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TRAFFIC ACCIDENT CAUSES AND COUNTERMEASURES OF ADDIS ABABA-ADAMA EXPRESSWAY

BY

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This is to certify that the thesis presented by Debela Deme, entitled: Traffic Accident Causes and Countermeasures of Addis Ababa-Adama Expressway and submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Road and Transportation Engineering) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Road traffic accidents are one of the most common reasons of deaths and injuries in the world. Ethiopia is among the leading countries in road traffic accident in the world. Addis Ababa – Adama Expressway is one of the newly introduced modern toll routs with a traffic accident not studied before. Both qualitative and empirical research method is used to assess the traffic accident level of this road. Black spot analysis and model development are the two major techniques used to identify the cause of traffic accidents and identify the major determinants of accidents. The research used comprehensive data collected on the daily road traffic accidents of Addis Ababa – Adama Expressway, which is collected through the Ethiopian Toll Road Enterprise for the period of one and half years (2014/15 – 2016). The research asses and quantify traffic accident causes and propose counter measures on Addis Ababa-Adama Expressway. Black spot identification and traffic accident model development was the focus of this research. Black spot analysis was made using accident severity value. Multinomial probit regression model was used for assessing factors contributing for road accident. The findings of the study indicated that there are four black spot regions on the expressway. The study also identified that Day of the Week, Collision Types, Types of Vehicles and Plate Number Region are significant at p-value of 0.05. This shows that the stated factors have been contributing greatly for the occurrence of traffic accidents on the expressway. On the other hand, factors seem to have no significant effect on the determination of accident on the road. As a result, all roads users, policy makers and road traffic regulators are expected to consider those significant determinant factors so as to minimize the level of accident on expressway.

TABLE OF CONTENTS

ACKNOWLEDGMENT i
ABSTRACT ii
ACRONYMS ix
CHAPTER ONE 1
1. INTRODUCTION 1
1.1 Overview of Traffic Accident in Ethiopia 3
1.2. Overview of Traffic Accident of Addis Ababa – Adama Expressway 5
1.3. Statement of the Problem 6
1.4. Objectives of the Study 7
1.4.1. General Objective 7
1.4.2. Specific Objectives 7
1.5. The Scope of Study 7
1.6. Significance of the Study 7
1.7. Organization of the Research Report 8
CHAPTER TWO 9
2. REVIEW OF THE LETERATURE 9
2.1. Road Crashes 9
2.1.1. Factors influencing Road Accidents 10
2.1.2. Car Crash Types 11
2.1.3. Causes of Crashes 12
2.2. Road Environment Contributing for Traffic Accident 13
2.2.1. Road Alignment 13
2.2.2. Sight Distance 14
2.2.3. Road Cross-Sectional Elements 14
2.3. Vehicle Factors Contributing for Traffic Accident 15
2.4. Driver Factors Contributing for Traffic Accident 15
2.5. Road User Information and Traffic Accident 16
2.6. Accident Classification 16
2.6.1. Current Accident Severity Definition in Ethiopia 17
2.7. Traffic Accident Cost and Method of Analysis 17
2.8. Concept of Black Spot 18

2.8.1. Expected Time Coverage for Black Spot Analysis 20
2.8.2. Criteria for Analyses of Black Spot 20
2.8.3. Black Spot Identification Method 21
2.8.4. Black Spot Treatment 24
2.8.5. Traffic accident black spot Elimination or Reduction mechanism 25
2.9. Road Accident Modeling 27
2.9.1. Types of Variables 27
2.4.1. Models for Polytomous Dependent Variables 29
2.4.2. Multinomial Probit Regression Model 29
2.5. Factor Identified for Developing Road Accident Model 31
CHAPTER THREE 32
3. RESEARCH METHODOLOGY 32
3.1. The Study Site 32
3.2. Data Source and Collection 32
3.3. Research Approach 35
3.4. Model Selection 35
3.5. Variables Definition 35
3.5.1. Independent Variables 36
3.5.2. Dependent Variables 36
3.6. Method of Analysis 36
3.7. Model Specification Test 41
CHAPTER FOUR 43
4. RESULTS OF ANALYSIS AND DISCUSION 43
4.1. Characteristics of Accidents 43
4.1.1 Causes of Accidents 43
4.1.2 Accident Distribution over Time 44
4.1.3 Traffic Accidents due to effect of Time of Day 45
4.1.4 Accident Distribution over Types of Vehicles 46
4.1.5 Collision Type related variables 47
4.1.6 Vehicular Direction of Flow related Variables 47
4.1.7 Plate Number related Variables 48
4.2. Empirical Analysis 49

4.2.1. Black Spot Identification and Recommended Counter Measures.....49
4.3. Traffic Accident Model Determination.....53
4.3.1. Empirical Relationship between Accident and Its Possible Causes 54
CHAPTER FIVE.....58
5. CONCLUSION AND RECOMMENDATION.....58
5.1. Conclusion.....58
5.2. Recommendation.....59
REFERENCE.....61
APPENDIX.....63

List of Tables

Table 1: Accident Costing (million birr) in Ethiopia, Year 2009/10 18
Table 2: Accident cost in Ethiopia for year 2016 (million birr) 38
Table 3: Accident Coasting for Addis Ababa – Adama expressway (million birr) 38
Table 4: Weighted value for Accident Severity for Addis Ababa – Adama expressway 39
Table 5: Correlation Matrix for TD, DW, DF, TV, CT, AC, A, PNR, AL 42
Table 6: Causes of Accidents related variables 44
Table 7: Causes of Traffic Accidents and their level of Impacts 44
Table 8: Daily Traffic Accident Frequency 45
Table 9: Hourly Traffic Accident Frequency 45
Table 10: Time of Day related Accident Frequency 46
Table 11: Table of Time of Day related variables 46
Table 12: Accident Frequency over types of vehicles 47
Table 13: Collusion Types Accident Frequency 47
Table 14: Direction of Flow Accident Frequency 48
Table 15: Vehicle Code Accident Frequency 48
Table 16: Plate Number Region Related Accident Frequency 49
Table 17: Descriptive Statistics of Variables Included in the Model 53
Table 18: Parameter Estimated Coefficient 54

List of Figures

Figure 1: Causes of fatal accidents for the periods 1998 to 2002 and 2003 to 2007 3
Figure 2: Speed Violation in East Shewa Cities and Towns..... 4
Figure 5: Accident Distribution Over Three Hours 50
Figure 6: Variation of Accident by Day of the Week 50
Figure 7: Accident Distribution Over Three Hours 51
Figure 8: Variation of Accident by Day of the Week 51

List of Diagram

Diagram 1: Process of eliminating or improving accident black spot in road network..... ..26

ACRONYMS

AADT	Average Annual Daily Traffic
AASHTO	America Association of State Highway and Transportation
ARCs	Accident Reporting Center
ARM	Accident Risk Model
AV	Abbreviation
CRA	Conventional Regression Analysis
CV	Coefficient of Variation
E.C	Ethiopian Calendar
GRSF	Global Road Safety Forum
HIV	Human Immunity Virus
ITE	Institute of Transport Engineering
GDP	Gross Domestic Product
KM2	Kilometer Two
MADD	Mothers against Drunk Driving
MNL	Multinomial Logistic
NRSC	National Road Safety Council
OR	Odd Ratio
OECD	Organization of Economical Co-Operation and Development
PI	Potential of Improvement
SPSS	Statical Package for social Science
UK	United Kingdom
UN	United Nation
WB	World Bank
WHO	World Health Organization

CHAPTER ONE

1. INTRODUCTION

World health organization and World Bank (1999) reported that road fatalities are expected to increase with a toll between 900,000 and 1.1 million in 2010. This figure expected to reach between 1.1 million and 1.3 million in 2020. Trend data shows that the total number of people killed in road crashes in developing world continues to increase. Considering this facts, many researchers have come out with the causes and effects to traffic accidents. The result of the studies indicated that alcoholic drink, technical failures, over speeding and others are identified as some of the major causes of traffic accidents. Some important global facts of road traffic accidents show that at least 1.3 million people have been killed every year due to road crashes. Some 20-50 million people suffer with various forms of disabilities. The report also shows that 90% of road casualties were in low and middle-income countries. The same reports estimated that road traffic crashes expected to be the 3rd leading cause of death worldwide by the year 2020 if rigorous and remarkable actions are not taken.

The report prepared on "The Global Burden of Disease", indicated that deaths from non-communicable diseases are expected to climb from 28.1 million a year in 1990 to 49.7 million by 2020 (an increase in absolute numbers of 77%). Road traffic crashes will contribute significantly to this rise. Concomitantly, the report show that road traffic injuries are expected to move from ninth place in 1990 to take third place in the rank order of disease burden by 2020 (World Health Organization & World Bank, 1999).

As stated above, road traffic accidents occur as a result of factors associated with traffic system. Africa has one of the highest road traffic death rates in the world, with little difference in rates between those countries categorized as low-income (32.3 deaths per 100,000 populations per year). Whereas the range of fatalities per 100,000 populations in countries of African region is not very wide, 70% of all the deaths in the Region occurred in the ten countries that account for 70% of the regional population: Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Madagascar, Mozambique, Nigeria, South Africa, and Tanzania (World Health Organization & World Bank, 1999).

Review of the magnitude of the problem revealed that 1.2 million people die due to road traffic crashes annually. On the average, in advanced and many developing countries, one out of every ten hospital beds is occupied by road traffic crash accident victims (National Road Safty Council, 2010). The 1999 WHO publication on "Injury: A Leading Cause of the Global Burden of Disease," reported that road traffic crashes were the major causes of severe injuries in most countries and the leading injury-related cause of death among people aged 15-44 years. The WHO report also indicated that around 38.8 million people were injured by motor vehicle crashes in 1998. Out of the 5.8 million people who died of injuries, around 1.1 million (20%) were died as result of injuries sustained by motor vehicle crashes. These facts reveal unacceptable levels of road traffic accidents and casualties. Therefore, traffic accident is becoming global and national problem and creating social and economic burden for countries. According to the World Health Organization report, the economic costs of road crashes and injuries are estimated to be 1% of Gross Domestic Product (GDP) in low-income countries. Road traffic crashes cost developing countries a staggering 1–2% of their gross domestic product (William Eckersley and et. al, Jan 21, 2010). Ethiopia is one of developing country with high traffic accident costing the country around 0.8% - 0.9% of the GDP for the past consecutive years (Ethiopian Federal Police Commission, 2008). To curb the problem, strong interventions and strategies are expected to deal with the challenges so as to reduce its impact by 50% at the end of 2020 (the United Nations Global Plan for the Decade of Action for Road Safety 2011-2020).

Like any developing economies, Ethiopia has been experiencing large number of traffic accident annually. The death rate presently stands near 70 per 10,000 vehicles. Of those killed, over half were pedestrians, of which 20% were children under the age of 18. The economic loss due to road accident is also significant. Unless the trend is arrested, the social and economic problem of road traffic accident will become more and more serious as the number of vehicle increases. In this regard, considering the importance of road safety, the Ethiopian government has requested the WB and its GRSF to review the road safety management capacity of the country. This review, based on benchmarked results of road safety management and the UN Global Plan guideline, were used for the development of national decade strategy for road safety (Minister of Transport, Febraury, 2011). Despite these all effort the challenges of road traffic accedent still increasing from time to time. This research is, therefore, prepared to identify the major causes of

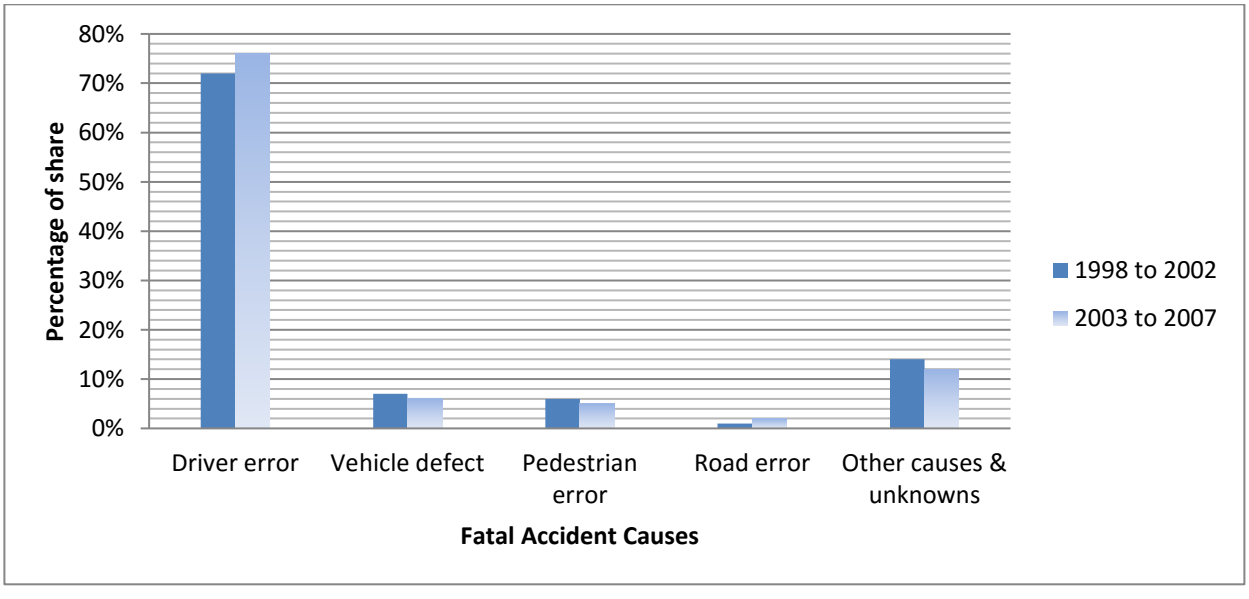
traffic accedent specifically focusing on Addis-Adama expresssway using both descriptive and emperial assessments.

1.1 Overview of Traffic Accident in Ethiopia

The 2011 traffic accident report of the Ministry of Transport National Road Safety Council indicated that next to pedestrians (51%), passengers' accident ranks second, accounting 46% of fatality. Of the total traffic accidents, 93% of the cases were associated with human factors, 5% accounted for vehicle factors, and 2% were associated with road related problems. Similarly, the Ethiopian Federal Police report of (2011) stated that road accident level of the country is one of the worst in the world, as expressed by per 10,000 vehicles. Moreover, the report stated that majority of road accidents were concentrated in Addis Ababa, which is the capital city of Ethiopia, and Oromia region, accounting 58 percent of all fatalities and two-third of all injuries.

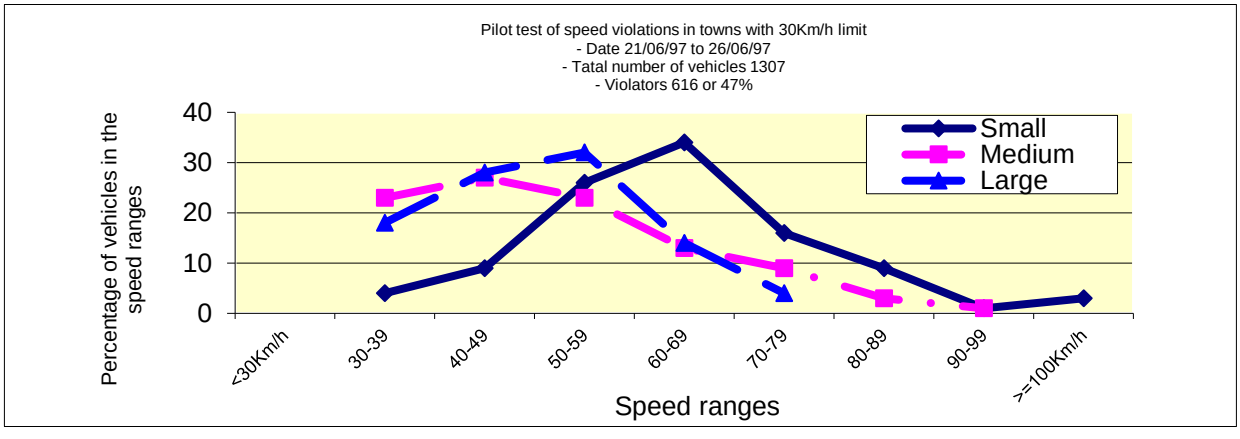
A five-year (2003 to 2007) average traffic accident record of the Federal Police Commission show that, of the total fatal accidents, 76% were caused due to drivers' error, 6% due to vehicle technical problems, 5% due to pedestrian error, 2% due to road defects and 12% due to other factors. This indicates that drivers' error has been contributing to majority of the road accidents in Ethiopia (Minister of Transport, Febraury, 2011).

Figure 1: Causes of fatal accidents for the periods 1998 to 2002 and 2003 to 2007



The report further indicated that problem of road defects as a direct cause of accident was very low. The summary report of the Federal Police Commission also shows that 82% of the accidents occur on straight and level roads with good surface, while 83% of all the accidents were occurred on good asphalt roads. During the last five years, the ratio of people who injured as a result of traffic accidents (fatal, serious and light) includes 48% pedestrians, 45% passengers and 7% drivers. This all facts show that majority of traffic accidents have been caused by poor driving skill or negligence towards traffic rules and regulations. This conclusion can be further supported with report prepared by Minister of Transport on pilot radar control program, which was conducted in East Shewa Zone of Ethiopia, indicating majority of drivers do not respect the speed limit rule of the road. The graph below shows that speed violation in some cities and towns is sometimes up to three times higher than the posted legal limit (Minister of Transport, Febraury, 2011).

Figure 2: Speed Violation in East Shewa Cities and Towns



In Addis Ababa, road traffic accidents have been creating about 4 fatalities in 5 days. This means that there is approximately a chance of 0.8 x 10–6 for an individual to fail into traffic fatalities every day (Samson, June 2006). As per the same report, which was prepared using road crash data collected from the Federal Police Commission, the underlying reasons for road traffic accidents were:

1. Improper behavior or low skill of drivers, which is associated with:
   - ✓ Drivers not respecting pedestrian priority
   - ✓ Over speeding

- ✓ Unsafe usage of freight vehicles for transporting people (shows improvement over the last 5 years)
- ✓ Over loading of passenger or improper loading
- ✓ Unsafe overtaking

2. Poor technical conditions of vehicles (shows improvement over the last 5 years)
3. Animals and carts using the highways
4. Pedestrians not taking proper precautions (shows improvement over the last 5 years)
5. Poor traffic law enforcement
6. Poor emergency medical services and
7. Safety consideration not sufficiently addressed during roads developments

Overview of the above assessment of road traffic accidents in Ethiopia indicated that majority of traffic accidents have been registered in major towns and cities where there is large number of vehicles. As a result, road traffic accident, especially in the main and city road, is now a major concern for the government and institutions working on road safety as well as the public in general. These shows that the challenges of traffic accident in major towns and cities require focused and coordinated effort to curb the problem at hand. In this regard, researches conducted on this area contributes more in identifying areas that needs special focus and proposing adequate solution for the problems.

1.2.Overview of Traffic Accident of Addis Ababa – Adama Expressway

Addis Ababa-Adama Expressway is the only expressway that connects Addis Ababa with the eastern part of Ethiopia. It is the first expressway in Ethiopia as well as in East Africa. It is also the first toll (charge) road in the nation. Toll gates are installed at Addis Ababa and Adama, as well as at the six interchanges connect the expressway with Dukem, Bishoftu and Modjo towns. Total road section contains 43 Overpass Bridge and 34 under Pass Bridge with in 19 entrance station and 29 exit station. It also covers a total of 31m width with a total of six lanes. The road also contains 3.5m width of medians and 2.5m shoulder. The road was opened for traffic in September 14, 2014, with an AADT of 30,000. These AADTs are high when compared to other Trunk Roads in the country. The modes of transport system allowed on Addis Ababa - Adama expressway is categorized as motorized. These modes of transport include Automobile, Pickup, Medium Truck, Truck, Trucker, Minibus, Medium Bus, Liquid Cargo and Other motorized

transport. The expansion and modernization of business activities in the country started to increase the use of motorized transport, which facilitates the integration between cities. Despite these changes, there have been no assessment made on the accident level of the road and no research has been conducted to identify the causes of road traffic accidents before. Even if the condition of the road and its traffic accident level were assessed, further assessment should be made to enhance public awareness. As a result, the road segment needs to be considered for an in-depth investigation due to its highest rate of traffic accident record during this short period of time.

The recent road safety record of Addis Ababa - Adama Expressway is also alarming the severity of the situation and calling for an integral effort of all pertinent stakeholders to reverse the trend. Data collected from the enterprise managing the road indicated that, on average, about 417 road crashes were reported in the past one and half years, i.e. since the road start giving services. A mixture of public and private operators is predominantly uses the expressway to transport goods and services from Addis Ababa to Adama and vice-versa. It is also important to identify the reason why traffic accident is high on this road and proposes their counter measures to curb the level of traffic accidents on Addis Ababa–Adama expressway through evaluating the accident frequency on the road section where there is high traffic accident comparing to efficiency and performance of the road.

1.3. Statement of the Problem

Road transport is one of the service sectors that contributed to human death, injuries as well as related property damage. A road traffic crash usually occurs on vehicles travelling on public road or highway. Commonly known types of crashes include collisions between vehicles, vehicles with animals, vehicles with pedestrians, or vehicles with other fixed objects. Despite its type, national or international, road traffic crashes is common problem for all nation and requires detail assessment to take proper measure that help to minimize the consequences of the problem.

Addis Ababa-Adama Expressway is one of the first class roads in Ethiopia with significant road traffic accident in the past one and half years. Data collected from the Ethiopian Toll Road Enterprises shows that there has been around 417 road crashes during the past one and half years, i.e. since the road start giving services. This problem started to alarm the need for undertaking coordinated effort to curb the problem. Despite is fact, there have been no assessment made on

the accident level of the road and no research has been conducted to identify the causes of these traffic accidents. This research is therefore motivated by the research gap on the area and focuses on identifying the causes of traffic accident, location and their consequence and proposes possible measures that help to minimize the level of traffic accident on Addis Ababa - Adama Expressways.

1.4. Objectives of the Study

1.4.1. General Objective

The overall aim of this research is to examine possible causes of road accidents and propose countermeasures for Addis Ababa-Adama Expressway;

1.4.2. Specific Objectives

The specific objectives of the study are:

- ✓ Assess and identify locations with black spot;
- ✓ Describe the major factors that contribute to traffic accidents; and
- ✓ Propose possible countermeasure that help to minimize the level of traffic accident

1.5. The Scope of Study

The study was limited to Addis Ababa-Adama Expressway, which runs from Addis Ababa through Tulu Dimtu Customs checking point to Adama and connects Adama to Awash road. The study site (road) has a total length of around 77 kilometers. The research also basis its assessment on the data collected for the period of one and half years since September 2014/15 - February 2016. The study mainly focuses on identifying black spot and/or sections along the route with high number of traffic accident and assess determinant of traffic accident on the expressway. It also proposes countermeasures for those sections/ black spots identified during the study.

1.6. Significance of the Study

As stated earlier, road traffic accidents have been increasing from time to time. Despite improvement made on the road services through developing modern expressways during the past one and half year, the level of accident registered on the expressway have been large and no effort was made to identify the root causes of the problem and propose possible solutions for the

past one and half years. This research and its findings are important for the following major reasons.

- ✓ The study will help to create awareness for road user about severity of traffic problems. Because as a road user they can contribute their own part in reducing road traffic accidents.
- ✓ The study will supplement the existing literature of road traffic accidents that will work to assess the situation of road traffic accidents in Ethiopia.
- ✓ The study assess existing situation and communicate readers how to act while using express roads and save their life and property through notifying the severity of road accidents on different part of the road segment.
- ✓ The study proposes prevention and protection measure that help policymakers, transport authorities, road engineers, and other concerned stakeholders to minimize road safety problems.
- ✓ The study also helps to keep the road safety through creating awareness on the areas of higher accident of road user surveillance.
- ✓ The research will also give information to those who are interested in conducting research on traffic accidents.

1.7. Organization of the Research Report

The report is organized into five (5) chapters. Chapter one focuses on the introduction to the study, which also contains the research background, statement of the problem, objectives, scope, and significance of the study. Chapter two provides a summary of the available literature in the area of safety, specifically on crash injuries, black spot and summary on model development of the crashes. The methods used while conducting the research is discussed under chapter three. In chapter four, detail analysis and characterizations of accidents were made and identification of black spot and proposal for accident model was done. In addition, analyses of black spots were undertaken in order to identify causes of accidents and propose engineering countermeasures for those black spots road section. Finally, based on the analyses, the research outcomes, conclusion and recommendation were summarized under chapter five.

CHAPTER TWO

2. REVIEW OF THE LETERATURE

Road transportation provides benefits both to nations and individual through facilitating the movement of people and commodity from place to place. Everybody travels either to work, play shop or market and etc. Even if road transport has benefit in economic and social development, it has also a considerable burden on people health–in the form of road traffic injuries, such health consequences has its own impact on human physical activities. This chapter contains review of previous studies on causes of road traffic accidents and possible countermeasures. It also identifies techniques of black spot identification and tries to develop model that help to identify determinant of traffic accident on Addis Ababa-Adama Expressway. In most cases the occurrences of traffic accidents are rare and random in space and time. Road safety and road incident reduction are related to many other fields of activity such as education, driver training, publicity campaigns, police enforcement, road traffic policing, the court system, National Health Service and vehicle engineering. As a result, road traffic accident review encompasses facts associated with transport services.

2.1. Road Crashes

Road crashes are a global problem affecting all parts of society. However, road safety has received insufficient attention at national and regional levels. As a result, traffic accident has been increasing dramatically from time to time. Some of the common reasons for this change include

- ✓ Lack of information on the magnitude of the problem and its preventability;
- ✓ Lack of political responsibility and multidisciplinary collaboration that are needed to tackle its effect.
- ✓ Lack of road safety infrastructure and quality of serviceability

This shows that, traffic crash is the result of multiplicity of factors and it is often the interaction of more than one variable that leads to the occurrence of crash. Crashes occur as a result of the interaction of different factors among which are road and traffic characteristics. Most of traffic crashes are happening due to human error. Large number of injuries and deaths that are occurring on roads does not describe the ability of drivers as alcohols and drugs affects the driver ability to

control the vehicle, which affects the concentration of derives. Studies made on the area and published on books, journals, reports and other literature share common understanding and shows that accident registered in different part of the regions are created due to factors indicated above.

According to Sonowal, accident is an event occurring suddenly, unexpectedly and inadvertently under unforeseen circumstances. It further expressed that road traffic accidents can be defined as "An accident that occurred on a way or street open to public traffic; resulted in one or more persons being killed or injured, and at least one moving vehicle was involved to (Sonowal, 2009).

Accident is defined as an error in driver-vehicle-roadway system and it must be recognized that different types of accidents are caused due to different at any given location namely, rear-end, side-swipes, head-on, night-time, bad-weather, etc. Bad weather accidents can results due to a road pavement which becomes dangerously slippery when wet or it may be due to inadequate signs for inclement weather (Kamal and et.al, 2008).

Generally, road accidents are analyzed by means of precisely defining the event involving damage to the property and/or injury to the road users, which are recorded first-hand by the police and/or emergency services (Bhat and et. al, Nov-2013). Accidents are rarely caused by a single factor. Usually, the interaction of the diverse set of factors such as roadway design parameters, road user behavior, environmental conditions, etc., cause accidents; however, one factor can be more responsible than the rest, and can easily be identified.

2.1.1. Factors influencing Road Accidents

There are four major factors influencing road traffic accident. These are:

A. **Vehicle related factors**: this may be due to inherent design limitations or defects to lack of maintenance, failure of components like brakes, tires and lighting. Visibility, speed and vehicle lighting are also important.

B. **Road related factors**: this includes pavement design and conditions, horizontal curves, insufficient lane and shoulder width, vertical curves.

C. **Road user related factors**: psychological factors of the users, alertness and intelligence, patience of driver, drivers experience and age

D. **Environmental related factors**: rain, reduced visibility, bad weather etc. heavy fog and mist and heavy rain also plays important role. Development and various factors causing road accident are described in the following sections.

Rui Garridoa report that an effective road safety management requires a good insight into the factors that are believed to be related to road traffic accidents (Rui Garridoa, 2-4 July 2014). In the area of accident severity, continuous efforts have been conducted in order to investigate the relationship between the level of severity (dependent variable) and a set of explanatory variables (Independent Variables).

2.1.2. Car Crash Types

A traffic crash is defined as any vehicle crash occurring on a public highway that is originating on, terminating on, or involving a vehicle partially on the highway. These crashes include collisions between vehicles, Collusion between Vehicles and static abject, vehicles and pedestrians or animals. Car crashes can happen at any time due to speeding, traffic gridlock, negligence or recklessness, unsafe driving and etc (Asrat, February, 2015).

A. Common Car Crash Collisions

- ✓ **Rear-end Collisions** -Rear-end collisions are very common. These types of traffic crashes are often caused by sudden deceleration (slowing down or braking). In some cases, another driver is following too closely or accelerates to a higher speed than the car in front of it.

- ✓ **Side-impact Collisions** -Side-impact collisions can cause grave injuries. Often called "T-bone" or "broadside" collisions, side impact crashes occur when the side of a vehicle is impacted. It can be impacted by the front or rear of another vehicle or in some cases a fixed object. Vehicle damage is often severe and drivers or passengers on the impacted side of the vehicle usually sustain far worse injuries than they would in another type of crash.

- ✓ **Sideswipe collisions** - Sideswipe collisions occur when two cars that are parallel touch. In many cases, the damage is only severe, as the cars have just "swiped" each other. Injuries

and damages are typically minimal, unless one of the drivers loses control of their vehicle as a result of the collision.

- ✓ **Vehicle Rollover** - Vehicle rollover crashes are extremely dangerous and frightening. A rollover occurs when a vehicle literally flips over onto its side or roof. Any vehicle can be involved in rollover crash. Often caused by sharp turns at high speed, rollover crashes can lead to serious injuries including spinal cord injuries and brain trauma.

- ✓ **Head-on Collisions** - These types of collisions are often fatal. Head-on collisions are exactly what they sound like - they occur when the front ends of two vehicles impact each other.

- ✓ **Single Car Crashes** - Crashes involving only one vehicle are also common. They occur when a vehicle strikes objects such as poles, trees, fire hydrants, and walls. In some cases they may involve pedestrians and other innocent bystanders. Single car collisions can result in driver and passenger injuries, pedestrian injuries, and often extensive property damage.

- ✓ **Multi-vehicle collisions** - Multi-vehicle collisions are sometimes referred to as "pile-ups" and often occur on busy roads such as highways and freeways. They can involve many vehicles and be the most dangerous. Vehicles can be impacted multiple times and it may be difficult to escape. It is also difficult to determine fault in these cases.

2.1.3. Causes of Crashes

Many factors result in car crashes, and sometimes multiple causes contribute to a single crash (Asrat, February, 2015). Factors include the following:

- ➢ **Driver distraction**, including fiddling with technical devices, talking with passengers, eating or grooming in the car, dealing with children or pets in the back seat, or attempting to retrieve dropped items;

- ➢ **Driver impairment** by tiredness, illness, alcohol or drugs, both legal and illegal. MADD (Mothers Against Drunk Driving) is an organization made up of the families of the dead who were killed in car crashes caused by drunk drivers;

- **Mechanical failure**, including flat tires or tires blowing out, brake failure, axle failure, steering mechanism failure;

- **Road conditions**, including foreign obstacles or substances on the road surface; making the roads slick; road damage including potholes.

- **Speed exceeding safe conditions**, such as the speed for which the road was designed, the road condition, the weather, the speed of surrounding motorists, and so on. Most authorities emphasis speed as a primary cause of crashes, although most experts agree that speed alone rarely causes a crash. Some argue in favor of speed restrictions to mitigate the consequences of crashes.

2.2. Road Environment Contributing for Traffic Accident

Road environments have impacts on occurrences of road traffic accidents. In Addis Ababa - Adama expressway, there are continuous efforts to meet the safety standards of roads through safety audit during the planning, designing, and operation stage.

2.2.1. Road Alignment

Road alignment is important factor, which affects the occurrence of road traffic accidents in terms of frequency and severity. Inconsistent horizontal alignments of roads, sharp curves and grades are known for their substantial and adverse safety impacts.

A) Horizontal Alignments

Different study shows that road accidents on horizontal curves are causes for concern in all countries. In France, over 20 percent of fatal crashes occur as a result of dangerous curves in rural areas. Crashes on bends are major problems in many developing countries, although the proportion of such crashes is dependent on both topography and demography of each country. A study in Denmark shows that about 20 percent of all personal injuries and 13 percent of all fatalities occur on curves in rural areas (Sweedler BM, August 1995).

B) Vertical Alignments

There are three main effects of vertical road alignments. These effects are closely associated with the occurrence of traffic accidents. These are excessive speeds and out-of-control vehicles on down grades, differential speed between vehicles created on both down and upgrades, and low

range of visibility that often occurs in the immediate vicinity of steep grades at the crest of vertical curves. Researchers indicated that it may be difficult for driver to appreciate the sight distance available on crust curve and he may overtake when it is insufficient for him to do so safely. This can be extremely expensive to provide safe overtaking sight distances on crust curves. However, a complete ban on overtaking would be difficult to enforce because of the presence of very slow moving vehicles, the lack of driver discipline in selecting places, poor maintenance of road marking and signs. Successive short vertical curves on straight section of road may produce misleading forward visibility (Ross silcock partnership, 1994).

The effects of vertical curve in steep grades have higher accident rates than mild ones (Berhanu. G, 2000). Grades of less than 6 percent have little effect, but grades steeper than this are associated with higher accident rates. Down grades are greater problems, particularly for truck safety than upgrades. A combination of horizontal curves under 450m and grades over 4 percent are not recommended. Poor condition of the horizontal and vertical alignments of a road can result in visual effects, which contribute to accidents and are detrimental to the appearance of the road.

2.2.2. Sight Distance

This is the ability to see ahead in order to stop safely or overtake vehicle or view approach intersection. Sight obstructions on the road, generally occur due to the presence of deep cuts, embankments, vegetation, walls and the like on the inside of the horizontal curves and intersection quadrants, and sharp crest vertical curves. Types of sight distances are: stopping, passing, intersection, and decision sight distance. These sight distances vary with design or operational speeds of road section, perception/reaction time, eye, height, object height and pavement friction. Study made in Sweden indicated that there is a decrease of accident rates with increasing sight distance; especially for single-vehicle accidents at night Study made in British reported that on rural roads sight distances shorter that 200m were relatively more likely to be found at accidents sites through their association with horizontal curves (Berhanu. G, 2000).

2.2.3. Road Cross-Sectional Elements

Various studies revealed that road cross sectional elements are the most important road related features which affect road safety. Road cross-sectional elements comprise lanes, shoulder, side slope, back slope, and clear zone.

A) Lane and Shoulder Width

Numerous studies revealed that lane and shoulder width affects run off the road and opposite direction accidents. The rates of these accidents decrease with both increasing lane and shoulder width, but the marginal effect of increasing width on accident rates decrease as either the base lane width or the base shoulder width increases. Lane width of 3.4 to 3.7 meters has the lowest accident rate and represents the balance between safety and traffic flow. The research revealed that for 3.0 meters lane it is recommendable a shoulder of 1.5 meters or greater, and for 3.3 to 3.6 meters lanes shoulders of 0.9 or greater reduces the accident rate significantly. Generally, lane width has greater effect on accident rates than shoulder width (Berhanu. G, 2000).

B) Road Side Features and Side Slopes

Roadside encroachments begin when the vehicle inadvertently leaves the travel lanes, veering toward the roadside. Most encroachments are quite harmless: the driver is able to regain control of the vehicle on the shoulder and safely return to the travel lanes. When coupled with nearby roadside hazards, however, encroachments can result in roadside accidents (Transport Research Board, 1987).

2.3. Vehicle Factors Contributing for Traffic Accident

It is not only the improvement in the standards and design of vehicles that matters, but also adequate maintenance of the vehicle during its working life. Older vehicles with mechanical defects and poor maintenance cause higher fatal injuries and property damage. For instance, studies in Britain show that about 20-30 percent of personal injury crashes involve a vehicle having some deficiency (Sweedler BM, August 1995). In most cases, defects associated with the break, tire, light and other mechanical defects are associated with crash. Size difference between colliding vehicles also affects the severity of injury, particularly in cases when heavy vehicles impact light vehicles.

2.4. Driver Factors Contributing for Traffic Accident

Study made by OECD on its member countries indicated that driver behaviors are the major contributing factor for traffic accidents. Studies in these countries show that about 80-90% of the road traffic accidents were attributed to the fault of the driver. Similarly, negligence of drivers is the main feature of traffic accident in Addis Ababa. Assessment made on the traffic accident data from the traffic police between 1993/94 - 1999/00, it is learned that driver faults account for 98%

of the causes. Drivers in the age group between 18 and 30 are responsible for 39, 36, 27 and 32 percent of the fatal, serious, and slight injuries and damage to property respectively during the specified period.

Another study made on traffic accident shows that male drivers were responsible for 84, 79, 60 and 78 percent of the fatal, serious, slight and total traffic accidents respectively. Drivers having driving experience of 2-5, 5-10 and above 10 years are responsible for 22, 20 and 28 percent of the casualties respectively. This condition negates the inverse relationship between driving experience and traffic accident. More than 70% of the traffic accidents in the city are attributed to those drivers having more than 5 years of driving experience. The other possible contributory factor for traffic accidents is the relation of the driver and the vehicle he/she drives. About 62% of damage to property, 58% of fatal, 51% of serious and 40% of slight injury accidents and about 57% of the total casualties are caused by employed drivers (Segni, April 2007).

2.5. Road User Information and Traffic Accident

Road users ought to acquire the knowledge needed to travel safely by means of formal training and their own experiences. Nonetheless, insufficient knowledge of traffic regulations, traffic signs, vehicles and other elements may be some of the factors contributing to unsafe behavior and road accidents. Road user information and campaigns are intended to reduce accidents by promoting safer behavior in traffic, by giving road users improved knowledge and more favorable attitudes towards such behavior. Also, most campaigns targeted at road accidents in general have not led to statistically significant changes in the number of accidents (Elvik and et.al, 2005).

2.6. Accident Classification

Estimation of road traffic accidents basically demands road accident statistics as a main input. As stated in the objective part of this paper one of the aim of this research is to develop proper accident definition by reviewing the most common practices internationally. In this regard assessing the definition of different category of road accident being used is very essential.

2.6.1. Current Accident Severity Definition in Ethiopia

In Ethiopia, even though a documented definition of different accident severity levels was not obtained for this study, the information obtained from the interview of some patrol and police officers shows that:

1. A **fatal accident** is the one in which one or more individuals die as a result of traffic accident within the same reporting 30 days of the occurrence of the accident.

2. A **serious injury** is one in which a victim sustains severe cuts, bleeding, breaks, and other damages which requires a medical treatment as "in-patient" in hospital.

3. A **slight injury** is the one as a result of which the victim sustains only small cuts, scratches, and other small damages which may be treated as an out-patient without requiring admission to a hospital.

4. **Property damage only** accident is the one as a result of which no person is injured only one or more vehicles involved in the accident are damaged.

Having understood benefits of costing road accidents and defining the different severity levels of accidents it is possible now to assess the various approaches available to cost road traffic accidents.

2.7. Traffic Accident Cost and Method of Analysis

Traffic accident cost refers to the economic value of damages (also called losses) caused by vehicle crashes (also called collisions, accidents or incidents). In order to analyze accident of different categories, the number of accident is weighted by the accident severity. In this case, Accident Cost (AC) is used to describe the combined effect of number and severity of accidents. Annual Average Accident Cost (ACa) is expressed in terms of Birr/year or USD/year, which is calculated with the following formula.

$$\mathrm{ACa(F+SI+LI+PD)} = \frac{\mathrm{A(F)*MCA(F)+A(SI)*MCA(SI)+A(LI)*MCA(LI)+A(PD)*MCA(PD)}}{\mathrm{t}}$$

Where:

A - Number of accident

MCA - Mean cost per accident and

t - Period of time under review

Murad Mohammed identified the traffic accident cost for Ethiopia using Human Capital Method. The result of his analysis is presented in the table below. As per the result of the study fatalities have the highest costing while property damage has the lowest costing (Murad Mohammed, October 2011).

Table 1: Accident Costing (million birr) in Ethiopia, Year 2009/10

Accident Cost in Ethiopia (million birr)			
Fatality	Series Injuries	Light Injuries	Property Damage
0.27	0.15	0.055	0.017

2.8. Concept of Black Spot

There is no universally accepted definition of a black spot. Rokytova defines black spot as location that are generally classified after an assessment of the level of risk and the likelihood of a crash occurring at a location (Rokytová J. , 2000). On the other hand, Kamal and et.al stated black spot as "a road location of limited with a high concentration of accidents" (Kamal & et.al, 2008). They also stated the cause of black spots and their remedial measures as follow.

A. Poor Visibilities - Inadequate sight distance, braking distances especially on curves are the major factors in the creation of black spots. At grade intersection, if links are not properly designed they may create visibility problem in the driver's vision. Adequate sight distance as provided by AASHTO helps drivers to safely negotiate the hazards while travelling at design speed. If there is insufficient street lighting at night, or the sun is low on the horizon, in mist, during rain, fires or storms, reduce the speed below the speed limit. These conditions reduce vision and prevent a driver from reacting in time to hazardous situations.

B. Geometric Effects - Wrong and incompatible geometric designs may lead to sever accidents. Number of black spot in the road length depends on many factors. In plan areas and straight alignment of the road, design speed, visibility, width and number of lanes, shoulders width

and conditions and median types have great effects towards the safe movement of vehicles and its service capacity.

C. **Over speeding and reckless driving** Speed is an important transportation consideration because it relates to safety, time, comfort, convenience, and economics. On account of the measures, which have been taken, the citizen has readily accepted the system of policing introduced on the motorway. The solution to over speeding and aggressive driving is to check the vehicle's spot speed on the roadway.

D. **Human errors** The key factor behind the human behavior towards road accidents is the age, profession, education and standard of living or the financial status. It has been observed that youngsters tend to be fast drivers than aged persons. Although this trend exists for both men and women, but women do not drive as fast as their male contemporaries and this habit pertains to an age of about 40 years.

E. **Vehicular conditions** Contribution of static and dynamic characteristics of vehicles cannot be denied in the analysis of black spots. Static characteristics of vehicle affecting road design are the dimensions, weight and height of driver's seat, clearance and maximum turning angle of vehicle. Whereas dynamic characteristics of vehicles affecting road design are speed, acceleration, vehicle stability, braking characteristics and some aspects of vehicle body design.

F. **Education factor** In order to effectively implement the road safety program, it is imperative to ensure that the key players possess the skills to accomplish what is required to them. The drivers should be allowed on the roads only after assuring that they have achieved an acceptable level of proficiency.

G. **Excessive encroachments** Vehicular access for residential and commercial areas involves provision of frontage access for the free flow of through traffic. The situation becomes more crucial when it is provided at primary roads. People take advantage of direct access and establishment encroachments along the access and even primary roads can often be seen. Most of the accidents occur due to land occupied along the road and excessive pedestrian's movements, parking, sellers, passenger's movements etc.

H. Accident reporting centers The planning and implementation of a comprehensive policy is a necessity in developing a countrywide strategy related to traffic management. Planning for the future is necessary, and in this context it is strongly recommended to compile all relevant information about accidents would be readily available for analysis and there by assist in decision making.

I. Provision of Traffic Calms Devices - Traffic calming has the objectives, including slowing traffic speed, reducing cut-through traffic and increasing safety of road users. Selection and implementation of specific traffic calming tool depends upon its appropriate application.

2.8.1. Expected Time Coverage for Black Spot Analysis

Different country can use expected time coverage for black spot analysis in respect to amount of accident exist repeatedly with the specified number and relative severity at specified period. As a result; accident data for the most recent 1 to 3-year period is normally used and is generally sufficient. 2 or 3 year analysis periods are more appropriate at locations with low traffic volumes, where a 1-year period may not provide sufficient information for location with low traffic volume. Accident data should only be used when there are no major changes in facility characteristics or land use. (Source: - Oregon state University, Analysis of Accident statistics http://cce.oregostate.edu/sites/cce.oregostate.edu/files/pw_accid.pdf). From a purely statistical point of view, it is favorable to have as many accidents as possible. If accidents from more than one year are added, the result would be more accidents (Kent Sjölinder and et.al, December 2001).

2.8.2. Criteria for Analyses of Black Spot

Different nations, states or researchers identify black spot area based on the number of accidents registered at specified time in particular location, and number of deaths, injuries, property damage etc. In Czech Republic, the black spot criterion is that junctions or 250 m-long road sections that are considered as black spots on condition that at least 3 road accidents with injuries occurred within 1 year or at least 3 road accidents with injuries of the same type occurred within 3 years or at least 5 road accidents of the same type occurred within 1 year (Rokytová J. , 2000). Black spot in the UK may have only five injury accidents in three years (Walmsley DA, 1998), while in city of Bangladesh may have black spot defined as having more than 10 injury accidents in a year. An accident black spot on a National Highway in Norway is defined as any place with

a maximum length of 100 meters, where at least four (4) injuries reported to the police during a four year period (Elvik, 2005).

Researchers have proposed several alternative methods for targeting and ranking black spots. However, there is no such thing as the correct ranking. Analysis of accident at individual sites:- Once the accident sites prioritized for investigation have been determined, there are usually three steps of accidents analysis, these are:

I) Preliminary Analysis- It is carried out on the accident data to understand the accident types and conditions. Collision diagrams and accident factor grids (or stick diagrams) are useful tools at this stage.

II) Site Investigation- It is carried out by specialist accident investigators to determine the exact conditions at the location. The investigation will observe traffic flows and road user behavior at the times of accidents most frequently occur, determine what other information may be required and start to define the problems associated with the location.

III) Detailed Analysis- Accidents occurring at that location is then carried out. This should include simple statistical tests to determine whether the accidents have resulted from a real increase in risk or are a result of random fluctuation. Once all black spot sites have been investigated, a prioritized list for action over the road network can be established and the implementation process set in motion.

2.8.3. Black Spot Identification Method

Based on the severity of accident different research stated different black spot identification mechanisms. The Rate – Quality – Control Method in Turkey consists of calculating three different parameters for each road section. The road section is defined as one kilometer of road (Kent Sjölinder and et.al, December 2001). The three parameters are:

- Accident rate
- Accident frequency
- Accident severity

Each of these values is compared with a critical value. If a certain road section shows higher values than the critical ones for all these three parameters, the section is considered to be a black

spot. In line with the above study, which was made for Turkey, accident severity was calculated using predetermined weight as follow. Accordingly, the severity value for road section number j is:

$$Sj = 9Ifj + 3Ibj + Idj \quad \text{..... (1)}$$

Severity = number of fatalities (f)*9 + number of injured persons (b)*3 + number of damaged vehicles (d)*1……..……..……...……. (1*)

This value can be divided by a suitable value. One such value could be the number of accidents. The relative severity value is then $Qj = Sj / Aj$, which means severity per accident. Here the assumption of Poisson-distribution cannot be used. The average value is estimated with:

$$\mathbf{Qave} = \frac{\sum_{i=1}^{n} \mathbf{Sj}}{\sum_{i=1}^{n} \mathbf{Aj}} \quad \text{..... (2)}$$

And the variance δ^2 is estimated with:

$$\boldsymbol{\delta^2} = \frac{1}{n}\sum_{i=1}^{n}(\mathbf{Qi} - \mathbf{Qave})^2 \quad \text{..... (3)}$$

The road section is considered to be a black spot, from the severity point of view, if: $Q_j > Q_c$, where; the critical value (Qc)

$$\mathbf{Q_C} = \mathbf{Qave} + \mathbf{k}\,\dot{\alpha}\,\sqrt{\boldsymbol{\delta^2}} - \frac{0.5}{L_j} \quad \text{..... (4)}$$

Where; $\frac{-0.5}{L_j}$ is a correction for continuity when approximating with the normal distribution at L_j is the length of the road section is assumed to be 1 km.

The above analysis assumes that the severity value assessment uses the following constants and parameters.

- ✓ $k\,\dot{\alpha} = 1.282$ Should be used from tα *table*, $\dot{\alpha} = 10\%$ (90% of confidence level). For more information (See Appendix 4)
- ✓ Severity value per accident should be used.
- ✓ Vehicle-kilometers should not be used in the formula. Instead road length or the number of accidents should be used, depending on which of "severity per section" or "severity per accident" that is used.

- ✓ The last term in the formula should be minus and not plus.

On the basis of the above theory, additional lists of potential black spots should be made and include road sections as soon as one parameter is above its critical value.

In addition, Kent proposes that severity should be based on weighting of accidents (that is fatal accidents, injury accidents and property damage accidents) instead of persons and vehicles. New weighting factors should be estimated and decided for each accident (Kent Sjölinder and et.al, December 2001).

As was mentioned in above statement rate-quality-control method defines a black spot as a road section that shows higher values than the critical ones. Sweroad would prefer to make three additional lists to be used in the black spot identification procedure, one for each parameter. A reason for this is that:

- ✓ Sections showing high accident rates do not often have many accidents.
- ✓ Sections having many accidents do not often have high rates.

In order to choose confidence levels in this kind of analysis, it is important to decide on the risk of making wrong decisions. Normally, a confidence level of 5% is used. This means that there is a 5% risk that a road section is considered a black spot when in fact it is not. Or said in a more understandable way, 5 out of 100 identified black spots are not really black spots. This is called type 1 error in statistical literature. These are spots where the random variations have been unfavorable during the actual period. But why do we accept to have 5 % risk? Why do we include false black spots at all and why do we not at least take a much smaller risk. 1% or 0.1% would be better than 5%.

The reason is that there is another type of error that can be made. Random variations can also be favorable for some spots. A spot can be a black spot, but due to favorable accident outcome during one year, the site is not identified as a black spot. This is a type 2 error in statistical literature. The errors are related in such a way that fewer type 1 errors give more type 2 errors.

If one really wants to be absolutely sure that almost no false black spots are included (by selecting a very low type 1 error) many real black spots will be missed. The level chosen must strike a balance between these two types of errors. The choice of 5 % by this method can be questioned and there are arguments for another confidence level, for example, 10 %. The reason is mainly that it is better to risk to include more false black spots and thereby get more real black spots.

Then it will be shown if the spots have potential for improvement or not. So the error made with a higher confidence level is that some "unnecessary" work has to be carried out for some spots. By selecting 10 % instead of 5 %, however, no serious errors are made. The only drawback is that the list to work with is extended. But also with a longer list, the work starts from the top. So having a longer list does not necessarily create more work. But, on the other hand, if a real black spot is missed, then a more serious error has been made, which cannot be corrected until new accident data is available for the next period. That is why it is better to have a 10 % confidence level than a 5 % level.

Based on the above over view of Black spot analysis mechanism it is prudent to use Accident Severity Value to prioritizing road section based on the traffic accident data recorded by Traffic Safety and Security Department of Ethiopia Toll Road Enterprises.

2.8.4. Black Spot Treatment

Treatment of black spots using low cost engineering measures is one of mechanism measures that help to reduce accidents at dangerous spots. The most popular low cost engineering measures incorporate: rumble strip, traffic signs and road markings, road light and roundabouts (Segni, April 2007).

A. Rumble Strip

It is a safety device that alerts and let the drivers to make a change on the driving operation. It consists of some repeated pattern on pavement surface, that creates vibration on vehicles when tires role over on it. Rumble strip is used to tip or alert drivers in changing geometric of the road or driver approaches to any unusual dangerous road sections or spots.

B. Traffic Signs and Road Marking

The main functions of traffic signs and road markings are to provide warnings, regulations, and guidance information for road users. Traffic signs provide a safe environment to road users by guiding drivers to directions for route finding; controlling the use of road with mandatory signs; warning drivers of any substandard or unusual features with warning signs.

C. Traffic Channelization

Traffic channelization is reducing conflicts between vehicles to vehicles and pedestrians. It facilitates correct trajectory selection; capacity increase and traffic control and maximizes driver/road communication. It also facilitates the easiness of driving processes by reducing the number of decisions that a driver must deal with at a certain place, giving him time to think of the next decision.

D. Road Lights

Road lights are intended to provide enough lighting for drivers to travel with comfort and safety during night periods or under low visibility conditions. This solution is commonly applied where there is the possibility of conflicts between vehicles and pedestrians or cyclists.

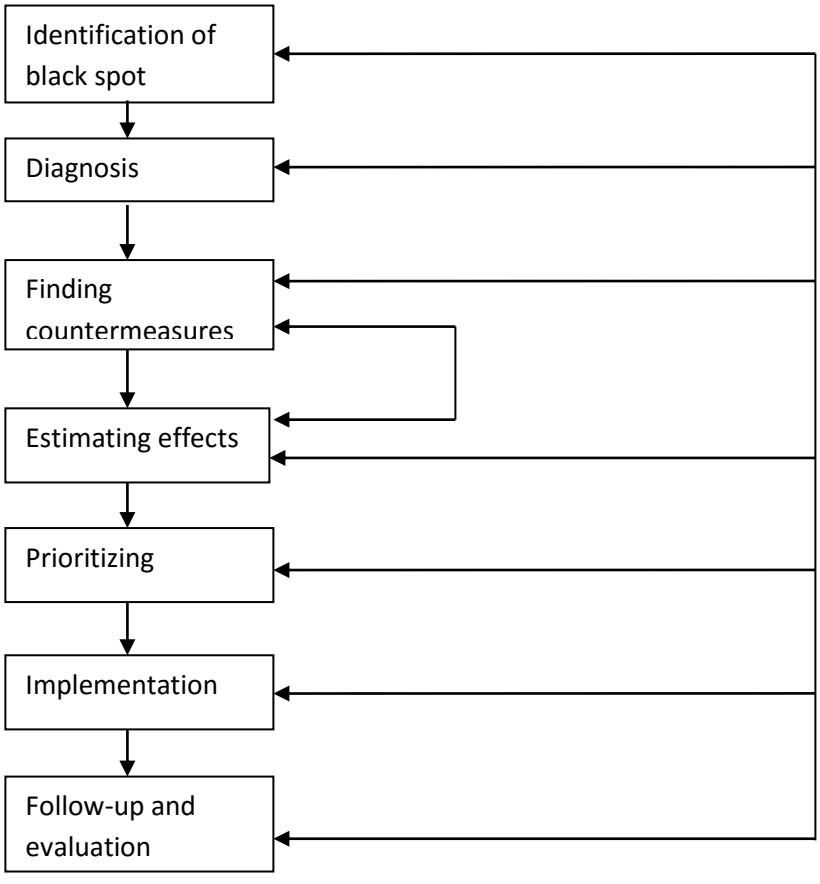
E. Round About

Roundabouts have the lowest accident rate per million vehicles as compare with all types of control. It reduces the number of injury accident by 10 to 40 percent depending on the number of legs and the provision of traffic control devices.

2.8.5. Traffic accident black spot Elimination or Reduction mechanism

The process of eliminating or improving accident black spots in a road network is composed of several activities, as illustrated in the following figure, (Karl-Olov Hedman, December 2001) (See Diagram 1).

Diagram 1: Process of eliminating or improving accident black spot in road net work



A. Identification of black spots- is the procedure to locate those spots in the road networks that are particularly dangerous.

B. Diagnosis- is the process to study what are the problems, the accident contributing factors and the deficiencies for each of the identified black spots.

C. Finding countermeasures- implies a methodical analysis to design suitable countermeasures for each black spot, based on actual problems and deficiencies.

D. Estimating effects- is the process to estimate the safety effects (and if necessary also other effects) and costs of suitable countermeasures.

E. Prioritizing- implies finding the best action plan (or investment program), according to some defined criteria, and based on estimated effects and costs as well as budget restrictions.

F. Implementation- is the actual realization of the prioritized measures included in the action plan (or investment program).

G. Follow-up and evaluation- is the last and very important step, which aim is to assess the actual results (effects and costs).

2.9. Road Accident Modeling

Road accident modeling is the way of developing accident predicting equation to forecast the future demand of the road accident based on the current crash information. So it is advisable to understand accident variables characterized as dependent (response) and independent (explanatory).

2.9.1. Types of Variables

Variables may take several forms, and it will be important later that someone aware of, and understand the nature of variables. The following variables are those which are most likely to encounter in deferent research.

1. Categorical Variables

Such variables include anything that is "qualitative" or otherwise not amenable to actual quantification. There are a few subclasses of such variables.

- **Dummy variables** take only two possible values, 0 and 1. They signify conceptual opposites: war vs. peace, fixed exchange rate vs. floating exchange rate, etc.
- **Nominal variables** can range over any number of non-negative integers. They signify conceptual categories that have no inherent relationship to one another: red vs. green vs. black, Christian vs. Jewish vs. Muslim, etc.
- **Ordinal variables** are like nominal variables, only there is an ordered relationship among them: no vs. maybe vs. yes, etc.

2. Numerical variables

Such variables describe data that can be readily quantified. Like categorical variables, there are a few relevant subclasses of numerical variables.

- **Continuous variables** can appear as fractions; in reality, they can have an infinite number of values. Examples include temperature, GDP, etc.

- **Discrete variables** can only take the form of whole numbers. Most often, these appear as count variables, signifying the number of times that something occurred: the number of firms invested in a country, the number of hate crimes committed in a county, etc.

The main goal of developing accident model is to predict the future outcomes based of the existing data of traffic accident in specified road section. Prediction of accidents is performed by analyzing the various factors (variables) responsible for accidents and quantifying their effect on the accidents using statistical techniques.

Several global studies have been carried out in the field of accident prediction modeling in the past few decades. Beginning with the pioneering effort conducted by popularly known as the Smeed's law developed in the year 1968; this is an empirical equation that relates the vehicle registration and population to the number of fatalities (Smeed, 1968).

The stability of the Smeed model for application to the various states over time was also investigated. The various models developed were compared based on the coefficients of variation (CV) using the Statistical Package for Social Science (SPSS) software. It was found that the original Smeed model overestimated the fatality rate per vehicle when applied to the Indian conditions.

To account for the probabilistic nature of accident occurrence Saccomanno and Blower have used a Poisson log linear model to explain variations in accident rates. This Poisson regression model is especially suitable for handling data with large numbers of zero counts. However, this model could be inappropriate for road accident counts, since it fails to account for extra-Poisson variation (the value of the variation could exceed the value of the mean) in the observed accidents counts. Accident severity is of special concern to researchers in traffic safety since this research is aimed not only at prevention of accidents but also at reduction of their severity. One way to accomplish the latter is to identify the most probable factors that affect accident severity.

2.4.1. Models for Polytomous Dependent Variables

Since the real traffic data nature for dependent variables is polytomous, evaluation was made to justify which model is more preferable for accident data registered by Ethiopia Toll Road Enterprises. Of course, many dependent variables of accident will have more than two possible categories. These categories might be unordered or ordered. On the basis of the survey data, overall dependent variables have polytomous nature with unordered categories (Fernando, March 23, 2011)**.** The description below emphasis on the model selected for the analysis of accident data on Addis Ababa - Adama Expressway.

Fernando states that to select a model that fits for specific data, it is necessary to consider the nature or property of the data. According to his logic different models fits different data series. In line with this fact the following models are identified with their nature as follow:

A) **Ordinal Logistic Regression**:- It is used when a dependent variable has more than two categories and the values of each category have a meaningful sequential order. It is applied where a value is indeed 'higher' than the previous one.

B) **Multinomial Logistic Regression**:- It is used when dependent variable has more than two categories and the variable is purely nominal, we can extend the dichotomous logit model, using one of the categories as reference and modeling the other responses j=1, 2, m-1 compared to the reference. Based on the above investigation and model result the overall analysis is not significant and Standardized coefficient cannot obtain.

C) **Multinomial Probit Regression**: - It is used when a dependent variable has more than two categories and the variable is really nominal, we use multinomial probit (probit). The probit in this model are for cumulative categories at each point, contrasting categories above with categories below. This model provides standardize estimated coefficient.

2.4.2. Multinomial Probit Regression Model

Multinomial probit model is a generalization of the probit model used when there are several possible categories that the dependent variable can fall into polytomous. As such it is an alternative to the multinomial logit model as one method of multiclass classification (Greene, 2012).

It is assumed that we have a series of observation y_i for i=1, 2… of the outcomes of multi way choices from categorical distribution of size m (there are m possible choices). Along with each observation y_i is a set of k observed values x_{1i}……..x_{ki} of explanatory variables (also known as independent variables, predictor variables, features etc)

The multinomial probit model is a statically model that can be used to predict the likely outcome of an unobserved multi way trial given the associated explanatory variables. In the process the model attempts to explain the relative effect of differing explanatory variables on the different outcomes. Formally the outcomes y_i are described as being categorically distributed data. Where each outcomes value h for observation i occurs with an unobserved probability that is specific to the observation i at hand because it is determined by the values of the explanatory variables associated with that observation. That is

$$Y_i \backslash x_{1i} \ldots\ldots\ldots\ldots\ldots x_{ki} \approx catagorical\,(P_{i1} \ldots\ldots\ldots\ldots P_{in}), for\ i=1,2,\ldots\ldots\ldots\ldots\ldots,n$$

Or equivalently

$\Pr[Y_i = h \backslash x_{1i} \ldots\ldots\ldots, x_{ki}] = Pih, for\ i = 1,2, \ldots\ldots\ldots, n$ For each of m possible values of h

Multinomial probit is often written in terms of a latent variable model

$$Y_i^{1*} = \beta_{1*} X_i + \varepsilon_1$$

$$Y_i^{2*} = \beta_{2*} X_i + \varepsilon_2$$

……

$$Y_i^{m*} = \beta_{m*} X_i + \varepsilon_m$$

Where;

$$\varepsilon \sim N(0, \sum)$$

Then

$$Y_{i=} \begin{cases} 1 \quad if\ Y_i^{1*} > Y_i^{2*} \ldots\ldots\ldots Y_i^{m*} \\ 2 \quad if\ Y_i^{2*} > Y_i^{1*},\ Y_i^{2}, \ldots\ldots\ldots Y_i^{m*} \\ \ldots\ldots \quad \ldots\ldots.. \\ m \quad otherwise \end{cases}$$

Some researchers prefer probit to logit because standardized coefficients can be obtained. With Multinomial probit analysis, there is no odds ratio, but researchers often use the standardized coefficient for competition of odd ratio. To make the assessment more informative the above general overview can be expressed as predicting equation Y_{hat} as follow:

$$\hat{Y}_{im} = \hat{\beta}_m + \hat{\beta}_1 X_{1m} + \hat{\beta}_2 X_{2m} + \cdots \ldots \ldots \ldots + \cdots \ldots \ldots . + \hat{\beta}_i X_{im} + \varepsilon_{im}$$

Where;

$\hat{Y}_{im}$ – Dependent (predicted) variable

$\hat{\beta}_m$ – Constant

$\hat{\beta}_i$ - Intercepts; for i = 1, 2, 3……

X_{im} - Independent variables

ε_{im} – Error term

2.5. Factor Identified for Developing Road Accident Model

In general, the number of crashes is affected by three factors (Sayed & Abdelwahab, 1998)

1. The road environment
2. The condition of vehicles using the road system
3. The skills, concentration and physical state of road users.

CHAPTER THREE

3. RESEARCH METHODOLOGY

This chapter covers the methods used to undertake the research. To attain the objectives of the study, the different methods applied for study is summarized and incorporated in this section. Accordingly, this chapter deals with data source and collection techniques, data analysis techniques, and interpretation of results. Details of these techniques are presented as shown below.

3.1. The Study Site

The study site is part of Addis Ababa-Adama expressway that starts from Tulu Dimtu Customs checking point ends on the east side of Adama that connects Adama Awash road. It has a total length of 76.3 kilometers. It has nineteen entrances and twenty-nine exist. The entrances gate serve for receiving bills while the exits use for charging services. The charge for the transportation can be paid based on tonnage of vehicles, quantity and distance covered. The number of wheels as well as the height of vehicles is considered for service charges. On the two way of the road, there are three lanes on each side that serve for those vehicles traveling with 60-80 km/hr, 80-100 km/hr and above 100 km/hr driving speed. The expressway can also serve for those nearby towns as an entrances and exit, Tulu Dimtu custom check points 16km Dukem, 33km Bishoftu, 52km Modjo, 60A and 60B Adama and 64km Welenchity. The road section incorporates road Lay By with an interval of 3km that serve the road user during emergency cases and to take rest. The routes pass through fertile lands that are suitable for agriculture. Products like large scale flower farmers, crops and other plants are produced along the sides of the road. The road is also a link between the capital cities with neighboring country and facilitates transactions of sea ports and support movement to recreation centers.

3.2. Data Source and Collection

Traffic accident data on expressway have been collected and recorded by the traffic patrol assigned by Ethiopian Toll Road Enterprises. As a result, the raw data used for this research is obtained from the Traffic Safety and Security Department of Ethiopia Toll Road Enterprises. The overall data covers a period of one and half year (September 2014 to February 2016). Some theories developed on similar topic indicated that the data used for analysis of accident depends

on the length of time for which the data is collected. Kent & et. al. (December, 2001) expressed their view on black spot determination by stating that data for 1 year and above is sufficient to undertake study on traffic accident and identify black spot on the road. In line with this fact, it is possible to say that the amount of data collected for the study is sufficient to undertake the study. Similarly, studies made in Bangladesh and Czech Republic indicated that one year and above data can be used for black spot and accident related analysis (Rokytová J. , 2000). From the above studies it is possible to understand that, though it is advisable to use data of three years and above to undertake such research, in case where there is no sufficient data on the area it is possible to use less than three years data for similar analysis. Accordingly, the research used all the data available since the expressway started operation.

The road traffic accident data collected from Traffic Safety and Security Office incorporated all relevant information including their cause, locations and types of accident in addition to number of fatalities, injuries and property damage in detail for the study period of one and half year. In order to collect reliable data and ensure proper compilation, a road traffic accident form was prepared and used during data collection. This data was further compiled using spread sheet so as to ensure proper analysis. However, the traffic accident data obtained from the enterprises do not shows the relationship between crash and geometrical design of the road system, like horizontal alignment, vertical alignment, ramp geometry of interchanges, etc. Rather, the data was recorded as daily event. Though road geometry has an effect on occurrence of road accident, the study road under consideration is high standard. As a result, the researcher was unable to get data on geometrical design. Therefore, the study used the data as recorded by the enterprise to draw logical conclusion.

To organize the data for various analyses and investigations, road traffic accident database was established using excel and used for the study. Data collected from the enterprises shows that, around 417 road crashes were registered on the expressway during the study period. All accidents were properly identified and registered. Furthermore, to determine the location of accident spot, each accident location was measured by the enterprise up to the accidents spot using available measurements.

A. Traffic Accident Data

All road sections are found on non built–up areas (rural) areas. To acquire reliable data, a road traffic accident form was designed. The form has the following major characteristics and these features are used for capturing data.

- ✓ Date, day and time of accident,
- ✓ Vehicle type
- ✓ Vehicle Plate number
- ✓ Accident type,
- ✓ Degree of severity, and
- ✓ Accident Causes
- ✓ Collusion types
- ✓ Number of victims (passenger)
- ✓ Location of accident,
- ✓ Direction of flow

B. Traffic Data

Traffic data is required to undertake analysis of road safety problems for roads under consideration. These data is helpful in determining the type of measures that is applicable at the site. Besides, the result of traffic counts and compositions is used as one of the inputs or yardsticks to develop criteria in delineating the road under study. Since the expressway registers the volume of traffic digitally, there is no need to undertake field traffic count.

Vehicle is defined as carriage, chariot, bicycle, motor vehicle, semi-trailer and trailer operated on a road (Council of Addis Ababa City Government, 1998). In case the study classified vehicles into nine groups. These are Automobile, Pickup (up to 10 quintal), Minibus (up to 12 seats), Medium Bus (13-45 seats), Large Bus (above 46 seats), Medium Truck (11-40 quintal), Truck (41-100 quintal), Trucker (above 100 quintal), and Liquid Cargo. The research used vehicles classification as Automobile, Pickup and Medium Truck (10 up to 40 quintal), Minibus and Bus (12 up to 46 seats), Truck and above (41-100 and above quintal) for model development.

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3.3. Research Approach

Both qualitative and quantitative research technique is used to systematically investigate the facts behind traffic accidents and to discover and analyze events, behaviors, or facts to draw logical conclusion that help to draft applicable rules, laws and theories for the area. As it is documented in different literatures, there are three main types of research approaches. These are:

1. **Explanatory Research:** It is a research that helps to test hypotheses and theories that explain how and why a phenomenon operates.
2. **Constructive Research:** It is a type of research used to develop a new solution to a problem.
3. **Empirical Research:** It is a type of research that provides empirical evidence on the feasibility of an existing solution to a problem.

In this particular study, the intention of the research is to design appropriate techniques that help to solve the problem of road traffic crash that have been created on Addis Ababa-Adama expressway. As a result, this study can be categorized partly as empirical research, since it uses empirical technique to show the level of traffic crash in Addis Ababa-Adama Expressway.

3.4. Model Selection

Different models uses different data set to effectively perform analysis and draw logical conclusion. Researches made on this area indicated that Binary Logistic Regression requires dummy variables to run the model. Ordinal Logistic Regression requires ordered polytomous data to run the model and execute the data. On the other hand, Multinomial Logistic and Probit regression requires nominal polytomous data to function properly. Given the nature and properties of data collected from Ethiopian Road Tall Enterprise, which has nominal and polytomous nature, the study preferred the use of multinomial probit regression model. The main benefit of using this model is that it gives cumulative standardize estimated coefficient for each parameter.

3.5. Variables Definition

Depending on the objective of the study and the type of data collected from the enterprise, the study identified the following independent and dependent variables to be used for research under consideration.

3.5.1. Independent Variables

- Day of the week related variables (Monday, Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday) for further analysis of model the research use day of the week as (Monday – Friday, Weekend)
- Time of Day (Day Time, Night Time)
- Accident Causes related variables (Unethical Driving, Technical Problem and Sleeping Problem)
- Collusion related variables (Crash Vehicle to Vehicle, Car Overthrow, Crash Vehicle to Static Object)
- Vehicle types related variables (Automobile, Pickup (up to 10 quintal), Minibus (up to 12 seats), Medium Bus (13-45 seats), Large Bus (above 46 seats), Medium Truck (11-40 quintal), Truck (41-100 quintal), Trucker (above 100 quintal), and Liquid Cargo) for further model analysis the research used vehicle types related variables as (Automobile, Pickup and Medium Truck, Minibus and Bus, Truck and above).
- Vehicular Direction of flow related variables (To Addis Ababa, To Adama, To Dukem, To Deberezeyit, To Modjo and To Welenchity)

3.5.2. Dependent Variables

In line with the objective of the research, the dependent variable is Accident. This variable can be expressed categorically in terms of variables like Fatality, Series Injuries, Light Injuries, and Property Damage.

3.6. Method of Analysis

3.6.1. Descriptive Analysis

The traffic accident data collected from the enterprise is analyzed and characterized using descriptive analysis to examine the relationships among variables and to identify possible source of cause and contributing factors. This helps to know which accident variables frequency are significantly higher compared to crashes of other relative variables. In spite of this, accident frequency can be used to analyze the relationship between accident variables. Accordingly, graphs, charts, tables etc are used to support the findings and give logical meanings for the output, which can help for realization and clear interpretation.

3.6.2. Statistical Analysis

In order to characterize the populations of crash, statistical analysis will be applied to determine the uniformity of the collected data. Statistics is the science and art of experimenting, collecting, analyzing, and making inferences from data. The following are most of Statical analysis approach for this study.

A) Severity Index

A widely used statistics for the description of relative crash severity is the severity index (SI), defined as the number of fatalities per crash or the number of Injuries per crash. Crash severity index is used for assessing the level of severity between accident variables. This approach is widely used for analysis of relative severity of crashes. This analysis fill the gap created on accident frequency, which expresses only the number of accidents registered on the expressway. Unlike accident frequency, crash severity index provide the severity of each crash relative to accidents registered during a specific time. Mathematically, Crash Severity Index can be expressed in terms of the following relation.

$$\text{Seveity Index (SI)} = \frac{\text{Number of Injuries}}{\text{Total Number of Crash}} \text{ or } \frac{\text{Number of Death}}{\text{Total Number of Crash}} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

B) Accident Cost

In order to identify the weighted value for accident severity of Addis Ababa – Adama expressway, it is important to define the cost of accident in Ethiopia. However, there is no cost of accident developed for year 2016 in Ethiopia. As a result, based on accident cost developed by Murad Mohammed (2011) it advocates the study further increased the 2011 values by 10% per annum considering inflation, average increase in wages or real changes GDP for the consecutive six (6) year 2010-2016 for identifying weighted value for accident severity (World Bank/IMF., 2003). In this case, Accident Cost (AC) is used to describe the combined effect of number and severity of accidents. Annual Average Accident Cost (ACa) is expressed in terms of Birr/year or $/year, which is calculated with the following formula.

$$\text{ACa(F + SI + LI + PD)} = \frac{\text{A(F)}*\text{MCA(F)}+\text{A(SI)}*\text{MCA(SI)}+\text{A(LI)}*\text{MCA(LI)}+\text{A(PD)}*\text{MCA(PD)}}{\text{t}}$$

Where:

A - Number of accident

MCA - Mean cost per accident and

t - Period of time under review

On the basis of the above analysis, the estimated accident cost for the year 2016 is presented in the table below. Accordingly, the highest accident cost is assigned for fatalities and the lowest accident cost is attached for property damage only.

Table 2: Accident cost in Ethiopia for year 2016 (million birr)

Accident Cost (million birr)			
Fatality	Series Injuries	Light Injuries	Property Damage only
0.47	0.26	0.097	0.03

Sources: (Murad Mohammed, October 2011)

These values are proposed to be used for estimating the weighted value for accident severity and the annual average accident cost of the expressway. Accordingly, the Addis Ababa – Adama expressway trunk road accident cost for death, serious injuries, light injuries and property damage is estimated below based on the above accident costing.

Table 3: Accident Coasting for Addis Ababa – Adama expressway (million birr)

Item	Fatality	Series Injuries	Light Injuries	Property Damage Only
Total	37	65	183	387
Accident Cost (Million birr)	0.47	0.26	0.097	0.03
Total Accident Cost (Million birr)	17.39	16.90	17.75	11.61

On the basis of the above result, the total accident cost for the expressway for the past one and half year is 63.65 million birr or 3.03 million $; where 17.39 million birr for fatality, 16.90 million birr for serious injuries, 17.75 million birr for light injuries, and 11.61 million birr for property damage. Accordingly, the annual average accident cost of Addis Ababa - Adama Expressway is estimated as Birr 42.43 million or $2.02 million (estimated with an exchange rate of Birr 21.00 for $1). This implies that Ethiopia cost around 43 million birr per year due to the

occurrences of accident on the expressway. As result the number of accident is weighted by the accident severity as follow:

Table 4: Weighted value for Accident Severity for Addis Ababa – Adama expressway

Accident	Fatality (F)	Serious Injuries (SI)	Slight Injuries (LI)	Property Damage only (PD)
Accident cost (million birr)	0.47	0.26	0.097	0.03
Weighting Value	15	8	3	1

The estimation result of the above analysis is used for black spot analysis using accident severity method as stated by Kent and et al. The section below shows how accident severity is estimated using the same method.

C) Accident Severity

The research also uses black spot analysis of traffic accident using rate quality control method (Kent Sjölinder and et.al, December 2001). To prioritize those black spots in Addis Ababa – Adama expressway, the ratios of accident costs to degree of severity were estimated using accident cost developed for Ethiopia. As a result, approximately the weight value for fatal accident is 15, for serious injury is 8, for slight injury and property damage are 3 and 1 respectively on Addis Ababa – Adama expressway. To come up easy identification of black spot, the research preferred to use severity value for each road section number j is calculated using:

$$\mathbf{S_J = 15F_j + 8SI_j + 3LI_j + PD_j} \quad \text{..... (2)}$$

Where:

S_J = Severity Value

F_j = Number of Fatality (Death)

SI_j = Number of Serious Injuries

LI_j = Number of Light Injuries

PD_j = Number of Property Damage

The result of the above model can be divided by a suitable value, the number of accidents. The relative severity value is then $Q_j = S_j / A_j$, which means severity per accident. The average value of severity per accident was estimated with:

$$\mathbf{Qave} = \frac{\sum_{i=1}^{n} S_j}{\sum_{i=1}^{n} A_j} \quad \text{..... (3)}$$

The variance δ^2 of the severity value is estimated with:

$$\boldsymbol{\delta^2} = \frac{1}{n}\sum_{i=1}^{n}(Q_i - Q_{avg})^2 \quad \text{..... (4)}$$

On the basis of the above severity computation, the location of black spot is found if: $Q_j > Q_c$, where; the critical severity value (Qc) is:

$$\mathbf{Q_c = Q_{avg} + k\dot{\alpha}\sqrt{\delta^2} - 0.5/Lj} \quad \text{..... (5)}$$

At Lj is 1km and $k\dot{\alpha} = 1.282$ Should be used, $\dot{\alpha} = 10\%$ (90% of confidence level). For more information (See Appendix 4).

$$\mathbf{Q_c = Q_{avg} + 1.282\sqrt{\delta^2} - 0.5} \quad \text{..... (5.1)}$$

D) Empirical Estimation Using Multinomial Probit Regression Model

On the basis of the nature of the data, the research used Multinomial Probit Regression model to assess the determinants of accident on Addis Ababa – Adama expressway. This means, empirical regression technique is used to identify factors contributing for road traffic accident. Multinomial Probit Model uses several possible categories that the dependent variable can fall into polytomous. In order to analyze the data, the study used Statical Package for Social Science (SPSS) software.

The model assumes that there are a series of observation (dependent variable) A_i for i=1, 2…6, Along each observation, A_i, there is a set of 8 observed values TD_1, ….., DF_8 of explanatory variables. The output A_i is categorically distributed data, which is analyzed using the following regression equation.

$$A_i \backslash TD_i \ldots\ldots DF_i \approx \text{catagorical}\,(P_{i1} \ldots\ldots P_{in}), \quad \text{for } i=1,2,\ldots\ldots,n$$

Multinomial probit is often written in terms of a latent variable model as stated below.

$$A_i^{1*} = \beta_{1*} TD_i + \varepsilon_1$$
$$A_i^{2*} = \beta_{2*} B_i + \varepsilon_2$$
……
$$A_i^{8*} = \beta_{8*} DF_i + \varepsilon_8$$

Where;

$\varepsilon \sim N(0, \sum)$

In order to predict the severity of accident, it is possible to express the model as:

$$A_i = \begin{cases} 1 & if\ A_i{}^{1*} > A_i{}^{2*} \dots\dots\dots A_i{}^{4*} \\ 2 & if\ A_i{}^{2*} > A_i{}^{1*}, \dots\dots\dots A_i{}^{4*} \\ 3 & if\ A_i{}^{3*} > A_i{}^{1*}, \dots\dots\dots A_i{}^{4*} \\ 4 & if\ A_i{}^{4*} > A_i{}^{1*}, \dots\dots\dots A_i{}^{3*} \end{cases}$$

Based on the above relationships, the model that helps to predict road traffic accident can be defined as a predicting variable A. The relationship of the variables is analyzed using probit model as follow.

$$\mathrm{A} = \beta + \beta_1 \mathrm{TD} + \beta_2 \mathrm{B} + \beta_3 \mathrm{DW} + \beta_4 \mathrm{TV} + \beta_5 \mathrm{CT} + \beta_6 \mathrm{AC} + \beta_7 \mathrm{PNR} + \beta_8 \mathrm{DF} + \varepsilon$$

Where: TD, B, DW, TV, CT, AC, PNR, DF; are independent variables; and A is dependent variable. In addition, A- Accident, TD- Hourly Distribution, B- Brightness, DW- Day of the Week, TV- Types of Vehicle, CT- Collusion Type, AC- Accident Cause, PNR- Plate Number Region, and DF- Direction of Flow (See Appendix 4, Table 11)

3.7. Model Specification Test

In order to check the appropriateness of the variables and validate the applicability of the model multicollinearity test was made using correlation coefficient and learned that the relationship between most of the variables are not significant, with a coefficient of less than 0.8 indicating the variables can be used for further analysis (See Table 5).

Table 5: Correlation Matrix for TD, DW, DF, TV, CT, AC, A, PNR, AL

Correlation Matrix									
Variables	**Time of Accident**	**Day of the Week**	**Direction of Traffic Flow**	**Types of Vehicles**	**Accident Types**	**Accident Causes**	**Accident**	**Plate Number Region**	**Accident Location**
Hourly Accident Distribution	1.000	-.093	-.059	.082	.057	-.138	-.072	-.011	-.059
Day of the Week	-.093	1.000	.163	-.030	-.016	-.008	-.055	.009	.049
Direction of Traffic Flow	-.059	.163	1.000	-.028	-.005	.078	.052	-.031	.527
Types of Vehicles	.082	-.030	-.028	1.000	-.154	-.044	-.224	.369	-.176
Accident Types	.057	-.016	-.005	-.154	1.000	-.058	.102	-.086	-.081
Accident Causes	-.138	-.008	.078	-.044	-.058	1.000	-.003	-.088	.079
Accident	-.072	-.055	.052	-.224	.102	-.003	1.000	-.067	-.013
Plate Number Region	-.011	.009	-.031	.369	-.086	-.088	-.067	1.000	.018
Accident Location	-.059	.049	.527	-.176	-.081	.079	-.013	.018	1.000

CHAPTER FOUR

4. RESULTS OF ANALYSIS AND DISCUSION

4.1. Characteristics of Accidents

In order to identify black spots and develop model of accident on Addis Ababa – Adama expressway, it is important to look for the characteristics of the total accidents registered on the road. In this case, the accident database for the Addis Ababa-Adama Expressway include all accidents reported by the Traffic Safety and Security sectors around 77 km long road for the period September 2014 to February 2016. Accordingly, a total of 417 traffic crashes were reported during the stated period. As a result of these crashes over 672 accidents were registered in the expressway. Out of these accidents human injuries is accounted for 285 and 387 property damage. Of the total human injuries, 37 were fatal, 65 and 183 were serious and slight injuries respectively.

To have better understanding, it is important to see the accident distribution in relation road sections. Accordingly, accident frequency analysis is made to identify the characteristics of the accidents and identify which variable is more responsible for the occurrence of crash relative to total accident frequency. Accident frequency provides rough estimation for exhibiting crash promoting factor. However, it cannot provide which parameter is severely contributing for road crash relative to the rest variables. In order to differentiate the level of severity of crash across the road, there are options of using Number of Death per Crash and Injuries per Crash. The following figures and tables provide descriptions on the level of accidents using normal distribution.

4.1.1 Causes of Accidents

Traffic accident can be caused by internal or external factors. Internal factors include technical faults of vehicles and drivers while external factors include road condition and road users. In line with the above facts, analysis results of the study indicated that the major causes of traffic accident on Addis Ababa – Adama Expressway associated with Unethical Driving (problem with sight distances, phone usage during driving, drug usage and etc) behaviors, accounting 59.8% of the total accidents. This shows that drivers are the major causes of traffic accidents due to unethical behavior on the use of roads (See Table 6).

Table 6: Causes of Accidents related variables

Sr. No.	Accident causes	Frequency	Percent
1	Unethical Driving	402	59.8
2	Technical Problem	251	37.4
3	Sleeping Problem	19	2.8
	Total	672	100.0

While looking at the number of injuries per crash, majority of them were emanated from Technical Problem of vehicles. The result of the analysis clearly identified that among the total three causes of accident technical problem constitutes highest mean 0.606 followed by unethical driving with a mean of 0.586. On the other hand, the rate of death per crash due to Unethical Driving is the highest of all the causes of accident with a mean of 0.121. These show that human behavior is critical for minimizing the level of accidents happening on the expressway.

Table 7: Causes of Traffic Accidents and their level of Impacts

Accident Cause	No. of Death	No. of Injuries	Total No. of Crashes	Mean of Injuries Per Crash	Mean of Death Per Crash
Unethical Driving	29	140	239	0.586	0.121
Technical Problem	8	100	165	0.606	0.048
Sleeping Problem	0	7	13	0.538	0.000
Total	8	107	417		
Average	2.667	35.667	139		

4.1.2 Accident Distribution over Time

Traffic accidents usually happen spontaneously over time due to external and internal factors. In line with this fact, the distribution of traffic accidents are analyzed for the Addis Ababa – Adama expressway and the study identified the following result.

A. Level of Traffic Accidents over Days of the Weeks

The frequency of accident high Monday - Friday within a percentage of 72.9 that followed by Weekend with a percentage of 27.1 (See Table 8).

Table 8: Daily Traffic Accident Frequency

Sr.No.	Day of the week	Frequency of Accident	Percent
1	Monday - Friday	490	72.9
2	Weekend	182	27.1
	Total	672	100.0

While looking at both the number of injuries per crash and death per crash, majority of them were recorded on Weekends. The result of the analysis clearly identified that weekend constitutes highest mean of 0.606 and 0.147 consequently. These shows that day of the week are critical determinant factor of accidents happening on the expressway (See Appendix 1, Table 3).

B. Hourly Variation of Accident

Subject to the results of the analysis, large number of accidents was recorded in the Afternoon between 6:01-12:00 Am with a percentage of 49.6. The lowest number of accidents was registered in the 18:01-24:00 Pm with a percentage of 12.9.

Table 9: Hourly Traffic Accident Frequency

Sr.No	Timely Variation	Frequency of Accident	Percent
1	0:01-6:00	150	22.3
2	6:01-12:00	333	49.6
3	12:01-18:00	102	15.2
4	18:01-24:00	87	12.9
	Total	672	100.0

While looking at the number of injuries per crash, majority of them were recorded on 18:01-24:00 Pm. The result of the analysis clearly identified that among 24 hours 18:01-24:00 Pm constitutes highest mean 0.75. On the other hand the rate of death per crash high on 6:01-12:00 Am with a mean of 0.139. These shows that time of the day are critical factor of accidents happening on the Expressway (See Appendix 1, Table 7).

4.1.3 Traffic Accidents due to effect of Time of Day

Analysis made on the effect of brightness towards traffic accident indicated that large number of accidents was registered during day time accounting 71.9 percent of the total. This may indicate

that drivers are conscious during night time while driving. As a result, the level of accident is low during night time.

Table 10: Time of Day related Accident Frequency

Sr.No	Time of Day	Frequency of Accident	Percent
1	Day Time	483	71.9
2	Night Time	189	28.1
	Total	672	100.0

However, when it comes to the number of injuries per crash, both day and night times depict nearly the same level of causalities with a mean of 0.6. On the other hand, the number of death per crash is high during day times with a mean of 0.097 than night time.

Table 11: Table of Time of Day related variables

Time of Day	No. of Death	No. of Injuries	Total No. of Crashes	Mean of Injuries Per Crash	Mean of Death Per Crash
Day Time	29	180	300	0.60	0.097
Night Time	8	67	117	0.57	0.068
Total	37	247	417		
Average	18.5	123.5	208.5		

4.1.4 Accident Distribution over Types of Vehicles

Type of Vehicle had their impact on accident severity. The study site had four categories of vehicles. Accident data collected in study area indicated that vehicles most frequently involved in accidents were Automobiles (27.8%). The table below shows the types of vehicles with respect to accident frequency. The second most frequently involved vehicle in accidents was Minibus and Bus that accounts for 27.7% (See Table 12).

Table 12: Accident Frequency over types of vehicles

Sr.No	Types of Vehicles	Frequency of Accident	Percent
1	Automobiles	187	27.8
2	Minibus and Bus	186	27.7
3	Pickup and Medium Truck	164	24.4
4	Truck and above	135	20.1
	Total	672	100.0

However, both mean injury per crash and death per crash of Minibus and Bus is the largest among the four categories, whereas the mean injuries per crash and death per crash for minibus and bus was 1.642 and 0.399 consequently (See Appendix 1, Table 1).

4.1.5 Collision Type related variables

In terms of collision types, majority of accidents that were registered on road users resulted from collision vehicle to vehicle, car overthrow and collision vehicles with static objects. As indicated in Table 13 below, collisions due to vehicle to vehicle accounted for about 35.7 percent of the total accident that are registered during one and half years.

Table 13: Collusion Types Accident Frequency

Sr.No	Collusion Type	Frequency of Accident	Percent
1	Crash Vehicle to Vehicle	240	35.7
2	Car Overthrow	226	33.6
3	Crash Vehicle to Vehicle	206	30.7
	Total	672	100.0

However, the mean injuries per crash due to Car Overthrow is around 0.983, which is the largest mean of the three categories, whereas the mean death per crash due Crashes registered between Vehicles is around 0.139, which is the largest of all categories (See Appendix 1, Table 5).

4.1.6 Vehicular Direction of Flow related Variables

As per the result of the analysis, traffic accident is high when vehicles move towards Adama, i.e. when moving from the main gate of Tulu Dimtu to Adama, which accounted for 48.2% of the total accidents (See Table 14).

Table 14: Direction of Flow Accident Frequency

Sr.No	Direction of Flow	Frequency of Accident	Percent
1	To Adama	324	48.2
2	To Addis Ababa	284	42.3
3	To Modjo	27	4.0
4	To Welenchity	26	3.9
5	To Deberezeyit	6	0.9
6	To Dukem	5	0.7
	Total	672	100.0

However, vehicles traveling to the direction of Dukem has a mean injuries per crash of 0.75, which is the largest mean of the six categories, whereas vehicle traveling to the direction of Adama has a mean death per crash of around 0.12, which is the largest mean of all categories. (See Appendix 1, Table 6).

4.1.7 Plate Number related Variables

A. Accident Frequency in terms of Vehicular Code

As per the result of the study, traffic accident is high for plate code 3, which accounted for 70.5% of the total accidents.

Table 15: Vehicle Code Accident Frequency

Sr.No	Plate number code	Frequency of Accident	Percent
1	1	5	0.7
2	2	157	23.4
3	3	474	70.5
4	4	27	4.0
5	5	9	1.3
	Total	672	100.0

However, both the mean injuries per crash and death per crash for code 3 are relatively high with the mean value around 0.96 and 0.13 consequently, which is the largest of the five categories (See Appendix 1, Table 8).

B. Plate Number Region Accident Frequency

Based on the analysis of observed data, traffic accident is high for plate region AA, which accounted around 48.4% of the total accident.

Table 16: Plate Number Region Related Accident Frequency

Sr.No	Plate Number Region	Frequency of Accident	Percent
1	AA	325	48.4
2	OR	181	26.9
3	ET	166	24.7
	Total	672	100.0

4.2. Empirical Analysis

4.2.1. Black Spot Identification and Recommended Counter Measures.

Using the criteria developed in chapter three, around 70 road sections were demarcated for severity of accident and black spots analysis within 1km interval. On the basis of the criteria, road sections which have relative severity value greater than severity critical value is considered as black spot and used for further treatment. Hence, out of the 70 road sections define for black spot analysis, four (4) road sections were fulfilled the criteria and identified for further treatment (See Appendix 2A, and Table 1).

According to black spot identification criterion, the following road stations had the highest relative severity value compare to its critical severity value. This implies that these road sections are the most risky area and dangerous road for users (See Appendix 2B; Table 2, 3, 4 and 5).

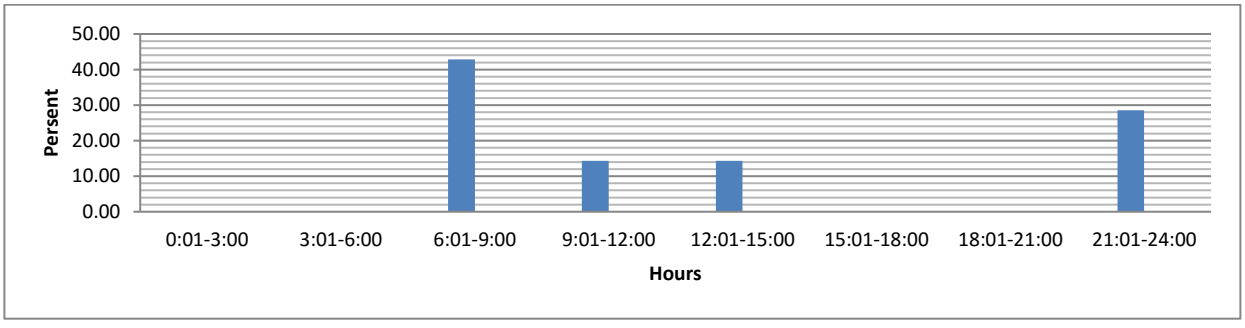
A) Station 13+001-14+000

Truck with 41-100 quintal accounted for 28.57 percent of the total accidents. From total number of 4 deaths 75 percent and from 6 personal injuries 66.67 percent can be happened by minibus as a result of tire problem (vehicular condition).

As shown below in figure 5, the distribution of accidents over three hour shows that the highest crushes occurred during 6:01-9:00 Am. Day time had a share of about 57.14 percent of accidents. Accident variation follows variation in the number of motorized traffic. Hence, vehicular

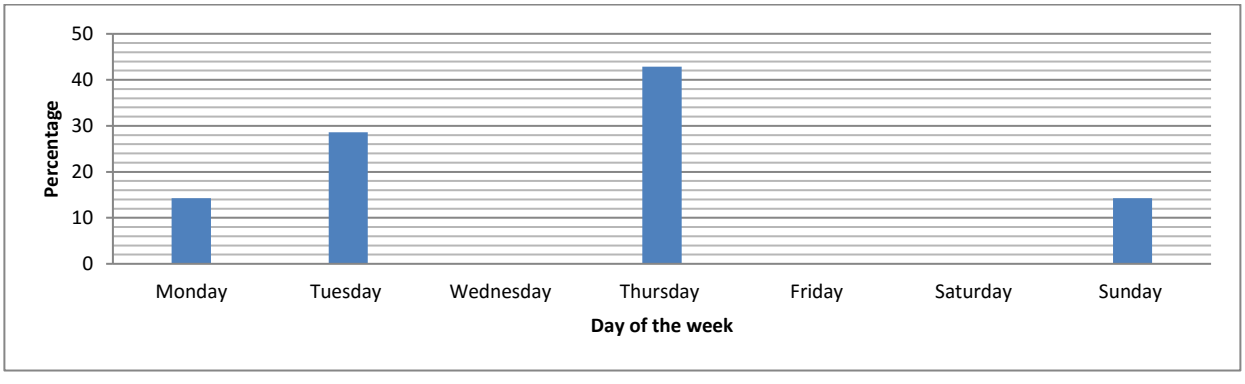
performance quality control machine can be used at entrances and exit of main gates to control the flow of vehicles and related accidents.

Figure 3: Accident Distribution Over Three Hours



Thursday had the highest number of accidents, whereas there is no traffic accident on Wednesday, Friday and Saturday. As figure 6 revealed below on the distribution of accidents by day of week.

Figure 4: Variation of Accident by Day of the Week



As shown in Table 2, Appendix 2B collision vehicles to vehicles, collision with static objects and car overthrow had their own contribution at these dangerous road sections.

B) Station 20+001-21+000

Table 3, Appendix 2B shows the number of Death, Personal Injuries and Property Damage happen in road section. Automobiles accounted for 60 percent of the total accidents. In terms of

death, the total number (11) of deaths is registered with minibuses. In terms of injuries, of the total 10 personal injuries, 9 of them were registered with minibuses.

In terms of time, the highest distribution of crashes registered during 9:01-12:00 Am. Day time had about 80 percent of accidents. Accidents variation follows with variation of motorized traffic.

Figure 5: Accident Distribution Over Three Hours

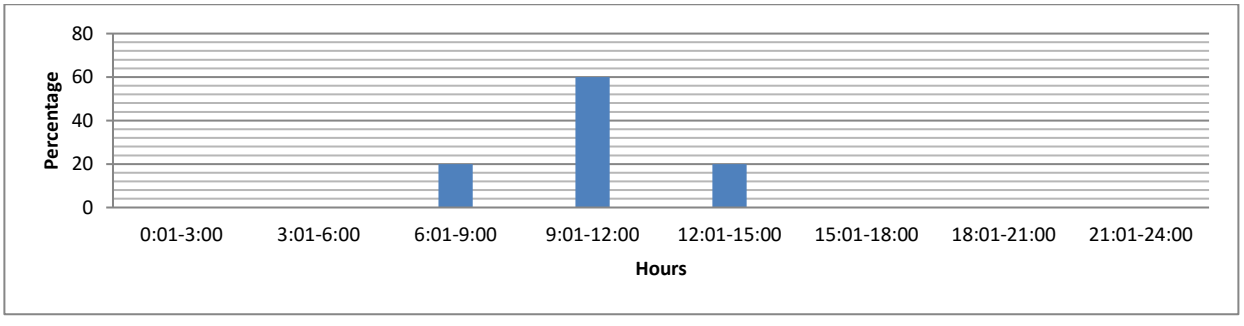
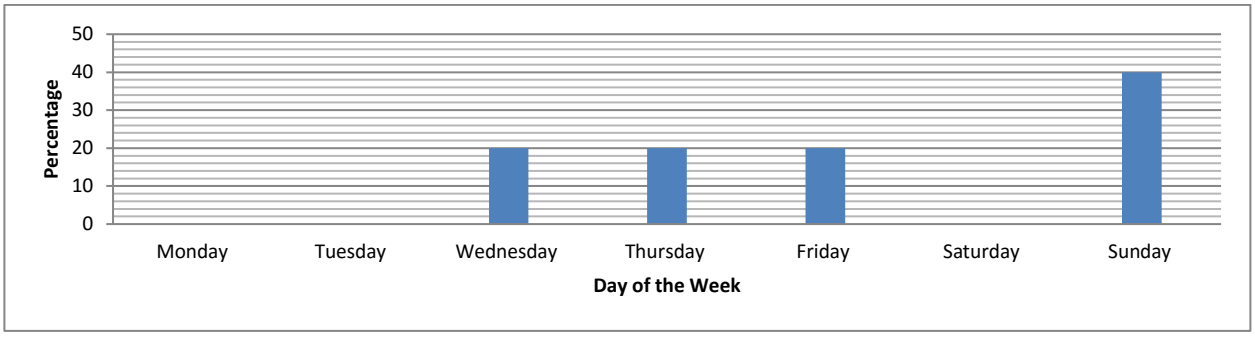


Figure 8 below presents the distribution of accidents by day of week. According to this figure, Sunday has the highest number of accidents,

Figure 6: Variation of Accident by Day of the Week



As shown in Table 3, Appendix 2B, others; collision vehicles to vehicles and collision with static objects had their own contribution at these dangerous road sections.

C) Station 35+001-36+000

In detail, Table 4, Appendix 2B shows the number of Death, Personal Injuries, Property Damage and other related variables happen in road section. Minibus accounted for 100 percent of the total

accidents. From total number of 1 death 100 percent and 7 personal injuries 100 percent can be happen by minibus due to Tire problem (vehicular condition) that causes vehicular crush with fixed objects. The total crushes occurred during 3:01-6:00 Am Day time had about 100 percent of accidents. Accidents variation follows with variation of motorized traffic.

On Table 4, Appendix 2B, collision with static objects had their own contribution at these dangerous road sections.

D) Station 68+001-69+000

In detail, Table 5, Appendix 2B shows the number of Death, Personal Injuries, Property Damage and other related variables happen in road section. Automobile accounted for 100 percent of the total accidents. From total number of 2 personal injuries 100 percent can be happen by automobile due to over speed that causes car overthrow. The total crushes occurred during 6:01-9:00 Am; Day time had about 100 percent of accidents. Accidents variation follows with variation of motorized traffic.

On Table 5, Appendix 2B, over speed had their own contribution at these dangerous road sections for car overthrow.

Generally, based on investigation held on the study of black spot area most of black spot location were straight. As a result the problem related to accident happen on those road section were not related to geometry problem rather than unethical driving (poor visibility, over speed) followed by technical problem (vehicular condition) and other contributory factors like provision of traffic calming devices and reckless driving. Particularly on chanage 20+001-21+000 during rainy season longitudinal slope followed with horizontal curve that made traversal runoff on the road section. In spite of this the movement of vehicles lead accident in this particular station result the presences of over speed that made slippery nature (reduce friction) between asphalt surface and tire of the vehicles ordered to overthrow. As a result it is recommendable that the movements of vehicles at this specific location must be below specified speed limit and sign of speed limit must be post at particular location.

Mostly the Sevier as well as high number of accident registered on straight road section. Likewise drainage (ditch) across the span of road in both side cannot covered with precast as a

result most probable Sevier accident can be increases due to insufficient provision of precast cover over ditch. Even if the occurs of accident at night time was low with respect to flow of traffic. Further to reduce the occurrences of accident on the expressway; it is advisable to install straight light on the road side and medians. In addition to the above investigation the study use the raw data as recorded by the enterprise to draw logical conclusion.

4.3. Traffic Accident Model Determination

The model will be used to assess the determinant of accidents in Addis Ababa - Adama expressway. The result of the study clearly indicated that there are relationships between Traffic Accident and some potential determinants. Accordingly, the summary of statistics, the level of significances and the likely justification of results are properly assessed and incorporated in the study.

Table 17: Descriptive Statistics of Variables Included in the Model

Variables		Total Number of Accident	Marginal Percentage
Accident	Death	37	5.5%
	Series Injuries	65	9.7%
	Slight Injuries	183	27.2%
	Property Damage	387	57.6%
Time of Day	Day Time	483	71.9%
	Night Time	189	28.1%
Day of the week	Monday - Friday	490	72.9%
	Weekend	182	27.1%
Accident causes	Unethical Driving	402	59.8%
	Technical Problem	251	37.4%
	Sleeping Problem	19	2.8%
Collision type	Crush Vehicle to Vehicle	240	35.7%
	Car Overthrow	226	33.6%
	Crush Vehicle to Vehicle	206	30.7%
Types of vehicles	Automobiles	187	27.8%
	Minibus and Bus	186	27.7%
	Pickup and Medium Truck	164	24.4%
	Truck and above	135	20.1%
Plate number region	AA	325	48.4%

	OR	181	26.9%
	ET	166	24.7%
Plate number code	1	5	0.7%
	2	157	23.4%
	3	474	70.5%
	4	27	4.0%
	5	9	1.3%
Timely Variation	0:01-6:00	150	22.3%
	6:01-12:00	333	49.6%
	12:01-18:00	102	15.2%
	18:01-24:00	87	12.9%
Direction of flow	To Adama	324	48.2%
	To Addis Ababa	284	42.3%
	To Modjo	27	4.0%
	To Welenchity	26	3.9%
	To Deberezeyit	6	0.9%
	To Dukem	5	0.7%
Valid		**672**	**100.0%**

4.3.1. Empirical Relationship between Accident and Its Possible Causes

The Multinomial Probit regression model results of Addis Ababa-Adama Expressway injury severity are presented in table 18. In the model, injury severity (fatal, serious and slight injuries) and property damage are the dependent variable, with property damage used as the reference category. Cause-effect analysis results of variables using multinomial probit model on Addis Ababa - Adama Expressway shows that Day of the Week (DW), Collision Types (CT), Types of Vehicles (TV) and Plate Number Region (PNR) have significant effect on traffic accident at P-value of 0.05. The remaining parameters that were considered in the study were removed from the relationship as they are found insignificant and have no effect for the occurrence of traffic accident on the Expressway.

Table 18: Parameter Estimated Coefficient

Parameter Estimates							
Accident[a]	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)

								Lower Bound	Upper Bound
Death	Intercept	-1.606	1.030	2.428	1	.119			
	[DW=1]	-.717	.381	3.539	1	.060	.488	.231	1.030
	[DW=2]	0[b]	.	.	0	.	.	.	.
	[CT=1]	-1.115	.480	5.391	1	.020	.328	.128	.840
	[CT=2]	-.751	.467	2.583	1	.108	.472	.189	1.179
	[CT=3]	0[b]	.	.	0	.	.	.	.
	[TV=1]	1.375	1.028	1.790	1	.181	3.957	.528	29.671
	[TV=2]	1.817	1.009	3.245	1	.072	6.153	.852	44.433
	[TV=3]	2.213	.922	5.763	1	.016	9.142	1.501	55.679
	[TV=4]	0[b]	.	.	0	.	.	.	.
	[PNR=1]	-2.250	.581	14.976	1	.000	.105	.034	.329
	[PNR=2]	-1.402	.738	3.608	1	.058	.246	.058	1.046
	[PNR=3]	0[b]	.	.	0	.	.	.	.
Series Injuries	Intercept	-.485	.297	2.663	1	.103			
	[CT=1]	-.508	.382	1.769	1	.184	.602	.285	1.272
	[CT=2]	.647	.330	3.851	1	.050	1.910	1.001	3.645
	[CT=3]	0[b]	.	.	0	.	.	.	.
	[PNR=1]	-1.940	.345	31.605	1	.000	.144	.073	.283
	[PNR=2]	-1.737	.362	22.987	1	.000	.176	.087	.358
	[PNR=3]	0[b]	.	.	0	.	.	.	.
Slight Injuries	Intercept	-2.162	.526	16.892	1	.000			
	[CT=1]	-.494	.263	3.544	1	.060	.610	.365	1.021
	[CT=2]	.838	.249	11.294	1	.001	2.312	1.418	3.769
	[CT=3]	0[b]	.	.	0	.	.	.	.
	[TV=1]	2.221	.445	24.966	1	.000	9.219	3.857	22.033
	[TV=2]	2.558	.489	27.345	1	.000	12.914	4.950	33.690
	[TV=3]	1.536	.438	12.301	1	.000	4.647	1.969	10.963
	[TV=4]	0[b]	.	.	0	.	.	.	.
	[PNR=1]	-.853	.332	6.591	1	.010	.426	.222	.817
	[PNR=2]	-.255	.411	.385	1	.535	.775	.346	1.734
	[PNR=3]	0[b]	.	.	0	.	.	.	.
a. The reference category is: Property Damage.									
b. This parameter is set to zero because it is redundant.									

The above empirical analysis results of the study show the various relationships between accident and its determinant. It also identified the key variables that play critical roles in the

determination of traffic accident. The result indicates the impact of each internal as well as external factor on the level of accidents to be registered on an expressway. Details of the analysis results and their implication are discussed and summarized as follow:

A. **Day of the Week (DW)**: Time contributes greatly to the occurrences of accident in the road crashes. As per the regression equation, the result of the study revealed that day of the week has significant relationship with the level of accident. These show that Monday-Friday has negative and significant effect on passenger fatal injuries of expressway at P-value of 0.05. As a result, an increase in day of the week particularly Monday-Friday decreases the level of fatal accident and vise versal.

B. **Collision Types (CT)**: The result of the regression equation revealed that a collusion type has significant effect on accident at P-value of 0.05. These show that collusion types seem significant in determination of accident. In case, crash vehicle to vehicles has negative and significant effect on passenger fatal injuries of expressway. Car overthrow has positive and significant effect on passenger serious injuries of expressway. Mean while, on passenger slight injuries, crash vehicle to vehicle has negative and car overthrow has positive significant effect on expressway. As a result of decrease in crash vehicle to vehicle increases the level of fatal and slight injuries and vise versal. Concomitantly, an increase in car overthrow increases the level of serious and slight injuries in the expressway.

C. **Types of Vehicles (CT):** The type of vehicle involved in Addis Ababa-Adama Expressway is a significant predictor of Accident. The parameter estimate for pickup and medium truck indicates a positive and significant effect on passenger fatal injuries. At the same occasion Automobiles, Minibus and Bus, Pickup and Medium Truck have positive and significant effect on passenger slight injuries at P-value of 0.05. As a result, an increase of pickup and medium truck on the expressway increase the level of fatal accident. At the same time, an increase in Automobiles, Minibus and Bus, Pickup and Medium Truck on the expressway increases the level of slight injuries.

D. **Plate Number Region (PNR)**: The result of the regression equation revealed that a Plate Number Region has significant effect on accident at P-value of 0.05. These show that plate number region seem significant in determination of accident. In case, AA has negative and

significant effect on passenger fatal, serious and slight injuries of the expressway. Whereas, OR has negative and significant effect on passenger fatal and serious injuries. As a result, decrease in AA increases the level of fatal, serious and slight injuries of the expressway and vise versal. Concomitantly, a decrease in OR increases the level of fatal and serious injuries.

In general, the finding of the model clearly indicated that both internal as well as external factors play significant roles in the determination of accident. Especially, that Day of the Week, Collision Types, Types of Vehicles and Plate Number Region have strong importance in the determination of accident. As a result, the expressway needs to focus on those factors so as to minimize the risk of accidents. On the basis of the above findings, the model that will help to determine the level of accident can be expressed using the following Traffic Accident predicting equation.

$$A = \beta + \beta_1 DW + + \beta_2 CT + \beta_3 TV + \beta_4 PNR + \varepsilon$$

This rough empirical estimation model can be used to assess traffic accidents on Addis Ababa – Adama Expressway. To enhance the level of accuracy, the coefficients of all independent variables are examined for their significance and those variables with higher significant relationship with road traffic accident is used for developing an equation that help to predict road accident - A. Accordingly, variables like that Day of the Week, Collision Types, Types of Vehicles and Plate Number Region are identified as independent variable to assess the level of traffic accident on the expressway.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The situation of road traffic accident at the national level is getting worse. Despite small number of vehicles operating in the country, the level of accident recorded each day made the country one of the top in the world. Similar experience is started to be registered on the newly developed Addis Ababa - Adama Expressway. The Expressway is the focus of this study and all the data used in the study is collected from traffic accidents registered on this road and accounted for 100% of the total accidents. The data was collected for all service period of the expressway, i.e. accident registered during one and half years. Both qualitative and quantitative methods are used to analyze the data and interpret results.

The result of the study shows that accident is higher in Monday-Friday of the week and between 06:01 to 12:00 Am hourly distributions. During 2014/15-16, the level of accident on the expressway using automobiles accounted for the largest of all, which is accounting around 28 percent of the total accidents. In terms of fatal accidents, Minibus and Bus has the worst records in Addis Ababa-Adama Expressway. Looking at Time of Day as factor of accident, Day time has been the worst accident registration period that accounted for 71.9 percent even if the movement of traffic at night time in not relatively equal to day time. The main gate at Tulu Dimtu that accounts at a chainage of 1+001-2+0000 (km2) road sections had worst accident recorded in terms of location.

On the other hand, Crash Vehicle to Vehicle is the worst collusion types in the road section. Most vehicles whose plate number region AA registered an accident level of 48.4 percent and Plate Number code 3 registered the highest record of accident accounting 70.5 percent. While looking their direction of flow, those vehicles move to Adama has been facing the worst accident relative to those moving to other direction accounting 48.2 percent.

The possible major causes of accidents that are identified in this research include unethical driving behavior of drivers (poor visibility and over speed) that accounted 59.8 percent. In terms of fatality unethical driving of vehicles is the worst of all records. Particularly, geometry design

is not the contributory factors for road accident registered on Addis Ababa-Adama expressway other than promoter the severity of accident.

Seventy (70) road sections were identified for analysis of black spot using developed criteria and severity index calculated and found that only four road sections were identified as black spot locations.

The multinomial probit regression model result identified that accident is highly dependent on Day of the Week, Collision Types, Types of Vehicles and Plate Number Region at p-value of 0.05. These variables have a determinant effect for an accident to happen. Based on the result of the regression analysis, accident predicting equation for Addis Ababa-Adama Expressway was defined using the variables stated above.

In general, it's clear that road accidents have been a serious problem in our everyday life. This study identified the causes of accident using engineering measurements for each road segment. In addition, develop accident prediction models was developed through investigating factors contributing to the occurrence of accident and that enlarge the severity of accidents on Addis Ababa – Adama Expressway using survey data obtained from Traffic Safety and Security Department of Ethiopia Toll Road Enterprises.

5.2. Recommendation

On the basis of the above findings, it is possible to propose the following recommendations. This recommendation will help the Ethiopia Toll Road Enterprises, policy makers and road user to focus on selected area of emphasis so as to minimize the level of accident on Addis Ababa-Adama Expressway.

- ✓ The finding of the study revealed that accident frequency is high at the main gates. As a result, Ethiopian Tool Road Enterprise revises the gate condition and implements technical amendment to minimize frequency of accident.

- ✓ Unethical driving (poor visibility and over speed) is the worst accident cause on Addis Ababa – Adama Expressway. Therefore, it is important to advocate training for drivers and ensure ethical behavior among those using the road, which may include enhancing personal driving capacity through participating different government and non-governmental initiatives

towards the transport sectors. Especial focus should be given for those drivers operating on public transport vehicles with a code 3.

- ✓ Even if fatality and human injuries are low relative to the size of the road service, unethical driving (poor visibility and over speed) is the worst causes of death on this road. As a result, it is advisable to use speed control technology like RADAR installation along the road way and others scientific based mechanism which helps to monitor speed of vehicles and implement punishment on those violating speed limit during exit.

- ✓ Since most accidents have been occurring at entrances and exits, it is important to install Rumple Strip (speed breaker) at a range of minimum stopping site distances from entrances and exit gate in a way that reduce accident frequency.

- ✓ Most of the collusion was registered as a result of crash vehicle to vehicle. The main contributory cause for the occurrences of this crash is particularly unethical driving behaviors of driver in respect to over speed and tire problem. As a result, it is important to reconsider the speed limit of the Expressway in relation to the advanced vehicular performance checking technology. Therefore; it is compulsory to reduce the number of accident happen due to crash vehicle to vehicle by carry out the speed limit and ethical way of driving.

- ✓ For Technical problems (vehicular condition), performance evaluation should be made using vehicles performance checking technology that are installed specially at the entrances of the main gates.

Despite the recommendations proposed above, this research advises the Ethiopian Toll Road Enterprise to use the Federal Traffic Police accident registration database format so that the data collected from the institution will have strong clarity and it is possible to easily compile the data for any type of traffic safety assessment. This will also help researchers and other users to easily use the data for road traffic accident related assessment.

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APPENDIX

APPENDIX 1

CRASH SEVERITY VALUE ANALYSIS

TABLE 1

TYPES OF VEHICLES	NO. OF DEATH	NO. OF INJURIES	TOTAL NO. OF CRASHES	MEAN OF INJURIES PER CRASH	MEAN OF DEATH PER CRASH
AUTOMOBILES	4	65	128	0.508	0.031
MINIBUS AND BUS	20	110	67	1.642	0.299
PICKUP AND MEDIUM TRUCK	11	47	109	0.431	0.101
TRUCK AND ABOVE	2	25	113	0.221	0.018
TOTAL	37	247	417		
AVERAGE	9.25	61.75	104.25		

TABLE 2

TIME OF DAY	NO. OF DEATH	NO. OF INJURIES	TOTAL NO. OF CRASHES	MEAN OF INJURIES PER CRASH	MEAN OF DEATH PER CRASH
DAY TIME	29	180	300	0.600	0.097
NIGHT TIME	8	67	117	0.573	0.068
TOTAL	37	247	417		
AVERAGE	18.5	123.5	208.5		

TABLE 3

DAY OF THE WEEK	NO. OF DEATH	NO. OF INJURIES	TOTAL NO. OF CRASHES	MEAN OF INJURIES PER CRASH	MEAN OF DEATH PER CRASH
MONDAY - FRIDAY	21	181	308	0.588	0.068
WEEKEND	16	66	109	0.606	0.147
TOTAL	37	247	417		
AVERAGE	18.500	123.500	208.500		

TABLE 4

DIRECTION OF FLOW	NO. OF DEATH	NO. OF INJURIES	TOTAL NO. OF CRASHES	MEAN OF INJURIES PER CRASH	MEAN OF DEATH PER CRASH
TO ADDIS ABABA	12	118	173	0.682	0.069
TO DUKEM	0	3	4	0.750	0.000
TO DEBREZEYIT	0	0	6	0.000	0.000
TO ADAMA	23	110	198	0.556	0.116
TO MOJO	1	6	20	0.300	0.050
TO WELECHITY	1	10	16	0.625	0.063
TOTAL	37	247	417		
AVERAGE	6.167	41.167	69.5		

TABLE 5

COLLUSION TYPES	NO. OF DEATH	NO. OF INJURIES	TOTAL NO. OF CRASHES	MEAN OF INJURIES PER CRASH	MEAN OF DEATH PER CRASH
CAR OVERTHROW	8	115	117	0.983	0.068
CRUSH VEHICLE TO VEHICLE	22	91	158	0.576	0.139
CRUSH VEHICLE TO STATIC OBJECT	6	41	142	0.289	0.042
TOTAL	36	247	417		
AVERAGE	9	82.333	139		

TABLE 6

ACCIDENT CAUSE	NO. OF DEATH	NO. OF INJURIES	TOTAL NO. OF CRASHES	MEAN OF INJURIES PER CRASH	MEAN OF DEATH PER CRASH
UNETHICAL DRIVING	29	140	239	0.586	0.121
TECHNICAL PROBLEM	8	100	165	0.606	0.048
SLEEPING PROBLEM	0	7	13	0.538	0.000
TOTAL	8	107	417		
AVERAGE	2.667	35.667	139		

TABLE 7

HOURLY DISTRIBUTION	NO. OF DEATH	NO. OF INJURIES	TOTAL NO. OF CRASHES	MEAN OF INJURIES PER CRASH	MEAN OF DEATH PER CRASH
0:01-6:00	1	45	113	0.398	0.009
6:01-12:00	26	136	187	0.727	0.139
12:01-18:00	4	30	69	0.435	0.058
18:01-24:00	2	36	48	0.750	0.042
TOTAL	33	247	417		
AVERAGE	8.250	61.750	104.25		

TABLE 8

PLATE NUMBER CODE	NO. OF DEATH	NO. OF INJURIES	TOTAL NO. OF CRASHES	MEAN OF INJURIES PER CRASH	MEAN OF DEATH PER CRASH
1	0	0	3	0.000	0.000
2	2	49	115	0.426	0.017
3	35	192	277	0.693	0.126
4	0	6	13	0.462	0.000
5	0	0	9	0.000	0.000
TOTAL	37	247	417		
AVERAGE	5.286	35.286	59.571		

TABLE 9

PLATE NUMBER REGION	NO. OF DEATH	NO. OF INJURIES	TOTAL NO. OF CRASHES	MEAN OF INJURIES PER CRASH	MEAN OF DEATH PER CRASH
AA	9	105	228	0.461	0.039
OR	23	99	55	1.800	0.418
ET	5	43	134	0.321	0.037
TOTAL	37	247	417		
AVERAGE	5.286	35.286	59.571		

APPENDEX 2A

TABLE 1

Detail Black Spot Analsis

Chainage/ Location	Fatality (F)	Serious Injuries (SI)	Light Injuries (LI)	Property Damage (Pd)	15*F	8*SI	3*LI	1*PD	Sj	Aj	Qj = Sj/Aj	Qave	Qj-Qave	(Qj-Qave)2	Black spot	Qc
1+001-2+000	1	13	28	45	15	104	84	45	248	49	5.061	4.806	0.255	0.065	No	12.549
3+001-4+000	0	0	3	6	0	0	9	6	15	6	2.500	4.806	-2.306	5.317	No	12.549
4+001-5+000	0	1	6	5	0	8	18	5	31	5	6.200	4.806	1.394	1.944	No	12.549
5+001-6+000	0	0	1	6	0	0	3	6	9	8	1.125	4.806	-3.681	13.548	No	12.549
6+001-7+000	0	0	0	9	0	0	0	9	9	11	0.818	4.806	-3.988	15.901	No	12.549
7+001-8+000	0	0	1	11	0	0	3	11	14	12	1.167	4.806	-3.639	13.243	No	12.549
8+001-9+000	0	1	0	4	0	8	0	4	12	4	3.000	4.806	-1.806	3.261	No	12.549
9+001-10+000	0	0	0	5	0	0	0	5	5	5	1.000	4.806	-3.806	14.484	No	12.549
10+001-11+000	0	0	3	7	0	0	9	7	16	9	1.778	4.806	-3.028	9.169	No	12.549
11+001-12+000	0	0	2	8	0	0	6	8	14	8	1.750	4.806	-3.056	9.338	No	12.549
12+001-13+000	0	0	1	6	0	0	3	6	9	5	1.800	4.806	-3.006	9.035	No	12.549
13+001-14+000	4	1	5	7	60	8	15	7	90	7	12.857	4.806	8.051	64.825	Blackspot	12.549
14+001-15+000	0	1	1	6	0	8	3	6	17	7	2.429	4.806	-2.377	5.651	No	12.549
15+001-16+000	2	2	10	14	30	16	30	14	90	15	6.000	4.806	1.194	1.426	No	12.549
16+001-17+000	0	0	2	2	0	0	6	2	8	2	4.000	4.806	-0.806	0.649	No	12.549
17+001-18+000	2	0	8	7	30	0	24	7	61	7	8.714	4.806	3.909	15.277	No	12.549
18+001-19+000	0	0	0	1	0	0	0	1	1	1	1.000	4.806	-3.806	14.484	No	12.549
19+001-20+000	0	1	1	6	0	8	3	6	17	7	2.429	4.806	-2.377	5.651	No	12.549
20+001-21+000	11	9	1	5	165	72	3	5	245	5	49.000	4.806	44.194	1953.131	Blackspot	12.549
21+001-22+000	0	0	1	2	0	0	3	2	5	2	2.500	4.806	-2.306	5.317	No	12.549
22+001-23+000	0	0	6	6	0	0	18	6	24	6	4.000	4.806	-0.806	0.649	No	12.549
23+001-24+000	0	0	8	8	0	0	24	8	32	9	3.556	4.806	-1.250	1.563	No	12.549
24+001-25+000	0	0	1	2	0	0	3	2	5	3	1.667	4.806	-3.139	9.854	No	12.549
25+001-26+000	0	1	0	4	0	8	0	4	12	4	3.000	4.806	-1.806	3.261	No	12.549
26+001-27+000	0	2	0	2	0	16	0	2	18	2	9.000	4.806	4.194	17.592	No	12.549
27+001-28+000	1	1	3	9	15	8	9	9	41	9	4.556	4.806	-0.250	0.063	No	12.549
28+001-29+000	0	0	0	1	0	0	0	1	1	1	1.000	4.806	-3.806	14.484	No	12.549
29+001-30+000	0	0	0	5	0	0	0	5	5	5	1.000	4.806	-3.806	14.484	No	12.549
30+001-31+000	0	0	0	2	0	0	0	2	2	2	1.000	4.806	-3.806	14.484	No	12.549
31+001-32+000	1	0	1	5	15	0	3	5	23	5	4.600	4.806	-0.206	0.042	No	12.549
32+001-33+000	3	4	10	13	45	32	30	13	120	14	8.571	4.806	3.766	14.180	No	12.549
33+001-34+000	0	1	1	3	0	8	3	3	14	3	4.667	4.806	-0.139	0.019	No	12.549
34+001-35+000	1	0	1	4	15	0	3	4	22	5	4.400	4.806	-0.406	0.165	No	12.549
35+001-36+000	1	4	3	3	15	32	9	3	59	3	19.667	4.806	14.861	220.847	Blackspot	12.549
36+001-37+000	0	0	1	2	0	0	3	2	5	2	2.500	4.806	-2.306	5.317	No	12.549
37+001-38+000	0	1	2	5	0	8	6	5	19	5	3.800	4.806	-1.006	1.012	No	12.549
38+001-39+000	2	0	1	7	30	0	3	7	40	7	5.714	4.806	0.909	0.825	No	12.549
39+001-40+000	0	0	0	4	0	0	0	4	4	4	1.000	4.806	-3.806	14.484	No	12.549

40+001-41+000	1	2	2	5	15	16	6	5	42	5	8.400	4.806	3.594	12.919	No	12.549
41+001-42+000	0	1	0	6	0	8	0	6	14	6	2.333	4.806	-2.472	6.113	No	12.549
42+001-43+000	1	5	1	8	15	40	3	8	66	9	7.333	4.806	2.528	6.389	No	12.549
43+001-44+000	0	0	3	0	0	0	9	0	9	1	9.000	4.806	4.194	17.592	No	12.549
44+001-45+000	0	0	0	1	0	0	0	1	1	1	1.000	4.806	-3.806	14.484	No	12.549
45+001-46+000	0	0	11	4	0	0	33	4	37	4	9.250	4.806	4.444	19.751	No	12.549
46+001-47+000	0	0	2	5	0	0	6	5	11	5	2.200	4.806	-2.606	6.790	No	12.549
47+001-48+000	0	0	0	5	0	0	0	5	5	5	1.000	4.806	-3.806	14.484	No	12.549
48+001-49+000	0	2	2	9	0	16	6	9	31	9	3.444	4.806	-1.361	1.853	No	12.549
49+001-50+000	0	0	2	5	0	0	6	5	11	5	2.200	4.806	-2.606	6.790	No	12.549
50+001-51+000	0	0	0	4	0	0	0	4	4	4	1.000	4.806	-3.806	14.484	No	12.549
51+001-52+000	0	0	8	17	0	0	24	17	41	20	2.050	4.806	-2.756	7.594	No	12.549
52+001-53+000	1	1	1	8	15	8	3	8	34	9	3.778	4.806	-1.028	1.057	No	12.549
53+001-54+000	0	0	2	2	0	0	6	2	8	2	4.000	4.806	-0.806	0.649	No	12.549
54+001-55+000	1	0	1	3	15	0	3	3	21	3	7.000	4.806	2.194	4.815	No	12.549
55+001-56+000	0	0	0	2	0	0	0	2	2	2	1.000	4.806	-3.806	14.484	No	12.549
57+001-58+000	0	0	0	2	0	0	0	2	2	2	1.000	4.806	-3.806	14.484	No	12.549
58+001-59+000	0	0	4	3	0	0	12	3	15	3	5.000	4.806	0.194	0.038	No	12.549
59+001-60+000	2	2	18	17	30	16	54	17	117	19	6.158	4.806	1.352	1.828	No	12.549
60+001-61+000	0	0	0	2	0	0	0	2	2	2	1.000	4.806	-3.806	14.484	No	12.549
62+001-63+000	0	0	0	2	0	0	0	2	2	2	1.000	4.806	-3.806	14.484	No	12.549
63+001-64+000	0	3	2	10	0	24	6	10	40	11	3.636	4.806	-1.169	1.367	No	12.549
64+001-65+000	0	1	2	2	0	8	6	2	16	2	8.000	4.806	3.194	10.203	No	12.549
67+001-68+000	0	0	1	1	0	0	3	1	4	1	4.000	4.806	-0.806	0.649	No	12.549
68+001-69+000	0	2	0	0	0	16	0	0	16	1	16.000	4.806	11.194	125.311	Blackspot	12.549
70+001-71+000	0	0	0	1	0	0	0	1	1	1	1.000	4.806	-3.806	14.484	No	12.549
71+001-72+000	0	0	0	1	0	0	0	1	1	1	1.000	4.806	-3.806	14.484	No	12.549
72+001-73+000	1	0	0	3	15	0	0	3	18	3	6.000	4.806	1.194	1.426	No	12.549
73+001-74+000	0	0	0	1	0	0	0	1	1	1	1.000	4.806	-3.806	14.484	No	12.549
74+001-75+000	0	0	0	1	0	0	0	1	1	1	1.000	4.806	-3.806	14.484	No	12.549
76+001-77+000	0	0	1	2	0	0	3	2	5	2	2.500	4.806	-2.306	5.317	No	12.549
77+001-78+000	1	2	8	9	15	16	24	9	64	11	5.818	4.806	1.012	1.025	No	12.549
Total	37	64	183	388	555	512	549	388	2004	417			-8.477	2893.834		

Qave	**4.806**
δ2	**41.340**
Qc	**12.549**
δ	**6.429**

APPENDEX 2B

TABALE 1

SELECTED BLACK SPOT IN DETAIL

Chainage/ Location	Fatality (F)	Serious Injuries (SI)	Light Injuries (LI)	Property Damage (Pd)	15*F	8*SI	3*LI	1*PD	Sj	Aj	Qj = Sj/Aj	Qave	Qj-Qave	(Qj-Qave)2	Black spot	Qc
13+001-14+000	4	1	5	7	60	8	15	7	90	7	12.857	4.856	8.001	64.016	Blackspot	12.549
20+001-21+000	11	9	1	5	165	72	3	5	245	5	49.000	4.856	44.144	1948.683	Blackspot	12.549
35+001-36+000	1	4	3	3	15	32	9	3	59	3	19.667	4.856	14.811	219.352	Blackspot	12.549
68+001-69+000	0	2	0	0	0	16	0	0	16	1	16.000	4.856	11.144	124.186	Blackspot	12.549

TABLE 2

Station 13+001-14+000

											Human Injuries		
No. Observation	Accident Date	Local Times	Day of the Week	Direction of Flow	Plate Number	Types of Vehicles	Collusion Types	Accident Location	Causes of Accident	Property Damage	Death	Series Injuries	Slight Injuries
43	19/04/2007	21:01-24:00	Sunday	To Addis Ababa	3AA 09273	Medium Truck	Crash vehicle witn static object	13+175	Unethical Driving		1	1	0
127	15/8/2007	6:01-9:00	Thursday	To Addis Ababa	3ET44368	Liqiud Cargo	Car Overthrow	13+550	Technical Problem		0	0	0
161	4/10/2007	9:01-12:00	Thursday	To Adama	3AA A05709	Automobiles	Crash vehicle to vehicle	13+350	Unethical Driving		0	0	0
182	22/10/2007	12:01-15:00	Monday	To Addis Ababa	4AA-03327	Pickup	Crash vehicle with static object	13+500	Unethical Driving		0	0	0
193	9/11/2007	21:01-24:00	Thurs	To Addis Ababa	3ET- 64613	Truck	Car Overthrow	13+960	Unethical Driving		0	0	1
367	17/5/2008	6:01-9:00	Tuesday	To Addis Ababa	3OR- 34353	Minibus	Crush Vehicle toVehicle	13+350	Technical Problem		3	0	4
368	17/5/2008	6:01-9:00	Tuesday	To Addis Ababa	3ET- 39936	Truck	Crush Vehicle toVehicle	13+350	Technical Problem		0	0	0

TABLE 3

Station 20+001-21+000

											Human Injuries		
No. Observation	Accident Date	Local Times	Day of the Week	Direction of Flow	Plate Number	Types of Vehicles	Collusion Types	Accident Location	Causes of Accident	Property Damage	Death	Series Injuries	Slight Injuries
18	20/02/07	6:01-9:00	Thursday	To Adama	3AA 11464	Automobiles	Crash vehicle with static object	20+500	Unethical Driving		0	1	0
60	10/5/2007	9:01-12:00	Sunday	To Adama	3ET 58579	Truck	Crash vehicle with vehicle	20+510	Unethical Driving		0	1	0
61	10/7/2007	9:01-12:00	Sunday	To Adama	3OR 28916	Minibus	Crash vehicle with vehicle	20+510	Unethical Driving		11	7	0
160	3/10/2007	12:01-15:00	Wensday	To Addis Ababa	3AA A00037	Automobiles	Crash vehicle with vehicle	20+020	Technical problem		0	0	1
205	17/11/2007	9:01-12:00	Friday	To Addis Ababa	2AA- 84484	Automobiles	Crash vehicle wity static object	20+210 (22+290)	Unethical Driving		0	0	0

TABLE 4

Station 35+001-36+000

											Human Injuries		
No. Observation	Accident Date	Local Times	Day of the Week	Direction of Flow	Plate Number	Types of Vehicles	Collusion Types	Accident Location	Causes of Accident	Property Damage	Death	Series Injuries	Slight Injuries
301	7/3/2008	3:01-6:00	Tuesday	To Adama	3OR- 32491	Minibus	Crash vehicle with static object	35-325	Technical Problem		1	4	3

TABLE 5

Station 68+001-69+000

											Human Injuries		
No. Observation	Accident Date	Local Times	Day of the Week	Direction of Flow	Plate Number	Types of Vehicles	Collusion Types	Accident Location	Causes of Accident	Property Damage	Death	Series Injuries	Slight Injuries
411	26/06/08	6:01-9:00	Friday	To Addis Ababa	2AA- 69787	Automobiles	Car Overthrow	68+550	Unethical Driving		0	2	0

APPENDIX 3

ACCIDENT VARIABLE CODE AND ABVEREVATION

TABLE 1

COLLUSION TYPE	AV	CODE
Car Overthrow	CO	1
Crush Vehicle with Vehicle	CV	2
Crush Vehicle with Statc Object	CS	3

TABLE 2

ACCIDENT CAUSE	AV	CODE
Unethical Driving	UC	1
Technical Problem	TCP	2
Sleeping Problem	SP	3

TABLE 3

HUMAN INJURIES	AV	CODE
Fatality	F	1
Series Injuries	SI	2
Light Injuries	LI	3

TABLE 4

PROPERTY DAMAGE	AV	CODE
Proprety Damage	PD	4

TABLE 5

DAY OF THE WEEK	AV	CODE
Monday - Friday	MF	1
Weekend	WD	2

TABLE 6

VEHICLE TYPE	AV	CODE
Automobiles	AU	1
Minibus and Bus	MBB	2
Pickup and Medium Truck	PMT	3
Truck and Above	TR	4

TABLE 7

DIRECTION OF FLOW	CODE
To Addis Ababa	1
To Dukem	2
To Deberezeyit	3
To Adama	4
To Welencity	5
To Modjo	6

TABLE 8

Time of Day	CODE
Day Time	1
Night Time	2

TABLE 9

PLATE NUMBER REGION	AV	CODE
ADDIS ABABA	AA	1
OROMIA	OR	2
ETHIOPIA	ET	3

TABLE 10

TITLE BAR	AV
NUMBER	No
DAY OF THE WEEK	DW
DIRECTION OF FLOW	DF
PLATE NUMBER CODE	PNC
TYPES OF VEHICLES	TV
PLATE NUMBER REGION	PNR
COLLUSION TYPES	CT
ACCIDENT CAUSES	AC
ACCIDENT	A

APPENDIX 4

t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										