# STATISTICAL ANALYSIS FOR IDENTIFICATION OF MOTOR VEHICLE CRASH BLACK SPOTS AND LOW COST IMPROVEMENTS

# (CASE OF ADDIS ABABA TO DEBRE BIRHAN ROAD)

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# STATISTICAL ANALYSIS FOR IDENTIFICATION OF MOTOR VEHICLE CRASH BLACK SPOTS AND LOW COST IMPROVEMENTS (CASE OF ADDIS ABABA TO DEBRE BIRHAN ROAD)

**A Thesis Submitted to the Addis Ababa University Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Science in Road and Transport Engineering**

**ADDIS ABABA UNIVERSITY**

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This is to certify that the thesis prepared by **ABDULMELIK ADEM**, entitled: **STATISTICAL ANALYSIS FOR IDENTIFICATION OF MOTOR VEHICLE CRASH BLACK SPOTS AND LOW COST IMPROVEMENTS** and submitted in partial fulfillment of the requirements for the Degree of Master of Science in **Road and Transport Engineering** complies with the regulation of the University and meets the accepted standards with respect to originality and quality.

**Signed By Examining Committee:**

1. Dr.Getu Segni ______ ______
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   Examiner signature date

3. ______ ______ ______
   Examiner signature date

## DECLARATION

This Thesis is my original work, and it has not been presented for a degree in any other university and that all sources of material used for the Thesis have been duly acknowledged.

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# ABSTRACT

A study was conducted to Statistical Analysis for Identification of Motor Vehicle Crash Black Spots and Low Cost Improvements on the road from Addis Ababa to Debre Birhan. The research was conducted exhausting both historically recorded crash data and Predictive Empirical Bayesian statistical methods of analysis for identifying and prioritizing black spot segments.

Consistent with results of black spot, the Upper Control Limit through Crash Rate (using Dangerous Factor, DF), Crash Score and Mixed Crash Frequency-Crash Rate statistical methods were simultaneously applied and used to rank the most probable hazardous road segments through crash consequence types.

The predictive Empirical Bayesian method of statistical analysis was further used to identify black spots which combine the observed actual number of Crash Frequency with the predicted number of Crash Frequency. Then subsequently, the excess number of Crash Frequency was used to identify and rank segments.

The total number of Motor Vehicle Crashes reported was 587 within 2012/13-2015/16 period of study years, but some crashes contributed for more than one fatal, serious, slight and property damage consequences. Hence, based on the crash severity results, there were 160 fatal, 254 serious injuries, 330 slight injuries and 488 property damages obtained from police recorded archive booklet files resulted for a total of 1,232 consequences.

Accordingly, 20 segments among the 108 segments were identified as black spots. Established on the results, for six segments low cost improvements were recommended.



**Key Words**: Motor Vehicle Crashes, Crash Rate, Crash Frequency, Crash Score, Mixed Crash Frequency-Crash Rate, Empirical Bayesian method, black spot and low cost improvements.

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AADT | Annual Average Daily Traffic |
| AASHTO | American Association of State Highways Transportation Officials |
| AAZPC | Addis Ababa Zone Police Commission |
| ABS | Australian Bureau of Statics, |
| ADT | Average Daily Traffic |
| AADT | Annual Average Daily Traffic |
| ASDT | Average Seasonal Daily Traffic |
| BAC | Blood Alcohol Concentrations |
| CCMTA | Canadian Council of Motor Traffic Accident |
| CMF | Crash Modification Factor |
| CSA | Central Statistics Agency |
| CS | Crash Score |
| DF | Dangerous Factor |
| EB | Empirical Bayes |
| ERA | Ethiopian Road Authority |
| ETA | Ethiopian Transport Authority |
| GDP | Gross Domestic Product |
| GPS | Geographical Position system |
| HSID | Hot Spot Identification |
| HSM | Highway Safety Manual |
| IRTAD | International Road Traffic Accident Dataset |
| MFR | Mixed Crash Frequency-Crash Rate |
| MUTCD | Manual on Uniform Traffic Control Devices |
| MVA | Motor Vehicle Accident |

| | |
|---|---|
| MVCs | Motor Vehicle Crashes |
| MVTC | Motor Vehicle Traffic Collision |
| NMV | Non-Motorized Vehicle |
| NRTSC | National Road Traffic Safety Council of Ethiopia |
| OECD | Organization for Economic Cooperation and Development |
| PDO | Property Damage Only |
| PSI | Performance Safety Improvement |
| PIARC | Permanent International Association of Road Congress |
| RTA | Road Traffic Accident |
| RTM | Regression-to-Mean |
| SPF | Safety Performance Function |
| SPSS | Scientific Product and Service Solution |
| UNECA | United Nations Economic Commission for Africa |
| UNESCO | United Nation Educational, Scientific and Cultural Organization |
| USA | United States of America |
| VKT | Vehicle Kilometer Travel |
| VMT | Vehicle Mile Travel |
| WHO | World Health Organization |

# CHAPTER 1: INTRODUCTION

## 1.1. Background of the Study

Motor Vehicle Crash injuries are among the prominent causes of loss of life and unpreventable disability universally (ETA, 2015). According to the World Health Organization (WHO) (2015), in road safety report reflecting information from 180 countries, specifies that internationally the overall number of road traffic fatality has resulted in 1.25 million per year, with the highest share of traffic fatality rates in low-income countries.

Transportation throughout Ethiopia is challenging and leads to a severe safety concern. Human beings use roads as a major initiator of work playing a vigorous role in the delivery of essential goods and services from place to place. Obviously, road transport has significant role in economic, social and cultural functioning of cities. The only easily available and inexpensive mode of transportation for every level of living standard used for mobility is road transport. While a road user routinely participates on roads and hence they face crashes. Crashes are highly devastating events damaging the healthiness and harmony of people living in a country especially in developing countries like Ethiopia. Motor Vehicle Crashes, both fatal and serious, are well-known problems. There are 700,000 vehicles in Ethiopia which stand for per capital car possession at 3 cars per 1,000 people (WHO, 2015) and resulted in a rate of 64 people to be killed in 10,000 crashes (Mekonnen F.H. et al., 2014) which are caused by only 84,000 registered vehicles (AAZPC, 2011).

The constituents participating in the crash occurrences are in general vehicles, road users (drivers, pedestrians and passengers), road characteristics and environment. An important and glaring trend that emerges is that more than half of the fatalities in Ethiopia involve pedestrians (NRTSC, 2013). The dominant crashes occurred during daytime hours, encompass males, and take account of persons in the 18-50 age group, which is Ethiopia's energetic workforce (NRTSC, 2013). The safety benefits that can be derived from identifying black spot locations through the careful analysis of MVC, studying sites, and then manipulating appropriate remedial measures have proven to be particularly high. The benefits achieved by low cost improvement measures can be many times the cost of their execution.

Several literatures focused on methods for the identification of black spot segments assessing an extensive set of issues. Some papers address simple ranking methods exhausting historical MVC records surrounding crash severity indexes, crash rates and crash frequencies while others try to create sense of cross-sectional data. Specifically, previous research (Persaud and Hauer, 1984; Persaud, 1986, 1988; Hauer, 1997) has presented methods relying on a simple ranking of crash frequencies or crash rates yield to wrong outputs due to the random fluctuation of MVC from year to year hence leading to the attempted remedy of safety problem at safe segments and the truly hazardious segments escape improvements. There are also papers that discuss the notion of Empirical Bayesian methods, relying both on historical MVC records and predictive or probably expected crashes for the identification of blackspots which avoids the random year to year fluctuation of MVC.

This paper uses and compares the alternative historically recorded MVC based methods and represents an ordinary extension of some researchs, Higle and Hecht (1989) study, with some differences and unique contributions. Firstly, Crash frequency, Crash rate, Mixed Crash Frequency-Crash Rate and Crash Score (suggested by the researcher) methods instead are used to assess black spot identification techniques.

On the other hand, the paper compares both the simple ranking methods and Empirical Bayesian statistical methods for better results.

### 1.2. Statement of the Problem

The occurrence of traffic crash in the country is increasing as the exposure to this risk increases with rapid motorization (without appropriate regulation), rapid population growth, and increase in the road network coupled with poor attitude and safety culture of road users. The study site, Addis Ababa to Debre Birhan road, particularly from Lege Tafo to Tebase (entrance of Debre Birhan ), shows that the Motor Vehicle Crash based on the crash severity is increasing from time to time (Figure-1, (NRTSC, 2013)) also as the population of the traffic intensity from Ethiopian Road Authority shows a similar phenomenon (with AADT of 1869 and VKT of 242, 970 (ERA, 2015), See Appendix I) explaining that it occurs at this intensity level because of the rapid promotion of infrastructures in Debre Birhan town.

In addition, this trunk road is one of the parts of Ethiopian major roads for transporting foreign tourists and connecting the Djibouti port and Semera-Tadjourah port to the central city of Ethiopia, i.e. Addis Ababa, alternatively from the road via Addis Ababa-Mojo-Djibouti. The majority of the road constructed in Oromia region, one of the nine regions of Ethiopia, witnesses the highest crashes in fatal and serious injuries and the rest part laid on Amhara region which also has the second highest crashes recorded from the regions does likewise in both fatal and serious injuries (NRTSC, 2013).

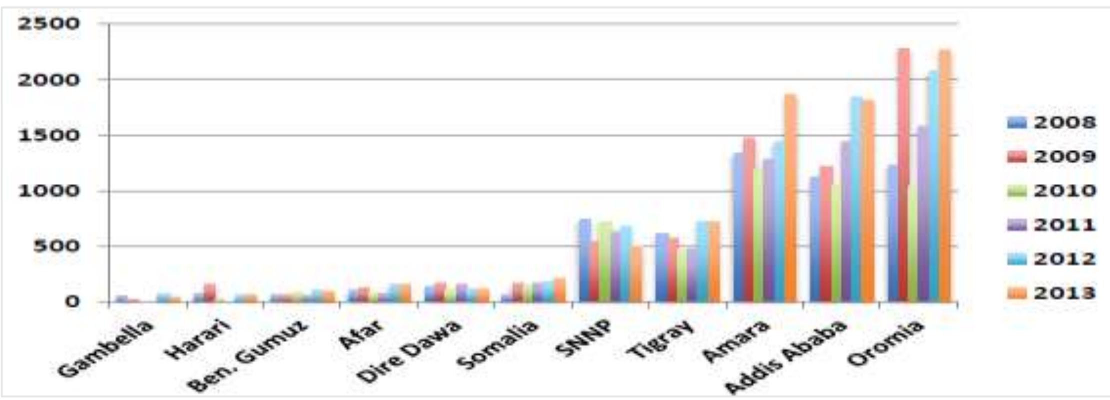



Figure-1: Fatalities & Serious Injuries by Region/City (12 months) (NRTSC, 2013)

The road showed in some segments that have repeated MVC, predominantly between Alelitu and Sheno Ketema towns, resulted in jeopardising of many lives that, as a result, the residents around the area believe as if there is a ‘Seittan’ (Devil) and have erected a religious sign to avoid crashes and be protected from it.

Furthermore, statistical methods used to identify black spots of MVC and ranking of segments for improvements was not set, identified, properly investigated and analysed formerly.

So to avoid this type of destructive and horrifying crashes, special responsiveness and due attention should be given to the problem to be addressed.

## 1.3. Research Questions and Objectives of the Study

### 1.3.1. Research Questions

- ✓ What are the possible causes and contributory factors of the road with MVC from Addis Ababa to Debre Birhan?
- ✓ Is there a spatial and temporal variation of MVC on this road? (Reviewing police recorded crash booklet archives.)
- ✓ Is there a difference in socio-demographic characteristics participating in crashes?
- ✓ In what way are roads identified as black spots?
- ✓ What are the methods used to rank segments for improvements?
- ✓ What kind of improvements can be implemented or already implemented on this ranked black spot segment?

### 1.3.2. General Objective

This study will collect and assess MVCs on the road from Addis Ababa to Debre Birhan from the period of 2012/13 to 2015/16 G.C. and black spot segments identification based on the police reported crash recorded data using both historically recorded crash data based methods and predictive Empirical Bayesian Method of statistical analysis for low cost improvements.

#### 1.3.3. Specific Objectives

- ✓ To identify the road traffic crashes variation by temporal and spatial variation of MVC on the road understudy. (From reviewing police recorded booklet crash files.)
- ✓ To assess MVCs and black spot segments that have strangely high number of MVCs, that is probably at specific sites (section of roads) or spots; from the period of 2012/13 to 2015/16 G.C.
- ✓ To demonstrate a black spot identification methods and segment ranking steps.
- ✓ To carry out the investigation and inspect the collision type on black spot segments.
- ✓ To evaluate possible low cost improvements for the ranked black spot segments.

### 1.4. Significance of the Study

The significance of the study can be stated as follows:

- ✓ The study will assist the police in law enforcement and distribution of man power for surveillance (observation) along the road;
- ✓ Inspiring in terms of resolving the problems associated with MVC;
- ✓ Indicating and encouraging the various participants to take suitable actions by integrating the issue in their policies and strategies;

- ✓ It will provide the government, the Ethiopian Transport Authority and the Ethiopian Roads Authority as well as policy makers with the insights to determine the need for road improvements, vehicle inspections, to initiate programs for educational purposes and introduce low cost treatments.

### 1.5. Scope of the Study

The scope of the study was restricted on the route from Addis Ababa (LegeTafo, 17+900) to Debre Birhan (Tebase 126+000 based on kilometre post stations) Trunk road covering 108.1 km long over four years of data ( 2012/13 to 2015/16 G.C).

### 1.6. The Study Area

The study site traverses the following towns: LegeTafo-Legedadi, Sendafa-Beke, Aleltu-Fiche-Genet, HamusGebeya-ShenoKetema-sembo and Cheki-Chacha via Tebase (part of Debre Birhan). The road map of the study area is shown below in the figure 2.


Figure 2: The road map of the study area from Addis Ababa to Debre Birhan (Google Map with some modifications)

**LegeTafo-LegeDadi** town is found in Oromia Special Zone surrounding Finfine in Oromia Reginal State of Ethiopia. It has two kebeles: LegeTafo Kebele 01 and Lege Daadhi 02. It is located at 21 kms in the north-east side of Addis Ababa. Astronomically, LegeTafo-LegeDadi town is located between 350º 51' 0''and 350º 56' 30'' north latitudes and between 90º 05' 0" and 90º 80' 0" east longitudes. The town has two Kebeles, namely Tafo 01 and Lege Dadi 02 with a total area of 2,431 hectares (LegeTafo-LegeDadi Town Municipality Yearly Report, 2016). LegeTafo-LegeDadi town has suitable and highly moderate climatic condition. The population projection values of 2016 based on 2007 CSA gives around 25,428 of total population, 12,810 males and 12,618 females (CSA, 2007). The mode of transportation in LegeTafo-LegeDadi town is mixed flow mostly three-wheeler, locally called Bajaja, Taxi, Minibus, Lonchina, horse-drawn (wagons and carts, in the vicinity named Gari) and pedestrians movement on foot (LegeTafo-LegeDadi Town Municipality Yearly Report, 2016).

**Sendafa Beke** town is located in Oromia Regional State, in Northern Shewa more specifically in the Bereh Woreda. The town is situated at a distance of 39Km north-east of national capital (Addis Ababa). Astronomically, the town is located between 9º06'14"to 9º10'30" in north latitude and 385º7'60" to 39º04'53" east longitudes. The population projection values of 2016 based on 2007 CSA gives around 18,920 of total population, 9,720 males and 9,200 females. Household size of the town is 5321, which indicates that the town is rapidly growing as well becoming preferred by Addis Ababa residents as the best living town. The mode of transportation is similar with that of LegeTafo-LegeDadi town (Sendafa Beke Town Municipality Yearly Report, 2016).

**Aleltu-FicheGelila** town is situated at a distance of 56.6km north-east of national capital (Addis Ababa) city. The astronomical location of Aleltu Woreda lies at 9o11'60'' latitude and 39o10'0'' longitude. The total population in this Woreda is 66,532 of out of whom

33,690 are men and 32,842 are women: 9,812 or 14.75% of its population are urban dwellers. Mode of transportation in this town is mixed flow mostly Minibus, carts and pedestrians movement on foot (http:// en. Wikipedia.org/ Aleltu).

**Sheno** is a town found in central Ethiopia in Kimbibit Woreda, which is located in the Semien Shewa Zone of the Oromia Region. Hamus Gebeya and Sembo are the kebeles of Sheno Ketema town. Sheno town is situated at a distance of 73 km north-east of the national capital (Addis Ababa) city. The astronomical location of Sheno town lies in 9°20′N latitude and 39°18′E altitude (Sheno Town Municipality, 2016). Sheno is the main town of Oromia which has an estimated urban population of 14,115 according to CSA population projections (to July 2016) and among this, 6,642 are men and. 7,473 are women. Hamus Gebeya and Sembo, are the two satellite villages included after restructuring. The municipality covers these two kebeles with a much higher population and mixed type mode of transportation is used in the town (Sheno Town Municipality, 2016).

Angolelana Terawereda has 21 kebeles and among these, 2 kebeles are city kebeles (i.e. Chacha and Cheki). Angolelana Tera Woreda is located in the Semien Shewa Zone of the Amhara region (Sheno Town Municipality, 2016).

**Cheki** town is situated at a distance of 96 km north-east of the national capital (Addis Ababa) city and 34 km from Debre Birhan town. The astronomical location of Cheki town lies at 10o01’00’’ north latitude and 39o18’00’’ east longitude. The topographic feature of Cheki town is 99.9% plain and 0.1% mountainous. The area has 64.4% brown soil, 22.1% black cotton soil, 9.7% red color soil, 3.7% grayish soil and 0.1% other type of soil. The total population of Cheki town is 6,400 of out of whom 3,500 are men and 2,700 are women. The mode of transportation in Cheki town is mostly minibuses, horse-drawn (wagons and carts, locally named Gari) and pedestrians movement on foot (Cheki Town Municipality Yearly Report, 2016).

**Chacha** town is situated at a distance of 110 km north-east of the national capital (Addis Ababa) city and 20 km from Debre Birhan town. The Chacha town is found on geographical location with an average elevation of 1,700-1304 meters above mean sea level. The climatic condition is classified as mostly highland, locally known as Dega, agro-climatic zone of Ethiopia. The detail climatic condition of Angolelana Tera Wereda is 85% highland, 13% is temperate and 2% is lowland. The total population of Chacha town is 5,089 out of whom 2,384 are men and 2,705 are women (Chacha Town Municipality Yearly Report, 2016).

### 1.7. Limitations of the Study

One of the main objectives of this study was identifying black spot segments by classifying the road in homogeneous segments and assigning the observed crash counts recorded from police crash recording booklets on each crash occurring segments, then ranking of segments for low cost improvements. In doing so, one will obviously need to collect primary data through long periods of site visiting and needs different technical personnel and adequate budgets. However, due to lack of finance and time constraints, the research focused on selected segments. The study area covered long distance, hence data collection from each traversed towns was so bothering that the traffic officers and the town municipal officers of each town could not be easily captured. Also, the booking system of crashes is so challenging to recite and transcribe.

### 1.8. Organization of the Thesis

The thesis is organized in six chapters as follow:

Chapter 1: Presents the background of the study, statement of the problem, research questions and objectives of the study, significance of the study, the study area, scope of the study, limitation of the study and to the end organization of the thesis followed.

Chapter 2: Describes previous studies attempting to identify and rank black spot segments to undertake low cost improvements.

Chapter 3: Discusses the sources of data, input and output variables, methodologies used and its method of statistical analysis in this study.

Chapter 4: Present the discussion and results of the study

Chapter 5: State the conclusion and

Chapter 6: Finalizes recommendations of the study for low cost improvements.

# CHAPTER 2: LITERATURE REVIEW

## 2.1. Introduction

Finding ways about the events leading up to a MVC is crucial in preventing the crash from occurring in the first place. Numerous studies have identified that the risk of MVC involvement and the severity of injury varies in accordance with geographic location. It is known that more crashes are recorded in built-up or metropolitan areas while non-urban area crashes are more likely to result in either the horrifying death or minor hospital treatment of an involved road user. The crash reports presented in this overview were gathered from crash insurance institutions, published researches, published reports about MVC, different countries' manuals etc. Previous works about MVC were skimmed in order to support the final output of the study. Spatial and Temporal variations of MVC were assessed followed by prioritizing black spot segments using both historically recorded crash data based methods and predictive Empirical Bayesian Method in road traffic were searched. Afterwards, risk factors influencing motor vehicle crash fatalities and injuries were kept an eye on and lastly, social and economic impacts of MVC were considered.

## 2.2. Operational Definition of Key Concepts

**Black Spot (Network screening)**: a segment on a road system where an extraordinary number of crashes have occurred contained by commonly 150m radius (AAZPTR, 2011).

**Crash**: is defined as a set of occasions that cause an injury or fatality involving one or multi-motorized vehicle(s) or a motor vehicle with bicycle, pedestrian or fixed object (Gharaybeh F A, 1991).

**Crash Frequency**: is defined as the number of observed crashes happening at a specific site within a reference period of time (Gharaybeh F A, 1991).

**Crash Rate**: is explained as the quantity of observed crashes that occurred at a particular site during a definite period of time related with a certain degree of exposure (e.g., per million VKT for a roadway segment, segment length etc.) (Gharaybeh F A, 1991).

**Crash Severity**: this can be expounded as;

- **Fatal Crash**: a crash where any person is killed or dies as a result of the crash within 30 days.
- **Serious Injury Crash**: a crash where victims sustain seriously injuries but not deaths.
- **Slight Injury Crash**: a crash where a victim is resulted for no death or serious injuries due to the crash but suffers slight injuries (outpatient).
- **Damage-only**: a crash that gives rise to only property or vehicles damage but no one is hurt (American National Standard, 2007).

**Degree of freedom:** the quantity of independent comparisons made between the sample elements (Douglas C.M. et al, 2003).

**Goodness of fit:** the agreement amongst a set of observed values and a set of expected values that depend on some propositions. (Douglas C.M. et al, 2003).

**Junction**: a path way formed when two or more roads mutually share a single location, including intersections, interchange areas, and entrance/exit ramps (AAZPTR, 2011).

**Manner of Collision/Crash**: the way how motor vehicles run into the incident. Its classification is as follows:

- **Angle**: impacts actuated at angles which are not head-on, rear-end, rear-to-rear, or sideswipe like right angle.
- **Head-on**: denotes to a crash where the front end of one vehicle collides with the front-end of another vehicle while the two vehicles are maneuvering in reverse ways.

- **Rear-end**: A collision in which the front bumper of one vehicle collides with the rear of another vehicle.
- **Sideswipe**: A collision in which the sides of both vehicles withstand slight endangerment (American National Standard, 2007).

**Motor Vehicle**: a road vehicle caused to move by an internal-combustion machine and defines a crash as strike aggressively with a hindrance or another vehicle (Judy Pearsall [ed], 1999).

**Pedestrian**: any person who is not part of a transport vehicle (American National Standard, 2007).

**Parameter**: an unknown figure that may vary over a set of values. Parameters occur in probability distributions and in statistical models, such as regression models (Douglas C.M. et al, 2003)

**Passenger**: any part of a transport motor vehicle other than a driver (American National Standard, 2007).

**Regression**: the statistical method used to examine the relationship between a dependent or response variable y and one or more independent variables x. The independent variables are usually called regressor variables or predictor variables. (Douglas C.M. et al, 2003).

**Regression to the Mean:** road segments or spots (intersections) with unexpected high figure of motor vehicle crashes can be mistakenly chosen as being unsafe (Hauer, 1986; Hauer and Persaud, 1987).

**Traffic Collision**: has a designation of motor vehicle collision/crash, traffic accident, motor vehicle accident, car accident, automobile accident, road traffic collision, road traffic accident, wreck, car crash, or car smash and happens when a vehicle collides with another vehicle, pedestrian, animal, road debris, or other fixed obstruction, such as a tree or utility pole (Wikipedia, retrieved on July, 2016).

As seen above, many different terms are commonly used to describe motor vehicle crashes/collision as the World Health Organization (WHO, 2011) uses the term “road traffic injury”, while the U.S. Census Bureau uses the term “motor vehicle accidents (MVA)” (The 2009 Statistical Abstract, 2009) and Transport Canada uses the term “motor vehicle traffic collision” (MVTC) (CCMTA, 2016).

Some organizations have begun to avoid the term “accident”. The expression ‘accident’ should be substituted by words such as crash, incident, fatality or road death in authorized declarations and official papers (Brigitte Chaudry, 2007; Victim Support for the families of road death victims, 1994; Nicholas Faith, 1997; Prof. Lan Roberts, 2001). In 2001, the British Medical Journal forebode the term ‘accident’ since most injuries and occurred actions are expectable and avoidable events, hence ‘accident’ is seen differently than crashes (British Medical Journal, 2007)

Therefore, all the way through this paper, Motor Vehicle Crash/Collision was used rather than Accident.

**Road**: is defined as a worthy linkage for fast development of a city for its survival and is a route that has beginning and destination. Roads are arteries of a city (Solomon Addisu, 2006)

**Road Traffic**: a movement of people, animals and vehicles from one place to another along roads and streets (Wikipedia, retrieved on July, 2016).

**Road Traffic Injuries**: fatal or non-fatal injuries experienced as a result of road traffic crash (WHO, 2004). Definition of an injury road crash involves a collision of a moving vehicle on a public road in which a road user, human or animal, is injured (IRTAD, 2013).

**Road Traffic Fatality**: death happening enclosed by 30 days of the road traffic crash (WHO, 2004).

**Road Vehicle Damage**: is an injury or an incidence on a road vehicle (American National Standard, 2007).

**Statistic**: a summary value calculated from a sample of observations. Usually, a statistic is an estimator of some population parameter (Douglas C.M. et al, 2003).

**Vulnerable Road Users**: means road users who are at risk in road traffic, like pedestrians, cyclists, passengers, children, older people and people with disabilities (IRTAD, 2013).

## 2.3. Spatial and Temporal Variations of Motor Vehicle Crash

### 2.3.1. Spatial Variation of Motor Vehicle Crashes

Motor vehicle crash is a major public health concern throughout the world. Approximately 1.25 million people are cut short each year as a result of road traffic crashes, i.e., one person is killed in 25 seconds, hence road traffic injuries are the leading cause of death among young people aged 15-29 years (WHO, 2015). Road traffic crashes are anticipated to escalate to become the 7$^{th}$ foremost cause of death by 2030 if there is no action undertaken (African road Safety Charter, 2013).

The type of crashes and their configuration highly correlates to the type of routes and the nature of user activities.

The condition of Motor vehicle crash is most severe in Sub-Saharan Africa where the lives of millions are lost and substantial amount of property is damaged. Approximately, 85% of these losses occur in low and middle in-come countries (UNECA, 2007/8; Journal of Sustainable Development in Africa, 2013).

Ethiopia is one of the African countries with the least vehicle-ownership. The available yearly inspected and registered national vehicle-fleet data showed that there was a considerable increase in traffic volume as a result of the economic development registered with an average annual GDP growth of 6.5% for the past ten to fifteen years and the total number of vehicles experienced significant increase, which is about 9% average growth, from 2005/6 to 2013/14 (NHTSSA'S, 2013).

Whenever the road infrastructure improves from time to time, crashes also increase in a manner that is directly related with the development. Ethiopia also showed rapid development of road infrastructures. From Table-1 below one can understand that in the last eighteen years the total road network of the country has significantly increased from 26,550 km with a road density of 0.46 per thousand people and 24.10 per thousand square km in the year 1997 to 99,522 km with a road density of 1.1 km per thousand people and 90.5 km per thousand square km in the year 2014 (ERA, 2015). According to a recent study, Ethiopia is the 22nd highest Motor Vehicle Crash Rate of death recorded country in the world reached 27, 147 or 4.27% of total deaths (WHO, 2017).

Table-1: Growth of the classified road network and change in road density (2000-2014)

| No. | Year | Road Network (km) | | | | | Growth Rate (%) | Road Density/1000 Popn. | Road Density /1000 sqr.km |
|---|---|---|---|---|---|---|---|---|---|
| | | Asphalt | Gravel | Rural | Wereda | Total | | | |
| 1 | 1997 | 3,708 | 12,162 | 10,680 | | 26,550 | - | 0.46 | 24.1 |
| 2 | 1998 | 3,760 | 12,240 | 11,737 | | 27,737 | 4.50% | 0.46 | 25.2 |
| 3 | 1999 | 3,812 | 12,250 | 12,600 | | 28,662 | 3.30% | 0.46 | 26.1 |
| 4 | 2000 | 3,824 | 12,250 | 15,480 | | 31,554 | 10.10% | 0.5 | 28.69 |
| 5 | 2001 | 3,924 | 12,467 | 16,480 | | 32,871 | 4.20% | 0.5 | 29.88 |
| 6 | 2002 | 4,053 | 12,564 | 16,680 | | 33,297 | 1.30% | 0.49 | 30.27 |
| 7 | 2003 | 4,362 | 12,340 | 17,154 | | 33,856 | 1.70% | 0.49 | 30.78 |
| 8 | 2004 | 4,635 | 13,905 | 17,956 | | 36,496 | 7.80% | 0.51 | 33.18 |
| 9 | 2005 | 4,972 | 13,640 | 18,406 | | 37,018 | 1.40% | 0.51 | 33.6 |
| 10 | 2006 | 5,002 | 14,311 | 20,164 | | 39,477 | 6.60% | 0.53 | 35.89 |
| 11 | 2007 | 5,452 | 14,628 | 22,349 | | 42,429 | 7.50% | 0.55 | 38.6 |
| 12 | 2008 | 6,066 | 14,363 | 23,930 | | 44,359 | 4.50% | 0.56 | 40.3 |
| 13 | 2009 | 6,938 | 14,234 | 25,640 | | 46,812 | 5.50% | 0.57 | 42.6 |
| 14 | 2010 | 7,476 | 14,373 | 26,944 | | 48,793 | 4.20% | 0.58 | 44.39 |
| 15 | 2011 | 8,295 | 14,136 | 30,712 | 854 | 53,997 | 10.70% | 0.66 | 49.1 |
| 16 | 2012 | 9,875 | 14,675 | 31,550 | 6,983 | 63,083 | 16.80% | 0.75 | 57.3 |
| 17 | 2013 | 11,301 | 14,455 | 32,582 | 27,628 | 85,966 | 36.30% | 1 | 78.2 |
| 18 | 2014 | 12,640 | 14,217 | 33,609 | 39,056 | 99,522 | 15.80% | 1.1 | 90.5 |

Many researchers wrote about the different Motor Vehicle Crashes contributory factors previously. Generally, on the following paragraphs it was tried to flick through on some of them.

Even though road injury affects the distribution of motor vehicle crashes in all age groups, it is a foremost cause of death universally for individuals aged 15-29 years, particularly drivers (WHO, 2009; World Bank, 2007). Among age groups, those aged under 18 account for only 21.6% of fatalities although they make up more than half of the population, such that the 18-30 and 31-50 age groups account for two-third of fatalities (Getu S., 2013; Anteneh K., 2013/2014; Misganaw B. et al., 2011).

Males, in the habit of our country Ethiopia, are mainly the active workers (producers) outside of home of the economy. Males are more vulnerable to death from crashes and roughly 15 times as many male drivers are killed compared to females (Getu S. et al., 2013). The majority of persons killed on the roads are young adults, i.e. three out of every four deaths were males (Anteneh K., 2013/2014; G. Jacobs et al., 2000; Teferi A., 2014).

Education is source of civilization for everything in the lives of mankind. Among the causes of crash mentioned is the education level of drivers. Drivers who have fully completed or not completed secondary education level and whose monthly income is high, resulted in high involvement for crashes (Getu S., et al., 2013; Hassen A. et al., 2011). Drivers who contributed for high percentage of fatality and injury crashes have accomplished junior school or below respectively (Hassen A. et al., 2011). Since drivers have a major role in many crashes, they are hence the crucial factors in most of the crashes, and this is due to drivers' judgment, skill and emotional makeup, age, sex, marital status, training, use of alcohol and drug, fatigue, use of crash helmets and safety belts, and speed (Atsbeha G., 2014).

Accordingly Nilsson G's (2004) study, an increase in average speed is directly related both to the likelihood of a crash occurring and to the severity of the crash consequences. A 5% increase in average speed leads to an approximately 10% increase in crashes that cause injuries, and a 20% increases in fatal crashes (Finch DJ. et al., 1994; Transport Research Center, 2006; Grundy C. et al., 2009). Speeding beyond the limit or uncontrollable speed leads the driver to have less perception and reaction time and pressurized force when the incidence happens (WHO, 2011; Merchant SP., 2008; WHO, 2013). Reducing the average driving speed has a purpose on health outcomes other than decreasing crash severities (Rekauskas et al., 2011)

Despite the evolvement made in many countries in cutting drink-driving, alcohol is still an overbearing and pervasive factor in road crashes. Drinking and driving increases both the risk of a crash and the likelihood of death or serious injury in the event of a crash (Peden M. et al., 2004). Crashes involving drink driving are often characterized by high speed and involve single vehicles running off the road (WHO, 2007).

There is an investigation indicating fatigue-ness undesirably affects tasks requiring alertness such as driving (P. Obst. et al., 2011). According to Diamantopoulou K. et al (2003) consistent with depressions in alertness associated with the human daily rhythm, fatigue-related road crash occurrences have been found to peak between 2:00 am and 6:00 am and 2:00 pm and 4:00 pm. Diamantopoulou K. et al. (2003) also suggests that younger drivers are at higher risk of fatigue-related crashes at night than other drivers. Several reports have identified driver fatigue as a particular safety issue for rural/ remote areas. This may be due to the high speed limits, long, straight, monotonous stretches of road with little scenery, long distances between towns and long distances travelled in these areas (Centre for Accident Research and Road Safety, 2005).

The horizontal and vertical alignments of the road are two important aspects of road design that can influence crash risk. Reasonably, one can expect the crashes to happen more often on curves or grades than straight tangent sections. Road alignment influences speed, variations in speed, friction and drivers' expectation of the road ahead. It has been reported that crash risk increases as the curvature of a road and number of unanticipated curves increase (Taylor et al., 2002 and Glennon J.C, 1987). Straight alignments of a road segment are the well-known type of crash prone locations (NRTSC, 2006).

Road gradient or slope of the road is an important road safety factor. Steep uphill slopes may restrict the visibility of the driver and steep downhill slopes may lead to excessive speeds, improper use of brakes and loss of control of the vehicle, particularly for heavy vehicles (Taylor et al., 2002). Highest grades, sharpened curves, the increase in ADT and number of lanes have a direct relation with the increase in number of crashes (NRTSC, 2006).

Rural and remote areas are locations with unsealed surfaces where crashes mostly occur (13.8%), compared to urban areas (0.9%) (Zegeer, C.V. and J.A. Deacon, 1987). Two-way and two-lane roads constitute the major proportion of the road network in Ethiopia and hence the fatal crashes participated majorly on two-way and undivided two-lane roadways (Getu S. et al., 2013). The fatal catastrophic rates increase in non-built up areas than built up areas (AASHTO, 1994). Most crashes occurred on paved two-way and two-lane roads, in cities and on regional highways, particularly in central business districts and residential areas (Getu S. et al., 2013).

Cross sectional elements such as lane width, shoulder width and shoulder type have been found to be very important in crash consequences. Lane and shoulder conditions directly influence run-off-road and opposite direction fixed object, rollover, head-on and sideswipe crashes (Griffin, L.I. and K. K. Mak., 1989). No feature of a highway has a greater influence on the safety and comfort of driving than the width and condition of the driving surface (AASHTO, 1994). As road widths increase for varying degrees of ADT, single-vehicle Crash Rates decrease (Legge, M., 2001). Crash Rate drops down with increasing lane width greater than 5.8 m, and the carriageway width of 5.8 m has the lowest Crash Rate on one lane roads (Gan, A. et al., 2005). High speeds and wide roads result in more crashes (Garder, P.E., 2004).

The main purpose of directional separation is to prevent conflicts by separating opposing traffic streams. Sometimes narrower lanes give aids for traffic operations, pedestrian safety and may also diminish neighboring disturbances besides making available for fixing safety assurance geometric features like medians and left turn lanes (Viner, Ray et al., 1994). When the median was used, a 19% decline of the number of crashes happened (Getu Segni, 2007).

Observance of sight distance is a question for road segments and intersections during designing phase. Alignment changes undertaken to increase very short sight distances to very long distances appear to be safety effective (Gan, A. et al., 2005). However, sight distance improvements may only be cost effective when traffic volumes are very high and major hazards are hidden by sight hindrances and also sight distance is predominantly significant for trucks since the braking performance is poor and greater sight distance must be adhered (Getu Segni, 2007). Crash Rates decrease with increasing of sight distance Narrow Bridge, inadequate sight distance, insufficient illumination, road curvature, and faded road markings are the main causes of crashes (P.J. Ossenbruggen, and J. Pendharkar, 2001).

The land use type is the main influential factor in crash occurrence. Village sites are not crash susceptible areas from inhabited and supermarket run sites since people inhabited sites have footpaths, crosswalks and traffic control devices that markedly made pedestrian companionable to the vehicle movement (Yayeh A., 2003).

Junctions are locations which are crash prone intersections. Urban areas and junctions are locations where crashes happen mostly than any other places (Yayeh A., 2003). Midblock road junctions are mostly described by extra crash prevalence than any other junctions. Moreover, Y-junction and T-junctions have revealed sufficient crashes (Atsbeha G., 2014). Intersections are the main type of geography especially at urban areas with high crash experiencing locations followed by on-stretch roads (Teferi A. et al., 2014). Concerning the vehicle movement before entering the crash, extremely the main crash occurs while vehicles operate heading straight (head on) followed by crashes while entering or leaving the junction from/to minor roads (Getu Segni, 2007).

Different research shows that there is a connection between traffic volumes, vehicle type and crash occurrence. Taxis and buses are vastly expressed as fatal crash causing vehicles (Almaz B., 2014). With regards to drivers' relationship with vehicles, hired drivers share the majority of crashes than vehicle owners. The increase of traffic volume on the road escalates the likelihood of road traffic crashes (European Agency for Safety and Health at Work, 2010). Heavy load vehicles causes crashes due to overcrowding accounted for 20% of the total and rear-end collisions are likewise major source of crashes secondly (Ryan GA., 1998). Because of higher travelling speeds, multi-vehicle crashes are commonly more severe in rural than urban areas. Besides, single vehicle crashes frequently occur at high speeds on curved and unsealed roads and often have more severe consequences than multi-vehicle crashes (Kassu J., 2009). Mixed type of vehicles occurs at rural and remote environments and this aggravates the magnitude of crash occurrences. Besides, in rural areas a single vehicle non-pedestrian crash takes the first rank (NRSCO, 2006). Ethiopians are more likely to make use of commercial vehicles, minibuses and buses to support mobility needs. So commercial vehicles, small buses, and large buses have a high involvement in crashes (Getu Segni., 2007; Andrey J. et al, 2001).

### 2.3.2. Temporal Variation

Weather condition plays a great role in MVC and has an impact in the subsequent areas:

i. Crashes escalate during precipitation from 50 to 100%
ii. Snow storm causes high crash consequence than rainfall. However, snow storm associated crashes have a tendency to be less serious than others.
iii. Type and intensity of precipitation can make risks to vary, hence risk appears to be extreme for freezing rain and the first snowfalls of the season and lowest for light drizzle or snow flurries.
iv. Visibility is affected during rainfall but it returns to normal stage even if roads continue to be wet, whereas snowfall-related risk often remains elevated as frictional effects dominate.
v. High winds and fog in combination with precipitation, even if they cause a small proportion of crashes, generally escalate the risk of crashes (Pennsylvania Department of Transportation, 2014).

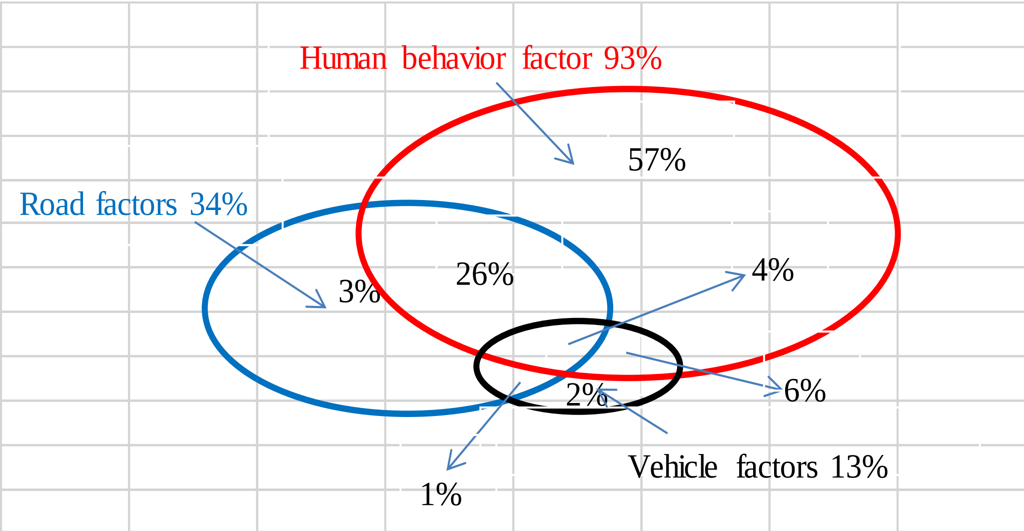
In Ethiopia, as some researches indicate, on weekends there are more fatalities than on weekdays with Saturday and Sunday having the highest incidence (AASHTO, 1994; Almaz B., 2014). The month with the highest incidence of crashes is July. Most fatal crashes occur between evening 18:00 and midnight, followed by morning 06:00 until midday and midday to 18:00 (Almaz B., 2014). More crashes occur in daylight than all other light intensities since more vehicles are on the road during daylight (AASHTO, 1994).

Weekends before normal working day and weekends after holidays have nearly several crashes and fatalities and sometimes even more unexpectedly (Persaud and Hauer, 1984;

Hauer, 1997). Unsuitable weather and road surface conditions, on the other hand, adversely affect vehicle handling and drivers' vision (Persaud and Hauer, 1984; Hauer, 1997). Environmental conditions such as climate have important distinctive causes for the manifestation of crashes. Among the five climate conditions mentioned (good whether/clear skies), rainy, foggy/cloudy, hot and cold), good whether/clear skies are meteorological conditions for most of the fatal crashes, followed by cold weather (PIARC, 2003).

In general, an enormous number of thorough crash investigation studies (see Figure-3) made available a more complete picture of the real crash causes.

Figure-3: Crash contributing factors (Rune E. et al, 2004).




This diagram depicts the link between individual areas of the road safety system. It indicates the important role of the road itself, particularly its essential interaction with human behaviour.

## 2.4. Black Spots in Road Traffic

### 2.4.1. Definition of Black Spot

Black spot in road traffic generally represents the situation in which number of traffic crashes occur in more than the average (Goran Z. et al., 2001). Internationally, authors are interpreting the term black spot in different ways, however black spots can be concisely defined as fragments of a road on which the escalation in extent of crashes with deaths and higher property damage happens (Cerovac, V., 2001). Dangerous road locations or black spots on the road are places on which the risk of traffic crashes is significantly higher than other road locations (OECD, 1999; Gatti et al., 2007; Polidori et al., 2012). The place in a highway where the traffic collision frequently occur is called a Black Spot or a Black Spot is a word used to designate a location where road traffic collisions have been deposited in the past (A.M. Jain, 2014).

Several alternative methods are presented to identify locations or roadway segments with potential of high crash promising locations.

### 2.4.2. Method of Statistical Analysis for Prioritizing Black Spot Locations

How to find black spots has been subject to extensive investigation and examination as they are a consequence of random unintended happenings which reveal reduced rate of recurrence and excessive distinction as a result of their Poisson nature (Kent S. and Hans Ek., 2011).

It is documented that most of safety issues are focussed on regional roads. Nevertheless, due to lower traffic volumes, rural high crash locations are less gathered, which makes their recognition problematic (HSM, 2014). Challenges mainly arise due to heterogeneities in crash frequencies caused by heterogeneous driving population, traffic conditions, roadside features and design considerations.

Though transportation agencies spend millions of dollars on preservative and preventive maintenance for ensuring the best possible safe environment for road users, it is unbearable to get systematic way to the black spot identification methods in Ethiopia. Previous efforts to identify potentially problematic crash locations were based on using historically recorded crash data. In this study, both historically observed crash data methods including more commonly known as conventional methods and predictive Empirical Bayesian methods were tried to assess for black spot identifications.

#### 2.4.2.1. Observed Crash Data Statistical Methods

At present, various techniques have been used in identifying black spot areas. A study proposed some black spot analysis techniques including Crash Frequency, Crash Rate, Rate Quality Control (Upper Control Limit with Crash Rate), Crash Severity and mixed techniques, which were popular methods (Gharaybeh FA., 1991).

The Observed Crash Frequency refers to the number of recorded crashes per year (Gharaybeh FA., 1991). Crash Rate refers to the number of crashes that occurred at a site during a time period to a particular measure of exposure (Gharaybeh FA., 1991; Persaud, 1986; Persaud, 1988; Persaud and Hauer, 1984; Hauer, 1997). Observed Crash Frequency and Crash Rates are often used as a tool to identify and prioritize sites in need of modifications and for evaluation of the effectiveness of treatments. Sites with the highest Crash Rate or rates higher than a particular Crash Rate are further analysed for potential modifications to reduce crashes (Persaud, 1986; Persaud, 1988; Persaud and Hauer, 1984; Hauer, 1997).

Upper Control Limit is the limit to determine crash risk black spot road segments where the value above the Upper Control Limit is considered as black spot and the method is completed by comparing the Crash Rate (CR) with Upper Control Limit (UCL) using the Dangerous Factor (DF) of each road segment (Gharaybeh FA., 1991).

Previous researches (Higle, J.L. and Hecht, M.B., 1989) have reported that black spot identification methods relying on a simple ranking of Crash Frequencies or Crash Rates, due to random fluctuation of crashes from year to year, can produce large number of false positives (safe sites falsely identified as unsafe) and false negatives (truly hazardous sites escape identification). These errors result in inefficient use of federal and/or state aid and local government resources applied for safety improvements.

Unfortunately, there are some basic limitations associated with the Crash Frequency and Crash Rate methods. For example, often a linear relationship between Crash Frequency and exposure is incorrectly assumed. Typically the association between traffic volumes and numbers of crashes is nonlinear. Crash Rates can also be misleading. The observed crash data methods also prohibit the ability to estimate the expected average Crash Frequency for the existing system under diverse traffic flows or geometric designs (Persaud, 1986; Persaud, 1988; Persaud and Hauer, 1984; Hauer, 1997).

One of the other limitations of the observed crash data methods is on observed data reporting processes. The observed data do not include all the crashes that happened, i.e. there is a difference in crash reporting thresholds, judgment of observer preparing crash report, data entry can introduce typographical errors, imprecise location data, incorrect entries, lack of training, subjectivity etc. (Persaud, 1986; Persaud, 1988; Persaud and Hauer, 1984; Hauer, 1997).

The use of the Crash Frequency and Crash Rate methods historically has been widely used for safety assessments. As a result, they are generally accepted methods that are straightforward and intuitive. They can also be used, on a limited basis, to evaluate certain alternative configurations based on cross-sectional comparisons of existing features. In addition, the results are easy to understand by most members of the public, so this method is acceptable to the public (Persaud, 1986; Persaud, 1988; Persaud and Hauer, 1984; Hauer, 1997).

#### 2.4.2.2. Predictive Empirical Bayesian (EB) (Expected) Statistical Method

MVC are normally infrequent and unplanned discrete events. They are typically occasional for most intersections or roadway segments. The Empirical Bayes (EB) method is best to have more precise evaluation of safety and regulations for the regression-to-mean susceptibility and built on not only crash frequencies but also similar units. The EB method, formally introduced by Ezra Hauer, has been adopted as the state of the practice for identification of black spots. The application of EB accounts for both crash history and expected crashes on similar sites and is given more attention by most researchers (Higle, J.L. and Hecht, M.B., 1989).

In EB method, the safety of a site is valued by giving a weighted average of Observed Crash Frequency on the focus site and probable crashes on similar sites, where the weight is regulated by the variance in estimating expected crashes of the reference sites (Higle, J.L. and Hecht, M.B., 1989). Empirical Bayesian method was used by many researchers (Cheng, W., and S.P. Washington, 2005, 2008; Elvik, R., 2008a, 2008b; Montella, A., 2010; HSM, 2014; Peden et al., 2004) and established that the EB method is in general superior to all other methods available for identifying high risk sites.

The detail procedures of Empirical Bayesian Method is described in the Estimating Safety by the Empirical Bayes Method tutorial (HSM, 2014).

#### 2.4.2.3. Route-km Post; Stationing

Road stationing is used to identify location with distance between known points. This method uses values assigned to road sections. Each road has an original station (zero point), and the distance from this point defines each location. Distances are indicated by km post markers. Groups of segments that are similar regarding geometry and other features are grouped homogeneously. Supporting this point, since crash reporting is subject to errors or less precise, i.e. rural areas or areas where field reference markers are far apart, longer segment lengths should be used for analysis purposes (Cheng, W., and S. P. Washington, 2005).

#### 2.4.2.4. Period under Review

Adequately large MVC data sets must be available for an analysis of the existing road safety. The analysis of crash history suggests that a 3-year crash history is the ‘optimum’ crash history, and up to 6 years of crash history is generally better than shorter histories (Cheng, W., and S. P. Washington, 2008). It is recommended that not less than 3 years of crash history duration be used in black spot identification analysis, and the most recent 6-year crash history record may be used if few fundamental changes at the location understudy period occurred (Cheng, W., and S. P. Washington, 2005). Shortest period results in fluctuation (i.e. regression to the mean effect) of traffic volumes, driver population, and maintenance activities surrounding changes to land use, weather fluctuations etc. of the site undergo, however longer crash history periods related with progressively unstable nonlinear functions with time (Cheng, W., and S. P. Washington, 2008).

## 2.5. Social and Economic Impact of Motor Vehicle Crashes

Deaths and injuries in road traffic crashes have posed a serious threat to global health and have had a negative impact on social and economic progress as well as sustainable development.

Motor vehicle Crashes have a number of adverse effects on the socio-economic development of the country. Since most of the victims are those in the generative age group, families lose their bread winners and the country its productive manpower. Hospitals in Ethiopia are stretched with the growing problems of traffic crashes in the country (Teferi A., et al., 2014). The impact of road crashes in social, economic and political aspects is widely spread all over the world (Pearson A., 2008). The loss of lives, damage to property and the sorrow it leaves in human mind are profound though the degree varies from nation to nation-developing nations suffering the hardest hit. In

Ethiopia injury is a foremost health problem contributing for more than a quarter of all surgical admissions, deaths or disabilities (Jacobs, GD. and Sayer, IA., 1983).

Globally, losses due to road traffic injuries are estimated to be worth $ 518 billion and charge governments between 1% and 3% of their GNP more than the total amount that these countries receive in support to improve their way of life (Teferi A. et al., 2014; Bureau of Infrastructure Transport and Regional Economics, 2006).

In Australia, four people die and 90 people suffer a serious road injury every day (African road Safety Charter, 2013) with the cost of the problem estimated to be worth $27 billion annually (Ethiopian Federal Police Commission, 2015). Ethiopia, as a developing nation, loses more than 800 million birr (ETB) every year due to road traffic crashes (Ethiopian Economics Association, 2012). Another concern for Ethiopia is the crash-caused property damages. The property damage due to traffic crashes increased from Birr 56.96 million in 2001/02 to Birr 325.71 million in 2009/10, but reduced to Birr 108.5 million in 2010/11. In terms of the percentage of GDP, it declined from 0.09 percent in 2001/02 to 0.03 percent in 2007/08, but rose again to 0.09 percent in 2009/10 and declined abruptly to 0.02 in 2010. This is due to the relatively higher growth of nominal GDP to the growth in the value of damaged property (Guyu F.D., 2013).

The economic sector is being highly affected when the energetic, creative, knowledgeable and experienced person who, as an individual, can contribute to national development perishes away because of road traffic crashes (AfDB, 2013).

The economic implications of MVC are highly devastating exclusively for developing countries since deaths due to these causes are highest among the most economically active population (15-59 years) (AfDB, 2013). A study has estimated the total health and life-related cost of motor vehicle injuries in Addis Ababa in 2010 to be about worth 31,692,892 Ethiopian Birr (Gebre M., 2010), showing the terrible nature of the problem.

In spite of the fact that Ethiopia is one of the underdeveloped countries in the world, it loses at least 12 million Ethiopian Birr per year on average. In addition, road traffic crash stands out to be the third killing factor (Fanueal, S., 2006).

From this evidence, it is noticeable that the work force of the world is under destruction by MVC causing considerable economic losses to victims, to victims' families, to the society, to the nation and then, consequently, to the world as a whole.

# CHAPTER 3: RESEARCH METHODOLOGY AND DATA ANALYSIS

## 3.1. The Research Approach

The key issue of this research was the identification of black spot locations and integrated ranking using techniques of historically recorded crash based and a predictive statistical methods. Historically recorded crash based statistical methods include Upper Control Limit established on Crash Rate, Crash Frequency Difference Density Deviance Score or in short Crash Score and Mixed Crash Frequency - Crash Rate methods. An Empirical Bayesian Statistical Method of Analysis was the predictive technique. The descriptive information on the Actual Observed Crash Frequency was displayed to make a clear vision. Then the four methods were compared in identification process. After identification of black spot areas, the probable low cost improvement was undertaken in support with site investigation for the top ranked and selected black spot segments.

## 3.2. Sampling of Data Collection Sources and Participants

Availability Sampling: is a specific type of nonprobability sampling method that relies on data collection from population members who are suitably accessible to partake in study. Availability sampling is a method of choosing subjects who are obtainable or easy to find. This method is also sometimes referred to as haphazard, accidental, or convenience sampling. The primary advantage of the method is that it is very easy to carry out, relative to other methods. A researcher can merely stand out on his/her favourite street corner or in his/her favourite roadhouse and hand out surveys (Saunders, M., 2012).

Hence, the Traffic Police Station of each respective sub-town which includes LegeTafo, LegeDadi, Sendafa-Bekie, Alelitu-FichieGenet, HamusGebeya-ShenoKetema-Sembo and Cheki-Chacha-Tebasie (entrance of Debre Birhan) were data collection locations of this study. The police in these areas are responsible to record and evaluate MVC for both built-up areas and the stretched rural road.

## 3.3. Sources of Data

This section deals with how information was collected. The data assembled were mainly from secondary data sources.

### 3.3.1. Traffic Volume Data

Evidence on traffic volume, composition and loading are important factors in the determination of appropriate standard of road and safety problem. Data about traffic volumes assists also with road geometric design and prioritising road networks for Traffic count data is also valued in evaluating road safety risk exposure and aiding identify how effective previous improvements have been. In this study, traffic flow volume (ADT) was collected from each corresponding sub-town's road and transporting governmental offices captured through manual counting which is conducted along the path of each particular main road boundaries of the town. Furthermore, the Ethiopian Roads Authority (ERA) conduct traffic volume count (ADT and VKT (ERA, 2015)) and prepare a traffic volume datasets and as well update each year and release an access for users. Hence, the data obtained from ERA was used to compare the traffic volume acquired from each respective sub-towns along the traversed road. According to ERA, the vehicles are classified in to eight categories based on their size and weight as group A: passenger vehicles; Car (Cars and Taxis), L/Rover (Land Rovers, Jeeps, Station Wagons, Land Cruisers etc.), S/Bus (Small Busses up to 27-passengers' seats), L/Bus (Large Buses over 27-passengers' seats) and group B: Freight Vehicles: S/Truck (Small and Light Trucks of 3.5 tons loading capacity), M/truck (Medium-sized Trucks of 3.5 to 7.5 tons loading capacity), H/Truck (Trucks and Tankers of 7.6 to 12 tons loading capacity), Truck-Trailer

(Truck-trailers and Tanker Trailers above 12 tons loading capacity). Also, similar classifications of vehicles were observed and used also in this research.

### 3.3.2. Police Reported Motor Vehicle Crash Data

Quantitative source of MVC data was obtained from the police recorded booklets file of the nearby police stations on each town where the study area navigates using specified MVC recording format (See Appendix II).

The information reported in the files were concerned on:

- Crash consequence: fatal, serious injury, slight injury, property damage only (PDO);
- Type of collision: frontal, side, pile-up, road crossover, pedestrian run-over, hitting fixed objects, running off the road;
- Period of the crash: crash hour, crash day of the week, crash date, crash month of the year, crash year;
- Drivers' status: sex, age, education background, driver vehicle relation, driving experience;
- Vehicle status: vehicle type, vehicle ownership, vehicle year of service, vehicle maneuvering before entering the crash, vehicular Defect;
- Road status: crash location (residential, urban road, rural road (on-stretch road), market area, religion area road), type by lane (two-lane undivided, two-lane divided, channelized);
- Road geographical location: (straight, curve, tunnel, bridge, intersection, exit, incline/decline), junction type (Y, T, +, O and 5 routes), road surface type (dry, slippery, snowy, wet, icy);
- Environmental status: road condition, road lighting condition;
- Weather condition: calm, cloudy, rainy, foggy/misty, snowy

- Victims' (pedestrian/passenger/driver) status: age, sex, occupation, previous gross physical & health condition etc.

A four year police reported crash data from 2012/13 to 2015/16 (2005 to 2008 in Ethiopian Calendar (E.C.)) was used in this study. In this case, as described in literature review part (Cheng, W., and S. Washington, 2008), data from three years up to six years is best to describe the location's precise crash data.

### 3.3.3. Road Data

This set of data provides the researcher with relevant road infrastructure information linked with the location of the MVC and other circumstances and factors contributing to the crash occurrence. The road data as built drawing was obtained from ERA (Ethiopian Road Authority) governmental offices; it accommodated:

- Geometric Design of the road: horizontal curve, vertical curve, junctions, super elevations, geometric profiles etc.
- Road barrier objects, delineators, road side obstructions
- Exact dimension of lanes, shoulder width etc.
- Length of the road, surface type of road (flexible)
- Crossing towns location with elevations
- Traffic signals, road markings with crossings if any
- Bridge and culverts, intersections, tunnel etc.

In this paper, a segment length with 1 km (i.e. 0.625 miles) each is used as a homogenous segment from kilometre posts assigned by ERA.

Even if these data were available, a complementary site walkover and investigation is desired and can lead to findings which were not obvious from the crash data analysis. Hence, drivers' circumstance, the environmental condition, the vehicles well-being, the areas' way of transportation, the police traffic cooperativeness, the precise position or repeatedly crash recording sites and others were easily assessed during site inspection after identification of ranked black spots.

## 3.4. Description of Variables Designated

### 3.4.1. Dependent Variables

The crash consequences were identified in four parts as described in the literature review (American National Standard, 2007). Crash severity or consequence was coded with the following options:

1. Number of fatalities
2. Number of serious injuries
3. Number of slight injuries
4. Property damage only

### 3.4.2. Independent Variables

The following independent variables were used as shown in table 3 below.

Table-2: Independent variables considered in the Motor Vehicle Crashes.

| No. | Variable Type | Description |
|---|---|---|
| 1 | Type of collision | Out of control<br>Angle<br>Side swipe<br>Rear end<br>Head on<br>Collision with motorcycle/bicycle<br>Multi-vehicle collision<br>Collision with pedestrian<br>Collision with animal<br>Collision with fixed object<br>Overturning<br>Other |
| 2 | Time of Crash | Day time<br>Night time |
| 3 | Crash hour | 1:00-2:59 11:00-12:59<br>3:00-4:59 13:00-14:59<br>5:00-6:59 15:00-16:59<br>7:00-8:59 17:00-18:59<br>9:00-10:59 19:00-20:59<br>Unknown 21:00-23:59 |
| 4 | Crash Day of the week | Monday to Sunday |
| 5 | Crash Month of the Year | September to August (including Puwagme) |

| No. | Variable Type | Description |
|---|---|---|
| 6 | Crash Date Crash Year | Date |
| 7 | Vehicle Ownership | Private, Governmental, Rental and Unknown |
| 8 | Vehicle Year of Service Vehicle | 1-2, 2-5, 5-10 and above 10 years |
| 9 | Vehicle maneuvering before entering the crash | Straying to the right<br>Illegal turning<br>Crossing at prohibited place<br>Driving on the wrong side of the road<br>Improper backing<br>Moving Straight<br>Swerving (turning sharply)<br>Unknown |
| 10 | Crash Location | Residential, On rural stretch or Unknown |
| 11 | Road Type by Lane | Divided with solid line, Divided with strike line, Channelized or Undivided |
| 12 | Road Geographical Location | Straight flat<br>Straight ups and downs<br>Straight down hill, Straight up hill, Curved, Twisted or Unknown |
| 13 | Junction Type | T, Y, 4 leg, No junction or Unknown |
| 14 | shoulder | With shoulder and No shoulder |
| 15 | Road Surface Type | Asphalt or Other |
| 16 | Road Type by Function | Trunk or Other |
| 17 | Road condition | Dry, Wet or Unknown |
| 18 | Road Lighting condition | Day light, Sun rise, Sun set, Dark, Moon light or Unknown |
| 19 | Weather condition | Clear/good, Cloudy, Rainy, Little rain or fogy |
| 20 | Driver sex | Male or Female |
| 21 | Driver vehicle relation | Owner, Employee or other |
| 22 | Driver Experience | 1-2, 2-5, 5-10 and above 10 or unknown |
| 23 | Pedestrian age | Below 18, 18-30, 30-50 and above 50 |
| 24 | Pedestrian sex | Male or Female |
| 25 | Pedestrian health | Healthy/Normal or Other |
| 26 | Passenger age | Below 18, 18-30, 30-50 and above 50 |
| 27 | Passenger sex | Male or Female |
| 28 | Passenger occupation | Driver assistant, Daily laborer, Driver, Farmer, Housewife, Jobless, Merchant<br>Officer, Private worker, Student, Teacher or Unknown |

### 3.5. Statistical Analysis of Black Spot Identification Methods

#### 3.5.1. Upper Control Limit through Crash Rate

The establishment for Upper Control Limit through Crash Rate method embraces the following five steps with the help of equations 1, 2 and 3 below as (Gharaybeh F.A., 1991).

i. Make a tabularization of crashes for each road segments based on severity consequences, i.e. fatal, serious injury, slight injury and property damage only.

ii. Calculate the total of Crash Rates for each road segments (using equation 1).

$$CR = \frac{\lambda o x 1,000,000}{n x AADT x L x 365} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where:

CR = Crash Rate of each road segment (no. of crashes per 1,000,000 vehicles)

λo = Actual number of observed Crash Frequency in the analysis period (4 yrs)

n = Time period of the study = 4 years

AADT= Average Annual Daily Traffic during the study period

L = Length of road segment (1 kilometer each, 0.625miles)

iii. Calculate the value UCL for each road segment (using equation 2) with statistical ratio factor (k) 2.576 value. (See Table 3 below).

$$UCL=CRa+K\left[\frac{\lambda o}{\frac{nxAADTxLx365}{1,000,000}}\right]^{1/2} + \frac{1}{2x\left[\frac{nxAADTxLx365}{1,000,000}\right]} \ldots\ldots\ldots\ldots 2$$

Where:

UCL = Upper Control Limit of each road segment (No. of crashes per 1,000,000 vehicles)

CRa = Average Crash Rate of all road segments (The Crash Rate divided by number of segments (i.e. 108))

T = Time period of the study = 4 years

AADT = Average Annual Daily Traffic during the study period

L = Length of road segment (1 kilometer for each segment, 0.625miles)

K = Statistical ratio factor

- ✓ Statistical ratio factor (k) is determined by the probability, which the Crash Rate is large enough so that this crash cannot be regarded as random events. The most commonly used value of k is 2.576 with a probability of

0.005 (or significance 99.5%) and 1.645 with probability of 0.05 (or 95% significance) (Gharaybeh F.A., 1991).

Table-3: Probability and statistical ratio factor value.

| Probability | 0.005 | 0.0075 | 0.05 | 0.075 | 0.10 |
|---|---|---|---|---|---|
| k | 2.576 | 1.960 | 1.645 | 1.440 | 1.282 |

iv. Calculate the Dangerous Factor (DF) (using equation 3) and list in descending order.

$$DF = \frac{CR}{UCL} \quad \ldots\ldots\ldots 3$$

Where:

CR - is Crash Rate obtained from calculation using the Crash Rate method and

UCL - is Upper Control Limit, which can be formulated as in Equation 1 and 2, respectively.

v. Determine the location of black spot based on the Dangerous Factor.

The Dangerous Factor (DF) referred as the technique considering the Crash Rate (CR) compared to the Critical Crash Rate which is the Upper Control Limit (UCL) and is used as a threshold for black spot identification (Gharaybeh F.A., 1991).

A segment is considered to be as the location of the black spot where the Dangerous Factor is greater than 1. In the other way, a segment is considered as a black spot segment where the value of the Crash Rate is above the Upper Control Limit.

### 3.5.2. Crash Frequency Difference Density Deviance Score

This method is a modified method of Crash Frequency to avoid the regression to the mean effect of historical crash data used by the researcher of this paper. It is determined as the difference of the Actual Observed Historical Crash Frequency of each segment with the Average Actual Observed Crash from the total crash of the total segment excluding property damage only divided by standard deviation multiplied with segment length. The segment with negative Crash Frequency Difference Density Deviance Score (Crash Score) is assumed to be safe segment hence removed from the list. The ranking process is done using Crash Score listed from the uppermost value to the lowermost value. The Crash Score is described below in Equation 4.

$$\mathrm{Cs} = \frac{\lambda o - \lambda \alpha}{\sigma x L} \qquad \text{.....} 4$$

Where:

Cs - Crash Score

λo - Actual Observed Crash Frequency of the segment

λα - Average Crash Frequency of the total segment

σ - Standard deviation of the total segment

L - Length of each segment in kilometer

### 3.5.3. Mixed Crash Frequency-Crash Rate Method

Mixed Crash Frequency-Crash Rate method is used to avoid the drawbacks of both Crash Frequency and Crash Rate methods that they have individually. Though both methods are simple and have their own benefits, both have shortcomings too. Crash Frequency does not account for exposure, favours high-volume and used mainly in urban locations and engineering fix may not be present, whereas Crash Rate method favours for low traffic volume resulted intended for low crash segments and similarly favours high traffic volume aimed at high crash segments. Crash Rate also cannot compare cross different traffic volumes (Gharaybeh F.A., 1991; Persaud, 1986; Persaud, 1988; Persaud and Hauer, 1984; Hauer, 1997). The following formula in Equation 5 is used to determine the Mixed Crash Frequency-Crash Rate method.

$$\mathrm{MFR} = \frac{\lambda \mathrm{o}}{\mathrm{L}} + \frac{\lambda \mathrm{o} x 1{,}000{,}000}{\mathrm{nxAADTxLx365}} \qquad \text{.....} 5$$

Where:

MFR - Mixed Crash Frequency - Crash Rate

$\lambda_o$ - Actual Observed Crash Frequency at the segment per 1,000,000 vehicle

L - Segment length in kilometer

n - Number of years in the analysis period (4 years)

AADT - Average Annual Daily Traffic in the analysis period

### 3.5.4. Predictive Empirical Bayesian Statistical Method

The Predictive Empirical Bayesian (EB) estimates combine historical crash data with crash predictions and are thus able to identify also potential hazardous road locations, where no crashes have yet occurred (Persaud, 1986; Persaud, 1988; Persaud and Hauer, 1984; Hauer, 1997).

The Empirical Bayesian (EB) process consists of five steps (Hauer E. and Bamfo J., 1997); determining:

1. The Safety Performance Function (SPF);
2. The Over-dispersion Parameter, $\phi$;
3. The Relative Weights, $\alpha$;
4. The Estimated Expected Crash for First Year, $\pi_1$ and
5. The Estimated Expected Crash for Final Year, $\pi_{n.}$

All these steps are briefly discussed one by one as follows:

#### 3.5.4.1. Determination of Safety Performance Function

The first step in the Empirical Bayesian method is to determine a unique safety performance function (SPF). The SPF can be used to predict the number of crashes expected to occur each year at the case sites had there been no improvements to the roadway.

Where no derived multivariate model, HSM provides predictive model that are developed for rural two-lane two-way facilities to estimate Safety Performance Function (SPF) (HSM, 2014). This SPF on HSM (2014) is derived based on the sites with the actual crash data and location intended to be investigated. If this type of function is allowed for different type of locations, the predicted Crash Frequency for base conditions for a rural two-lane, two-way roadway segment is selected and multiplied by Crash Modification Factors (CMF).

The Predicted Crash Frequency, i.e. the safety performance function, for base conditions for a rural two-lane, two-way roadway segment is (HSM, 2014):

$$N_{SPFx} = (AADT)\ (L)\ (365)\ (10^{-6})\ e^{(-0.312)} \qquad \text{……6}$$

Where:

AADT = Average Annual Daily Traffic

L = Length of Roadway Segment (mile) - (1km~0.625miles is taken)

The following Table-4 gives the general input data of the base condition for roadway segments on rural two-lane two-way roads (HSM, 2014).

Table-4: Base condition for SPF derivation.

| Input Data | Base Conditions |
|---|---|
| Length of segment, L (mi) | -- |
| AADT (veh/day)$AADT_{max}$=17,800 veh/day | -- |
| Lane width (ft) | 12 |
| Shoulder width (ft) | 6 |
| Shoulder type | Paved |
| Length of horizontal curve (mi) | 0 |
| Radius of curvature (ft) | 0 |
| Spiral transition curve (present/not present) | Not Present |
| Super elevation variance (ft/ft) | < 0.01 |
| Grade (%) | 0 |
| Driveway density (driveways/mile) | 5 |
| Centerline rumble strips (present/not present) | Not Present |
| Passing lanes (present(1 lane or 2 lane) / not present) | Not Present |
| Roadside hazard rating (1-7 scale) | 3 |
| Segment lighting (present/not present) | Not Present |
| Auto speed enforcement (present/not present) | Not Present |
| Calibration Factor, Cr | 1 |

#### 3.5.4.2. Crash Modification Factor (CMF)

CMF represents the relative change in Crash Frequency due to a change in one specific condition, when all other conditions and characteristics remain constant (HSM, 2014). CMFs may serve as an assessment of the effect of a specific geometric design or traffic control feature or the efficiency of a specific action or situation.

The CMFs for geometric design and traffic control features of rural two-lane two-way roadway segments are presented in Table-5. The base condition SPF needs local CMF equations to adjust the local geometric design and traffic control features. Therefore, the following equations listed are used to derive the local adjusted SPF (HSM, 2014). Some input data are avoided where it is similar to the base condition.

Table-5: CMF equations to adjust SPF for local usage on the road from Addis Ababa to Debre Birhan understudy.

| Item | Input Data | Local CMF Equations | Variables |
|---|---|---|---|
| 1 | Lane width (ft) | $CMF_{r1}$= ($CMF_{ra}$ - 1.0) *$P_{ra}$ +1.0 | $CMF_{ra}$=CMF of lane width related Crashes, $P_{ra}$=proportion of related crashes |
| 2 | Shoulder width (ft) | $CMF_{2r}$= ($CMF_{wra}$ * $CMF_{tra}$ - 1.0) * $P_{ra}$ + 1.00 | $CMF_{wra}$= CMF of shoulder width related Crashes<br>$CMF_{tra}$= CMF of shoulder type related crashes |
| 3 | Length of horizontal curve (mi), radius of curvature (ft) and spiral transition curve (present/not present) | $CMF_{3r} = \frac{1.55 * L_c + \frac{80.2}{R} - 0.012 * s}{1.55 * L_c}$ | $L_c$=length of the curve, R=radius & $S^*$=spiral curve |
| 4 | Super elevation variance (ft/ft) | $CMF_{4r}$ = 1.00 for SV < 0.01;<br>$CMF_{4r}$= 1.00+6 *(SV - 0.01) for 0.01 ≤ SV < 0.02; and<br>$CMF_{4r}$ = 1.06 + 3 * (SV - 0.02) for SV ≥ 0.02 | SV=super elevation variation |
| 5 | Grade (%) | G≤ 3%, $CMF_{5r}$=1;<br>3 %< G ≤ 6%, $CMF_{5r}$ =1.1; and G>6%, $CMF_{5r}$ = 1.16 | G = grade |
| 6 | Driveway density (driveways/mile) | $CMF_{6r}= \frac{0.322+DD*(0.05-0.005*\ln(AADT))}{0.322+5*(0.05-0.005*\ln(AADT))}$ | DD = driveway Density AADT = Annual Average Daily Traffic Volume for the segment |
| 7 | Centerline and edge line rumble strips | $CMF_{7r}$ = 0.76 | |
| 8 | Roadside hazard rating (1-7 scale) | $CMF_{8r}= \frac{\exp(-0.6869 + 0.0668*RHR)}{\exp(-0.4865)}$ | RHR = driveway density |

| Item | Input Data | Local CMF Equations | Variables |
|---|---|---|---|
| 9 | Segment lighting | $CMF_{9r}$ = 1- [(1 – 0.72* $P_{inr}$ – 0.83*$P_{pnr}$)*$P_{nr}$] | $P_{inr}$= proportion of total nighttime crash to unlighted roadway crash for fatality and Injury<br>$P_{pnr}$= proportion of total nighttime crash to unlighted roadway crash for property damage<br>$P_{nr}$= proportion of total crashes for unlighted roadway that occur at night |
| 10 | Install any type of median barrier | $CMF_{10r}$ = 0.57 for all types of fatal<br>$CMF_{10r}$ = 0.70 for all types of Injury | |

$S^*$=1 if spiral transition curve is present; 0 if spiral transition curve is not present; 0.5 if a spiral transition curve is present at one but not both ends of the horizontal curve.

### 3.5.4.2.1. Calibration Factors (C)

Calibration Factors (C) account for dissimilarities in geographical areas, drivers' characteristics, terrain, climate, animal, population, crash reporting threshold, crash reporting practices etc. The calibration factor is the sum of all the observed crashes for all the sites selected, divided by the predicted crashes using the equation for all the same sites (HSM, 2014).

$$C = \frac{\sum_{\text{all selected sites}} \text{Observed Crashes}}{\sum_{\text{all selected sites}} N_{\text{Predicted(Uncalibrated)}}} \quad \ldots\ldots 7$$

The number of predicted crash as it was explained in the literature review was formulated when the safety performance function (also derived from HSM (2014)), the crash modification factor (CMF) and calibration factors was combined and applied, as the next equation (HSM, 2014):

$$N_{predicted} = N_{SPFx} \times (CMF_{1x} \times CMF_{2x} \times \ldots \times CMF_{yx}) \times C_x \quad \ldots\ldots 8$$

Where:

$N_{predicted}$ = The general formula for site specific crash prediction model after adjustment.

$N_{SPFx}$ = Base condition Crash Frequency from SPF for site type x

$CMF_{yx}$ = Crash Modification Factors

$C_x$ = Calibration factor for site type x

### 3.5.5. Determination of Over-dispersion Parameter, ϕ

Crash Frequencies were often assumed to follow a Poisson distribution that assumes both the mean and the variance are equal which leads to the outcome result not precise (Hauer E., 2001a). A negative binomial distribution avoids this type of error by assuming the mean and the variance in different way (i.e. not equal). The parameter to identify this is overdispersion, ϕ, and happened where the variance of the dependent variable is above the mean, usually supported by a statistically significant ϕ-value, at the 95% confidence level (Hauer E., 2001b).

The overdispersion parameter can be estimated as a function of mean and variance of the mean of crash count as shown in equation 9 (Hauer E., 2001b):

$$VAR(\lambda_i) = \mu_i + \phi\mu_i^2 \quad \ldots\ldots 9$$

Where:

$VAR(Y_i)$ = variance of crash count; and

$\mu_i$ = mean of crash count.

$\lambda_i$ = actual observed Crash Frequency

The overdispersion parameter is associated with the type of model that SPF is formulated and the following relation was used to calculate the overdispersion parameter as in equation 10 below (HSM, 2014):

$$\phi = \frac{0.236}{L} \quad \ldots\ldots 10$$

Where:

L-Length of the segment in miles

#### 3.5.5.1. Calculation of Annual Correction Factor ($C_n$)

The annual correction factor is given as predicted average Crash Frequency for year n divided by the predicted average Crash Frequency for year 1. This factor is proposed to avoid the effect that annual variations in traffic, weather, and vehicle mix have on crash occurrences (HSM, 2014; Hardwood, D.W. et al, 2003). It can be a good practice to differentiate the crashes based on their crash severity types as (Equation 11):

$$C_{n(total)} = \frac{N_{Predicted,n(total)}}{N_{Predicted,I(total)}} \text{ and } C_{n(FI)} = \frac{N_{Predicted,n(FI)}}{N_{Predicted,I(FI)}} \quad \ldots\ldots\ldots\ldots 11$$

Where:

$C_{n\,(total)}$ = Annual correction factor for total crashes

$C_{n\,(FI)}$ = Annual correction factor for fatal or injury crashes, or both

$N_{predicted,\,n\,(total)}$ = Predicted number of total crashes for year n

$N_{predicted,\,I\,(FI)}$ = Predicted number of fatal or injury crashes, or both, for year n

### 3.5.6. Determination of Relative Weight, α

To adjust for varying degrees of over-dispersion, a relative weight, αi, is applied to each roadway segment (Hauer E. and Bamfo J., 1997). The segment specific relative weight is determined as follows:

$$\alpha_i = \frac{1}{1+SPF_i/\phi_i} \quad \ldots\ldots\ldots\ldots 12$$

Where:

$\alpha_i$ - denotes the relative weight applied to roadway segment *i* and all other variables are as previously defined

### 3.5.7. Determination of Estimated Expected Crashes, π

The estimate of the expected crashes for a given roadway segment can be calculated using the following Equation 13 (Hauer E., 2001b; Hauer E. and Bamfo J., 1997; Hauer, E., 2002):

$$\pi_i = (\alpha_i).(\mathrm{SPF_i}) + (1-\alpha_i).(\lambda_i) \quad \ldots\ldots\ldots\ldots 13$$

Where:

$\pi_i$ - denotes the expected number of crashes per number of years on roadway segment, *i*

$\lambda_i$ - denotes the actual number of crashes per No. of years on roadway segment, *i* and all other variables are as previously defined.

### 3.5.8. EB-Adjusted Expected Average Crash Frequency

The expected number of crash frequencies signifies the crash probability of a segment that actually occurred. This stage of the procedure incorporates the observed Crash Frequency with the predicted average Crash Frequency by weight factor. The larger the weighting factor, the greater the reliance on the predicted crashes than the observed to estimate the long-term predicted average Crash Frequency per year at the site. The final year EB-adjusted average Crash Frequency $(\pi_n)$ and expected long term first year crashes $(\pi_1)$ on the roadway segments are estimated by using Equations 14 and 15 respectively (HSM, 2014):

$$\pi_n = \pi_1 * (C_n) \qquad (14)$$

Where:

$$\pi_1 = (\alpha_1).(SPF_1) + (1 - \alpha_1).\left(\frac{\sum_{\text{all year}} \lambda_i}{\sum_{\text{all year}} C_n}\right) \qquad (15)$$

The symbols are as defined before.

### 3.6. Overall Measures of Goodness-of-fit

The overall measures of goodness-of-fit used for this paper is Chi-square measure to check the computed model.

### 3.6.1. Chi-square Measure ($\chi^2$-statistic)

This is used when there is one independent variable (i.e. categories of segments), and required to compare an observed frequency-distribution to a theoretical expected frequency-distribution.

The Pearson chi-square statistic is a quantity commonly used to test whether any given data are well described by some hypothesized function or not. The $\chi^2$-statistic that is based on standardized residuals, is given as in equation 16 (Washington, S., 2003; S.P. Miaou, 1996):

$$\chi 2 = \sum_{i=1}^{n} \left[\frac{(n_i - \mu_i)^2}{\mu_i + \phi\mu_i^2}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 16$$

In Equations 16, $n_i$ is the observed number and μi is the predicted number of crashes occurring at the road segment i using SPF and ϕ is the overdispersion parameter. Evaluation of the validity of the fit between observed values and the predicted values using SPF model can pass the goodness of fit criteria when the value of Pearson $\chi^2$ is greater than or equal to the value of $\chi^2$ statistics distribution with (n-1) degree of freedom for certain confidence level, which is 95% and the $\chi^2$ statistics distribution is obtained from table. If the obtained Chi-Square value is bigger than the one in the table, then it is possible to conclude that the obtained Chi-Square value is too large to have arisen by chance; it is more likely to stem from the fact that there were real differences between the observed and expected frequencies. In other words, contrary to our null hypothesis, the categories did not occur with similar frequencies (Douglas C.M. et al, 2003).

If, on the other hand, the obtained Chi-Square value is smaller than the one in the table, one can conclude that there is no reason to think that the observed pattern of frequencies is not due simply to chance (i.e., retain to the initial assumption that the discrepancies between the observed and expected frequencies are due merely to random sampling variation) (Douglas C.M. et al, 2003).

### 3.7. Ranking of Segments

The last step in the EB process was to express the resulting effectiveness of any treatment, i.e. roadway reconstruction and pavement preservation improvements, safety improvements, as in general for low cost engineering treatment etc, as a relative difference in crash occurrence between actual and expected. With the expected crash occurrence determined in the previous steps and the actual crash occurrence observed, the difference can be calculated directly.

Based on the selected performance measure which is Excess Expected Average Crash Frequency commonly called Potential for Safety Improvement (PSI), dangerous sites can be identified. It is also defined as the positive difference between EB estimate and the normal number of crashes expected from such types of segments (HSM, 2014).

$$PSI = \pi_n - N_{observed} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 17$$

Where:

PSI - is the excess expected average Crash Frequency

$N_{observed}$ - is the actual observed Crash Frequency in the site.

### 3.8. Low Cost Improvements

Based on the Dangerous Factor, Crash Score, Mixed Crash Frequency-Crash Rate and Potential for Safety Improvement, the segments were ordered for low cost improvement in hand of financial plan and priority. These treatments were intended to give cost minimization solutions to improve the traffic safety performance by significantly reducing crash occurrence risks and crash severities if possible to avoid completely.

# CHAPTER 4: RESULTS AND DISCUSSION

## 4.1. Introduction

This section discusses with calculation of descriptive and frequency information displays for the research variables. These techniques summarize various aspects about the data, giving details about the sample and providing information about the population from which the sample was drawn. Frequency techniques were the main descriptive statistics used with discrete variables which include absolute frequencies (raw counts), relative frequencies (proportions or percentages of the total number of observations) and cumulative frequencies for successive categories of ordinal variables. The MVC and its related exposure, which is used to know the cause and effects, create general know how of the road under study and assist in black spot identification, will be clearly explained. The historically MVC recorded based and Predictive Empirical Bayesian statistical methods will be estimated for identification of black spots and the anticipated low cost improvement for each selected black spot segments will proceed consequentially.

## 4.2. Descriptive Information of Motor Vehicle Crashes

The total number of Motor Vehicle Crashes reported by traffic police personnel booklet files were 587. But some crashes contributed for more than one fatal, serious, slight and property damage consequences. Based on the crash severity results within 2012/13-2015/16 period of study (from Addis Ababa (LegeTafo) to Debre Birhan (Tebase) road), there were 160 fatal, 254 serious injuries, 330 slight injuries and 488 property damages resulted in total of 1,232 consequences. The following table shows the total number of crashes recorded in the study area.

Table-6: Total number of crashes recorded in the study area (2012/13-205/16).

| Crash Severity | Fatal Crash | Serious injury | Slight injury | Property Damage Only | Total |
|---|---|---|---|---|---|
| Crash Frequency | 160 | 254 | 330 | 488 | 1,232 |

### 4.2.1. Drivers' Characteristics

The behaviour of drivers partake a pronounced starring role on the effect of crashes. Under the study area, drivers involved in those all crashes were totally of 587 while all of them were males and no female drivers were recorded in the calamity (See Table-7).

Table-7: Driver's age category, gender, educational back ground, vehicle driver relationship and driving experience participated in the study area.

| Crash Severity | Fatal Crash | | Serious Injury | | Slight Injury | | PDO | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age Category of Drivers (Years) | Frequency | % | Frequency | % | Frequency | % | Frequency | % | Frequency | % |
| <18 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.00 |
| 18-30 | 66 | 41.3 | 105 | 41.3 | 143 | 43.3 | 203 | 41.6 | 517 | 41.88 |
| 30-50 | 80 | 50.0 | 124 | 48.8 | 130 | 39.4 | 227 | 46.5 | 561 | 46.18 |
| >50 | 5 | 3.1 | 9 | 3.5 | 15 | 4.5 | 31 | 6.4 | 60 | 4.39 |
| Unknown | 9 | 5.6 | 16 | 6.3 | 42 | 12.7 | 27 | 5.5 | 94 | 7.55 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |
| Gender | | | | | | | | | | |
| Male | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |
| Female | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |
| Educational Background | | | | | | | | | | |
| Illiterate | 9 | 5.6 | 9 | 3.5 | 57 | 17.3 | 43 | 8.8 | 118 | 8.81 |
| 1-8 | 26 | 16.3 | 34 | 13.4 | 37 | 11.2 | 103 | 21.1 | 200 | 15.49 |
| 9-10 | 81 | 50.6 | 94 | 37.0 | 90 | 27.3 | 153 | 31.4 | 418 | 36.56 |
| 11-12 | 10 | 6.3 | 41 | 16.1 | 53 | 16.1 | 64 | 13.1 | 168 | 12.89 |
| Diploma | 13 | 8.1 | 47 | 18.5 | 56 | 17.0 | 58 | 11.9 | 174 | 13.87 |
| First Degree | 7 | 4.4 | 8 | 3.1 | 1 | 0.3 | 29 | 5.9 | 45 | 3.44 |
| Second degree | 2 | 1.3 | 0 | 0.0 | 1 | 0.3 | 6 | 1.2 | 9 | 0.70 |
| Unknown | 12 | 7.5 | 21 | 8.3 | 35 | 10.6 | 32 | 6.6 | 100 | 8.23 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |
| Vehicle Driver Relationship | | | | | | | | | | |
| Employee | 131 | 81.9 | 214 | 84.3 | 248 | 75.2 | 360 | 73.8 | 953 | 78.76 |
| Owner | 22 | 13.8 | 28 | 11.0 | 25 | 7.6 | 88 | 18.0 | 163 | 12.60 |
| Others | 2 | 1.3 | 4 | 1.6 | 15 | 4.5 | 18 | 3.7 | 39 | 2.76 |
| Unknown | 5 | 3.1 | 8 | 3.1 | 42 | 12.7 | 22 | 4.5 | 77 | 5.88 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |
| <1 | 16 | 10.0 | 29 | 11.4 | 38 | 11.5 | 39 | 8.0 | 122 | 10.23 |
| 1-2 | 0 | 0.0 | 22 | 8.7 | 71 | 21.5 | 75 | 15.4 | 168 | 11.39 |
| 2-5 | 23 | 14.4 | 59 | 23.2 | 47 | 14.2 | 74 | 15.2 | 203 | 16.75 |
| 5-10 | 31 | 19.4 | 29 | 11.4 | 51 | 15.5 | 110 | 22.5 | 221 | 17.20 |
| >10 | 60 | 37.5 | 59 | 23.2 | 27 | 8.2 | 86 | 17.6 | 232 | 21.63 |
| Unknown | 30 | 18.8 | 56 | 22.0 | 96 | 29.1 | 104 | 21.3 | 286 | 22.80 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |
| Movement of the vehicle before entering the crash | | | | | | | | | | |
| Driving backward | 0 | 0.0 | 1 | 0.4 | 0 | 0.0 | 2 | 0.4 | 3 | 0.20 |
| During stopping | 7 | 4.4 | 8 | 3.1 | 13 | 3.9 | 62 | 12.7 | 90 | 6.04 |
| Forward moving | 62 | 38.8 | 107 | 42.1 | 188 | 57.0 | 240 | 49.2 | 597 | 46.76 |
| Overtaking moving vehicle | 1 | 0.6 | 7 | 2.8 | 3 | 0.9 | 12 | 2.5 | 23 | 1.69 |

| Crash Severity | Fatal Crash | | Serious Injury | | Slight Injury | | PDO | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Movement of the vehicle before entering the crash | Frequ ency | % | Frequ ency | % | Freque ncy | % | Frequen cy | % | Freque ncy | % |
| Overtaking stopped vehicle | 5 | 3.1 | 10 | 3.9 | 7 | 2.1 | 31 | 6.4 | 53 | 3.88 |
| Turning at the left | 12 | 7.5 | 49 | 19.3 | 69 | 20.9 | 69 | 14.1 | 199 | 15.46 |
| Turning at the right | 62 | 38.8 | 51 | 20.1 | 40 | 12.1 | 49 | 10.0 | 202 | 20.25 |
| U turning | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 | 1 | 0.2 | 2 | 0.13 |
| Unknown | 11 | 6.9 | 21 | 8.3 | 9 | 2.7 | 22 | 4.5 | 63 | 5.59 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |

### 4.2.2. Pedestrians' Characteristics

Pedestrians' behavior and observance to road traffic rules is vital in the hindrance and control of MVC. There were a total of 225 pedestrians participating in crash. Established on the total crashes, 49 resulted in fatal crashes, 63 in serious injury crashes and 113 in slight injury crashes (See Table-8 below).

Table-8: Pedestrian's age group, gender, occupation and movement before entering the crash.

| Crash severity | Fatal | | Serious | | Slight | | Total Frequency | |
|---|---|---|---|---|---|---|---|---|
| Pedestrian age | Freq uency | % | Frequ ency | % | Freq uency | % | Frequen cy | % |
| <18 | 12 | 24.5 | 2 | 3.2 | 53 | 46.9 | 67 | 26.62 |
| 18-30 | 15 | 30.6 | 28 | 44.4 | 40 | 35.4 | 83 | 37.72 |
| 30-50 | 14 | 28.6 | 13 | 20.6 | 20 | 17.7 | 71 | 23.11 |
| >50 | 0 | 0.0 | 2 | 3.2 | 0 | 0.0 | 2 | 1.06 |
| Unknown | 8 | 16.3 | 18 | 28.6 | 0 | 0.0 | 26 | 11.49 |
| Total | 49 | 100 | 63 | 100.0 | 113 | 100 | 225 | 100 |
| Gender | | | | | | | | |
| Female | 7 | 14.3 | 12 | 19.0 | 6 | 5.3 | 25 | 11.11 |
| Male | 41 | 83.7 | 50 | 79.4 | 59 | 52.2 | 150 | 66.67 |
| Unknown | 1 | 2.0 | 1 | 1.6 | 48 | 42.5 | 50 | 22.22 |
| Total | 49 | 100 | 63 | 100 | 113 | 100 | 225 | 100 |
| Pedestrian Occupation | | | | | | | | |
| Daily laborer | 3 | 6.1 | 12 | 19.0 | 5 | 4.4 | 20 | 8.89 |
| Driver | 3 | 6.1 | 0 | 0.0 | 5 | 4.4 | 8 | 3.56 |
| Farmer | 15 | 30.6 | 13 | 20.6 | 15 | 13.3 | 43 | 19.11 |
| Housewife | 3 | 6.1 | 2 | 3.2 | 9 | 8.0 | 14 | 6.22 |
| Jobless | 2 | 4.1 | 2 | 3.2 | 1 | 0.9 | 5 | 2.22 |
| Merchant | 5 | 10.2 | 3 | 4.8 | 3 | 2.7 | 11 | 4.89 |
| Office worker | 1 | 2.0 | 0 | 0.0 | 1 | 0.9 | 2 | 0.89 |
| Private worker | 4 | 8.2 | 4 | 6.3 | 4 | 3.5 | 12 | 5.33 |
| Student | 12 | 24.5 | 21 | 33.3 | 25 | 22.1 | 58 | 25.78 |
| Unknown | 1 | 2.0 | 6 | 9.5 | 45 | 39.8 | 52 | 23.11 |
| Total | 49 | 100 | 63 | 100 | 113 | 100 | 225 | 100 |

| Crash severity | Fatal | | Serious | | Slight | | Total Frequency | |
|---|---|---|---|---|---|---|---|---|
| Movement of pedestrian before entering the crash | Freq uency | % | Frequ ency | % | Freq uency | % | Frequen cy | % |
| Crossing by cycle | 1 | 2.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.44 |
| Crossing on zebra | 3 | 6.1 | 2 | 3.2 | 1 | 0.9 | 6 | 2.67 |
| Crossing without zebra | 15 | 30.6 | 29 | 46.0 | 38 | 33.6 | 82 | 36.44 |
| Crossing hidden by vehicle | 9 | 18.4 | 4 | 6.3 | 4 | 3.5 | 17 | 7.56 |
| Moving on left side with pedestrian walkway | 7 | 14.3 | 7 | 11.1 | 18 | 15.9 | 32 | 14.22 |
| Moving on right side with pedestrian walkway | 3 | 6.1 | 2 | 3.2 | 0 | 0.0 | 5 | 2.22 |
| Moving on right side on shoulder | 4 | 8.2 | 7 | 11.1 | 4 | 3.5 | 15 | 6.67 |
| Playing inside carriageway | 7 | 14.3 | 7 | 11.1 | 5 | 4.4 | 19 | 8.44 |
| Stopped outside carriageway | 0 | 0.0 | 2 | 3.2 | 3 | 2.7 | 5 | 2.22 |
| Unknown | 0 | 0.0 | 3 | 4.8 | 40 | 35.4 | 43 | 19.11 |
| Total | 49 | 100 | 63 | 100.0 | 113 | 100 | 225 | 100 |

### 4.2.3. Passengers' Characteristics

The risk of crashes among pedestrians with different behaviors is verily unlike. There were a total of 412 passengers who took part in the crashes. (See Table-9).

Table-9: Passengers age group, gender and occupation condition participated in crash

| Crash severity | Fatal | | Serious | | Slight | | Total Frequency | |
|---|---|---|---|---|---|---|---|---|
| Passengers age | Freq uency | % | Frequ ency | % | Freq uency | % | Frequency | % |
| <18 | 1 | 1.8 | 1 | 0.8 | 3 | 1.3 | 5 | 0.97 |
| 18-30 | 17 | 30.4 | 26 | 19.7 | 33 | 14.7 | 76 | 16.20 |
| 30-50 | 13 | 23.2 | 63 | 47.7 | 80 | 35.7 | 156 | 26.66 |
| >50 | 3 | 5.4 | 0 | 0.0 | 12 | 5.4 | 15 | 2.68 |
| Unknown | 22 | 39.3 | 42 | 31.8 | 96 | 42.9 | 160 | 28.49 |
| Total | 56 | 100 | 132 | 100 | 224 | 100 | 412 | 75.00 |
| Passengers Gender | | | | | | | | |
| Female | 4 | 7.1 | 5 | 3.8 | 3 | 1.3 | 12 | 3.07 |
| Male | 52 | 92.9 | 127 | 96.2 | 221 | 98.7 | 400 | 71.93 |
| Unknown | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.00 |
| Total | 56 | 100 | 132 | 100 | 224 | 100 | 412 | 75.00 |
| Passenger's occupation | | | | | | | | |
| Driver assistant | 2 | 3.6 | 1 | 0.8 | 0 | 0.0 | 3 | 1.08 |
| Daily laborer | 1 | 1.8 | 1 | 0.8 | 0 | 0.0 | 2 | 0.64 |
| Driver | 15 | 26.8 | 14 | 10.6 | 9 | 4.0 | 38 | 10.35 |
| Farmer | 14 | 25.0 | 27 | 20.5 | 30 | 13.4 | 71 | 14.71 |
| Housewife | 1 | 1.8 | 1 | 0.8 | 1 | 0.4 | 3 | 0.75 |
| Jobless | 0 | 0.0 | 2 | 1.5 | 1 | 0.4 | 3 | 0.49 |
| Merchant | 5 | 8.9 | 6 | 4.5 | 51 | 22.8 | 62 | 9.06 |
| Officer | 1 | 1.8 | 1 | 0.8 | 3 | 1.3 | 5 | 0.97 |

| Crash severity | Fatal | | Serious | | Slight | | Total Frequency | |
|---|---|---|---|---|---|---|---|---|
| Passenger's occupation | Freq uency | % | Frequ ency | % | Freq uency | % | Frequency | % |
| Private worker | 7 | 12.5 | 13 | 9.8 | 38 | 17.0 | 58 | 9.83 |
| Student | 4 | 7.1 | 2 | 1.5 | 26 | 11.6 | 32 | 5.07 |
| Teacher | 0 | 0.0 | 1 | 0.8 | 1 | 0.4 | 2 | 0.30 |
| Unknown | 6 | 10.7 | 63 | 47.7 | 64 | 28.6 | 133 | 21.75 |
| Total | 56 | 100 | 132 | 100 | 224 | 100 | 412 | 75.00 |

### 4.2.4. Vehicular Characteristics

There is evidence linking certain vehicle characteristics to crash involvement that influence drivers' risk taking behavior. (See Table-10 below).

Table-10: Vehicle ownership, vehicle year of service, movement of the vehicle before entering the crash, vehicular defect and crash causing vehicle.

| Crash severity | Fatal | | Serious | | Slight | | PDO | | Total Frequency | |
|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle ownership | Freq uency | % | Frequ ency | % | Freq uency | % | Freque ncy | % | Frequ ency | % |
| Company | 3 | 1.9 | 6 | 2.4 | 1 | 0.3 | 9 | 1.8 | 19 | 1.60 |
| Government | 13 | 8.1 | 15 | 5.9 | 22 | 6.7 | 47 | 9.6 | 97 | 7.58 |
| Private | 138 | 86.3 | 226 | 89 | 264 | 80.0 | 412 | 84.4 | 1040 | 84.91 |
| Unknown | 6 | 3.8 | 7 | 2.8 | 43 | 13.0 | 20 | 4.1 | 76 | 5.91 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |
| Vehicle year of service | | | | | | | | | | |
| 1-2 | 23 | 14.4 | 24 | 9.4 | 77 | 23.3 | 99 | 20.3 | 223 | 16.86 |
| 2-5 | 31 | 19.4 | 57 | 22.4 | 108 | 32.7 | 96 | 19.7 | 292 | 23.55 |
| 5-10 | 57 | 35.6 | 64 | 25.2 | 35 | 10.6 | 178 | 36.5 | 334 | 26.98 |
| >10 | 12 | 7.5 | 65 | 25.6 | 82 | 24.8 | 76 | 15.6 | 235 | 18.38 |
| Unknown | 37 | 23.1 | 44 | 17.3 | 28 | 8.5 | 39 | 8.0 | 148 | 14.23 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100.0 | 1232 | 100 |
| Vehicular defect | | | | | | | | | | |
| Brake fault | 0 | 0.0 | 2 | 0.8 | 10 | 3.0 | 5 | 1.0 | 17 | 1.21 |
| Light problem | 1 | 0.6 | 1 | 0.4 | 0 | 0.0 | 5 | 1.0 | 7 | 0.51 |
| Mechanical problem | 1 | 0.6 | 1 | 0.4 | 7 | 2.1 | 8 | 1.6 | 17 | 1.19 |
| Tyre problem | 6 | 3.8 | 7 | 2.8 | 5 | 1.5 | 26 | 5.3 | 44 | 3.34 |
| No problem | 148 | 92.5 | 236 | 92.9 | 262 | 79.4 | 442 | 90.6 | 1088 | 88.85 |
| Unknown | 4 | 2.5 | 7 | 2.8 | 46 | 13.9 | 2 | 0.4 | 59 | 4.90 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |
| Crash Causing Vehicle | | | | | | | | | | |
| Automobile | 8 | 5.0 | 17 | 6.7 | 10 | 3.0 | 52 | 10.7 | 87 | 6.34 |
| Cars | 7 | 4.4 | 21 | 8.3 | 22 | 6.7 | 40 | 8.2 | 90 | 6.88 |
| H/truck 7.5-12 tone | 6 | 3.8 | 8 | 3.1 | 13 | 3.9 | 42 | 8.6 | 69 | 4.86 |
| L/bus above 27 seats | 53 | 33.1 | 94 | 37.0 | 66 | 20.0 | 36 | 7.4 | 249 | 24.38 |
| L/rover | 5 | 3.1 | 4 | 1.6 | 28 | 8.5 | 28 | 5.7 | 65 | 4.73 |
| M/truck 3.5-7.5 tone | 14 | 8.8 | 9 | 3.5 | 13 | 3.9 | 76 | 15.6 | 112 | 7.95 |
| Motorcycle | 1 | 0.6 | 1 | 0.4 | 4 | 1.2 | 6 | 1.2 | 12 | 0.87 |

| Crash severity | Fatal | | Serious | | Slight | | PDO | | Total Frequency | |
|---|---|---|---|---|---|---|---|---|---|---|
| Crash Causing Vehicle | Frequency | % | Frequency | % | Frequency | % | Frequency | % | Frequency | % |
| S/bus <27 seats | 47 | 29.4 | 78 | 30.7 | 147 | 44.5 | 156 | 32.0 | 428 | 34.15 |
| S/truck <3.5 tone | 4 | 2.5 | 10 | 3.9 | 10 | 3.0 | 24 | 4.9 | 48 | 3.60 |
| Truck trailer | 8 | 5.0 | 3 | 1.2 | 6 | 1.8 | 23 | 4.7 | 40 | 3.18 |
| Others | 2 | 1.3 | 0 | 0.0 | 0 | 0.0 | 5 | 1.0 | 7 | 0.57 |
| Unknown | 5 | 3.1 | 9 | 3.5 | 11 | 3.3 | 0 | 0.0 | 25 | 2.50 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |

### 4.2.5. Crashes by Temporal Variation (Hour of the Day, Day of the Week and Month of the Year) and by Collision Types

MVC varies upon the nature of the hour of the day, the day of the week and the month of the year mostly manifested when the pedestrian and passenger movements stretched maximum levels. In this regard, the study revealed that highest crashes were reported between 9:00-10:59 am with 260(20.96%) crashes (See Table-12).

Table-11: Crashes by temporal variation.

| Crash severity | Fatal | | Serious | | Slight | | PDO | | Total Frequency | |
|---|---|---|---|---|---|---|---|---|---|---|
| Crash month | Frequency | % | Frequency | % | Frequency | % | Frequency | % | Frequency | % |
| September | 5 | 3.1 | 10 | 3.9 | 9 | 2.7 | 33 | 6.8 | 57 | 4.14 |
| October | 11 | 6.9 | 6 | 2.4 | 21 | 6.4 | 29 | 5.9 | 67 | 5.39 |
| November | 9 | 5.6 | 14 | 5.5 | 25 | 7.6 | 42 | 8.6 | 90 | 6.83 |
| December | 20 | 12.5 | 37 | 14.6 | 32 | 9.7 | 33 | 6.8 | 122 | 10.88 |
| January | 2 | 1.3 | 14 | 5.5 | 54 | 16.4 | 47 | 9.6 | 117 | 8.19 |
| February | 10 | 6.3 | 27 | 10.6 | 29 | 8.8 | 44 | 9.0 | 110 | 8.67 |
| March | 14 | 8.8 | 6 | 2.4 | 22 | 6.7 | 47 | 9.6 | 89 | 6.85 |
| April | 9 | 5.6 | 29 | 11.4 | 29 | 8.8 | 55 | 11.3 | 122 | 9.28 |
| May | 13 | 8.1 | 16 | 6.3 | 29 | 8.8 | 45 | 9.2 | 103 | 8.11 |
| June | 51 | 31.9 | 60 | 23.6 | 42 | 12.7 | 28 | 5.7 | 181 | 18.49 |
| July | 3 | 1.9 | 12 | 4.7 | 10 | 3.0 | 34 | 7.0 | 59 | 4.15 |
| August | 5 | 3.1 | 13 | 5.1 | 15 | 4.5 | 33 | 6.8 | 66 | 4.89 |
| Puwagme | 5 | 3.1 | 5 | 2.0 | 0 | 0.0 | 14 | 2.9 | 24 | 1.99 |
| Unknown | 3 | 1.9 | 5 | 2.0 | 13 | 3.9 | 4 | 0.8 | 25 | 2.15 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |
| Collision type | | | | | | | | | | |
| Vehicle with animal | 5 | 3.2 | 2 | 0.9 | 1 | 0.3 | 11 | 2.3 | 19 | 1.68 |
| Fall from vehicle | 4 | 2.6 | 10 | 4.7 | 19 | 5.8 | 12 | 2.5 | 45 | 3.88 |
| Entering depression | 1 | 0.6 | 0 | 0.0 | 0 | 0.0 | 5 | 1.0 | 6 | 0.42 |
| Head on | 55 | 35.3 | 56 | 26.5 | 46 | 13.9 | 186 | 38.1 | 343 | 28.46 |
| Rear end | 2 | 1.3 | 6 | 2.8 | 4 | 1.2 | 13 | 2.7 | 25 | 2.00 |
| Angle crash | 0 | 0.0 | 2 | 0.9 | 1 | 0.3 | 15 | 3.1 | 18 | 1.08 |

| Crash severity | Fatal | | Serious | | Slight | | PDO | | Total Frequency | |
|---|---|---|---|---|---|---|---|---|---|---|
| Crash month | Frequency | % | Frequency | % | Frequency | % | Frequency | % | Frequency | % |
| Vehicle with pedestrian | 51 | 32.7 | 71 | 33.6 | 57 | 17.3 | 70 | 14.3 | 249 | 24.49 |
| Overturning | 26 | 16.7 | 55 | 26.1 | 136 | 41.2 | 36 | 7.4 | 253 | 22.83 |
| Sideswipe | 7 | 4.5 | 8 | 3.8 | 23 | 7.0 | 104 | 21.3 | 142 | 9.14 |
| Vehicle with motorcycle | 0 | 0.0 | 1 | 0.5 | 1 | 0.3 | 2 | 0.4 | 4 | 0.30 |
| Unknown | 4 | 2.6 | 40 | 19.0 | 13 | 3.9 | 8 | 1.6 | 65 | 6.78 |
| Total | 160 | 100 | 255 | 100 | 330 | 100 | 488 | 100 | 1233 | 100 |

Most crashes were recorded on Sundays (267, 22.45% in total crashes) and followed by Wednesdays (197, 17.55%) (See Figure-5).

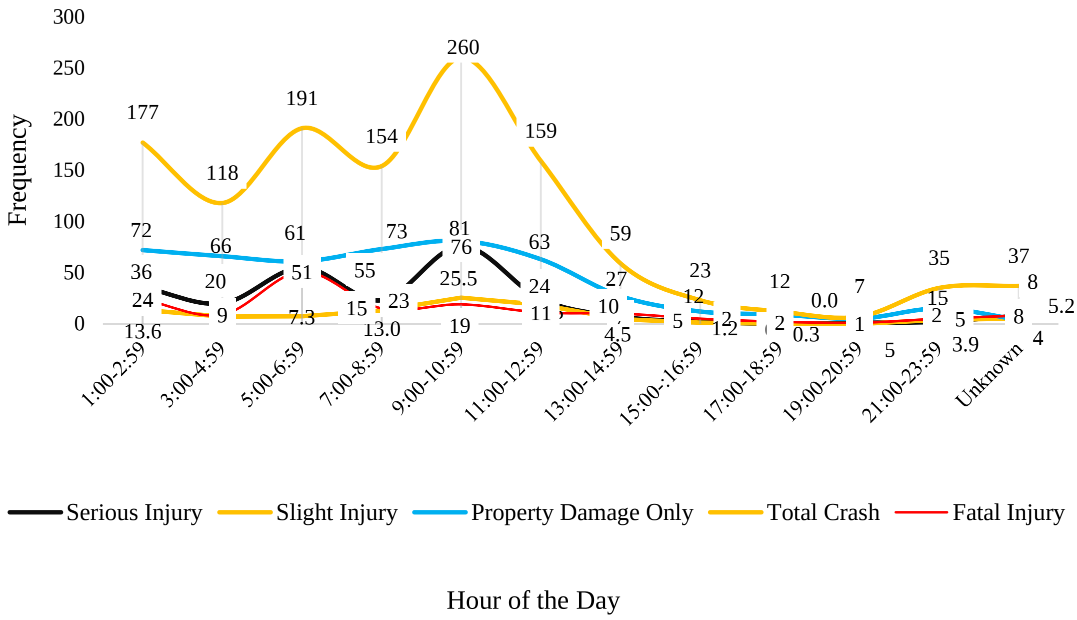



Figure-4: Hour of the day and frequency of the crash understudy area.

Crashes in the month of June were concentrated highly (181 (18.49%)) from other months and followed by December (122 (10.88%)) (See Table-12).

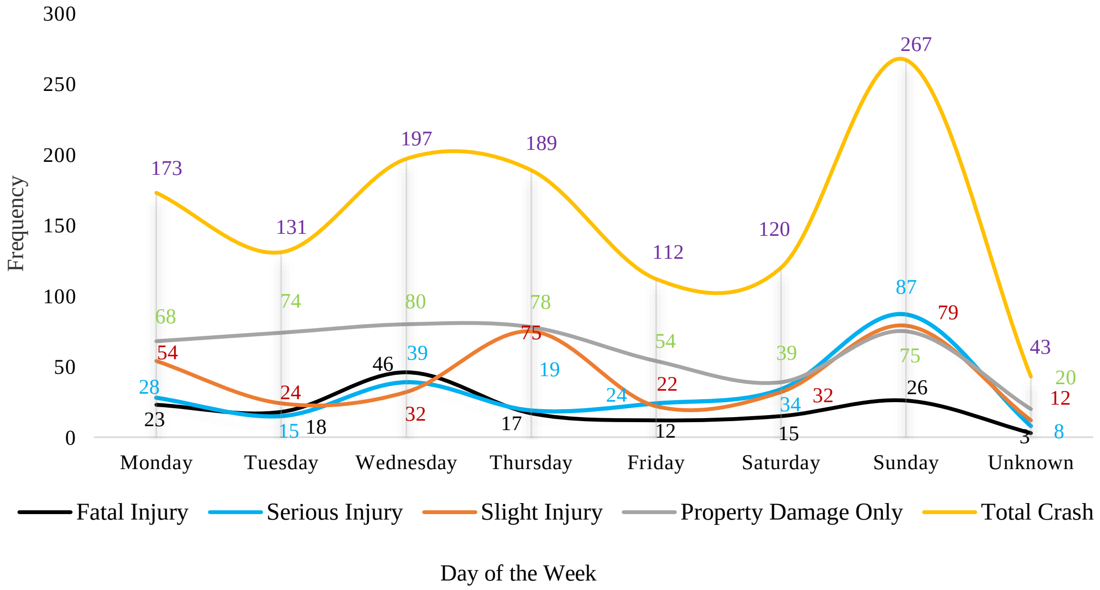



Figure-5: Crash Frequency and day of the week understudy.

### 4.2.6. Crash Variations by Road and Environmental Conditions

Almost all the crashes were held without junctions on the segments, dry road surface, lane divided by solid line paint, good light condition, levelled or flat geographic situations and around commercial centers.

Table-12: Crash Frequency and percent by junction type, road lighting condition, weather condition, road type by lane and road geographical location

| Crash severity | Fatal | | Serious | | Slight | | PDO | | Total Frequency | |
|---|---|---|---|---|---|---|---|---|---|---|
| Junction type | Freq uency | % | Frequ ency | % | Freq uency | % | Freq uency | % | Freq uency | % |
| 4 leg | 1 | 0.6 | 1 | 0.4 | 3 | 0.9 | 2 | 0.4 | 7 | 0.58 |
| No junction | 152 | 95.0 | 243 | 95.7 | 278 | 84.2 | 451 | 92.4 | 1124 | 91.83 |
| T or Y leg | 3 | 1.9 | 5 | 2.0 | 10 | 3.0 | 19 | 3.9 | 37 | 2.69 |
| Unknown | 4 | 2.5 | 5 | 2.0 | 39 | 11.8 | 16 | 3.3 | 64 | 4.89 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |
| Road surface condition | | | | | | | | | | |
| Dry | 137 | 85.6 | 233 | 91.7 | 261 | 79.1 | 300 | 61.5 | 931 | 79.48 |
| Wet | 14 | 8.8 | 12 | 4.7 | 22 | 6.7 | 90 | 18.4 | 138 | 9.65 |
| Unknown | 9 | 5.6 | 9 | 3.5 | 47 | 14.2 | 98 | 20.1 | 163 | 10.87 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100.0 | 1232 | 100 |
| Dark leaving | 0 | 0.0 | 3 | 1.2 | 1 | 0.3 | 7 | 1.4 | 11 | 0.73 |
| Dark | 26 | 16.3 | 12 | 4.7 | 30 | 9.1 | 58 | 11.9 | 126 | 10.49 |
| Day/good light | 129 | 80.6 | 228 | 89.8 | 249 | 75.5 | 356 | 73.0 | 962 | 79.70 |
| Sun rise | 1 | 0.6 | 1 | 0.4 | 11 | 3.3 | 22 | 4.5 | 35 | 2.22 |
| Sun set | 0 | 0.0 | 2 | 0.8 | 0 | 0.0 | 2 | 0.4 | 4 | 0.30 |
| Unknown | 4 | 2.5 | 8 | 3.1 | 39 | 11.8 | 43 | 8.8 | 94 | 6.57 |
| Total | 160 | 100.0 | 254 | 100 | 330 | 100 | 488 | 100.0 | 1232 | 100 |

| Crash severity | Fatal | | Serious | | Slight | | PDO | | Total Frequency | |
|---|---|---|---|---|---|---|---|---|---|---|
| Weather Condition | Freq uency | % | Frequ ency | % | Freq uency | % | Freq uency | % | Freq uency | % |
| Cloudy/foggy | 3 | 1.9 | 4 | 1.6 | 0 | 0.0 | 17 | 3.5 | 24 | 1.77 |
| Cold weather | 2 | 1.3 | 4 | 1.6 | 2 | 0.6 | 10 | 2.0 | 18 | 1.40 |
| Rainy | 10 | 6.5 | 8 | 3.3 | 14 | 4.3 | 22 | 4.5 | 54 | 4.65 |
| windy | 1 | 0.6 | 2 | 0.8 | 9 | 2.8 | 16 | 3.3 | 28 | 1.88 |
| Good/ clear sky | 138 | 89.6 | 225 | 92.2 | 261 | 80.6 | 412 | 84.4 | 1036 | 86.70 |
| Unknown | 0 | 0.0 | 1 | 0.4 | 38 | 11.7 | 11 | 2.3 | 50 | 3.60 |
| Total | 154 | 100 | 244 | 100 | 324 | 100 | 488 | 100.0 | 1210 | 100 |
| Road type by lane | | | | | | | | | | |
| Divided by Solid line paint | 81 | 51.3 | 158 | 62.2 | 179 | 54.2 | 210 | 43.0 | 628 | 52.69 |
| Divided by strike line paint | 46 | 29.1 | 79 | 31.1 | 70 | 21.2 | 184 | 37.7 | 379 | 29.78 |
| Two way undivided | 24 | 15.2 | 3 | 1.2 | 41 | 12.4 | 62 | 12.7 | 130 | 10.38 |
| Channelization | 7 | 4.4 | 14 | 5.5 | 5 | 1.5 | 28 | 5.7 | 54 | 4.30 |
| Unknown | 2 | 1.3 | 0 | 0.0 | 35 | 10.6 | 4 | 0.8 | 41 | 3.17 |
| Total | 160 | 101.27 | 254 | 100.0 | 330 | 100.0 | 488 | 100.0 | 1232 | 100 |
| Road geographical condition | | | | | | | | | | |
| Downward slopped | 1 | 0.6 | 2 | 0.8 | 2 | 0.6 | 15 | 3.1 | 20 | 1.27 |
| Highly curved | 3 | 1.9 | 3 | 1.2 | 15 | 4.5 | 4 | 0.8 | 25 | 2.11 |
| Little curve | 10 | 6.3 | 13 | 5.1 | 14 | 4.2 | 45 | 9.2 | 82 | 6.21 |
| Medium curve | 5 | 3.1 | 37 | 14.6 | 54 | 16.4 | 32 | 6.6 | 128 | 10.15 |
| Straight downward | 17 | 10.6 | 41 | 16.1 | 25 | 7.6 | 38 | 7.8 | 121 | 10.53 |
| Straight flat | 61 | 38.1 | 96 | 37.8 | 144 | 43.6 | 256 | 52.5 | 557 | 43.00 |
| Straight upward | 2 | 1.3 | 11 | 4.3 | 10 | 3.0 | 10 | 2.0 | 33 | 2.67 |
| Twist curve | 55 | 34.4 | 43 | 16.9 | 29 | 8.8 | 46 | 9.4 | 173 | 17.38 |
| Unknown | 6 | 3.8 | 8 | 3.1 | 37 | 11.2 | 42 | 8.6 | 93 | 6.68 |
| Total | 160 | 100 | 254 | 100 | 330 | 100 | 488 | 100 | 1232 | 100 |

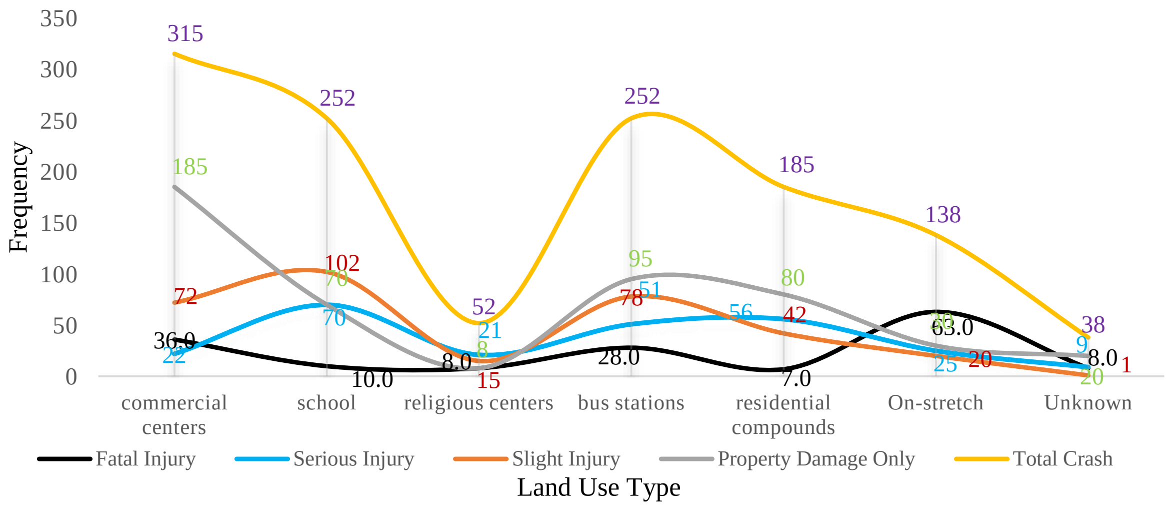



Figure-6 Crash Frequency by land use type

### 4.2.7. Crashes by Different Types of Causes

The majority of road crashes were caused by drivers' errors like over-speeding and reckless driving as it was recorded in this study, bad road alignment and violating the principles of giving priority for vehicles also placed in the order of highest crash causality (Figure-7).

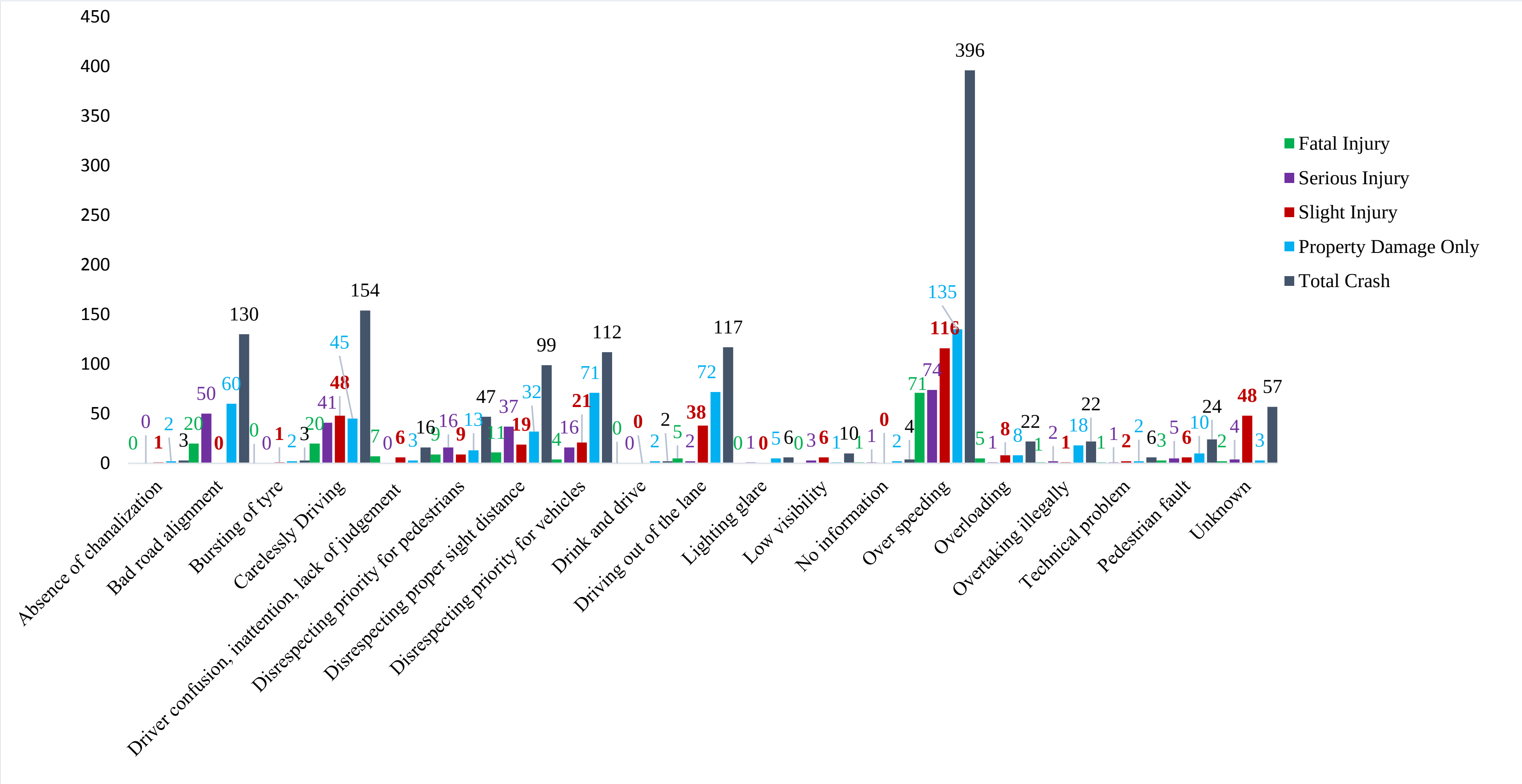



Figure-7: Crash Frequency and cause of the crash understudy

### 4.3. Historical Black spot identification Statistical Methods

Identification of black spot using historically recorded crash data based statistical method was conducted being established on the steps described on detailed methodology chapter.

#### 4.3.1. Upper Control Limit through Crash Rate

The MVC frequency for each crash severity consequences within the homogenous segment groups, i.e. 0.625 km; 1 mile, was enumerated on the road at a given four year period of time. The Crash Rate using Equation 2 was calculated and located in Table 13 column 6, 7, and 8. Then the Upper Control Limit using Equation 3 was evaluated and located in Table 13 column 9, 10 and 11. After all, the Dangerous Factor (Equation 1) which is the ratio of Crash Rate to Upper Control Limit was rectified to rank the top crash promised segments in descending order as shown in Table 13 column 12, 13 and 14. To clarify, let us take segment 18; based on the crash severity type Crash Rate can be calculated by taking λo=4 Observed Crash Frequency per year for only fatal consequences, n=4 years, AADT=2355 and length of segment (L) =1 mile (0.625 km). Then the Crash Rate for fatal severity type is estimated as:

$$\mathrm{CR}_{F} = \frac{\lambda \mathrm{o x} 1{,}000{,}000}{\mathrm{nxAADTxLx365}}$$

$$\mathrm{CR}_{F} = \frac{1\mathrm{x}1{,}000{,}000}{4\mathrm{x}2355\mathrm{x}0.625\mathrm{x}365}$$

$$\underline{\mathrm{CR_F} = 0.47 \text{ crashes per million vehicle kilometer travelled}}$$

The Upper Control Limit (UCL) also can be calculated as a sample for fatal crash consequence with $CR_a$ (Average Crash Rate value as the average of all the segments Crash Rate from bottom of Table 13) = 0.19 and K=2.576 and the other values as an example described above:

$$\mathrm{UCL{=}CRa{+}K}\left[\frac{\lambda \mathrm{o}}{\left[\frac{\mathrm{nxAADTxLx365}}{1{,}000{,}000}\right]}\right]^{1/2} + \frac{1}{2\mathrm{x}\left[\frac{\mathrm{nxAADTxLx365}}{1{,}000{,}000}\right]}$$

$$UCL=0.19+2.576\left[\frac{1}{\left[\frac{4x2355x0.625x365}{1,000,000}\right]}\right]^{1/2}+\frac{1}{2x\left[\frac{4x2355x0.625x365}{1,000,000}\right]}$$

UCL=1.95 crashes per million vehicle kilometer travelled.

Then, the Dangerous Factor (DF) is estimated as:

$$DF=\frac{CR}{UCL}$$

$$DF=\frac{0.47}{1.95}$$

DF=0.24 <1, which indicates that a segment is not a black spot.

### 4.3.2. Crash Frequency Difference Density Deviance Score (Crash Score)

The Crash Score was applied to prioritizing highly concentrated crash segments using Equation 4 described in methodology section. First of all, the Crash Frequencies by Crash Severity type for each segments and the mean Crash Frequency from the total segment was considered. The standard deviation which is the measure of dispersion from mean of the crash along each segment is shown below in Table 13 column 16, 17 and 18. Finally, the Crash Score is displayed as in Table 13 column 19, 20 and 21.

The Crash Score for segment 18 was done as an illustration for fatal crash consequences. The observed average Crash Frequency, $\lambda_o$, is described above. The average Crash Frequency, $\lambda_\alpha$, is the average Crash Frequency of all 108 segments projected at the bottom of Table 13 column 2, 3 and 4. So $\lambda_\alpha$=0.36. The standard deviation, σ is calculated using a well-known formula as $\sigma = \sqrt{\sum(x-\bar{x})^2/N}$ (Douglas C.M. et al, 2003). Where x is the Crash Frequency, x̄ is mean of the Crash Frequency and N is the total number of segments = 0.001 (bottom of column 16). Then take the segment length, L, 1mile (0.625km).

$$Cs = \frac{\lambda o - \lambda\alpha}{\sigma x L}$$

$$Cs = \frac{1-0.36}{0.001x0.625}$$

$Cs = 1024$ Crashes per kilometer travelled.

### 4.3.3. Mixed Crash Frequency-Crash Rate Method

The Mixed Crash Frequency-Crash Rate method is simply the combined effect of both Crash Frequency and Crash Rate methods to avoid the drawbacks of both black spot identification methods. By means of Equation 5 expressed in the earlier methodology section, Mixed Crash Frequency-Crash Rate method can be projected as in Table-13 column 22, 23, 24 and 25.

The segment 18 involved at fatal crash consequences is exemplified as follow.

$$\text{MFR} = \frac{\lambda o}{L} + \frac{\lambda o x 1{,}000{,}000}{nxAADTxLx365}$$

All the above variables are expressed earlier.

$$\text{MFR} = \frac{1}{0.625} + \frac{1x1{,}000{,}000}{4x2355x0.625x365}$$

MFR = 2.07 crashes per million/kilometer.

Table-13: Historically recorded crash based black spot identification statistical methods

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Segment | Observed Crash Frequency per year λ | | | AADT | CR | | | UCL | | | DF | | | Total DF | σ | | | Cs | | | MFR | | | Total MFR |
| | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | |
| 18 | 1.00 | 0.75 | 1.75 | 2355 | 0.47 | 0.35 | 0.81 | 1.95 | 2.19 | 2.93 | 0.24 | 0.16 | 0.28 | 0.23 | 0.64 | -0.56 | 0.57 | 1024.00 | -40.73 | 130.29 | 2.07 | 1.55 | 3.61 | 7.23 |
| 19 | 0.25 | 1.50 | 1.25 | 2355 | 0.12 | 0.70 | 0.58 | 1.07 | 2.82 | 2.57 | 0.11 | 0.25 | 0.23 | 0.19 | -0.11 | 0.19 | 0.07 | -176.00 | 13.82 | 16.00 | 0.52 | 3.10 | 2.58 | 6.20 |
| 20 | 1.00 | 1.50 | 3.50 | 2355 | 0.47 | 0.70 | 1.63 | 1.95 | 2.82 | 3.90 | 0.24 | 0.25 | 0.42 | 0.30 | 0.64 | 0.19 | 2.32 | 1024.00 | 13.82 | 530.29 | 2.07 | 3.10 | 7.23 | 12.39 |
| 21 | 0.25 | 0.50 | 0.75 | 2355 | 0.12 | 0.23 | 0.35 | 1.07 | 1.91 | 2.13 | 0.11 | 0.12 | 0.16 | 0.13 | -0.11 | -0.81 | -0.43 | -176.00 | -58.91 | -98.29 | 0.52 | 1.03 | 1.55 | 3.10 |
| 22 | 0.00 | 0.75 | 3.00 | 2355 | 0.00 | 0.35 | 1.40 | 0.19 | 2.19 | 3.65 | 0.00 | 0.16 | 0.38 | 0.18 | -0.36 | -0.56 | 1.82 | -576.00 | -40.73 | 416.00 | 0.00 | 1.55 | 6.20 | 7.75 |
| 23 | 0.75 | 1.50 | 1.25 | 2355 | 0.35 | 0.70 | 0.58 | 1.71 | 2.82 | 2.57 | 0.20 | 0.25 | 0.23 | 0.23 | 0.39 | 0.19 | 0.07 | 624.00 | 13.82 | 16.00 | 1.55 | 3.10 | 2.58 | 7.23 |
| 24 | 0.00 | 0.75 | 1.25 | 2355 | 0.00 | 0.35 | 0.58 | 0.19 | 2.19 | 2.57 | 0.00 | 0.16 | 0.23 | 0.13 | -0.36 | -0.56 | 0.07 | -576.00 | -40.73 | 16.00 | 0.00 | 1.55 | 2.58 | 4.13 |
| 25 | 0.00 | 1.00 | 0.25 | 2355 | 0.00 | 0.47 | 0.12 | 0.19 | 2.43 | 1.49 | 0.00 | 0.19 | 0.08 | 0.09 | -0.36 | -0.31 | -0.93 | -576.00 | -22.55 | -212.57 | 0.00 | 2.07 | 0.52 | 2.58 |
| 26 | 0.00 | 1.00 | 3.00 | 2355 | 0.00 | 0.47 | 1.40 | 0.19 | 2.43 | 3.65 | 0.00 | 0.19 | 0.38 | 0.19 | -0.36 | -0.31 | 1.82 | -576.00 | -22.55 | 416.00 | 0.00 | 2.07 | 6.20 | 8.26 |
| 27 | 0.50 | 5.50 | 6.25 | 2355 | 0.23 | 2.56 | 2.91 | 1.43 | 4.79 | 5.00 | 0.16 | 0.53 | 0.58 | 0.43 | 0.14 | 4.19 | 5.07 | 224.00 | 304.73 | 1158.86 | 1.03 | 11.36 | 12.91 | 25.30 |
| 28 | 0.00 | 1.00 | 3.00 | 2355 | 0.00 | 0.47 | 1.40 | 0.19 | 2.43 | 3.65 | 0.00 | 0.19 | 0.38 | 0.19 | -0.36 | -0.31 | 1.82 | -576.00 | -22.55 | 416.00 | 0.00 | 2.07 | 6.20 | 8.26 |
| 29 | 0.00 | 0.25 | 1.25 | 2355 | 0.00 | 0.12 | 0.58 | 0.19 | 1.55 | 2.57 | 0.00 | 0.08 | 0.23 | 0.10 | -0.36 | -1.06 | 0.07 | -576.00 | -77.09 | 16.00 | 0.00 | 0.52 | 2.58 | 3.10 |
| 30 | 2.25 | 9.50 | 11.00 | 2355 | 1.05 | 4.42 | 5.12 | 2.83 | 6.09 | 6.44 | 0.37 | 0.73 | 0.80 | 0.63 | 1.89 | 8.19 | 9.82 | 3024.00 | 595.64 | 2244.57 | 4.65 | 19.62 | 22.72 | 46.99 |
| 31 | 0.00 | 0.00 | 0.00 | 2355 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 32 | 0.50 | 3.75 | 0.75 | 2355 | 0.23 | 1.75 | 0.35 | 1.43 | 4.07 | 2.13 | 0.16 | 0.43 | 0.16 | 0.25 | 0.14 | 2.44 | -0.43 | 224.00 | 177.45 | -98.29 | 1.03 | 7.75 | 1.55 | 10.33 |
| 33 | 0.00 | 0.50 | 0.25 | 2355 | 0.00 | 0.23 | 0.12 | 0.19 | 1.91 | 1.49 | 0.00 | 0.12 | 0.08 | 0.07 | -0.36 | -0.81 | -0.93 | -576.00 | -58.91 | -212.57 | 0.00 | 1.03 | 0.52 | 1.55 |
| 34 | 2.00 | 10.75 | 8.75 | 2355 | 0.93 | 5.00 | 4.07 | 2.68 | 6.43 | 5.81 | 0.35 | 0.78 | 0.70 | 0.61 | 1.64 | 9.44 | 7.57 | 2624.00 | 686.55 | 1730.29 | 4.13 | 22.20 | 18.07 | 44.40 |
| 35 | 0.00 | 1.25 | 2.25 | 2355 | 0.00 | 0.58 | 1.05 | 0.19 | 2.63 | 3.25 | 0.00 | 0.22 | 0.32 | 0.18 | -0.36 | -0.06 | 1.07 | -576.00 | -4.36 | 244.57 | 0.00 | 2.58 | 4.65 | 7.23 |
| 36 | 0.00 | 0.00 | 0.00 | 2355 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Segment | Observed Crash Frequency per year λ | | | AADT | CR | | | UCL | | | DF | | | Total DF | σ | | | Cs | | | MFR | | | Total MFR |
| | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | |
| 37 | 0.00 | 0.00 | 0.00 | 2355 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 38 | 0.75 | 6.00 | 5.50 | 2355 | 0.35 | 2.79 | 2.56 | 1.71 | 4.97 | 4.73 | 0.20 | 0.56 | 0.54 | 0.44 | 0.39 | 4.69 | 4.32 | 624.00 | 341.09 | 987.43 | 1.55 | 12.39 | 11.36 | 25.30 |
| 39 | 0.00 | 0.00 | 0.00 | 2355 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 40 | 0.00 | 0.00 | 0.00 | 2355 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 41 | 0.00 | 0.00 | 0.00 | 2355 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 42 | 0.00 | 0.00 | 0.00 | 2355 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 43 | 0.00 | 1.25 | 2.50 | 1870 | 0.00 | 0.73 | 1.47 | 0.19 | 2.87 | 3.73 | 0.00 | 0.25 | 0.39 | 0.22 | -0.36 | -0.06 | 1.32 | -576.00 | -4.36 | 301.71 | 0.00 | 2.73 | 5.47 | 8.20 |
| 44 | 1.00 | 3.00 | 3.25 | 1870 | 0.59 | 1.76 | 1.90 | 2.16 | 4.09 | 4.17 | 0.27 | 0.43 | 0.46 | 0.39 | 0.64 | 1.69 | 2.07 | 1024.00 | 122.91 | 473.14 | 2.19 | 6.56 | 7.10 | 15.85 |
| 45 | 0.00 | 0.75 | 1.00 | 1870 | 0.00 | 0.44 | 0.59 | 0.19 | 2.38 | 2.58 | 0.00 | 0.18 | 0.23 | 0.14 | -0.36 | -0.56 | -0.18 | -576.00 | -40.73 | -41.14 | 0.00 | 1.64 | 2.19 | 3.83 |
| 46 | 0.00 | 0.00 | 0.00 | 1870 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 47 | 0.00 | 0.00 | 0.00 | 1870 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 48 | 0.00 | 0.75 | 1.00 | 1870 | 0.00 | 0.44 | 0.59 | 0.19 | 2.38 | 2.58 | 0.00 | 0.18 | 0.23 | 0.14 | -0.36 | -0.56 | -0.18 | -576.00 | -40.73 | -41.14 | 0.00 | 1.64 | 2.19 | 3.83 |
| 49 | 0.00 | 0.00 | 0.00 | 1870 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 50 | 0.00 | 0.00 | 0.00 | 1870 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 51 | 0.00 | 0.00 | 0.00 | 1870 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 52 | 0.00 | 0.00 | 0.00 | 1870 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 53 | 0.00 | 0.00 | 0.00 | 1870 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 54 | 0.25 | 0.00 | 2.25 | 1870 | 0.15 | 0.00 | 1.32 | 1.18 | 0.67 | 3.57 | 0.12 | 0.00 | 0.37 | 0.16 | -0.11 | -1.31 | 1.07 | -176.00 | -95.27 | 244.57 | 0.55 | 0.00 | 4.92 | 5.47 |
| 55 | 0.75 | 3.50 | 3.75 | 1870 | 0.44 | 2.05 | 2.20 | 1.90 | 4.36 | 4.43 | 0.23 | 0.47 | 0.50 | 0.40 | 0.39 | 2.19 | 2.57 | 624.00 | 159.27 | 587.43 | 1.64 | 7.65 | 8.20 | 17.49 |
| 56 | 1.00 | 2.50 | 3.50 | 1870 | 0.59 | 1.47 | 2.05 | 2.16 | 3.79 | 4.30 | 0.27 | 0.39 | 0.48 | 0.38 | 0.64 | 1.19 | 2.32 | 1024.00 | 86.55 | 530.29 | 2.19 | 5.47 | 7.65 | 15.30 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Segment | Observed Crash Frequency per year λ | | | AADT | CR | | | UCL | | | DF | | | Total DF | σ | | | Cs | | | MFR | | | Total MFR |
| | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | |
| 57 | 10.00 | 15.25 | 9.50 | 1870 | 5.86 | 8.94 | 5.57 | 6.43 | 8.37 | 6.69 | 0.91 | 1.07 | 0.83 | 0.94 | 9.64 | 13.94 | 8.32 | 15424.00 | 1013.82 | 1901.71 | 21.86 | 33.34 | 20.77 | 75.96 |
| 58 | 0.75 | 1.50 | 4.75 | 1870 | 0.44 | 0.88 | 2.78 | 1.90 | 3.09 | 4.91 | 0.23 | 0.28 | 0.57 | 0.36 | 0.39 | 0.19 | 3.57 | 624.00 | 13.82 | 816.00 | 1.64 | 3.28 | 10.38 | 15.30 |
| 59 | 0.00 | 0.50 | 2.00 | 1870 | 0.00 | 0.29 | 1.17 | 0.19 | 2.06 | 3.40 | 0.00 | 0.14 | 0.34 | 0.16 | -0.36 | -0.81 | 0.82 | -576.00 | -58.91 | 187.43 | 0.00 | 1.09 | 4.37 | 5.47 |
| 60 | 1.50 | 14.25 | 7.75 | 1870 | 0.88 | 8.35 | 4.54 | 2.61 | 8.11 | 6.10 | 0.34 | 1.03 | 0.74 | 0.70 | 1.14 | 12.94 | 6.57 | 1824.00 | 941.09 | 1501.71 | 3.28 | 31.15 | 16.94 | 51.37 |
| 61 | 0.00 | 0.00 | 0.00 | 1870 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 62 | 0.00 | 0.00 | 0.00 | 1870 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 63 | 0.00 | 0.00 | 0.25 | 2220 | 0.00 | 0.00 | 0.12 | 0.19 | 0.67 | 1.51 | 0.00 | 0.00 | 0.08 | 0.03 | -0.36 | -1.31 | -0.93 | -576.00 | -95.27 | -212.57 | 0.00 | 0.00 | 0.52 | 0.52 |
| 64 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 65 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 66 | 0.00 | 0.00 | 0.25 | 2220 | 0.00 | 0.00 | 0.12 | 0.19 | 0.67 | 1.51 | 0.00 | 0.00 | 0.08 | 0.03 | -0.36 | -1.31 | -0.93 | -576.00 | -95.27 | -212.57 | 0.00 | 0.00 | 0.52 | 0.52 |
| 67 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 68 | 0.25 | 0.75 | 2.25 | 2220 | 0.12 | 0.37 | 1.11 | 1.09 | 2.24 | 3.32 | 0.11 | 0.17 | 0.33 | 0.20 | -0.11 | -0.56 | 1.07 | -176.00 | -40.73 | 244.57 | 0.52 | 1.57 | 4.71 | 6.80 |
| 69 | 0.00 | 2.00 | 0.50 | 2220 | 0.00 | 0.99 | 0.25 | 0.19 | 3.23 | 1.89 | 0.00 | 0.31 | 0.13 | 0.15 | -0.36 | 0.69 | -0.68 | -576.00 | 50.18 | -155.43 | 0.00 | 4.19 | 1.05 | 5.23 |
| 70 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 71 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 72 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 73 | 2.25 | 25.25 | 2.75 | 2220 | 1.11 | 12.46 | 1.36 | 2.90 | 9.76 | 3.61 | 0.38 | 1.28 | 0.38 | 0.68 | 1.89 | 23.94 | 1.57 | 3024.00 | 1741.09 | 358.86 | 4.71 | 52.86 | 5.76 | 63.33 |
| 74 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 75 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Segment | Observed Crash Frequency per year λ | | | AADT | CR | | | UCL | | | DF | | | Total DF | σ | | | Cs | | | MFR | | | Total MFR |
| | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | |
| 77 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 78 | 0.25 | 0.25 | 0.75 | 2220 | 0.12 | 0.12 | 0.37 | 1.09 | 1.57 | 2.18 | 0.11 | 0.08 | 0.17 | 0.12 | -0.11 | -1.06 | -0.43 | -176.00 | -77.09 | -98.29 | 0.52 | 0.52 | 1.57 | 2.62 |
| 79 | 0.00 | 0.25 | 0.25 | 2220 | 0.00 | 0.12 | 0.12 | 0.19 | 1.57 | 1.51 | 0.00 | 0.08 | 0.08 | 0.05 | -0.36 | -1.06 | -0.93 | -576.00 | -77.09 | -212.57 | 0.00 | 0.52 | 0.52 | 1.05 |
| 80 | 1.00 | 2.00 | 5.25 | 2220 | 0.49 | 0.99 | 2.59 | 2.00 | 3.23 | 4.76 | 0.25 | 0.31 | 0.54 | 0.37 | 0.64 | 0.69 | 4.07 | 1024.00 | 50.18 | 930.29 | 2.09 | 4.19 | 10.99 | 17.27 |
| 81 | 0.25 | 0.50 | 0.75 | 2220 | 0.12 | 0.25 | 0.37 | 1.09 | 1.95 | 2.18 | 0.11 | 0.13 | 0.17 | 0.14 | -0.11 | -0.81 | -0.43 | -176.00 | -58.91 | -98.29 | 0.52 | 1.05 | 1.57 | 3.14 |
| 82 | 0.25 | 0.50 | 0.00 | 2220 | 0.12 | 0.25 | 0.00 | 1.09 | 1.95 | 0.61 | 0.11 | 0.13 | 0.00 | 0.08 | -0.11 | -0.81 | -1.18 | -176.00 | -58.91 | -269.71 | 0.52 | 1.05 | 0.00 | 1.57 |
| 83 | 1.75 | 1.75 | 0.00 | 2220 | 0.86 | 0.86 | 0.00 | 2.58 | 3.06 | 0.61 | 0.33 | 0.28 | 0.00 | 0.21 | 1.39 | 0.44 | -1.18 | 2224.00 | 32.00 | -269.71 | 3.66 | 3.66 | 0.00 | 7.33 |
| 84 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 85 | 0.25 | 1.25 | 3.00 | 2355 | 0.12 | 0.58 | 1.40 | 1.07 | 2.63 | 3.65 | 0.11 | 0.22 | 0.38 | 0.24 | -0.11 | -0.06 | 1.82 | -176.00 | -4.36 | 416.00 | 0.52 | 2.58 | 6.20 | 9.29 |
| 86 | 0.50 | 1.00 | 2.00 | 2220 | 0.25 | 0.49 | 0.99 | 1.47 | 2.48 | 3.17 | 0.17 | 0.20 | 0.31 | 0.23 | 0.14 | -0.31 | 0.82 | 224.00 | -22.55 | 187.43 | 1.05 | 2.09 | 4.19 | 7.33 |
| 87 | 0.25 | 2.50 | 0.00 | 2220 | 0.12 | 1.23 | 0.00 | 1.09 | 3.53 | 0.61 | 0.11 | 0.35 | 0.00 | 0.15 | -0.11 | 1.19 | -1.18 | -176.00 | 86.55 | -269.71 | 0.52 | 5.23 | 0.00 | 5.76 |
| 88 | 0.00 | 0.75 | 1.00 | 2220 | 0.00 | 0.37 | 0.49 | 0.19 | 2.24 | 2.42 | 0.00 | 0.17 | 0.20 | 0.12 | -0.36 | -0.56 | -0.18 | -576.00 | -40.73 | -41.14 | 0.00 | 1.57 | 2.09 | 3.66 |
| 89 | 0.00 | 0.00 | 0.00 | 2220 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 90 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 91 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 92 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 93 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 94 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 95 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 96 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Segment | Observed Crash Frequency per year λ | | | AADT | CR | | | UCL | | | DF | | | Total DF | σ | | | Cs | | | MFR | | | Total MFR |
| | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | |
| 97 | 1.25 | 2.00 | 1.00 | 2021 | 0.68 | 1.08 | 0.54 | 2.31 | 3.35 | 2.51 | 0.29 | 0.32 | 0.22 | 0.28 | 0.89 | 0.69 | -0.18 | 1424.00 | 50.18 | -41.14 | 2.68 | 4.28 | 2.14 | 9.10 |
| 98 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 99 | 0.50 | 0.25 | 0.00 | 2021 | 0.27 | 0.14 | 0.00 | 1.53 | 1.62 | 0.61 | 0.18 | 0.08 | 0.00 | 0.09 | 0.14 | -1.06 | -1.18 | 224.00 | -77.09 | -269.71 | 1.07 | 0.54 | 0.00 | 1.61 |
| 100 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 101 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 102 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 103 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 104 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 105 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 106 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 107 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 108 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 109 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 110 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 111 | 0.50 | 0.50 | 1.50 | 2021 | 0.27 | 0.27 | 0.81 | 1.53 | 2.01 | 2.93 | 0.18 | 0.13 | 0.28 | 0.20 | 0.14 | -0.81 | 0.32 | 224.00 | -58.91 | 73.14 | 1.07 | 1.07 | 3.21 | 5.36 |
| 112 | 1.25 | 1.00 | 1.25 | 2021 | 0.68 | 0.54 | 0.68 | 2.31 | 2.57 | 2.73 | 0.29 | 0.21 | 0.25 | 0.25 | 0.89 | -0.31 | 0.07 | 1424.00 | -22.55 | 16.00 | 2.68 | 2.14 | 2.68 | 7.50 |
| 113 | 0.50 | 0.25 | 0.25 | 2021 | 0.27 | 0.14 | 0.14 | 1.53 | 1.62 | 1.56 | 0.18 | 0.08 | 0.09 | 0.12 | 0.14 | -1.06 | -0.93 | 224.00 | -77.09 | -212.57 | 1.07 | 0.54 | 0.54 | 2.14 |
| 114 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 115 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 116 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Segment | Observed Crash Frequency per year | | | AADT | CR | | | UCL | | | DF | | | Total DF | σ | | | Cs | | | MFR | | | Total MFR |
| | λ | | | | | | | | | | | | | | | | | | | | | | | |
| | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | Fatal | Serious and slight | PDO | |
| 117 | 2.00 | 4.00 | 5.50 | 2021 | 1.08 | 2.17 | 2.98 | 2.87 | 4.46 | 5.06 | 0.38 | 0.49 | 0.59 | 0.48 | 1.64 | 2.69 | 4.32 | 2624.00 | 195.64 | 987.43 | 4.28 | 8.57 | 11.78 | 24.64 |
| 118 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 119 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 120 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 121 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| 122 | 0.00 | 0.25 | 0.25 | 2021 | 0.00 | 0.14 | 0.14 | 0.19 | 1.62 | 1.56 | 0.00 | 0.08 | 0.09 | 0.06 | -0.36 | -1.06 | -0.93 | -576.00 | -77.09 | -212.57 | 0.00 | 0.54 | 0.54 | 1.07 |
| 123 | 0.50 | 2.50 | 1.75 | 2021 | 0.27 | 1.36 | 0.95 | 1.53 | 3.67 | 3.12 | 0.18 | 0.37 | 0.30 | 0.28 | 0.14 | 1.19 | 0.57 | 224.00 | 86.55 | 130.29 | 1.07 | 5.36 | 3.75 | 10.18 |
| 124 | 0.75 | 0.75 | 0.75 | 2021 | 0.41 | 0.41 | 0.41 | 1.83 | 2.31 | 2.25 | 0.22 | 0.18 | 0.18 | 0.19 | 0.39 | -0.56 | -0.43 | 624.00 | -40.73 | -98.29 | 1.61 | 1.61 | 1.61 | 4.82 |
| 125 | 0.25 | 0.00 | 0.25 | 2021 | 0.14 | 0.00 | 0.14 | 1.14 | 0.67 | 1.56 | 0.12 | 0.00 | 0.09 | 0.07 | -0.11 | -1.31 | -0.93 | -176.00 | -95.27 | -212.57 | 0.54 | 0.00 | 0.54 | 1.07 |
| 126 | 0.00 | 0.00 | 0.00 | 2021 | 0.00 | 0.00 | 0.00 | 0.19 | 0.67 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | -0.36 | -1.31 | -1.18 | -576.00 | -95.27 | -269.71 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sum | 39.00 | 141.25 | 127.75 | Avg | 0.19 | 0.67 | 0.61 | | | | | | | Σ | -0.24 | -1.54 | -0.87 | | | | | | | |
| Avg | 0.36 | 1.31 | 1.18 | | | | | | | | | | | σ | 0.001 | 0.022 | 0.007 | | | | | | | |

### 4.4. Empirical Bayesian Black Spot Identification Method

Empirical Bayesian method is applied for prioritizing black spot locations. Empirical Bayesian (EB) estimates combines historical crash data with crash predictions, and are thus able to identify also potential hazardous road locations, where no crashes have yet occurred. The following procedures were used to calculate the EB method:

1) The safety performance function (SPF)
2) The over-dispersion parameter, $\phi$
3) The relative weights, $\alpha$
4) The estimated expected crash for first year $\pi_1$, and
5) The estimated expected crash for final year $\pi_n$.
6) Excess number of crashes for ranking purpose

#### 4.4.1. The Predicted Number of Crashes Using SPF Model

The predicted number of crashes by using calibrated base condition Equation-13 and combined CMF, the predicted numbers of crashes was estimated for each study year of each road segments.

##### 4.4.1.1. The Crash Modification Factor

The CMFs for geometric design and traffic control features for rural two-lane two-way roadway segments are given under the methodology chapter in Table-5. These CMFs were applied in steps of the predictive method to adjust the SPF equation for rural two-lane two-way roadway segments to account for differences between the base conditions and the local site conditions.

##### 4.4.1.2. The Calibration Factor

The calibration factor is the sum of all the observed crashes for all the sites selected, divided by the predicted crashes using the equation for all the same sites.

To estimate the calibration factor the predicted number of crashes for each segment was calculated by using base condition and crash modification factors (CMF). Thus,

- Total number of four years predicted crashes for fatal crashes before calibration was estimated to be 145.45 and the corresponding actually observed number of fatal crashes was 160;
- The total number of four years predicted crashes for injury (i,e. serious and slight) crashes before calibration was projected to be 503.45 and the corresponding actually observed number of fatal crashes was 584;
- The total number of four years predicted crashes for property damage only crashes before calibration was estimated to be 492.93 and the equivalent actually observed number of property damage only crash was 488.
- Then, the calibration factor can be estimated as described in Equation 7 as:

$$C_r = \frac{\sum_{\text{all selected sites}} \text{Observed Crashes}}{\sum_{\text{all selected sites}} N_{\text{Predicted(Uncalibrated)}}}$$

Calibration Factor for fatal crashes:

$$C_{rF} = \frac{160}{145.45} = 1.10$$

Calibration Factor for serious injury and slight injury crashes:

$$C_{rI} = \frac{584}{503.45} = 1.16$$

Calibration Factor for property damage only crashes:

$$C_{rp} = \frac{488}{492.93} = 0.99$$

The calculated calibration factor $C_{rF}$ = 1.10 for fatal crashes, $C_{rI}$ = 1.16 for serious and slight injury and $C_{rp}$ = 0.99 for property damage only crashes are added in the suitable predictive model of each segment. After application of the calibration factor, the base condition Negative Binomial Predictive Model for a rural 2-lane, 2-way roadway segment SPF given in Equation 8 is modified in to the local condition because of the difference in base conditions and the local site conditions and is given as in Equations 19, 20 and 21 respectively.

$N_{SPFxf}$= 1.10*(AADT) (L) (365) ($10^{-6}$) $e^{(-0.312)}$………………………………..18

$N_{SPFxI}$= 1.16*(AADT) (L) (365) ($10^{-6}$) $e^{(-0.312)}$………………………………..19

$N_{SPFxI}$= 0.99*(AADT) (L) (365) ($10^{-6}$) $e^{(-0.312)}$………………………………..20

The results of year 1, 2, 3 and 4 predicted crashes, was presented in column 1 up to 12 of Table-14 respectively for each crash severity types.

The annual correction factor is given as predicted average Crash Frequency for year n (i.e. 4 years) divided by the predicted average Crash Frequency for year 1 as described in Equation 11 and applied in Table-14 column 13, 14, 15 and 16 respectively. The total annual correction factor as the summation of all the four year annual correction factors is presented in Table-14 column 17.

### 4.4.2. The Relative Weights, $\alpha$

The over-dispersion parameter,$\phi$, is calculated using Equation 10. This over-dispersion is used to determine the weight factor and presented in column 18 of Table-14.

To adjust for varying degrees of over-dispersion, a relative weight, $\alpha_i$, is applied to each roadway segment. The segment-specific relative weight is determined by Equation 12.

The result of the relative weight is presented in column 19 to 21 of Table-14 for each type of crash severity.

Table-14: Predictive average crash per year, annual correction factor, over-dispersion and weight factor.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| segment | Predicted Average Crash Frequency per year for fatality | | | | Predicted Average Crash Frequency per year for serious and slight Injury | | | | Predicted Average Crash Frequency per year for Property Damage | | | | Annual Correction Factors for predicted average Crash Frequency | | | | Total Annual Correction Factor | Over Dispersion | Weight Factor for year 1 | | |
| | Fatal Crash | | | | Serious and Slight Injury | | | | Property Damage Only Crash | | | | $C_x$ | | | | | | α | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_n$ | ø | Fatal crash | Serious and slight injury | Property damage only |
| 18 | 0.39 | 0.46 | 0.48 | 0.53 | 0.51 | 0.59 | 0.63 | 0.69 | 0.49 | 0.51 | 0.53 | 0.59 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.17 | 0.14 | 0.15 |
| 19 | 0.31 | 0.36 | 0.38 | 0.42 | 0.40 | 0.47 | 0.49 | 0.54 | 0.38 | 0.40 | 0.42 | 0.46 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.21 | 0.17 | 0.19 |
| 20 | 0.29 | 0.30 | 0.32 | 0.35 | 0.37 | 0.39 | 0.41 | 0.46 | 0.32 | 0.34 | 0.35 | 0.39 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.23 | 0.19 | 0.21 |
| 21 | 0.30 | 0.31 | 0.33 | 0.36 | 0.38 | 0.40 | 0.42 | 0.47 | 0.33 | 0.34 | 0.36 | 0.40 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.23 | 0.18 | 0.21 |
| 22 | 0.25 | 0.29 | 0.31 | 0.34 | 0.33 | 0.38 | 0.40 | 0.44 | 0.31 | 0.33 | 0.34 | 0.38 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.24 | 0.20 | 0.22 |
| 23 | 0.39 | 0.41 | 0.43 | 0.47 | 0.50 | 0.53 | 0.55 | 0.61 | 0.43 | 0.45 | 0.47 | 0.52 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.18 | 0.15 | 0.17 |
| 24 | 0.31 | 0.33 | 0.34 | 0.38 | 0.40 | 0.42 | 0.45 | 0.49 | 0.35 | 0.36 | 0.38 | 0.42 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.22 | 0.18 | 0.20 |
| 25 | 0.46 | 0.49 | 0.51 | 0.56 | 0.60 | 0.63 | 0.66 | 0.73 | 0.51 | 0.54 | 0.57 | 0.62 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.16 | 0.13 | 0.14 |
| 26 | 0.85 | 0.99 | 1.04 | 1.15 | 1.10 | 1.29 | 1.35 | 1.49 | 1.05 | 1.10 | 1.16 | 1.28 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.09 | 0.07 | 0.08 |
| 27 | 0.30 | 0.31 | 0.33 | 0.36 | 0.38 | 0.40 | 0.42 | 0.47 | 0.33 | 0.34 | 0.36 | 0.40 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.23 | 0.18 | 0.21 |
| 28 | 0.56 | 0.66 | 0.69 | 0.76 | 0.73 | 0.85 | 0.89 | 0.99 | 0.69 | 0.73 | 0.76 | 0.84 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.12 | 0.10 | 0.11 |
| 29 | 0.35 | 0.41 | 0.44 | 0.48 | 0.46 | 0.54 | 0.56 | 0.62 | 0.44 | 0.46 | 0.48 | 0.53 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.18 | 0.15 | 0.17 |
| 30 | 0.30 | 0.35 | 0.37 | 0.41 | 0.39 | 0.46 | 0.48 | 0.53 | 0.37 | 0.39 | 0.41 | 0.45 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.21 | 0.17 | 0.19 |
| 31 | 0.39 | 0.46 | 0.48 | 0.53 | 0.51 | 0.59 | 0.62 | 0.69 | 0.48 | 0.51 | 0.53 | 0.59 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.17 | 0.14 | 0.15 |
| 32 | 0.55 | 0.64 | 0.67 | 0.74 | 0.71 | 0.83 | 0.87 | 0.96 | 0.68 | 0.71 | 0.75 | 0.82 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.13 | 0.10 | 0.11 |
| 33 | 0.56 | 0.66 | 0.69 | 0.76 | 0.73 | 0.85 | 0.90 | 0.99 | 0.70 | 0.73 | 0.77 | 0.84 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.12 | 0.10 | 0.11 |
| 34 | 0.27 | 0.32 | 0.34 | 0.37 | 0.35 | 0.41 | 0.43 | 0.48 | 0.34 | 0.35 | 0.37 | 0.41 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.23 | 0.18 | 0.20 |

| segment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Predicted Average Crash Frequency per year for fatality | | | | Predicted Average Crash Frequency per year for serious and slight Injury | | | | Predicted Average Crash Frequency per year for Property Damage | | | | Annual Correction Factors for predicted average Crash Frequency | | | | Total Annual Correction Factor | Over Dispersion | Weight Factor for year 1 | | |
| | Fatal Crash | | | | Serious and Slight Injury | | | | Property Damage Only Crash | | | | $C_x$ | | | | | | α | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_n$ | ø | Fatal crash | Serious and slight injury | Property damage only |
| 35 | 0.28 | 0.29 | 0.31 | 0.34 | 0.36 | 0.38 | 0.40 | 0.44 | 0.31 | 0.33 | 0.34 | 0.38 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.24 | 0.19 | 0.22 |
| 36 | 0.39 | 0.45 | 0.47 | 0.52 | 0.50 | 0.58 | 0.61 | 0.68 | 0.48 | 0.50 | 0.52 | 0.58 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.17 | 0.14 | 0.15 |
| 37 | 0.23 | 0.27 | 0.29 | 0.32 | 0.30 | 0.36 | 0.37 | 0.41 | 0.29 | 0.30 | 0.32 | 0.35 | 1.00 | 1.17 | 1.23 | 1.36 | 4.76 | 0.38 | 0.25 | 0.21 | 0.23 |
| 38 | 0.28 | 0.29 | 0.31 | 0.34 | 0.36 | 0.38 | 0.40 | 0.44 | 0.31 | 0.33 | 0.34 | 0.38 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.24 | 0.19 | 0.22 |
| 39 | 0.42 | 0.44 | 0.46 | 0.51 | 0.54 | 0.57 | 0.60 | 0.66 | 0.46 | 0.49 | 0.51 | 0.56 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.17 | 0.14 | 0.16 |
| 40 | 0.36 | 0.37 | 0.39 | 0.43 | 0.46 | 0.48 | 0.51 | 0.56 | 0.40 | 0.42 | 0.44 | 0.48 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.20 | 0.16 | 0.18 |
| 41 | 0.41 | 0.44 | 0.46 | 0.51 | 0.54 | 0.56 | 0.59 | 0.66 | 0.46 | 0.48 | 0.51 | 0.56 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.17 | 0.14 | 0.16 |
| 42 | 0.75 | 0.79 | 0.83 | 0.92 | 0.97 | 1.02 | 1.08 | 1.19 | 0.84 | 0.88 | 0.92 | 1.02 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.10 | 0.08 | 0.09 |
| 43 | 0.23 | 0.25 | 0.26 | 0.29 | 0.30 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.29 | 0.32 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.27 | 0.22 | 0.25 |
| 44 | 0.25 | 0.29 | 0.31 | 0.34 | 0.32 | 0.38 | 0.40 | 0.44 | 0.31 | 0.32 | 0.34 | 0.38 | 1.00 | 1.18 | 1.24 | 1.37 | 4.80 | 0.38 | 0.24 | 0.20 | 0.22 |
| 45 | 0.25 | 0.26 | 0.27 | 0.30 | 0.32 | 0.34 | 0.36 | 0.39 | 0.28 | 0.29 | 0.30 | 0.34 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.26 | 0.21 | 0.24 |
| 46 | 0.21 | 0.24 | 0.26 | 0.28 | 0.27 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.29 | 0.31 | 1.00 | 1.18 | 1.24 | 1.37 | 4.80 | 0.38 | 0.28 | 0.23 | 0.25 |
| 47 | 0.22 | 0.23 | 0.25 | 0.27 | 0.29 | 0.30 | 0.32 | 0.35 | 0.25 | 0.26 | 0.27 | 0.30 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.28 | 0.23 | 0.26 |
| 48 | 0.19 | 0.23 | 0.24 | 0.26 | 0.25 | 0.30 | 0.31 | 0.34 | 0.24 | 0.25 | 0.27 | 0.29 | 1.00 | 1.18 | 1.24 | 1.37 | 4.80 | 0.38 | 0.29 | 0.24 | 0.27 |
| 49 | 0.21 | 0.22 | 0.23 | 0.26 | 0.27 | 0.29 | 0.30 | 0.34 | 0.24 | 0.25 | 0.26 | 0.29 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 50 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.80 | 0.38 | 0.30 | 0.25 | 0.27 |
| 51 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.30 | 0.25 | 0.28 |
| 52 | 0.18 | 0.21 | 0.23 | 0.25 | 0.24 | 0.28 | 0.29 | 0.32 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.80 | 0.38 | 0.30 | 0.25 | 0.28 |
| 53 | 0.20 | 0.21 | 0.22 | 0.25 | 0.26 | 0.28 | 0.29 | 0.32 | 0.22 | 0.24 | 0.25 | 0.27 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.30 | 0.25 | 0.28 |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| segment | Predicted Average Crash Frequency per year for fatality | | | | Predicted Average Crash Frequency per year for serious and slight Injury | | | | Predicted Average Crash Frequency per year for Property Damage | | | | Annual Correction Factors for predicted average Crash Frequency | | | | Total Annual Correction Factor | Over Dispersion | Weight Factor for year 1 | | |
| | Fatal Crash | | | | Serious and Slight Injury | | | | Property Damage Only Crash | | | | $C_x$ | | | | | | α | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_n$ | ø | Fatal crash | Serious and slight injury | Property damage only |
| 54 | 0.18 | 0.21 | 0.22 | 0.25 | 0.23 | 0.27 | 0.29 | 0.32 | 0.22 | 0.23 | 0.25 | 0.27 | 1.00 | 1.18 | 1.24 | 1.37 | 4.80 | 0.38 | 0.31 | 0.25 | 0.28 |
| 55 | 0.20 | 0.21 | 0.22 | 0.24 | 0.26 | 0.27 | 0.29 | 0.32 | 0.22 | 0.23 | 0.25 | 0.27 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.30 | 0.25 | 0.28 |
| 56 | 0.18 | 0.21 | 0.22 | 0.24 | 0.23 | 0.27 | 0.29 | 0.32 | 0.22 | 0.23 | 0.24 | 0.27 | 1.00 | 1.18 | 1.24 | 1.37 | 4.80 | 0.38 | 0.31 | 0.26 | 0.28 |
| 57 | 0.20 | 0.21 | 0.22 | 0.24 | 0.26 | 0.27 | 0.28 | 0.31 | 0.22 | 0.23 | 0.24 | 0.27 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.30 | 0.25 | 0.28 |
| 58 | 0.18 | 0.21 | 0.22 | 0.24 | 0.23 | 0.27 | 0.28 | 0.31 | 0.22 | 0.23 | 0.24 | 0.27 | 1.00 | 1.18 | 1.24 | 1.37 | 4.80 | 0.38 | 0.31 | 0.26 | 0.28 |
| 59 | 0.20 | 0.21 | 0.22 | 0.24 | 0.26 | 0.27 | 0.28 | 0.31 | 0.22 | 0.23 | 0.24 | 0.27 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.31 | 0.25 | 0.28 |
| 60 | 0.18 | 0.21 | 0.22 | 0.24 | 0.23 | 0.27 | 0.28 | 0.31 | 0.22 | 0.23 | 0.24 | 0.27 | 1.00 | 1.18 | 1.24 | 1.37 | 4.80 | 0.38 | 0.31 | 0.26 | 0.28 |
| 61 | 0.20 | 0.21 | 0.22 | 0.24 | 0.25 | 0.27 | 0.28 | 0.31 | 0.22 | 0.23 | 0.24 | 0.27 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.31 | 0.25 | 0.28 |
| 62 | 0.17 | 0.21 | 0.22 | 0.24 | 0.23 | 0.27 | 0.28 | 0.31 | 0.22 | 0.23 | 0.24 | 0.26 | 1.00 | 1.18 | 1.24 | 1.37 | 4.80 | 0.38 | 0.31 | 0.26 | 0.29 |
| 63 | 0.23 | 0.25 | 0.26 | 0.28 | 0.30 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.29 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.22 | 0.25 |
| 64 | 0.21 | 0.24 | 0.26 | 0.28 | 0.27 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.29 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 65 | 0.23 | 0.24 | 0.26 | 0.28 | 0.30 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.22 | 0.25 |
| 66 | 0.21 | 0.24 | 0.26 | 0.28 | 0.27 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 67 | 0.23 | 0.24 | 0.26 | 0.28 | 0.30 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.22 | 0.25 |
| 68 | 0.21 | 0.24 | 0.26 | 0.28 | 0.27 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 69 | 0.23 | 0.24 | 0.26 | 0.28 | 0.30 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.22 | 0.25 |
| 70 | 0.21 | 0.24 | 0.26 | 0.28 | 0.27 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 71 | 0.23 | 0.24 | 0.26 | 0.28 | 0.30 | 0.32 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.22 | 0.25 |
| 72 | 0.21 | 0.24 | 0.26 | 0.28 | 0.27 | 0.31 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |

| segment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Predicted Average Crash Frequency per year for fatality | | | | Predicted Average Crash Frequency per year for serious and slight Injury | | | | Predicted Average Crash Frequency per year for Property Damage | | | | Annual Correction Factors for predicted average Crash Frequency | | | | Total Annual Correction Factor | Over Dispersion | Weight Factor for year 1 | | |
| | Fatal Crash | | | | Serious and Slight Injury | | | | Property Damage Only Crash | | | | $C_x$ | | | | | | α | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_n$ | ø | Fatal crash | Serious and slight injury | Property damage only |
| 73 | 0.23 | 0.24 | 0.26 | 0.28 | 0.30 | 0.31 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.22 | 0.25 |
| 74 | 0.21 | 0.24 | 0.26 | 0.28 | 0.27 | 0.31 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 75 | 0.23 | 0.24 | 0.26 | 0.28 | 0.30 | 0.31 | 0.33 | 0.37 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.22 | 0.25 |
| 76 | 0.21 | 0.24 | 0.25 | 0.28 | 0.27 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 77 | 0.23 | 0.24 | 0.25 | 0.28 | 0.30 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.23 | 0.25 |
| 78 | 0.21 | 0.24 | 0.25 | 0.28 | 0.27 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 79 | 0.23 | 0.24 | 0.25 | 0.28 | 0.30 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.23 | 0.25 |
| 80 | 0.21 | 0.24 | 0.25 | 0.28 | 0.27 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 81 | 0.23 | 0.24 | 0.25 | 0.28 | 0.30 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.23 | 0.25 |
| 82 | 0.21 | 0.24 | 0.25 | 0.28 | 0.27 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 83 | 0.23 | 0.24 | 0.25 | 0.28 | 0.30 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.23 | 0.25 |
| 84 | 0.21 | 0.24 | 0.25 | 0.28 | 0.27 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 85 | 0.24 | 0.26 | 0.27 | 0.30 | 0.32 | 0.33 | 0.35 | 0.39 | 0.27 | 0.28 | 0.30 | 0.33 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.26 | 0.22 | 0.24 |
| 86 | 0.21 | 0.24 | 0.25 | 0.28 | 0.27 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 87 | 0.23 | 0.24 | 0.25 | 0.28 | 0.30 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.23 | 0.25 |
| 88 | 0.21 | 0.24 | 0.25 | 0.28 | 0.27 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.17 | 1.23 | 1.36 | 4.77 | 0.38 | 0.28 | 0.23 | 0.25 |
| 89 | 0.23 | 0.24 | 0.25 | 0.28 | 0.30 | 0.31 | 0.33 | 0.36 | 0.26 | 0.27 | 0.28 | 0.31 | 1.00 | 1.05 | 1.11 | 1.22 | 4.38 | 0.38 | 0.27 | 0.23 | 0.25 |
| 90 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 91 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |

| segment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Predicted Average Crash Frequency per year for fatality | | | | Predicted Average Crash Frequency per year for serious and slight Injury | | | | Predicted Average Crash Frequency per year for Property Damage | | | | Annual Correction Factors for predicted average Crash Frequency | | | | Total Annual Correction Factor | Over Dispersion | Weight Factor for year 1 | | |
| | Fatal Crash | | | | Serious and Slight Injury | | | | Property Damage Only Crash | | | | $C_x$ | | | | | | α | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_n$ | ø | Fatal crash | Serious and slight injury | Property damage only |
| 92 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 93 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 94 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 95 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 96 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 97 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 98 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 99 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 100 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 101 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 102 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 103 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 104 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.26 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 105 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 106 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 107 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 108 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 109 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |

| segment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Predicted Average Crash Frequency per year for fatality | | | | Predicted Average Crash Frequency per year for serious and slight Injury | | | | Predicted Average Crash Frequency per year for Property Damage | | | | Annual Correction Factors for predicted average Crash Frequency | | | | Total Annual Correction Factor | Over Dispersion | Weight Factor for year 1 | | |
| | Fatal Crash | | | | Serious and Slight Injury | | | | Property Damage Only Crash | | | | $C_x$ | | | | | | α | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_n$ | ø | Fatal crash | Serious and slight Injury | Property damage only |
| 110 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 111 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 112 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 113 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 114 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 115 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 116 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 117 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 118 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 119 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 120 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 121 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 122 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 123 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 124 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |
| 125 | 0.21 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.05 | 1.10 | 1.22 | 4.38 | 0.38 | 0.29 | 0.24 | 0.27 |
| 126 | 0.19 | 0.22 | 0.23 | 0.25 | 0.24 | 0.28 | 0.30 | 0.33 | 0.23 | 0.24 | 0.25 | 0.28 | 1.00 | 1.18 | 1.24 | 1.37 | 4.78 | 0.38 | 0.30 | 0.25 | 0.27 |

### 4.4.3. The Estimated Expected Average Crash Frequency, π

The expected number of Crash Frequency represents the crash potential of a site or the long-term average actually observed number of crashes. This phase of the procedure incorporates the observed Crash Frequency with the Predicted Average Crash Frequency by weight factor. The result of expected long term EB-adjusted average Crash Frequency on the roadway segment (using Equation 14 and 15) is estimated by using first year EB-adjusted expected average Crash Frequency (Table-15, column 25, 26 and 27) expressed as it is established by applying the correction factor, $C_n$, for fatal crash, serious and slight injury crashes in joint and property damage crashes using Equations 9 and presented in Table-15, column 28, 29 and 30 respectively.

### 4.4.4. Excess Predicted Crash Frequency

Finally, the excess predicted Crash Frequency $N_{excess}$ (or PSI using Equation 18) was determined as in Table-15 column 31. The excess predicted Crash Frequency was the difference between the summation of observed Crash Frequency and the EB adjusted expected average Crash Frequency which indicate whether the expected average crash was above or below the actual observed crash. Whenever the expected crash exceeds the actual observed crash, the roadway segments do not need safety improvement. The negative value in $N_{excess}$ indicate that the adjusted expected average Crash Frequency was greater than the observed Crash Frequency for the selected segment.

Consequently, the difference between the expected average crash and observed crash (i.e. PSI) as described in Table-15 column 31, not applicable (NA) abbreviation is used for no safety improvement.

Table-15: Average observed Crash Frequency per year and EB adjusted expected average Crash Frequency.

| Seg. | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Average Observed Crash Frequency per year | | | EB Adjusted Expected Average Crash Frequency for year 1 | | | EB Adjusted Expected Average Crash Frequency | | | $N_{excess}=N_{observed}-N_{expected}$ |
| | $\lambda$ | | | $\pi_1$ | | | $\pi_n$ | | | $N_{excess}$ |
| | Fatal crash | Serious and slight injury | PDO | Fatal crash | Serious and slight injury | PDO | Fatal crash | Serious and slight injury | PDO | Summation for all crashes |
| 18 | 1.00 | 0.75 | 1.75 | 0.24 | 0.21 | 0.39 | 1.15 | 0.98 | 1.83 | NA |
| 19 | 0.25 | 1.50 | 1.25 | 0.11 | 0.33 | 0.28 | 0.50 | 1.57 | 1.35 | NA |
| 20 | 1.00 | 1.50 | 3.50 | 0.24 | 0.35 | 0.70 | 1.06 | 1.52 | 3.05 | 0.36 |
| 21 | 0.25 | 0.50 | 0.75 | 0.11 | 0.16 | 0.20 | 0.49 | 0.72 | 0.89 | NA |
| 22 | 0.00 | 0.75 | 3.00 | 0.06 | 0.19 | 0.56 | 0.29 | 0.91 | 2.67 | NA |
| 23 | 0.75 | 1.50 | 1.25 | 0.21 | 0.37 | 0.31 | 0.92 | 1.60 | 1.36 | NA |
| 24 | 0.00 | 0.75 | 1.25 | 0.07 | 0.21 | 0.30 | 0.30 | 0.93 | 1.30 | NA |
| 25 | 0.00 | 1.00 | 0.25 | 0.07 | 0.28 | 0.12 | 0.32 | 1.21 | 0.54 | NA |
| 26 | 0.00 | 1.00 | 3.00 | 0.07 | 0.27 | 0.66 | 0.35 | 1.29 | 3.15 | NA |
| 27 | 0.50 | 5.50 | 6.25 | 0.16 | 1.10 | 1.20 | 0.68 | 4.79 | 5.24 | 1.53 |
| 28 | 0.00 | 1.00 | 3.00 | 0.07 | 0.26 | 0.64 | 0.33 | 1.24 | 3.03 | NA |
| 29 | 0.00 | 0.25 | 1.25 | 0.07 | 0.11 | 0.29 | 0.31 | 0.54 | 1.39 | NA |
| 30 | 2.25 | 9.50 | 11.00 | 0.44 | 1.72 | 1.94 | 2.08 | 8.20 | 9.26 | 3.21 |
| 31 | 0.00 | 0.00 | 0.00 | 0.07 | 0.07 | 0.07 | 0.32 | 0.33 | 0.35 | NA |
| 32 | 0.50 | 3.75 | 0.75 | 0.16 | 0.78 | 0.22 | 0.77 | 3.71 | 1.03 | NA |
| 33 | 0.00 | 0.50 | 0.25 | 0.07 | 0.17 | 0.12 | 0.33 | 0.79 | 0.59 | NA |
| 34 | 2.00 | 10.75 | 8.75 | 0.39 | 1.91 | 1.53 | 1.84 | 9.08 | 7.29 | 3.29 |
| 35 | 0.00 | 1.25 | 2.25 | 0.07 | 0.30 | 0.47 | 0.29 | 1.32 | 2.06 | NA |
| 36 | 0.00 | 0.00 | 0.00 | 0.07 | 0.07 | 0.07 | 0.31 | 0.33 | 0.35 | NA |
| 37 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.07 | 0.28 | 0.30 | 0.32 | NA |
| 38 | 0.75 | 6.00 | 5.50 | 0.20 | 1.18 | 1.05 | 0.86 | 5.15 | 4.60 | 1.64 |
| 39 | 0.00 | 0.00 | 0.00 | 0.07 | 0.07 | 0.07 | 0.31 | 0.33 | 0.32 | NA |
| 40 | 0.00 | 0.00 | 0.00 | 0.07 | 0.07 | 0.07 | 0.31 | 0.32 | 0.31 | NA |
| 41 | 0.00 | 0.00 | 0.00 | 0.07 | 0.07 | 0.07 | 0.31 | 0.33 | 0.32 | NA |
| 42 | 0.00 | 0.00 | 0.00 | 0.08 | 0.08 | 0.08 | 0.34 | 0.35 | 0.34 | NA |
| 43 | 0.00 | 1.25 | 2.50 | 0.06 | 0.29 | 0.49 | 0.28 | 1.27 | 2.16 | 0.05 |
| 44 | 1.00 | 3.00 | 3.25 | 0.22 | 0.57 | 0.60 | 1.05 | 2.71 | 2.86 | 0.63 |
| 45 | 0.00 | 0.75 | 1.00 | 0.06 | 0.20 | 0.24 | 0.28 | 0.89 | 1.05 | NA |
| 46 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.07 | 0.27 | 0.29 | 0.31 | NA |
| 47 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |

| Seg | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Average Observed Crash Frequency per year | | | EB Adjusted Expected Average Crash Frequency for year 1 | | | EB Adjusted Expected Average Crash Frequency | | | $N_{excess}=N_{observed} - N_{expected}$ |
| | λ | | | $\pi_1$ | | | $\pi_n$ | | | $N_{excess}$ |
| | Fatal crash | Serious and slight Injury | PDO | Fatal crash | Serious and slight Injury | PDO | Fatal crash | Serious and slight Injury | PDO | Summation for all crashes |
| 48 | 0.00 | 0.75 | 1.00 | 0.06 | 0.18 | 0.22 | 0.27 | 0.86 | 1.04 | NA |
| 49 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 50 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 51 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 52 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.26 | 0.28 | 0.30 | NA |
| 53 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.27 | NA |
| 54 | 0.25 | 0.00 | 1.25 | 0.09 | 0.06 | 0.25 | 0.44 | 0.28 | 1.20 | NA |
| 55 | 0.75 | 3.50 | 1.75 | 0.18 | 0.66 | 0.35 | 0.79 | 2.91 | 1.53 | 0.77 |
| 56 | 1.00 | 4.75 | 3.50 | 0.20 | 0.80 | 0.59 | 0.95 | 3.81 | 2.81 | 1.67 |
| 57 | 10.00 | 15.25 | 7.00 | 1.65 | 2.67 | 1.21 | 7.22 | 11.69 | 5.29 | 8.05 |
| 58 | 0.75 | 2.75 | 4.75 | 0.16 | 0.48 | 0.77 | 0.78 | 2.32 | 3.70 | 1.45 |
| 59 | 0.00 | 0.50 | 2.00 | 0.06 | 0.15 | 0.39 | 0.26 | 0.66 | 1.70 | NA |
| 60 | 2.50 | 14.25 | 7.75 | 0.41 | 2.26 | 1.22 | 1.98 | 10.84 | 5.84 | 5.83 |
| 61 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.26 | 0.28 | 0.27 | NA |
| 62 | 0.00 | 0.00 | 0.00 | 0.05 | 0.06 | 0.06 | 0.26 | 0.28 | 0.30 | NA |
| 63 | 0.00 | 0.00 | 0.25 | 0.06 | 0.07 | 0.11 | 0.28 | 0.30 | 0.47 | NA |
| 64 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.07 | 0.27 | 0.29 | 0.31 | NA |
| 65 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.07 | 0.28 | 0.29 | 0.28 | NA |
| 66 | 0.00 | 0.00 | 0.25 | 0.06 | 0.06 | 0.10 | 0.27 | 0.29 | 0.50 | NA |
| 67 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.07 | 0.28 | 0.29 | 0.28 | NA |
| 68 | 0.25 | 0.75 | 2.25 | 0.10 | 0.18 | 0.42 | 0.46 | 0.87 | 1.99 | NA |
| 69 | 0.00 | 2.00 | 0.50 | 0.06 | 0.42 | 0.15 | 0.28 | 1.85 | 0.66 | NA |
| 70 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.31 | NA |
| 71 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.28 | 0.29 | 0.28 | NA |
| 72 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.31 | NA |
| 73 | 2.25 | 25.25 | 2.75 | 0.44 | 4.54 | 0.53 | 1.91 | 19.87 | 2.34 | 6.13 |
| 74 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.31 | NA |
| 75 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.28 | 0.29 | 0.28 | NA |
| 76 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.31 | NA |
| 77 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.28 | 0.29 | 0.28 | NA |
| 78 | 0.25 | 0.25 | 0.75 | 0.10 | 0.10 | 0.18 | 0.45 | 0.49 | 0.87 | NA |
| 79 | 0.00 | 0.25 | 0.25 | 0.06 | 0.11 | 0.11 | 0.28 | 0.49 | 0.47 | NA |
| 80 | 1.00 | 2.00 | 5.25 | 0.21 | 0.38 | 0.89 | 1.00 | 1.83 | 4.23 | 1.19 |
| 81 | 0.25 | 0.50 | 0.75 | 0.10 | 0.16 | 0.19 | 0.46 | 0.68 | 0.84 | NA |

| Seg. | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Average Observed Crash Frequency per year | | | EB Adjusted Expected Average Crash Frequency for year 1 | | | EB Adjusted Expected Average Crash Frequency | | | $N_{excess}=N_{observed}-N_{expected}$ |
| | $\lambda$ | | | $\pi_1$ | | | $\pi_n$ | | | $N_{excess}$ |
| | Fatal crash | Serious and slight | PDO | Fatal crash | Serious and slight Injury | PDO | Fatal crash | Serious and slight Injury | PDO | Summation for all crashes |
| 82 | 0.25 | 0.50 | 0.00 | 0.10 | 0.14 | 0.06 | 0.45 | 0.68 | 0.31 | NA |
| 83 | 1.75 | 1.75 | 0.00 | 0.35 | 0.38 | 0.06 | 1.55 | 1.65 | 0.28 | 0.02 |
| 84 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.31 | NA |
| 85 | 0.25 | 1.25 | 3.00 | 0.11 | 0.29 | 0.58 | 0.46 | 1.28 | 2.56 | 0.20 |
| 86 | 0.50 | 1.00 | 2.00 | 0.13 | 0.22 | 0.38 | 0.63 | 1.06 | 1.80 | 0.00 |
| 87 | 0.25 | 2.50 | 0.00 | 0.10 | 0.51 | 0.06 | 0.46 | 2.23 | 0.28 | NA |
| 88 | 0.00 | 0.75 | 1.00 | 0.06 | 0.18 | 0.22 | 0.27 | 0.87 | 1.06 | NA |
| 89 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.28 | 0.29 | 0.28 | NA |
| 90 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 91 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 92 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 93 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 94 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 95 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 96 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 97 | 1.25 | 2.00 | 1.00 | 0.26 | 0.41 | 0.23 | 1.15 | 1.80 | 1.00 | 0.29 |
| 98 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 99 | 0.50 | 0.25 | 0.00 | 0.14 | 0.11 | 0.06 | 0.62 | 0.48 | 0.28 | NA |
| 100 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 101 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 102 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 103 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 104 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 105 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 106 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 107 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 108 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 109 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 110 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 111 | 0.50 | 0.50 | 1.50 | 0.14 | 0.15 | 0.31 | 0.62 | 0.67 | 1.37 | NA |
| 112 | 1.25 | 1.00 | 1.25 | 0.24 | 0.22 | 0.25 | 1.14 | 1.04 | 1.21 | 0.11 |
| 113 | 0.50 | 0.25 | 0.25 | 0.14 | 0.11 | 0.10 | 0.62 | 0.48 | 0.46 | NA |
| 114 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 115 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 116 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |

| Seg. | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Average Observed Crash Frequency per year | | | EB Adjusted Expected Average Crash Frequency for year 1 | | | EB Adjusted Expected Average Crash Frequency | | | $N_{excess}=N_{observed}-N_{expected}$ |
| | $\lambda$ | | | $\pi_1$ | | | $\pi_n$ | | | $N_{excess}$ |
| | Fatal crash | Serious and slight | PDO | Fatal crash | Serious and slight Injury | PDO | Fatal crash | Serious and slight Injury | PDO | Summation for all crashes |
| 117 | 2.00 | 5.25 | 5.25 | 0.38 | 0.97 | 0.93 | 1.68 | 4.26 | 4.09 | 2.47 |
| 118 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 119 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 120 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |
| 121 | 0.00 | 0.00 | 0.00 | 0.06 | 0.07 | 0.06 | 0.27 | 0.29 | 0.28 | NA |
| 122 | 0.00 | 0.25 | 0.25 | 0.06 | 0.10 | 0.10 | 0.27 | 0.47 | 0.48 | NA |
| 123 | 0.50 | 2.50 | 1.75 | 0.14 | 0.50 | 0.35 | 0.62 | 2.18 | 1.55 | 0.40 |
| 124 | 0.75 | 0.75 | 0.75 | 0.17 | 0.18 | 0.18 | 0.79 | 0.85 | 0.85 | NA |
| 125 | 0.25 | 0.00 | 0.25 | 0.10 | 0.07 | 0.10 | 0.44 | 0.29 | 0.46 | NA |
| 126 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.06 | 0.27 | 0.29 | 0.30 | NA |

### 4.5. Measure of Goodness-of-Fit

The overall measures of goodness-of-fit used was chi-square measure in assessing the validity of the model developed and was described in Equation 16 methodology chapter section 3.6.1. Evaluation of the validity of the fit between observed values and the predicted (expected) values using SPF model can pass the goodness of fit criteria when the value of Pearson $\chi^2$ is greater than or equal to the value of $\chi^2$ statistics distribution with (n-1) degree of freedom for certain confidence level, which is 95% and the $\chi^2$ statistics distribution which is the critical value is obtained from table, (Douglas C.M. et al, 2003 or chi-square calculators). The Pearson Chi-square statistics were estimated to be 235.46 for fatal, 540.83 for serious and slight injury and 603.71 for property damage only consequences. Using the chart, at the 0.05 (5%) significance level, with 107 degree of freedom (i.e. n-1=108-1=107), the critical value can be established as 133.27. Since the obtained Chi-Square is larger than a value in the table, it implies that it is unlikely to have occurred by chance. Therefore, it is possible to be confident to conclude that the observed frequencies were significantly different from the frequencies that would be expected. In other words, it is more likely to stem from the fact that there were real differences between the observed and expected frequencies. Hence, the goodness-of-fit statistics for the model shows that the model fitted reasonably well with the data.

### 4.6. Ranking of Segments for Improvements

#### 4.6.1. Ranking through Historically Recorded Data Based Methods

The findings based on analysis and prioritization of black spots on the road from Addis Ababa (LegeTafo roundabout) to Debre Birhan (Tebase) using historically recorded data based methods is demonstrated in Table 16 by assigning the values and ranked in descending order.

Therefore, the Upper Control Limit thru Crash Rate method resulted for (when considering the DF values > 1) no segment via fatal and property damage only consequences; three segments (i.e. 73, 57 and 60) via serious and slight injury crash black spot areas and illustrated in Table 16 column 1-6. Further investigation is needed to confirm and select other segments in addition for improvement since it tolerates only few segments.

The Crash Score method ensured the segment as a black spot where the observed crash was above the mean of all the segments understudy adjusted using standard deviation and segment length. So, segments with positive values are recorded as a black spot. Table 16 (column (7-12)) revealed among the 108 segments: 26 segments by fatal crash, 22 segments by serious and slight injuries and 27 segments by property damage only crashes as black spot segments.

The Mixed Crash Frequency-Crash Rate method (MFR) identified the segments based on the Crash Frequency density and Crash Rates used in the Upper Control Limit by Crash Rate method. This black spot identification method did not allow the segments to be vanished but ranked in descending order until the last segment until no recorded Crash Frequency remained. All the designated black spots (36 fatal, 50 serious and slight injury and 50 property damage only) are presented in Table 16 (column (13-18)).

Table-16: Ranking of segments by DF, CS and MFR methods

| Rank | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DF | | | | | | Cs | | | | | | MFR | | | | | |
| | Fatal | Segment | Serious and slight | Segment | PDO | Segment | Fatal | Segment | Serious and slight | Segment | PDO | Segment | Fatal | Segment | Serious and slight | Segment | PDO | Segment |
| 1 | 0.91 | 57 | 1.28 | 73 | 0.83 | 57 | 15424 | 57 | 1741.09 | 73 | 2244.57 | 30 | 21.86 | 57 | 52.86 | 73 | 22.72 | 30 |
| 2 | 0.38 | 73 | 1.07 | 57 | 0.80 | 30 | 3024 | 30 | 1013.82 | 57 | 1901.71 | 57 | 4.71 | 73 | 33.34 | 57 | 20.77 | 57 |
| 3 | 0.38 | 117 | 1.03 | 60 | 0.74 | 60 | 3024 | 73 | 941.09 | 60 | 1730.29 | 34 | 4.65 | 30 | 31.15 | 60 | 18.07 | 34 |
| 4 | 0.37 | 30 | 0.78 | 34 | 0.70 | 34 | 2624 | 34 | 686.55 | 34 | 1501.71 | 60 | 4.28 | 117 | 22.20 | 34 | 16.94 | 60 |
| 5 | 0.35 | 34 | 0.73 | 30 | 0.59 | 117 | 2624 | 117 | 595.64 | 30 | 1158.86 | 27 | 4.13 | 34 | 19.62 | 30 | 12.91 | 27 |
| 6 | 0.34 | 60 | 0.56 | 38 | 0.58 | 27 | 2224 | 83 | 341.09 | 38 | 987.43 | 38 | 3.66 | 83 | 12.39 | 38 | 11.78 | 117 |
| 7 | 0.33 | 83 | 0.53 | 27 | 0.57 | 58 | 1824 | 60 | 304.73 | 27 | 987.43 | 117 | 3.28 | 60 | 11.36 | 27 | 11.36 | 38 |
| 8 | 0.29 | 97 | 0.49 | 117 | 0.54 | 80 | 1424 | 97 | 195.64 | 117 | 930.29 | 80 | 2.68 | 97 | 8.57 | 117 | 10.99 | 80 |
| 9 | 0.29 | 112 | 0.47 | 55 | 0.54 | 38 | 1424 | 112 | 177.45 | 32 | 816.00 | 58 | 2.68 | 112 | 7.75 | 32 | 10.38 | 58 |
| 10 | 0.27 | 44 | 0.43 | 44 | 0.50 | 55 | 1024 | 18 | 159.27 | 55 | 587.43 | 55 | 2.19 | 44 | 7.65 | 55 | 8.20 | 55 |
| 11 | 0.27 | 56 | 0.43 | 32 | 0.48 | 56 | 1024 | 20 | 122.91 | 44 | 530.29 | 20 | 2.19 | 56 | 6.56 | 44 | 7.65 | 56 |
| 12 | 0.25 | 80 | 0.39 | 56 | 0.46 | 44 | 1024 | 44 | 86.55 | 56 | 530.29 | 56 | 2.09 | 80 | 5.47 | 56 | 7.23 | 20 |
| 13 | 0.24 | 18 | 0.37 | 123 | 0.42 | 20 | 1024 | 56 | 86.55 | 87 | 473.14 | 44 | 2.07 | 18 | 5.36 | 123 | 7.10 | 44 |
| 14 | 0.24 | 20 | 0.35 | 87 | 0.39 | 43 | 1024 | 80 | 86.55 | 123 | 416.00 | 22 | 2.07 | 20 | 5.23 | 87 | 6.20 | 22 |
| 15 | 0.23 | 55 | 0.32 | 97 | 0.38 | 22 | 624 | 23 | 50.18 | 69 | 416.00 | 26 | 1.64 | 55 | 4.28 | 97 | 6.20 | 26 |
| 16 | 0.23 | 58 | 0.31 | 69 | 0.38 | 26 | 624 | 38 | 50.18 | 80 | 416.00 | 28 | 1.64 | 58 | 4.19 | 69 | 6.20 | 28 |
| 17 | 0.22 | 124 | 0.31 | 80 | 0.38 | 28 | 624 | 55 | 50.18 | 97 | 416.00 | 85 | 1.61 | 124 | 4.19 | 80 | 6.20 | 85 |
| 18 | 0.20 | 23 | 0.28 | 58 | 0.38 | 85 | 624 | 58 | 32.00 | 83 | 358.86 | 73 | 1.55 | 23 | 3.66 | 83 | 5.76 | 73 |
| 19 | 0.20 | 38 | 0.28 | 83 | 0.38 | 73 | 624 | 124 | 13.82 | 19 | 301.71 | 43 | 1.55 | 38 | 3.28 | 58 | 5.47 | 43 |
| 20 | 0.18 | 99 | 0.25 | 43 | 0.37 | 54 | 224 | 27 | 13.82 | 20 | 244.57 | 35 | 1.07 | 99 | 3.10 | 19 | 4.92 | 54 |
| 21 | 0.18 | 111 | 0.25 | 19 | 0.34 | 59 | 224 | 32 | 13.82 | 23 | 244.57 | 54 | 1.07 | 111 | 3.10 | 20 | 4.71 | 68 |
| 22 | 0.18 | 113 | 0.25 | 20 | 0.33 | 68 | 224 | 86 | 13.82 | 58 | 244.57 | 68 | 1.07 | 113 | 3.10 | 23 | 4.65 | 35 |

| Rank | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DF | | | | | | Cs | | | | | | MFR | | | | | |
| | Fatal | Segment | Serious and slight | segment | PDO | Segment | Fatal | Segment | Serious and slight | Segment | PDO | Segment | Fatal | Segment | Serious and slight | Segment | PDO | Segment |
| 23 | 0.18 | 123 | 0.25 | 23 | 0.32 | 35 | 224 | 99 | -4.36 | 35 | 187.43 | 59 | 1.07 | 123 | 2.73 | 43 | 4.37 | 59 |
| 24 | 0.17 | 86 | 0.22 | 35 | 0.31 | 86 | 224 | 111 | -4.36 | 43 | 187.43 | 86 | 1.05 | 86 | 2.58 | 35 | 4.19 | 86 |
| 25 | 0.16 | 27 | 0.22 | 85 | 0.30 | 123 | 224 | 113 | -4.36 | 85 | 130.29 | 18 | 1.03 | 27 | 2.58 | 85 | 3.75 | 123 |
| 26 | 0.16 | 32 | 0.21 | 112 | 0.28 | 18 | 224 | 123 | -22.55 | 25 | 130.29 | 123 | 1.03 | 32 | 2.14 | 112 | 3.61 | 18 |
| 27 | 0.12 | 54 | 0.20 | 86 | 0.28 | 111 | -176 | 19 | -22.55 | 26 | 73.14 | 111 | 0.55 | 54 | 2.09 | 86 | 3.21 | 111 |
| 28 | 0.12 | 125 | 0.19 | 25 | 0.25 | 112 | -176 | 21 | -22.55 | 28 | 16.00 | 19 | 0.54 | 125 | 2.07 | 25 | 2.68 | 112 |
| 29 | 0.11 | 68 | 0.19 | 26 | 0.23 | 45 | -176 | 54 | -22.55 | 86 | 16.00 | 23 | 0.52 | 68 | 2.07 | 26 | 2.58 | 19 |
| 30 | 0.11 | 78 | 0.19 | 28 | 0.23 | 48 | -176 | 68 | -22.55 | 112 | 16.00 | 24 | 0.52 | 78 | 2.07 | 28 | 2.58 | 23 |
| 31 | 0.11 | 81 | 0.18 | 45 | 0.23 | 19 | -176 | 78 | -40.73 | 18 | 16.00 | 29 | 0.52 | 81 | 1.64 | 45 | 2.58 | 24 |
| 32 | 0.11 | 82 | 0.18 | 48 | 0.23 | 23 | -176 | 81 | -40.73 | 22 | 16.00 | 112 | 0.52 | 82 | 1.64 | 48 | 2.58 | 29 |
| 33 | 0.11 | 87 | 0.18 | 124 | 0.23 | 24 | -176 | 82 | -40.73 | 24 | -41.14 | 45 | 0.52 | 87 | 1.61 | 124 | 2.19 | 45 |
| 34 | 0.11 | 19 | 0.17 | 68 | 0.23 | 29 | -176 | 85 | -40.73 | 45 | -41.14 | 48 | 0.52 | 19 | 1.57 | 68 | 2.19 | 48 |
| 35 | 0.11 | 21 | 0.17 | 88 | 0.22 | 97 | -176 | 87 | -40.73 | 48 | -41.14 | 88 | 0.52 | 21 | 1.57 | 88 | 2.14 | 97 |
| 36 | 0.11 | 85 | 0.16 | 18 | 0.20 | 88 | -176 | 125 | -40.73 | 68 | -41.14 | 97 | 0.52 | 85 | 1.55 | 18 | 2.09 | 88 |
| 37 | 0.00 | 22 | 0.16 | 22 | 0.18 | 124 | -576 | 22 | -40.73 | 88 | -98.29 | 21 | 0.00 | 22 | 1.55 | 22 | 1.61 | 124 |
| 38 | 0.00 | 24 | 0.16 | 24 | 0.17 | 78 | -576 | 24 | -40.73 | 124 | -98.29 | 32 | 0.00 | 24 | 1.55 | 24 | 1.57 | 78 |
| 39 | 0.00 | 25 | 0.14 | 59 | 0.17 | 81 | -576 | 25 | -58.91 | 21 | -98.29 | 78 | 0.00 | 25 | 1.09 | 59 | 1.57 | 81 |
| 40 | 0.00 | 26 | 0.13 | 111 | 0.16 | 21 | -576 | 26 | -58.91 | 33 | -98.29 | 81 | 0.00 | 26 | 1.07 | 111 | 1.55 | 21 |
| 41 | 0.00 | 28 | 0.13 | 81 | 0.16 | 32 | -576 | 28 | -58.91 | 59 | -98.29 | 124 | 0.00 | 28 | 1.05 | 81 | 1.55 | 32 |
| 42 | 0.00 | 29 | 0.13 | 82 | 0.13 | 69 | -576 | 29 | -58.91 | 81 | -155.43 | 69 | 0.00 | 29 | 1.05 | 82 | 1.05 | 69 |
| 43 | 0.00 | 31 | 0.12 | 21 | 0.09 | 113 | -576 | 31 | -58.91 | 82 | -212.57 | 25 | 0.00 | 31 | 1.03 | 21 | 0.54 | 113 |
| 44 | 0.00 | 33 | 0.12 | 33 | 0.09 | 122 | -576 | 33 | -58.91 | 111 | -212.57 | 33 | 0.00 | 33 | 1.03 | 33 | 0.54 | 122 |
| 45 | 0.00 | 35 | 0.08 | 99 | 0.09 | 125 | -576 | 35 | -77.09 | 29 | -212.57 | 63 | 0.00 | 35 | 0.54 | 99 | 0.54 | 125 |
| 46 | 0.00 | 36 | 0.08 | 113 | 0.08 | 63 | -576 | 36 | -77.09 | 78 | -212.57 | 66 | 0.00 | 36 | 0.54 | 113 | 0.52 | 63 |
| 47 | 0.00 | 37 | 0.08 | 122 | 0.08 | 66 | -576 | 37 | -77.09 | 79 | -212.57 | 79 | 0.00 | 37 | 0.54 | 122 | 0.52 | 66 |
| 48 | 0.00 | 39 | 0.08 | 78 | 0.08 | 79 | -576 | 39 | -77.09 | 99 | -212.57 | 113 | 0.00 | 39 | 0.52 | 78 | 0.52 | 79 |
| 49 | 0.00 | 40 | 0.08 | 79 | 0.08 | 25 | -576 | 40 | -77.09 | 113 | -212.57 | 122 | 0.00 | 40 | 0.52 | 79 | 0.52 | 25 |
| 50 | 0.00 | 41 | 0.08 | 29 | 0.08 | 33 | -576 | 41 | -77.09 | 122 | -212.57 | 125 | 0.00 | 41 | 0.52 | 29 | 0.52 | 33 |

### 4.6.2. Ranking through Predictive Empirical Bayesian Statistical Methods

The identification of black spot road segments by Empirical Bayesian Statistical Method was based on the Excess Crash Frequency with reference to the other segment. At that juncture, the segment with high Excess Crash Frequency, commonly known as Potential for Safety Improvement (PSI), was selected as a dangerous or black spot segment to undertake an improvement before any other sites. Positive values from Table-15, column 31 were identified as black spot segments and ranked from top to low value as indicated in Table-17.

Consequently, the above historically based methods (simple ranking or conventional methods that rely on previously recorded MVC data: Dangerous Factor, Crash Score, Mixed Crash Frequency-Crash Rate method) allow some true black spot sites to escape improvements even a large amount of catastrophic consequences recorded (investigated and confirmed on the site walkover) as seen in Table 17 above. All the methods contributed to different black spots (except few segments) since this methods suffer from changes by influential factors such as traffic volumes, driver population, maintenance activities, surrounding changes to land use, weather fluctuation, road geometry element parameters, etc. Hence, the predictive Empirical Bayesian method will be adopted to rank for improvements as it proves all these sidebacks.

Therefore, based on the Excess Crash Frequency, the following Table-17 was used to identify the dangerous road locations in the study area according to the statistical analysis of historical crash data and traffic characteristic in the study period of 2012/13-2015/16. The sites were ranked as dangerous from highest to lowest in descending order for special improvement by giving prior consideration to the type of maintenance and amount of budget of the concerned agent. In general, the higher the position of the road segment in the list, the more hazardous it was compared to the other segments of the same group.

So, the following 20 segments were identified as black spot segments from total of 108 segments. However, the first 6 segments that accounted for 73.73% from the 20 black spot segments were given a brief investigation to the site and the anticipated countermeasures for low cost improvements. In other words, if these 6 segments get an intended improvements, the road under the study will be free of MVCs by 73.73%.

Table-17: Dangerous segments ranked from top to bottom through PSI method

| Rank | Seg. | $N_{excess} = \lambda_{observed} - \pi_{expected}$ | Percent (%) | Cumulative | Rank | Seg. | $N_{excess} = \lambda_{observed} - \pi_{expected}$ | Percent (%) | Cumulative |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 57 | 8.05 | 20.47 | 20.47 | 11 | 80 | 1.19 | 3.04 | 92.77 |
| 2 | 73 | 6.13 | 15.59 | 36.06 | 12 | 55 | 0.77 | 1.97 | 94.73 |
| 3 | 60 | 5.83 | 14.83 | 50.89 | 13 | 44 | 0.63 | 1.61 | 96.34 |
| 4 | 34 | 3.29 | 8.38 | 59.28 | 14 | 123 | 0.40 | 1.02 | 97.37 |
| 5 | 30 | 3.21 | 8.17 | 67.45 | 15 | 20 | 0.36 | 0.93 | 98.30 |
| 6 | 117 | 2.47 | 6.28 | 73.73 | 16 | 97 | 0.29 | 0.75 | 99.04 |
| 7 | 56 | 1.67 | 4.25 | 77.98 | 17 | 85 | 0.20 | 0.50 | 99.54 |
| 8 | 38 | 1.64 | 4.17 | 82.15 | 18 | 112 | 0.11 | 0.28 | 99.82 |
| 9 | 27 | 1.53 | 3.90 | 86.05 | 19 | 43 | 0.05 | 0.13 | 99.95 |
| 10 | 58 | 1.45 | 3.68 | 89.73 | 20 | 83 | 0.02 | 0.05 | 100.00 |

### 4.7. Selected Black Spot's Low Cost Improvement

#### *i.* <u>Segment 57</u>

The first top ranked segment 57 was a segment in the 57 km from Addis Ababa in Alelitu town exit around locally known as 'Ejersa Kumute' Bridge and also a high percentage of actually observed crash specially crashes that result for fatality recorded. Among the ranked excess Crash Frequency, segment 57 share 20.47% cover increase from the whole black spot segments. Overturning was highly recorded crash type of the area. Small buses up to 27 seats were extremely participated.

**<u>Crash Contributing Factors for Segment 57:</u>**

The segment's crash contributing factors were: sharp and twisting curve after long tangent in high gradient route location, inappropriate coordination of horizontal and vertical curves, and bottle neck formation because of a bridge located in the horizontal curve and slopped geography. A long tangent road with higher design speed followed by a twisted and sharpened curve leads to the vehicle uncontrollable and results specially to the new drivers' unexpected crashes. Otherwise, drivers were more alert when passed the bend road. The bridge is laid down on the curve and not pependicular to the approach road.

Figure-8: A long tangent followed by twisted curve at Ejersa Kumute Bridge

Figure-9: Ejersa Kumute Bridge and its down slopped alignment from right.

Figure-10: Ejersa Kumute Bridge androad side sight distance problem.

Figure-11: Ejersa kumute Bridge and guard rails under extinction by vehicles.

**The Anticipated Improvement for Segment 57:**

Warning sign with recommended speed and warning signs that describe hazard routes to take caution to the drivers, road surface and animal crossing, construction of painted guardrails at curves and delineation, rumble strips to reduce speed, safety poles, increasing shoulder width, flattering side slope, design or improve roads to separate road users going at different speeds and in different directions, improve the visibility of roads, road signs, vehicles, and road users during both day and night are some of the first class treatments; otherwise, a new realignment that avoid the previous crash causes, must be provided.

***ii.*** **Segment 73**

Segment 73 is located in Sheno Ketema 73 km far from Addis Ababa around bus station and the area is surrounded by shopping areas and hotels. Among the ranked excess Crash Frequency, segment 73 accounted for 15.59% portion increase from the total dangerous segments. The frequency of communities to these places are very high and hence, the area practiced the high fatal, serious, slight and property damage crashes, which aggravates the rate of causalities and accidents of MVC. The highest MVC occurs at 3pm- 6:30 pm. In addition, 96.5% of the crash has occurred from Monday to Saturday day of the week. The collision types facing on the area are angle collision, rear end collisions, sideswipe collision and collisions with pedestrians.

Figure-12: Sheno Ketema traffic flow at bus station and the probability for angle crashes.

Figure-13: Sheno Ketema traffic flow at bus station.

**Contributing Crash Factors for Segment 73:**

Not giving priority for vehicles, driving leaving the right lane, speeding beyond the limit, confusion, inattentiveness and lack of judgment of driver, overloading, sight distance problem (left and right sides occupied by shelters) were crash contributing factors. Mixed flow in the road.

**The Anticipated Improvement for Segment 73:**

Erecting guardrails if it is very difficult to improve the roadside area; posting warning signs, chevrons, delineators, and speed-limit signs; improving the visual guidance; constructing pedestrian crossing facilities; designing or improving roads by separating them from road users going at different speeds and in different directions; controlling speed with traffic calming road design and enforce speed limits consistently by using devices such as speed cameras; prohibiting roadside parking (there is high volume of on-street parking), and parked vehicles are not safely parked inside the travelling lane. These conditions continue disturbing the smooth traffic movement, and they create serious problems for drivers and vulnerable road users. To overcome overloading, police enforcement should be strengthened. Zebra crossing should be marked with vertical signs and horizontal marking. Warning sign of pedestrian crossing should be placed at zebra crossing on both sides in order to minimize the crash with pedestrians. Separating motorized vehicles from non-motorized vehicles; creating awareness in the society about how to cross the road, giving priority, and the severity of traffic crashes as a whole.

***iii.* <u>Segment 60</u>**

The third top ranked segment 60 is a segment in the 60 km from Addis Ababa between Alelitu and FicheGentet towns around locally known as 'Sostaf Dildiy' and also a high percentage of actually observed crash specially crashes that result for fatality is recorded. Among the ranked excess Crash Frequency, segment 60 share for 14.83% percent increase from the total dangerous segments. Overturning and entering to the depression was highly recorded crash type of the area. Small buses up to 27 seats are extremely participated.

**<u>Crash Contributing Factors for Segment 60:</u>**

The segment's crash contributing factors are; sharp and twisting curve after long tangent in high gradient route location, inappropriate coordination of horizontal and vertical curves a bottle neck formation, because of an arch bridge with three boxes why it is said Sosta Dildiy in Amharic Language, is created along the curved terrain. There was a road side or horizontal sight distance obstruction.

Figure-14: Sostaf Dildiy near Aleltu (an arch bridge with three boxes).

Figure-15: Sostaf Dildiy sight distance obstruction to the opposing vehicles

**The Anticipated Improvement for Segment 60:**

Erecting warning sign with recommended speed and warning signs that describe hazard routes to take caution to the drivers, road surface and animal crossing; constructing painted guardrails at curves and delineation, rumble strips to reduce speed; erecting safety poles; increasing shoulder width and flattering side slope; designing or improving roads to separate road users going at different speeds and in different directions; improving the visibility of roads, road signs, vehicles, and road users during both day and night are some of the first class Treatments otherwise a new realignment that avoid the previous crash causes must be provided.

***iv.*** **Segment 34**

Segment 34 is located also in Sendafa town 34 km from Addis Ababa around lacally named 'Dabie'. Among the ranked excess Crash Frequency, segment 34 accounted for 8.38% percent increase from the total dangerous segments. The segment area practiced traffic movements subjected to small buses up to 27 seats capacity, commuting factory workers, small and medium industry centers. Besides, there are also high and frequent pedestrians, taxis, and buses movements. Hence, the area practiced fatal, serious, slight and property damage crashes which maximize the frequency of causalities of the area.

The highest crash hours occurred during (2:00 am-3:30 am) time of the day and 76% head on of the total and 21% of crashes are due to broadside collision, collision with pedestrians, sideswipe and the rest unknown crashes.

**Crash Contributing Factors for Segment 34:**

The road marking condition was very poor at almost all sections route, particularly at the travelling way where there was no road marking completely, the route has faded markings, especially at the pedestrian crossing location, no median to avoid head on collisions, there was complete absence of transverse markings of the route which could lead to serious intersection crashes and large amount of accesses entering to the main route. Absence of proper routine maintenance, which caused vehicles to have sudden break or park on the outer travelling lane, which could lead to crashes has been observed.

Figure-16: Flow of vehicles at Dabie

Figure-17: Flow of vehicles at Dabie and un-functioning of delineators.

Figure-18: Flow of vehicles at Dabie and the long tangent with no walkways.

Figure-19: Long clear tangent at Dabie that enforces for high speed.

**The Anticipated Improvement for Segment 34:**

Installation of marking, signs, zebra crossing should be marked with vertical signs and horizontal marking, warning sign of pedestrian crossing should be placed at zebra crossing on both sides in order to minimize the collision with pedestrians; providing and properly constructing side walkways and guarding rails; prohibiting overtaking to minimize the rear end collisions and sideswipe collisions and the median should be identified by road marking or any other channelization methods.

### *v.* <u>**Segment 30**</u>

Segment 30 is located between Legedadi and Legeberi (part of Sendafa) at the Deri Dam (Gefersa) junction 30 km from Addis Ababa around locally known as 44 Mazoria. Among the ranked Excess Crash Frequency, segment 30 accounted for 8.17% percent measure from the total dangerous segments. The segment area practiced crowded traffic movements which dominated by small buses up to 27 seats, commuting factory workers, laborers, small exchanging centers, and small, medium and large industries sectors made the street crowded. Besides, there are also high and frequent pedestrians, taxis, and three-wheeler movements. Hence, the area practiced fatal, serious, slight and property damage crashes which inflate the frequency of causalities of the area. The highest crush hours occurred during (4:00 pm-5:30 pm) time of the day and 54% head on of the total and 32% of crashes are due to broadside collision, collision with pedestrians, sideswipe, rear end and the rest unknown crashes.

**Crash Contributing Factors for Segment 30:**

Absence of controlled pedestrian crossing facilities, there was no properly constructed side walkway, parking of freight vehicles on roadside shoulders, the route has faded markings especially at the pedestrian crossing location, and there was complete absence of transverse markings of the route. Also, there was drainage problem that prohibited the movement of pedestrians, and loading unloading activities at every place which could lead to unwanted crashes.

Figure-20: Drainage problem and some vehicle flow types at 44 Mazoria (Sendafa)

Figure-21: Loading unloading, shoulder and walkways occupied by other functions at 44 Mazoria (Sendafa)

Figure-22: Deri Dam junction ingress and pedestrians unregular movement with drainage problem.

**The Anticipated Improvement for Segment 30:**

Zebra crossing should be marked with vertical signs and horizontal marking; warning sign of pedestrian crossing should be placed at zebra crossing on both sides in order to minimize the collision with pedestrians; prohibiting overtaking to minimize the rear end collisions and sideswipe collisions; the median should be identified by road marking, warning sign with recommended speed, special marking of road edge, text on road surface and increase shoulder width; constructing good drainage structures; removing unwanted shelters and other functions like exchanging at the walkways and shoulders. Also, totally separating walkways from carriage ways by guardrails; creating awareness about traffic crashes to the society.

***vi.*** **Segment 117**

Segment 117 is located near Chacha town; 117 km far from Addis Ababa around locally named 'Chafanan'. Among the ranked Excess Crash Frequency, segment 117 accounted for 6.28% portion from the total dangerous segments. Almost 90% of the crash is recorded on the week days from Monday to Friday especially on Tuesday since Tuesday is the market day for the town. Hence, the movements of the pedestrians are more frequent besides the local communities' massive movement for church. The countryside people use this road to commute from place to place. The speed of vehicle traverse this road is above the limit since no signs describing about the village was not installed or demolished. Besides, no alarms to pronounce to diminish the speed level was not mounted. There was a sight distance problem obstructing the vision of drivers along the curve. There is a beer factory at the edge of the road and the external gate is extends to the road hence workers use this road to and from work for their daily life. Thus, the area practiced the highest rate of causalities and crash of MVC. The highest crash hours occurred during (8:00 am-6:00 pm) time of the day, and 67% of the total crash is with pedestrian and 30% of the crash is due to the collision type of vehicle with pedestrians, head on, sideswipe also in slight way with carts and the rest unknown crashes.

**Crash Contributing Factors for Segment 117:**

Avoiding over speeding and the tendency of not giving priority to pedestrians is the main reason of crashes on this segment. There is no properly constructed side walkway and there is no pedestrian crossing marking. There is high intensity of intercity small bus up to 27 seats capacity and small trucks traffic passes through the area. There are no traffic calming, religious location signs, and animal crossing ahead signs. Carts engrossing to the main road from feeder roads was also observed and this was mainly because there are no stop and slow down signs.

**The Anticipated Improvement for Segment 117:**

Warning sign with recommended speed should be fixed. Rumble strips to reduce speed, text on road surface, pedestrian and animal crossing a head posts must be in place. Prohibiting overtaking at the curve to avoid conflict and reduce sideswipe collision; the median should be identified by highly reflective road marking and special raised channelization; warning sign of pedestrian crossing should be placed ahead of 50 meters of zebra crossing. Also, creating awareness on the harshness of road traffic crashes to the society by any means like educating them at schools, work places, religious places, in the market etc.

Figure-23: Chefanen road feature around the church and sight distance with low visibility problem

Figure-24: Chefanen road feature around beer (local Areki) factory.

Figure-25: Chefanen road feature showing the ingress of carts at speed road.

# CHAPTER 5: CONCLUSION

According to the findings revealed about Motor Vehicle Crashes on the road from Addis Ababa (LegeTaffo) to Debre Birhan (Tebasie), the following conclusions were drawn:

- ✓ The study understood the existence of large difference in road traffic victims among drivers, passengers, and pedestrians in respect to sex and age, that is, male drivers, passengers, and pedestrians were the most affected compared to their female counterparts.

- ✓ Besides, the result confirmed that road Motor Vehicle Crashes with regard to fatality, serious and slight injuries in the road mostly affected age category of 18-50 regardless of their sex and started declining after age 50. This indicates that the effect of age on the type and level of occurrences of the road MVC is tremendous and changes with the age of the drivers.

- ✓ Generally, most of the road MVC, were highly distressing the economically active citizens, i.e. youths and young adult groups, which, in turn, negatively affects the economy of the country and social structure of the population.

- ✓ The MVC vary in hours of a day in the road from 2012/13 -2015/16(2005-2008 E.C), and hence the crash has extended maximum points when pedestrians, passengers, and drivers incidence of movement increased (9:00-10:59 followed by 5:00-6:59).

- ✓ The study identified collision types mostly occurred in the road, and hence collisions like head on, rear end, sideswipes, broadside and collision with pedestrian were the most frequently occurring crashes in the segment in the 2012/13 -2015/16(2005-2008 E.C) study period.

- ✓ Besides, highest crashes were recorded in straight and flat road characteristics in the segment but road characters like straight and grade, straight with up and down, curve and level, curve and grade, uphill, and downhill witnessed significant Crash Frequency in the second step. According to the road geometry, straight roads were even more prone to traffic crashes compared to roads with twist geometric shape. This result was reasonable since most drivers tended to be careless and drove their vehicles at high speed in straight road.
- ✓ The statistical analysis of crashes by vehicle type showed that most of the crashes were caused by small buses up to 27 seats capacity and small truck carrying up to 3.5 ton weight and large buses above 27 seats capacity.
- ✓ Moreover, most of the MVC occurred in dry road surface conditions rather than in wet road surface conditions and in good weather rather than in other undesirable weather conditions.
- ✓ The statistical analysis of black spot locations established on historically recorded crash data via Upper Control Limit thru Crash Rate and Dangerous Factor which is the ratio of Crash Rate with Upper Control Limit, Crash Score and Mixed Crash Frequency-Crash Rate showed evidence of black spot locations which were ranked in descending order from high to low. According to findings, the inspection identified the most hazardous black spot locations. Therefore, the Upper Control Limit thru Crash Rate method resulted for (when considering the DF values > 1) no segment via fatal and property damage only consequences; three segments (i.e. 73, 57 and 60) via serious and slight injury crash black spot areas.

- ✓ The Crash Score method ensured the segment as a black spot where the observed crash was above the mean of all the segments understudy adjusted using standard deviation and segment length. So, segments with positive values are recorded as a black spot. Subsequently, among the 108 segments: 26 segments by fatal crash, 22 segments by serious and slight injuries and 27 segments by property damage only crashes as black spot segments.
- ✓ The Mixed Crash Frequency-Crash Rate method (MFR) identified the segments based on the Crash Frequency density and Crash Rates used in the Upper Control Limit by Crash Rate method. Hence, recognized 36 fatal, 50 serious and slight injury and 50 property damage only black spot segments.
- ✓ Based on the Empirical Bayesian statistical method of identification of black spot, out of 108 segments 20 segments were screened out as black spot road segments and ranked based on their excess number of expected crashes. Out of 20 ranked dangerous segments, 6 road segments hence, identified as the most black spot or dangerous segments that account 73.73% from the total segment and detail site investigation for low cost engineering treatments were undertaken.
- ✓ The study also recognized major contributing road and traffic factors for the most black spot segments such as sharp horizontal curves after a long tangent, numbers of horizontal and vertical curves per 1 mile (0.625 km) road segment, poor coordination of horizontal and vertical alignments (mis-phasing), center and edge strips, road markings, medians and others.

Finally, the researcher established that the Empirical Bayesian Statistical Method of Analysis which relates the Actual Observed Crash Frequency and the Expected Crash Frequency using statistical package models should be practiced to get best results than conventional way of simple ranking methods. Further, a simple comparison is presented in the following Table-18.

Table-18: Comparison of Predictive Empirical Bayesian and Conventional statistical methods.

| Approach | Merit | Demerit |
|---|---|---|
| Predictive Empirical Methods | • Use both crash history and expected crashes on similar sites<br>• Regression to the mean effect is addressed.<br>• Existing SPFs, if any had been developed earlier, can be used for other locations.<br>• Give more precise evaluation of safety and regulations | • Challenge to analyze and interpret.<br>• Confounding variables can be accounted for only if CMF values are known and with certainly that they are applicable in study context.<br>• Large numbers of reference sites are required for the development of an SPF.<br>• SPFs are likely to differ through diverse geographic situations |
| Conventional Methods | • Simple to analyze.<br>• Sites can be related such that confounding variables accounted for.<br>• Generally accepted methods that are straightforward and intuitive.<br>• They can also be used, on a limited basis.<br>• In addition, the results are easy to understand by most members of the public, so this method is acceptable to the public | • Regression to the mean effects usually not considered for. So, Can produce large number of false positives<br>• Crash Frequency and exposure is incorrectly assumed<br>• Do not include all the crashes that happened, i.e. there is a difference in crash reporting thresholds, judgment of observer preparing crash report, data entry can introduce typographical errors, imprecise location data, incorrect entries, lack of training, subjectivity<br>• Unable to evaluate sites with zero MVC.<br>• Need for relating and comparability when choosing reference sites. |

So, Empirical Bayesian method of analysis should be trained for the purpose of black spot identification in the world including developing countries like Ethiopia.

# CHAPTER 6: RECOMMENDATIONS AND FURTHER RESEARCH

Based on the common understanding of the main causes of crashes, the low cost improvements should be considered to minimize the current high frequency of crashes at the black spots for the most ranked segments, the proposed details in the analysis and discussion parts were given. To recap, the following recommendations should be implemented.

- ✓ Encouraging use of safer modes of transport like to use large buses rather than speedy small buses.
- ✓ Isolated pedestrian crossing should be provided especially where the concentration of pedestrian crossing the main road is high like around market places.
- ✓ Zebra crossing should be marked with vertical signs.
- ✓ Improve road layout and design to encourage better use.
- ✓ Construction of separate parking lots from the main road to avoid sideswipe crashes and create free driving space for psychological purpose and unrestricted pedestrian movement.
- ✓ Provide and properly construct side walkway with guard rails or raised side walkways.
- ✓ Providing slow-moving traffic and for vulnerable road users and lanes for overtaking as well as lanes for vehicles waiting to turn across the path of oncoming traffic; putting median barriers or channelization to prevent overtaking and to eliminate head-on crashes; facilitating better highlighting of hazards through road lighting at junctions; putting advisory speed limits in place at sharp bends and availing regular speed-limit signs; working on the systematic removal of roadside hazards such as trees, utility poles and other solid objects.

- ✓ Separating residential access roads from the main road designed to achieve very low speeds.
- ✓ Protecting roadside objects with barriers to absorb part of the impact energy; protecting vehicle occupants (passengers) from the consequences of collisions with roadside objects.
- ✓ Availing speed revision including the setting of speed limits according to road function, enforcement of limits by the police, radar and speed cameras. Using selective enforcement strategies to target particular risk behaviors and choosing specific locations both to improve the effectiveness of enforcement.
- ✓ Setting and enforcing alcohol impairment laws.
- ✓ Road Engineers should, as much as possible, dodge provision of long straight and flat sections on highways to advance traffic safety. Recurrent smooth curves could be familiarized to break the monotony.
- ✓ Creating limit for drivers' hours of work in commercial and public transport to avoid fatigue.

For further research, it would be useful if the Predictive Empirical Bayesian method of analysis is provided with safety performance function derived from the local condition of Ethiopia and more clearly the historically recorded crash based statistical methods should be related through more exposures associated with the scene and specific location to have more evidence to support the notion.

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## APPENDIX I – Average Daily Traffic by road section and Vehicle Kilometer of Travel (ERA, 2015)

Year 2014
Cycle 1

AVERAGE DAILY TRAFFIC BY ROAD SECTION AND VEHICLE KILOMETER OF TRAVEL ANNEX 2

17/03/2015
Page 1 of 18

| ROUTE NO | ROAD NO | ROUTE NAME | | LENGTH | CARS | BUSES | TRUCKS | TRUCK TRAILER | TOTAL | VEHICLE KILOMETER OF TRAVEL: CARS | BUSES | TRUCKS | TRUCK & TRAILER | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | ADDIS ABABA | DEBRE BERHA | 130 | 329 | 614 | 782 | 167 | 1,892 | 42,770 | 79,820 | 101,660 | 21,710 | 245,960 |
| | 2 | DEBRE BERHAN | KARAKORE | 153 | 182 | 386 | 569 | 82 | 1,219 | 27,846 | 59,058 | 87,057 | 12,546 | 186,507 |
| | 3 | KARKORE | COMBOLCHA | 93 | 299 | 497 | 579 | 121 | 1,496 | 27,807 | 46,221 | 53,847 | 11,253 | 139,128 |
| | 4 | COMBOLCHA | DESSIE | 25 | 366 | 966 | 607 | 102 | 2,041 | 9,150 | 24,150 | 15,175 | 2,550 | 51,025 |
| | 5 | DESSIE | WELDIYA | 121 | 172 | 589 | 354 | 95 | 1,210 | 20,812 | 71,269 | 42,834 | 11,495 | 146,410 |
| | 6 | WELDIYA | MAICHEW | 141 | 146 | 351 | 232 | 102 | 831 | 20,586 | 49,491 | 32,712 | 14,382 | 117,171 |
| | 7 | MAICHEW | QUIHA | 111 | 46 | 218 | 214 | 55 | 533 | 5,106 | 24,198 | 23,754 | 6,105 | 59,163 |
| | 8 | MAIMEKDEN | ADIGRAT | 97 | 257 | 651 | 963 | 113 | 1,984 | 24,929 | 63,147 | 93,411 | 10,961 | 192,448 |
| | 9 | ADIGRAT | ZALAMBESA | 35 | 82 | 196 | 194 | 49 | 521 | 2,870 | 6,860 | 6,790 | 1,715 | 18,235 |
| | | | **Sub Total** | **906** | | | | | | **181,876** | **424,214** | **457,240** | **92,717** | **1,156,047** |
| 2 | 1 | COMBOLCHA | BATTI | 41 | 95 | 204 | 181 | 99 | 579 | 3,895 | 8,364 | 7,421 | 4,059 | 23,739 |
| | 2 | BATTI | MILLE | 97 | 50 | 68 | 110 | 78 | 306 | 4,850 | 6,596 | 10,670 | 7,566 | 29,682 |
| | 3 | MILLE | ASSEB | 368 | 70 | 39 | 144 | 329 | 582 | 25,760 | 14,352 | 52,992 | 121,072 | 214,176 |
| | | | **Sub Total** | **506** | | | | | | **34,505** | **29,312** | **71,083** | **132,697** | **267,597** |

## APPENDIX II - Traffic police MVC recording format organized by the researcher

| No. | *Crash Characteristics* | | | | | | | | | *Period of the Crash* | | | | | *Vehicle Status* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Crash severity* | | | | | | | | | | | | | | | | | | |
| | *fatality* | *serious* | *medium* | *slight* | *property damage* | *No of damaged vehicles* | *property damage in birr* | *Type of Collision* | *Collision diagram* | *Crash hour* | *Crash Day of the week* | *Crash Month of the Year* | *Crash Date* | *Crash Year* | *Vehicle Type* | *Vehicle Ownership* | *Vehicle Year of Service* | *Vehicle maneuvering before entering the crash* | *Vehicular Defect* |
| *1* | | | | | | | | | | | | | | | | | | | |
| *2* | | | | | | | | | | | | | | | | | | | |
| *3* | | | | | | | | | | | | | | | | | | | |
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## Traffic police MVC recording format organized by the researcher

| ***No*** | ***Road Status*** | | | | | | | | ***Environmental Status*** | | | ***GPS coordinates [if any]*** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| | ***Crash Location*** | ***special place*** | ***Road Type by Lane*** | ***Road Geographical Location*** | ***Junction Type*** | ***shoulder width [if any]*** | ***Road Surface Type*** | ***Road Type by Function*** | ***Road condition*** | ***Road Lighting condition*** | ***Weather condition*** | ***x*** | ***y*** |
| ***1*** | | | | | | | | | | | | | |
| ***2*** | | | | | | | | | | | | | |
| ***3*** | | | | | | | | | | | | | |
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## Traffic police MVC recording format organized by the researcher

| ***No*** | ***victims Status*** | | | | | | | | | | | | | | | | | ***Cause of the crash*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Driver Status*** | | | | | | | ***Passenger Status*** | | | | ***Pedestrian status*** | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | ***Driver Age*** | ***Driver Sex*** | ***Defendant No.*** | ***Age*** | ***Education Back ground*** | ***Driver Vehicle Relation*** | ***Driving Experience*** | ***Age*** | ***Sex*** | ***Education Back ground*** | ***Occupation*** | ***Age*** | ***Sex*** | ***Education Back ground*** | ***Occupation*** | ***Previous Gross Physical & Health condition*** | ***Movement of Pedes-trian During the Crash*** | |
| ***1*** | | | | | | | | | | | | | | | | | | |
| ***2*** | | | | | | | | | | | | | | | | | | |
| ***3*** | | | | | | | | | | | | | | | | | | |
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