**ADDIS ABABA UNIVERSITY**
**ADDIS ABABA INSTITUTE OF TECHNOLOGY**
**SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING**
**GRADUATE STUDIES**

# *"Investigation of the Effect of Roadway Elements on Traffic safety in Addis Ababa: A Case of Nifas Silk Lafto Sub City"*

By

**ESKINDIR ZEKIOS**

Thesis Submitted to School of Civil and Environmental Engineering of Addis Ababa Institute of Technology in Partial Fulfillment of the Requirements for the Degree of
Master of Science
In
Civil Engineering
(Road and Transport Engineering)

Advisor

Dr. Bikila Teklu (PhD)

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Addis Ababa, Ethiopia.

# Addis Ababa University
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Approved by Board of Examiners:

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|---|---|---|
| Dr. Bikila Teklu<br>Advisor | ____________________<br>Signature | _______________<br>Date |
| Dr. Getu Segni<br>Internal Examiner | ____________________<br>Signature | _______________<br>Date |
| Mr. Ataklti Gedylew<br>External Examiner | ____________________<br>Signature | _______________<br>Date |
| Ms. Mahlet<br>Chairman | ____________________<br>Signature | _______________<br>Date |

## DECLARATION

I, the undersigned, declare that this thesis with the title of ***Investigation of the Effect of Roadway Elements on Traffic safety in Addis Ababa: A Case of Nifas Silk Lafto Sub City*** is my original work, has not been Presented for a degree or diploma in this or any other university, and all sources of materials used for the thesis have been fully acknowledged.

**Eskindir Zekios** ________________

Name Signature

Place: Addis Ababa

Date of Submission: ________________

This thesis has been submitted for examination with my approval as a university advisor.

Dr. Bikila Teklu (PhD) ________________

Advisor's Name Signature

ABSTRACT

Globally, road safety issue is the major economic, social and health problems, especially it becomes the critical concern of developing countries like Ethiopia. In addition, it was forecasted to be the fifth leading cause of death in 2030 but currently it holds the $8^{th}$ position. According to WHO report (2018), an estimated 1.35 million people are killed in road crashes and up to 50 million injured worldwide every year. That's nearly 3,700 people dying on the world's roads every day. Research report of WHO (2018) has also revealed that Ethiopia was found one of the world worst accident recorded country where it accounts for fatality rate of 26.7 per 100,000 populations from which the capital city Addis Ababa has took the highest share.

Hence, this research was mainly performed to investigate the effects of roadway elements for road traffic accidents on arterial streets of Addis Ababa city specifically, on Nifas Silk sub city. On account of engineering relevance and systematic sampling approach, thirty-Six road segments were extracted from five streets using homogeneity principle. Subsequently, fifteen accident prone locations were selected from the samples by employing point weightage approach and statistical check using three years of accident database from AAPC and Nifas silk police department. Moreover, accident prone locations were digitalized using ARCH – GIS 10.3 tool.

According to the objective of the research, seven explanatory variables were found significant from the presumed twenty-six risk factors. And they are average travel lane width, number of U-turn, Average Daily Traffic Volume (ADT), $85^{th}$ % spot speed, availability of parking, median opening and presence of visual clutter. In addition, point biserial correlation analysis was executed using SPSS tool and it was adopted along with subjective engineering judgment and argument from previously executed researches to select the stated explanatory variables. Therefore, excluding the strength of the relationship, all variables have shown positive relationship with the number of road traffic accident. Hence, change in any variable will affect the probability and magnitude of the accident number. On the other hand, average travel lane width, availability of parking, average daily traffic (ADT) and presence of visual clutter has shown strong correlation with coefficient of 0.778, 0.656, 0.646 and 0.635 respectively. While the remaining three variables have shown moderate relationship with the dependent variable.

**KEY WORDS: Accident-prone location, GIS tool, Traffic Safety, Point-Biserial Correlation, Roadway elements, Significant Explanatory Variables.**

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First of all, I would like to thank the almighty and eternal lord, GOD for his willing and merciful gift to enables me accomplish the best through the whole journey of the postgraduate study. Later on, I would like to present my sincere and king gratitude to my advisor Dr. Bikila Teklu for his continuous assistance and guide from the commencement to the completion of the research. My honorable appreciation also goes to my Co-advisor Emnete Tadesse for her valuable support and genuine assistance till the accomplishment of the paper. The same time, I have such a precious acknowledgement to my sponsorship, ERA and the collaborative institution Addis Ababa University (AAiT).

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## ACRONYMS

**4WD:** Four Wheel Drive.

**A:** Automobile.

**AADT:** Average Annual Daily Traffic.

**AAPC:** Addis Ababa Police Commission.

**AASHTO:** American Association of State Highway and Transportation Officials.

**ADT:** Average Daily Traffic.

**AN:** Accident Number.

**APN:** Access Point Number.

**AT:** Articulated Truck.

**ATLW:** Average Travel Lane Width.

**CL:** Curved Layout.

**CO:** Commercial.

**ECE:** Economic Commission of Europe.

**ERA:** Ethiopian Road Authority.

**Excel STAT:** Excel Statistics tool.

**F:** Fatal.

**FHWA:** Federal Highway Administration.

**GDP:** Growth Development per Capita.

**HA:** Horizontal Alignment.

**HSM:** Highway Safety Manual.

**HT:** Heavy Truck.

**IHSDM:**

**ILF:** Illegal Function.

**IRTAD:**

**ITE:**

**L:** Light.

**M:** Machine.

**mB:** Mini Bus.

**MB:** Medium Bus.

**MBA:** Median Barrier Availability.

**MO:** Median Opening.

**MT:** Medium Truck.

**MUTCD:** Manual for Uniform Traffic Control Device.

**NSM:** Network System Management.

**NUT:** Number of U-Turn.

**PA:** Parking Availability.

**PAS:** Principal Arterial Street.

**PF:** Passenger Fall.

**POD:** Property Damage Only.

**PVC:** Presence of Visual Clutter.

**R:** Residential.

**RA:** Round About.

**RTA:** Road Traffic Accident.

**S:** Severe.

**SAS:** Sub-Arterial Street.

**SB:** South Bound.

**SBB:** Set Back distance of Building.

**SBS:** Set Back distance of Signage.

**SL:** Sign Legibility.

**SPSS:** Statistical Package for the Social Science.

**TWLTL:** Two Way Left Turn Lane.

**UN:** United Nation.

**VA:** Vehicle to Animal.

**VB:** Vehicle to Bajaj.

**VBC:** Vehicle to Bicycle.

**VCA:** Vehicle to Cart.

**VMS:** Variable Message Sign.

**VO:** Vehicle to Object.

**VOT:** Vehicle Over Turn.

**VP:** Vehicle to Passenger.

**VV:** Vehicle to vehicle.

**WHO:** World Health Organization.

**WWW:** Walk Way Width.

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# Chapter 1 - INTRODUCTION

## 1.1. Background

Globally, road safety issue is the major economic, social and health problems, especially it becomes the critical concern of developing countries like Ethiopia. In addition, it was forecasted to be the fifth leading cause of death in 2030 but currently it holds the 8$^{th}$ position. According to WHO report (2018), an estimated 1.35 million people are killed in road crashes and up to 50 million injured worldwide every year. That's nearly 3700 people dying on the world's roads every day. About 90% of the world's fatalities on the roads occur in low income and middle-income countries, which have only 54% of the world's registered vehicles.

Research report of WHO (2018), has also revealed that Ethiopia was found one of the world worst accident recorded country where it accounts with fatality rate of 26.7 per 100,000 populations. Accordingly, the city of Addis Ababa has taken the highest share of the total recorded road crashes. In addition, road traffic crash in Addis Ababa is a cause of significant losses of human and economic resources. Three years of recorded accident data (July 2009 to June 2012) of Federal Police Commission disclosed that more than 34 thousand of crashes were recorded and among which 2,379 number of crashes were leading to losses of life. Besides, the report emphasizes death rate due to a car crash is significantly increasing among pedestrians and passengers from time to time in Ethiopia. As data from the Addis Abeba Police Commission (AAPC) indicate, during the year 2013/14, there were 391 deaths, 1,484 serious injuries and 1,128 minor injuries incurred. Furthermore, ten years of accident data report indicates that a total of 25,110 crashes and 3,415 fatalities were recorded in Addis Ababa during 2000-2009.

A traffic accident may have many contributing factors, such as those related to driver behavior, road geometry, traffic volumes, vehicle, and environment. And those contributing factors are categorized into three major groups: a) Human Factors b) Vehicle Factors and c) Roadway/Environment Factors. Among the above-mentioned factors human factors are the most common cause for the occurrences of road traffic accidents. But looking to the works of previous researchers the contributions of roadway and vehicle factors are small as compared to that of the human factors. Conversely, the effect of roadway factors has a significant effect when they are integrated with the human factors.

Looking to the provision of accident free and safe road, UN have proposed a long-term plan where, by the year 2020 Global plan to promote Safer roads and the mobility since action for Road Safety is one of the five pillars of plan.

This can be achieved through measures including improved safety-conscious planning, design, construction and operation of roads. Consequently, the increasing interest in traffic safe world promotes the elaboration of numerous studies.

In contrary, research regarding the safety aspects of road networks in Ethiopia, specifically in Addis Ababa is very much insufficient. Therefore, this research is aimed to perform its study by adopting five arterial roads of Nifas Silk sub city to set an initial platform for future studies. Subsequently, this study is aimed to investigate the effect of roadway design elements and features on accident frequency and severity in Addis Ababa, specifically on Arterial road networks of Nifas silk sub city. Consecutively, it recommends possible engineering improvements for the respective situations.

Moreover, the study follows some procedures to accomplish the pre-specified objectives. Chronologically it is presented as follows: accident data collection, descriptive analysis of accident data, definition of study sample size, identification of accident prone location, mapping the selected accident prone locations using ARCH-GIS 10.3 tool, collection of traffic and roadway data, organization and analysis of traffic and roadway data, performing correlation analysis using accident, traffic and roadway data using SPSS and finally identifying the most significant roadway elements which are liable to cause frequent and severe road traffic accident.

Finally, the structure of the research report follows the aforementioned format: the next part of this section presents the problem statement, objective of study and the scope of study. Chapter two of the report mainly focuses on recent literature reviews of previous works. On the other hand, chapter three presents with the employed methodology to achieve the stated objectives. Besides, chapter four comprises results and discussion part whilst chapter five presents conclusions and recommendation of the study. All in all, chapter six of the study presents the possible countermeasures for the respective situations of the selected sites.

## 1.2. Problem Statement

According to WHO report (2018) Ethiopia is found as with one of the world's worst accident records when estimated by fatality rate of 26.7 per 100,000 populations which is higher than estimated fatality rate of Africa i.e 26.6. Where the capital city Addis Ababa took the highest share. In addition, majority of the road networks of Addis Ababa are very much susceptible in experiencing frequent and severe road traffic accidents.

Generally speaking, the provision of transportation facilities in Ethiopia, specifically in Addis Ababa have grown dramatically from time to time. Though the facilities generally lack due consideration of safety, one can observe easily unsafe sections of the road network due to lack of appropriate safety considerations during design, construction, operation and/or maintenance. And the current employed safety provision approach that are adopted by the city administration can be taken as the concrete exhibit such as providing speed hump and speed breaks on major roads of the city.

In this regard, the safety aspects of principal arterial roads in Addis Ababa has also become the pressing issue with regard to causing frequent and severe injury on road users specifically, on pedestrians. And these issues have been exaggerated and experienced with high intensity on three sub cities of the city namely Kolfe Keranyo, Nifas Silk and Bole sub city. Primarily, Nifas Silk sub city has taken the third spot from experiencing the highest percentage of road traffic accident, i.e. 12.3 % of the total number of accidents of the city. Whereas Bole and Kirkos sub city holds the top two ranks with a percentage share of 18.4% and 16.5% respectively (Source: AAPC 2011/12 – 2014/15 Report). Secondly, the sub city holds the second most position with experiencing frequent severe and fatal type of crashes. Moreover, many reasons can be hypothesized for the occurrences of frequent and severe accidents on the stated road types such as improper geometric designs, effects of road side features and friction, improper design and location of pedestrian facilities, effects of traffic characteristics etc.

All in all, this research focuses its study on investigating the effects of roadway elements regarding the safety aspects of arterial roads of Nifas silk sub city, where intensive and applicable research have not been executed previously in the sub city as compared to the exaggerated safety issues.

## 1.3. Objective of Research

### 1.3.1. General Objective

To investigate the contribution of roadway elements on the occurrence of road traffic accident on the arterial streets of Addis Ababa city.

### 1.3.2. Specific objective

The specific objective of the research is listed as follows: -

- ✓ To perform descriptive analysis of road traffic accident on Nifas silk sub city;
- ✓ To analyze the roadway and traffic characteristics of selected road samples;
- ✓ To identify accident-prone location of Nifas silk sub city;
- ✓ To correlate the prevalent roadway element and traffic characteristics with traffic accident pattern of the arterial roads;
- ✓ To determine the prevalent roadway element and traffic characteristics of arterial roads.

## 1.4. Scope of the Study

The research scopes are limited to the following issues: -

- ✓ The research is executed on arterial roads of Addis Ababa, specifically on Nifas silk sub city;
- ✓ The study investigation is limited to effects of roadway elements on the occurrences of traffic accidents;
- ✓ It is also aimed to perform an intense investigation on six lanes roads.
- ✓ The study adopted three years of accident data, i.e. from January, 2015 to January, 2017.

# Chapter 2 - LITERATURE REVIEW

## 2.1. Introduction

This section presents the most relevant reviews of recently published researches and supportive books. In addition, various sources were referred for reinforcing the research topic such as published journals, accident investigation guidelines, traffic engineering manuals, traffic safety manuals etc. Moreover, it also comprises brief reviews of pertinent topics such as overview of road traffic accident (RTAs), major contributing factors of RTAs, effects of roadway elements on the aspects of traffic safety and possible approaches of road traffic accident investigation.

## 2.2. General Overview of Road Traffic Accidents (RTAs)

### 2.2.1. Definition of Road Traffic Accidents

The manifestation of World Health Organization, WHO (1977) defines transport accident as; "any accident involving a device designed primarily for, or being used at the time primarily for, conveying persons or goods from one place to another".

On the other hand, IRTAD (1992), at Vienna convention defined road traffic accident in terms of injury approach as road crash involves a collision of a moving vehicle on a public road in which a road user (human or animal), is injured. Similarly, ABS (1990) used to define road accidents based as the accident resulted in: the death of a person within 30 days of the accident; or personal injury to the extent that the injured person was admitted to hospital; the accident occurred on any road, street, or any place open to public road; the accident involved one or more road vehicles which were in motion at the time of the accident.

Furthermore, an integrated definition set by Economic Commission for Europe (ECE) defined it as those accidents that occur on a way or street open to public traffic; resulted in one or more persons being killed or injured, and at least one moving vehicle was involved. Thus, RTA is collisions between vehicles; between vehicles and pedestrians; between vehicles and animals; or between vehicles and fixed obstacles. And referring to many previous researches, this definition has got better acceptance among various scholars, road safety practitioner engineers, safety professionals and researchers. Therefore, for accomplishing the objective of the research, the study has adopted the definition set by Economic Commission of Europe.

### 2.2.2. Current Status of Global Road Traffic Accident

Road traffic accidents (RTAs) have turned-out to be a huge global public health and development problem, and it is predicted to be the fifth leading cause of death by the year 2030 whilst currently ranked $8^{th}$. According to a report by WHO, 2018, an estimated 1.35 million people are killed in road crashes and up to 50 million peoples are injured worldwide every year. That's nearly 3700 people dying on the world's roads every day

Globally, most road traffic crashes are occurred by young peoples, among which those aged between 15–29 years are the most responsible ones. And almost half of all deaths on the world's roads are among those with the least protection – motorcyclists, cyclists and pedestrians. However, the likelihood of dying on the road as a motorcyclist, cyclist or pedestrian varies by region: The African Region has the highest proportion of pedestrian and cyclist deaths at 43% of all road traffic deaths, while these rates are relatively low in the South-East Asia Region (WHO 2014). Accordingly, looking to demographic statistics, males account for more deaths than females. According to the study made by WHO Global Burden of Disease project, 2002, the road traffic death rates were 27.6 per 100 000 males and 10.4 per 100 000 females.

About 90% of the world's fatalities on the roads occur in low income and middle-income countries, which have only 54% of the world's registered vehicles. So, the level of death in these countries shows an inconsistent pattern as compared to the level of motorization. Moreover, data suggest that road traffic deaths and injuries in low- and middle-income countries are estimated to cause economic losses of up 5% of GDP.

The study by Dahdah S, McMahon K. (2008), revealed that Globally an estimated 3% of GDP is lost due to road traffic deaths and injuries as far as the African Region is concerned, the continent has also the highest road fatality rates of all the world's regions that is 26.6 per 100, 000 populations relative to global rate of 17.5 per 100, 000 populations. In contrary, looking to vehicle ownership, the Region owns only 2% of the world's vehicles with a percentage share of 16% of the entire global deaths. Furthermore, the region will continue to have the highest road traffic death rates due to high rate of urbanization and motorization but lagging road infrastructural development as well as poor road and vehicles' safety (WHO 2015).

To sum up, Ethiopia is also found among those low and middle-income countries with a highly growing population, transportation demand and urban settlement along with a significant increase in road traffic accident both in severity and frequency. In addition, the road infrastructural facilities of the country are very much insufficient as compared to the traffic demand of the country.

### 2.2.3. Road Traffic Accident in Ethiopia

As part of developing and low-income country, Ethiopia is also suffered from the occurrences of frequent and severe road traffic accidents. And many reasons can be picked up for the presence of the stated problem such as the dramatic growth of transportation demand, an increment in population density, urbanization, augmentation of vehicle ownership regardless of the provision of additional transportation facilities, availability of poor safety handling mechanisms and so on.

Hence, Ethiopia is categorized among those countries that experiences the highest number of traffic accident deaths in the world. For instance, according to the report of WHO, 2013 the road crash fatality rate in Ethiopia was 4984.3 deaths per 100,000 vehicles per year whilst 574 deaths per 100,000 vehicles per year was recorded across sub-Saharan African countries. Indeed, Various studies have indicated that Ethiopia has one of the highest fatality rates per vehicle in the world and it is excess of 100 fatalities per 10,000 vehicles. This should be compared with Kenya and United Kingdom, where the figure is about 19 and 2 per vehicles, respectively. With regard to severity perspective to the number of people injured or killed in one crash in Ethiopia is about 30 times higher than that in the US. In general, the scale and the severity of the problem are increasing from time to time and adversely affecting the economy of the country in general and the livelihood of individuals in particular.

Moreover, the report of WHO, April 2011 disclosed that deaths resulting from RTAs in Ethiopia reached 22,786 or 2.77% of the total deaths in the nation. The age adjusted death rate Ethiopia is 37.83 per 100,000 populations. Federal Police Commission of Ethiopia (2012) was reported the 3 years' accident record from July 2009 to June 2012, accordingly more than 34 thousand of crashes were recorded in the countries from which 2,379 crash were responsible for many losses of life. In addition, the Federal Police Commission report indicated that the death rate due to a car crash is significantly increasing among pedestrians and passengers from time to time. From this figure, the city of Addis Ababa has taken the highest share of the road crashes.

Road traffic crash in Addis Ababa is the major cause of significant losses of human and economic resources of the country. A total of 25,110 crashes and 3,415 fatalities were recorded in Addis Ababa during 2000-2009.

With regard to severity, Addis Ababa Police Commission (AAPC) report for the period of 2010/11 to 2013/14 indicated that during the year 2013/14, there were 391 deaths, 1,484 heavy injuries and 1,128 light injuries incurred. In the year 2012/13, 367 deaths, 1,336 heavy injuries and 1,263 light injuries were caused by accidents on the road while by the year 2011/12, there were 369 deaths, 1,190 heavy injuries and 820 light injuries occurred. In the year 2010/11, 332 deaths, 904 heavy injuries and 831 simple injuries occurred. In addition, the number of accidents in the city is increasing from 2,067 in 2010/11 to 2,379 in 2011/12 then to 2,966 in 2012/13, to 3,003 in 2013/14. And in the half year of 2014/15, the road fatalities totaled 224.

Furthermore, based on the age of the drivers that cause the fatalities show that three fatal accidents were caused by drivers under 18, 172 deaths by drivers between 18 and 30, 137 deaths by drivers between 31 and 50 and 51 deaths by drivers over the age of 51. Male drivers caused 361 of the deadly accidents, with female drivers being responsible for two while 28 are unidentified.

## 2.3. Major Contributing Factors of Road Traffic Accidents

Most studies have described that the major contributing risk factors for traffic crashes are Human factors, vehicle factor and roadway/environment. Among which, human factor is the dominant one for the occurrences of most traffic crash on urban and rural road street. Besides, the contribution of the other two factors are also significant for the occurrences of various traffic crash specifically their effect becomes augmented while they are combined with other factors. Hereafter, this section tries to review the recently published literatures regarding the major contributing risk factors of road traffic crashes.

A research by Dr. William Haddon Jr. (1970), tries to developed a Matrix using three major risk factors such as: a) Human Factors b) Vehicle Factors and c) Roadway/Environment Factors. And as per his work, all the three major factors were considered individually by subdivided in to sub categories.

As such Human factors were subdivided into six categories (Driver, Passenger, Pedestrian, Motorcyclist, Bicyclist and Other), the Vehicle and Equipment factor into two (Physical characteristics, and Movement/Location), and the Environment factor into two (Physical and Sociocultural). This showed how his framework could be expanded and adapted as appropriate. Similarly, Mc Mahon and Ward (2005) were revealed three major causes of vehicle accidents; road user's error/human factors, vehicle defects and road condition or environment. Among the most prominent factors, human factor takes much responsibility of which drivers' errors takes the majority of the blames. Paper by Helen Abebe (2018), disclosed that the major driver related risk factors which are responsible for the occurrences of road traffic accident, specifically for sever crashes include age, education level, experience, gender, time related factors and land use. Similar study made by Yosef Asrat (2015) has shown that driver’s age, educational background and place of crash significantly affect the number of death/injuries per crash.

Furthermore, the research published by Caliendo, C., Guida, M. and Parisi, A. (2007) concluded that traffic accidents are caused by risk factors such as those related to driver behavior, road geometry, traffic volumes, vehicle, and environment.

Nonetheless, Van Elslande *et al* (2008) argued that most accident analysts tend to conclude by considering 'human error' as the main cause of accidents. The problem behind such a statement is that, it leads to oversimplification of the problem. In contrary, Salmon *et al* (2005) stated that, there are two theoretical approaches to human error: the 'person approach' which focus upon the last step of system operation and by so treats human error as the cause of most of the accidents; and the 'safe system approach' which looks further in the accident process considering the role of the various organizational levels that contribute to the production of system outputs (rules, design, management, etc.) and looking for the 'holes' or 'weaknesses' in the various defense layers which are supposed to constitute a safe system, well adapted to its users.

As well as Van Elslande *et al* (2008) argued that, most safety studies have been based upon a person approach and stress the role of human error in the production of 75-90% of accidents. But it would be wrong to regard this 'error' as the primary cause of accidents. A safe system approach will rather consider it as a consequence of malfunctions further upstream, so that human error is only a link in the chain of events leading up to an accident.

And, he is a necessary link as far as the driving system is unable to function without drivers. The so called 'human error' may be explored in many different approaches on the basis of how it is perceived. The common sense of using 'human error' in the framework of everyday life and in safety research, gives the rise to an oversimplified conception of how events occur. Such an outlook neglects the complexity of accident phenomena which are the result of an amalgamation of factors. This affects the way to manage the root causes of accidents (Hollnagel and Amalberti, 2001).

Highway Safety Manual (HSM) of the American Association of State Highway and Transportation Officials (AASHTO), three percent (3%) of road crashes are due to only roadway factors, but thirty-four percent (34%) of road crashes are a combination of roadway factors and other factors.

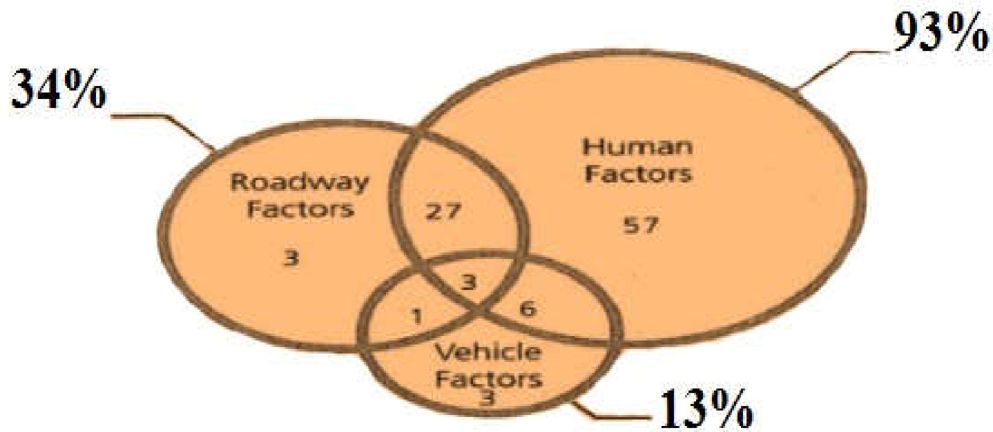


**Figure 2-1. Contributing Factors of Road Traffic Accidents.**

Furthermore, a report of Addis Ababa Police Commission (AAPC) shows that the contribution of the above stated factors is different where Environmental/road user factors account for 48.8% followed by environmental / vehicle road user factors (16.4%), road user factors (12.4%), vehicle/ road user factors (7.2%), environmental factors (5.6%) and environmental/vehicle factors (4.8%). Road environments have impacts on the occurrences of road traffic crashes. In developed countries, there have been exercised a continuous effort in provision of safety tools to meet the safety standards of roads through safety audit during the planning, designing, and operation stage. Looking to the case of Ethiopia, researches regarding the significant effects of roadway and roadside elements are so much insufficient.

Therefore, this research is aimed to perform intense study on the significant effects of the roadway and roadside elements on the occurrences of road traffic accidents.

## 2.4. General Overview of Roadway and Road Side Elements

The roadway and road side elements include risk factors that are related to the geometric design, traffic control devices, roadway activities and roadside features. And the referred literatures and brief explanation of the stated elements is presented accordingly under four major categories including geometric design elements, traffic control devices, roadway activity, and environmental considerations.

### 2.4.1. Geometric Design Elements

Geometric design could be defined as "the process of applying some engineering principles to the design of transportation facilities to ensure safety and efficiency for all users" (AASHTO, 2001). Geometric design elements include a wide range of roadway features such as horizontal and vertical alignment, cross section, roadside development, intersections, pavement, lighting, and design speed.

#### 2.4.1.1. Speed

Speed is a critical factor affecting safety and it reduces the visual field, restricts peripheral vision, and limits the time available for drivers to receive and process information. AASHTO describes three types of speed including operating speed, running speed, and design speed. Operating speed is the speed at which drivers are observed operating their vehicles during free-flow conditions. The $85^{th}$ percentile speed is the most frequently used measure of the operating speed. Running speed is the speed at which an individual vehicle travels and is usually measured by the average speed. Design speed is a selected speed used to determine the various geometric design features of the roadway. All geometric design elements of the roadway should be related to the design speed to ensure consistency and avoid misleading motorists (ASSHTO, 2001).

#### 2.4.1.2. Road Alignment

Road alignment comprises horizontal and vertical alignment (profile), which are amongst the most significant risk factors and permanent design elements of the roadway. The design standard and phasing of these combination increases usefulness and safety, encourages uniform speed, and improves appearance. The most important points to consider regarding horizontal and vertical alignments is that they should be consistent with the topography, preserve developed properties along the road, and incorporate community values. Grade, super elevation, radii, and transition lengths are all important elements in road alignment design.

One of the essential design elements related to road alignment is sight distance, which is defined as the length of roadway ahead visible to the driver. For safety on highways, the designer should provide sight distance of sufficient length that drivers can control the operation of their vehicles.

#### 2.4.1.3. Roadside Environment

The roadside environment consists of all the surroundings that are visible from the road, particularly those objects near to the road that have the potential to become obstacles in the path of vehicles that run off the road. Although not part of the road geometry, these aspects can be considered part of the road design.

#### 2.4.1.4. Cross Section

The roadway cross section consists of those geometric features perpendicular to the direction of travel. Common cross-section elements include travel lanes, medians, shoulders, and marginal elements such as sidewalks, curbs, gutters and barriers.

#### 2.4.1.5. Intersections

Intersections may possibly be the most critical elements of the urban highway system. The efficiency, safety, speed, cost of operation, and capacity of the highway system mostly depends on the design of its intersections.

AASHTO (2001) defines intersection as “the general area where two or more highways join or cross, including the roadways and roadside facilities for traffic movements within the area”. Each roadway radiating from an intersection is called a "leg." Most intersections have four legs, which is recommended by AASHTO as the maximum number for safety and capacity reasons.

The basic intersection types include the three-leg intersection or T intersection, the four-leg intersection, the multi-leg intersection, and the modern roundabout.

#### 2.4.1.6. Clear Zones and Crash Barriers

According to the definition set by AASHTO, clear zone is defined as "the unobstructed, relatively flat area provided beyond the edge of the traveled way for the recovery of errant vehicles". The width of the clear zone is influenced by several factors, the most important of which are traffic volume, design speed of the highway, and slope of the embankments. The AASHTO "Roadside Design Guide" is a primary reference for determining clear zone widths for freeways, rural arterials, and high-speed rural collectors.

For low speed rural collectors and rural local roads, the AASHTO Green Book suggests providing a minimum clear zone width of 2.0 to 3.0 m (7 to10 ft) (47). For urban arterials, collectors, and local streets with curbs, space for clear zones is typically restricted. A minimum offset distance of 500 mm (18 inches) should be provided beyond the face of the curb, with wider offsets provided where practical (ASSHTO, 2001).

### 2.4.2. Traffic Control Devices

Traffic control devices are the communication elements of the roadway, which must provide the driver with a message in a clear, unambiguous, and uniform way. They include pavement markings, signs, traffic signals, and object markers. The Manual on Uniform Traffic Control Devices (MUTCD) defines traffic control devices as "all signs, signals, markings, and other devices used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, pedestrian facility, or bikeway by authority of a public agency having jurisdiction".

#### 2.4.2.1. Signs

The MUTCD describes three general categories of signs including regulatory signs, warning signs, and guide signs. Regulatory signs convey information about a specific traffic regulation with which drivers must comply, warning signs give notice of a situation that might not be readily apparent, and guide signs assist drivers in selecting appropriate routes to their desired destination (McShane et al., 1998).

#### 2.4.2.2. Traffic signals

The MUTCD (2001) defines traffic control signal as "any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed". Traffic includes pedestrians, bicycles, vehicles, streetcars, and other conveyances using the roadway with travel purposes.

#### 2.4.2.3. Markings and delineation

Traffic markings are the most frequently used traffic control device. Major marking types include longitudinal markings, such as lines separating traffic and curb markings; transverse markings, such as crosswalks stop lines and parking markings; and object markers and delineators. These elements can be used alone or as a supplement of other traffic control devices such as signs, signals, or other markings.

### 2.4.3. Roadway Activity

#### 2.4.3.1. Pedestrians and Cyclists

Every user of the roadway must be considered in the road survey. To ensure safety of all users, safe and comfortable space for bicycling and walking should be provided along the roadway. Appropriate sidewalks and crossing points for pedestrians should be provided along the roadway, especially in urban and suburban areas. Children, sometimes harder to see because they are shorter, and older pedestrians, which often require more time to cross and to react, also warrant special consideration (ITE, 1999).

#### 2.4.3.2. Parking and Public Transport

The existence of parking lanes along the roadway creates additional side friction for vehicles in the adjacent lane and disruption due to vehicles entering and leaving from the parking spaces to the traveled lane, thereby affecting the overall safety and efficiency of the roadway (McShane et al., 1998).

Vehicles parked are hazards to passing vehicles or bicycles from opening doors, obstructions that hide pedestrians, and obstructions that block visibility at intersections and access points. The presence of public transport, and especially the existence of stops along the roadway, influences the overall flow of vehicles and therefore the safety of the roadway. Bus stops must be located ensuring safety for both vehicles and other users (Austroads, 2002).

### 2.4.4. Environmental Considerations

#### 2.4.4.1. Weather

As it has been previously noted, adverse weather affects design features such as visibility, and consequently affects roadway safety. In the road survey, the effects of rain, fog, ice, and wind on design features must be checked.

## 2.5. Effects of Roadway Elements on the Aspects of Traffic Safety

This section has summarized previously executed studies on the effects of roadway design factors on crash occurrence. As it was previously mentioned before on the upper section of the paper, roadway design factors are one of the major factors which affect traffic crash occurrence but solely its effect is small as compared to human factors. In contrary, its contribution to crash is not underweighted when combined to the effects of another contributing factors.

In addition, this factors indirectly affect human behaviors for example drivers mostly used higher speed in straight section of road and preferred to lowering their speed when they are exposed to curved features. Therefore, road environment has positively or negatively affect road user behaviors. Hereafter, the paper presents with some relevant studies that are very much related to road environment. Subsequently, this section tries to address the major roadway design elements which have an adverse effect on the safety performance of road networks i.e Cross sectional design elements, vertical and horizontal alignments, roadside environments, etc. Among all, the paper gives more attention on the effects of cross-sectional and roadside design elements that have a significant effect for the occurrences of road traffic accident.

### 2.5.1. Effect of Geometric Design Elements on Traffic Safety

In this part the literature tries to cover impact of two major geometric design elements on crash risk such as cross-sectional elements, horizontal and vertical alignments.

Zegeer and deacon (1987), Lee, SooBeom (2009), and Theodore A. Petritsch, P.E. Srikalyan Challa, Herman F. Huang (2007), on their study showed that increasing lane width and shoulder width could decrease expected Accident rate. Similarly, Transportation Research Board (1987) conclude that widening lanes without shoulder improvement reduces crashes.

Hadi, Mohammed A., Jacob Aruldhas, Lee-Fang Chow and Joseph A. Wattle worth (1995) Theodore A. Petritsch, P.E. Srikalyan Challa, Herman F. Huang (2007), concluded that median width is significant in affecting safety for all types of divided highways. Besides it also affects crash rates where four-lane urban divided highways with flush unpaved (grass) medians are the safest, followed by raised curb medians, then crossover resistance, then TWLTL.

Works of Sarbaz Othman & Robert Thomson (2006) have found that accident ratio (AR as defined as number of accidents per millions of vehicle kilometers) has a distinct tendency to decrease with lane widths greater than 5.8m. Accident prediction model study on principal arterial roads of Addis Ababa made by Mitiku Dinsamo (2017) identified four prevalent geometric variables that have significant influence on road traffic accidents and they include AADT (average peak hour volume), $85^{th}$ percentile spot speed, availability of U-turn and number of access point.

A study of two scholars, Sarbaz Othman & Robert Thomson (2006), concluded that accident rate decreases with increasing radii of curve for right and left-turn curves. Left-turn curves have higher accident rate than right-turn. Road sections with left-turn curve radii of less than 100m have highest accident rate; they are four times as high as those with curve radii greater than 500m and twice as high as right-turn curve radii less than 100m.

Glennon (1987) was disclosed that the average crash rate for curves is three times that of tangents, and average single vehicle, run off road crash rate is four times higher. Moreover, curved road segments have higher proportions of sever, wet road, and ice road crashes.

Roy Jorgensen Associates (1978, p 7) suggested that both crash rate and severity increases with gradient, both upgrade and downgrade. Organization for Economic Cooperation and Development (1976) and Hillier and Wardrop (1966) reached a similar conclusion, but suggested that downgrades were a greater problem. Hoban (1988) concluded that steep grades above about **6** percent are associated with a higher crash rate.

The study done by Lee, SooBeom (2009) in Seoul, Korea suggested that in four lane highway, the horizontal curvature is getting smaller, more traffic accidents happen. also, more accidents happen with greater vertical curvature in the homogenous segments.

Theodore A. Petritsch, P.E. Srikalyan Challa, Herman F. Huang (2007), were studied the effect of geometric and operational characteristics of six lane divided roadway on road traffic safety.

Subsequently, the study found that number of signals per miles and the number of driveways per mile increased the crash rate. On other hand, increased inside shoulder width, horizontal degree of curvature, outside shoulder width, median width, & the surface width all reduced the crash rate.

A study by four researchers, JP, Fletcher, CJ Baguley B Sexton and S Done (2006), which have been made for the case of developing countries (Tanzania and India) proved that surface type, surface condition, sign provision, shoulder width were the significant factors for traffic crashes occurred for the case of Tanzania. On other hand; side friction, road marking provision, number of lanes and shoulder width were the contributing factors for accidents occurred on highway of India; road condition, road markings and number of lanes were the contributing factors for State highways; Shoulder width, number of curves for District Roads; and Road condition and number of curves factors on Hilly roads.

The study done by Getu Segni (2007) indicated that increases in accident rates were highly associated with gradient and sharp curves. Besides, he has found that ADT, numbers of lanes and road grade have positive relationships with accident rates.

### 2.5.2. Effect of Roadside Environment on Traffic Safety

The roadside environment consists of all of the surrounding that are visible from the road, particularly those objects near to the road that have the potential to become obstacles in the path of vehicles that run off the road. Although not part of the road geometry, these aspects can be considered part of the road design. Besides, roadside represents the area between the shoulder (or curb) and the edge of the right-of-way.

Indeed, the roadside is a common location for pedestrian activity, utility placement, landscaping, transit stops, driveway placement, mailbox placement, and placement of a variety of other roadside features typical of the urban environment. Here below discuss some of roadside environmental factors that highly affect traffic safety such as Objects next to road, set back, Access point, sign and sign legibility, distraction and overload...etc.

#### 2.5.2.1. Objects Next to Road

Objects immediately next to the road (posts, railings, wall, vegetation) may affect speed and crash risk in several ways. First, they may provide improved guidance as to the direction of the road, which would be expected to increase speed.

However, certain patterns (for examples clumps of trees) may lead to an increase in peripheral visual flow, which should increase the driver's perception of their own speed and lead to speed decreases (Martens et al., 1997). Objects next to the road are also potential obstacles, and drivers may adapt their speed in response to the potential severity of the consequence.

Objects further away from the road, but still visible, can also affect speed. Roads with open fields and no prominent side features on either side have little stimuli to create peripheral visual flow and thus speeds are likely to be underestimated (Fildes & Lee, 199). The presence of the trees or buildings can decrease this effect, allowing drivers to better calibrate their speed to the conditions. The presence of houses implies the presence of other road users (pedestrians and cars that may pull out of driveways) and this could be a reason why drivers tend to slow down on roads with houses (Elliot et al., 2003). Tall buildings can also create the impression that the road is 'walled in 'and therefore less safe, leading to lower speeds; however, this effect is not consistent. Some studies have found lower speeds when building height (or the height of other vertical elements) is greater than the width of the road (Allsop & European Transport Safety Council, 1995).

In contrary, sometimes roadside objects may be considered as potential obstacles since it could be led to increase severity of crash. Keith Midson and Nueman et al. (1999) found that poles and trees are the most struck roadside hazards. This is largely because they are the predominant roadside object and are often located within the clear zone and can be difficult and expensive to remove, relocate or shield. Traffic islands, fire hydrants, guideposts and guardrails all were only struck 1% or 2% of the collisions within the assessed road lengths. Besides, Lee and Fred L.
Mannering (1999), on their study identify the significant Roadside features that affect the severity of run-off-roadway accidents included bridges, cut-type slopes, ditches, culverts, fences, tree groups, sign supports, utility poles, isolated trees, and guardrails.

#### 2.5.2.2. Set Back

Another important moderating variable in the effect of roadside objects on driver's speed choice is the distance at which objects are set back from the road. The setback between the road edge and any buildings, trees or objects affects the perceived width of driveable area.

Where possible, drivers will away from the edge of the road if they feel the lateral clearance is too narrow; where this movement is not possible drivers may compensate by slowing down (Martens et al.,1997; Van de Horst & de Ridder,2007).

#### 2.5.2.3. Access Point

The number of entries and exits on the side of the road (including side roads and drivers) affects, speed, presumably because drivers anticipate the need to slow for other vehicles pulling onto the road in front (Elliot et al., 2003). Likewise, the presence of a service road (running parallel to the main road such that driveways and minor roads access the service road rather than the main road) is associated with increases in overall traffic speed (Fildes & Lee,1993). Some studies suggest that this effect occurs only when junctions are located on the driver's side of the road (Martens et al., 1997), perhaps because vehicles emerging from these junctions are more likely to interfere with the driver's path.

#### 2.5.2.4. Sign and Sign Legibility

Road sign are an important source of roadside information for drivers. Unlike the other factors discussed in this section, road signs give drivers information explicitly rather than implicitly. Signs can provide drivers with information about the speed limit of the road, or navigation information, all of which may result in drivers changing their speed. The effect of explicit information from signs on speed choice will be discussed further in section 5.

Another important aspect of signs is not the content, but the format. Signs that are not legible from a distance may force drivers to slow down in order to read them. If only some drivers do this, the speed variability between vehicles will increase, which will increase the crash risk. Similarly, the amount of information on a sign affects the time needed to identify the sign (Liu, 2005), so drivers may slow down to give themselves more time to read the information.

A study into the effects of variable message signs (VMS) of over 4000 vehicles on Norwegian motorways found that when the signs were displaying a message, up to 19% of vehicles braked and average speeds dropped by 5-6 km/hr. (Sagberg, Hagman, & Erke, 2005). Sudden braking or slowing is likely to cause shorter headways and potential conflicts between vehicles.

The authors note that these effects could have been due to difficulties in reading the sign at a distance, or in processing the message text. Using large fonts and symbols where possible rather than words could minimize these impacts. Increasing the size of signs and using symbols can also improve the conspicuity of the sign. i.e drivers are likely to notice the sign against the background earliest and thus will have more time to read it (Hughes & Cole,1984).

Early research into sign legibility found that although highway signs can be read at a distance of 800 feet (-240m) without preforming any other activity, participants who were driving did not call out signs until they were 200-400 feet (600-120m) away (Forbes, 1939). The same research also suggested that highway sign should contain no more than three words to ensure drivers can read the sign with sufficient time.

The Australian Manual of Uniform Traffic Control Devices sets out the sign and font sizes that should be used in various speed zones. The formula used in Victoria takes into account the number of words on the sign and lateral distance from the driver's path as well as the approach speed; it also suggests increasing font size by 25% in urban area in order to increase conspicuity (VicRoads, 2007). However, it is not clear what research these standards are based on, and whether they are sufficient to ensure sign conspicuity and legibility in today's cluttered road environments.

Kline and Dewar (2004) note that the visual decline faced by older drivers may make these drivers particularly vulnerable to the effects of unclear signage. Strategies which will help the increasing number of older drivers, such as increasing sign conspicuity and font size, will also assist other who have difficulties reading signs.

#### 2.5.2.5. Distraction and Overload

The level of visual information or clutter in the environment is an important factor that may affect speed and crash risk. For example, it is known that as the number of signs present in a road scene increases, the number of signs that observers can correctly identify in a limited observation time decreases (Oyama, 1989). It would be expected that drivers would slow down in order to process a higher level of information from road signs or similar objects.

In fact, two MUARC simulator studies found that, compared to complex environments, drivers chose lower speeds when driving through complex environment (Horberry, Anderson, Rwgan, Triggs, & Brown, 2006) or near advertising billboards (Edquist, 2008).

The level of visual clutter is determined by intersection between the amount and complexity of signage, how difficult it is to pick out important objects from the background, distracting objects like shops and advertising billboards, and other facets of the environment that influence driver workload such as the amount of traffic (Edquist, 2008).

Visual clutter may result in driver overload, which occur when the demands of the driving task exceed the driver's attentional resources. And often results in impaired driving performance. Visual clutter in the form of background complexity impairs the selection of relevant information from the environment. This ability is required for hazard detection (Lee & Triggs, 1976) and maintaining situation awareness (Endsley, 1995). In particular, visual clutter in the form of irrelevant signage interferes with visual search for traffic signs (Ho, Scialfa, Caird, & Graw, 2001; McPhee, Scialfa, Dennis, Ho, & Caird, 2004; shop tough & Whitaker, 1984). These effects will increase the demands placed on the driver. The increased cognitive load may result in slower speed, which would be expected to decrease the crash rate (as long as the effect are consistent across different drivers). However, some drivers may respond to increased demands with undesirable behavior such as speeding up, or ignoring potential hazards. Therefore, the overall net effect of visual clutter may be to increase crash rate (Elliot et al..2003).

Visual clutter in the form of highly conspicuous objects may distract the driver by temporarily capturing their attention resources (Theeuwes, Kramer, Hahn, & Irwin, 19998). Drivers may also need to focus their attention on reading a particular sign, for example, which will have a similar effect to concentrating on an in-vehicle task. Such tasks are known to affect speed control.

Drivers have been found to reduce their speed when distracted by an in-vehicle visual task (Engstrom, Johansson, & Ostlund, 2005). While distractions from auditory, manual or visual tasks have been shown to result in greater speed variability (Merat, Anttila, & Luoma, 2005; Parkes, Luke, Burns, & Lansdown, 2007).

Visual clutter may affect speed choice, but vehicle speed will also moderate the effect of visual clutter. At higher speeds, the effect of clutter will be greater because the driver has less time to process visual information from an object such as a sign. So, in high-speed areas, simple and well-spaced signs are needed to avoid driver distraction.

## 2.6. Road Traffic Accident Investigation

### 2.6.1. Definition

PIARC, Road Accident Investigation Guideline (2007) define that Road Traffic Accident Investigation (RAI) is a set of procedure which carried out on the existing roads to identify the amount of road infrastructure deficiencies that influence an accident occurrence, and to guide a safety engineer to implement the appropriate countermeasures.

Hence, according to PIARIC guide line the following procedure should be included: a collection of information about accidents and about all the facts linked to them, about road and traffic parameters and other related circumstances; an assessment of the accident distribution on the road network, on the particular road or road section/location; a detailed data analysis of accidents and their circumstances in the targeted spots/sections of roads by using collision diagrams**;** a determination of the road related deficiencies and elaboration of suggestions for their suppression or treatment.

### 2.6.2. Accident Investigation Approaches

This section of the paper describes the general procedures of road traffic accident investigation along with their specific methods such as road classification principle, localization of accident and identification of accident-prone locations.

#### 2.6.2.1. Classification of Road Networks System

Most traffic accident investigations are performed by dividing the research road networks in to several road segment for increasing the research reliability and accuracy. The most common types are homogenous segment approach, sliding window approach, constant length approach etc.

#### 2.6.2.1.1. Homogenous Segment Approach

According to the Highway Safety Manual (HSM), a homogeneous highway segment is defined as a highway segment which is divided by major intersections, or a change of the horizontal alignment and the geometric elements, or a major change of land use. A highway is considered to be homogeneous if it is not divided into segments and if there is no change in ADT, lane width, shoulder width, presence of median, median width, side slope, and major intersection.

In the HSM, traffic accidents in the highway segment include only those accidents which are not related to the intersections, and the intersection accidents include only those accidents which occurred within 76m of the center of the intersection.

Similarly, according to the Design Consistency Module in the IHSDM, the homogeneity of the segment is judged by the following four elements in which statistically significant factors are related to the number of traffic accidents: Expected speed drivers would reduce compared to the speed in the upstream straight or curved segments, Average horizontal curvature of all segments, Average vertical curvature of highway and Average horizontal curvature of highway segment.

Furthermore, Lee, SooBeom (2009) state that the highway segment is considered to be homogeneous as far as none of the following design elements - horizontal curvature, vertical curvature, median width and lane width - is changing. In addition, Michael Sorensen (2006) was state that division of road networks into homogenous segment can be done by depend on the following four division principles.

Section based principle, point based principle, Accident based principle and Combination The two first principles can be characterized as road and traffic-based division principles. In the first principle, the road system is divided into sections that are homogeneous with regard to selected traffic and road design parameters. Normally the selected parameters are some that have significant influence on the number of accidents. Several of parameters are normally used (Sorensen 2006): Road category, Cross section including number of lanes, lane width, shoulder and the presence of bicycle lanes and side strips, Speed limit, Number of access roads, Alignment including hills and bends, Road side building, Traffic including AADT and types. On other hand the second principle is a point-based principle, where intersections, towns or other ‘’points’’ are used as division points.

In contrary, the third principle is based on registered accidents in the identification period. Finally, the fourth principle is to combine the previously described principles.

Nicholson (1990, p 3) described the various factors that needed to be considered for subdivision of roads into sections these are: roadway and traffic factors should be fairly uniform within the section, the section length should be in keeping with the level of precision and degree of error in reporting crash location, and statistical reliability. With respect reliability, as the section length gets very small the probability of either zero or one crash in the period tends towards unity.

Conversely, as the section length gets very large, the effects of isolated hazardous features will be submerged and lost. Zegeer (1982) suggests that data for road segments of less than approx. 0.5 km or carrying less than 500 veh/d are unreliable.

Ogden (1994), SEMCOG (1997), and TRB (2009) pointed out that spots should be defined to include the area of influence of the features in question. For example, driver behavior can be influenced as far as 150 meters from a curve and 76 meters from an intersection (or further with severe congestion and queuing). Considering an influence area of at least 150 meters from both ends of a non-intersection spot location also helps ensure that a larger share of relevant crashes is properly identified, given typical uncertainties and errors in reporting crash position.

#### 2.6.2.1.2. Segments Length

Generally, the segment lengths can be divided into ‘’short’’ and ‘’long’’ section lengths. The ‘’short’’ section lengths have typical a minimum length of 0.5-3 kilometers and maximum lengths of 8-11 kilometers. These road system divisions among others include the Norwegian, the German and the American methods for NSM reviewed in Elvik (2007), and the Danish PhD-project (Sorensen 2006), where the use of different section length in NSM is discussed in great detail.

The ‘’long’’ section lenghts have typically a minimum lengh of 10-20 kilometeres and a maximum length of typically 50-60 kilometeres, where the longest section length is more than 100 kilometeres. The long sections are used in denmark, finland, france and sweden (Mertner et al.2006, European Commission 2003, Setra 2003).

The basic philosophy for the division of road system into ‘’short’’ sections is to identifiy road sections with local road related risk factors. This philosophy builds on the fact that local road related risk factors by difinition would vary a lot on the a very long section. By contrast, the basic philosophy for the division of the road system into’’long‘’ sections is to identify the most problematic general road types and designs, and change them to more save road types.

Elvik (2007) state that the disadvantage of using short road sections is that it greatly reduces variation in the number of accidents and the prospect of reliably identifying factors expaining varition in accident counts is then greatly diminished, as nearly all observed varition will random.

Furthermore, some of the causal factors for accidents exert their infuence over a stretch of the road at least as long as the braking distance. On other hand, the use of very long sections necessitates the smoothing of the date pertaining to shorter subsections. This obviously also represents a loss of the information and a loss of statistical power to identify source of variation in the number of accidents.

Regarding to the above philosophy three systems of division for the case of three countries were presented below. In germany, it is advised to use as long road sections as possible-limits of what is considered as possible being, for example, major change in road layout, speed limit or traffic volume. In the united states, on other hand, elementary road sections as short as 0.1 mile (0.16 km) are used, but a procedure for aggregating these into longer sections for the purpose of accident analysis has been developed. In norway 1 kilometere road sections have been used.

In addition, Michael Sorensen (2007) in his best principle guidelines report described that ‘’short’’ length philosophy should be used to divided network system into road sections with variable length to ensure homogeneity with regard to the parameters that have significant influence on the number of accidents and are used as independent variable in accident models. The section length should be in the interval between 2 and 10 kilometers, with an average section length around 5-6 kilometers. Sujin Mungnimit, et al. (2009*)* stated that black spots should be determined based on variable section length instead of fixed length.

### 2.6.3. Traffic Accident Study

#### 2.6.3.1. Accident Data Analysis

Dr. Tom V. Mathew, IIT Bombay (2014) state that the statistical analysis of accident is carried out periodically at critical locations or road stretches which will help to arrive at suitable measures to effectively decrease accident rates. It is the measure (or estimates) of the number and severity of accident. In addition, the interpretation of the statistical data is very important to provide insight to the problem.

Sarbaz Othman and Robert Thomson (2006) presented a method for accident analysis. After choosing an area and a period of investigation the analysis method was carried out in four phases: -Collecting accident data, collecting road characteristics data, locating accidents and combining them with the road data, analyzing collected-combined data statistically to locate and identify black spots. And finally, for evaluation of the effects of the road parameters, simple and multiple regression techniques were used, in which accident data was the dependent variable while geometry parameters were independent variables.

### 2.6.3.2. Accident localization

The assignment of accident location by the police at the time of accident was not always precise. Errors of up to a couple of hundred meters can occur in accident localization. But accident localization can be considered as normal distributed around the real accident location. Because of this, an average value of around 200 m (100 m before and 100 m after the 20 m section where the accident occurred) has been taken for the mentioned parameters.

In the rest of sections where no accidents occurred, a mean value has been taken for the road parameters. In this case length of sections varies between 150 and 400, which is length of the NVDB sections.

### 2.6.3.3. Identification of Hazardous Location

#### 2.6.3.3.1. Definition and Terminology

In Norway, a distinction is made between black spots and black sections. A black spot is any location with a length of not more than 100 meters where at least 4 injury accidents have been recorded in the last 5 years. A black section is any road section with a length of not more than 1000 meters where at least 10 injury accidents have been recorded during the last 5 years. In Flanders, Geurts 2006 definition is applied based on which a road accident black spot defined as each site where in the last three years three or more accidents have occurred, is selected, then, a site is considered to be dangerous when its score for priority (S), calculated using the following formula, equal 15 or more: S= LI +3SI +5DI. In Austria, black spots are defined in the Austrian guideline code. According to the guideline, scenes of accidents are distinguished in black spots and hazardous locations, depending on their recorded crash history. To be classify as a back spot, one of the following two criteria has to be met i.e 3 or more similar injury accidents within 3 years and a relative coefficient $R_k$ of at least 0.8. the value of this coefficient is calculated as follows: $R_k$ = U/(0.5+7*10-5*AADT). Where 'U' is the number of injury accidents within 3 years.

#### 2.6.3.3.2. Criteria for Identifying Black Spots

This section chronologically reviews the developments of black spot identification methods in which different accident parameters are employed as identification criteria. Over time, new parameters have been added so as to optimized the efficiency and the flexibility of black spot treatment. Such gradual addition depicts the evolution of criteria for black spot identification which is illustrated by the following researches.

The most commonly used criteria for the identification of hazardous routes are (Nicholson, 199O, p4).

- ✓ The crash frequency exceeding some threshold value (this ignores variations in route length and traffic flow);
- ✓ The crash frequency per kilometer of road exceeding some threshold value (this ignores variations in traffic flow), or
- ✓ The crash rate (per vehicle km) exceeding some threshold value.

Either of the last two is acceptable. As before, a frequency-based measure focuses on routes with high flows and crashes, whereas a rate-based approach focuses on routes which have low flows. A combination of the two may be appropriate.

Norden et al. (1956), Rudy (1962), and Morin (1967) used the method of industrial statistical quality control for highway safety. In this method upper control limit of accident count and upper control limit of accident rate were used as criteria in identifying black spots. Such black spot identification method employed only two parameters: the observed accident number and the traffic volume.

Tamburri and Smith (1970) introduced the notion of the safety index which is actually a combined criterion of accident number and accident severity. The establishment of this criterion led to the development of a method of black spot identification which initially incorporated the accident-severity based prioritization in identifying black spots. As a result, accident severity was employed as a new parameter in black spot identification.

Jorgensen (1972) introduced a new method which employed two new factors: (1) mean of expected accident counts calculated by multivariable model, and (2) the observed accident number. The identification of black spots is based on the difference between the expected number and the observed number of accidents. As a result, expected number of accident was employed as a new parameter in black spot identification.

Overgaard (2005) tries to discuss the detail criteria for identifying black spot locations. As such the author disclosed that an adequate black spot location should satisfy four criteria:

(1) It should control for random fluctuations in the number of accidents;
(2) It should account for as many of the factors that are known to influence road safety as possible;
(3) It should identify sites at which fatal and serious injury accidents are over-represented;
(4) It should identify sites at which local risk factors related to road design and traffic control make a substantial contribution to accidents.

#### 2.6.3.3.3. Point Weightage Principle

Accident with different severity should be included in the identification and they should be weighted to get increased focus on severity. In literature review the following six weighting principles where identified (Deacon et al.2002, Hauer et al.1996, Taylor and Thompson 1977, Ogden 1996, Ragnoy et al.2002, Hauer et al 2002, European commission 2003, German Road and Transportation Research Association 2003, Overgaard Madsen 2005, Sorensen 2006):

1. Same weight for all accidents
2. Only the most severe accidents included
3. Weighting by number of vehicles
4. Weighting by accident type
5. Weighting by injured road users
6. Combination

As per the best practice guide line on black spot management and road network analysis, the identification criteria for hazardous road section should be comprise severity in addition to frequency. Thus, this study adopts a method of weighting by injured road users since it considers both the frequency and severity of crash recorded.

#### 2.6.3.3.4. Severity Categories

Note that some countries like Norway, Germany and USA also operate with other categories. Norway divides seriously injured into very seriously injured and seriously injured (Ragnoy et al.2002), Germany divides accidents with only property damage into three different categories (German Road and Transportation Research Association 2003), and USA divides minor injury in minor injury and probably minor injury (Khisty 1990).

In addition, the best practice guideline was recommended that the weight for the different severity categories are calculated by use of the monetary valuation and the average number of injured road users of different severity in the different severity categories. This is similar to the method described in German Road and Transportation Research Association (2003) and Sorensen (2006). The argument for the weighting by uses of monetary valuations is that it is more objective and professional than the arbitrary decision, which can be very biased and political. Note, that monetary calculation also consists of some different assumptions, that can be biased.

### 2.6.4. Traffic volume study

Traffic volume studies are conducted to determine the number, movements, and classifications of roadway vehicles at a given location. The length of the sampling period depends on the type of count being taken and the intended use of the data recorded. Count periods may range from 5 minutes to 1 year.

Typical count periods are 15 minutes or 2 hours for peak periods, 4 hours for morning and afternoon peaks, 6 hours for morning, midday, and afternoon peaks, and 12 hours for daytime periods (Robertson 1994). For example, if you were conducting a 2-hour peak period count, eight 15-minute counts would be required.

There are two methods of count are commonly described which are manual method and automatic count method.

#### 2.6.4.1. Manual Count Method

Most applications of manual counts require small samples of data at any given location. Manual counts are sometimes used when the effort and expense of automated equipment are not justified. Manual counts are necessary when automatic equipment is not available.

Manual counts are typically used for periods of less than a day. Normal intervals for a manual count are 5, 10, or 15 minutes. Traffic counts during a Monday morning rush hour and a Friday evening rush hour may show exceptionally high volumes and are not normally used in analysis; therefore, counts are usually conducted on a Tuesday, Wednesday, or Thursday.

Manual counts are recorded using one of three methods: tally sheets, mechanical counting boards, or electronic counting boards. Recording data onto tally sheets is the simplest means of conducting manual counts. The data can be recorded with a tick mark on a pre-prepared field form. A watch or stopwatch is necessary to measure the desired count interval.

#### 2.6.4.2. Vehicle Classification Counts

Vehicle classification counts are used in establishing structural and geometric design criteria, computing expected highway user revenue, and computing capacity. If a high percentage of heavy trucks exists or if the vehicle mix at the crash site is suspected as contributing to the crash problem, then classification counts should be conducted. Typically, cars, station wagons, pickup and panel trucks, and motorcycles are classified as passenger cars. Other trucks and buses are classified as trucks. School buses and farm equipment may be recorded separately. The observer records the classification of the vehicles and the vehicles' direction of travel at the intersection.

# Chapter 3 - METHODOLOGY OF THE RESEARCH

## 3.1. Introduction

The research was executed at Nifas silk Lafto sub city, a sub city that holds the third position by land coverage subsequent to Bole and Yeka sub city. Besides, it holds the second position in experiencing severe type of accidents (AAPC). In addition, it is also known as the third most sub city with occurrences of frequent road traffic accidents. Hence, the study was made on Five arterial road networks of the sub city.

As it was stated before the adopted methodology is executed on arterial roads of Nifas silk sub city and the study was started by collecting three years of accident data from police department of the sub city and Addis Ababa Police Commission. Subsequently, it was followed by statistical analysis and descriptive analysis of accident data. Moreover, the traffic accident pattern of the stated roadways was performed along with the collection and analysis of roadway elements. Finally, the critical roadway elements which are responsible to cause frequent number of accidents were determined. All in all, the detailed methodology is presented on Figure 3-1.

# METHODOLOGY

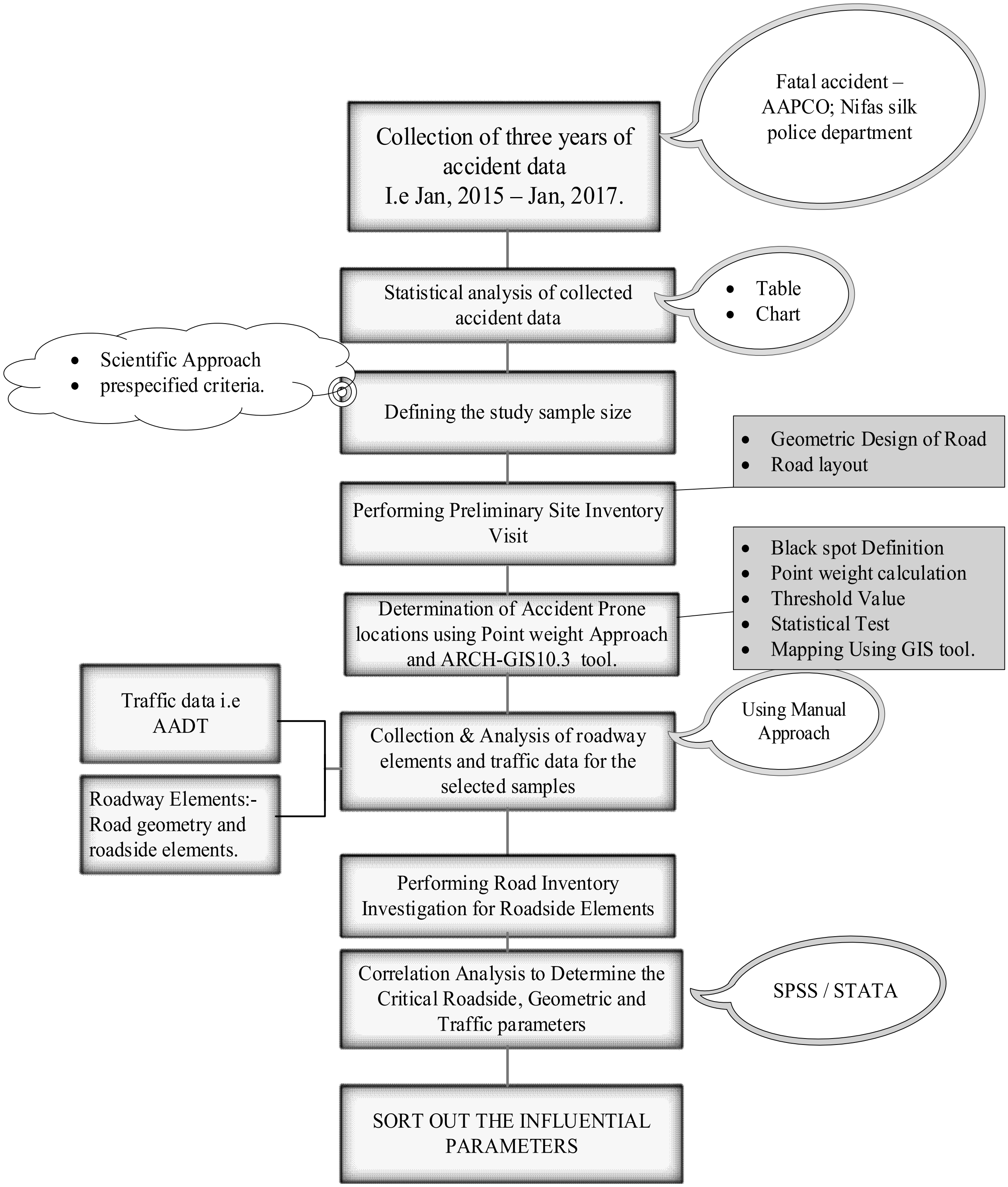


**Figure 3-1. Methodology of the Research.**

## 3.2. Study Area Selection

Generally, as it was mentioned on the previous section of the paper, the research was executed on the safety aspects of existing Arterial roads of Nifas silk Sub City. Specifically, on the occurrences of road traffic accidents and the conceptual reasoning behind selecting the sub city relays on three major facts. Primarily, the sub city has taken the third spot from experiencing the highest percentage of road traffic accident, i.e. 12.3 % of the total number of accidents of the city. while it was preceded by Bole and Kirkos sub city with a percentage share of 18.4 and 16.5 respectively (Source: AAPC 2011/12 – 2014/15 Report).

Secondly, the sub city holds the second most position with experiencing frequent severe and fatal type of crashes. On the other hand, it is also regarded as the second largest sub city of Addis Ababa with a total coverage area of 65.3 square kilometer and it is shown pictorially on Figure 3-2.

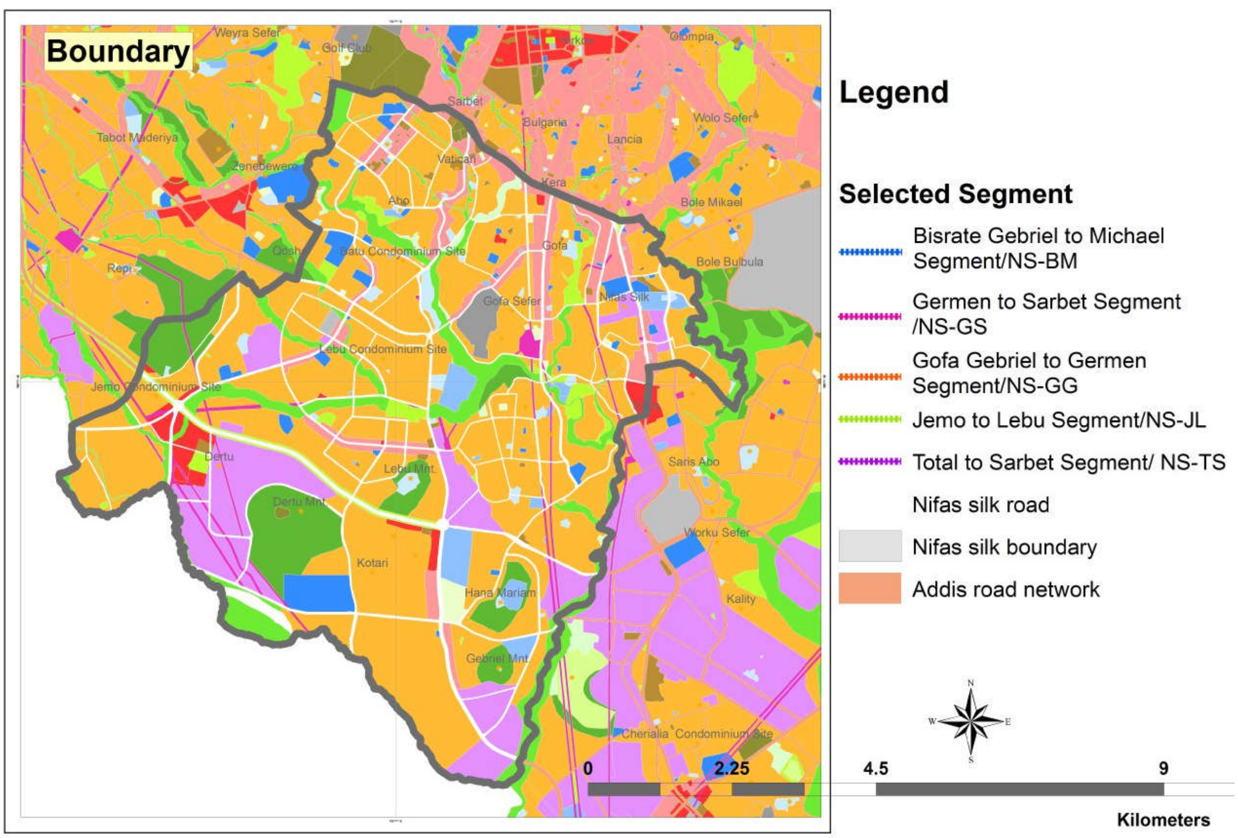


**Figure 3-2. Pictorial Representation of the Study Area Using GIS.**

Moreover, the study road networks were selected from the whole sub city on the basis of its lane number, i.e. Arterial roads with six number of lanes. Accordingly, Five Arterial road networks were selected for executing the stated research and they are presented below in tabular and pictorial representation format on Table 3-1 and Figure 3-3 respectively as follows:

**Table 3-1. Selected Road Networks of the Study.**

| No | Starting Point | Ending Point | Alphanumeric Coding | Total Length (Km) |
|---|---|---|---|---|
| **1** | Biserate Gabriel RA | Michael RA | NS-BM | 2.7 |
| **2** | Jemmo 67 | Lebu RA | NS-JL | 3.0 |
| **3** | Sarbet RA | German RA | NS-GS | 3.7 |
| **4** | Sarbet RA | Total | NS-ST | 3.5 |
| **5** | Gofa Gabriel | German RA | NS-GG | 2.8 |
| | | Total Road Length | | **15.14** |

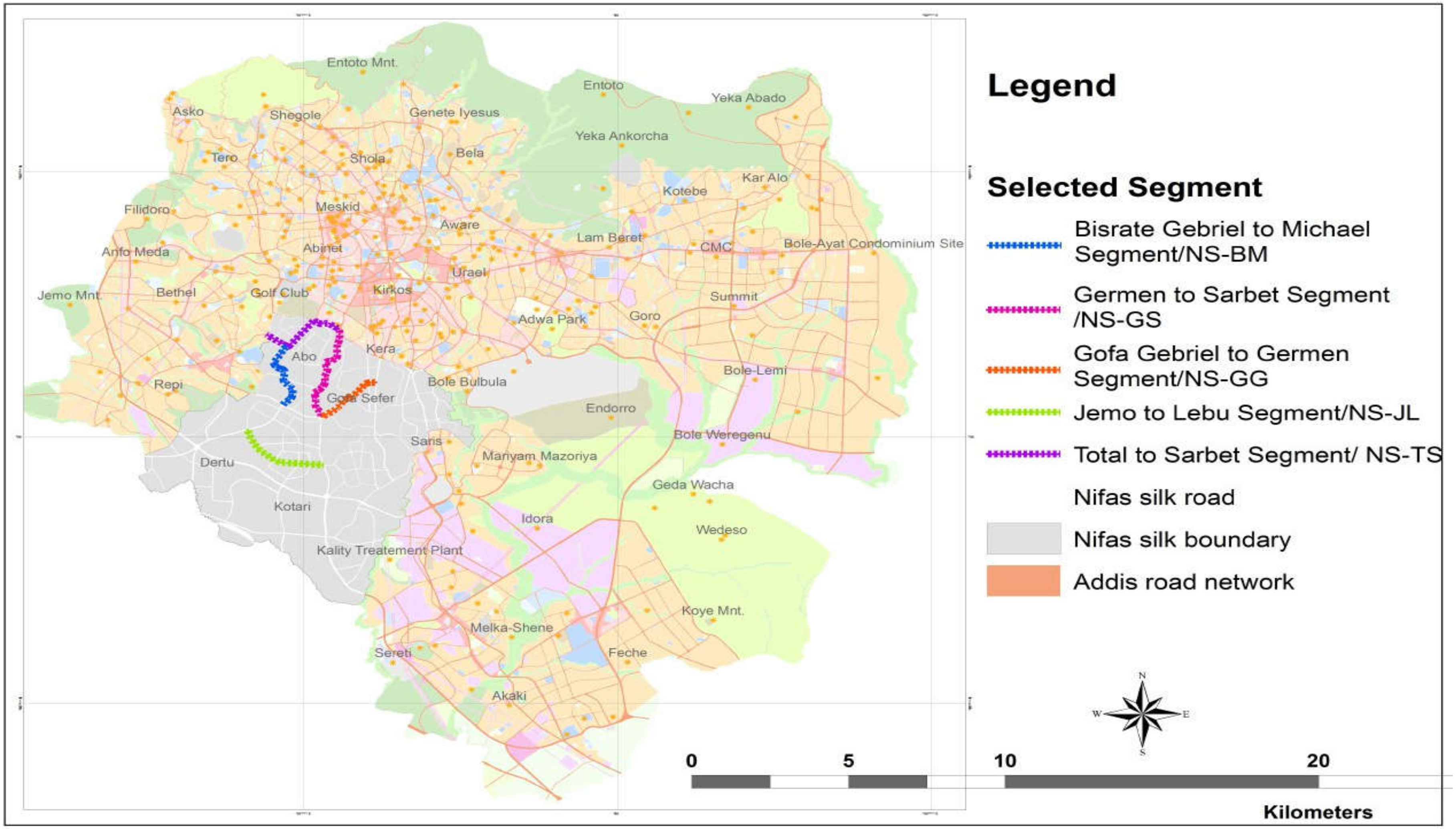


**Figure 3-3. Pictorial Representation of Selected Streets using GIS.**

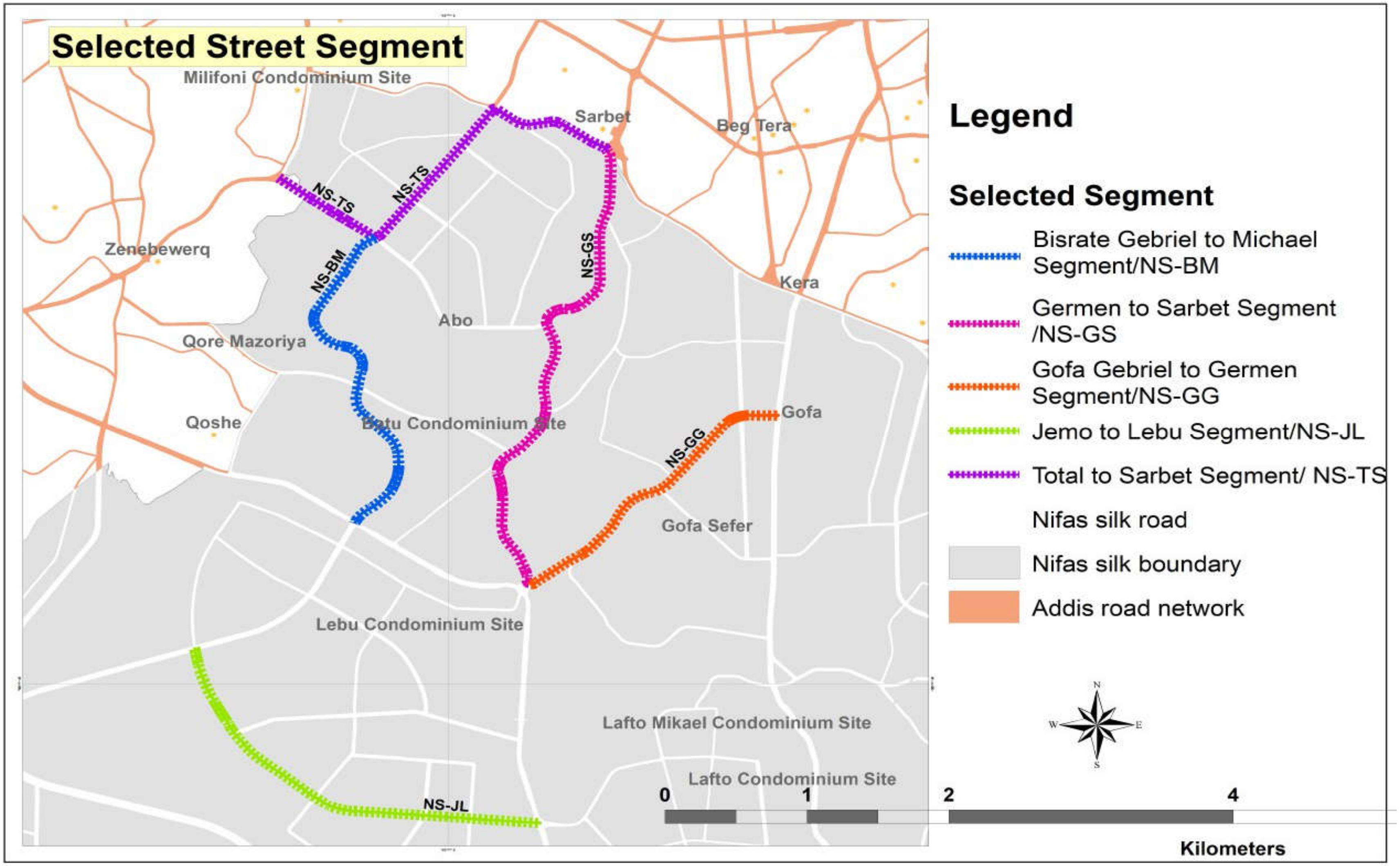


**Figure 3-4. Brief Presentation of the Selected Study Streets using GIS.**

The study samples were extracted from five arterial road networks on the basis of systematic and pre-specified criteria. Moreover, the criteria were organized using engineering approaches and subjective judgement. The study samples were sorted out by dividing the above selected arterial road networks into smaller defined road sections on the basis of homogenous geometric alignment and concept of traffic characteristics principle. Hence, the road sections are characterized by having variable road length, alignment (horizontal and vertical), grade (upgrade, flat and downgrade) and traffic volume. Finally, thirty-six (36) samples were found relevant and selected to execute the research. Moreover, the selected road segments are represented using alphanumeric coding according to the previously stated coding on Table 3-1 and presented in pictorial format on Figure 3-5.

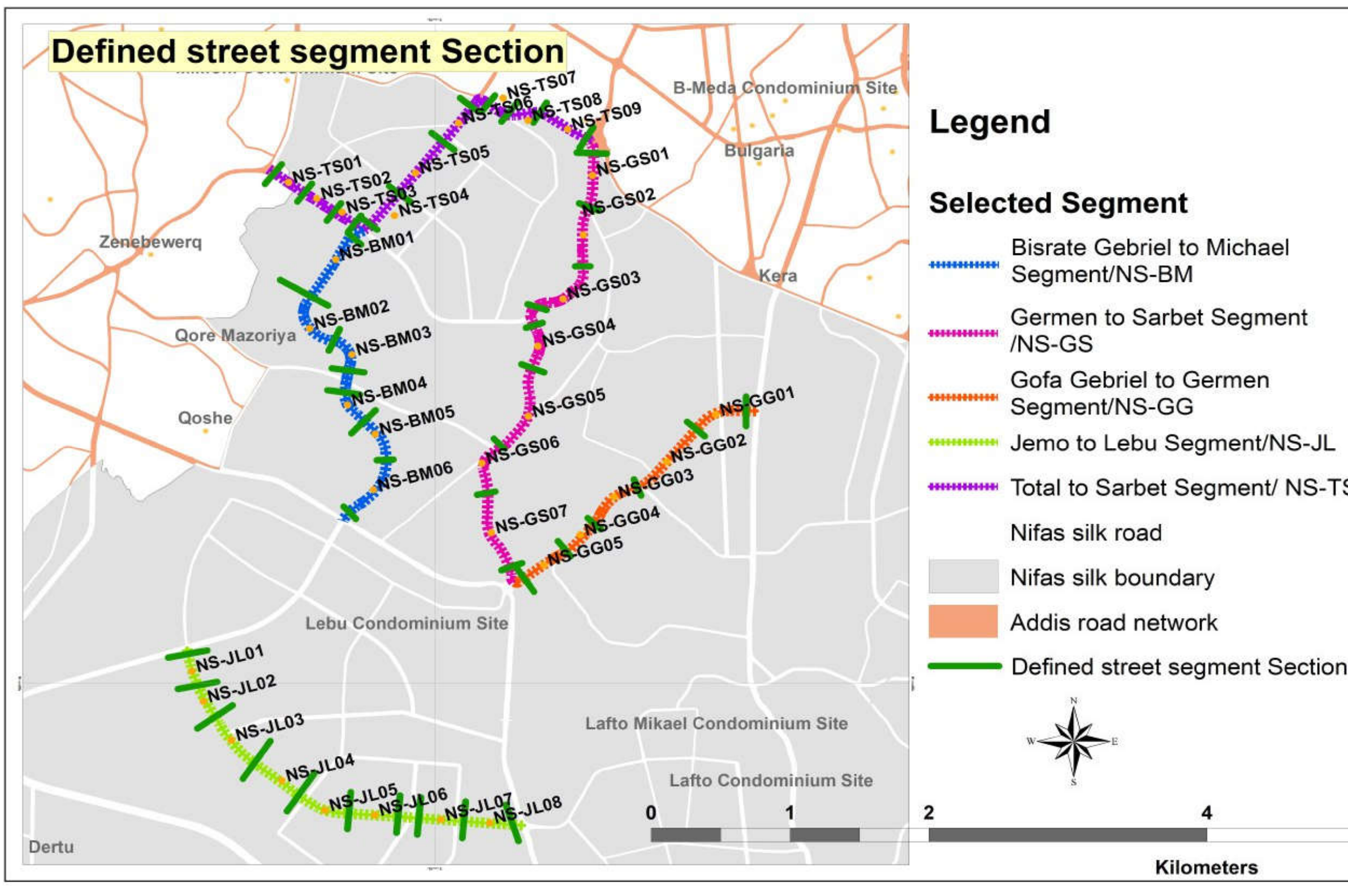


**Figure 3-5. Pictorial Representation of the Selected Samples.**

## 3.3. Data Collection

The research has employed two types of data namely; primary and secondary data where secondary data was collected to understand and determine the accident characteristics of the entire road networks. Conversely, primary data comprises geometric data, traffic characteristics of the selected road networks and roadside elements where geometric data consists of lane width, horizontal alignment (straight and curve), Vertical (upgrade and downgrade), median width, set back distance, presence of median opening, median type, walkway width, availability of parking, number of U-turn and right of way width. While traffic characteristics include variables such as vehicular traffic volume, pedestrian volume and spot speed.

On the other hand, road side elements include various parameters such as objects next to the road (posts, walls, vegetation's), set back distance (trees, buildings, vegetation, signage, furniture, light pole), road side access point, sign and sign legibility (availability and sign functionality), roadside activities (land use, different unforeseen roadside barriers), and finally distraction and overload (No of sign traffic and presence of visual clutter).

Moreover, the employed primary data are used to synthesis the overall analysis of the study. Subsequently, it is adopted to accomplish the general and specific objectives of the study. Hereafter, the above stated data types are presented along with their respective indicators in a detailed approach.

### 3.3.1. Secondary Data

#### 3.3.1.1. Accident Data

Road traffic accident data is the secondary source for the research and it mainly deals with the historical accident data of the selected road networks. In addition, three years of accident data, from January 01, 2015 to January 01, 2017 have been employed for performing the accident analysis where the data were gathered from two major sources such as Addis Ababa Police Commission (AAPC) and police department of Nifas silk sub city. Accordingly, the three years' accident data were found relevant enough to perform traffic safety analysis through referring previously executed researches.

A study made by Elvik (2008b) disclosed that three years of accident data is marginal to execute black spot study and it was also employed frequently on studies of many scholars such as Cheng and Washington (2005), LNTZ (2004).

The accident data were collected from the prepared data sheet of the police station and AAPCO using manual approach where a concise format was developed by selecting suitable parameters such as date of accident, time of accident, accident type, severity level, vehicle type, specific location, road layout and land use.

Therefore, up on the collected accident data, Nifas silk sub city has been experiencing a total of 8,622 number of accidents were recorded within three years where 7,198 are of POD types. While 533, 694 and 210 accidents were light injury, severe injury and fatal types of accident respectively. Moreover, summarized collected data of the entire sub city is presented accordingly on Table 3-2.

**Table 3-2. Accident Distribution of Nifas Silk Sub City According to Three Year.**

| Year | Frequency | POD | L | S | F |
|---|---|---|---|---|---|
| **2015** | 2601 | 2079 | 226 | 232 | 64 |
| **2016** | 2870 | 2423 | 158 | 231 | 69 |
| **2017** | 3151 | 2696 | 149 | 231 | 77 |
| **Total** | **8,622** | **7,198** | **533** | **694** | **210** |

**Table 3-3. Accident Data Collecting Format with Sample Data.**

| No | Date | Time | Accident Type | Vehicle Type | Severity | Land Use | Road Layout | Specific Location | *Legend* | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22/4/2007 | 21:00 | VP | A | S | C | SL | Abo RA | **Accident Type** | |
| 2 | 22/4/2007 | 13:45 | VV | A | POD | C | SL | Varnero | Vehicle to Vehicle | VV |
| 3 | 22/4/2007 | 2:00 | VV | mB | POD | C | CL | Biserate Gebriel RA | Vehicle to Pedestrian | VP |
| 4 | 22/4/2007 | 18:30 | VV | mB | POD | C | SL | Meskel Kitfo | Vehicle to Object | VO |
| 5 | 22/4/2007 | 14:30 | VV | A | S | C | SL | Bridge | Vehicle Overturn | VOT |
| 6 | 22/4/2007 | 7:00 | VV | A | S | C | SL | Abo Gulit | Passenger Fall | PF |
| 7 | 22/4/2007 | 8:30 | VV | A | POD | C | SL | Safeway Supermarket | Vehicle to Bajaj | VB |
| 8 | 22/4/2007 | 1:20 | VO | A | POD | C | SL | Meskel Kitfo | Vehicle to Motor C. | VM |
| 9 | 22/4/2007 | 7:00 | VV | mB | POD | C | SL | Shell Depo | Vehicle to Bicycle | VBC |
| 10 | 22/4/2007 | 9:45 | VV | A | POD | C | SL | Bridge | VCART | VCA |
| 11 | 23/4/2007 | 9:00 | VV | A | POD | O | SL | Canada Embassy | Vehicle to Animal | VA |
| 13 | 23/4/2007 | 13:30 | VV | A | POD | Ch | SL | Adey Abeba | **Vehicle Type** | |
| 14 | 23/4/2007 | 3:10 | VV | A | POD | C | CL | Biserate Gebriel RA | Automobile | A |
| 15 | 23/4/2007 | 17:30 | VP | mB | S | C | SL | Glass Factory | Minibus | mB |
| 16 | 23/4/2007 | 10:45 | VV | MT | POD | C | CL | German RA | Medium Bus | MB |
| 17 | 23/4/2007 | 23:00 | VV | A | POD | C | CL | German RA | Bus | B |
| 18 | 23/4/2007 | 16:00 | VV | A | POD | R | SL | Kore Condominium | Medium Truck | MT |
| 19 | 24/4/2007 | 7:30 | VV | A | POD | O | SL | INSA | Heavy Truck | HT |
| 20 | 24/4/2007 | 17:30 | VP | mB | S | R | SL | Condominium | Articulated Truck | AT |
| 21 | 24/4/2007 | 14:30 | VV | HT | POD | C | SL | Bridge | Machines | M |
| 23 | 24/4/2007 | 9:40 | VV | A | POD | C | SL | Glass Factory | **Severity** | |
| 24 | 24/4/2007 | 11:30 | VV | A | POD | C | SL | Bridge | Severe | S |
| 25 | 24/4/2007 | 23:30 | VP | mB | S | O | SL | Ethiopian Cu. & Re. | Medium | M |
| 26 | 25/4/2007 | 10:10 | VV | MT | POD | O | SL | Ethiopian Cu. & Re. | Light | L |
| 27 | 25/4/2007 | 7:20 | VV | BAJAJ | POD | C | SL | Meskel Kitfo | Property only damage | POD |
| 28 | 25/4/2007 | 11:00 | VV | MT | POD | C | SL | Muzika bet | Fatal | F |
| 30 | 25/4/2007 | 19:30 | VV | A | POD | O | SL | Meskelegna | **Land Use** | |
| 31 | 25/4/2007 | 15:45 | VV | A | POD | C | SL | Safeway Supermarket | Residential | R |
| 32 | 25/4/2007 | 9:30 | VV | mB | POD | O | SL | Vatican Embassy | Commercial | C |
| 33 | 26/4/2007 | 12:00 | VV | A | POD | R | SL | Condominium | Office | O |

### 3.3.2. Primary Data

This section presents the collected data under three independent categories such as geometric, traffic characteristics and finally roadside elements where each of them consists of many more indicators. Hence, each categories of data are presented along with the detail parameters as follows.

#### 3.3.2.1. Geometric Data

Generally, geometric data deals about the entire engineering design of the road network, it mainly comprises the design of cross-sectional elements, vertical alignments, horizontal alignment and intersections. And these parameters have a direct and indirect influence for the occurrences of road traffic accidents. Particularly, this research used to adopt geometric parameters that are presumed to cause frequent road traffic accidents such as lane number, lane width, median width, walk way width, clear zone distance, road layout (straight / curve), vertical grade (flat, sloppy), availability of U-turn, presence of median opening etc. Moreover, the detail geometric variables were collected by manual approach using the prepared geometric check lists. And it is presented in tabular form on Table 3-4 as follows: -

**Table 3-4. Geometric Data Collection Format.**

| No | GEOMETRIC DESIGN ELEMENTS | | ROAD SEGMENTS | | | | | | | REMARK |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Cross - sectional elements** | | | | | | | | | |
| 1.1 | *Walkway Width (m)* | | | | | | | | | |
| 1.2 | *Median width (m)* | | | | | | | | | |
| 1.3 | *Median side Lane width (m)* | | | | | | | | | |
| 1.4 | *Middle Lane width (m)* | | | | | | | | | |
| 1.5 | *Edge lane width (m)* | | | | | | | | | |
| 1.6 | *Traveled lane average width (m)* | | | | | | | | | |
| 1.7 | *Right of way average width (m)* | | | | | | | | | |
| 1.8 | *Number of U-Turn* | | | | | | | | | |
| 1.9 | *Types of median* | *20cm curb stone* | | | | | | | | |
| | | *Concrete grade separated* | | | | | | | | |
| | | *Without barrier* | | | | | | | | |
| | | *With barrier* | | | | | | | | |
| 1.10 | *Median Opening* | *Absent* | | | | | | | | |
| | | *Present* | | | | | | | | |
| | | *Number* | | | | | | | | |
| 1.11 | *Parking Availability* | *Yes* | | | | | | | | |
| | | *No* | | | | | | | | |
| 2 | **Horizontal Alignment** | *Straight* | | | | | | | | |
| | | *Curve* | | | | | | | | |
| 3 | **Vertical Alignment** | *Flat* | | | | | | | | |
| | | *Sloppy* | | | | | | | | |

### 3.3.2.2. Roadside Environment Data

The roadside environment consists of all of the surrounding that are visible from the road, particularly those objects near to the road that have the potential to become obstacles in the path of vehicles that run off the road. Although not part of the road geometry, these aspects can be considered part of the road design. And this research considered the roadside environment elements under six major pillars such as object next to the road, set back distances, access points, signs and its functionality, distraction and overload etc. Moreover, individual indicators that are found under the above stated categories are presented accordingly on Table 3-5 as follows.

**Table 3-5. Roadside Environment Data Collection Format.**

| Roadside Environment Data | | ROAD SEGMENTS | | | | | | | REMARK |
|---|---|---|---|---|---|---|---|---|---|
| **1.Object next to the road** | | | | | | | | | |
| 1.1. | Posts (Yes/No) | | | | | | | | |
| 1.2. | Walls (Yes/No) | | | | | | | | |
| 1.3. | Vegetation (Yes/No) | | | | | | | | |
| **2.Set back distance (m)** | | | | | | | | | |
| 2.1. | Tree | | | | | | | | |
| 2.2. | Building | | | | | | | | |
| 2.3. | Vegetation | | | | | | | | |
| 2.4. | Signage/Traffic Sign | | | | | | | | |
| 2.5. | Furniture's | | | | | | | | |
| 2.6. | Light pole | | | | | | | | |
| 2.7. | Trash cane/Receptacle | | | | | | | | |
| **3.Access point** | | | | | | | | | |
| 3.1. | Number | | | | | | | | |
| 3.2. | Entry/Exit | | | | | | | | |
| **4.Sign & Sign legibility** | | | | | | | | | |
| 4.1. | Availability (Yes/No) | | | | | | | | |
| 4.2. | Sign legibility (Yes/No) | | | | | | | | |
| **5.Distraction & Overload** | | | | | | | | | |
| 5.1. | No of traffic sign | | | | | | | | |
| 5.2. | Presence of visual clutter (Yes/No) | | | | | | | | |
| **6. Different Unseen Roadside Barriers,** | | | | | | | | | |
| 6.1. | Illegal functions like street vendors, | | | | | | | | |
| 6.2. | Construction Materials on sidewalk &waste accumulation | | | | | | | | |

### 3.3.2.3. Traffic Characteristics Data

The traffic characteristics of road networks generally consists of data regarding the traffic volume (vehicular traffic), and speed (spot speed). But this research focuses on collecting relevant traffic characteristics data of the selected road networks from two independent studies such as vehicular traffic volume and spot speed studies. The traffic volume studies were performed by using manual approach on the identified accident-prone locations. Similarly, the spot speed study was also executed on those roads using stop-watch approach. Moreover, detailed explanation regarding the respective studies are presented below under two sub topics.

#### 3.3.2.3.1. Vehicular Traffic Volume Studies

Traffic volume studies are conducted to determine the number, movements, and classifications of roadway vehicles at a given location. The length of the sampling period depends on the type of count being taken and the intended use of the data recorded. Count periods may range from 5 minutes to 1 year. Typical count periods are 15 minutes or 2 hours for peak periods, 4 hours for morning and afternoon peaks, 6 hours for morning, midday, and afternoon peaks, and 12 hours for daytime periods (Robertson 1994). Moreover. According to the hand book of simplified practice for traffic studies, 2002, traffic counts during Monday morning rush hour and a Friday evening rush hour may show exceptionally high volumes and are not normally used in the analysis; therefore, counts are usually conducted on a Tuesday, Wednesday and Thursday. Hence, this research used 4 hours count for morning and afternoon peaks for four days where one day is from the weekend i.e. Saturday and three days from the weekday i.e. on Tuesday, Wednesday and Thursday respectively. And the study was executed on the selected accident-prone segments. The traffic counts were collected by manual approach using the prepared traffic counting sheet.

Furthermore, the data collection was executed by ten employed data collectors where they have conducted the counting activity on similar days of three consecutive weeks i.e. on Tuesday, Wednesday, Thursday and Saturday. Since fifteen accident prone locations were identified, primarily, traffic volume studies of five locations were executed on the first week i.e. on April 10, 11, 12 and 14, 2018 while the second count was made on the subsequent week starting from April 17, 18, 19 and 21, 2018. Finally, the last week counting was made for the remaining four accident prone locations on April 24, 25, 26 and 28. Besides, the prepared sheet is presented on the table below, Table 3-6.

**Table 3-6. Manual traffic count collection format.**

<table>
<tr><th colspan="5">Manual Traffic Count</th></tr>
<tr><td colspan="2">Date:</td><td>Day of Week: Tu O We O Th O Sa O Counting Duration:</td><td colspan="2">Counting Direction</td></tr>
<tr><td rowspan="2">No</td><td rowspan="2">Vehicle type</td><td>Data Collector Name: Segment Designation:</td><td>NB O</td><td>SB O</td></tr>
<tr><td colspan="2">Traffic Volume</td><td>Remark</td></tr>
<tr><td>1</td><td>Small Cars</td><td colspan="2"></td><td></td></tr>
<tr><td>2</td><td>Pick-up/4WD</td><td colspan="2"></td><td></td></tr>
<tr><td>3</td><td>Small Bus</td><td colspan="2"></td><td></td></tr>
<tr><td>4</td><td>Bus</td><td colspan="2"></td><td></td></tr>
<tr><td>5</td><td>Small truck</td><td colspan="2"></td><td></td></tr>
<tr><td>6</td><td>Medium truck</td><td colspan="2"></td><td></td></tr>
<tr><td>7</td><td>Heavy truck</td><td colspan="2"></td><td></td></tr>
<tr><td>8</td><td>Articulated truck</td><td colspan="2"></td><td></td></tr>
</table>

Furthermore, the employed vehicle classification was taken from Ethiopian road authority (ERA) pavement design manual Volume I, 2013, chapter two and it is presented accordingly on Table 3-7 as follows.

**Table 3-7. Vehicle classification (Source: ERA-Chapter 2, 2013).**

| Class | Type | Description |
|---|---|---|
| 1 | Car | Passenger cars and taxis |
| 2 | Pick-up/4WD | Pick-up, minibus, Land Rovers, Land Cruisers |
| 3 | Small Bus | <= 27 Seats |
| 4 | Bus/Coach | > 27 seats |
| 5 | Small truck | <= 3.5 tonnes |
| 6 | Medium truck | 3.5-7.5 tonnes |
| 7 | Heavy truck | > 7.5 tonnes |
| 8 | Articulated truck | >7.5 tonnes and Truck with additional extension |

### 3.3.2.3.2. Spot Speed Studies

Speed is an important transportation consideration because it relates to safety, time, comfort, convenience, and economics. Spot speed studies are used to determine the speed distribution of a traffic stream at a specific location. The data gathered in spot speed studies are used to determine vehicle speed percentiles, which are useful in making many speed-related decisions. Robertson, 1994, disclosed that spot speed data have a number of safety applications such as Determining existing traffic operations and evaluation of traffic control devices; Establishing roadway design elements; Assessing roadway safety questions; Monitoring traffic speed trends by systematic ongoing speed studies and Measuring effectiveness of traffic control devices or traffic programs, including signs and markings, traffic operational changes, and speed enforcement programs.

For a spot speed study at a selected location, a sample size of at least 50 and preferably 100 vehicles are usually obtained (Ewing 1999). Therefore, this research performed the spot speed studies on the identified black spot locations using manual approach and it was executed on 100 samples.

On the other hand, the procedure and selected length for making the appropriate spot speed studies was taken from the hand book of simplified practice for traffic studies, 2004; chapter one. Furthermore, the recommended length is presented on the following table as follows, Table 3-8.

**Table 3-8. Recommended Spot Speed Study Lengths.**

| Traffic Stream Average Speed | Recommended study Length (feet) |
|---|---|
| Below 25mph | 88 |
| 25-40 mph | 176 |
| Above 40 mph | 264 |

Besides, the study was performed using standard tally sheet and presented accordingly on Table 3-9.

**Table 3-9. Spot Speed Study Collection Format.**

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | | | | | | | Start Time: | | | | | | | | | | |
| Name: | | | | | | | | End Time: | | | | | | | | | | |
| Accident - Prone Location ID: | | | | | | | | Down Time: | | | | | | | | | | |
| Data Collector Name: | | | | | | | | Weather: | | | | | | | | | | |
| Seconds | Km/hr for 53.6 m. | **Smaller Cars** | | **Pickup / 4WD** | | **Small Bus** | | **Bus** | | **Small truck** | | **Medium Truck** | | **Heavy Truck** | | **Articulated Truck** | | **Total** |
| | | Record | No. | Record | No. | Record | No. | Record | No. | Record | No. | Record | No. | Record | No. | Record | No. | |
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## 3.4. Research and Data Analysis Approach

This section presents a brief regarding the adopted approaches for dividing the selected road networks, point weightage approach and the provided definition of black spot locations.

### 3.4.1. Accident data Analysis

#### 3.4.1.1. Relevant Definition of Prone Location (Black Spot location)

Many Scholars define black spot with various format and terminology, and referring to many previously executed researches and literatures, this research found a relevant definition and employed it for the accomplishment of the research. The definition was set by Overgaard (2005) and tried to discuss the detail criteria for identifying black spot locations. As such the author disclosed that an adequate black spot location should satisfy four criteria:

1. It should control for random fluctuations in the number of accidents;
2. It should account for as many of the factors that are known to influence road safety as possible;
3. It should identify sites at which fatal and serious injury accidents are over-represented;
4. It should identify sites at which local risk factors related to road design and traffic control make a substantial contribution to accidents.

#### 3.4.1.2. Road Division Approach

As it was stated in the previous section of this chapter, the selected five road networks were subjected to road division approaches for augmenting the reliability and accuracy of the research analysis. And the employed road division methodology is of homogeneity type where road networks are divided according to similar road layout and traffic characteristics. In addition, the road division approach was developed according to the previously executed researches and literatures. For instance, best practice guideline on BSM and safety analysis by Elvik. R recommended to divide the road systems with homogenous principles (homogenous traffic and roadway elements). In addition, the road networks should be divided in to smaller and variable roadway lengths (Elvik. R, 2007). Moreover, the study made by Hauer et.al, 2002 also reinforced that adopting smaller and variable road segment length is the better approach to deal with analysis of accident-prone locations.

#### 3.4.1.3. Adopted Point Weightage Approach

The three years of accident data of the respective locations were cumulated using point weightage approaches where the approach considers various injury types by giving different point weights. Speaking of point weightage approach, many scholars have made researches and developed various point weights.

And this research adopted point weight approach developed by Malaysia. (Guideline on Accident-Prone Area Identification for Malaysia, 2013; Page 12). The basic reason behind adopting the approach relays on two basic reasons: Primarily, it considers all types of accident severity levels (POD, Light (slight) Injury, Serious Injury and Fatal). On the other hand, the point weights were developed for developing country, Malaysia. Hence, as part of the developing country, it was found relevant to adopt the weights for our country, Ethiopia. Moreover, the employed point weight approaches are presented on the Table 3-10 below.

**Table 3-10. Selected Point Weightage Approach.**

| No | **Accident Severity** | **Weightage points** |
|---|---|---|
| 1 | Fatal | 6 |
| 2 | Serious | 4 |
| 3 | Slight | 2 |
| 4 | Damage only | 1 |

#### 3.4.1.4. Determination of Accident-Prone Location

The accident-prone locations of the road networks were identified by following three critical procedures where the first procedure deals with calculation of total accident number using the employed point weights. Subsequently, the threshold value was determined to identify accident prone locations. Hence, accident locations which exceeded the threshold value are identified as an accident-prone location and subjected for further statistical test to check whether they were selected by chance. The statistical test was found to be a useful tool to augment the accuracy and reliability of the selection process. Hereafter, detail description of the adopted threshold value and statistical checking method are presented below.

#### 3.4.1.4.1. Threshold Value

This step is aimed to identify a list of accident-prone locations from the selected samples of divided road sections. And the identification is based on the threshold value of observed numbers of injury accidents at every location in the sample in three consecutive years. According to the paper of Nguyen.et.al, 2016, the simplest way to select the threshold value for the sample is presented on the aforementioned Equation;

$$\mathbf{Threshold - value \ = \ max\ (X, m)}$$

Where: X = the average value, and

m = the median value of the sample.

Since our country, Ethiopia did not speculate a standard reference or approach to identify accident prone locations, this research has adopted simple statistical approach for identifying high accident-prone locations i.e. Threshold – value. In addition, the method was developed to select accident prone locations for the case of developing country, Malaysia.

Any site with observed number of accidents higher than the threshold value is listed as a high accident frequency location. Sites that have more accidents than the mean plus one standard deviation (X + deviation) should be the first to be single out for further consideration.

### 3.4.1.5. Mapping Accident Prone Locations Using Arch-GIS 10.3 Tool

The relevant data of the identified accident-prone locations are organized and subjected to mapping using GIS tool. And the procedure of the mapping is presented as follows:

A. The prepared accident database of the study samples is converted to geospatial data i.e their specific location is encoded relevantly;
B. The density of accident number is encoded using boundary approach;
C. Finally, mapping of the accident-prone location is executed using the encoded spatial accident database.

### 3.4.2. Correlation Analysis Using SPSS

Prior to the correlation analysis, the collected roadway data such as geometric, roadside and traffic characteristics data of the identified accident-prone locations are sorted out and organized in a relevant manner. Subsequently, proper correlation approach is adopted according to the type of the selected explanatory variables. Furthermore, the organized roadway data of the identified accident-prone locations are encoded relevantly in to the SPSS software package. Finally, the required correlation analysis is executed using the adopted approach. In conclusion, the result of the correlation analysis is used in chapter 4 of the paper along with knowledge from previous studies and engineering judgement to draw proper discussion and conclusion.

# Chapter 4 - RESULTS AND DISCUSSION

## 4.1. Descriptive Analysis of the Accident Data

As it can be depicted easily from the exhibited data of the three-year accident analysis both the accident frequency and POD type of crash shows a consecutive augmentation through 2015 to 2017. In contrary, the number of light injuries reduced year to year i.e. the highest recorded on 2015, 226 while the lowest was on 2017, 149 which is followed by 2016 with a frequency of 158. Looking to severe type of accident the sub city has been experienced similar pattern with an equal number of accident occurrence. Moreover, fatal type of accident increased from year to year with a recorded accident number of 64, 57 and 75 respectively. All in all, the accident pattern of the three years points out there must be given a special attention towards executing intense researches on the possible risk factors that are presumed to cause road traffic accidents.

Generally, the Addis Ababa police commission has been adopted a unique format to register the road traffic accident. The format comprises various indictors to represent a specific accident such as day of month, time of day, severity, type of crash, location, road condition, age of driver, type of vehicle …etc. although, this section focuses its attention on six relevant parameters which indirectly or directly have an association with roadway elements for the occurrence of traffic accidents such as time of day, type of crash, type of vehicle, severity, land use, functional classification and specific location. Accordingly, the three years' traffic accident data were compiled and sorted for preparing the respective histogram to narrate about the situation based on subjective and scientific manner.

### 4.1.1. Traffic Accident Analysis According to Time of Day

Moreover, the basic justification behind the first scenario relays on the fact that the highest traffic volume demand or number of trips generated to works, schools etc. are experienced during early morning. Whilst, the occurrence of maximum severe and fatal accidents recorded during early evening owing to the presence of fatigue and improper alertness of drivers, inconsistent lighting condition, aggressive crossing behavior of pedestrians etc.

Speaking of the lowest accident number, the minimum frequency has been experienced from 3:01 – 4:00. And the possible reasoning might be either the traffic volume during this duration is very low or the number of pedestrians is low as compared to that of the peak hours.

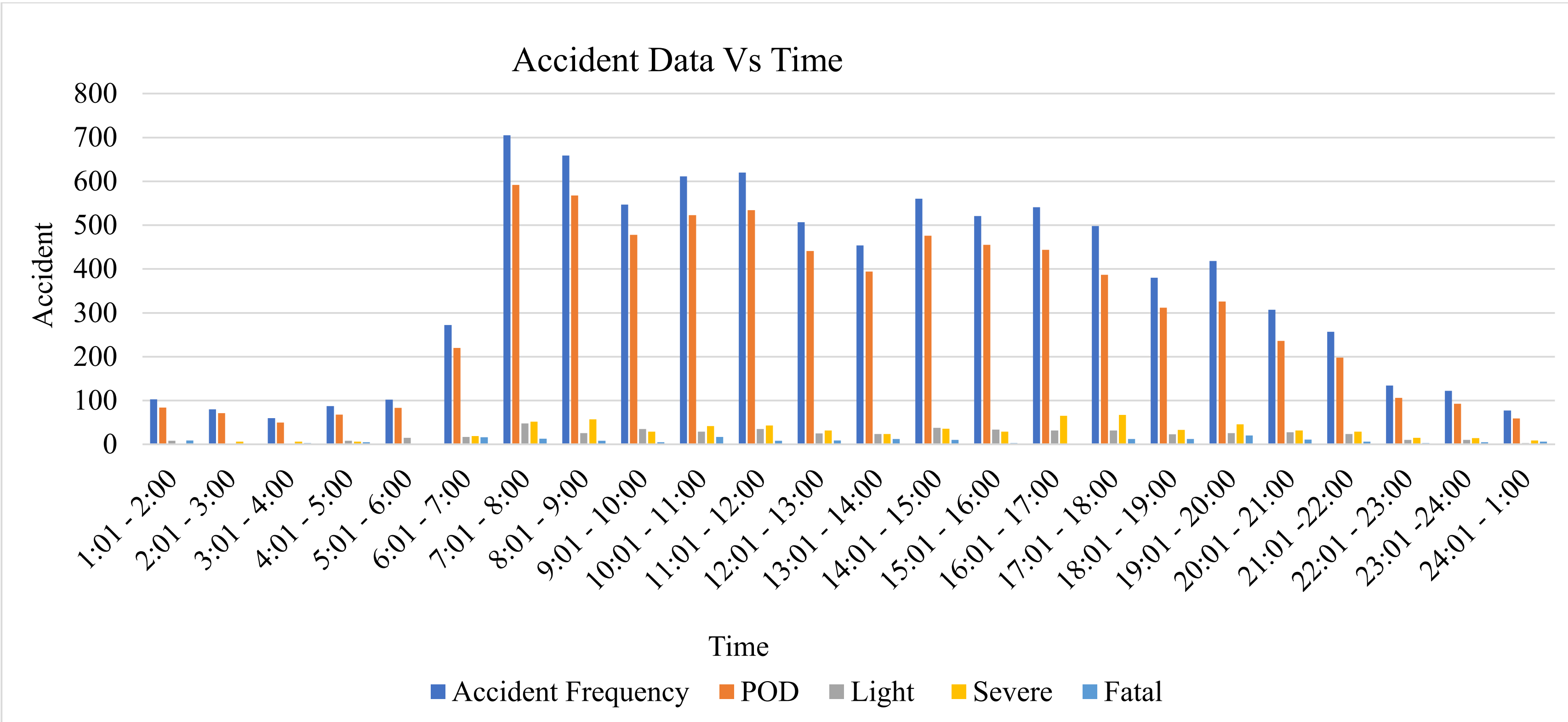
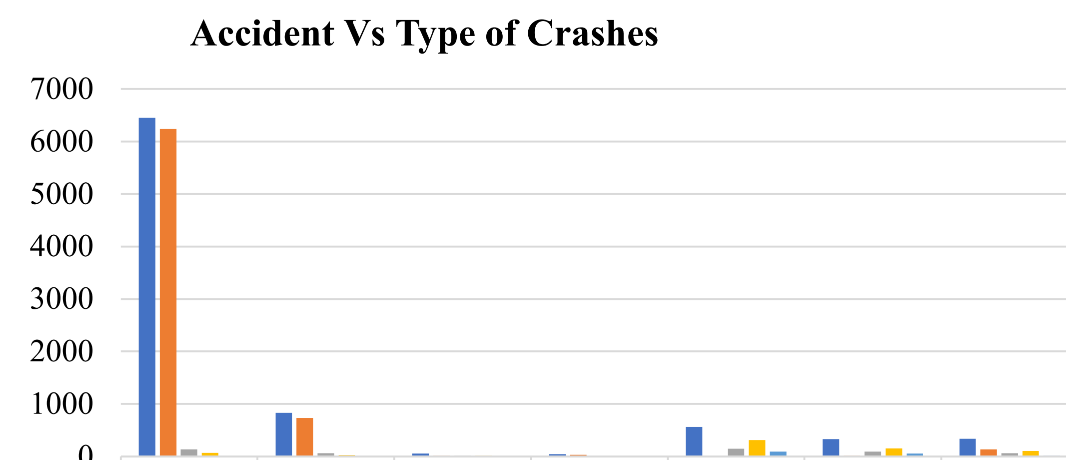



**Figure 4-1. Accident Analysis According to Time of the Day.**

### 4.1.2. Traffic Accident Variation Based on Type of Crash

As it is presented on the figure below, Figure 4-2, the highest number of road traffic accident was recorded between vehicles i.e. 6,446 while crashes between vehicle to object takes the second rank with a recorded accident number of 832. On the other hand, the maximum fatal and severe type of crash was recorded between vehicle to pedestrian type of collision. And the subsequent position was handled by vehicle over-turn. Conversely, the lowest number of severe types of crash was recorded on crash between Vehicle-Motor-Pedestrian with a numerical value of 4 where it was preceded by vehicle to motor bicycle type of crash with a value of 18. Moreover, the highest light injury type of accident was recorded between vehicle to pedestrian type of crash followed by vehicle to vehicle and vehicle over-turn i.e. 152, 134 and 95 respectively.




| | VV | VO | VM | VMPa | VP | VOT | Other |
|---|---|---|---|---|---|---|---|
| Accident Frequency | 6446 | 832 | 58 | 48 | 563 | 331 | 341 |
| POD | 6235 | 736 | 20 | 36 | 0 | 24 | 139 |
| Light | 134 | 63 | 18 | 4 | 152 | 95 | 66 |
| Severe | 72 | 25 | 18 | 4 | 316 | 154 | 106 |
| Fatal | 5 | 8 | 2 | 4 | 94 | 59 | 23 |

**Figure 4-2. Accident Analysis According to the Type of Crash.**

### 4.1.3. Accident Analysis According to Vehicle Type

As it is shown on the figure below, Figure 4-3, about 55% of the total recorded crash in Nifas silk lafto sub city were by automobile. Subsequently, heavy trucks hold the 2nd position with a percentage share of 13%. While the 3rd and 4th positions were handled by heavy trucks and medium trucks with 13% and 6% respectively. Conversely, the lowest percentage contribution was recorded by machineries, i.e. 1% of the recorded traffic accident.

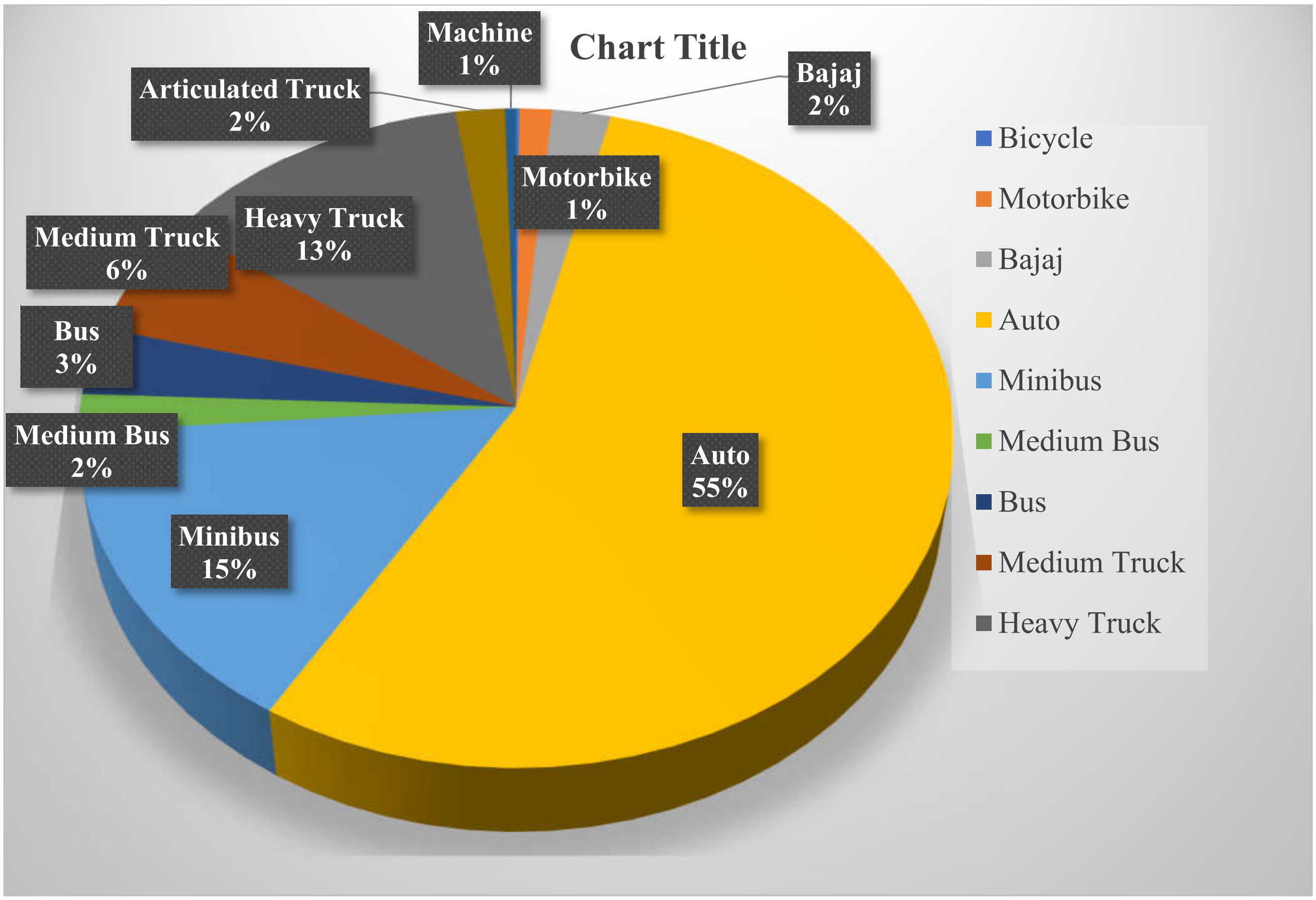



**Figure 4-3. Accident Analysis According to Vehicle Type.**

### 4.1.4. Analysis of Accidents According to Severity

Generally, as it is shown on the figure below, Figure 4-4 the accident frequency and POD type of crashes were shows a significant increment from 2015 to 2017. Numerically 2601,2870 and 3151 accident number were recorded on the year 2015, 2016 and 2017 respectively. Similarly, 2079, 2423 and 2696 POD type of crashes were recorded in the year of 2015, 2016 and 2017 respectively. While light injury shows decreasing from 2014 to 2016 which is 226 in 2015, 158 in 2016 and 149 in 2017. Although, sever injury goes to down in the year of 2016 then it would be constant in 2017. Regarding fatal type of crashes, the number shows fluctuation where the higher was recorded by 2017 but it was a little bit lower by the year 2016 than that of 2015.

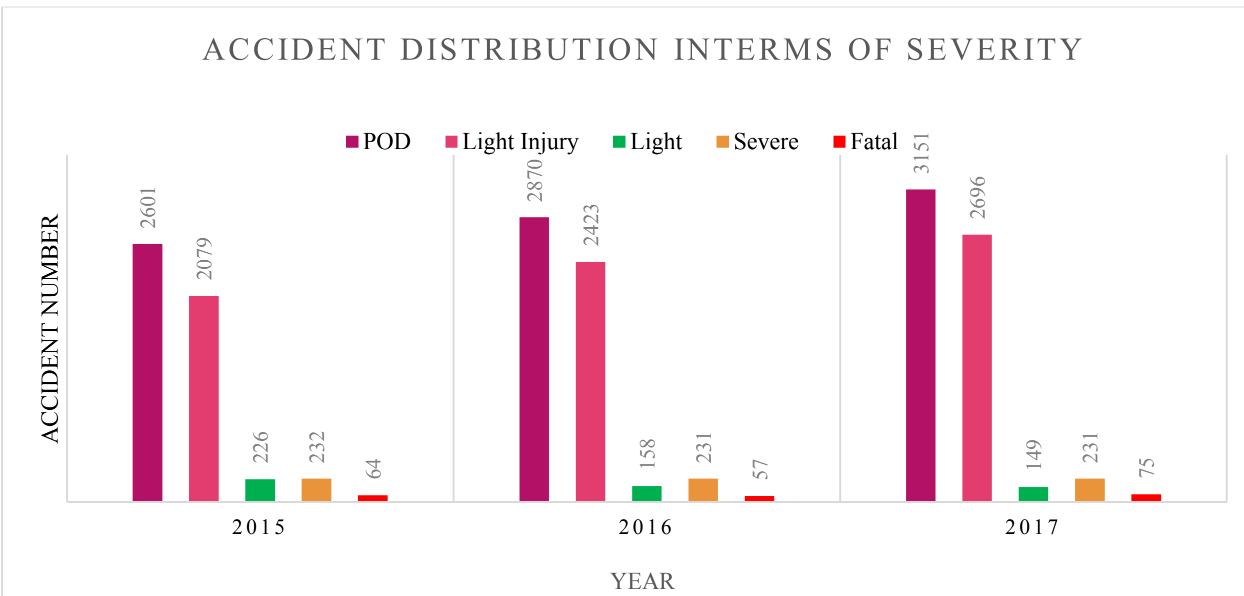
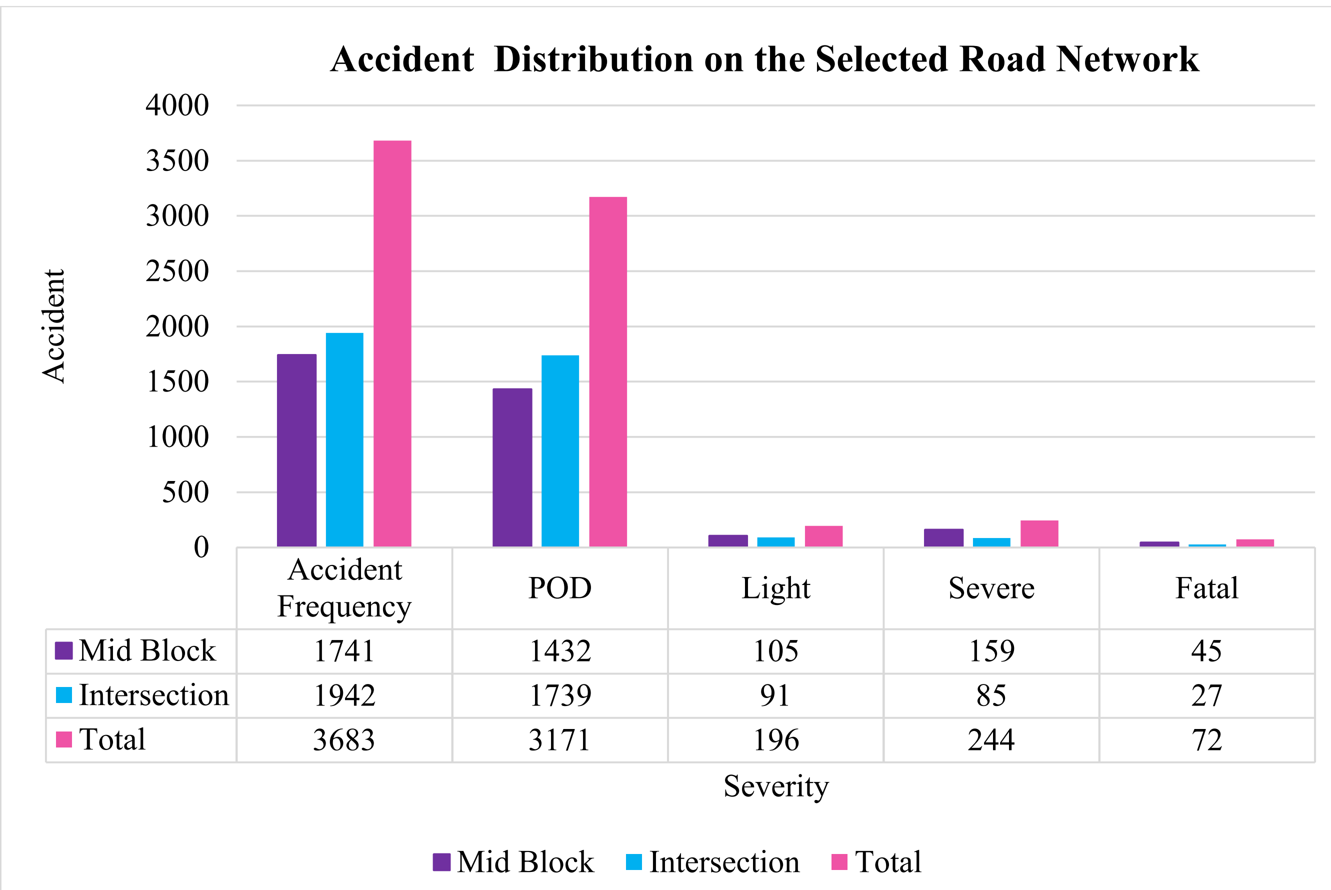



**Figure 4-4. Accident Distribution in terms of Severity.**

### 4.1.5. Accident Distribution Along the Selected Road Segment

As it can be noticed from the figure below, Figure 4-5 light, severe and fatal type of accidents are maximum on the mid – block section of the roads as compared to those recorded on the intersection. And the argument for the stated data is that drivers tend to increase their speed on mid-block sections of the road. Similarly, the pedestrian crossing behavior is harsher on mid-block sections of the road than at the intersection. In contrary, the highest POD type of accident is recorded on intersection of the selected road networks. And the basic justification of this situation is drivers tend to be alerted while they are exposed to intersection and curved road sections.




| | Accident Frequency | POD | Light | Severe | Fatal |
|---|---|---|---|---|---|
| Mid Block | 1741 | 1432 | 105 | 159 | 45 |
| Intersection | 1942 | 1739 | 91 | 85 | 27 |
| Total | 3683 | 3171 | 196 | 244 | 72 |

**Figure 4-5. Accident Distribution on The Selected Road Network.**

### 4.1.6. Analysis of Accidents According to Land Use

According to the Figure 4-6, about 65% of the recorded road traffic accident was at commercial area while office area was responsible for the occurrences of 16% of the crashes followed by residential areas with a percentage share of 9%. In contrary, the lowest percentage share were handled by School areas with a numerical value of 1% while the remaining 1% of the total crashes was recorded at the unregistered land use area.

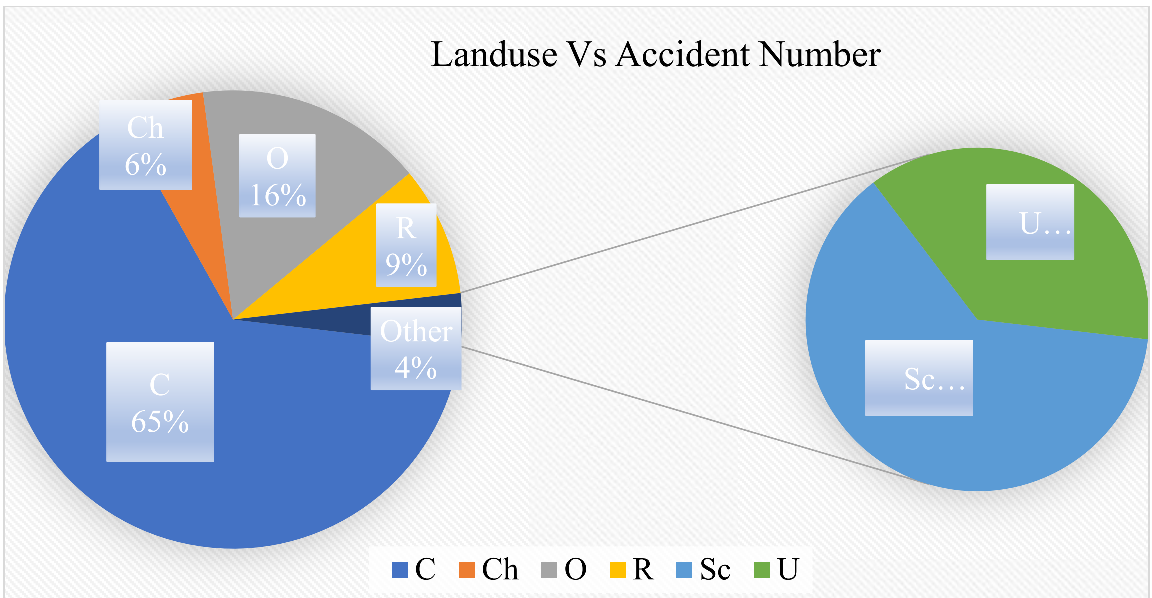



**Figure 4-6. Accident Distribution in terms of Land Use.**

## 4.2. Relocation of Accident Number

The entire divided road segments are thirty-six (36) and the recorded accidents on the selected road networks are relocated on the divided segments accordingly. Moreover, the tabulated accident relocation of the whole segments is presented below on Table 4-4 as follows.

**Table 4-1. Relocation of Accident Number.**

| No | Station ID | Starting point | Destination | Length (m) | Frequency | Accident No | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | PDO | Light Injury | Severe Injury | Fatal |
| 1 | **NS-GS01** | Sarbet underpass | Vatican Embassy | 404 | 25 | 21 | 3 | 1 | 0 |
| 2 | **NS-GS02** | Vatican Embassy | CBE Management Facility | 451 | 208 | 178 | 10 | 16 | 4 |
| 3 | **NS-GS03** | CBE Management Facility | Mekane Eyesus Church | 551 | 83 | 68 | 3 | 10 | 2 |
| 4 | **NS-GS04** | 76m away from RA | Mekanisa Gulit | 368 | 39 | 30 | 3 | 5 | 1 |
| 5 | **NS-GS05** | Mekanisa Gulit | Mekanisa Bridge | 668 | 101 | 68 | 5 | 17 | 11 |
| 6 | **NS-GS06** | Mekanisa Bridge | Oromia Bank Mekanisa Branch | 350 | 71 | 63 | 1 | 6 | 1 |
| 7 | **NS-GS07** | Oromia Bank Bekenisa Branch | Mekane Eyesus Seminare | 341 | 17 | 15 | 0 | 2 | 0 |
| 8 | **NS-GS08** | Mekane Eyesus Seminare | Girma Buil'g | 334 | 0 | 0 | 0 | 0 | 0 |
| 9 | **NS-TS01** | Total RA | Dima Cul.R. | 264 | 39 | 38 | 0 | 1 | 0 |
| 10 | **NS-TS02** | Dima Cul.R. | End of Norewegnan Re. | 369 | 53 | 39 | 4 | 9 | 1 |
| 11 | **NS-TS03** | End of Norewegnan Re. | EPHARM | 119 | 36 | 28 | 4 | 4 | 0 |
| 12 | **NS-TS04** | Desalegne Hotel | End of Bayne Builg | 252 | 21 | 16 | 5 | 0 | 0 |
| 13 | **NS-TS05** | Biserate Geb. Church | Africa Insurance Builg | 410 | 61 | 47 | 5 | 7 | 2 |
| 14 | **NS-TS06** | Africa Insurance Builg | Africana Bar & Restaurant | 333 | 140 | 122 | 7 | 11 | 0 |
| 15 | **NS-TS07** | Tele | Yod Abissinia | 99 | 23 | 20 | 1 | 1 | 1 |
| 16 | **NS-TS08** | Yod Abissinia | Mechare Meda | 300 | 44 | 39 | 0 | 4 | 1 |
| 17 | **NS-TS09** | Mechare Meda | Canada Embassy | 384 | 76 | 72 | 3 | 1 | 0 |
| 18 | **NS-GG01** | Gofa gibrail RA | Gofa camp com eth | 402 | 47 | 40 | 2 | 4 | 1 |
| 19 | **NS-GG02** | Gofa camp com eth | entry of gofa camp | 615 | 135 | 109 | 8 | 15 | 3 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 20 | **NS-GG03** | entry of gofa camp | gofa primary school | 432 | 86 | 70 | 3 | 8 | 5 |
| 21 | **NS-GG04** | gofa primary school | U turn infront kong builg | 276 | 6 | 4 | 0 | 2 | 0 |
| 22 | **NS-GG05** | U turn infront kong builg | German RA | 360 | 20 | 17 | 1 | 2 | 0 |
| 23 | **NS-BM01** | B/gibrail RA | Start of grade saparation | 538 | 8 | 8 | 0 | 0 | 0 |
| 24 | **NS-BM02** | Start of grade saparation | Ending of grade saparation | 468 | 4 | 2 | 1 | 1 | 0 |
| 25 | **NS-BM03** | Ending of grade saparation | Kore RA | 287 | 25 | 20 | 3 | 0 | 2 |
| 26 | **NS-BM04** | Kore RA | end of grade separation | 239 | 33 | 26 | 3 | 2 | 2 |
| 27 | **NS-BM05** | end of grade separation | start of Dombosko school | 431 | 11 | 10 | 1 | 0 | 0 |
| 28 | **NS-BM06** | start of Dombosko school | Mikail RA | 431 | 54 | 41 | 4 | 7 | 2 |
| 29 | **NS-JL01** | 67 Mazoria | Jemo 1 Condo. | 245 | 43 | 37 | 3 | 2 | 1 |
| 30 | **NS-JL02** | Jemo 1 Condo. | Kiru Bar & R. | 266 | 52 | 42 | 5 | 5 | 0 |
| 31 | **NS-JL03** | Kiru Bar & R. | Medhanialem Church | 449 | 3 | 1 | 2 | 0 | 0 |
| 32 | **NS-JL04** | Medhanialem Church | Muzika Bet | 400 | 32 | 20 | 3 | 5 | 4 |
| 33 | **NS-JL05** | Muzika Bet | Ashu Segabet | 395 | 60 | 44 | 9 | 6 | 1 |
| 34 | **NS-JL06** | Ashu Segabet | 76m prior to Varnero RA | 355 | 32 | 29 | 2 | 1 | 0 |
| 35 | **NS-JL07** | Chicken Hut | Tsege Shero | 325 | 14 | 13 | 0 | 1 | 0 |
| 36 | **NS-JL08** | Tsege Shero | Safeway Supermarket | 353 | 39 | 35 | 1 | 3 | 0 |

### 4.2.1. Point Weightage Calculation

As per the adopted point weights, the recorded accidents were converted into common expression where fatal type of accidents where multiplied by Six point while severe injury, light injurie and POD type of accidents where multiplied by four, two and one respectively. In addition, the point given for different type of severity level has been presented accordingly on the table below, Table

**Table 4-2. Point Weightage.**

| No | **Accident Severity** | **Weightage points** |
|---|---|---|
| 1 | Fatal | 6 |
| 2 | Serious | 4 |
| 3 | Slight | 2 |
| 4 | Damage only | 1 |

***(Source: Guideline on Accident-Prone Area Identification for Malaysia, 2013; Page 12).***

Moreover, sample calculation has been made for one representative sample along German to Sarbet street, NS-GS02. The segment experiences 178 POD, 10 Light injuries, 16 severe and 4 Fatal accidents.

**SAMPLE CALCULATION ON NSGS02**

AN/3 years = 6*Fatal + 4*Sever +2*Light +POD

=6*4+4*16+ 2*10+178

=286

Furthermore, the detailed calculation executed for the whole samples are presented r form on the table below, Table 4-5.

**Table 4-3. Point weighted Accident Data.**

| No | Station ID | Starting point | Destination | Length (m) | Frequency | Accident No | | | | AN using PWA = 1*PDO + 2*LI + 4*SI + 6*F |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | PDO | Light Injury | Severe Injury | Fatal | |
| 1 | NS-**GS01** | Sarbet underpass | Vatican Embassy | 404 | 25 | 21 | 3 | 1 | 0 | **31** |
| 2 | NS-**GS02** | Vatican Embassy | CBE Management Facility | 451 | 208 | 178 | 10 | 16 | 4 | **286** |
| 3 | NS-**GS03** | CBE Management Facility | Mekane Eyesus Church | 551 | 83 | 68 | 3 | 10 | 2 | **126** |
| 4 | NS-**GS04** | 76m away from RA | Mekanisa Gulit | 368 | 39 | 30 | 3 | 5 | 1 | **62** |
| 5 | NS-**GS05** | Mekanisa Gulit | Mekanisa Bridge | 668 | 101 | 68 | 5 | 17 | 11 | **212** |
| 6 | NS-**GS06** | Mekanisa Bridge | Oromia Bank Bekenisa Branch | 350 | 71 | 63 | 1 | 6 | 1 | **95** |
| 7 | NS-**GS07** | Oromia Bank Bekenisa Branch | Mekane Eyesus Seminare | 341 | 17 | 15 | 0 | 2 | 0 | **23** |
| 8 | NS-**GS08** | Mekane Eyesus Seminare | Girma Buil'g | 334 | 0 | 0 | 0 | 0 | 0 | **0** |
| 9 | NS-**TS01** | Total RA | Dima Cul.R. | 264 | 39 | 38 | 0 | 1 | 0 | **42** |
| 10 | NS-**TS02** | Dima Cul.R. | End of Norewegnan Re. | 369 | 53 | 39 | 4 | 9 | 1 | **89** |
| 11 | NS-**TS03** | End of Norewegnan Re. | EPHARM | 119 | 36 | 28 | 4 | 4 | 0 | **52** |
| 12 | NS-**TS04** | Desalegne Hotel | End of Bayne Builg | 252 | 21 | 16 | 5 | 0 | 0 | **26** |
| 13 | NS-**TS05** | Biserate Geb. Church | Africa Insurance Builg | 410 | 61 | 47 | 5 | 7 | 2 | **97** |
| 14 | NS-**TS06** | Africa Insurance Builg | Africana Bar & Restaurant | 333 | 140 | 122 | 7 | 11 | 0 | **180** |
| 15 | NS-**TS07** | Tele | Yod Abissinia | 99 | 23 | 20 | 1 | 1 | 1 | **32** |
| 16 | NS-**TS08** | Yod Abissinia | Mechare Meda | 300 | 44 | 39 | 0 | 4 | 1 | **61** |
| 17 | NS-**TS09** | Mechare Meda | Canada Embassy | 384 | 76 | 72 | 3 | 1 | 0 | **82** |
| 18 | NS-**GG01** | Gofa gibrail RA | Gofa camp com eth | 402 | 47 | 40 | 2 | 4 | 1 | **66** |
| 19 | NS-**GG02** | Gofa camp com eth | entry of gofa camp | 615 | 135 | 109 | 8 | 15 | 3 | **203** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | NS-**GG03** | entry of gofa camp | gofa primary school | 432 | 86 | 70 | 3 | 8 | 5 | **138** |
| 21 | NS-**GG04** | gofa primary school | U turn infront kong builg | 276 | 6 | 4 | 0 | 2 | 0 | **12** |
| 22 | NS-**GG05** | U turn infront kong builg | German RA | 360 | 20 | 17 | 1 | 2 | 0 | **27** |
| 23 | NS-**BM01** | B/gibrai RA | Start of grade saparation | 538 | 8 | 8 | 0 | 0 | 0 | **8** |
| 24 | NS-**BM02** | Start of grade saparation | Ending of grade saparation | 468 | 4 | 2 | 1 | 1 | 0 | **8** |
| 25 | NS-**BM03** | Ending of grade saparation | Kore RA | 287 | 25 | 20 | 3 | 0 | 2 | **38** |
| 26 | NS-**BM04** | Kore RA | end of grade separation | 239 | 33 | 26 | 3 | 2 | 2 | **52** |
| 27 | NS-**BM05** | end of grade separation | start of Dombosko school | 431 | 11 | 10 | 1 | 0 | 0 | **12** |
| 28 | NS-**BM06** | start of Dombosko school | Mikail RA | 431 | 54 | 41 | 4 | 7 | 2 | **89** |
| 29 | NS-**JL01** | 67 Mazoria | Jemo 1 Condo. | 245 | 43 | 37 | 3 | 2 | 1 | **57** |
| 30 | NS-**JL02** | Jemo 1 Condo. | Kiru Bar & R. | 266 | 52 | 42 | 5 | 5 | 0 | **72** |
| 31 | NS-**JL03** | Kiru Bar & R. | Medhanialem Church | 449 | 3 | 1 | 2 | 0 | 0 | **5** |
| 32 | NS-**JL04** | Medhanialem Church | Muzika Bet | 400 | 32 | 20 | 3 | 5 | 4 | **70** |
| 33 | NS-**JL05** | Muzika Bet | Ashu Segabet | 395 | 60 | 44 | 9 | 6 | 1 | **92** |
| 34 | NS-**JL06** | Ashu Segabet | 76m prior to Varnero RA | 355 | 32 | 29 | 2 | 1 | 0 | **37** |
| 35 | NS-**JL07** | Chicken Hut | Tsege Shero | 325 | 14 | 13 | 0 | 1 | 0 | **17** |
| 36 | NS-**JL08** | Tsege Shero | Safeway Supermarket | 353 | 39 | 35 | 1 | 3 | 0 | **49** |

### 4.2.2. Normalizing Weighted Accident Number

Since the road segments were divided using homogenous road layout and basic traffic pattern concept, the segments have different lengths. Hence, in order to proceed to the black spot identification part, this effect should be normalized into common ground through dividing the point weighted accidents with segment lengths. But primarily the segment length should be converted into kilometer unit. Sample calculation is made for segment NS-GS02 and presented below accordingly.

**SAMPLE CALCULATION**

$$\text{Normalized weighted Accident Number} = \frac{\text{Weighted Accident Number}}{\text{Length (Km)}}$$

$$\text{Normalized weighted Accident Number} = \frac{286}{0.451} = \mathbf{634}$$

On the other hand, the overall calculation executed for the entire segment is tabulated below on Table 4-6.

**Table 4-4. Normalized Point Weighted Accident Data.**

| No | Station ID | Length (Km) | Frequency | Accident No | | | | AN using PWA = 1*PDO + 2*LI + 4*SI + 6*F | AN/3Yr/length |
|---|---|---|---|---|---|---|---|---|---|
| | | | | PDO | Light Injury | Severe Injury | Fatal | | |
| 1 | **NS-GS01** | 0.404 | 25 | 21 | 3 | 1 | 0 | **31** | 77 |
| 2 | **NS-GS02** | 0.451 | 208 | 178 | 10 | 16 | 4 | **286** | 634 |
| 3 | **NS-GS03** | 0.551 | 83 | 68 | 3 | 10 | 2 | **126** | 229 |
| 4 | **NS-GS04** | 0.368 | 39 | 30 | 3 | 5 | 1 | **62** | 168 |
| 5 | **NS-GS05** | 0.668 | 101 | 68 | 5 | 17 | 11 | **212** | 317 |
| 6 | **NS-GS06** | 0.35 | 71 | 63 | 1 | 6 | 1 | **95** | 271 |
| 7 | **NS-GS07** | 0.341 | 17 | 15 | 0 | 2 | 0 | **23** | 67 |
| 8 | **NS-GS08** | 0.334 | 0 | 0 | 0 | 0 | 0 | **0** | 0 |
| 9 | **NS-TS01** | 0.264 | 39 | 38 | 0 | 1 | 0 | **42** | 159 |
| 10 | **NS-TS02** | 0.369 | 53 | 39 | 4 | 9 | 1 | **89** | 241 |
| 11 | **NS-TS03** | 0.119 | 36 | 28 | 4 | 4 | 0 | **52** | 437 |
| 12 | **NS-TS04** | 0.252 | 21 | 16 | 5 | 0 | 0 | **26** | 103 |
| 13 | **NS-TS05** | 0.41 | 61 | 47 | 5 | 7 | 2 | **97** | 237 |
| 14 | **NS-TS06** | 0.333 | 140 | 122 | 7 | 11 | 0 | **180** | 541 |
| 15 | **NS-TS07** | 0.099 | 23 | 20 | 1 | 1 | 1 | **32** | 323 |
| 16 | **NS-TS08** | 0.3 | 44 | 39 | 0 | 4 | 1 | **61** | 203 |
| 17 | **NS-TS09** | 0.384 | 76 | 72 | 3 | 1 | 0 | **82** | 214 |
| 18 | **NS-GG01** | 0.402 | 47 | 40 | 2 | 4 | 1 | **66** | 164 |
| 19 | **NS-GG02** | 0.615 | 135 | 109 | 8 | 15 | 3 | **203** | 330 |
| 20 | **NS-GG03** | 0.432 | 86 | 70 | 3 | 8 | 5 | **138** | 319 |
| 21 | **NS-GG04** | 0.276 | 6 | 4 | 0 | 2 | 0 | **12** | 43 |
| 22 | **NS-GG05** | 0.36 | 20 | 17 | 1 | 2 | 0 | **27** | 75 |
| 23 | **NS-BM01** | 0.538 | 8 | 8 | 0 | 0 | 0 | **8** | 15 |
| 24 | **NS-BM02** | 0.468 | 4 | 2 | 1 | 1 | 0 | **8** | 17 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 25 | NS-**BM03** | 0.287 | 25 | 20 | 3 | 0 | 2 | **38** | 132 |
| 26 | NS-**BM04** | 0.239 | 33 | 26 | 3 | 2 | 2 | **52** | 218 |
| 27 | NS-**BM05** | 0.431 | 11 | 10 | 1 | 0 | 0 | **12** | 28 |
| 28 | NS-**BM06** | 0.431 | 54 | 41 | 4 | 7 | 2 | **89** | 206 |
| 29 | NS-**JL01** | 0.245 | 43 | 37 | 3 | 2 | 1 | **57** | 233 |
| 30 | NS-**JL02** | 0.266 | 52 | 42 | 5 | 5 | 0 | **72** | 271 |
| 31 | NS-**JL03** | 0.449 | 3 | 1 | 2 | 0 | 0 | **5** | 11 |
| 32 | NS-**JL04** | 0.4 | 32 | 20 | 3 | 5 | 4 | **70** | 175 |
| 33 | NS-**JL05** | 0.395 | 60 | 44 | 9 | 6 | 1 | **92** | 233 |
| 34 | NS-**JL06** | 0.355 | 32 | 29 | 2 | 1 | 0 | **37** | 104 |
| 35 | NS-**JL07** | 0.325 | 14 | 13 | 0 | 1 | 0 | **17** | 52 |
| 36 | NS-**JL08** | 0.353 | 39 | 35 | 1 | 3 | 0 | **49** | 139 |

### 4.2.3. Identification of Accident-Prone Location

As it was stated on the methodology of the research, the accident-prone locations were selected after setting a threshold value using normalized weighted accident number. But prior to this statistically insignificant accident locations were removed through subjective and statistical judgment. As such segment with a normalized weighted accident number less than twenty were found negligible as compared to the individual samples and neglected from further analysis. Finally, out of thirty-six samples, thirty-two samples were found relevant and extracted to execute subsequent analysis. Therefore, the selected samples are presented in tabular form on Table 4-7 as follows.

**Table 4-5. Data for Accident-Prone Location Analysis.**

| No | Station ID | Frequency | Accident No | | | | AN using PWA = 1*PDO + 2*LI + 4*SI + 6*F | AN/3Yr/length |
|---|---|---|---|---|---|---|---|---|
| | | | PDO | Light Injury | Severe Injury | Fatal | | |
| 1 | **NS-GS01** | 25 | 21 | 3 | 1 | 0 | **31** | 77 |
| 2 | **NS-GS02** | 208 | 178 | 10 | 16 | 4 | **286** | 634 |
| 3 | **NS-GS03** | 83 | 68 | 3 | 10 | 2 | **126** | 229 |
| 4 | **NS-GS04** | 39 | 30 | 3 | 5 | 1 | **62** | 168 |
| 5 | **NS-GS05** | 101 | 68 | 5 | 17 | 11 | **212** | 317 |
| 6 | **NS-GS06** | 71 | 63 | 1 | 6 | 1 | **95** | 271 |
| 7 | **NS-GS07** | 17 | 15 | 0 | 2 | 0 | **23** | 67 |
| 8 | **NS-TS01** | 39 | 38 | 0 | 1 | 0 | **42** | 159 |
| 9 | **NS-TS02** | 53 | 39 | 4 | 9 | 1 | **89** | 241 |
| 10 | **NS-TS03** | 36 | 28 | 4 | 4 | 0 | **52** | 437 |
| 11 | **NS-TS04** | 21 | 16 | 5 | 0 | 0 | **26** | 103 |
| 12 | **NS-TS05** | 61 | 47 | 5 | 7 | 2 | **97** | 237 |
| 13 | **NS-TS06** | 140 | 122 | 7 | 11 | 0 | **180** | 541 |
| 14 | **NS-TS07** | 23 | 20 | 1 | 1 | 1 | **32** | 323 |
| 15 | **NS-TS08** | 44 | 39 | 0 | 4 | 1 | **61** | 203 |
| 16 | **NS-TS09** | 76 | 72 | 3 | 1 | 0 | **82** | 214 |
| 17 | **NS-GG01** | 47 | 40 | 2 | 4 | 1 | **66** | 164 |
| 18 | **NS-GG02** | 135 | 109 | 8 | 15 | 3 | **203** | 330 |
| 19 | **NS-GG03** | 86 | 70 | 3 | 8 | 5 | **138** | 319 |
| 20 | **NS-GG04** | 6 | 4 | 0 | 2 | 0 | **12** | 43 |
| 21 | **NS-GG05** | 20 | 17 | 1 | 2 | 0 | **27** | 75 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 22 | **NS-BM03** | 25 | 20 | 3 | 0 | 2 | **38** | 132 |
| 23 | **NS-BM04** | 33 | 26 | 3 | 2 | 2 | **52** | 218 |
| 24 | **NS-BM05** | 11 | 10 | 1 | 0 | 0 | **12** | 28 |
| 25 | **NS-BM06** | 54 | 41 | 4 | 7 | 2 | **89** | 206 |
| 26 | **NS-JL01** | 43 | 37 | 3 | 2 | 1 | **57** | 233 |
| 27 | **NS-JL02** | 52 | 42 | 5 | 5 | 0 | **72** | 271 |
| 28 | **NS-JL04** | 32 | 20 | 3 | 5 | 4 | **70** | 175 |
| 29 | **NS-JL05** | 60 | 44 | 9 | 6 | 1 | **92** | 233 |
| 30 | **NS-JL06** | 32 | 29 | 2 | 1 | 0 | **37** | 104 |
| 31 | **NS-JL07** | 14 | 13 | 0 | 1 | 0 | **17** | 52 |
| 32 | **NS-JL08** | 39 | 35 | 1 | 3 | 0 | **49** | 139 |

#### 4.2.3.1. Determination of Threshold Value

Referring to reviewed literatures and previously executed researches, simple statistical approach is adopted to develop a threshold value where the selected samples were taken to extract the mean and median value. Besides, the selected samples neglect values which shows exceptional difference among the individual samples. So, four samples have shown an exaggerated variation among the entire sample size and eliminated from being used to extract the mean and median value of the sample size. Then after, the threshold value was taken after calculating the mean and median of the sample where the maximum of the two will govern its magnitude using MS-Excel tool. And the normalized weighted accident number which were found less than the developed threshold value was neglected from further analysis. Hence, as per the calculation below, the threshold value of the samples became the mean value of the study sample. The performed calculation which were made to determine the threshold value is presented immediate to the sample calculation on Table 4-8.

Threshold value = Max (Mean, Median)

= max (**218**, 211) = 218.

**Table 4-6. Determination of Threshold Value.**

| No | Station ID | AN/3Yr/length | Mean | Median | Threshold Value |
|---|---|---|---|---|---|
| 1 | **NS-GS01** | 77 | **218** | 211 | **218** |
| 2 | **NS-GS02** | 634 | | | |
| 3 | **NS-GS03** | 229 | | | |
| 4 | **NS-GS04** | 168 | | | |
| 5 | **NS-GS05** | 317 | | | |
| 6 | **NS-GS06** | 271 | | | |
| 7 | **NS-GS07** | 67 | | | |
| 8 | **NS-TS01** | 159 | | | |
| 9 | **NS-TS02** | 241 | | | |
| 10 | **NS-TS03** | 437 | | | |
| 11 | **NS-TS04** | 103 | | | |
| 12 | **NS-TS05** | 237 | | | |
| 13 | **NS-TS06** | 541 | | | |
| 14 | **NS-TS07** | 323 | | | |
| 15 | **NS-TS08** | 203 | | | |
| 16 | **NS-TS09** | 214 | | | |
| 17 | **NS-GG01** | 164 | | | |
| 18 | **NS-GG02** | 330 | | | |
| 19 | **NS-GG03** | 319 | | | |
| 20 | **NS-GG04** | 43 | | | |
| 21 | **NS-GG05** | 75 | | | |
| 22 | **NS-BM03** | 132 | | | |
| 23 | **NS-BM04** | 218 | | | |
| 24 | **NS-BM05** | 28 | | | |
| 25 | **NS-BM06** | 206 | | | |
| 26 | **NS-JL01** | 233 | | | |
| 27 | **NS-JL02** | 271 | | | |
| 28 | **NS-JL04** | 175 | | | |
| 29 | **NS-JL05** | 233 | | | |
| 30 | **NS-JL06** | 104 | | | |
| 31 | **NS-JL07** | 52 | | | |
| 32 | **NS-JL08** | 139 | | | |

Finally, after comparing the individual samples with the threshold value, fifteen road segments were found the relevant accident-prone locations. Moreover, sections which have a normalized weighted accident number exceeding the mean plus one standard deviation needs a special consideration for treatment. Therefore, three road segments were exceeding the stated value and needs a special consideration while providing treatment. In addition, locations that have a value more than the threshold value are forwarded on the table below, Table 4-9.

**Table 4-7. Selected Accident-Prone Locations.**

| No | Station ID | Threshold Value | Mean | Standard Deviation | Mean + Standard Deviation | AN / 3Yr / Segment |
|---|---|---|---|---|---|---|
| **01** | **NS-GS02** | **218** | 218 | 138 | **356** | 634 |
| **02** | **NS-GS03** | | | | | 229 |
| **03** | **NS-GS05** | | | | | 317 |
| **04** | **NS-GS06** | | | | | 289 |
| **05** | **NS-TS02** | | | | | 241 |
| **06** | **NS-TS03** | | | | | 437 |
| **07** | **NS-TS05** | | | | | 237 |
| **08** | **NS-TS06** | | | | | 541 |
| **09** | **NS-TS07** | | | | | 323 |
| **10** | **NS-GG02** | | | | | 330 |
| **11** | **NS-GG03** | | | | | 319 |
| **12** | **NS-BM04** | | | | | 218 |
| **13** | **NS-JL01** | | | | | 233 |
| **14** | **NS-JL02** | | | | | 271 |
| **15** | **NS-JL05** | | | | | 256 |

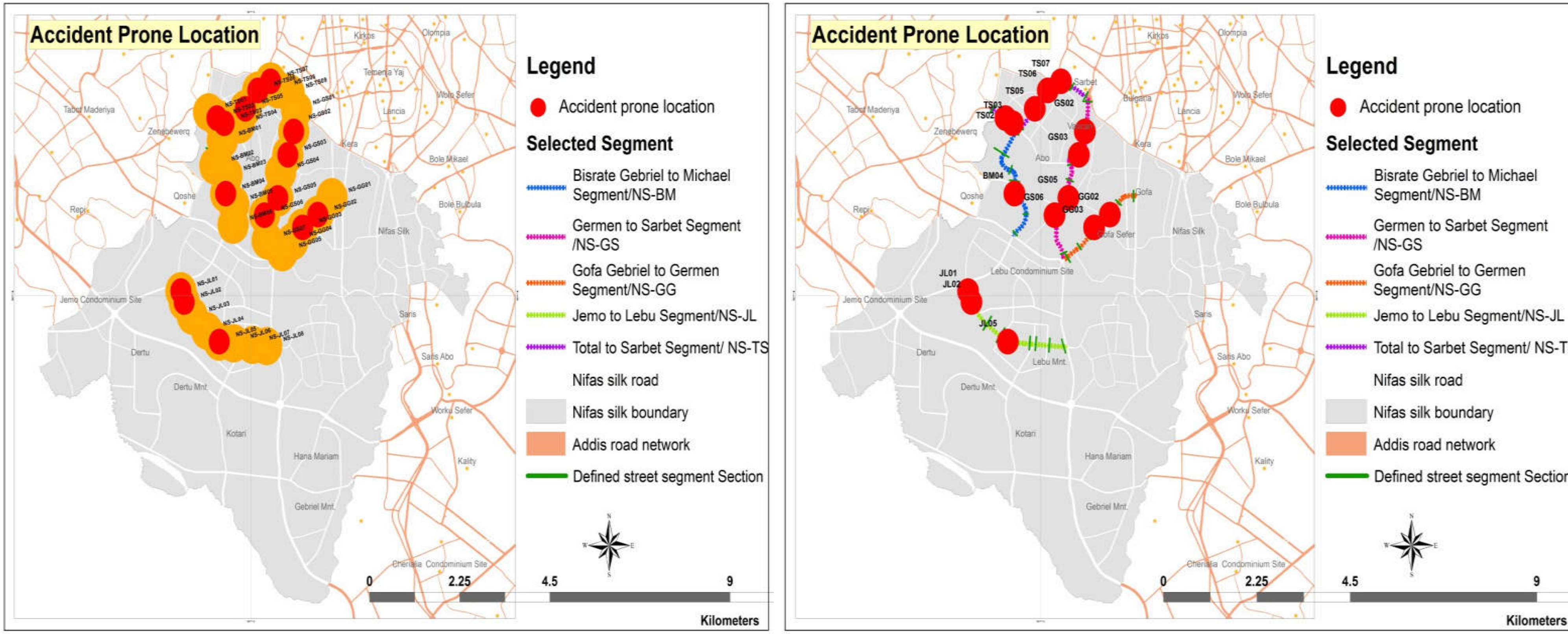



**Figure 4-7. Pictorial Representations of the Selected Accident-Prone Locations Using GIS tool.**

Moreover, brief pictorial representations of the selected accident-prone locations were presented in detail under Annex 6.

#### 4.2.3.2. Statistical Check

This part is very much necessary to make sure weather segments are selected by chance or not, and it is accompanied through following some procedures. First the reliability and the required accuracy of the study is determined using a parameter known as Confidence Interval and then the standard deviation of the sample is determined accordingly. Finally, the lower and upper boundary of the research is determined from confidence interval plus or minus the standard deviation. Therefore, values with in the boundary were selected as a "true accident-prone" locations.

While those segments which have lower normalized weighted accident number than the lower boundary were removed and regarded as "False prone locations". Moreover, the detailed calculation analysis is presented on Table 4-8 as follows.

**Table 4-8. Statistical Check for 95% Confidence Interval.**

| No | **Calculation of confidence interval of statistical sample in 3 years period** | | |
|---|---|---|---|
| 1 | **Mean of Selected Samples** | | 218 |
| 2 | **Standard Deviation** | | 138 |
| 3 | **Confidence Level 95%** | | 49 |
| 4 | **95 % Confidence Interval** | **Lower boundary** | 169 |
| | | **Upper boundary** | 268 |

Looking to the above table, Table 4-8, the calculated lower and upper boundary are 169 and 268 respectively. Hence, the accident-prone locations which were selected using the threshold value are above the lower boundary while upper boundary is not the challenge for the study. Though all values which are found to be beyond the upper values implies there should be a provision of intense consideration while providing safety countermeasures. Finally, according to the integrated threshold value approach and statistical check, fifteen road segments were selected on the above table, Table 4-9 were found the relevant accident-prone locations among the entire sample size. In addition, the identified prone locations were taken for executing the subsequent analysis.

## 4.3. Analyzed Vehicular Traffic Volume and Spot Speed Data

The collected traffic volume and spot speed data were sorted and organized relevantly according to the identified accident-prone locations. Sample calculation of the average daily traffic volume, 50$^{th}$ percentile spot speed and 85$^{th}$ percentile spot speed is forwarded below accordingly.

### 4.3.1. Computation of ADT

The average traffic volume was computed on the identified accident-prone locations using the collected raw traffic counting data. And the ADT computation formula was adopted from the approach used by Berhanu, 2000.

$$\mathbf{ADT} = \frac{\boldsymbol{PHV}}{\boldsymbol{K}}$$

Where ADT = Average Daily Traffic, PHV = Peak Hour Volume and K is multiplying factor and it is equal to 0.12 (12%) in case of Addis Ababa. In addition, the peak hour volume was determined from the collected traffic volume count. First, four days' traffic volume count were analyzed and the maximum peak hour volume of each day was taken as a representative PHV of the day. Subsequently, average PHV of the four days were computed in order to consider the traffic volume variations of the specific day and a concept of random effect. Finally, ADT of the specific segment was calculated using the above equation using the summarized traffic volume data. Furthermore, computation of sample PHV and ADT are presented below.

**Sample Calculation @ NSBM02 (Dombosko School)**

- ✓ PHV = summation of every 15 – minute traffic volume.

Max. PHV (Tuesday) = **2,983**

Max. PHV (Wednesday) = **3,083**

Max. PHV (Thursday) = **3,014**

Max. PHV (Saturday) = **2,755**

- ✓ Average PHV = $\frac{PHV\ (Tue)+PHV\ (Wed)+PHV\ (Th)+PHV\ (Sat)}{4}$

**Average PHV = 2,959**

- ✓ **The magnitude of multiplied factor (K) for Addis Ababa, K = 0.12.**
- ✓ **Therefore, as per the above stated formula, ADT = PHV / K.**

**ADT = 2,959 / 0.12 = 24,654**

Similarly, the ADT of the remaining locations were determined and summarized along with the summarized spot speed studies below on Table 4.14.

**Table 4-9. Computation of PHV and ADT along Biserate Gabriel to Michael Street.**

| Summarized Volume Count @ NSBM 04 | | | | | |
|---|---|---|---|---|---|
| **Date** | **Counting Day** | **PHV** | **Average PHV** | **K** | **ADT** |
| 10-Apr-18 | Tuesday | 2983 | **2959** | **0.12** | **24,654** |
| 11-Apr-18 | Wednesday | 3083 | | | |
| 12-Apr-18 | Thursday | 3014 | | | |
| 14-Apr-18 | Saturday | 2755 | | | |

## 4.3.2. Computation of Spot Speed Studies

A frequency distribution table is a convenient way to determine speed percentiles. The frequency of vehicles is the number of vehicles recorded at each speed. The cumulative frequency is the total of each of the numbers (frequencies) added together row by row from lower to higher speed. The fourth column is a running percentage of the cumulative frequency.

The 50th and 85th speed percentiles are determined from the cumulative percent column. The calculation of speed percentiles is easier if a sample size of 100 vehicles is collected. When the sample size equals 100 vehicles, the cumulative frequency and cumulative percent are the same. the exact 50% and 85% (50th and 85th percentiles) are not found in the cumulative percent column. To reach these exact percentages, a calculation is completed using percentages and speeds from the distribution table. And the interpolation formula that is adopted to execute the analysis is stated as follows:

$$S_D = \frac{P_D - P_{min}}{P_{max} - P_{min}}(S_{max} - S_{min}) + S_{min}$$

Where $S_D$ = Speed at $P_D$; $P_D$ = Percentile Speed; $P_{max}$ = higher cumulative percent; $P_{min}$ = lower cumulative percent; $S_{max}$ = higher speed; and $S_{min}$ = lower speed.

## Sample Calculation @ NS-GS02, Vatican Embassy

The 50th percentile of speed ($P_D$ = 50%) falls between 45.9 km/hr and 48.2 km/hr (see Table 4-13), so $S_{max}$ = 48.2 km/hr and $S_{min}$ = 45.9 km/hr. The higher cumulative percent ($P_{max}$) is 51%, and the lower cumulative percent ($P_{min}$) is 41%. Therefore, to find $S_D$ at $P_D$ = 50%:

$$S_D = \frac{50\% - 41\%}{51\% - 41\%} * (48.2 \text{ km/hr} - 45.9 \text{ km/hr}) + 45.9 \text{ km/hr}$$

**$S_D$ = 48 km/hr.**

While The 85th percentile of speed ($P_D$ = 85%) falls between 56.8 km/hr and 60.3 km/hr (see Table 4-13), so $S_{max}$ = 60.3 km/hr and $S_{min}$ = 56.8 km/hr. The higher cumulative percent ($P_{max}$) is 91%, and the lower cumulative percent ($P_{min}$) is 80%. Therefore, to find $S_D$ at $P_D$ = 85%:

$$S_D = \frac{85\% - 80\%}{91\% - 80\%} * (60.3 \text{ km/hr} - 56.8 \text{ km/hr}) + 56.8 \text{ km/hr}$$

**$S_D$ = 58.7 km/hr.**

**Table 4-10. Sample Spot Speed Calculation.**

| Analysis of Spot speed @ NS-GS02 | | | | | |
|---|---|---|---|---|---|
| **Speed (km/hr)** | **Frequency of vehicles** | **Cumulative frequency** | **Cumulative percent** | **Speed percentile** | |
| 27.6 | 0 | 0 | 0.00 | | |
| 28.4 | 0 | 0 | 0.00 | | |
| 29.2 | 0 | 0 | 0.00 | | |
| 30.2 | 0 | 0 | 0.00 | | |
| 31.1 | 0 | 0 | 0.00 | | |
| 32.2 | 0 | 0 | 0.00 | | |
| 33.3 | 0 | 0 | 0.00 | | |
| 34.5 | 0 | 0 | 0.00 | | |
| 35.7 | 0 | 0 | 0.00 | | |
| 37.1 | 0 | 0 | 0.00 | | |
| 38.6 | 12 | 12 | 12.00 | | |
| 40.2 | 6 | 18 | 18.00 | | |
| 41.9 | 7 | 25 | 25.00 | | |
| 43.9 | 8 | 33 | 33.00 | | |
| 45.9 | 8 | 41 | 41.00 | **48.0** | **50th %** |
| 48.2 | 10 | 51 | 51.00 | | |
| 50.8 | 7 | 58 | 58.00 | | |
| 53.6 | 7 | 65 | 65.00 | | |
| 56.8 | 15 | 80 | 80.00 | **58.7** | **85th %** |
| 60.3 | 11 | 91 | 91.00 | | |
| 64.3 | 9 | 100 | 100.00 | | |

Moreover, summarized ADT and 85$^{th}$ percentile spot speed is presented on subsequent table below, Table 4-11.

**Table 4-11. Summarized Traffic Volume and 85$^{th}$ Percentile Spot Speed Result.**

| Station ID | Counting Station | Traffic Volume (ADT) | Spot Speed (km/hr), 85$^{th}$% |
|---|---|---|---|
| **NS-GS02** | Vatican Embassy | 27873 | 56.10 |
| **NS-GS03** | Vatican Embassy | 27873 | 48.40 |
| **NS-GS05** | Abo Gulit | 24231 | 49.00 |
| **NS-GS06** | Seminary | 24939 | 61.00 |
| **NS-TS02** | Norway Resident | 26345 | 57.80 |
| **NS-TS03** | EPHARM | 26345 | 59.20 |
| **NS-TS05** | Lafto Mall | 26845 | 55.60 |
| **NS-TS06** | Africa Insurance | 26845 | 61.45 |
| **NS-TS07** | Medroc Office | 26133 | 51.20 |
| **NS-GG02** | Gofa Primary School | 24293 | 60.30 |
| **NS-GG03** | Gofa Primary School | 24293 | 55.50 |
| **NS-BM04** | Dombosco School | 24653 | 58.10 |
| **NS-JL01** | Birhan Bank (Jemmo) | 24341 | 48.70 |
| **NS-JL02** | Hope University | 24341 | 47.50 |
| **NS-JL05** | Muzika Bet | 23564 | 53.70 |

## 4.4. Analysis of Roadway Elements Data

Here the presumed roadway element data were organized and presented in summarized tabular format for making further analysis.

### 4.4.1. Roadside Features

Include availability and measurements of elements that are found near to the carriageway of the road network such as object next to the road, set back distances, access point, sign and sign legibility, distraction and overload, and finally different unseen roadside barriers. In addition, the entire roadside features data of the selected accident-prone locations are presented below on Table 4-12.

**Table 4-12. Road side Environmental Data.**

| Road side Environment | | Road Segments | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NSGS 02 | NSGS 03 | NSGS 05 | NSGS 06 | NSTS 02 | NSTS 03 | NSTS 05 | NSTS 06 | NSTS 07 | NSGG 02 | NSGG 03 | NSBM 04 | NSJL 01 | NSJL 02 | NSJL 05 |
| **1.Object next to the road** | | | | | | | | | | | | | | | | |
| 1.1. | Tree (Yes/No) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **2.Set back distance (m)** | | | | | | | | | | | | | | | | |
| 2.1. | Tree | 0.9 | 0.8 | 0.8 | 0.75 | 0.8 | 1 | 0.8 | 0.85 | 0.7 | 1 | 1.2 | 1.1 | 1 | 0.85 | 0.75 |
| 2.2. | Building | 5 | 4 | 4 | 4.5 | 4.5 | 4.8 | 4 | 4.3 | 4 | 3.1 | 4 | 4.7 | 4 | 3.8 | 3.5 |
| 2.3. | Signage/Traffic Sign | 0.55 | 0.6 | 0.6 | 0.55 | 0.5 | 0.6 | 0.75 | 0.55 | 0.7 | 0.55 | 0.7 | 0.7 | 0.55 | 0.8 | 0.55 |
| 2.4. | Light pole | 0.55 | 0.55 | 0.65 | 0.5 | 0.5 | 0.7 | 0.8 | 0.9 | 0.6 | 0.6 | 0.6 | 0.6 | 0.65 | 0.55 | 0.65 |
| **3.Access point** | | | | | | | | | | | | | | | | |
| 3.1. | Number | 0 | 1 | 1 | 2 | 2 | 0 | 2 | 4 | 0 | 11 | 5 | 1 | 0 | 1 | 2 |
| 3.2. | Entry/Exit | None | Exit | Entry | Both | Both | None | Both | Both | None | Both | Both | Exit | 0 | Exit | 1 |
| **4.Sign & Sign legibility** | | | | | | | | | | | | | | | | |
| 4.1. | Availability (Yes/No) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 4.2. | Sign legibility (Yes/No) | Yes | No | No | No | No | No | No | No | Yes | No | Yes | Yes | No | Yes | No |
| **5.Distraction & Overload** | | | | | | | | | | | | | | | | |
| 5.1. | Presence of visual clutter (Yes/No) | No | Yes | Yes | No | Yes | Yes | Yes | Yes | No | Yes | No | No | No | No | No |
| **6. Different Unseen Roadside Barriers,** | | | | | | | | | | | | | | | | |
| 6.1. | Illegal functions like street vendors, | No | No | Yes | Yes | No | No | Yes | Yes | No | Yes | No | No | Yes | Yes | No |

## 4.4.2. Analyzed Geometric Data

**Table 4-13. Geometric Data of the Selected Road Segments.**

| No | GEOMETRIC DESIGN ELEMENTS | | Identified Accident Prone locations | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Cross - sectional elements** | | **NS-GS02** | **NS-GS03** | **NS-GS05** | **NS-GS06** | **NS-TS02** | **NS-TS03** | **NS-TS05** | **NS-TS06** | **NS-TS07** | **NS-GG02** | **NS-GG03** | **NS-BM04** | **NS-JL01** | **NS-JL02** | **NS-JL05** |
| 1.1 | *WW. W (m)* | | 4.4 | 4.45 | 4.5 | 4.4 | 4.3 | 4.5 | 4.5 | 4.5 | 4.5 | 2.95 | 2.9 | 4.4 | 4.2 | 4.4 | 4.1 |
| 1.2 | *M.W (m)* | | 0.9 | 0.85 | 0.9 | 0.9 | 0.9 | 0.85 | 0.9 | 0.9 | 0.9 | 0.85 | 0.85 | 0.85 | 0.8 | 0.85 | 0.88 |
| 1.3 | *MSLW(m)* | | 3.55 | 3.55 | 3.55 | 3.55 | 3.55 | 3.55 | 3.55 | 3.55 | 3.55 | 3.5 | 3.6 | 3.55 | 3.5 | 3.4 | 3.4 |
| 1.4 | *MLW (m)* | | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.3 | 3.5 | 3.5 | 3.5 | 3.5 | 3.45 |
| 1.5 | *ELW (m)* | | 3 | 2.9 | 3 | 2.8 | 3 | 2.9 | 3 | 2.95 | 3 | 2.4 | 2.5 | 2.9 | 2.8 | 2.9 | 2.8 |
| 1.6 | *ATLW (m)* | | 10.05 | 9.95 | 10.05 | 9.85 | 10.05 | 9.95 | 10.05 | 10 | 10.05 | 9.2 | 9.6 | 9.95 | 9.8 | 9.8 | 9.65 |
| 1.7 | *ARWW (m)* | | 29.8 | 29.65 | 30 | 29.4 | 29.6 | 29.75 | 30 | 29.9 | 30 | 25.15 | 25.85 | 29.55 | 28.8 | 29.25 | 28.38 |
| 1.8 | *NUT (pc)* | | 0 | 0 | 1 | 2 | 1 | 0 | 1 | 2 | 0 | 0 | 2 | 0 | 1 | 1 | 1 |
| 1.9 | *Types of median* | *20cm curb stone/grade separated/ (0&1)* | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| | | *Barrier Ava. (0&1)* | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| 1.10 | *Median Opening* | *Ab-0; Pre-1* | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 1 | 1 | 1 |
| | | *Number* | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 2 | 0 | 0 | 2 | 0 | 1 | 1 | 1 |
| 1.11 | *Parking Availability* | *Yes/No* | No | No | Yes | Yes | No | No | Yes | Yes | No | Yes | No | No | Yes | Yes | Yes |
| 2 | **Horizontal Alignment** | *Straight (0) &Curve (1)* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 |
| 3 | **Topography** | *Flat / Sloppy* | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |

## 4.5. Correlation Analysis of Selected Explanatory Variables.

This section contains correlation analysis of selected roadway explanatory variables and accident number. And the selected roadway explanatory variables are categorized under three sections such as traffic characteristics, geometric data and road side element data. Moreover, the explanatory variables are also considered in to two groups such as continuous and categorical (dichotomous) variables. Hereafter, categories of explanatory variables are presented in tabular form through Table 4-14 to Table 4-16 as follows.

**Table 4-14. Traffic Characteristics Explanatory Variables.**

| | Explanatory Variables | Variable Information | |
|---|---|---|---|
| **Item** | **Traffic Characteristics** | **Variable Type** | **Measure** |
| 1 | *Traffic Volume ($N_O$)* | Continuous | Scale |
| 2 | *Spot Speed (Km/hr)* | Continuous | Scale |

**Table 4-15. Geometric Explanatory Variables.**

| **Item** | **Explanatory Variable**<br>**Geometric Variable** | **Variable Information** | |
|---|---|---|---|
| 1 | **Cross sectional elements** | **Variable Type** | **Measure** |
| 1.01 | *Walkway Width (m)* | Continuous | Scale |
| 1.02 | *Median width (m)* | Continuous | Scale |
| 1.03 | *Median side Lane width (m)* | Continuous | Scale |
| 1.04 | *Middle Lane width (m)* | Continuous | Scale |
| 1.05 | *Edge lane width (m)* | Continuous | Scale |
| 1.06 | *Average traveled lane Width (m)* | Continuous | Scale |
| 1.07 | *Average right of way width (m)* | Continuous | Scale |
| 1.08 | *Number of U-Turn* | Continuous | Scale |
| 1.09 | *Types of median* | Categorical | Nominal |
| 1.10 | *Median Opening* | Categorical | Nominal |
| 1.11 | *Parking Availability* | Categorical | Nominal |
| 2 | **Horizontal Alignment** | Categorical | Nominal |
| 3 | **Topography** | Categorical | Nominal |

**Table 4-16. Roadside Explanatory Variables.**

| Item | Explanatory Variables<br>Roadside Elements | Variable Information<br>Variable Type | Measure |
|---|---|---|---|
| 1 | **Object next to the road** | | |
| 1.1 | *Tree (Yes/No)* | Continuous | Scale |
| 2 | **Set back distance (m)** | | |
| 2.1 | *Tree* | Continuous | Scale |
| 2.2 | *Building* | Continuous | Scale |
| 2.3 | *Signage/Traffic Sign* | Continuous | Scale |
| 2.4 | *Light pole* | Continuous | Scale |
| 3 | **Access point** | | |
| 3.1 | *Number* | Continuous | Scale |
| 3.2 | *Entry/Exit* | Continuous | Scale |
| 4 | **Sign & Sign legibility** | | |
| 4.1 | *Availability (Yes/No)* | Categorical | Nominal |
| 4.2 | *Sign legibility (Yes/No)* | Categorical | Nominal |
| 5 | **Distraction & Overload** | | |
| 5.1 | *Presence of visual clutter (Yes/No)* | Categorical | Nominal |
| 6 | **Different Unseen Roadside Barriers,** | | |
| 6.1 | *Illegal functions like street vendors,* | Categorical | Nominal |

## 4.5.1. Elimination of Constant Explanatory Variables

According to the collected traffic, geometric and roadside element data, some of the geometric and road side explanatory variables have shown constant pattern throughout the whole segment and are considered as negligible. Hence, they are taken as a constant variable and neglected from being subjected to the correlation analysis. In addition, the excluded geometric variables include walkway width, median width, median side lane width, middle travel lane width, type of median, while the neglected roadside elements include variables such as object next to the road, setback distance of tree, and light pole; type of access point and availability of sign. Moreover, the other stated explanatory variables were subjected to point biserial correlation analysis for determining the strength of their effect.

### 4.5.2. Selection of Appropriate Correlation Approach

The explanatory variables which are selected for making the correlation analysis are categorized in to continuous and categorical (dichotomous) variables. Consequently, it is not possible to made a correlation analysis either using Pearson or spearman correlation analysis because the former is effective for making correlation analysis for continuous variables while the latter is suitable to determine strength of relationship among categorical or dichotomous variables. Subsequently, a special case of Pearson product-moment correlation is employed to execute the correlation analysis of the study where it is relevant to measure the strength and direction of association that exists between continuous variable and dichotomous / categorical variable.

#### 4.5.2.1. Point - Biserial Correlation

The point-biserial correlation is a special case of the product-moment correlation in which one variable is continuous and the other variable is binary (dichotomous). The categories of the binary variable do not have a natural ordering. For example, the binary variable gender does not have a natural ordering. That is, it does not matter whether the males are coded as a zero or a one. Such variables are often referred to as nominal binary variables. It is assumed that the continuous data within each group created by the binary variable are normally distributed with equal variances and possibly different means.

Point-Biserial Correlation Suppose you want to find the correlation between a continuous random variable Y and a binary random variable X which takes the values zero and one. Assume that n paired observations (Yk, Xk), k = 1, 2, …, n are available. If the common product-moment correlation r is calculated from these data, the resulting correlation is called the point-biserial correlation. Sheskin (2011) gives the formula for the point-biserial correlation coefficient as:

$$r_{pb} = (y_1 - y_o) * \frac{\sqrt{npo(1-po)}}{\sqrt{n-1}}$$

where

$$S_Y = \frac{\sqrt{\sum_{k=1}^{n}(Yk - Y)2}}{\sqrt{n-1}}$$

$$Y = \frac{\sum_{k=1}^{n} Yk}{n}$$

$$P_1 = \frac{\sum_{k=1}^{n} Xk}{n}$$

$$P_o = 1 - p_1$$

Tate (1954) shows that, for large samples, the distribution of $r_{pb}$ is normal with mean ρ and variance.

$$\sigma_r^2 = \frac{(1-\rho^2)^2}{n}\left[1 + \rho^2\left(\frac{1 - 6p_0(1-p_0)}{4p_0(1-p_0)}\right)\right]$$

This population variance can be estimated by substituting the sample value $r_{pb}$ for ρ. An approximate confidence interval based on the normal distribution can be calculated from these quantities using

$$r_{pb} \pm z_{\alpha/2}\sqrt{\frac{\left(1 - r_{pb}^2\right)^2}{n}\left[1 + r_{pb}^2\left(\frac{1 - 6p_0(1-p_0)}{4p_0(1-p_0)}\right)\right]}$$

The hypothesis that ρ = 0 can be tested using the following test which is equivalent to the two-sample t-test

$$t_{pb} = \frac{r_{pb\sqrt{n-2}}}{\sqrt{1 - r_{pb}^2}}$$

### 4.5.3. Point Biserial Correlation Analysis Using SPSS Tool

Therefore, point biserial correlation analysis was preferred and adopted for making correlation analysis among the selected explanatory variables. Besides, the analysis was executed using SPSS software package tool. Furthermore, the selected explanatory variables are presented along with the collected data on the table below, Table 4-17.

**Table 4-17. Selected Explanatory Variables for Point Biserial Correlation Analysis.**

| AN | Building | Signage | APN | SL | PVC | illegal Function | Traveled lane width | Number of U-turn | Median Barrier | Median Opening | Parking Availability | HA | Topo. | $85^{th}$% Speed | ADT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 218 | 4.7 | 0.70 | 1 | legible | No | No | 8.70 | 0 | Yes | No | No | Curve | Sloppy | 51.30 | 24653 |
| 229 | 4.0 | 0.60 | 1 | legible | No | No | 9.95 | 0 | Yes | No | No | Curve | Sloppy | 48.40 | 23456 |
| 233 | 4.0 | 0.55 | 0 | illegible | No | Yes | 9.80 | 1 | No | No | No | Straight | Flat | 55.60 | 24341 |
| 237 | 4.0 | 0.75 | 2 | legible | No | Yes | 9.60 | 0 | Yes | No | No | Straight | Sloppy | 49.60 | 26845 |
| 241 | 4.3 | 0.50 | 4 | legible | No | Yes | 9.00 | 2 | Yes | No | No | Straight | Sloppy | 53.70 | 26345 |
| 256 | 3.5 | 0.55 | 2 | illegible | Yes | Yes | 9.65 | 1 | No | Yes | Yes | Straight | Flat | 48.70 | 23564 |
| 271 | 3.8 | 0.80 | 1 | legible | No | Yes | 9.80 | 0 | No | No | No | Straight | Flat | 61.00 | 24341 |
| 289 | 4.5 | 0.55 | 2 | illegible | No | Yes | 9.85 | 1 | Yes | Yes | No | Curve | Sloppy | 47.50 | 24939 |
| 317 | 4.0 | 0.60 | 1 | illegible | Yes | Yes | 9.95 | 1 | Yes | No | No | Curve | Sloppy | 49.00 | 24231 |
| 319 | 4.0 | 0.60 | 5 | legible | Yes | No | 9.50 | 2 | No | Yes | Yes | Curve | Sloppy | 55.50 | 24293 |
| 323 | 4.0 | 0.70 | 0 | legible | No | No | 10.05 | 0 | Yes | Yes | No | Curve | Flat | 51.20 | 26133 |
| 330 | 3.1 | 0.55 | 2 | illegible | Yes | Yes | 9.20 | 0 | Yes | No | Yes | Curve | Sloppy | 60.30 | 24293 |
| 437 | 4.5 | 0.60 | 0 | illegible | Yes | No | 10.05 | 2 | No | Yes | Yes | Straight | Sloppy | 59.20 | 26345 |
| 541 | 4.5 | 0.55 | 4 | illegible | Yes | Yes | 10.50 | 2 | Yes | Yes | Yes | Straight | Sloppy | 61.45 | 26845 |
| 634 | 5.0 | 0.55 | 0 | illegible | Yes | No | 11.05 | 2 | No | Yes | Yes | Curve | Sloppy | 58.60 | 27873 |

**Table 4-18. Point Biserial Correlation Analysis Result.**

**Point Biserial Correlations**

| | | AN/3yr | SBB | SBS | APN | SL | PVC | Il. F | ATLW | NUT | MBA | MO | PA | HA | Topography | 85th % Spot Speed | ADT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AN/3yr | Pearson Correlation | 1 | .486 | -.291 | -.053 | -.496 | .635* | -.243 | .778** | .590* | -.231 | .595* | .656** | -.067 | .278 | .579* | .646** |
| | Sig. (2-tailed) | | .066 | .293 | .852 | .060 | .011 | .383 | .001 | .021 | .407 | .019 | .008 | .812 | .316 | .024 | .001 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| SBB | Pearson Correlation | .486 | 1 | -.084 | -.119 | -.025 | -.083 | -.425 | .366 | .479 | -.012 | .323 | -.047 | -.083 | .395 | .034 | .617* |
| | Sig. (2-tailed) | .066 | | .765 | .672 | .929 | .768 | .114 | .180 | .071 | .967 | .241 | .867 | .768 | .146 | .905 | .014 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| SBS | Pearson Correlation | -.291 | -.084 | 1 | -.284 | .604* | -.429 | -.146 | -.135 | -.641* | .016 | -.270 | -.421 | .048 | -.287 | -.032 | -.023 |
| | Sig. (2-tailed) | .293 | .765 | | .305 | .017 | .110 | .604 | .632 | .010 | .954 | .330 | .118 | .866 | .300 | .910 | .935 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| APN | Pearson Correlation | -.053 | -.119 | -.284 | 1 | .203 | .203 | .266 | -.308 | .390 | .177 | .116 | .266 | .116 | .360 | .073 | -.021 |
| | Sig. (2-tailed) | .852 | .672 | .305 | | .468 | .468 | .338 | .264 | .151 | .527 | .680 | .338 | .680 | .187 | .795 | .941 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| SL | Pearson Correlation | -.496 | -.025 | .604* | .203 | 1 | -.607* | -.327 | -.444 | -.397 | .218 | -.339 | -.491 | -.071 | -.040 | -.213 | -.057 |
| | Sig. (2-tailed) | .060 | .929 | .017 | .468 | | .016 | .234 | .097 | .143 | .435 | .216 | .063 | .800 | .887 | .446 | .839 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| PVC | Pearson Correlation | .635* | -.083 | -.429 | .203 | -.607* | 1 | -.055 | .354 | .543* | -.327 | .464 | .873** | -.071 | .262 | .390 | .082 |
| | Sig. (2-tailed) | .011 | .768 | .110 | .468 | .016 | | .847 | .196 | .037 | .234 | .081 | .000 | .800 | .346 | .151 | .771 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Il.F | Pearson Correlation | -.243 | -.425 | -.146 | .266 | -.327 | -.055 | 1 | -.158 | -.064 | .167 | -.327 | -.167 | .491 | -.185 | .006 | -.139 |
| | Sig. (2-tailed) | .383 | .114 | .604 | .338 | .234 | .847 | | .575 | .821 | .553 | .234 | .553 | .063 | .510 | .983 | .620 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| ATLW | Pearson Correlation | .778** | .366 | -.135 | -.308 | -.444 | .354 | -.158 | 1 | .364 | -.293 | .535* | .318 | -.009 | -.053 | .255 | .459 |
| | Sig. (2-tailed) | .001 | .180 | .632 | .264 | .097 | .196 | .575 | | .182 | .289 | .040 | .249 | .975 | .852 | .359 | .085 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NUT | Pearson Correlation | .590* | .479 | -.641* | .390 | -.397 | .543* | -.064 | .364 | 1 | -.383 | .543* | .542* | .230 | .306 | .331 | .426 |
| | Sig. (2-tailed) | .021 | .071 | .010 | .151 | .143 | .037 | .821 | .182 | | .159 | .037 | .037 | .410 | .267 | .228 | .113 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| MBA | Pearson Correlation | -.231 | -.012 | .016 | .177 | .218 | -.327 | .167 | -.293 | -.383 | 1 | -.327 | -.444 | -.327 | .431 | -.395 | .066 |
| | Sig. (2-tailed) | .407 | .967 | .954 | .527 | .435 | .234 | .553 | .289 | .159 | | .234 | .097 | .234 | .109 | .145 | .815 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| MO | Pearson Correlation | .595* | .323 | -.270 | .116 | -.339 | .464 | -.327 | .535* | .543* | -.327 | 1 | .600* | -.071 | -.040 | .100 | .340 |
| | Sig. (2-tailed) | .019 | .241 | .330 | .680 | .216 | .081 | .234 | .040 | .037 | .234 | | .018 | .800 | .887 | .723 | .215 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| PA | Pearson Correlation | .656** | -.047 | -.421 | .266 | -.491 | .873** | -.167 | .318 | .542* | -.444 | .600* | 1 | .055 | .185 | .538* | .187 |
| | Sig. (2-tailed) | .008 | .867 | .118 | .338 | .063 | .000 | .553 | .249 | .037 | .097 | .018 | | .847 | .510 | .039 | .505 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| HA | Pearson Correlation | -.067 | -.083 | .048 | .116 | -.071 | -.071 | .491 | -.009 | .230 | -.327 | -.071 | .055 | 1 | -.342 | .294 | .202 |
| | Sig. (2-tailed) | .812 | .768 | .866 | .680 | .800 | .800 | .063 | .975 | .410 | .234 | .800 | .847 | | .211 | .287 | .521 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Topography | Pearson Correlation | .278 | .395 | -.287 | .360 | -.040 | .262 | -.185 | -.053 | .306 | .431 | -.040 | .185 | -.342 | 1 | -.007 | .291 |
| | Sig. (2-tailed) | .316 | .146 | .300 | .187 | .887 | .346 | .510 | .852 | .267 | .109 | .887 | .510 | .211 | | .981 | .292 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| $85^{th}$ % Spot Speed | Pearson Correlation | .579* | .034 | -.032 | .073 | -.213 | .390 | .006 | .255 | .331 | -.395 | .100 | .538* | .294 | -.007 | 1 | .333 |
| | Sig. (2-tailed) | .024 | .905 | .910 | .795 | .446 | .151 | .983 | .359 | .228 | .145 | .723 | .039 | .287 | .981 | | .225 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| ADT | Pearson Correlation | .664** | .617* | -.023 | -.021 | -.057 | .087 | -.139 | .459 | .426 | .066 | .340 | .187 | .202 | .291 | .333 | 1 |
| | Sig. (2-tailed) | .007 | .014 | .935 | .941 | .839 | .771 | .620 | .085 | .113 | .815 | .215 | .505 | .471 | .292 | .225 | |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

## 4.6. Interpretation of The Correlation Analysis

This section presents with the interpretation of point-biserial coefficient along with the description of 2-tailed significant parameter. Since a correlation coefficient measures the extent to which two variables tend to change together. It describes both the strength and direction of relationship. In addition, since Point-Biserial correlation is a special case of Pearson's product-moment correlation, the interaction and strength of relationship among the variables are expressed with Pearson correlation coefficient. Hereafter the standard correlation interpretation guide is presented on the table below, Table 4-19.

**Table 4-19. Correlation Coefficient Interpretation Guide.**

| No | Pearson Correlation Coefficient | Spearman Correlation Coefficient | Description |
|---|---|---|---|
| 1 | 0.00 - 0.19 | 0.00 - 0.19 | Very weak |
| 2 | 0.20 - 0.39 | 0.20 - 0.39 | Weak |
| 3 | 0.40 - 0.59 | 0.40 - 0.59 | Moderate |
| 4 | 0.60 - 0.79 | 0.60 - 0.79 | Strong |
| 5 | 0.80 - 1.00 | 0.80 - 1.00 | Very Strong |

As we can easily have noticed from Table 4-20, the Pearson correlation coefficient values of the explanatory variables are greater than 0.5, statistically they are significant enough to influence the dependent variable. In addition, the three upper most explanatory variables are significant at 0.01 significance level while the remaining four variables are significant at 0.05 significance level. Speaking of Pearson correlation coefficient, it represents the strength and association among the subjected variables, and theoretically, values greater than 0.50 represents an interaction between the two variables. In addition, variables with 2-tailed significant value less than 0.05 are statistically significant to represent the relationship among the variables. Hence, according to the above table all variables are found significant.

**Table 4-20. Significant Explanatory Variables.**

| NO | Explanatory Variables | Variable Type | Variable Category | Pearson Correlation Coefficient | Significance (2-tailed) | Correlation Strength |
|---|---|---|---|---|---|---|
| 1 | Average travel lane width | Geometric Variable | Continuous | **0.778**** | **0.001** | Strong |
| 2 | Parking availability | Roadside Element | Categorical | **0.656**** | **0.008** | Strong |
| 3 | Average Daily Traffic | Traffic Characteristics | Continuous | **0.664**** | **0.001** | Strong |
| 4 | Presence of Visual Clutter | Roadside Element | Categorical | **0.635*** | **0.011** | Strong |
| 5 | Median Opening | Roadside Element | Categorical | **0.595*** | **0.019** | Moderate |
| 6 | Number of U-turn | Geometric Variable | Continuous | **0.590*** | **0.021** | Moderate |
| 7 | 85th % Spot Speed | Traffic Characteristics | Continuous | **0.579*** | **0.024** | Moderate |

***. Correlation is significant at the 0.05 level (1-tailed).**

****. Correlation is significant at the 0.01 level (2-tailed).**

According to the above table, Table 4-20, the entire values of the Pearson correlation coefficients are positive in magnitude and it implies that the selected variables affects the dependent variable i.e. accident occurrence in a positively manner. For instance, the Pearson correlation coefficient of the average travel lane width is 0.778, which implies it is positively and strongly related to the occurrences of road traffic accidents. Statistically speaking, the wider the average travel lane width, the higher the probability of accident occurrence. Looking to the availability of parking, its correlation coefficient is positive, 0.656 and it represents the availability of parking will increase the likelihood of occurrences of road traffic accidents.

Similarly, average daily traffic volume is also significant variable with a coefficient value of 0.756, implies when the traffic volume increases, the possibility of accident occurrences also increases. Moreover, the above stated explanatory variables have shown a strong relationship with accident occurrence and were found relevant at 99% confidence interval. Subsequently, presence of visual clutter has shown a strong relationship with the dependent variable with a coefficient value of 0.635. Hence, the more the presence of visual clutter on the proposed signage, the more will be the traffic accident.

On the other hand, the remaining four variables were also found significant with positive value of Pearson correlation coefficient and according to the adopted correlation coefficient guide, their strength is in moderate level. Moreover, the more the availability of the median opening, the more will be the accident occurrence; the more the availability of U-turn, again the more the accident will be and finally when the $85^{th}$ percentile spot speed increases, the likelihood of road traffic accident occurrence will also increase.

## 4.7. Discussion

According to the result of the Point-Biserial correlation analysis, and engineering judgement seven variables were found significant to influence the dependent variable i.e. the accident number. In addition, three of them are categorical variables such as presence of visual clutter, parking availability and median opening while the remaining four are continuous variables. And the continuous variables comprise average travel lane width, average daily traffic, number of U-turn and finally the $85^{th}$ percentile spot speed. Hereafter, the respective influence of the stated explanatory variables is discussed in detail on the following sub topics as follows:

### 4.7.1. Average Travel Lane Width

The number of Accident number has a positive relation with average travel lane width. It implies that when the average travel lane width increases, the number of traffic accident also increases. And the argument for this situation relays on the fact that when the average travel lane width is wider, there will be enough space for the drivers. Hence, road users particularly drivers tend to drive with a higher speed and they frequently change their lane. Consequently, the probability of occurrences of road traffic accident will be higher. Research by Neuman, Glennon and Saag (1983) also disclosed that width of the travelled way has a significant effect on the occurrences of road traffic accidents. Hence, as the travel lane width is wider, the likelihood of accident occurrence will be higher.

### 4.7.2. Parking Availability

As of the average travel lane width, the availability of parking has also positive relationship with the accident number. According to the result of Point-Biserial correlation analysis, it has shown positive and strong relation with a numerical value of 0.656. When parking facilities present along the road network, the likelihood of accident occurrence will be augmented due to the interruption of vehicle flow from the parking lot to the major road.

Additionally, when drivers on the major road have noticed vehicles from the parking lot are about to join the main stream, they will likely to increase their speed and tries to pass before the intercepted vehicle joins the stream. So, this will lead to the occurrence of road traffic accident. Moreover, vehicles which tries to enter from the access roads and vehicles on the major roads are restricted to watch each other due to the parked vehicles. So, the likelihood of occurrence of road traffic accident is higher as compared to networks without parking facility.

### 4.7.3. Average Daily Traffic

Since road traffic accident is not occurred without exposure variables such as traffic volume and vehicle speed, it is very much critical to deal with average traffic volume and spot speed. Fortunately, average daily traffic volume was found significant with positive effect on the accident number. Therefore, when the average daily traffic volume increases, the likelihood of accident occurrence also increases. And this situation is applicable both from theoretical and practical point of view.

### 4.7.4. Presence of Visual Clutter

It is categorized among the roadside elements and as of the other significant variables it has shown positive relationship with the dependent variable. According to the publication of Edquist, 2008, the level of visual clutter is determined by intersection between the amount and complexity of signage, how difficult it is to pick out important objects from the background, distracting objects like shops and advertising billboards, and other facets of the environment that influence driver workload such as the amount of traffic. Hence, according to the result of correlation analysis, as the level of visual clutter is more, the probability of accident occurrences will be higher. Similar research by Edquist, 2008 revealed that as there exist much more distracting elements on the road sections, the occurrences of accidents will be higher.

### 4.7.5. Median Opening

Median opening is the other presumed explanatory variables and categorized under geometric parameter. And it mainly deals with road user exposure either vehicular movement or pedestrian movement to major travel stream. And according to the result of correlation analysis, median opening has positive and moderate correlation with the dependent variable. Hence, it implies road networks with median opening either for vehicular or pedestrian movement are more susceptible for accident occurrences than those without this facility.

Moreover, the greater number of median opening on the road network, the higher will be the occurrences of road traffic accidents. An improvement study made by China Research Institute of Highway, 2014 concluded that road network with a restricted median opening has shown better safety performance and those networks with availability of median opening are susceptible for the occurrences of road traffic accidents.

### 4.7.6. Number of U-Turn

As it was presented on the above table, Table 4-20, the number of U-turn has positive and moderate correlation strength with the number of road traffic accident. Generally, the presence of U-turn will allow vehicles to turn reverse back and it affects the traffic on major stream. So, as the number of U-turn increases, the probability of accident occurrences on the major stream will be higher. Looking to the result of correlation analysis, as the number of U-turn increases the likelihood of accident occurrences will be augmented.

### 4.7.7. 85th % Spot Speed

Speed is categorized among the exposure variable and theoretically it has been taken as the major contributing factor for the occurrences of numerous road traffic accidents. Besides, it was also found as a significant explanatory variable for the given data set. Numerically, it was moderately significant with a correlation coefficient of 0.579 and two-tailed significant value of 0.024. Moreover, it infers that when vehicular speed increases, the number and likelihood of accident occurrences also increases in a significant manner.

# Chapter 5 - CONCLUSIONS AND RECOMMENDATIONS

## 5.1. Conclusions

The objective of the research was to made an investigation on the effects of roadway elements on safety aspects of arterial road networks particularly on streets of Nifas silk sub city. And according to the performed investigation, the sub city is found to be the most susceptible in experiencing frequent and severe type of road traffic accidents. In addition, the exhibited data of the three-year accident analysis proved that the accident frequency shows consecutive augmentation through 2015 to 2017.

The research has adopted thirty-six samples for executing the study and as per the performed analysis fifteen segments were found the prominent accident-prone locations. Besides, the selection process was made using the exhibited three years of accident data, relevant statistical approach and engineering judgement. In addition, among the selected fifteen segments, three of them have shown a significant variation and needs special consideration while providing countermeasure.

As it was briefly stated in the discussion part of the paper, among the selected sixteen variables, seven variables were identified as a significant explanatory variable for the occurrences of frequent number of road traffic accidents. In addition, three out of the seven variables are road side explanatory variables such as availability of parking, presence of visual clutter and median opening. On the other hand, two variables were from traffic characteristics and they are average daily traffic volume and $85^{th}$ % spot speed. Finally, the remaining two variables are categorized under geometric explanatory variables and they are average travel lane width and number of U-turn.

In addition, average travel lane width, average daily traffic volume, availability of parking and presence of visual clutter have shown strong and positive relationship with the dependent variable i.e. number of traffic accident. Conversely, the other three variables such as median opening, number of U-turn and $85^{th}$ percentile spot speed have shown moderate correlation with number of road traffic accident.

Fortunately, all significant explanatory variables have shown positive correlation with the dependent variable. For instance, when the number of U-turn and average travel lane width increases, the number of traffic accident also increases.

Similarly, as the availability of parking and median opening is augmented, the probability of accident occurrence is also increased as compared to those without the stated parameters. In addition, the more there is a visual clutter, the more will be the likelihood of accident occurrences. Most importantly, as the average daily traffic volume and $85^{th}$ percentile spot speed increases, the number and possibility of traffic accident occurrences will also increase in a significant manner.

## 5.2. Recommendations

As it was presented earlier, the safety aspects of arterial roads in the sub city is in a critical stage, therefore, road safety management agencies of the city should give intense consideration towards providing possible solution for the respective identified issues for the existing roads. In addition, the safety aspects of the road segments should be well incorporated in the design of newly constructed road. For instance, the travel lane width of arterial roads is wider as compared to other road classifications which allows the drivers to drive with a higher speed. In contrary, pedestrians are subjected to experience large crossing time which in turn leads them to be exposed to road traffic accident.

In addition, the accident database of the police stations is not well structured, therefore, it lacks accuracy in representing crash event in a reliable manner. Besides, there is under reporting of data and most of the recorded data doesn't provide full information of crash event such as specific location of accident, causes of accident, collision diagram etc. Hence, it has a diverse effect on preparing accurate statistical report on the trend of road traffic accident and it is also difficult to identify the basic causes of the crash.

Speaking of traffic volume database, even the city's road authority did not have a continuous traffic counting program. Additionally, it also lacks well prepared traffic counting manual as of the other countries. So, most researchers have got a headache while trying to made traffic volume studies with in the city. Therefore, AACRA should work its best in organizing and preparing well-structured traffic counting manual in collaboration with safety management institutions and universities of the country. Moreover, lack of road inventory database is also a big challenge of the city's road authority. So, similarly AACRA and its collaborative institutions should have to proposed periodic road inventory studies to collect and to know the current status of the road networks. As such it will be used as a useful weapon for making practical problem-solving researches, and it will also be utilized to made relevant asset management on the road networks of the city.

# Chapter 6 – COUNTERMEASURE

After having analyzed the accident data and identified the relevant accident-prone locations, the next step to do is providing proper countermeasure for the specific site conditions. According to the recommendation made by two scholars Jordan and Veith, 1989, it is recommended to forward proper countermeasure for the respective situation of the accident-prone location. And this paper tries to provide the general countermeasures that are suitable to reduce the occurrences of road traffic accidents. In addition, considering the real essence of the identified accident-prone locations and the selected significant explanatory variables, the countermeasures are forwarded under four major topics:

A. For accident prone locations involving improper roadside elements such as the presence of visual cutter, improper location of trees, vegetation and roadside furniture's, are improved through the following recommended measures:

- ✓ Relocating trees into proper position, increasing the spacing of trees, removing huge trees;
- ✓ Consider Barrier lining to alert the drivers;
- ✓ Reducing density of roadside Equipment on commercial areas and driveway locations;
- ✓ Avoiding provision of large billboards and advertising posters.

B. To reduce accidents resulting from the presence of unnecessary median opening (both for pedestrian crossing and vehicular U-turn movement) and smaller medians, it is recommended to:

- ✓ Closing of risky median opening, installing of barriers on risk crossing areas;
- ✓ Improving delineation, widening of the median or provision of a median barrier;
- ✓ Provide footpath extensions into parking lanes and reduce pedestrian crossing distance;
- ✓ Consider installation of pedestrian refuge islands where very wide two-way carriageway is to be crossed;
- ✓ Provision of median barrier, providing of pedestrian Island, widening of median, improve visibility of marking at crossing and clear delineation of lanes;
- ✓ Restricting U-turn on risky areas;
- ✓ Installing direction sign to allowing drivers to position their vehicles prior to making turns, reassuring drivers so that they are not hesitant and thereby potentially disrupting traffic flow, and drawing attention to the presence of U turn (Nairn, 1987,)

C. In order to reduce road traffic accidents resulting from adopting higher driving speed, it is recommended to:
   - ✓ Provide several speed calming measures such as Road humps, ramble strips etc. to reduce vehicle speeds;
   - ✓ Consistent design on roadside environment to guide drivers speed selection;
   - ✓ Installing of speed monitoring Rader on selected accident-prone location;
   - ✓ Provision of warning sign on curve and steep gradient to minimize vehicular speed;
   - ✓ Provision of signals and signs to reduce speed.

D. For reducing the effects of improper parking facility on the occurrences of frequent road traffic accidents, it is recommended to:
   - ✓ Restrict parking services at road segments with several access road facilities;
   - ✓ Consider parking prohibition to improve pedestrian sight lines and driveway movements;
   - ✓ Delineation of parking areas;
   - ✓ Provision of off-street parking.

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# ANNEX

## 1. Raw Input Data

## A. Sample Raw Accident Data

| No | Date | Time | Accident Type | Vehicle Type | Severity | Land Use | Road Layout | Specific Location | *Legend* | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22/4/2007 | 21:00 | VP | A | S | C | SL | Abo RA | **Accident Type** | |
| 2 | 22/4/2007 | 13:45 | VV | A | POD | C | SL | Varnero | Vehicle to Vehicle | VV |
| 3 | 22/4/2007 | 2:00 | VV | mB | POD | C | CL | Biserate Gebriel RA | Vehicle to Pedestrian | VP |
| 4 | 22/4/2007 | 18:30 | VV | mB | POD | C | SL | Meskel Kitfo | Vehicle to Object | VO |
| 5 | 22/4/2007 | 14:30 | VV | A | S | C | SL | Bridge | Vehicle Overturn | VOT |
| 6 | 22/4/2007 | 7:00 | VV | A | S | C | SL | Abo Gulit | Passenger Fall | PF |
| 7 | 22/4/2007 | 8:30 | VV | A | POD | C | SL | Safeway Supermarket | Vehicle to Bajaj | VB |
| 8 | 22/4/2007 | 1:20 | VO | A | POD | C | SL | Meskel Kitfo | Vehicle to Motor C. | VM |
| 9 | 22/4/2007 | 7:00 | VV | mB | POD | C | SL | Shell Depo | Vehicle to Bicycle | VBC |
| 10 | 22/4/2007 | 9:45 | VV | A | POD | C | SL | Bridge | VCART | VCA |
| 11 | 23/4/2007 | 9:00 | VV | A | POD | O | SL | Canada Embassy | Vehicle to Animal | VA |
| 13 | 23/4/2007 | 13:30 | VV | A | POD | Ch | SL | Adey Abeba | **Vehicle Type** | |
| 14 | 23/4/2007 | 3:10 | VV | A | POD | C | CL | Biserate Gebriel RA | Automobile | A |
| 15 | 23/4/2007 | 17:30 | VP | mB | S | C | SL | Glass Factory | Minibus | mB |
| 16 | 23/4/2007 | 10:45 | VV | MT | POD | C | CL | German RA | Medium Bus | MB |
| 17 | 23/4/2007 | 23:00 | VV | A | POD | C | CL | German RA | Bus | B |
| 18 | 23/4/2007 | 16:00 | VV | A | POD | R | SL | Kore Condominium | Medium Truck | MT |
| 19 | 24/4/2007 | 7:30 | VV | A | POD | O | SL | INSA | Heavy Truck | HT |
| 20 | 24/4/2007 | 17:30 | VP | mB | S | R | SL | Condominium | Articulated Truck | AT |
| 21 | 24/4/2007 | 14:30 | VV | HT | POD | C | SL | Bridge | Machines | M |
| 23 | 24/4/2007 | 9:40 | VV | A | POD | C | SL | Glass Factory | **Severity** | |
| 24 | 24/4/2007 | 11:30 | VV | A | POD | C | SL | Bridge | Severe | S |
| 25 | 24/4/2007 | 23:30 | VP | mB | S | O | SL | Ethiopian Cu. & Re. | Medium | M |
| 26 | 25/4/2007 | 10:10 | VV | MT | POD | O | SL | Ethiopian Cu. & Re. | Light | L |
| 27 | 25/4/2007 | 7:20 | VV | BAJAJ | POD | C | SL | Meskel Kitfo | Property only damage | POD |
| 28 | 25/4/2007 | 11:00 | VV | MT | POD | C | SL | Muzika bet | Fatal | F |
| 30 | 25/4/2007 | 19:30 | VV | A | POD | O | SL | Meskelegna | **Land Use** | |
| 31 | 25/4/2007 | 15:45 | VV | A | POD | C | SL | Safeway Supermarket | Residential | R |
| 32 | 25/4/2007 | 9:30 | VV | mB | POD | O | SL | Vatican Embassy | Commercial | C |

## B. Sample Geometric Data

### GEOMETRIC DATA

| No | GEOMETRIC DESIGN ELEMENTS | | Accident - Prone Location | | | |
|---|---|---|---|---|---|---|
| | Gofa Gibrial Sfr to German Sfr | | Segment ID: NSGG03 | | | |
| 1 | **Cross -sectional elements** | | | | | |
| | | | Pt.1 | Pt.2 | Pt.3 | Average |
| 1.1 | *Walk way Width (m)* | | 2.9 | 2.85 | 2.95 | 2.9 |
| 1.2 | *Median Width (m)* | | 0.8 | 0.9 | 0.85 | 0.85 |
| 1.3 | *Midian side lane Width(m)* | | 3.6 | 3.6 | 3.6 | 3.6 |
| 1.4 | *Middle Lane Width (m)* | | 3.5 | 3.5 | 3.5 | 3.5 |
| 1.5 | *Edge Lane Width (m)* | | 2.4 | 2.6 | 2.5 | 2.5 |
| 1.6 | *Average Traffic Lane Width (m)* | | — | — | — | 9.6 |
| 1.7 | *Average Right of Way Width (m)* | | — | — | — | 25.8 |
| 1.8 | *Number of U - Turn (pc)* | | 2 | | | |
| 1.9 | *Types of median* | *20cm curb stone/grade separated/ (0&1)* | 0 | 0 | 0 | 0 |
| | | *Barrier Ava. (0&1)* | 0 | | | |
| 1.10 | *Median Opening* | *Ab-0; Pre-1* | 1 | | | |
| | | *Number* | 2 | | | |
| 1.11 | *Parking Availability* | *Yes/No* | Yes | | | |
| 2 | **Horizontal Alignment** | *Straight (0)&Curve (1)* | Straight (0) | | | |
| 3 | **Topography** | *Flat / Sloppy* | Sloppy | | | |

## C. Sample Raw Roadside Element Data

### Road Side Element Data

| | | | | | | |
|---|---|---|---|---|---|---|
| **ROADSIDE ENVIRONMENT DATA** | | **Network name:** Gofa Gibrail sqr to German sqr. | | | | |
| | | **Accident - Prone Location ID:** NSGG02. | | | | |
| **1.Object next to the road** | | — | | | | |
| 1.1. | *Tree (Yes/No)* | Yes | Yes | Yes | Yes | Yes |
| | | — | — | — | — | — |
| **2.Set back distance (m)** | | **Pt1** | **Pt2** | **Pt3** | **Pt4** | **average** |
| 2.1. | *Tree* | 1 | 0.8 | 1 | 1.2 | 1. |
| 2.2. | *Building* | 3 | 3.1 | 3.15 | 3.1 | 3.1. |
| 2.3. | *Signage/Traffic Sign* | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| 2.4. | *Light pole* | 0.55 | 0.6 | 0.6 | 0.65 | 0.6 |
| **3.Access point** | | | | | | |
| 3.1. | *Number* | ~~8~~ 2 | | | | |
| 3.2. | *Entry/Exit* | — | | | | |
| **4.Sign & Sign legibility** | | — | — | — | — | — |
| 4.1. | *Availability (Yes/No)* | Yes | | | | |
| 4.2. | *Sign legibility (Yes/No)* | No | | | | |
| **5.Distraction & Overload** | | — | — | — | — | — |
| 5.1. | *Presence of visual clutter (Yes/No)* | Yes | | | | |
| **6. Different Unseen Roadside Barriers,** | | — | — | — | — | — |
| 6.1. | *Illegal functions like street vendors,* | Yes | | | | |

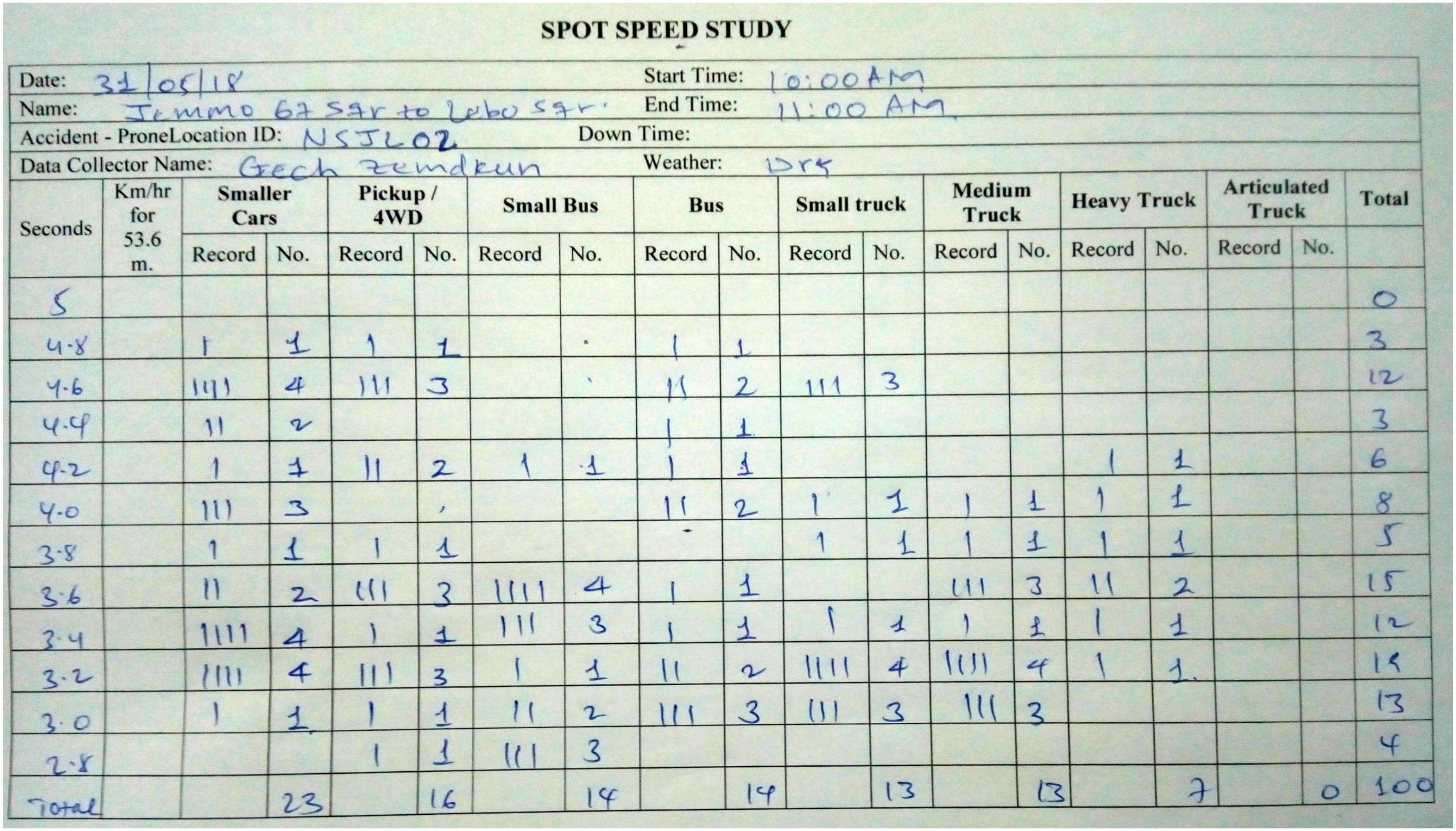
## D. Sample Raw Traffic Data

### D.1. Traffic Volume Data

**TRAFFIC VOLUME COUNT**

| Manual Traffic Count | | | |
|---|---|---|---|
| Date: 28/04/18 | Day of Week: Tu O We O Th O Sa ● Counting Duration: 08:00AM - 08:15Am | | Counting Direction |
| | Data Collector Name: Rute Girma. Segment Designation: NSTS02 | | NB O / SB ● |
| No | Vehicle type | Counting location: Norway resident Traffic Volume 334 | Remark |
| 1 | Small Cars | | |
| 2 | Pick-up/4WD | | |
| 3 | Small Bus | | |
| 4 | Bus | | |
| 5 | Small Truck | | |
| 6 | Medium Truck | | |
| 7 | Heavy Truck | | |
| 8 | Articulated Truck | | |

## D.2. Spot Speed Data



**SPOT SPEED STUDY**

Date: 31/05/18 Start Time: 10:00 AM
Name: Jemmo 67 sqr to Lebu sqr. End Time: 11:00 AM
Accident - ProneLocation ID: NSJL02 Down Time:
Data Collector Name: Grech Zemdkun Weather: Dry

| Seconds | Km/hr for 53.6 m. | Smaller Cars | | Pickup / 4WD | | Small Bus | | Bus | | Small truck | | Medium Truck | | Heavy Truck | | Articulated Truck | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Record | No. | Record | No. | Record | No. | Record | No. | Record | No. | Record | No. | Record | No. | Record | No. | |
| 5 | | | | | | | | | | | | | | | | | | 0 |
| 4.8 | | I | 1 | I | 1 | | | I | 1 | | | | | | | | | 3 |
| 4.6 | | IIII | 4 | III | 3 | | | II | 2 | III | 3 | | | | | | | 12 |
| 4.4 | | II | 2 | | | | | I | 1 | | | | | | | | | 3 |
| 4.2 | | I | 1 | II | 2 | I | 1 | I | 1 | | | | | I | 1 | | | 6 |
| 4.0 | | III | 3 | | | | | II | 2 | I | 1 | I | 1 | I | 1 | | | 8 |
| 3.8 | | I | 1 | I | 1 | | | | | I | 1 | I | 1 | I | 1 | | | 5 |
| 3.6 | | II | 2 | III | 3 | IIII | 4 | I | 1 | | | III | 3 | II | 2 | | | 15 |
| 3.4 | | IIII | 4 | I | 1 | III | 3 | I | 1 | I | 1 | I | 1 | I | 1 | | | 12 |
| 3.2 | | IIII | 4 | III | 3 | I | 1 | II | 2 | IIII | 4 | IIII | 4 | I | 1 | | | 19 |
| 3.0 | | I | 1 | I | 1 | II | 2 | III | 3 | III | 3 | III | 3 | | | | | 13 |
| 2.8 | | | | I | 1 | III | 3 | | | | | | | | | | | 4 |
| Total | | | 23 | | 16 | | 14 | | 14 | | 13 | | 13 | | 7 | | 0 | 100 |

## 2. Traffic Volume Data Analysis Table

### A. Road Network Name: Mikael Square to Bisrate Gabriel Square

| Date:11/4/2018 | | | | | |
|---|---|---|---|---|---|
| Day of week: Wednesday | | | | | |
| Max PHV= 3083 Between 8:00AM and 9:00AM | | | | | |
| Counting Location: Dombosko School | | | | | |
| Road network: **Mikael Square to Bisrate Gabriel Square** | | | | | |
| **Time** | **Direction** | | **Total** | **Hourly Sum** | **PHV** |
| | **South bound** | **North bound** | | | |
| 07:00-07:15 | 281 | 375 | 655 | | |
| 07:15-07:30 | 336 | 373 | 709 | | |
| 07:30-07:45 | 368 | 401 | 769 | | |
| 07:45-08:00 | 365 | 342 | 707 | 2839 | |
| 08:00-08:15 | 390 | 405 | 795 | | |
| 08:15-08:30 | 396 | 326 | 722 | | |
| 08:30-08:45 | 424 | 350 | 774 | | |
| 08:45-09:00 | 413 | 380 | 793 | 3083 | |
| 04:00 - 04:15 | 349 | 404 | 753 | | |
| 04:15 - 04:30 | 429 | 348 | 777 | | **3083** |
| 04:30 - 04:45 | 387 | 288 | 675 | | |
| 04:45 - 05:00 | 382 | 291 | 673 | 2877 | |
| 05:00 - 05:15 | 402 | 319 | 721 | | |
| 05:15 - 05:30 | 337 | 288 | 625 | | |
| 05:30 - 05:45 | 350 | 255 | 605 | | |
| 05:45 - 06:00 | 278 | 260 | 538 | **2488** | |
| **Total** | **5885** | **5401** | | | |

**B. Road Network Name: Gofa Gabriel To German Square.**

| | | | | | |
|---|---|---|---|---|---|
| Date:17/4/2018 | | | | | |
| Day of week: Tuesday | | | | | |
| Max PHV=2902 Between 10:00PM & 11:00PM | | | | | |
| Counting Location: Gofa primary school | | | | | |
| Road network: German to Gofa Gabriel | | | | | |
| Time | Direction | | Total | Hourly Sum | PHV |
| | South bound | North bound | | | |
| 07:00-07:15 | 230 | 403 | 633 | | |
| 07:15-07:30 | 279 | 370 | 649 | | |
| 07:30-07:45 | 323 | 348 | 671 | | |
| 07:45-08:00 | 333 | 302 | 635 | 2587 | |
| 08:00-08:15 | 355 | 332 | 687 | | |
| 08:15-08:30 | 320 | 299 | 619 | | |
| 08:30-08:45 | 334 | 298 | 631 | | |
| 08:45-09:00 | 357 | 261 | 618 | 2554 | |
| 04:00 - 04:15 | 494 | 353 | 847 | | |
| 04:15 - 04:30 | 403 | 302 | 705 | | 2902 |
| 04:30 - 04:45 | 414 | 268 | 682 | | |
| 04:45 - 05:00 | 414 | 255 | 669 | 2902 | |
| 05:00 - 05:15 | 370 | 276 | 646 | | |
| 05:15 - 05:30 | 314 | 274 | 588 | | |
| 05:30 - 05:45 | 291 | 265 | 555 | | |
| 05:45 - 06:00 | 291 | 275 | 565 | 2353 | |
| Total | 5518 | 4878 | | | |

**C. Road Network Name: Jemo 67 Square to Lebu Square**

| Date:10/4/2018 | | | | | |
|---|---|---|---|---|---|
| Day of week: Tuesday | | | | | |
| Max PHV=2918 Between 4:00PM & 5:00PM | | | | | |
| Counting Location: Kiru bar and Restaurant | | | | | |
| Road network: Jemo 67 Square to Lebu Square | | | | | |
| Time | Direction | | Total | Hourly Sum | PHV |
| | South bound | North bound | | | |
| 07:00-07:15 | 336 | 411 | 747 | | |
| 07:15-07:30 | 293 | 382 | 674 | | |
| 07:30-07:45 | 372 | 380 | 751 | | |
| 07:45-08:00 | 377 | 332 | 708 | 2880 | |
| 08:00-08:15 | 324 | 341 | 665 | | |
| 08:15-08:30 | 235 | 333 | 568 | | |
| 08:30-08:45 | 231 | 283 | 513 | | |
| 08:45-09:00 | 313 | 345 | 658 | 2404 | |
| 04:00 - 04:15 | 403 | 393 | 796 | | |
| 04:15 - 04:30 | 356 | 364 | 720 | | 2918 |
| 04:30 - 04:45 | 348 | 349 | 697 | | |
| 04:45 - 05:00 | 349 | 357 | 706 | 2918 | |
| 05:00 - 05:15 | 373 | 306 | 679 | | |
| 05:15 - 05:30 | 333 | 298 | 630 | | |
| 05:30 - 05:45 | 339 | 304 | 643 | | |
| 05:45 - 06:00 | 333 | 245 | 578 | 2529 | |
| Total | 5311 | 5420 | | | |

**D. Road Network Name: Sarbet Square to Germen Square**

| Date:19/4/2018 | | | | | |
|---|---|---|---|---|---|
| Day of week: Thursday | | | | | |
| Max PHV= 3402 Time 7:00AM and 8:00AM | | | | | |
| Counting Location: Vatican Embassy | | | | | |
| Road network: Sarbet Square to Germen Square | | | | | |
| Time | Direction | | Total | Hourly Sum | **PHV** |
| | South bound | North bound | | | |
| 07:00-07:15 | 328 | 481 | 808 | | |
| 07:15-07:30 | 433 | 518 | 951 | | |
| 07:30-07:45 | 365 | 487 | 852 | | |
| 07:45-08:00 | 386 | 406 | 792 | 3402 | |
| 08:00-08:15 | 409 | 431 | 840 | | |
| 08:15-08:30 | 330 | 394 | 724 | | |
| 08:30-08:45 | 398 | 413 | 811 | | |
| 08:45-09:00 | 424 | 359 | 782 | 3156 | |
| 04:00 - 04:15 | 415 | 395 | 810 | | |
| 04:15 - 04:30 | 436 | 434 | 870 | | **3402** |
| 04:30 - 04:45 | 452 | 397 | 849 | | |
| 04:45 - 05:00 | 395 | 358 | 753 | 3281 | |
| 05:00 - 05:15 | 425 | 481 | 906 | | |
| 05:15 - 05:30 | 391 | 362 | 752 | | |
| 05:30 - 05:45 | 330 | 377 | 706 | | |
| 05:45 - 06:00 | 321 | 393 | 713 | 3077 | |
| Total | 6234.5 | 6681 | | | |

**E. Road Network Name: Total Square to Bisrate Gabriel Square**

| Date:28/4/2018 | | | | | |
|---|---|---|---|---|---|
| Day of week: Saturday | | | | | |
| Max PHV= 3094 Time 4:00PM and 5:00PM | | | | | |
| Counting Location: Norway Resident | | | | | |
| Road network: Total Square to Bisrate Gabriel Square | | | | | |
| Time | Direction | | Total | Hourly Sum | PHV |
| | South bound | North bound | | | |
| 07:00-07:15 | 327 | 420 | 747 | | |
| 07:15-07:30 | 373 | 434 | 807 | | |
| 07:30-07:45 | 303 | 462 | 764 | | |
| 07:45-08:00 | 322 | 438 | 759 | 3076.5 | |
| 08:00-08:15 | 355 | 361 | 716 | | |
| 08:15-08:30 | 411 | 418 | 829 | | |
| 08:30-08:45 | 419 | 272 | 691 | | |
| 08:45-09:00 | 446 | 393 | 839 | 3073.5 | |
| 04:00 - 04:15 | 374 | 382 | 756 | | |
| 04:15 - 04:30 | 379 | 425 | 804 | | 3094 |
| 04:30 - 04:45 | 397 | 376 | 772 | | |
| 04:45 - 05:00 | 442 | 321 | 762 | 3094 | |
| 05:00 - 05:15 | 429 | 326 | 755 | | |
| 05:15 - 05:30 | 434 | 308 | 742 | | |
| 05:30 - 05:45 | 380 | 288 | 667 | | |
| 05:45 - 06:00 | 346 | 322 | 667 | 2831 | |
| Total | 6133 | 5942 | | | |

### 3. Spot Speed Analysis Table

#### A. Road Network Name: Mikael Square to Bisrate Gabriel Square.

| Analysis of Spot speed @ NS-BM04 | | | | | |
|---|---|---|---|---|---|
| **Speed (km/hr)** | **Frequency of vehicles** | **Cumulative frequency** | **Cumulative percent** | **Speed percentile** | |
| 27.6 | 0 | 0 | 0.00 | | |
| 28.4 | 0 | 0 | 0.00 | | |
| 29.2 | 0 | 0 | 0.00 | | |
| 30.2 | 0 | 0 | 0.00 | | |
| 31.1 | 0 | 0 | 0.00 | | |
| 32.2 | 0 | 0 | 0.00 | | |
| 33.3 | 0 | 0 | 0.00 | | |
| 34.5 | 0 | 0 | 0.00 | | |
| 35.7 | 0 | 0 | 0.00 | | |
| 37.1 | 4 | 4 | 3.96 | | |
| 38.6 | 12 | 16 | 15.84 | | |
| 40.2 | 8 | 24 | 23.76 | | |
| 41.9 | 12 | 36 | 35.64 | **43.9** | **50th %** |
| 43.9 | 14 | 50 | 49.50 | | |
| 45.9 | 13 | 63 | 62.38 | | |
| 48.2 | 12 | 75 | 74.26 | | |
| 50.8 | 9 | 84 | 83.17 | **51.6** | **85th %** |
| 53.6 | 6 | 90 | 89.11 | | |
| 56.8 | 8 | 98 | 97.03 | | |
| 60.3 | 3 | 101 | 100.00 | | |

## B. Road Network Name: Gofa Gabriel Square to German Square

| Analysis of Spot speed @ NS-GG02 | | | | | |
|---|---|---|---|---|---|
| **Speed (km/hr)** | **Frequency of vehicles** | **Cumulative frequency** | **Cumulative percent** | **Speed percentile** | |
| 27.6 | 0 | 0 | 0.00 | | |
| 28.4 | 0 | 0 | 0.00 | | |
| 29.2 | 0 | 0 | 0.00 | | |
| 30.2 | 0 | 0 | 0.00 | | |
| 31.1 | 0 | 0 | 0.00 | | |
| 32.2 | 0 | 0 | 0.00 | | |
| 33.3 | 0 | 0 | 0.00 | | |
| 34.5 | 0 | 0 | 0.00 | | |
| 35.7 | 0 | 0 | 0.00 | | |
| 37.1 | 0 | 0 | 0.00 | | |
| 38.6 | 0 | 0 | 0.00 | | |
| 40.2 | 1 | 1 | 1.00 | | |
| 41.9 | 6 | 7 | 7.00 | | |
| 43.9 | 10 | 17 | 17.00 | | |
| 45.9 | 10 | 27 | 27.00 | | |
| 48.2 | 13 | 40 | 40.00 | **49.4** | **50th %** |
| 50.8 | 18 | 58 | 58.00 | | |
| 53.6 | 14 | 72 | 72.00 | | |
| 56.8 | 13 | 85 | 85.00 | **60.3** | **85th %** |
| 60.3 | 9 | 94 | 94.00 | | |
| 64.3 | 3 | 97 | 97.00 | | |
| 68.9 | 2 | 99 | 99.00 | | |

## C. Road Network Name: Sarbet Square to Abo Square

| Analysis of Spot speed @ NS-GS02 | | | | | |
|---|---|---|---|---|---|
| **Speed (km/hr)** | **Frequency of vehicles** | **Cumulative frequency** | **Cumulative percent** | **Speed percentile** | |
| 27.6 | 0 | 0 | 0.00 | | |
| 28.4 | 0 | 0 | 0.00 | | |
| 29.2 | 0 | 0 | 0.00 | | |
| 30.2 | 0 | 0 | 0.00 | | |
| 31.1 | 0 | 0 | 0.00 | | |
| 32.2 | 0 | 0 | 0.00 | | |
| 33.3 | 0 | 0 | 0.00 | | |
| 34.5 | 0 | 0 | 0.00 | | |
| 35.7 | 0 | 0 | 0.00 | | |
| 37.1 | 0 | 0 | 0.00 | | |
| 38.6 | 12 | 12 | 12.00 | | |
| 40.2 | 6 | 18 | 18.00 | | |
| 41.9 | 7 | 25 | 25.00 | | |
| 43.9 | 8 | 33 | 33.00 | | |
| 45.9 | 8 | 41 | 41.00 | 46.2 | 50th % |
| 48.2 | 10 | 51 | 51.00 | | |
| 50.8 | 7 | 58 | 58.00 | | |
| 53.6 | 7 | 65 | 65.00 | | |
| 56.8 | 15 | 80 | 80.00 | 58.7 | 85th % |
| 60.3 | 11 | 91 | 91.00 | | |
| 64.3 | 9 | 100 | 100.00 | | |

## D. Road Network Name: Jemmo 67 Square to Lebu Square

| Analysis of Spot speed @ NS-GS02 | | | | | |
|---|---|---|---|---|---|
| **Speed (km/hr)** | **Frequency of vehicles** | **Cumulative frequency** | **Cumulative percent** | **Speed percentile** | |
| 27.6 | 0 | 0 | 0.00 | | |
| 28.4 | 0 | 0 | 0.00 | | |
| 29.2 | 0 | 0 | 0.00 | | |
| 30.2 | 0 | 0 | 0.00 | | |
| 31.1 | 0 | 0 | 0.00 | | |
| 32.2 | 0 | 0 | 0.00 | | |
| 33.3 | 0 | 0 | 0.00 | | |
| 34.5 | 0 | 0 | 0.00 | | |
| 35.7 | 0 | 0 | 0.00 | | |
| 37.1 | 0 | 0 | 0.00 | | |
| 38.6 | 0 | 0 | 0.00 | | |
| 40.2 | 3 | 3 | 3.00 | | |
| 41.9 | 12 | 15 | 15.00 | | |
| 43.9 | 3 | 18 | 18.00 | | |
| 45.9 | 6 | 24 | 24.00 | | |
| 48.2 | 8 | 32 | 32.00 | | |
| 50.8 | 5 | 37 | 37.00 | 53.2 | 50th % |
| 53.6 | 15 | 52 | 52.00 | | |
| 56.8 | 12 | 64 | 64.00 | | |
| 60.3 | 19 | 83 | 83.00 | 60.9 | 85th % |
| 64.3 | 13 | 96 | 96.00 | | |
| 68.9 | 4 | 100 | 100.00 | | |

## E. Road Network Name: Total Square to Sarbet Square

| Analysis of Spot speed @ NS-GS02 | | | | | |
|---|---|---|---|---|---|
| **Speed (km/hr)** | **Frequency of vehicles** | **Cumulative frequency** | **Cumulative percent** | **Speed percentile** | |
| 27.6 | 0 | 0 | 0.00 | | |
| 28.4 | 0 | 0 | 0.00 | | |
| 29.2 | 0 | 0 | 0.00 | | |
| 30.2 | 0 | 0 | 0.00 | | |
| 31.1 | 0 | 0 | 0.00 | | |
| 32.2 | 0 | 0 | 0.00 | | |
| 33.3 | 0 | 0 | 0.00 | | |
| 34.5 | 0 | 0 | 0.00 | | |
| 35.7 | 0 | 0 | 0.00 | | |
| 37.1 | 0 | 0 | 0.00 | | |
| 38.6 | 3 | 3 | 3.00 | | |
| 40.2 | 12 | 15 | 15.00 | | |
| 41.9 | 6 | 21 | 21.00 | | |
| 43.9 | 11 | 32 | 32.00 | | |
| 45.9 | 16 | 48 | 48.00 | **45.6** | **50th %** |
| 48.2 | 12 | 60 | 60.00 | | |
| 50.8 | 17 | 77 | 77.00 | **51.3** | **85th %** |
| 53.6 | 10 | 87 | 87.00 | | |
| 56.8 | 9 | 96 | 96.00 | | |
| 60.3 | 4 | 100 | 100.00 | | |

## 4. Syntax and Output of Point Biserial Correlation Analysis

### A. Syntax of Point Biserial Correlation

```
GET
FILE='C:\Users\enok\Desktop\Final Zek\SPSS Data\FinalZek.sav'.
DATASET NAME DataSet1 WINDOW=FRONT.
CORRELATIONS
/VARIABLES=AN Building Signage APN SL PVC iIlegalFunction Traveledlanewidth
NumberofUturn
MedianBarrier Medianopening ParkingAvailability HorizonalAlignment Topography SpotSpeed
TrafficVolume
/PRINT=TWOTAIL NOSIG
/MISSING=PAIRWISE.
```

## B. Output of Point Biserial Correlation Analysis

### Point Biserial Correlations

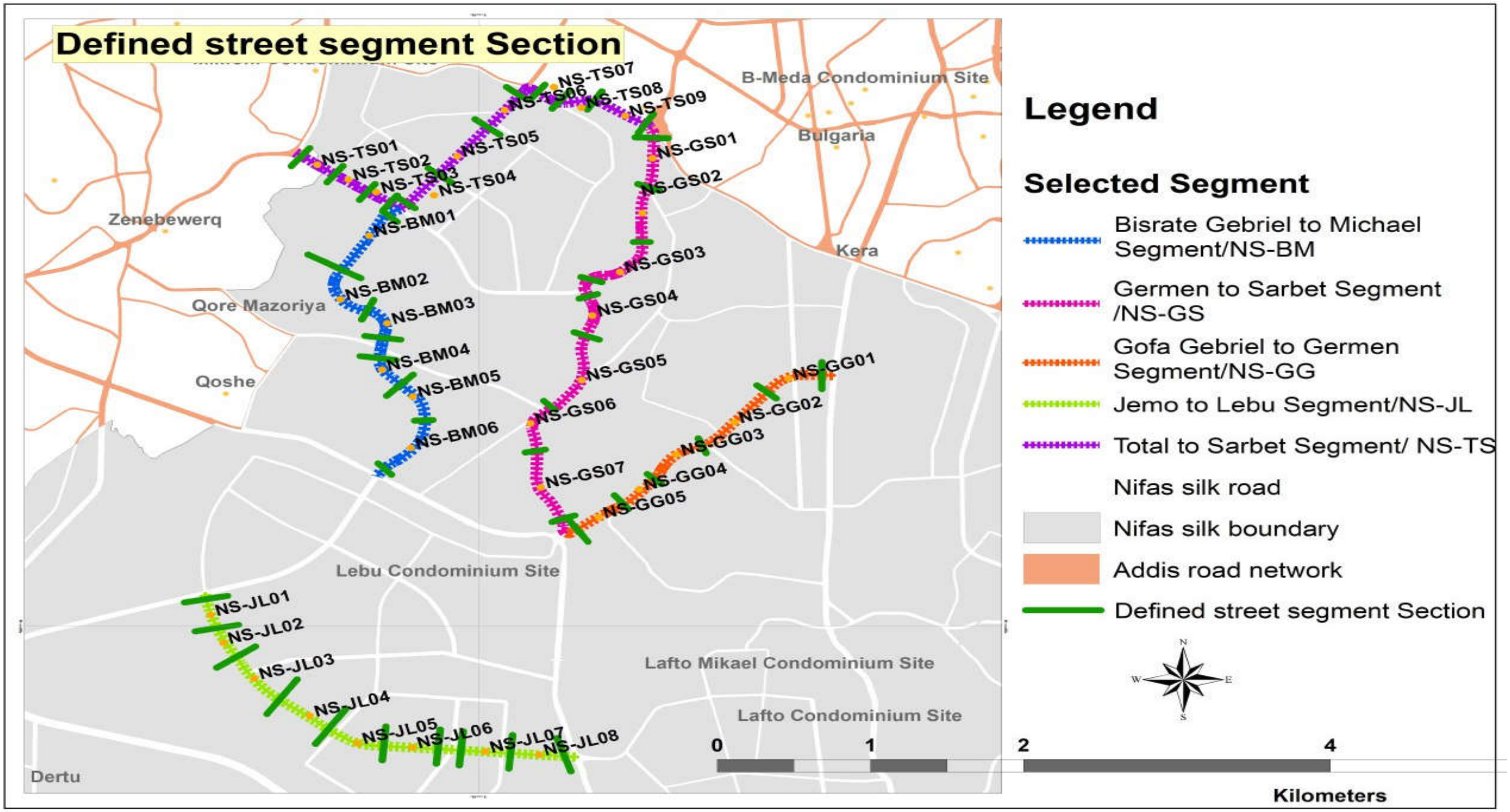
| | | AN/3yr | SBB | SBS | APN | SL | PVC | Il. F | ATLW | NUT | MBA | MO | PA | HA | Topography | 85th % Spot Speed | ADT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AN/3yr | Pearson Correlation | 1 | .486 | -.291 | -.053 | -.496 | .635* | -.243 | .778** | .590* | -.231 | .595* | .656** | -.067 | .278 | .579* | .646* |
| | Sig. (2-tailed) | | .066 | .293 | .852 | .060 | .011 | .383 | .001 | .021 | .407 | .019 | .008 | .812 | .316 | .024 | .001 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| SBB | Pearson Correlation | .486 | 1 | -.084 | -.119 | -.025 | -.083 | -.425 | .366 | .479 | -.012 | .323 | -.047 | -.083 | .395 | .034 | .617* |
| | Sig. (2-tailed) | .066 | | .765 | .672 | .929 | .768 | .114 | .180 | .071 | .967 | .241 | .867 | .768 | .146 | .905 | .014 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| SBS | Pearson Correlation | -.291 | -.084 | 1 | -.284 | .604* | -.429 | -.146 | -.135 | -.641* | .016 | -.270 | -.421 | .048 | -.287 | -.032 | -.023 |
| | Sig. (2-tailed) | .293 | .765 | | .305 | .017 | .110 | .604 | .632 | .010 | .954 | .330 | .118 | .866 | .300 | .910 | .935 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| APN | Pearson Correlation | -.053 | -.119 | -.284 | 1 | .203 | .203 | .266 | -.308 | .390 | .177 | .116 | .266 | .116 | .360 | .073 | -.021 |
| | Sig. (2-tailed) | .852 | .672 | .305 | | .468 | .468 | .338 | .264 | .151 | .527 | .680 | .338 | .680 | .187 | .795 | .941 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| SL | Pearson Correlation | -.496 | -.025 | .604* | .203 | 1 | -.607* | -.327 | -.444 | -.397 | .218 | -.339 | -.491 | -.071 | -.040 | -.213 | -.057 |
| | Sig. (2-tailed) | .060 | .929 | .017 | .468 | | .016 | .234 | .097 | .143 | .435 | .216 | .063 | .800 | .887 | .446 | .839 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| PVC | Pearson Correlation | .635* | -.083 | -.429 | .203 | -.607* | 1 | -.055 | .354 | .543* | -.327 | .464 | .873** | -.071 | .262 | .390 | .082 |
| | Sig. (2-tailed) | .011 | .768 | .110 | .468 | .016 | | .847 | .196 | .037 | .234 | .081 | .000 | .800 | .346 | .151 | .771 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Il.F | Pearson Correlation | -.243 | -.425 | -.146 | .266 | -.327 | -.055 | 1 | -.158 | -.064 | .167 | -.327 | -.167 | .491 | -.185 | .006 | -.139 |
| | Sig. (2-tailed) | .383 | .114 | .604 | .338 | .234 | .847 | | .575 | .821 | .553 | .234 | .553 | .063 | .510 | .983 | .620 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| ATLW | Pearson Correlation | .778** | .366 | -.135 | -.308 | -.444 | .354 | -.158 | 1 | .364 | -.293 | .535* | .318 | -.009 | -.053 | .255 | .459 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sig. (2-tailed) | .001 | .180 | .632 | .264 | .097 | .196 | .575 | | .182 | .289 | .040 | .249 | .975 | .852 | .359 | .085 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| NUT | Pearson Correlation | .590* | .479 | -.641* | .390 | -.397 | .543* | -.064 | .364 | 1 | -.383 | .543* | .542* | .230 | .306 | .331 | .426 |
| | Sig. (2-tailed) | .021 | .071 | .010 | .151 | .143 | .037 | .821 | .182 | | .159 | .037 | .037 | .410 | .267 | .228 | .113 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| MBA | Pearson Correlation | -.231 | -.012 | .016 | .177 | .218 | -.327 | .167 | -.293 | -.383 | 1 | -.327 | -.444 | -.327 | .431 | -.395 | .066 |
| | Sig. (2-tailed) | .407 | .967 | .954 | .527 | .435 | .234 | .553 | .289 | .159 | | .234 | .097 | .234 | .109 | .145 | .815 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| MO | Pearson Correlation | .595* | .323 | -.270 | .116 | -.339 | .464 | -.327 | .535* | .543* | -.327 | 1 | .600* | -.071 | -.040 | .100 | .340 |
| | Sig. (2-tailed) | .019 | .241 | .330 | .680 | .216 | .081 | .234 | .040 | .037 | .234 | | .018 | .800 | .887 | .723 | .215 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| PA | Pearson Correlation | .656** | -.047 | -.421 | .266 | -.491 | .873** | -.167 | .318 | .542* | -.444 | .600* | 1 | .055 | .185 | .538* | .187 |
| | Sig. (2-tailed) | .008 | .867 | .118 | .338 | .063 | .000 | .553 | .249 | .037 | .097 | .018 | | .847 | .510 | .039 | .505 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| HA | Pearson Correlation | -.067 | -.083 | .048 | .116 | -.071 | -.071 | .491 | -.009 | .230 | -.327 | -.071 | .055 | 1 | -.342 | .294 | .202 |
| | Sig. (2-tailed) | .812 | .768 | .866 | .680 | .800 | .800 | .063 | .975 | .410 | .234 | .800 | .847 | | .211 | .287 | .521 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Topography | Pearson Correlation | .278 | .395 | -.287 | .360 | -.040 | .262 | -.185 | -.053 | .306 | .431 | -.040 | .185 | -.342 | 1 | -.007 | .291 |
| | Sig. (2-tailed) | .316 | .146 | .300 | .187 | .887 | .346 | .510 | .852 | .267 | .109 | .887 | .510 | .211 | | .981 | .292 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 85th % Spot Speed | Pearson Correlation | .579* | .034 | -.032 | .073 | -.213 | .390 | .006 | .255 | .331 | -.395 | .100 | .538* | .294 | -.007 | 1 | .333 |
| | Sig. (2-tailed) | .024 | .905 | .910 | .795 | .446 | .151 | .983 | .359 | .228 | .145 | .723 | .039 | .287 | .981 | | .225 |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| ADT | Pearson Correlation | .664** | .617* | -.023 | -.021 | -.057 | .087 | -.139 | .459 | .426 | .066 | .340 | .187 | .202 | .291 | .333 | 1 |
| | Sig. (2-tailed) | .007 | .014 | .935 | .941 | .839 | .771 | .620 | .085 | .113 | .815 | .215 | .505 | .471 | .292 | .225 | |
| | N | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |

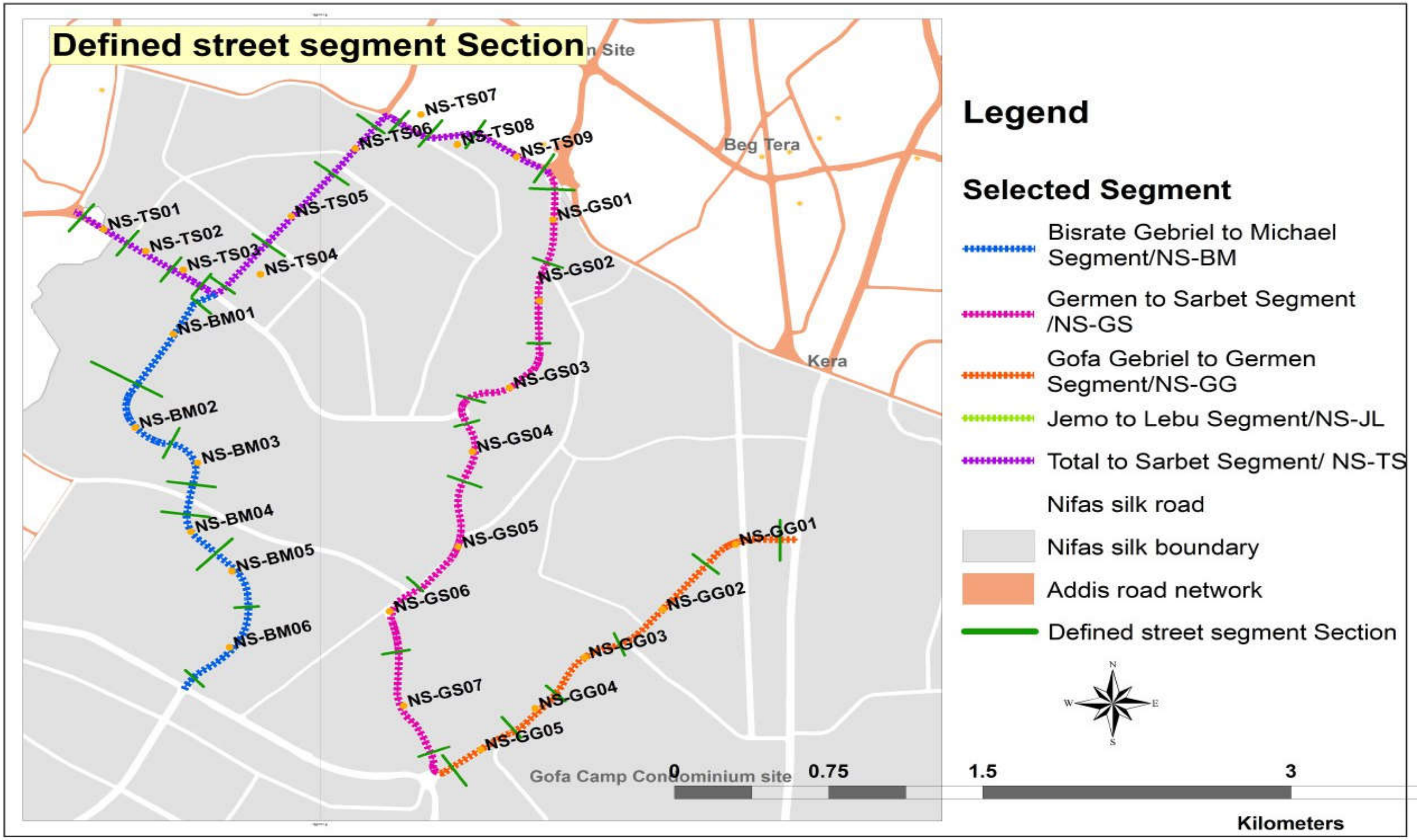
*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

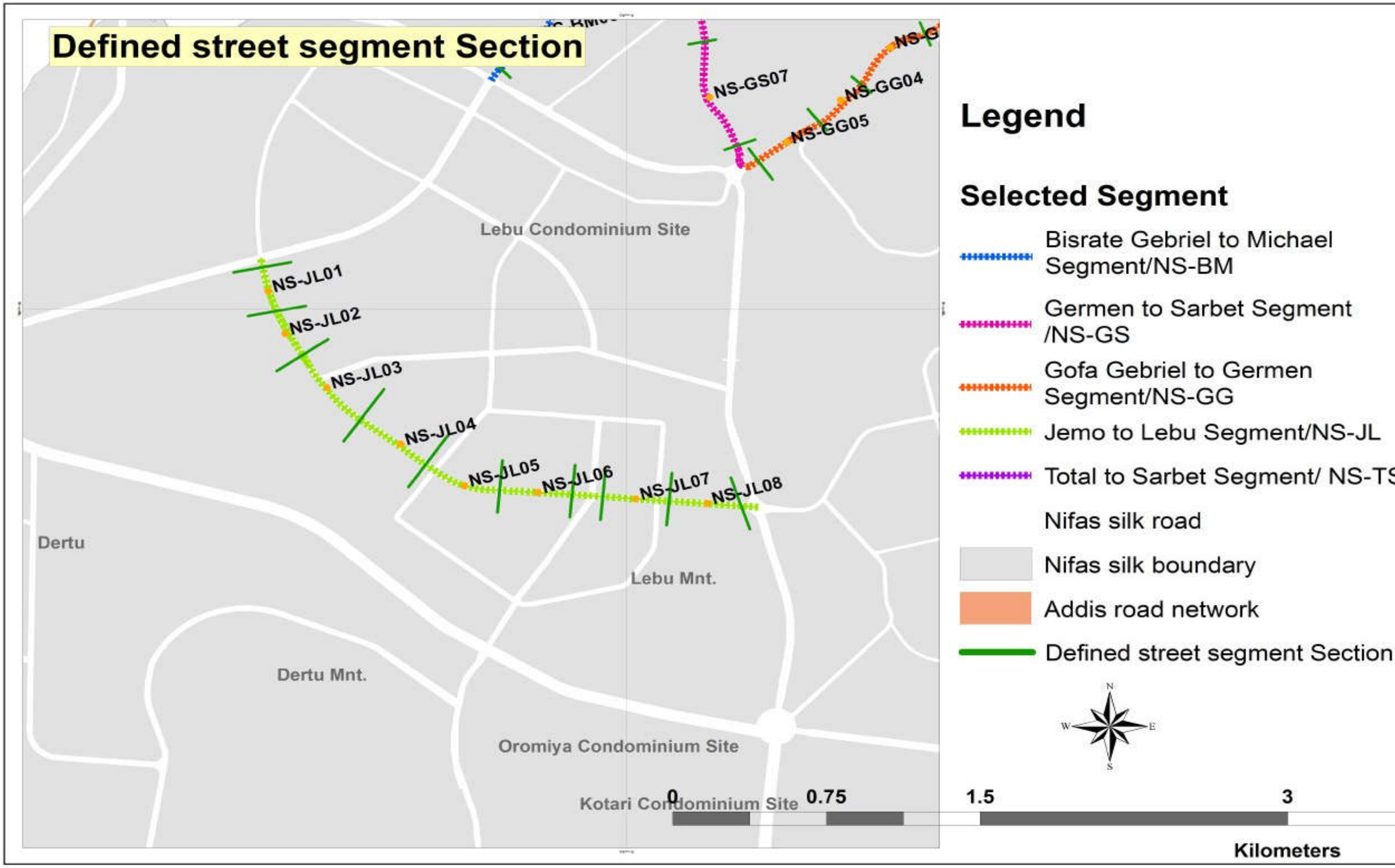
## 5. Pictorial Presentations Using ARCH-GIS 10.3.

### A. Pictorial Presentation of Defined Segment Sections.

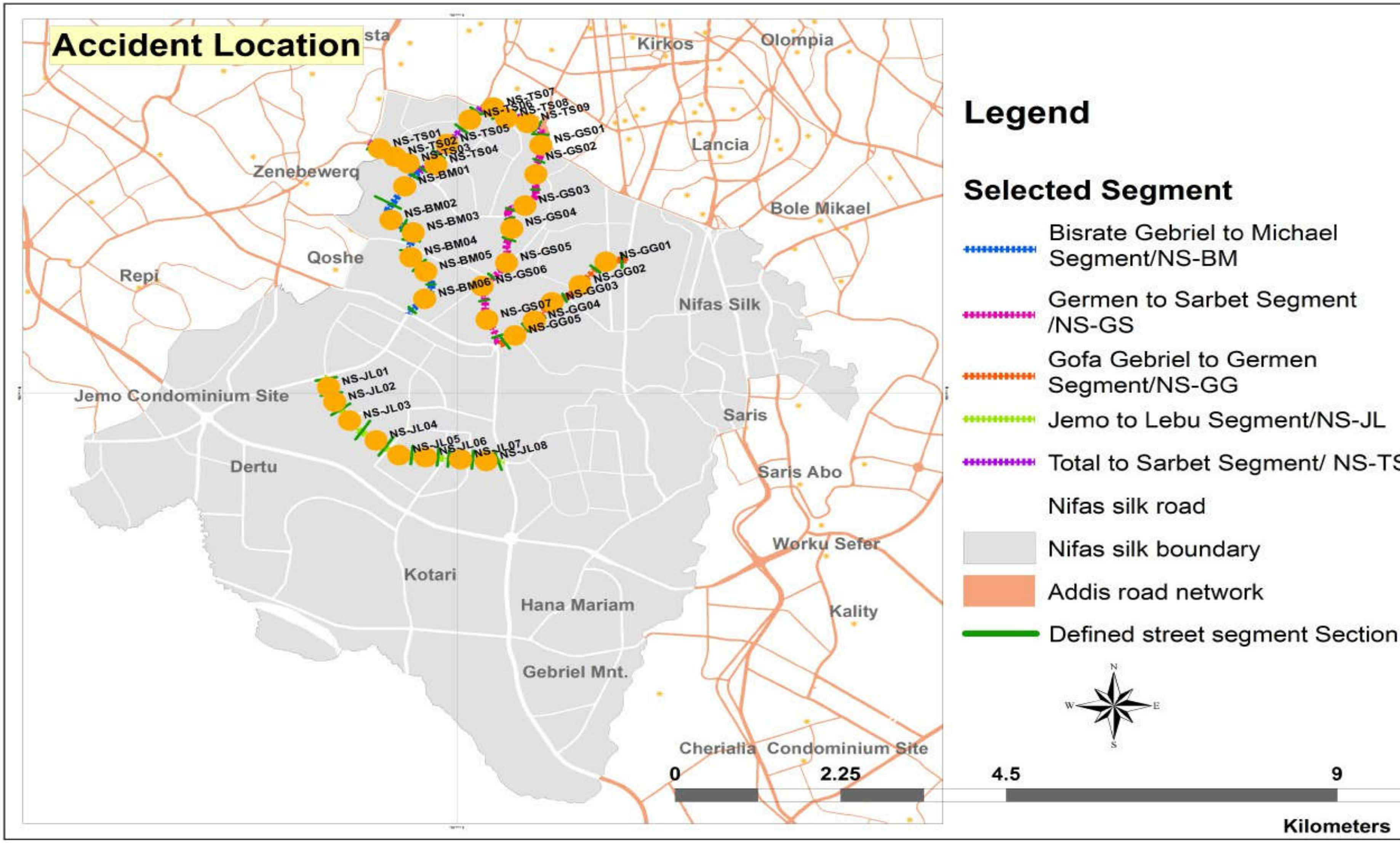


**B. Detailed Pictorial Presentations of the Defined Segment Sections.**



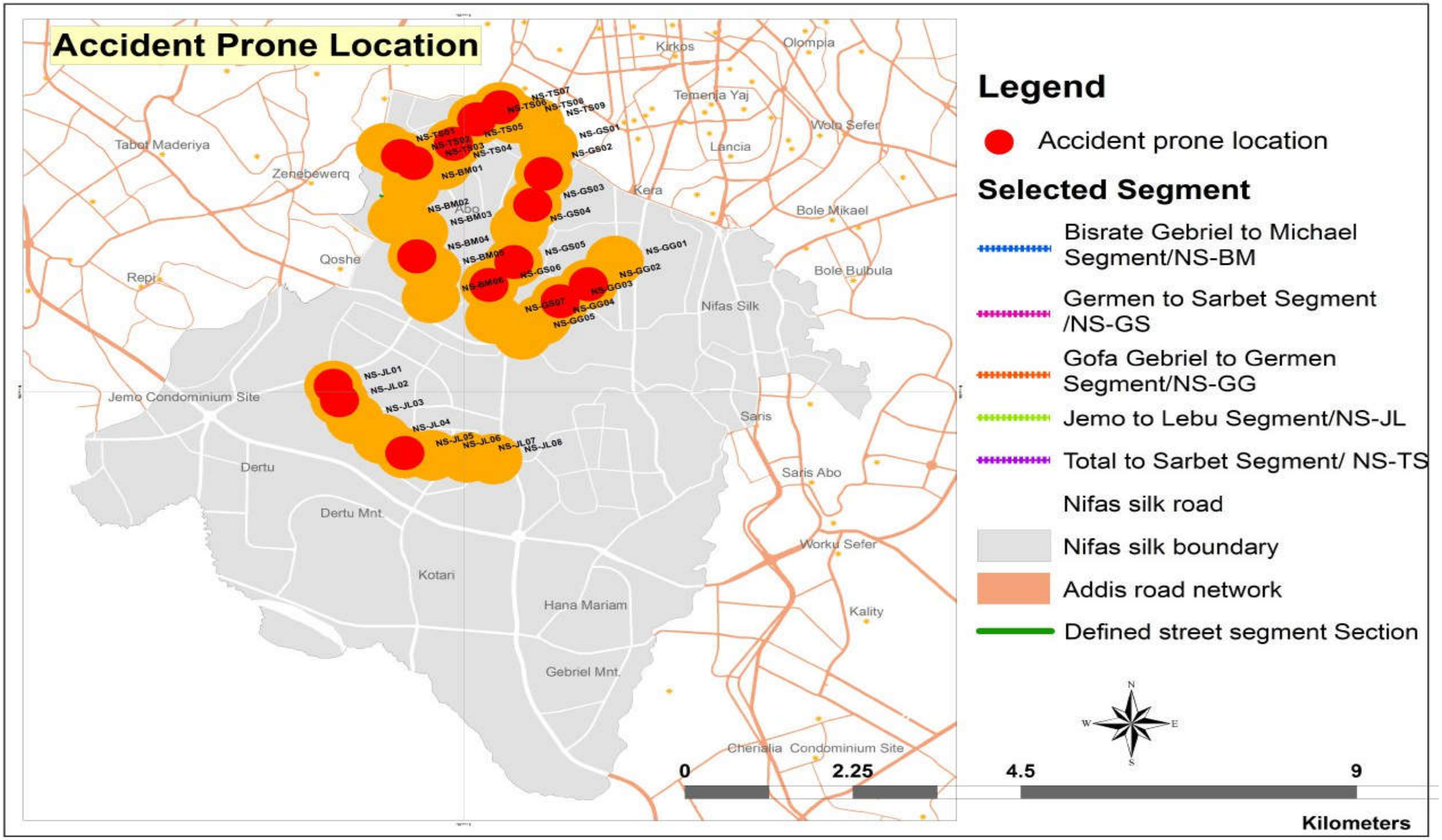

Defined street segment Section
NS-GS07
NS-GG04
NS-GG05
Lebu Condominium Site
NS-JL01
NS-JL02
NS-JL03
NS-JL04
NS-JL05
NS-JL06
NS-JL07
NS-JL08
Dertu
Lebu Mnt.
Dertu Mnt.
Oromiya Condominium Site
Kotari Condominium Site
Legend
Selected Segment
Bisrate Gebriel to Michael Segment/NS-BM
Germen to Sarbet Segment /NS-GS
Gofa Gebriel to Germen Segment/NS-GG
Jemo to Lebu Segment/NS-JL
Total to Sarbet Segment/ NS-TS
Nifas silk road
Nifas silk boundary
Addis road network
Defined street segment Section
0
0.75
1.5
3
Kilometers

**C. Pictorial Representation of the Selected 32 Segment Sections.**

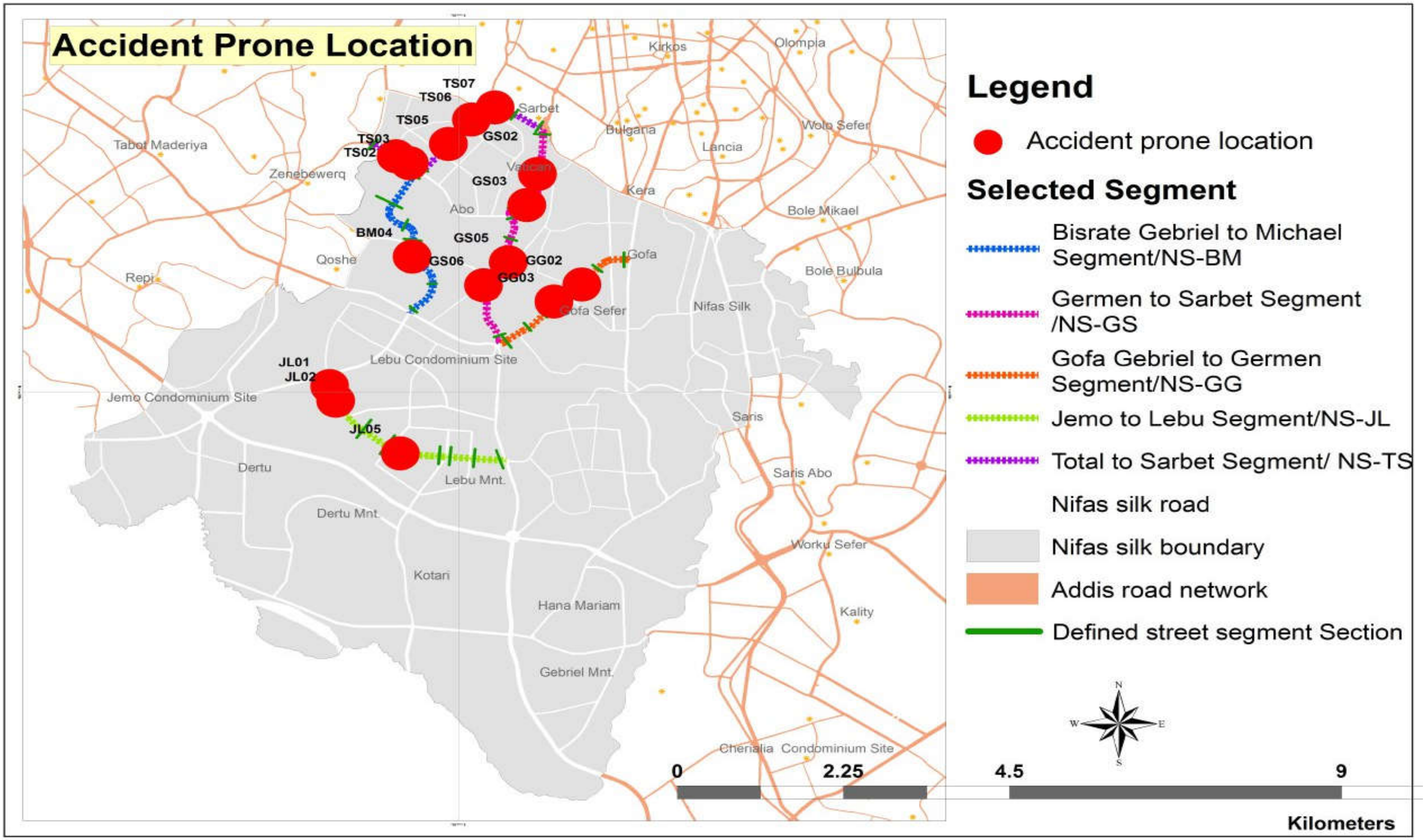


**D. Pictorial Representation of the Selected Accident-Prone Locations.**

**D.1. Pictorial Representation of Accident-Prone Locations along with Sample Segments**



**D.2. Pictorial Representation of Accident-Prone Locations**



## 6. Photos of Study Segment Sections

### A. Visual Clutter



**B. Median Opening**

**C. Sign Illegibility**

**D. Illegal Function**