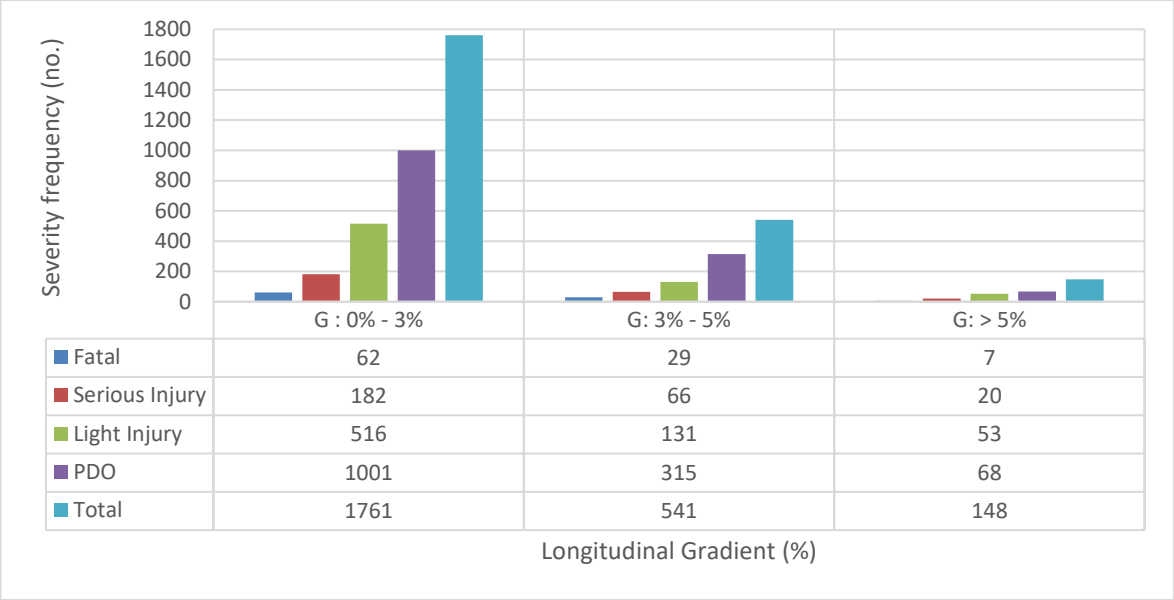


Figure 4.4: Severity of crashes due to the vertical grade of the expressway

4.2.1.5 Road gradient direction

The descriptive statistics results of the effect of road gradient direction on crash frequency and severity shows that, the traffic crash at the road gradient direction for upgrade, downgrade has 54 %, 44 % cases for fatal injury; 52 %, 46 % cases for serious injury; 46 %, 51 % cases for slight injury and 54.9%, 41.7% for property damage only (PDo) respectively. The cumulative result shows that about 52.4% of the crash occurred on downgrade direction whereas the crash occurred on upgrade direction and level grades are 47.7% and 2.9% respectively. This result is consistent with (Glennon et al, 1987) which results downgrade roads have more potential accident rates than upgrade roads.

4.2.1.6 R<200 and G>4 %:

To evaluate the combined effect of horizontal geometry and vertical alignments, the effect of sharp curves and steep gradient of the expressway is analyzed with an independent variable of radius of curves less than 200m and gradients greater than 4 % (i.e. R<200 m and G>4 %). The descriptive statistics result shows that out of the total of 98 fatalities, 7 (7 %) fatalities were occurred in this section, whereas serious and slight injuries are 8.6 % and 10.1 %

respectively. From the analysis result, the combined effect of the relatively sharp radius of curve and steep gradient (R<200 and G>4 %) is less when compared with straight road sections and gentle vertical gradient.

4.2.1.7 Day of the week

Traffic crash severity on the days of the week show that the severity of the traffic crash is high on weekday than weekends. The descriptive statistics result shows that the percent share of the severity on weekdays, and weekends has 61.2 %, 38.8 % cases for fatal injury; 61.2 %, 38.8 % cases for serious injury; 66.6 %, 33.4 % cases for slight injury and 70.9 %, 29.1 % cases for PDo respectively. Table 4.12 shows that the frequency of crash and severity on weekdays and weekends.

Table 4-12: Frequency of crash and severity on weekdays and weekends.

	Severity						**PDO**		Total	
	Fatal		**Serious Injury**		**Light Injury**					
Day of the week	No.	%	No.	%	No.	%	No.	%	No.	%
• Weekends	38	38.8%	104	38.8%	234	33.4%	403	29.1%	779	31.8%
• Weekdays	60	61.2%	164	61.2%	466	66.6%	981	70.9%	1671	68.2%

4.2.1.8 Accident involved vehicle type

The frequency of Traffic crash and severity due to accident involved vehicle types are evaluated for light vehicles, medium vehicles and large vehicles. The descriptive statistics result shows that light vehicle has the highest contribution on the occurrence of the traffic crash and severity. From the total casualty, 58.9% of caused by light vehicle. Whereas, medium and large vehicles are 21.6 % and 19.5 % respectively almost similar contribution on the causalities of the severity on the expressway. Figure 4.5 and 4.6 show percent share of vehicle type on the occurrence of traffic crash and severity of crashes by vehicle types respectively.

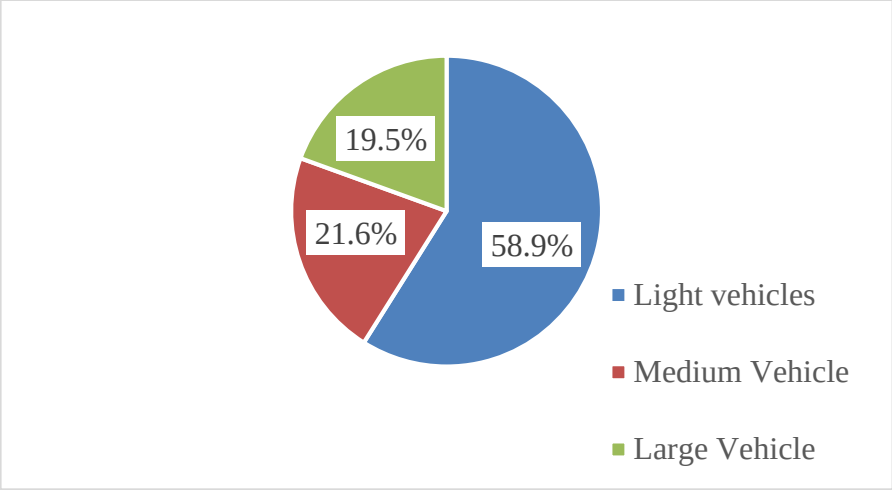
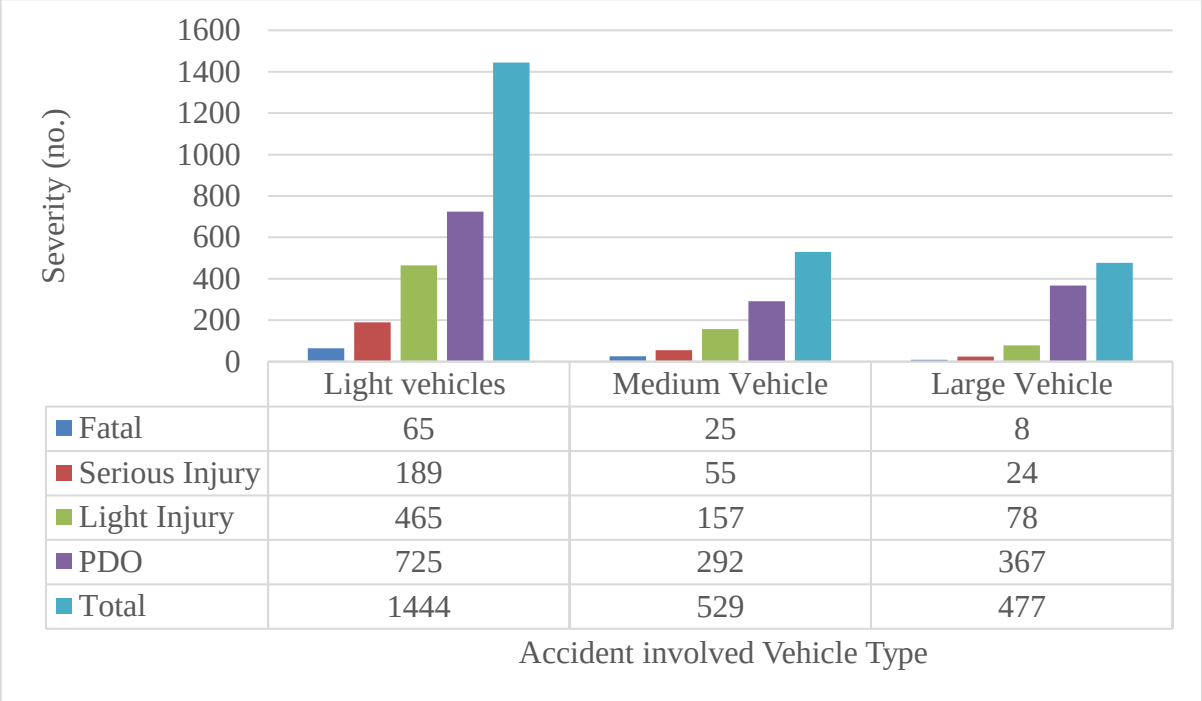


Figure 4.5: Crash frequency based on Vehicle Type



	Light vehicles	Medium Vehicle	Large Vehicle
Fatal	65	25	8
Serious Injury	189	55	24
Light Injury	465	157	78
PDO	725	292	367
Total	1444	529	477

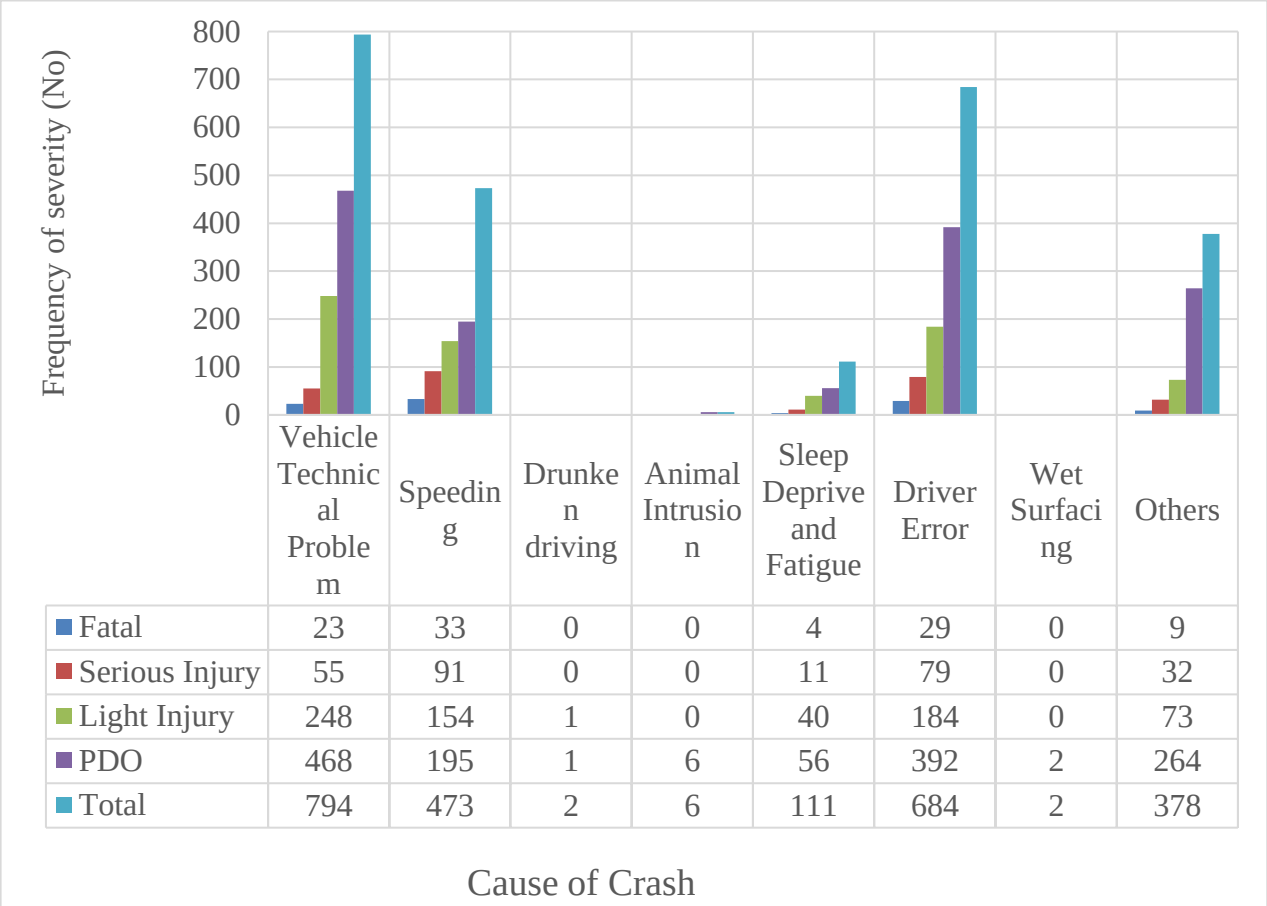
Figure 4.6: Severity of crash based on Accident involved Vehicle type

The analysis result also shows that the majority of fatality is occurred due to light vehicle which is 66.3 %. whereas, the fatality due to medium and large vehicles are 25.5 % and 8.2 % respectively. For serious and slight injuries, the light vehicle, medium vehicle and large vehicles have a contribution for 70.5 %, 20.5 %, and 9 % for serious injuries; and 66.4 %,

22.4 %, and 11.1 % for slight injuries respectively. Figure 4.6 shows the severity of crash based on the vehicle type.

4.2.1.9 Causes of crash

The causes of crash on the expressway reported from traffic police to ETRE was due to speeding, driver error (negligence, driving under influence), vehicle technical problem (brake problem, steering problem, tyre problem) have 34 %, 30 %, and 23 % for fatality; 34 %, 29 %, and 21 % for serious injuries and 22 %, 26 %, and 35 % for slight injury respectively. The result indicates that speeding, vehicles technical problem, drivers' error and others (the cause is not recorded) have higher contribution for higher crash severity on the expressway.

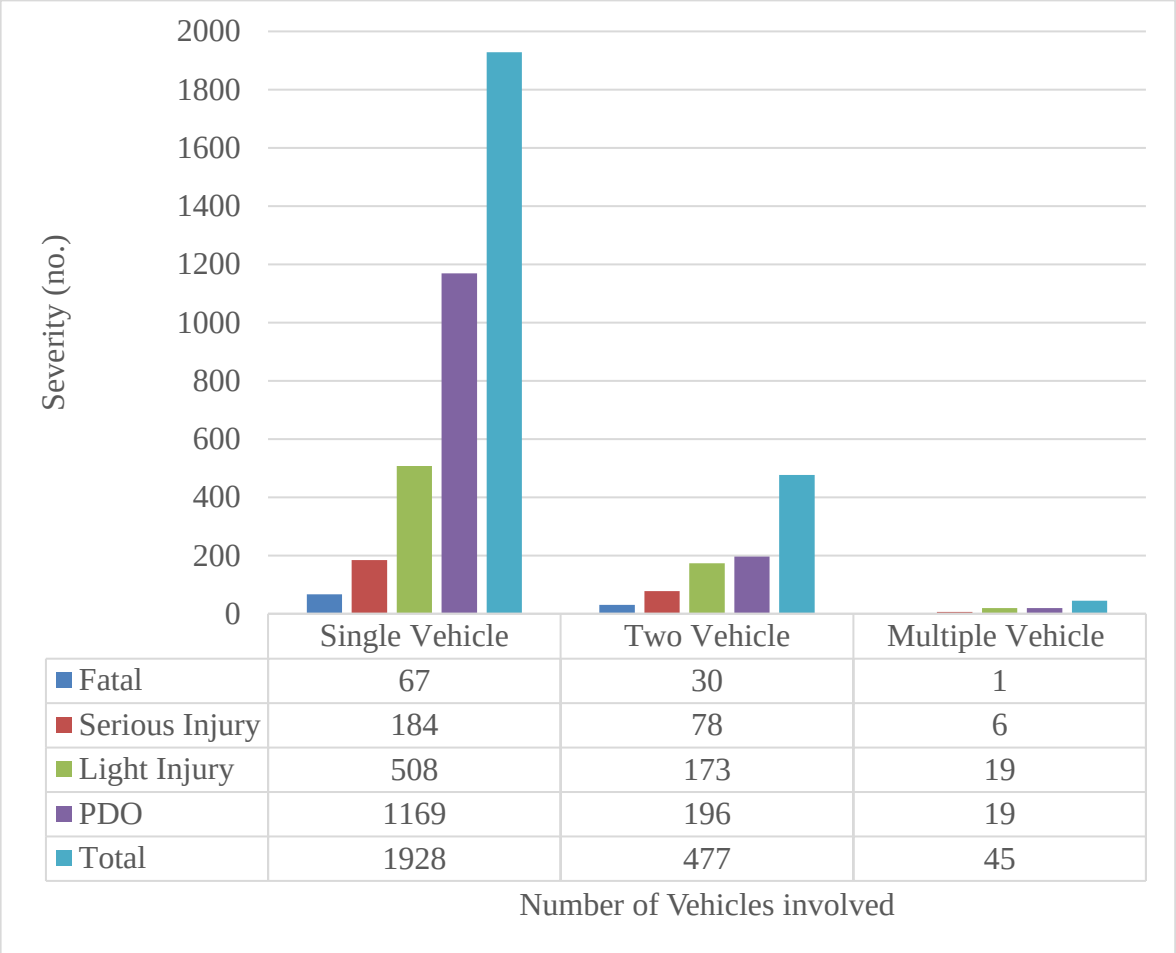


	Vehicle Technical Problem	Speeding	Drunken driving	Animal Intrusion	Sleep Deprive and Fatigue	Driver Error	Wet Surfacing	Others
Fatal	23	33	0	0	4	29	0	9
Serious Injury	55	91	0	0	11	79	0	32
Light Injury	248	154	1	0	40	184	0	73
PDO	468	195	1	6	56	392	2	264
Total	794	473	2	6	111	684	2	378

Figure 4.7: Severity of crashes based on causes of crash

4.2.1.10 Number of Vehicles Involved

Traffic crash with number of vehicles involved by single vehicles and two vehicles was 68 %, 31 % for fatality cases; 69 %, 29 % for serious injury cases; 73 %, 25 % for Slight injury cases; 84 %, 14 % for PDo respectively. Hence, the expressway freeway highway, crash is more dominant by single vehicles crash. The descriptive statistics result is presented in Appendix 6. Figure 4.8 shows the severity of crashes by number of vehicle.



	Single Vehicle	Two Vehicle	Multiple Vehicle
Fatal	67	30	1
Serious Injury	184	78	6
Light Injury	508	173	19
PDO	1169	196	19
Total	1928	477	45

Figure 4.8: Severity of crashes based on number of vehicles involved in crash

4.2.1.11 Vehicle travel direction

Traffic crash and severity is high travelling to Adama direction in all severity cases of fatal, serious injury and slight injuries. The descriptive statistics (Appendix 6) shows that 64.3 % of

fatality occurred in the Adama direction, whereas serious injury and slight injuries have similar percentages of severity which is about 53%. To Addis Ababa direction severity of crashes are 36 % , 47 % and 46 % cases for fatal injury, serious injury and slight injury respectively. The result shows the effect of the travel direction on the severity of traffic crash is higher towards Adama direction than to Addis Ababa direction. Figure 4.9 shows the severity of the traffic crash in Adama direction and Addis Ababa direction.

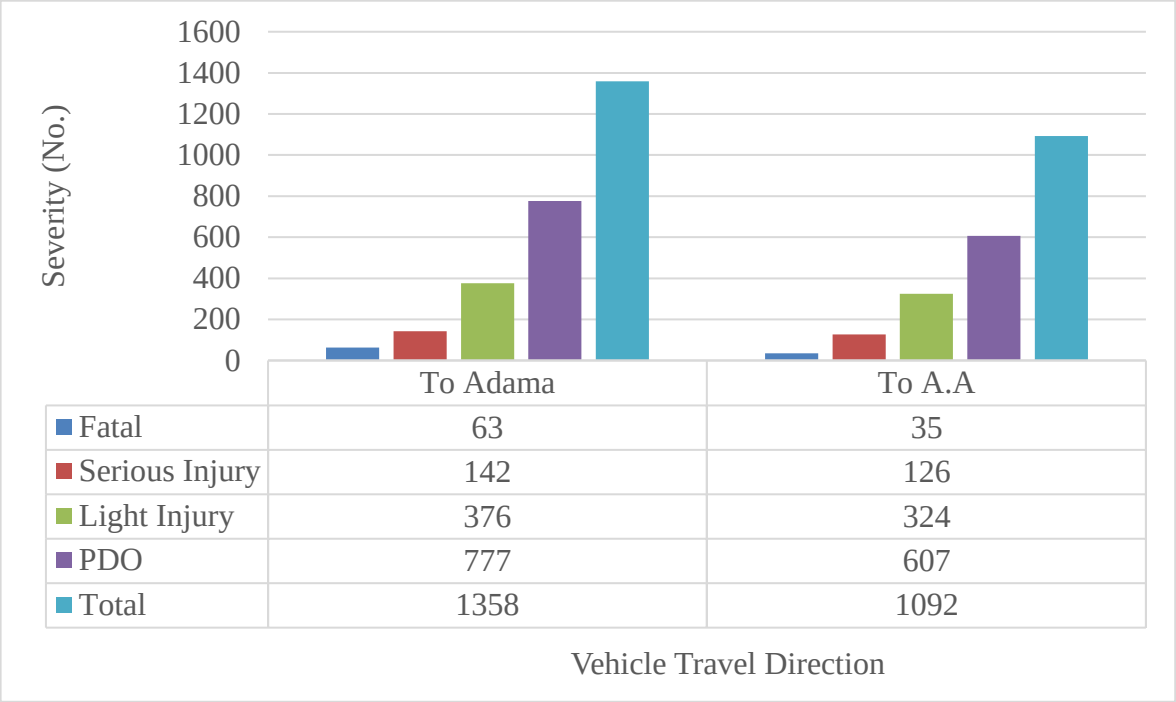


Figure 4.9: Severity of the traffic crash in to Adama direction and Addis- Ababa direction of the expressway

4.2.1.12 Accident occurrence time

Traffic crash occurrence time for day time, and night time has 79 %, 21 % cases for fatal injury; 84 %, 16 % cases for serious injury; 76%, 24% cases for slight injury; 69 %, 31 % cases for PDo respectively. The descriptive statistics result (Appendix 6) shows that the crash severity is high during day time. This is due to the high volume of traffic travelled during day time and over speeding of the drivers while driving in day time rather than driving night time.

Table 4.13 presents the severity of crash due to accident occurrence time, road surface condition, weather condition and light condition.

4.2.1.13 Road Surface condition

Traffic crash due to road surface condition on dry, wet has 76.5 %, 23.5 % cases for fatal crashes; 87.7 %, 12.3 % cases for serious injury; 89.6%, 10.4 % cases for slight injury; 82 %, 18 % cases for PDo respectively. From the total casualty, 84.6% of the crash occurred on dry surface condition. Table 4.13 presents the severity of crash due to road surface condition.

4.2.1.14 Weather condition

Traffic crash due to weather condition for normal (sunny), windy/cloudy/ rainy has 59.2 %, 35.7 % cases for fatal injury; 65.7 %, 32.5 % cases for serious injury; 66.1 %, 32.4 % cases for slight injury; 53.1 %, 44.6 % cases for PDo respectively. The result shows the crash frequency and severity is high in good weather condition. This may be the effect of over speeding and drivers error while driving in good weather condition rather than driving on bad weather condition. Table 4.13 presents the severity of crash due to weather condition.

4.2.1.15 Light Condition

Likewise, the accident occurrence time, traffic crash and severity is high during day time with natural sunlight condition. The effect of traffic crash and severity due to lighting condition for sun light, night with street light and without street light has 79 %, 21 % cases for fatal injury; 83 %, 17 % cases for serious injury; 75 %, 25 % cases for light injury; 68 %, 32 % cases for PDo respectively. Traffic crash due to occurrence time and lighting condition have nearly equal. Table 4.13 presents the severity of crash due to light condition.

Table 4-13: Results of descriptive statistics due to Accident occurrence time, road surface, weather and light condition

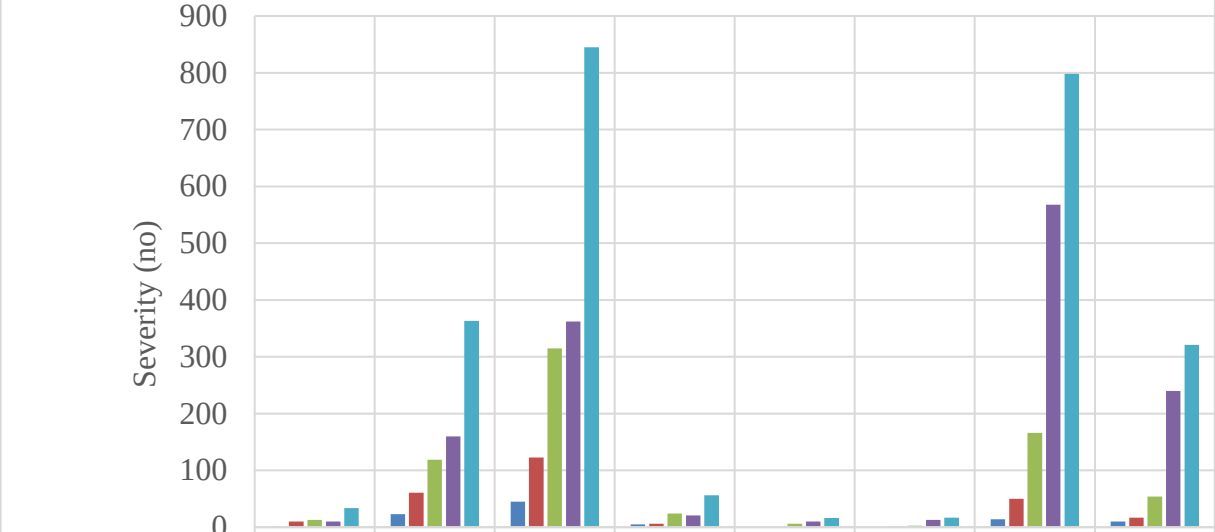
Variables	Severity							
	Fatal		Serious Injury		Light Injury		PDO	
Accident Occurrence Time	No.	%	No.	%	No.	%	No.	%
• Day time	77	78.6%	224	83.6%	532	76.0%	954	68.9%
• Night time	21	21.4%	44	16.4%	168	24.0%	430	31.1%
Road Surface Condition								
• Dry	75	76.5%	235	87.7%	627	89.6%	1135	82.0%
• Wet	23	23.5%	33	12.3%	73	10.4%	249	18.0%
Weather Condition								
• sunny, Normal	58	59.2%	176	65.7%	463	66.1%	735	53.1%
• Windy/Cloudy/Rainy	35	35.7%	87	32.5%	227	32.4%	631	45.6%
• Unidentified	5	5.1%	5	1.9%	10	1.4%	18	1.3%
Light Condition								
• Sun light	77	78.6%	222	82.8%	523	74.7%	939	67.8%
• Night with Street Light	1	1.0%	4	1.5%	19	2.7%	81	5.9%
• Night without Light	20	20.4%	42	15.7%	158	22.6%	364	26.3%

wet has 76.5 %, 23.5 % cases for fatal crashes; 87.7 %, 12.3 % cases for serious injury; 89.6%, 10.4 % cases for slight injury; 82 %, 18 % cases for PDo respectively. From the total casualty, 84.6% of the crash occurred on dry surface condition.

4.2.1.16 Types of crash

The major types of crash on the expressway were roll over, rear-end, crash with fixed objects, and other crashes (crash type not recorded). The severity of the crash due to roll over, rear-end , crash with fixed object and others constitutes 46 %, 23 %, 14 %, and 10 % for fatal injury; 46 %, 23 %, 19 %, and 6 % for serious injury; 45 %, 17 %, 24 %, and 41 % for slight injury; 26 %, 12 %, 24 %, and 17 % for PDo respectively. From the descriptive analysis result, the percentage of roll over crash is higher for all severity cases followed by rear-end crash and

crashes with fixed object. Figure 4.10 shows the graph of the severity based on types of crash on Addis Ababa- Adama expressway. The detailed descriptive analysis result is presented in Appendix 6.



Types of Crash	Head On	Rear-End	Roll over	Side swipes	Side Impact	Runoff	Crush (Fixed objects)	Others
Fatal	1	23	45	5	0	0	14	10
Serious Injury	10	61	123	6	0	1	50	17
Light Injury	13	119	315	24	6	3	166	54
PDO	10	160	362	21	10	13	568	240
Total	34	363	845	56	16	17	798	321

Figure 4.10:- Crash severity of Addis Ababa- Adama Expressway based on types of crash

4.2.1.17 Driver gender

From the total causality, 96.1% occurred by male drivers and only 1.8% occurred by female drivers, the remaining 2.1% is unidentified gender. The result is due to number of male drivers is higher than female drivers as per recorded accidents data from ETRE. In addition, by nature males are more careless than females which leads driver's negligence.

4.2.1.18 Age of driver

From the total causality, 43.1% of the crash severity occurred by drivers with age group of 31-50 yrs. The result also shows these age group has high contribution in all of the severity of

crash. Next to age groups 31-50yrs, age group from 18-30yrs. contributes for 39.9% of crash severity whereas age group above 51yrs has a contribution of only 4.8%.

Table 4-14: Results of descriptive statistics on drivers gender and age

Variables	Severity						PDO	
	Fatal		Serious Injury		Light Injury			
Gender of the driver	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	%
• Male	92	93.9%	247	92.2%	676	96.6%	1339	96.7%
• Female	1	1.0%	9	3.4%	14	2.0%	21	1.5%
• Un identified	5	5.1%	12	4.5%	10	1.4%	24	1.7%
Age of the driver								
• 18-30	31	31.6%	80	29.9%	279	39.9%	587	42.4%
• 31-50	33	33.7%	106	39.6%	285	40.7%	632	45.7%
• >51	1	1.0%	12	4.5%	41	5.9%	64	4.6%
• Un identified	33	33.7%	70	26.1%	95	13.6%	101	7.3%

4.2.2 Statistical analysis of accident severity by regression model

Besides the descriptive statistics analysis, empirical statistical analysis has been done by STATA software to check whether these independent variables are significant influencing factors on the crash severity or not. The dependent variables in this study are accident severity levels of crashes categorized into four groups; namely fatal, serious injury, slight injury and property damage only (PDo).

Likewise the descriptive statistics, the empirical statistics analysis of logistics regression was consider a total of eighteen main variables, which are derived from the three main traffic accident factors namely; human factors, vehicles factors and road environment factors. These variables have influencing factor on the traffic crash severity. Each influencing variables has two or more sub variables and consequently the effect of sixty two sub variables on fatality, serious injuries and slight injuries are considered in the analysis.

Before the statistical analysis carried, the sixty-two independent variables are checked for correlation test if there are multicollinearity among the independent variables. The correlation test result showed that some of the independent variables such as main line, Normal crown (NC), Vertical grade >5 %, upgrade direction, weekends, large vehicle, night time, others, multiple vehicle, To Addis Ababa direction (AA), wet surface condition, unidentified, night without light, others are collinear with other independent variables. Therefore, from the sixty two independent variables, twenty-five variables are excluded from further consideration due to multicollinearity.

Three statistical analysis models namely; Ordered logistics regression model, Ordered Probit regression model and multinomial logistic regression (MNL) model were selected for comparison and selection of goodness of fit of the model. To select best model, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) for each model are compared and the model with the smallest AIC and minimum BIC value of is selected for statistical analysis. Table 4.15 shows the comparison of the AIC and BIC for the three models.

Table 4-15: Results of Akaike's information criterion (AIC) and Bayesian information criterion (BIC)

Model	Obs	ll(null)	ll(model)	df	AIC	BIC
Ordered logit	**2450**	**-2575.846**	**-2292.822**	**41**	**4667.643**	**4905.601**
Multinomial Logit	2450	-2575.846	-2229.805	117	4693.609	5372.659
Ordered probit regression	2450	-2575.846	-2300.173	41	4682.346	4920.303

Note: N = Obs used in calculating BIC

The AIC and BIC result of each statistical model shows that the ordered logistic regression model has smaller AIC and minimum BIC when compared with the ordered probilt regression model and multinomial logistic regression model. Therefore, ordered logistic regression model is selected for this study.

Accordingly, the remaining thirty seven independent variables are analyzed by the Ordered logistic regression model. The result of the regression analysis is shown in the table 4.16.

Table 4-16: Analysis results of ordered logistics regression model

Iteration 0:00	Log likelihood	=	-2575.8459
Iteration 1:00	Log likelihood	=	-2304.022
Iteration 2:00	Log likelihood	=	-2293.0841
Iteration 3:00	Log likelihood	=	-2292.99
Iteration 4:00	Log likelihood	=	-2292.99

Ordered logistic regression		Number of obs	= 2450
		LR chi2(37)	= 565.71
		Prob > chi2	= 0.0000
Log likelihood = -2292.99		Pseudo R2	= 0.1098

Severity	Coef.	Std. Err	z	P>z	[95% Conf. Interval]	
Toll Plaza	0.138717	0.1533427	0.90	0.366	-0.1618293	0.4392632
Radius 61m-120m	2.344952	0.5741622	4.08	0.000	1.219614	3.470289
Radius 251m-900m	1.082043	0.3427764	3.16	0.002	0.410214	1.753873
Radius 901m-1500m	0.3508289	0.2588694	1.36	0.175	-0.1565458	0.8582035
Radius 1501m-2600m	0.3412562	0.2208524	1.55	0.122	-0.0916065	0.774119
Radius 2601m-6000m	0.0059316	0.1109114	0.05	0.957	-0.2114506	0.2233139
Normal crown	0.338076	0.2207132	1.53	0.126	-0.0945139	0.7706659
Gradelessthan3	0.1577226	0.2697485	0.58	0.559	-0.3709748	0.68642
Gradebetween3and5	0.1127095	0.2732326	0.41	0.680	-0.4228165	0.6482355
Grade Level (0)	0.5813192	0.2711592	2.14	0.032	0.0498569	1.112782
Downgrade	0.2603127	0.0941533	2.76	0.006	0.0757757	0.4448498
Weekdays	0.246898	0.0905675	2.73	0.006	0.069389	0.4244071
Light vehicles	-1.17992	0.135253	-8.72	0.000	-1.445011	-0.9148294
Medium Vehicle	-0.8638124	0.1485325	-5.82	0.000	-1.154931	-0.572694
Daytime	-0.0754804	0.4114473	-0.18	0.854	-0.8819024	0.7309416
Vehicle Technical Problem	-0.4230269	0.1471723	-2.87	0.004	-0.7114793	-0.1345746
Speeding	-0.9407149	0.1533839	-6.13	0.000	-1.241342	-0.640088
Sleep Deprivation	-1.135238	0.2323477	-4.89	0.000	-1.590631	-0.6798444
Driver Error	-0.4615813	0.1468199	-3.14	0.002	-0.749343	-0.1738196
Single Vehicle	0.2353044	0.3454426	0.68	0.496	-0.4417507	0.9123595
Two Vehicle	-0.4214686	0.3228878	-1.31	0.192	-1.054317	0.2113799
To Adama	0.069058	0.0919326	0.75	0.453	-0.1111265	0.2492425
Dry surface	-0.135307	0.1514433	-0.89	0.372	-0.4321304	0.1615165
Sunny Normal	-0.1701892	0.1149951	-1.48	0.139	-0.3955755	0.0551971

Severity	Coef.	Std. Err	z	P>z	[95% Conf. Interval]	
Sunlight	-0.1268256	0.408629	-0.31	0.756	-0.9277236	0.6740725
Night with Street Light	0.4814494	0.2657356	1.81	0.070	-0.0393828	1.002282
Head On	-1.272364	0.3884404	-3.28	0.001	-2.033693	-0.5110351
Rear End	-0.8527879	0.2230407	-3.82	0.000	-1.28994	-0.4156362
Rollover	-1.12777	0.1555587	-7.25	0.000	-1.43266	-0.8228808
Sideswipes	-0.8331641	0.336657	-2.47	0.013	-1.493	-0.1733285
Side Impact	-0.2547672	0.5561862	-0.46	0.647	-1.344872	0.8353378
Runoff	-0.1389601	0.6362072	-0.22	0.827	-1.385903	1.107983
Crush With Fixed object	-0.1097768	0.1624341	-0.68	0.499	-0.4281418	0.2085883
Female	-0.3153705	0.4206535	-0.75	0.453	-1.139836	0.5090953
Male	-0.1685065	0.2988972	-0.56	0.573	-0.7543342	0.4173213
Agebetween18yrsto30yrs	0.9122914	0.1238267	7.37	0.000	0.6695956	1.154987
Agebetwn31yrsto50yrs	0.9345234	0.1231212	7.59	0.000	0.6932102	1.175837
/cut1	-4.35557	0.5607268			-5.4546	-3.257
/cut2	-2.811522	0.5541756			-3.8977	-1.725
/cut3	-1.053366	0.551978			-2.1352	0.028

The result of the statistical analysis using ordered logistics model shows that, among the thirty seven independent variables, seventeen independent variables are statistically significant. These independent variables have significance influence on accident severity with p-value of <0.05 with 95 % Confidence Interval (CI-95%). The independent variables which have significant influencing factors on the accident severity are;

- From the radius of horizontal curve, radius of horizontal curve in the range from 61m - 120m, and from 251m - 900 m are statistically significant with a p-value of 0.000 and 0.002 respectively. These radius ranges have significant influences on the crash severity of crashes.
- From road gradient direction, level grade (0%) and down grade are statistically significant with p-value of 0.032 and 0.006 respectively. The level grade and down slope grades have significant influence on the severity of crash on the expressway.
- From day of the week, weekdays is statistically significant with p-value of 0.006.

- From accident-involved vehicle type: light vehicles and medium vehicles are highly significant influence on the crash severity with p-value of 0.000 for both vehicle types.
- Among the eight variables on the causes of crash, four of the cause of crash are statistically significant with p-value < 0.05. These are vehicle technical problem, speeding, sleep deprivation and driver error which have significant influence on the severity of traffic crash with p-value of 0.004, 0.00 , 0.00 and 0.002 respectively.
- From type of crash; head on collision, rear-end collision, rollover and sideswipes collision are high significant influence on the crash severity with p-value of 0.001, 0.00, 0.00 and 0.013 respectively.
- Driver age 18-30 (yrs.) and 31-50 yrs. are significant influencing factor on the severity of crash on the expressway with p-value of 0.000.

4.2.3 Computation of operation speed and 85th percentile speed

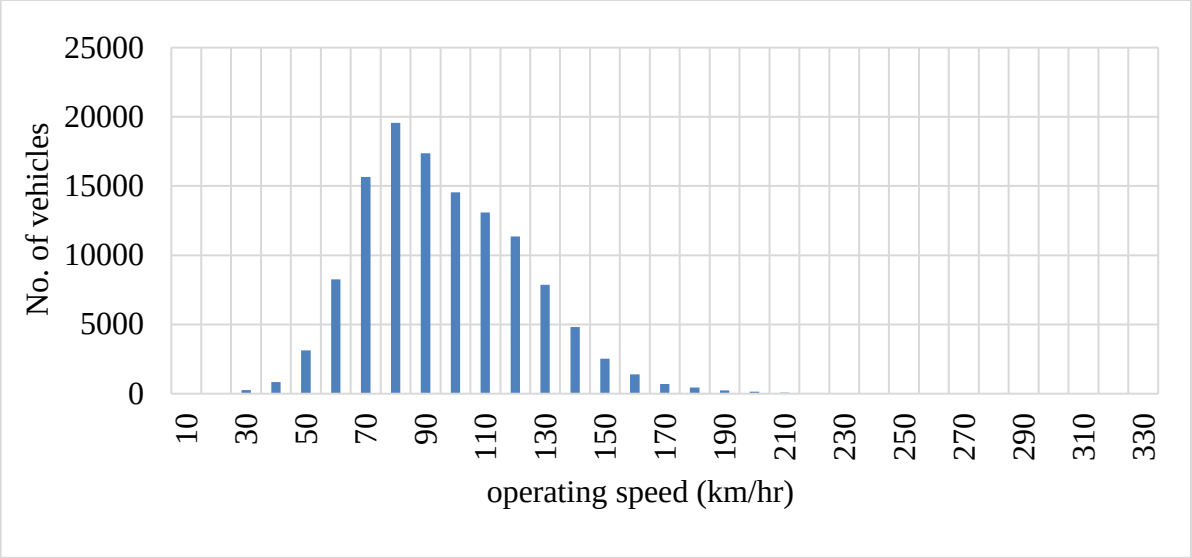
The speed of vehicles has a significant role in the roadway safety. The risk of being involved in a crash, as well as the severity of the outcome, could be affected by the speed of the moving vehicle. The 85th percentile speed is a standard to set the speed limit at a safe speed, minimizing crashes and promoting uniform traffic flow along a corridor.

To identify the number of vehicles exceeding the speed limit of the expressway, the 85th percentile speed of the vehicles is computed for the three types of vehicles travelling on the expressway from the traffic flow database taken from ETRE. The analysis is carried out on a sample of traffic flow data taken from January 1, 2021 to January 7, 2021 (7 days), amounting 199,314 number of vehicles is considered for 85th percentile speed analysis.

The result of the analysis for light vehicles, medium vehicles and large vehicles are presented as follows.

Table 4-17: 85th percentile speed computation for light vehicles

No.	Computed speed (km/hr)			No. of vehicles	% of vehicle	Cumulative (%)
	Min.	Max.	Label			
1	0	10.00	10	0.00	0.000	0.00
2	10.00	20.00	20	0.00	0.000	0.00
3	20.00	30.00	30	264.00	0.216	0.22
4	30.00	40.00	40	848.00	0.693	0.91
5	40.00	50.00	50	3120.00	2.549	3.46
6	50.00	60.00	60	8261.00	6.748	10.21
7	60.00	70.00	70	15657.00	12.790	22.99
8	70.00	80.00	80	19560.00	15.978	38.97
9	80.00	90.00	90	17368.00	14.187	53.16
10	90.00	100.00	100	14556.00	11.890	65.05
11	100.00	110.00	110	13090.00	10.693	75.74
12	**110.00**	**120.30**	**120**	**11352.00**	**9.273**	**85.02**
13	120.30	130.00	130	7860.00	6.421	91.44
14	130.00	140.00	140	4811.00	3.930	95.37
15	140.00	150.00	150	2519.00	2.058	97.42
16	150.00	160.00	160	1399.00	1.143	98.57
17	160.00	170.00	170	707.00	0.578	99.14
18	170.00	180.00	180	447.00	0.365	99.51
19	180.00	190.00	190	234.00	0.191	99.70
20	190.00	200.00	200	156.00	0.127	99.83
21	200.00	210.00	210	78.00	0.064	99.89
22	210.00	220.00	220	49.00	0.040	99.93
23	220.00	230.00	230	32.00	0.026	99.96
24	230.00	240.00	240	16.00	0.013	99.97
25	240.00	250.00	250	10.00	0.008	99.98
26	250.00	260.00	260	8.00	0.007	99.99
27	260.00	270.00	270	4.00	0.003	99.99
28	270.00	280.00	280	2.00	0.002	99.99
29	280.00	290.00	290	7.00	0.006	100.00
30	290.00	300.00	300	2.00	0.002	100.00
31	300.00	310.00	310	2.00	0.002	100.00
32	310.00	320.00	320	1.00	0.001	100.00
33	320.00	330.00	330	0.00	0.000	100.00
Total sampled no. of vehicles				122,420.00		



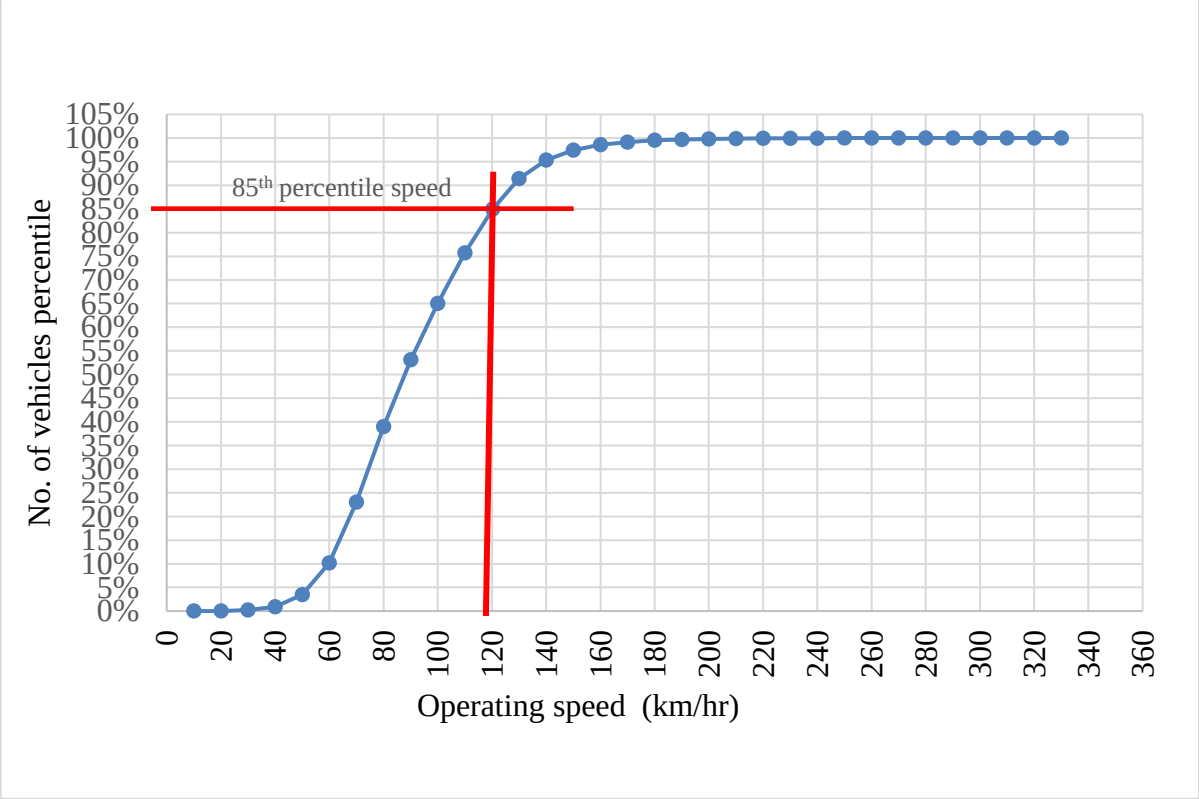
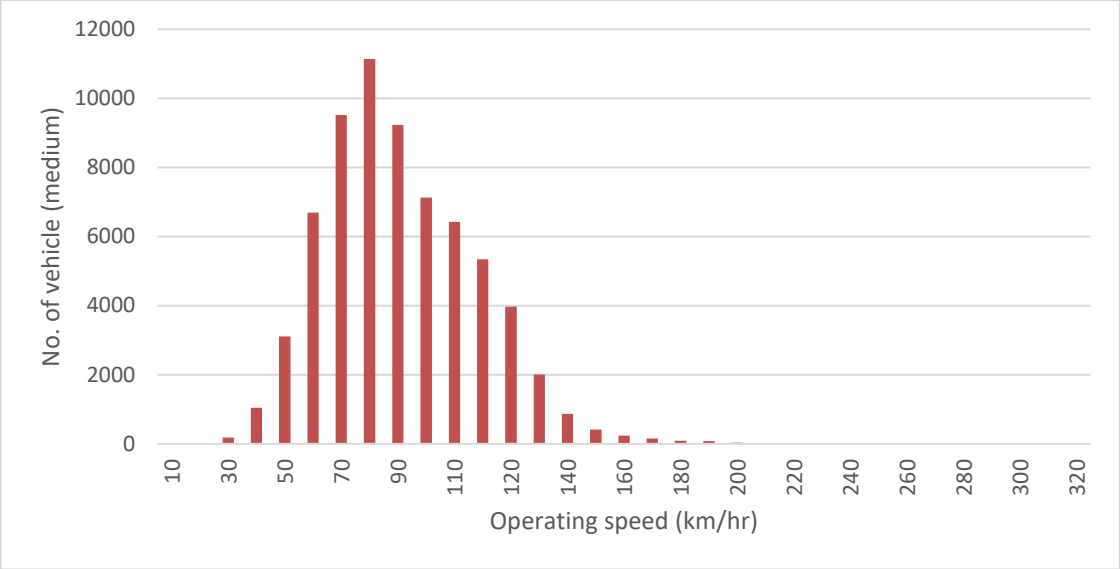


Figure 4.11: 85th percentile speed for Light Vehicles

Table 4-18: 85th percentile speed computation for Medium Vehicles

No.	Computed speed (km/hr)			No of vehicles	% of vehicle	Cumulative (%)
	Min.	Max.	Label			
1	0	10	10	0.00	0.000	0.00
2	10	20	20	0.00	0.000	0.00
3	20	30	30	178.00	0.263	0.26
4	30	40	40	1040.00	1.535	1.80
5	40	50	50	3108.00	4.588	6.39
6	50	60	60	6693.00	9.880	16.27
7	60	70	70	9519.00	14.052	30.32
8	70	80	80	11141.00	16.447	46.77
9	80	90	90	9236.00	13.634	60.40
10	90	100	100	7128.00	10.523	70.92
11	100	110	110	6428.00	9.489	80.41
12	110	116	116	3108.00	4.588	85.00
13	116	120	120	2232.00	3.295	88.29
14	120	130	130	3973.00	5.865	94.16
15	130	140	140	2006.00	2.961	97.12
16	140	150	150	868.00	1.281	98.40
17	150	160	160	416.00	0.614	99.02
18	160	170	170	236.00	0.348	99.37
19	170	180	180	150.00	0.221	99.59
20	180	190	190	91.00	0.134	99.72
21	190	200	200	81.00	0.120	99.84
22	200	210	210	37.00	0.055	99.90
23	210	220	220	27.00	0.040	99.94
24	220	230	230	18.00	0.027	99.96
25	230	240	240	11.00	0.016	99.98
26	240	250	250	9.00	0.013	99.99
27	250	260	260	2.00	0.003	99.99
28	260	270	270	1.00	0.001	100.00
29	270	280	280	0.00	0.000	100.00
30	280	290	290	0.00	0.000	100.00
31	290	300	300	0.00	0.000	100.00
32	300	310	310	2.00	0.003	100.00
33	310	320	320	1.00	0.001	100.00
	Total sampled vehicle			67740.00		



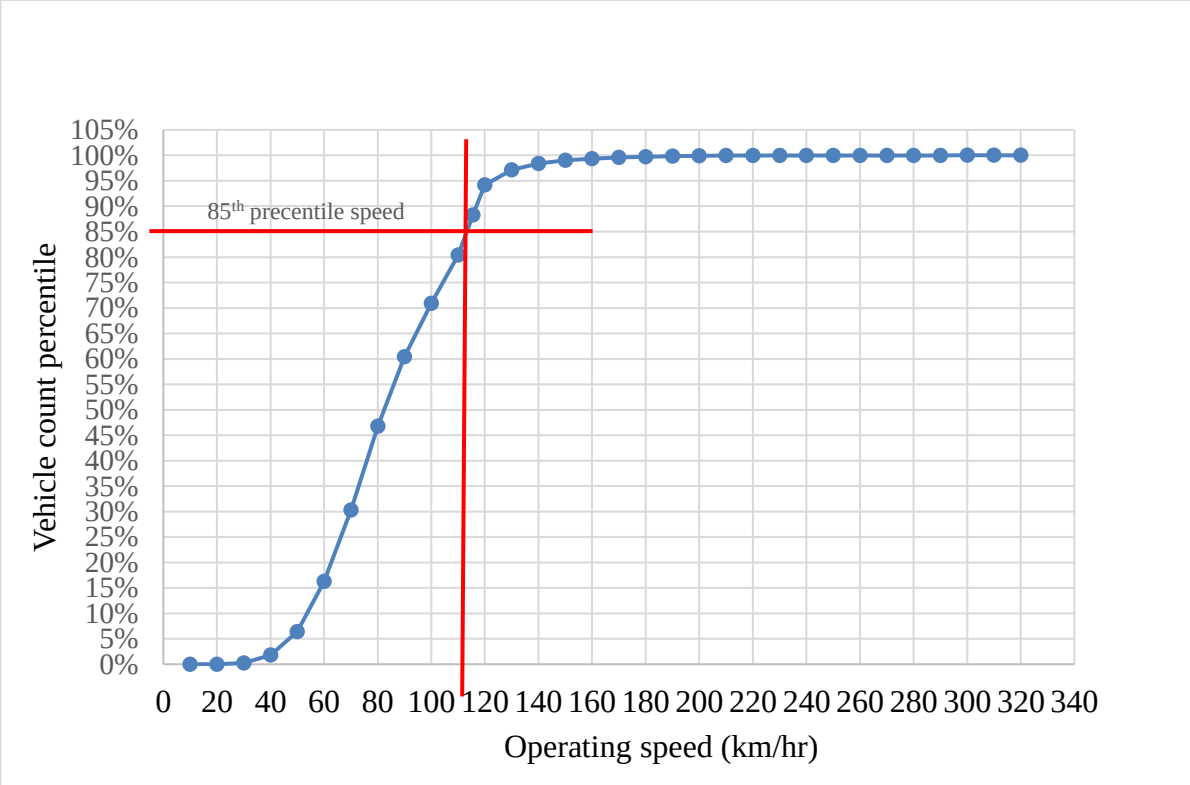
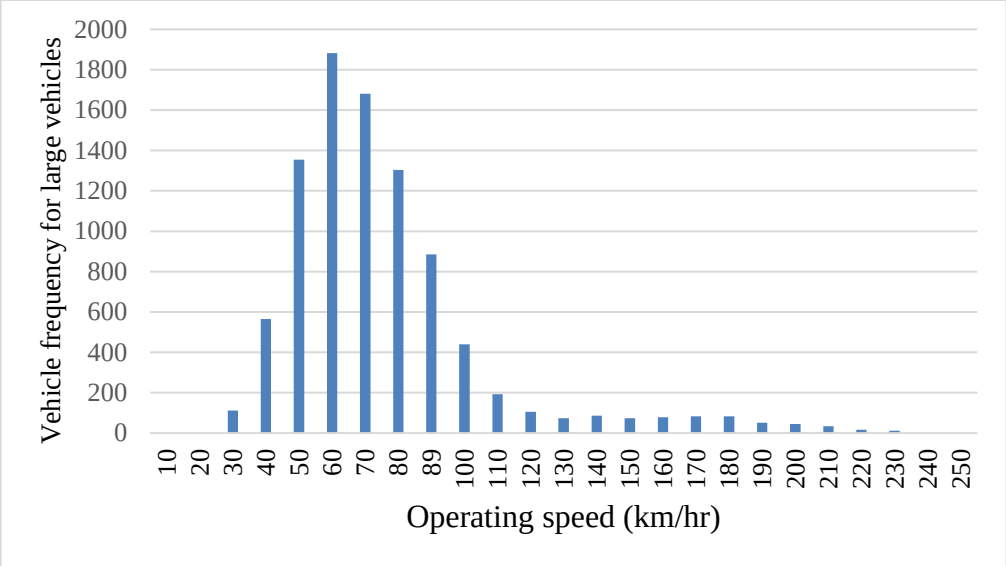


Figure 4.12: 85th percentile speed for Medium Vehicles

Table 4-19: 85th percentile speed computation for Large Vehicles

No.	Speed (km/hr.)			Frequency No. of vehicle	% of vehicle	Cumulative (%)
	Min.	Max.	Label			
1	0	10	10	0	0.00	0.00
2	10	20	20	0	0.00	0.00
3	20	30	30	111	1.21	1.21
4	30	40	40	565	6.17	7.38
5	40	50	50	1354	14.79	22.17
6	50	60	60	1882	20.56	42.73
7	60	70	70	1681	18.36	61.09
8	70	80	80	1303	14.23	75.32
9	80	89	89	885	9.67	84.99
10	89	100	100	439	4.80	89.79
11	100	110	110	193	2.11	91.90
12	110	120	120	106	1.16	93.05
13	120	130	130	74	0.81	93.86
14	130	140	140	86	0.94	94.80
15	140	150	150	74	0.81	95.61
16	150	160	160	78	0.85	96.46
17	160	170	170	83	0.91	97.37
18	170	180	180	79	0.86	98.23
19	180	190	190	55	0.60	98.83
20	190	200	200	45	0.49	99.32
21	200	210	210	34	0.37	99.69
22	210	220	220	17	0.19	99.88
23	220	230	230	11	0.12	100.00
24	230	240	240	0	0.00	100.00
25	240	250	250	0	0.00	100.00
Total number of sampled vehicles				9155	100.00	



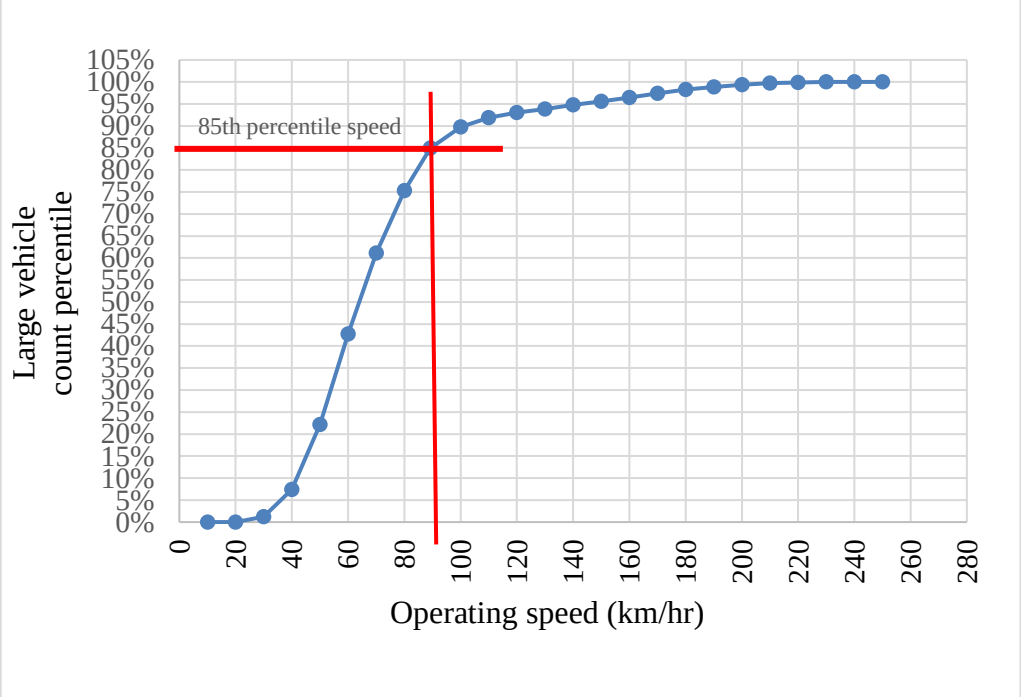


Figure 4.13: 85th percentile speed for Large Vehicles

The analysis results show that the 85th percentile speeds of light, medium and large vehicles on the expressway are 120 km/hr., 115 km/hr. and 89 km/hr. respectively and these speeds are safe speed limit.

From the total sample 122420 (61.4 %) are light vehicle consisting of small automobiles, pickup and mini buses, 67739 (33 %) are medium vehicles consists of medium buses, Isuzu and medium trucks 9155 (4.5 %) are large vehicles consisting of heavy trucks & trailers.

The 85th percentile speed analysis shows 104071 (85 %) of light vehicles travelled at and below 120 km/hr., 57587 (85 %) of medium vehicles that are travelling at and below 115 km/hr. and 7787 (85 %) of large vehicles travelled at 89 km/hr. which are safe speed on the expressway.

The 85th percentile analysis of speed also shows that 18349 (15 %) of light vehicles travelled above 120 km/hr., 10161 (15 %) of medium vehicles travelled 115 km/hr and 1373 (15 %) of large vehicles travelled above 89 km/hr.

Table 4-20: No. of vehicle exceed 85th percentile speed (within seven days)

No.	Vehicle Type	No. of sampled vehicle	Computed 85th percentile speed (km/hr.)	No. of vehicles (exceed 85th percentile speed)	% of Vehicle exceed 85th percentile speed
1	Light vehicle	122,420.00	120	18,349.00	14.99
2	Medium vehicle	67,740.00	115	10,161.00	15.00
3	Large vehicle	9,155.00	89	1,373.00	15.00
Total		199,315.00		29,883.00	

Average daily number of vehicles that are travelling at, below and above the 85th percentile speed is computed from seven days samples of vehicles by dividing the total week samples by seven.

Table 4-21: No. of vehicle exceed 85th percentile speed (daily average)

No.	Vehicle type	No. of sampled vehicle	Computed 85th percentile speed (km/hr.)	No. of vehicles (exceed 85th percentile speed)	% of vehicle exceed 85th percentile speed
1	Light vehicle	17,489	120	2,621	14.99
2	Medium vehicle	9,677	115	1,452	15.00
3	Large vehicle	1,308	89	196	15.00
		28,474		4,269	

According to the computation, on the average a total of 28474 (85 %) of all types of vehicles travelled at and below their respective 85th percentile speed per day whereas a total of 4269 (15 %) of vehicles of all types travelled above their respective 85th percentile speed.

Vehicle travelling speed is the core of traffic safety and they have inverse relationship each other. As the speeding increases the traffic safety becomes in questions. Speeding is not only increase traffic accident but also increases accident severity.

According to the reports (WHO, 2018), the majority of accident in the world is directly or indirectly linked to speed. As per the report, speed is the essential contributor factor for 30% fatal accident. (National Highway Traffic Safety Administration, 2002) also reports that 32% of all fatal crashes were related to speeding, that is, exceeding the posted speed limit or traveling too fast for the existing condition.

World Health Organization (WHO, 2021) also reports on News Alert, excessive speed is the core of the road traffic injury problem, with 1 in 3 deaths on the roads in high-income countries attributed to speed. It is estimated that 40-50% of people drive above the speed limit, with every 1 km/h increase in speed resulting in a 4-5% increase in fatal crashes. The risk of death and injury reduces considerably when speeds are lowered.

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The objective of the study is to explore the causes of traffic crash and severity on Addis Ababa – Adama expressway. For the study, the last five years traffic flow and traffic crash data taken (i.e. from July 8/2016 to July 7, 2021) to investigate the major contribution on the cause of crash and severity. During the last five years of the study period, on the average, one traffic accident occurred on the expressway every day. Not only frequency of traffic accident on the expressway is highest but also severity of accidents is also highest in the last five years.

All potential factors that may have contribution to the highest severity of traffic accidents on the expressway are analyzed through descriptive statistics and empirical statistics analysis by ordered logistic regression model. Moreover, operating speed of vehicles on the expressway are computed to evaluate the 85^{th} percentile speed of each type of vehicle category to compare with the posted speed limit.

According to the analysis of traffic flow in terms of AADT and crash frequency on the five segments of the expressway, driving on the expressway to Adama direction has greater contribution to fatality, serious injury and light injury than driving on the expressway in to Addis Ababa direction. Which could be explained by higher volumes of traffic per day, higher number of accidents and downslope grades of the expressway in to Adama direction.

Both, the descriptive statistics and empirical statistics analysis consistently revealed that among the three main traffic safety factors; namely human factors, vehicle factors and road/environment factors, the vehicle factors and human factors have major contribution to the highest severity of traffic accidents on the Addis Ababa – Adama Expressway.

The road/ environment factors is not the major cause of the traffic crash and severity, since majority of the traffic crash and high severity is occurred in better road way/environment condition having good horizontal and vertical geometry, in the main line of the expressway, during day time having natural sun light, on dry surface, and good/ normal weather condition.

The human factors and vehicle factors which are the major contribution to traffic crash and high severity are

- Crashes due to drivers error, over speeding, sleep deprivation and fatigue have high contribution to traffic crash and severity. The analysis of speed of the vehicles result shows that, on average daily 4,269 number of vehicles exceeded the posted speed limit. Over speeding reduces a driver's ability to steer safely around curves or objects in the roadway, extends the distance necessary to stop a vehicle, and increases the distance a vehicle travels while a driver reacts to a dangerous situation. The speed analysis results shows that, light vehicle drivers are the major violators of speed limit followed by driver of medium and large vehicles.
- According to the analysis, the vehicle factors which consists of vehicles technical problems, (like brake failure, steering problem, suspension problems and tire blowouts) have significant contribution to the highest severity of traffic accidents. Among the three types of vehicles category operating on the expressway, light vehicles (Automobile, Pickup 4W Drives and Minibus) and medium vehicles (Isuzu, Mid bus and Medium Bus) have major contribution to highest severity. Traffic crash with single number of vehicle have highest contribution to severity in the crash.
- Roll over crash, Rear - end crash and crash with fixed objects also have the major cause of high severity of crashes. These also related to over speeding, driver error and vehicle technical problems.
- Contribution male drivers (96.1%) to the occurrence of traffic crash and severity (fatality, serious injury and slight injury) is the highest as there are much more male drivers on the expressway who are travelling for work, businesses, leisure, administrative matters. This shows that male drivers are more likely to involve in risky driving behaviors than their female counterparts.
- Drivers in the age group between 18-50yr. have major contribution to fatality, serious injury and slight injury.
- The other variables that have major contribution to fatality, serious injury and slight injury are identified as, down slope grade, driving on weekdays, day time and dry surface.

5.2 Recommendations

Based on the detailed exploration on the causes of traffic crash and severity, contribution of the human factors and vehicle factors are the highest. On the basis of these findings, the following recommendations are proposed .

- Overspending is the major causes of traffic crash and severity on Addis Ababa -Adama expressway. The study result reveal significant number of crashes occurred in the main line of the expressway. To curb this problem, Ethiopian Toll Road Enterprise (ETRA) shall install speed monitoring radar on selected location on the mainline of the expressway. Besides these, the enterprise shall implement speed control mechanism at the toll plazas exit point to check whether the driver is obeying the speed limit of the expressway or not. For driver who violets the speed limit, traffic punishment shall be implemented.
- The other major causes of traffic crash is vehicles technical problem. Awareness shall be given to drivers to carryout regular inspection on their vehicles if there are any vehicle technical problem with the steering, suspension or transmission, tyre condition. Because these technical problems can cause a loss of control over the vehicle specially while driving on freeway speed and causes sever crashes.
- The study result reveals that the traffic volume on the expressway is increasing from year to year. It is natural to expect traffic crash to increase when the volume of traffic travelling at free flow speed increases on the expressway. Therefore, it is essential to check the speed limit and revise the free flow speed limit on the expressway as the volume of traffic increase by significant number over time.
- Regarding the quality of crash data, Ethiopian Toll Roads Enterprise (ETRE) shall record all the necessary data on the data sheet format to provide full information of crash data.
- Moreover, the data on severity of traffic crash (i.e. data on fatal, serious injury and slight injury) shall be updated by creating link among the stakeholders (i.e. the traffic police, hospitals and the safety section of Ethiopian Toll Road Enterprise (ETRE)) by giving follow up on the condition of the victims during hospitalization. These gives realistic record on the severity of traffic crash occurred on the expressway.

5.3 Future Study

Construction of expressway is a recent development in Ethiopia. After the construction of Addis Ababa - Adama expressway was completed and opened to traffic in 2014/15, the government has constructing the second expressway from Modjo to Hawassa and the third expressway from Adama to Awash which is an extension of existing Addis Ababa – Adama expressway. Government plans to construct other expressways in the 10years National Development Plan, expressway being new to our country we know little about their impact on traffic safety, development of industries and businesses, values of properties, growth of towns etc.

Research on impact of expressways on traffic safety needs to be given attention as this impact could be seen in few years while other impacts needs more years to be seen in full magnitude. We do not know the impact of expressway on traffic safety compared with conventional highways.

So, I suggest research on the impact of expressways on traffic safety to be conducted in order to determine if traffic accidents and severity on expressways increased or decreased compared with adjacent conventional highway.

The outcome of this suggested research is useful to make decision regarding development and use of expressways.

REFERENCES

Abebe, M.T. (2019). Quantifying the Influence of Road Geometric Parameters on Road Safety (Case Study: Hawassa-Shashemene-Bulbula Rural Two-Lane Highway, Ethiopia). Journal of Transportation Technologies, 9, pp. 354-380.

Abegaz, T., and Gebremedhin, S., (2018). Magnitude of Road Traffic Accident Related Injuries and Fatalities in Ethiopia. PLoS ONE 14(1): DOI: 10.1101/382333, p.e0202240.

Abegaz T, Berhane Y, Worku A, Assrat A, Assefa A., (2014). Road Traffic Deaths and Injuries Are Under-Reported in Ethiopia: A Capture-Recapture Method. PLoS ONE 9(7): e103001. doi:10.1371/journal.pone.0103001.

Al-Omari.et.al., B., 2013. Effect of Driver & Vehicle Characteristics on Speeds at a Tangent Section of a Rural Highway in Jordan. IEEE . Jordan University of Science & Technology Irbid, Jordan e-mail: bahomari@just.edu.jo.

American Association of Highway and Transportation Officials, (2011). A Policy on Geometric Design of Highways and Streets. AASHTO, Washington, DC.

American Association of Highway and Transportation Officials, (2010). Highway Safety Manual, Part D, AASHTO, Washington, DC, USA, 19192.

Aram, A., (2010). Effective Safety Factors on Horizontal Curves of Two-lane Highways. Journal of Applied Sciences, 10(22), pp.2814-2822.

Beshah, T. and Hill, S., (2010). Mining Road Traffic Accident Data to Improve Safety: Role of Road-related Factors on Accident Severity in Ethiopia. AAAI Spring Symposium Series.

Deme, D., Bari M., (2018). Traffic Accident Causes and Its Countermeasures on Addis Ababa-Adama Expressway. Journal of Equity in Sciences and sustainable Development (JESSD), 2(2), pp.13-23.

Deme, D., (2019). Road Traffic Accident in Ethiopia from 2007/08-2017/18 (Since Ethiopian Millennium). Journal of Architecture and Construction, 2(2), pp.20-29.

Eckersley, W., Salmon, R. and Gebru, M., (2010). Khat, Driver Impairment and Road Traffic Injuries: a view from Ethiopia. Bulletin of the World Health Organization, 88, pp. 235-236.

Glennon, J.C., (1987). Effect of Alignment on Highway Safety. State of the Art Report, 6, pp.48-63.

Goswami, A. and Sonowal, R., (2009). A Statistical Analysis of Road Traffic Accidents in Dibrugarh City, Assam, India. Division of Epidemiology and Nutrition, Regional Medical Research Centre, Dibrugarh, Assam, India.

Haddon, W. (1972). A Logistic Framework for Categorizing Highway Safety Phenomena and Activity. The Journal of Trauma, Vol. 12, Lippincon Williams and Wilkins, Washington, DC, pp. 193-207.

Hauer, E., (2004). Statistical Road Safety Modeling. Transportation Research Record, 1897(1), pp.81-87.

Hedman, K., (1990). Road Design and Safety. Proceedings of Strategic Highway Research Program and Traffic Safety on Two Continents, Gothenburg, Sweden, 2-29 September, 1989 (No. 351A).

Hosseinpour, M., Yahaya, A.S. and Sadullah, A.F., (2014). Exploring the Effects of Roadway Characteristics on the Frequency and Severity of Head-on Crashes: Case Studies from Malaysian Federal Roads. Accident Analysis & Prevention, 62, pp.209-222.

Islam, M.H., Hua, L.T., Hamid, H. and Azarkerdar, A., (2019). Relationship of Accident Rates and Road Geometric Design. IOP Conference Series: Earth and Environmental Science, Vol. 357, No. 1, p. 012040, IOP Publishing.

Jalilian, M.M., Safarpour, H., Bazyar, J., Keykaleh, M.S., Malekyan, L. and Khorshidi, A., (2019). Environmental related risk factors to road traffic accidents in Ilam, Iran. Medical Archives, 73(3), p.169.

Jiang, C., Lu, L., Chen, S. and Lu, J.J., (2016). Hit-and-Run Crashes in Urban River-Crossing Road Tunnels. Accident Analysis & Prevention, 95, pp.373-380.

Jones, I.S. and Whitfield, R.A., (1988). Predicting Injury Risk with "New Car Assessment Program" Crashworthiness ratings. Accident Analysis & Prevention, 20(6), pp.411-419.

Kriswardhana, W., Hasanuddin, A. and Palestine, I.M., (2020). Modeling Road Traffic Accident rate and Road Geometric Parameters Relationship. In AIP Conference Proceedings, AIP Publishing LLC, Vol. 2278(1), p. 020003.

M.A.Rahim, M.A.Adnan, S.Z.Zamalik & N.Sulaiman, 2015. Evaluation of operating speed at Multilane Highway along Jalan Meru: Case study of reliability of posted speed limit. INCIEC2015 proc. int. civ. Infrastruct. eng. conf., pp. 995-1005.

Mekonnen, F.H. and Teshager, S., (2014). Road Traffic Accident: The Neglected Health Problem in Amhara National Regional State, Ethiopia. Ethiopian Journal of Health Development, 28(1), pp.3-10.

Mengyuan Z., (2016). Freeway Interchange Crash Characteristics and Influence Areas. MSc, University of Missouri-Columbia.

Abera, M.A., (2019). Evaluation of Road Traffic Accident in Addis Ababa - Adama Expressway. International Journal of Advance Research, Ideas and Innovations in Technology, 5(5).

Mekonnen, T.H., Tesfaye, Y.A., Moges, H.G. and Gebremedin, R.B., (2019). Factors Associated with Risky Driving Behaviors for Road Traffic Crashes Among Professional Car Drivers in Bahirdar City, Northwest Ethiopia: A Cross-Sectional Study. Environmental Health and Preventive Medicine, 24(1), pp.1-9.

Mohammed, H., (2013). The Influence of Road Geometric Design Elements on Highway Safety, International Journal of Civil Engineering and Technology, 4(4), pp. 146-162.

Mustefa, Y.A. and Belayhun, A., (2021). Expressway Traffic Accidents Involving Human Injuries and Fatalities in Ethiopia: Negative Binomial Regression Model.

Nangana, L.S., Monga, B., Ngatu, N.R., Mbelambela, E.P., Mbutshu, L.H. and Malonga, K.F., (2016). Frequency, Causes and Human Impact of Motor Vehicle-Related Road Traffic Accident (RTA) in Lubumbashi, Democratic Republic of Congo. Environmental Health and Preventive Medicine, 21(5), pp.350-355.

Pakgohar, A., Tabrizi, R.S., Khalili, M. and Esmaeili, A., (2011). The Role of Human Factor in Incidence and Severity of Road Crashes based on the CART and LR Regression: A Data Mining Approach. Procedia Computer Science, pp.764-769.

Retallack, A.E and Ostendrof B., (2020). Relationship Between Traffic Volume and Accident Frequency at Intersections, Int. J. Environ. Res. Public Health 2020, 17, 1393

Road Traffic Technology. (2016). Addis Ababa Adama (Nazereth) Expressway [Online]. Available from: https://www.roadtraffic-technology.com/projects/addis-adaba-adama-nazareth-expressway/ [accessed 26 January 2022].

Rohaizan , Y. R. B. & Mashros,, N., 2016. Effect of Posted Speed Limit on Drivers Speed Choice during Off-Peak Period,. Nigerian journal of Technology, 3 July. Volume 35.

Sameen, M.I. and Pradhan B., (2016). Forecasting Severity of Traffic Accidents Using Road Geometry Extracted from Mobile Laser Scanning Data. Geospatial Information Science Research Center, Malaysia.

Simpson, D. and Kerman, J.A., (1982). The Research and Development Background to "Highway Link Design". Traffic Engineering & Control, 23(HS-033 744).

S.Wu, X. Y. & T.Xu, 2010. Research on coordination between operating speed and posted speed limit on clasofied Highway. ICLEM, Issue Logist.sustain.econ.eev.infrastructure, information, integer, pp. 1987-1992.

Tadege, M., (2020). Determinants of Fatal Car Accident Risk in Finote Selam Town, Northwest Ethiopia. BMC Public Health, 20(1), pp.1-8.

Tutz, G., (2011). Regression for Categorical Data. Vol. 34. Cambridge University Press.

United Nations Economic Commission for Africa, United Nations Economic Commission for Europe, (2020). Road Safety Performance Review in Ethiopia, UN, Report No. ECE/INF/2020/6, Geneva, Switzerland.

World Health Organization, (2018). Global Status Report on Road Safety: Summary, Report No. WHO/NMH/NVI/18.20, Geneva, Switzerland.

World Health Organization - News Alert. (2021). Geneva [online]. Available from: https://www.unroadsafetyweek.org/en/news/news-item/t/world-health-organization-news-alert/ [accessed 11 July 11, 2022].

Zhang, Y., (2009), Analysis of the Relation between Highway Horizontal Curve and Traffic Safety. International Conference on Measuring Technology and Mechatronics Automation, Vol. 3, pp. 479-481, IEEE.

Zhang , Y., 2015. Research on the Relationship between Speed Limits and Operating Speed on Straight Roads of Ordinary Provincial Arterial Highways. Key Laboratory for Special Area Highway Engineering of Ministry of Education, Highway and Railway Engineering, Chang'an University, Xi'an 710064. E-mail: nancyaishenghuo@foxmail.com.

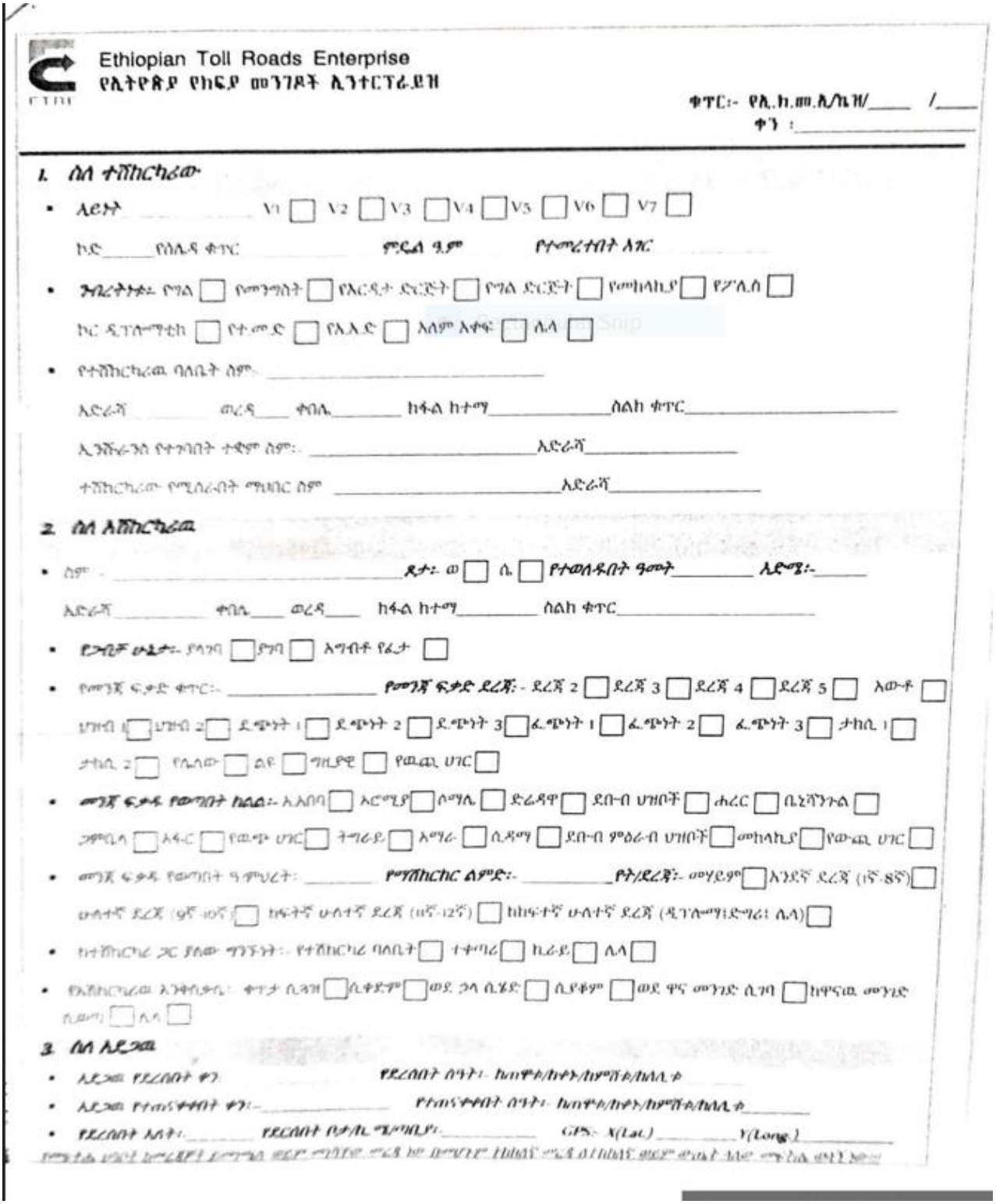
APPENDIXES

APPENDIX 1: Ethiopian Toll Roads Enterprise Vehicle Classification

Vehicle's category	Classification parameters					
	I - Axle number	II - Tire number	III - Height of vehicles head (m)	IV - Axle distance (m)	Character description of vehicles	Remarks
V-1	2	4	<1.3	<2.4	Small automobiles, cars, Jeep, Land rover, taxi, pick up	At the same time to satisfy the parameters I, II, and III or IV in any conditions
V-2	2	4	≥1.3	≥2.4	Minibus	At the same time to satisfy the parameters I, II, III and IV conditions
V-3	2	6	—	—	Medium bus Isuzu	
V-4	3	—	—	—	Big size bus Medium truck	
V-5	4	—	—	—	Heavy truck Trailers	
V-6	5	—	—	—	Heavy truck Trailers	
V-7	≥6	—	—	—	Heavy truck Trailers	

APPENDIX 2: Traffic Crash Data Collecting Format

Form 1 of 3



Ethiopian Toll Roads Enterprise
የኢትዮጵያ የክፍያ መንገዶች ኢንተርፕራይዝ

ቁጥር፡- የኢ.ክ.መ.ኢ/ኪዝ/____ /____
ቀን ፡ _____

1. ስለ ተሸከርካሪው

- ላይኦት _____ V1 ☐ V2 ☐ V3 ☐ V4 ☐ V5 ☐ V6 ☐ V7 ☐

  ኮድ_____ የስሌዳ ቁጥር _____ ሞዴል ዓ.ም _____ የተመረተበት ለዝ _____

- ንብረትነቱ፡ የግል ☐ የመንግስት ☐ የእርዳታ ድርጅት ☐ የግል ድርጅት ☐ የመከላከያ ☐ የፖሊስ ☐

  ኮ/ር ዲፕሎማቲክ ☐ የተ.መ.ድ ☐ የኢ.ኤ.ድ ☐ አለም አቀፍ ☐ ሌላ ☐

- የተሸከርካሪዉ ባለቤት ስም፡ _____

  አድራሻ _____ ወረዳ____ ቀበሌ_____ ከፋል ከተማ_____ስልክ ቁጥር_____

  ኢንሹራንስ የተገባበት ተቋም ስም፡ _____አድራሻ_____

  ተሸከርካሪው የሚሰራበት ማህበር ስም _____አድራሻ_____

2. ስለ አሽከርካሪዉ

- ስም፡ _____ጾታ፡ ወ ☐ ሴ ☐ የተወለዱበት ዓመት_____ ኢሮሜ፡-_____

  አድራሻ _____ ቀበሌ____ ወረዳ____ ከፋል ከተማ_____ ስልክ ቁጥር_____

- የጋብቻ ሁኔታ፡- ያላገባ ☐ያገባ ☐ አግብቶ የፈታ ☐

- የመንጃ ፍቃድ ቁጥር፡- _____ የመንጃ ፍቃድ ደረጃ፡- ደረጃ 2 ☐ ደረጃ 3 ☐ ደረጃ 4 ☐ ደረጃ 5 ☐ አውቶ ☐

  ህዝብ 1☐ ህዝብ 2☐ ደ ሞኑት 1☐ ደ ሞኑት 2 ☐ ደ ሞኑት 3☐ ፈ ሞኑት 1☐ ፈ ሞኑት 2☐ ፈ ሞኑት 3☐ ታክሲ 1☐

  ታክሲ 2☐ የሌለው ☐ ልዩ ☐ ግዚያዊ ☐ የዉጪ ሀገር☐

- መንጃ ፍቃዱ የወጣበት ክልል፡- አ.አ.አ☐ አ.ሮ.ሚ.ያ☐ ሶ.ማ.ሌ ☐ ድ.ሬ.ዳ.ዋ☐ ደ.ቡ.ብ ህ.ዝ.ቦ.ች☐ ሐ.ረ.ር ☐ ቤ.ኒ.ሻ.ን.ጉ.ል ☐

  ጋ.ም.ቤ.ላ ☐ አ.ፋ.ር ☐ የ.ዉ.ጭ ሀ.ገ.ር☐ ት.ግ.ራ.ይ ☐ አ.ማ.ራ ☐ ሲ.ዳ.ማ ☐ ደ.ቡ.ብ ም.ዕ.ራ.ብ ህ.ዝ.ቦ.ች☐ መ.ከ.ላ.ኪ.ያ☐ የ.ው.ጪ ሀ.ገ.ር ☐

- መንጃ ፍቃዱ የወጣበት ዓ.ም.ህ.ረ.ት፡ _____ የማሽከርከር ልምድ፡- _____ የት/ደረጃ፡- መሃይም☐ አንደኛ ደረጃ (1ኛ-8ኛ)☐

  ሁ.ለ.ተ.ኛ ደ.ረ.ጃ (9ኛ-10ኛ)☐ ከ.ፍ.ተ.ኛ ሁ.ለ.ተ.ኛ ደ.ረ.ጃ (11ኛ-12ኛ) ☐ ከ.ከ.ፍ.ተ.ኛ ሁ.ለ.ተ.ኛ ደ.ረ.ጃ (ዲ.ፕ.ሎ.ማ፣ዲ.ግ.ሪ፣ ሌ.ላ)☐

- ከተሸከርካሪ ጋር ያለው ግንኙነት፡- የተሸከርካሪ ባለቤት☐ ተቀጣሪ☐ ከ.ራ.ይ☐ ሌ.ላ☐

- የአሽከርካሪዉ እንቅስቃሴ፡ ቀጥታ ሲጓዝ☐ ሲቀይም☐ ወደ ጋ.ላ ሲ.ሄ.ድ ☐ ሲ.ያ.ቆ.ም ☐ ወደ ዋና መንገድ ሲገባ ☐ ከዋናዉ መንገድ ሲ.ወ.ጣ ☐ ሌ.ላ ☐

3. ስለ አደጋዉ

- አደጋዉ የደረሰበት ቀን _____ የደረሰበት ሰዓት፡ ከጠ/ቀ/ከቀ/ከ/ማ/ቀ/ከ/ሌ/ቀ _____
- አደጋዉ የተጠናቀቀበት ቀን፡- _____ የተጠናቀቀበት ሰዓት፡ ከጠ/ቀ/ከቀ/ከ/ማ/ቀ/ከ/ሌ/ቀ _____
- የደረሰበት አ.አ.ት፡ _____ የደረሰበት ቦታ/ኪ.ሜ/ሜ.ር፡ _____ ኮ.ኦ.ር፡- X(Lat.) _____ Y(Long.) _____

Form 2 of 3

Ethiopian Toll Roads Enterprise
የኢትዮጵያ የክፍያ መንገዶች ኢንተርፕራይዝ

ቁጥር:- የኢ.ክ.መ.ኢ/ኪዝ/____ /____
ቀን :____________

- ተሽከርካሪዉ የገባበት የክፍያ ጣቢያ:-__________ ተሽከርካሪዉ የሚወጣበት የክፍያ ጣቢያ:-__________
- የደረሰበት አቅጣጫ:- ወደ አዳማ ☐ ወደ አ/አበባ ☐ ወደ ወለንጪቲ ☐ የክፍያ ጣቢያ ☐ መጋቢ መንገድ ☐ ሌላ ☐
- የብርሃን ሁኔታ:- በቀን ብርሃን ☐ ንጋት (ፀሐይ በመውጣት ላይ) ☐ አመሻሽ (ፀሐይ በመጥለቅ ላይ) ☐ ጨለማ መብራት በሌለበት ☐ ጨለማ የመንገድ መብራት ባለበት ☐ ጨለማ የተፈጥሮ መብራት ባለበት ☐ ሌላ ☐
- የመንገድ አቀማመጥ:- ቀጥ ለጥ ያለ ☐ ቁልቁለት ☐ ዳገታማ ☐ ኩርባ ☐ ሌላ ☐
- የአየር ሁኔታ:- ፀሐያማ ☐ ዝናባማ ☐ ሞቃት ☐ ከባድ ንፋስ ☐ ጭጋግ ☐ ዳመናማ ☐ ንፁህ አየር ☐ ብርድ ☐ በረዶ ☐ ሌላ ☐
- የመንገድ ንጣፍ ሁኔታ:- ደረቅ ☐ እርጥብ ☐ በረዶ ☐
- ሹፌሩን ጨምሮ ተሽርካሪዉ ዉስጥ የነበረዉ ሰዉ ብዛት:- ወንድ ☐ ሴት ☐ ጠቅላላ ☐
- የሹፌሩ የወንበር ቀበቶ:- አስሯል ☐ አላሰረም ☐ የተሳፋሪ የወንበር ቀበቶ:- አስሯል ☐ አላሰረም ☐ ሁሉም የወንበር ቀበቶ:- ይሰራል ☐ አይሰራም ☐
- ያደረሰው ጉዳት በሠው ላይ:- ሞት_____ የከፋ ጉዳት_____ ቀላል ጉዳት_____ ሊታይ የማይችል ጉዳት_____ ንብረት ጉዳት ብቻ ☐
- በደረሰዉ አደጋ የተጎዱ ሠዎች:-
  - ➡ አሽከርካሪ:- ሞት ወ ☐ ሴ ☐ የከፋ ጉዳት ወ ☐ ሴ ☐ ቀላል ጉዳት ወ ☐ ሴ ☐ ሊታይ የማይችል ጉዳት ☐
  - ➡ ተሳፋሪ:- ሞት ወ ☐ ሴ ☐ የከፋ ጉዳት ወ ☐ ሴ ☐ ቀላል ጉዳት ወ ☐ ሴ ☐ ሊታይ የማይችል ጉዳት ወ ☐ ሴ ☐
- በአደጋው ጉዳት ከደረሰባቸው ጠቅላላ ብዛት ውስጥ የተጎጂዉ/ዋ ስራ:- የግል_____ የመንግስት_____ ተማሪ_____ ገበሬ_____ ስራ የሌለው_____
- የአደጋዉ አይነት:- መገልበጥ ☐ ከግዑዝ አካል ጋር መጋጨት ☐ ፊት ናኋላ ግጭት ☐ ጎን ለጎን ግጭት ☐ ፊትና ጎን ግጭት ☐ ☐ ፊት ለፊት ግጭት ☐ እንስሳት መግጨት ☐ የቆመ ተሽከርካሪ መግጨት ☐ እግረኛ መግጨት ☐ የተሽከርካሪ በእሳት መቃጠል ☐ ከመንገድ መውጣት ☐ ከላይ ያልተጠቀሰ ከሆነ የአደጋዉ አይነት ቢጠቀስ______________________
- የአደጋው መንስኤ:- ከተወሰነዉ ፍጥነት በላይ ማሽከርከር ☐ የጎማ መፈንዳት/መዉለቅ ☐ አደንዛዥ ዕፅ ተጠቅሞ ማሽከርከር ☐ የፍሬን ጉድለት ☐ ከጥንቃቄ ጉድለት ☐ በድካም ስሜት ማሽከርከር ☐
  ከላይ ያልተጠቀሰ ከሆነ የአደጋ ምክንያቱ/መንስኤ ቢጠቀስ-______________________

4. **የመንገድ እና ትራፊክ ደህንነትና አስተዳደር ቡድን**

- መረጃዉ የደረሰት ሠዓት:-________ ቀን ☐ ማታ ☐ መረጃዉ ምንጭ (የተገኘዉ):- ከሞኒተር ☐ ከደንበኛ ☐ ከሴፍቲ ቡድን ☐ በፓትሮል ወቅት ☐ ከኢ.ክ.መ.ኢ. ሌሎች ሠራተኞች ☐ ከመንገድ ጥበቃ አባላት ☐ በአደጋ ቦታ ላይ ☐ ሌላ ☐
- ፓትሮል ተሽከርካሪዉ የነበረበት ማቢያ/ኪ.ሜ:-________ አደጋዉ ቦታ የደረሰንበት ሠዓት:-________ ቀን ☐ ማታ ☐
- መንገዱ ሙሉ ለሙሉ ለትራፊክ ክፍት የሆነበት ሠዓት________ ቀን ☐ ማታ ☐

5. **ድንገተኛ አደጋ አገልግሎት**

- ለእርዳታ አምቡላንስ ተሽከርካሪው የተደወለበት ሠዓት:-_____ ቀን ☐ ማታ ☐ የነበረበት ማቢያ/ኪ.ሜ:-_____ የደረሰበት ሠዓት________ ቀን ☐ ማታ ☐ ለእረዳተታ ሌላ ዘዴ ከተጠቀሙ:-______________
- አደጋ የደረሰባቸዉ ሠዎች የሄዱበት ሆስፒታል/ክሊኒክ/ቦታ:-______________
- ለሬከር ከሬን የተደወለበት ሠዓት:-_____ ቀን ☐ ማታ ☐ የነበረበት ማቢያ/ኪ.ሜ:-________ የደረሰበት ሠዓት:-_____ ቀን ☐ ማታ ☐
- ለካቶ ወይም ለሞገን ከሬን የተደወለበት ሠዓት:-_____ ቀን ☐ ማታ ☐
- የነበረበት ማቢያ/ኪ.ሜ:________ የደረሰበት ሠዓት:_____ ቀን ☐ ማታ ☐

[illegible]

Form 3 of 3

Ethiopian Toll Roads Enterprise
የኢትዮጵያ የክፍያ መንገዶች ኢንተርፕራይዝ
ETRE

ቁጥር፡- የኢ.ክ.መ.ኢ/ኬዝ/____/____
ቀን ፡ _____

- ተሽከርካሪው በወቅቱ ካለተነሳ ያልተነሳበትን ምክንያት፡- _____
- ከሌላ ተቋም የመጣ የእርዳታ የመጣ ተሽከርካሪ የተደወለበት ሰዓት_____የደረሰበት ሰዓት_____ያጠናቀቀበት ሰዓት_____

6. ኦርሚያ (ኢንተርፕራይዙ) የትራፊክ ፖሊስ ቁጥጥርና ደህንነት ክፍል

- ለትራፊክ ፖሊስ ፓትሮል የተደወለበት ሰዓት፡-_____ቀን☐ ማታ☐ የደረሰበት ሰዓት፡-_____ ቀን☐ ማታ☐
  የአሽከርካሪዉ ስም፡-_____ስልክ ቁጥር: - _____
- ለትራፊክ ፖሊስ የተደወለበት ሰዓት፡-_____ቀን☐ ማታ☐ የደረሱበት ሰዓት፡-_____ቀን ☐ ማታ☐
  ማዕረግ፡-_____ስም፡-_____ስልክ ቁጥር፡-_____

7. አደጋዉ ከደረሰ ብኃላ ያጋጠሙ ችግሮች

_____

8. የተወሰዱ መፍትሄዎች

_____

9. በወቅቱ መፍትሔ ያላገኙ ችግሮች

_____

10. በወቅቱ ያልተያዙ የእደጋ መረጃዎች

1. _____ 2. _____ 3. _____
4. _____ 5. _____ 6. _____

11. በኢንተርፕራይዙ ላይ የደረሰ የጉዳቱ ዝርዝር

ተ.ቁ	የንብረት ዓይነት	ብዛት	የተጎዳበት ኪ.ሜ	አቅጣጫ	የአሽከርካሪው ስም	የአሽከርካሪው ፈርማ

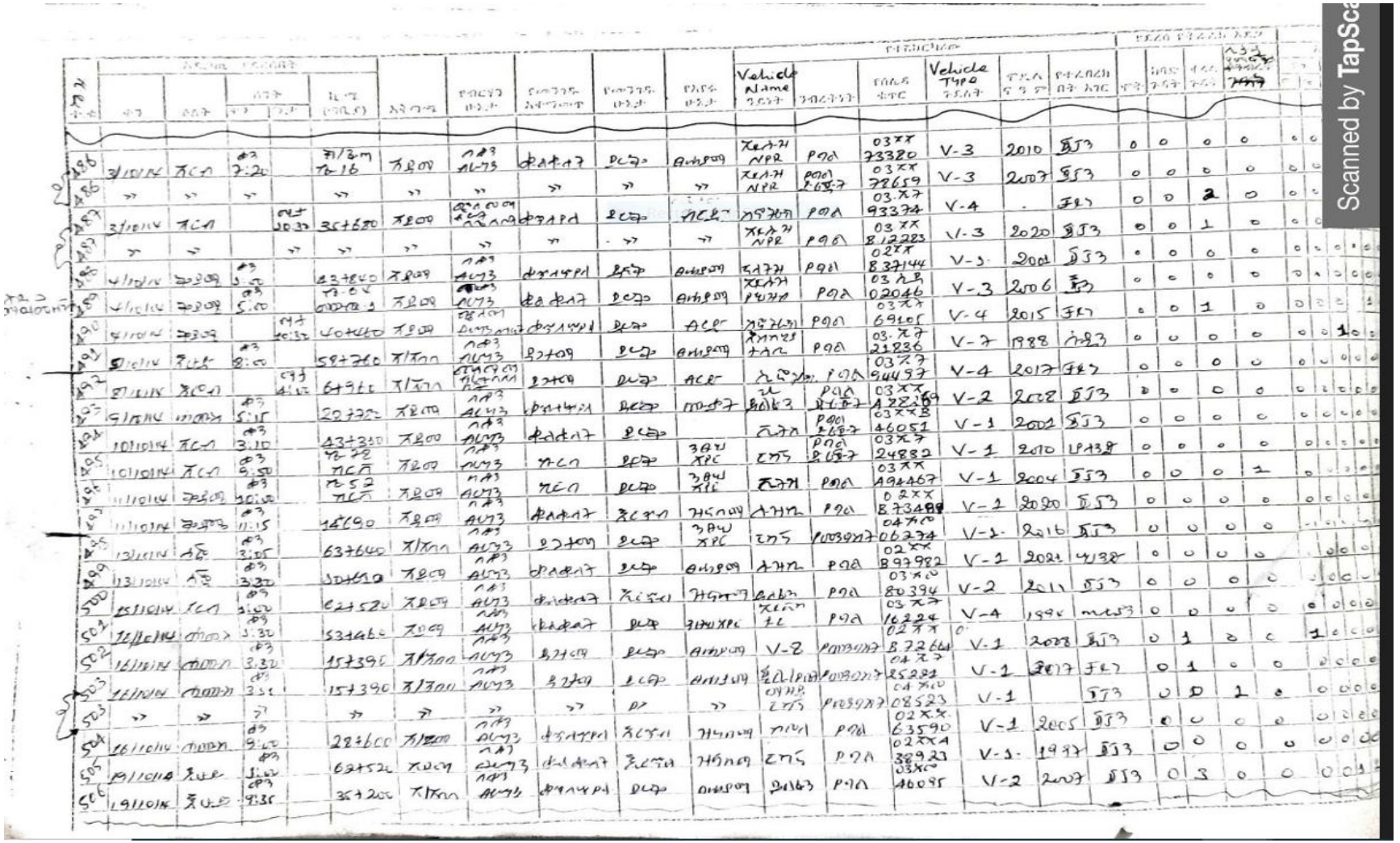
12. ስለ አደጋዉ ዝርዝር ሐሳብ/መግለጫ/

_____

ሪፖርቱን ያዘጋጀዉ ሴፊቲ ኦፊሰሮች ስም፡-_____እና_____ፈርማ፡-_____ፈርማ፡-_____
ሪፖርቱን ያረጋገጠው ሱፐርቫይዘር ስም፡-_____ቀን፡-_____ፈርማ፡-_____

የመፍትሔ ሀሳቦች ከመረጃዎች ይመነጫሉ ወይም መነሻቸው መረጃ ነው በመሆኑም ትክክለኛ መረጃ ለትክክለኛ ወይም ውጤት ላለው መፍትሔ ወሳኝ ነው!!!

APPENDIX 3: Sample Data of Traffic Crash




Scanned by TapScanner

APPENDIX 4: Traffic Flow Data Format

Exit			Veh. Type	Distance travelled	Entrance		
Exit Plaza_ID	Occur Date	Occur Time			ENT_Plaza ID	Occur Date	Occur Time

APPENDIX 5: Description of Independent Variables

No.	Main Variables	Sub Variables	Descriptions of Variables
1	Accident Occurrence Place	Toll Plaza	At Toll Plaza, approaching to the entrance or the exit of toll plaza
		Main Line	Interior of the Expressway other than the toll plaza, approach to entrance and exit of toll plaza
2	Radius of Horizontal Curve (m)	R : 40m-60m	Radius of horizontal curves in between 40m and 60m
		R : 61m-120m	Radius of horizontal curves in between 61 and 120m
		R: 121m-250m	Radius of horizontal curves in between 121m and 250m
		R: 251m-900m	Radius of horizontal curves in between 251m and 900m
		R: 901m 1500m	Radius of horizontal curves in between 901m and 1500m
		R: 1501–2600 m	Radius of horizontal curves in between 1501m and 2600m
		R: 2600m -6000m	Radius of horizontal curves in between 2601m and 6000m
		R= ∞(Straight Section)	Tangent (Straight Section)
3	Cross sectional transverse slope	SE	Super elevated cross section
		NC	Normal Crown Cross section
4	Longitudinal Slope (Grade) (%)	G : 0% - 3%	Vertical grade in between 0% - 3% ($G \leq 3\%$)
		G: 3% - 5%	Vertical grade in between 3% - 5% ($3 < G \leq 5\%$)
		G: > 5%	Vertical grade G> 5%
5	Road Gradient direction	Level (0%)	Level (0%)
		Down Grade	Descending elevation on traffic flow direction
		Up grade	Ascending elevation on traffic flow directions
6	Radius <200 with grade>4%	R<200 and G>4%	Radius of horizontal curve less than 200 and Gradient of vertical alignment greater than 4%

No.	Main Variables	Sub Variables	Descriptions of Variables
7	Day of the week	Weekends	Saturday and Sunday
		Weekdays	From Monday to Friday
8	Accident-involved Vehicle Type	Light vehicles	Automobile, Pickup, 4W Drives, and Mini bus
		Medium Vehicle	Isuzu, Mid bus, Medium Bus
		Large Vehicle	Trucks, Low bed, High bed, Large Bus and Trucks and Trailer
9	Accident Occurrence Time	Day time	6:00am to 5:59pm
		Night time	6:00pm to 5:59am
10	Causes of Crash	Vehicle Technical Problem	Brake problem, steering problem, tyre problem and other mechanical problems on vehicle
		Speeding	Traveling over the posted speed limit
		Drunken driving	Driving while under the influence of alcohol
		Animal Intrusion	Intrusion of animals in the expressway
		Sleep Deprive and Fatigue	Driving under Sleep Deprive and Fatigue
		Driver Error	crashes due to aggressive driving, changing lanes too quickly
		Wet Surfacing	Moisture on the road, including snow, rain, and ice
		Others	Cause of crash not recorded
11	Number of Vehicles Involved	Single Vehicle	only One vehicle involved in the crash
		Two Vehicle	only Two vehicles involved in the crash
		Multiple Vehicle	More than two vehicles involved in the crash
12	Vehicle Travel Direction	To Adama	Vehicles traveling to Adama direction
		To A.A	Vehicles traveling to Addis Ababa direction)
13	Road Surface Condition	Dry	Dry
		Wet	Wet

No.	Main Variables	Sub Variables	Descriptions of Variables
14	Weather Condition	sunny, Normal	Good weather condition
		Windy/Cloudy/Rainy	Bad weather condition
		Unidentified	Weather condition not recorded
15	Light Condition	Sun light	Day with natural sunlight
		Night with Street Light	Night with Street Light
		Night without Light	Night without Light
16	Type of Crush	Head On	Face to Face Collision of vehicles
		Rear-End	Rear to end collision of vehicles
		Rollover	Crash occurred when overturning of vehicle
		Sideswipes	Side to side collision of vehicles
		Side Impact	vehicle moving in one direction strikes another vehicle at a perpendicular angle
		Runoff	collision that occurs when a vehicle leaves the roadway.
		Crush With Fixed objects	crash that occurs when a vehicle collides with something that's permanently placed wherever it is instead of another vehicle.
		Other	Type of crash not recorded
17	Driver Gender	Male	Male
		Female	Female
		Un identified	Sex not recorded
18	Driver Age (Yrs.)	18-30	From 18yrs to 30yrs.
		31-50	From 31yrs to 50yrs
		>50	>50yrs
		Un identified	Driver age not recorded

APPENDIX 6:-Analysis Results of Descriptive statistics of the crash data on independent variables

No.	Main variables	Sub variables	Severity						PDo		Total	
			Fatal		Serious injury		Light injury					
			No.	%	No.	%	No.	%	No.	%	No.	%
1	Accident occurrence place	Toll plaza	14	14.3	33	12.3	120	17.1	226	16.3	393	16.0
		Main line	84	85.7	235	87.7	580	82.9	1158	83.7	2057	84.0
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
2	Radius of horizontal curve (m)	R : 40m-60m	0	0.0	6	2.2	9	1.3	15	1.1	30	1.2
		R : 61m-120m	0	0.0	1	0.4	4	0.6	42	3.0	47	1.9
		R: 121m-250m	7	7.1	17	6.3	62	8.9	75	5.4	161	6.6
		R: 251m-900m	1	1.0	4	1.5	18	2.6	58	4.2	81	3.3
		R: 901m 1500m	6	6.1	19	7.1	59	8.4	125	9.0	209	8.5
		R: 1501–2600 m	16	16.3	46	17.2	90	12.9	236	17.1	388	15.8
		R: 2600m -6000m	33	33.7	99	36.9	251	35.9	431	31.1	814	33.2
		R= ∞(Straight Section)	35	35.7	76	28.4	207	29.6	402	29.0	720	29.4
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
3	Cross sectional transverse slope	Super elevated (SE)	28	28.6	88	32.8	225	32.1	506	36.6	847	34.6
		Normal Crown (NC)	70	71.4	180	67.2	475	67.9	878	63.4	1603	65.4
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
4	Longitudinal slope (grade) (%)	G : 0% - 3%	62	63.3	182	67.9	516	73.7	1001	72.3	1761	71.9
		G: 3% - 5%	29	29.6	66	24.6	131	18.7	315	22.8	541	22.1
		G: > 5%	7	7.1	20	7.5	53	7.6	68	4.9	148	6.0
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
5	Road gradient direction	Level (0 %)	2	2.0	6	2.2	17	2.4	47	3.4	72	2.9
		Down grade	43	43.9	122	45.5	358	51.1	760	54.9	1283	52.4

No.	Main variables	Sub variables	Severity						PDo		Total	
			Fatal		Serious injury		Light injury					
			No.	%	No.	%	No.	%	No.	%	No.	%
		Up grade	53	54.1	140	52.2	325	46.4	577	41.7	1095	44.7
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
6	Radius <200 with grade>4%	R<200m and G>4%	7	100.0	23	100.0	71	100.0	89	100.0	190	
			7	100.0	23	100.0	71	100.0	89	100.0	190	
7	Day of the week	Weekends	38	38.8	104	38.8	234	33.4	403	29.1	779	31.8
		Weekdays	60	61.2	164	61.2	466	66.6	981	70.9	1671	68.2
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
8	Accident-involved vehicle type	Light vehicles	65	66.3	189	70.5	465	66.4	725	52.4	1444	58.9
		Medium vehicle	25	25.5	55	20.5	157	22.4	292	21.1	529	21.6
		Large vehicle	8	8.2	24	9.0	78	11.1	367	26.5	477	19.5
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
9	Accident Occurrence Time	Day time	77	78.6	224	83.6	532	76.0	954	68.9	1787	72.9
		Night time	21	21.4	44	16.4	168	24.0	430	31.1	663	27.1
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
10	Causes of Crash	Vehicle technical problem	23	23.5	55	20.5	248	35.4	468	33.8	794	32.4
		Speeding	33	33.7	91	34.0	154	22.0	195	14.1	473	19.3
		Drunken driving	0	0.0	0	0.0	1	0.1	1	0.1	2	0.1
		Animal intrusion	0	0.0	0	0.0	0	0.0	6	0.4	6	0.2
		Sleep deprive and fatigue	4	4.1	11	4.1	40	5.7	56	4.0	111	4.5
		Driver error	29	29.6	79	29.5	184	26.3	392	28.3	684	27.9
		Wet surfacing	0	0.0	0	0.0	0	0.0	2	0.1	2	0.1

No.	Main variables	Sub variables	Severity									
			Fatal		Serious injury		Light injury		PDo		Total	
			No.	%	No.	%	No.	%	No.	%	No.	%
		Others (cause not mentioned)	9	9.2	32	11.9	73	10.4	264	19.1	378	15.4
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
11	Number of Vehicles Involved	Single vehicle	67	68.4	184	68.7	508	72.6	1169	84.5	1928	78.7
		Two vehicles	30	30.6	78	29.1	173	24.7	196	14.2	477	19.5
		Multiple vehicle	1	1.0	6	2.2	19	2.7	19	1.4	45	1.8
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
12	Vehicles travel direction	To Adama	63	64.3	142	53.0	376	53.7	777	56.1	1358	55.4
		To A. A	35	35.7	126	47.0	324	46.3	607	43.9	1092	44.6
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
13	Road surface condition	Dry	75	76.5	235	87.7	627	89.6	1135	82.0	2072	84.6
		Wet	23	23.5	33	12.3	73	10.4	249	18.0	378	15.4
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
14	Weather condition	sunny, normal	58	59.2	176	65.7	463	66.1	735	53.1	1432	58.4
		Windy/cloudy/rainy	35	35.7	87	32.5	227	32.4	631	45.6	980	40.0
		Unidentified	5	5.1	5	1.9	10	1.4	18	1.3%	38	1.6
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
15	Light condition	Sun light	77	78.6	222	82.8	523	74.7	939	67.8	1761	71.9
		Night with street light	1	1.0	4	1.5	19	2.7	81	5.9	105	4.3
		Night without Light	20	20.4	42	15.7	158	22.6	364	26.3	584	23.8
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
16	Type of crash	Head on	1	1.0	10	3.7	13	1.9	10	0.7	34	1.4
		Rear-end	23	23.5	61	22.8	119	17.0	160	11.6	363	14.8
		Rollover	45	45.9	123	45.9	315	45.0	362	26.2	845	34.5

No.	Main variables	Sub variables	Severity						PDo		Total	
			Fatal		Serious injury		Light injury					
			No.	%	No.	%	No.	%	No.	%	No.	%
		Sideswipes	5	5.1	6	2.2	24	3.4	21	1.5	56	2.3
		Side impact	0	0.0	0	0.0	6	0.9	10	0.7	16	0.7
		Runoff	0	0.0	1	0.4	3	0.4	13	0.9	17	0.7
		Crash with fixed	14	14.3	50	18.7	166	23.7	568	41.0	798	32.6
		Other (not mentioned)	10	10.2	17	6.3	54	7.7	240	17.3	321	13.1
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
17	Driver gender	Male	92	93.9	247	92.2	676	96.6	1339	96.7	2354	96.1
		Female	1	1.0	9	3.4	14	2.0	21	1.5	45	1.8
		Unidentified (Sex not recorded)	5	5.1	12	4.5	10	1.4	24	1.7	51	2.1
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100
18	Driver age (yrs.)	18-30	31	31.6	80	29.9	279	39.9	587	42.4	977	39.9
		31-50	33	33.7	106	39.6	285	40.7	632	45.7	1056	43.1
		>51	1	1.0	12	4.5	41	5.9	64	4.6	118	4.8
		Un identified (Age not recorded)	33	33.7	70	26.1	95	13.6	101	7.3	299	12.2
			98	100.0	268	100.0	700	100.0	1384	100.0	2450	100