DEVELOPING PREDICTION MODEL FOR TRAFFIC ACCIDENT WITH PARKING LANE WIDTH AND MEDIAN (A CASE STUDY OF BOLE SUB-CITY)

BY

BULCHA BEGNA

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ABSTRACT

Approximately 1.3 million people are killed yearly in road accidents worldwide. With one of the world’s highest rate of road accidents resulting in fatalities and a fast growing economy, Ethiopia is facing a challenge with tackling the road safety problems while trying to develop the country’s infrastructure. Addis Ababa, the capital city of Ethiopia, experiences the highest rate of fatal accidents having the highest concentration of vehicles, pedestrians and traffic in the country. The high number of fatal traffic accidents and injuries has a severe impact on the socio economic development of the city. This study aims to develop crash prediction model for Bole Sub city of Addis Ababa, which is one of the top three sub cities related to crash severities following Akaki-Kality and Kirkos Sub cities. The study builds upon the data collected from Addis Ababa Police Commission of Bole sub city department from 2013/2014 to 2016/2017 to determine the effect of the two parameters, parking lane and median width. 19 roads of the Sub city with different parking and median width were incorporated to develop regression model using Stata-SE13 statistical software. The model has presented the mathematical relationship between crashes per traffic volume, and the two independent variables. The crash prediction model has enabled a better understanding of how safety is impacted by these factors and allow an understanding of how they interact with each other. They can also be used to determine which improvements are best to reduce crashes.

KEY WORDS: Parking lane width, Median width, Crash prediction, Bole sub city
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# Table of Contents

ACKNOWLEDGMENT ........................................................................................................ ii

LIST OF FIGURES ........................................................................................................... v

LIST OF TABLES .............................................................................................................. vi

LIST OF ABBREVIATIONS .............................................................................................. vii

CHAPTER ONE ..................................................................................................................... 8

Introduction ....................................................................................................................... 8

1.1 Background ................................................................................................................... 8

1.2 Statement of the problem ............................................................................................. 9

1.3 General Objective ....................................................................................................... 11

1.4 Research questions .................................................................................................... 11

1.5 Limitation of the study .............................................................................................. 11

1.6 Thesis organization .................................................................................................... 11

CHAPTER TWO .................................................................................................................... 12

LITERATURE REVIEW .................................................................................................... 12

2.1 Addis Ababa Road Network and Traffic Accident Reports .......................................... 12

2.2 Traffic accident spots on road geometry .................................................................... 13

2.3 Relation between accidents and AADT ..................................................................... 17

2.4 Road crash accident prediction models ...................................................................... 18

2.4 Road traffic collision types and road side crashes ..................................................... 21

2.5 Regressions models .................................................................................................. 24

CHAPTER THREE .............................................................................................................. 26

RESEARCH METHODOLOGY .......................................................................................... 26

3.1 Study Area .................................................................................................................. 26

3.2 Data Collection .......................................................................................................... 28

3.3 Data Analysis ............................................................................................................. 29

3.4 Crash Trend in Bole Sub city ...................................................................................... 30

3.5 Model Development ................................................................................................ 31

3.5.1 Model Selection ................................................................................................... 31

3.5.2 Available Models ................................................................................................. 34

3.5.3 Merits of Stata and its application to develop the model ......................................... 35
LIST OF FIGURES

Figure 1- 1 Major causes of traffic accident in Ethiopia (WHO, 2015) ................................. 9
Figure 1- 2 Road crash fatality rate per 10,000 vehicles in African countries (WHO, 2013) . 10
Figure 2- 1 Typical roadway cross section elements (Turner, 2012) ................................. 15
Figure 2- 2 Change in road Character (Abdel et al., 2000) .......................................................... 15
Figure 2- 3 Median opening to reduce conflicts (FDOT, 2014) .................................................. 17
Figure 3- 1 Location of the Bole Sub city (www.addisababa.gov.et, 2018) ............................... 26
Figure 3- 2 Location of studied routes in Addis Ababa, A, B & C (Google Map, 2018) ...... 28
Figure 3- 3 Traffic crash trend of Bole sub city from 2013/2014 to 2016/2017 ...................... 30
Figure 4- 1 Predicted traffic crash occurrence ........................................................................ 50
LIST OF TABLES

Table 2- 2: Crash types included in the Star rating models of iRAP ...........................................24
Table 3- 1 Model selection ........................................................................................................32

Table 3- 2 Relation of each parameter with Accident per Annual Average Daily Traffic ......33
Table 3- 3 merits of Stata /Se-13(Charles Jumbe etal., 2014). ................................................. 36
Table 3- 4 Stata input data .........................................................................................................36
Table 3- 5 Statistical Analysis output ANOVA analysis .......................................................... 38
Table 3- 6 Analysis result of accident predictive model by STATA/Se-13 ...............................40
Table 4- 1 Traffic parameter data from field study.................................................................41

Table 4- 2 Sample on site seven days traffic count ................................................................. 42
Table 4- 3 Traffic parameter data from field study ................................................................43
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AACRA</td>
<td>Addis Ababa City Roads Authority</td>
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<td>AADT</td>
<td>Annual Average Daily Traffic</td>
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<td>AASHTO</td>
<td>American Association of State Highway and Transport Officials</td>
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<td>AATPR</td>
<td>Addis Ababa Traffic Police Report</td>
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<td>ADT</td>
<td>Average Daily Traffic</td>
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<td>ANOVA</td>
<td>Analysis of Variance</td>
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<td>ERA</td>
<td>Ethiopian Roads Authority</td>
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<td>FDOT</td>
<td>Florida Department of Transport</td>
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<td>IRAP</td>
<td>Ireland Road Assessment Program</td>
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<td>HCM</td>
<td>Highway Capacity Manual</td>
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<td>RTA</td>
<td>Road Traffic Accident</td>
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<td>WHO</td>
<td>World Health Organization</td>
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CHAPTER ONE

Introduction

1.1 Background

To reduce traffic accidents, we need to understand what cause them. The highway transportation system, which contains the driver, the vehicle and the road & its environment, suffers from different problems (Beshah, 2011).

One of these problems is the highly increasing rate of traffic crash accidents. Factors that help causes accidents usually fit one of those categories i.e. driver, vehicle or the road geometry.

Human factors of road accidents include things like inattention or distraction, fatigue, alcohol use, and vision problems. Vehicle factors may be mechanical failures, bad breaks or tires, or any similar problems. Road geometry related factors can be insufficient sight distance, poor or missing road signs, change in road way width, slippery surface, in appropriate horizontal & vertical curves, in appropriate shoulder & lane width for the traffic on the given road section (Beshah, 2011). Generally, roads with high traffic volumes are expected to have more crash rate than low volume roads.

Vehicle speed is a major contributing factor in crashes of all types, and is especially hazardous for pedestrians and cyclists. ‘Speeding’ includes travelling above the speed limit, as well as travelling too fast for the road and traffic conditions, and the mix of road users.

Many accidents occur at paces where the road character changes. Transitions from straight to curved alignments, reductions in width, and boarders between rural and built up area are examples of character change where accidents can happen (Guillosseau, 2014).

According to Addis Ababa Traffic Police Report (AATPR, 2011), the following were depicted as major causes of road traffic accident in 2011. Nearly 74% of the accident was attributable to the driver (WHO, 2015). Six percent of the accidents in Addis also occur by Pedestrian 8% by condition of car, 3% by condition of road & the remaining 9% is by other causes (WHO, 2015).
Due to its severity estimating the number of accidents that may result for a given highway, design is a matter of great interest to the highway engineering community in the previous years. Different researches have been performed in order to determine the effects of different geometric elements. Because safety is a primary consideration in highway design, the safety consequences of highways tend to have been and will remain a matter of continuing interest.

Road traffic accidents (RTAs) are the major public health concern, resulting in an estimated 1.2 million deaths and 50 million injuries worldwide each year (WHO, 2015). In the developing world, RTAs are among the leading cause of death and injury; Ethiopia in particular experiences the highest rate of such accidents. Thus, methods to reduce accident severity are of great interest to traffic agencies and the public at large. In this study, multiple regression models are applied in order to predict the crash ratio of Parking lane & Median width, based on the data collected from Addis Ababa city government Police Commission Bole sub city department.

1.2 Statement of the problem

Road accident in Ethiopia is one of the worst accident records in the World and Africa, as expressed per 10,000 vehicles. Moreover, road accidents are concentrated in Addis Ababa, which is the capital city of Ethiopia and Oromia region accounting for 58 per cent of all fatalities and two-third of all injuries.
Figure 1-2 below illustrates road crash fatality rates per 10,000 vehicles in African Countries as provided by WHO (2013).

As we can read from the graph presented in Figure 1-2 above road crash fatality is one of the highest in Africa and Ethiopia is ranked as eight country with high fatality rate.

Traffic accidents have significant impact on the society. It results in enormous costs in terms of lost productivity and property damage. Efforts are required to have better understanding of the factors that influence accident. The knowledge about the relationship between the accident and the factors responsible is incomplete. The causes of road accidents are always complicated due to presence of many factors such as, roadway geometric design, traffic characteristics, human factor, weather condition etc. Most of the studies so far have focused on some risk factors such as drinking and driving, restraint systems and tried to determine their relationship with accident rate. Previous research has shown that accidents involving trucks have a likelihood of producing a severe injury or fatality. However, the relative impacts of various factors (Roadway geometry, traffic characteristics, etc.) have not been quantified.

This thesis will present a model to show the relationship between traffic accidents per AADT, parking lane width and median width hence it will help to determine designers to decide the
appropriate width with least predicted traffic accident ratio & to establish better safety management system based on the proposed model.

1.3 General Objective

- To develop a prediction model for traffic accidents parking lane width and median width

1.4 Research questions

✓ Which prediction model fits the relation between traffic crash accidents and parking lane and Median?
✓ What are the most appropriate measures recommended to reduce crashes related with parking lane and median based on this study

1.5 Limitation of the study

- The data were collocated only from Addis Ababa City Police Commission Bole Sub city police department; due to time constraints, it was hardly possible to incorporate data from all concerned sectors like Hospitals and Insurance companies.

- It was very difficult to conduct traffic counts from 8:00 pm to 6:00 am night time. Therefore, in order to incorporate the night traffic the day count was used with assumed night factor.

- Due to unrecorded data on the ledger, it was hardly possible to include other traffic and traffic parameter.

1.6 Thesis organization

Chapter one dealt with the introductory part of the Thesis. Literature reviews were dealt within chapter Two. Chapter three dealt with the research methods. In chapter Four, the result of the research with the discussion presented. Chapter Five conclusion and recommendation were presented. Finally, Appendices A, B, C, D and E are incorporated in the report.
CHAPTER TWO
LITERATURE REVIEW

2.1 Addis Ababa Road Network and Traffic Accident Reports

Addis Ababa, the capital city of Ethiopia, is a vibrant and fast changing urban metropolitan city, with an estimated population of more than 3,384,569 (CSA, 2007). The relatively rapid economic growth in the City in recent years, has resulted in serious challenges and stresses to the socio-economic infrastructure, including on its transportation network. The GDP of the city, calculated at constant price, show that it was USD 677.70 in 2009 and USD 649.43 in 2014 Ethiopian calendar.

Recent data from the Addis Ababa City Road Authority (AACRA) and Transport Bureau shows that there are about 580,000. Anbessa city-bus users on daily bases. Passengers using mini bus taxis to travel around the city are substantial with 479,18231 daily users. There are about 16,462 public transport vehicles (minibus taxi of 9,200; midi bus of 462; Anbessa city buses of 760 (functioning), and 6,000 other passenger transportation in the city providing public transport services (AACRA, 2016).

Lack of adequate walking facilities along the roads coupled with inefficient traffic control and management systems have led to poor safety conditions and frequent traffic accidents in the City. It is estimated that pedestrians constitute more than 55% of the trips generated in the City. Among the main reasons for the high level of traffic accidents in the City is the lack of proper traffic control and management system, along with a poor pedestrian friendly transportation network. Available information indicates that about 64 people die per 10,000 vehicles annually on Ethiopian roads, which is comparatively high by international standards (Kassa, 2015).

In year 2008 Ethiopian calendar i.e. 2015/2016, around 418 people died in traffic accidents in Addis Ababa and property damages were valued at Br 194 million. A total of 17,052 vehicle accidents caused this damage with loss of lives (Kassa, 2015). The situation has worsened since 2013/2014, when the number of accidents was 14,921, showing a dramatic increase from the 9,150 accidents only two years earlier, when 390 people died (Kassa, 2015).
Around 1,676 people faced serious injuries in 2014/2015, increasing from 1,454 people in 2013/2014, while the number was 1,190 people in 2012/2013. These injuries all occurred in traffic accidents in Addis Ababa (Kassa, 2015).

From these ten sub cities in Addis Ababa, Kolfe-Keranio has a considerably large area covering 65 sqkm. It is the fourth largest district in Addis Ababa with a total population of half a million. It is the highest in the city. The numbers of traffic accidents are high but the density is relatively low (Alemayehu A., 2016).

In contrast, the sparsely populated district of Akaki-Kality, in relation to its population and area, has experienced the highest rate of heavy injuries and deaths. On average, cars hit 148 out of every 100,000 people in Akaki-Kality sub city that sustain injuries every year. Among these 84 are classified as heavily injured while 23 of those die (Alemayehu A., 2016).

While Aqaqi-Kality has the highest rate of heavy accidents, Bole ranks within the top three districts whose two-year record shows it to be one of the districts most susceptible to accidents in general, and categorically, to death and serious injury (Alemayehu A., 2016).

The Bole Sub city’s statistics show that 14 out of every 100,000 people die in the district every year and 74 are severely injured. Forty-eight deaths from traffic accidents were recorded in 2015 (Alemayehu, 2016). Yet some roads have witnessed enough accidents to have caught the Addis Ababa Roads authorities’ attention and have been labelled as “black spots”. These are around the areas commonly referred to as Bole Customs, 18 Mazoria, Wossen Grocery in Yeka district, and Jacross Square in Bole Sub city (Alemayehu A., 2016).

2.2 Traffic accident spots on road geometry

The conclusion that safety increases as lane width increases is based on the premise that wider lanes reduce the consequences of driver deviations from their intended path. Vehicles traveling in opposite directions on undivided, two-way roads are separated by larger distances if lanes are wider. Vehicles traveling in the same direction on multilane roads are also separated by larger distances if lanes are wider. Wider lanes provide more room for recovery in near-crash situations
(e.g., evasive maneuvers to miss an object on the roadway or inadvertently drifting toward the roadside) (Abdel et al., 2000).

Using the same logic, it is also assumed that wider shoulders are associated with increased safety because they provide increased separation between a parked or disabled vehicle and the traveled way. Wider shoulders also provide more room for recovery following an unintentional (e.g., inattentive driver drift) or intentional (e.g., evasive maneuver) shoulder encroachment. Wider shoulders are also associated with larger lateral clearances from roadside objects and longer available sight distances when there are sight obstructions to the inside of horizontal curves (Abdel et al., 2000).

Wider lanes and shoulders also appear to result in faster operating speeds (Acadamies, 2011). For example, methodologies in the *Highway Capacity Manual* (HCM) predict an approximately 1.3 to 1.7 mph increase in speeds for every 1 ft increase in shoulder width on two-lane highways. Similarly, the HCM 2010 predicts an approximately 0.4 to 1.1 mph increase in speeds on two-lane highways for every 1 ft increase in lane width (AASHTO, 2010). All else being equal, drivers traveling at faster speeds may be less likely to successfully react to unexpected situations (e.g., changes in lead vehicle behavior, non-motorized users crossing traveled way, changes in roadway alignment, roadside encroaches) than drivers traveling at slower speeds. In addition, the energy dissipated during a crash is directly proportional to the square of travel speed at the time of the crash. Impact forces that driver’s experience increase as this initial speed increases and decreases as the time over which energy is dissipated decreases. The crash severity (i.e., probability of fatality or severe injury) therefore increases as initial travel speed increases (Turner, 2012).

The cross section of road is what we see if we removed a slice across it and looked at it end-on. From a safety standpoint, we are interested in cross slopes, lane widths, shoulders or curbs and roadside slopes. Figure 2-1 and Figure 2-2 below are typical roadway cross section elements and in road character respectively.
Figure 2- 1 typical roadway cross section elements (Turner, 2012)

Figure 2- 2 Change in road Character (Abdel et al., 2000)

According to ERA Geometric Design Manual, the shoulder width for urban areas has to be greater than 1.2 meters with normal cross fall of 4%. For rural areas, the shoulder width is between 0.6-1.2 meters (ERA, Geometric Design Manual, 2013).
On street parking can contribute to a lot of accidents in urban areas replacing on street parking with municipal lots can reduce accidents. Angle parking is also another source of accidents because drivers have difficulty in seeing approaching traffic while backing out of a parking space.

Other locations of traffic accidents are curves. Some of them are:

- Sight distance problems caused by obstructions on the inside of the curve;
- Unexpected curves at the end of long straight sections; and
- Curves hidden by hillcrests

Intersections, being a place where vehicle paths cross, are other traffic accident spots. Traffic accident may also be caused if the driver goes off the pavement edge. Soft or loose shoulders can cause a similar effect, because of the sudden increase in traction when tires leave the shoulder and return to the pavement.

Overall, the road geometry highly influences the traffic system. Therefore, especial attention should have to be given during design & construction in order to minimize accidents due to inappropriate road geometries. Properly implemented medians and median openings will result in improvements to traffic operations, minimize adverse environmental impacts, and increase highway safety. As traffic flow is improved, delay is reduced, as are vehicle emissions. In addition, corridor efficiency/throughput and fuel economy are increased, and most importantly, crashes are less numerous and/or less severe (FDOT, 2014). Figure 2-3 below shows median opening to reduce conflicts.
Median width in most urban situations should accommodate turning lanes and a separator. The width of both the left-turn lane and separator are critical to the operations of the median opening.

2.3 Relation between accidents and AADT

Shankar et al. (1997) developed an accident frequency model for local arterials in Washington State where they defined roadway sections by their homogeneous features such as number of lanes, roadway width, shoulder width, Annual Average Daily Traffic (AADT), speed, and peak hour factors. One of the primary findings of this study indicated that accident frequency increases with the AADT per lane.

In a related study, Persaud and Dzbik (1993) explored the nonlinear relationship between accident frequency and volume. In their conclusion, it was noted that on congested roadways there was a higher occurrence of accidents than on uncongested roadways with comparable volume levels. In addition, Abdel et al. (2000) used both Poisson and negative binomial regressions to model traffic accident occurrence and involvement on a sample freeway. They also used the likelihood ratio test to evaluate the over-dispersion of the Poisson model and re-estimate their models with Negative Binomial (NB) regression when over-dispersion was detected. The results indicated that an increase in AADT per lane also increases the likelihood of higher accident frequency.

Greibe, (2002) used generalized linear Poisson regression to establish the accident prediction models for urban roads. The AADT was found to be the most significant variable in the prediction of accident frequency. Abbas, (2003) developed a number of statistical models based on the accident data over 10 years in Egypt. These models were based on the assumption that the number of accidents, injuries, fatalities and casualties are a function of exposure represented with AADT and AAVK (annual average vehicle kilometers).

Five functional forms were evaluated in the study conducted by Abbas; they included linear, power, logarithmic, exponential and quadratic polynomial. The model, however, includes only AADT and AAVK as explanatory variables. Note that in all of the aforementioned studies AADT per lane was always used as a surrogate variable of congestion. Besides AADT, only a small set of geometric and weather condition variables were used in the model specification (Abbas, 2003).
The weather conditions were accounted by variables such as number of rainy days and the maximum daily rainfall in a month. The results of additional studies on accident frequency seem to share a common finding that accident frequency is more likely to increase with the volume per lane. It is also important to note that Poisson and NB regressions are recognized as appropriate methods for accident related analysis (Miaou, 1994), and Shankar, Mannering and Barfield, (1995).

### 2.4 Road crash accident prediction models

Many researchers have investigated the relationship of accident rates with different road geometric parameters by applying different statistical crash prediction models. Garber, (2000) used different types of deterministic models such as multiple line regression, robust regression, and multivariate ratio of polynomials to fit the accident data collected from police stations (police accident report for 3 years i.e. from 1993-1995) with speed limits of 89 or 105 km/hr with different parameters including lane width and shoulder width to crash prediction models (Garber, 2000).

A Research by Hauer (2004) developed statistical road safety modeling by using the Negative Binomial distribution. The dependent variable was the number of accident per year, while the independent ones were geometric characteristics and traffic flow. In this study, the author suggested guidelines for assigning the functional form to each variable in the model, and observed that the model equation should have both a multiplicative and an additive component (Hauer, 2004).

Cenek et al (2004) developed crash prediction models for state highways using 11,000Km of road assessment maintenance management database data (over 22,000 lane-km). Variables that Cenek et al, 2004 investigated included:

- Traffic volume (AADT);
- Road geometry (horizontal curvature, gradient and cross-fall);
- Road surface condition (roughness, rut depth, texture depth and skid resistance); and
- Carriageway characteristics

A study conducted by Potts et al., (2007) addressed the relationship of lane width to safety for urban and sub urban sites.
Turner *et al.*, (2012) in their research developed crash prediction models for two lane rural roads using data from almost 7000Km of the rural state highway network of New Zealand. The models quantified the mathematical relationship between crashes and traffic volumes, road geometry, cross-section, road surfacing, roadside hazards and driveway density. These crash prediction models have enabled a better understanding of how safety is impacted by these factors. (Turner *et al.*, 2012).

Abdallah *et al.*, (1997) also studied the relationship between casualty frequency and the distance of an accident from residential zones. Not surprisingly, casualty frequencies were higher in accidents that occurred nearer to residential zones, possibly due to higher exposure. Ossenbruggen, *et al.*, 2001) used a logistic regression model to identify the prediction factors of crashes and crash-related injuries, using models to perform a risk assessment of a given region. These models included attributes describing a site by its land use activity, roadside design, use of traffic control devices, and traffic exposure. Their study illustrated that village sites were less hazardous than residential or shopping sites.

Crash prediction models have been increasingly used in the identification and evaluation of road safety issues since the mid-1990s, when initial forms of crash prediction models were first developed for the majority of road intersections and links in urban and rural areas. Crash prediction models are useful tools for evaluating the crash risk of existing small road sections, and also for evaluating the benefits of changes to each road network. These benefits are recognized internationally and many countries have developed comprehensive crash prediction models for just these purposes (Shane, 2012).

Paved roads typically have lines marking the delineation between the carriageway and the shoulder. For unpaved roads, the shoulder refers to the extra width of roadway beyond the gravel surface up to the inner edge of the side ditch and is typically covered by grass. The shoulder serves as a recovery zone where errant vehicles may be brought under control and also provides a zone where a driver may seek refuge to avoid being struck by another vehicle intruding into its path. Shoulders also lend lateral structural stability to the carriageway pavement (Labi, 2006).
Chang and Chen (2005) conducted data mining research focusing on building tree-based models to analyze freeway accident frequency. Using the 2001-2002 accident data of National Freeway 1 in Taiwan, the authors developed classification and regression tree (CART) and negative binomial regression models to establish the empirical relationship between traffic accidents and highway geometric variables, traffic characteristics, and environmental factors. CART is a powerful tool that does not require any pre-defined underlying relationship between targets (dependent variables) and predictors (independent variables). These authors found that the average daily traffic volume and precipitation variables were the key determinants of freeway accident frequency.

Tibebe (2005) analyzed historical RTA data, including 4,658 accident records at the Addis Ababa Traffic Office, to investigate the application of data mining technology to the analysis of accident severity in Addis Ababa, Ethiopia. Using the decision tree technique and applying the Knowledge SEEKER algorithm of the Knowledge STUDIO data mining tool, the developed model classified accident severity into four classes: fatalities, serious injury, slight injury, and property-damage. Accident cause, accident type, road condition, vehicle type, light condition, road surface type, and driver age were the basic determinant variables for injury severity level. The classification accuracy of this decision tree classifier was reported to be 87.47%.

Chang and Wang (2006) applied non-parametric classification tree techniques to analyze accident data from the year 2001 for Taipei, Taiwan. ACART model was developed to establish the relationship between injury severity and driver/vehicle characteristics, highway/environment variables, and accident variables. The most important variable associated with crash severity was the vehicle type, with pedestrians, motorcycles, and bicyclists having the highest injury risks of all driver types in the RTAs.

Getu et al., 2013 studied pedestrian crashes and relevant factors in relation to their impact in Ethiopia. Gholamail et al., (2015) set explanatory parameters for traffic accident and these were traffic flow parameters, geometric infrastructure characteristics and pavement conditions. Statistical analysis was done by SPSS on the basis of nonlinear regression modeling and during the analysis, principal components were identified to assist the principal component analysis method and more important variables recognized that could indicate the best description of crash occurrence on the
basis of available logics. Results indicate that the number of accidents per year increase with length, peak hour volume and longitudinal slope whereas it decreases with radius.

Tibebe & shewandra, 2013 tried to show the role of road-related factors in accident severity, using RTA data from Ethiopia. Zelalem, (2009) in his study explored classification algorithms for the study of accident severity and driver characteristics. The study focused on predicting the degree of drivers’ responsibility for car accidents. The majority of crash model research in Ethiopia has focused on road user’s behavior and internationally has focused on one-off studies to investigate specific features, such as the impact on the safety of roadside hazards, curves, carriageway width and surface friction. There are no comprehensive models that contain all the salient features and in doing so allow various options or strategies to be compared.

The current stage of knowledge about the relation between lane width & crash is incomplete & controversial. A wide consensus was undertaken to determine the effect of lane width on crash through centuries. The Highway Capacity Manual (1985 edition) generally states that “The capacity of a roadway is markedly affected by lane width.” The most recent version of the manual states that there is no capacity reduction until the lane width falls below 10 ft (3m) (Furth, 2015). Professor Ezra Hauer from university of Toronto in 2000 in his study concluded that “Little is known about the effect of lane width on multilane or urban roadways” (Furth, 2015).

A study conducted in Washington DC in 1996 shows that 3.4-3.7 m lanes are safest and those lanes narrower than 3.0 m contribute to multi-vehicle crashes (Ogaden, 1996).

2.4 Road traffic collision types and road side crashes

A traffic crash is defined as any vehicle crash occurring on a public highway (i.e. originating on, terminating on, or involving a vehicle partially on the highway). These crashes therefore include collisions between vehicles and animals, vehicles and pedestrians, or vehicles and fixed obstacles. Single vehicle crash, in which one vehicle alone (and no other road user) was involved, are included by the World Health Organization, (2002).

The Common Car Crash Collisions are -

➢ Rear-end collisions: Rear-end collisions are very common. These types of traffic crashes are often caused by sudden deceleration (slowing down or braking). In some cases, another driver is
following too closely or accelerates to a higher speed than the car in front of it. Whiplash is a common injury that occurs in a rear end collision and usually affects drivers and passengers of the impacted car. Fault is usually attributed to the driver of the car that rear-ends the other vehicle.

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

- **Vehicle Rollover**: Vehicle rollover crashes are extremely dangerous and frightening. A rollover occurs when a vehicle literally flips over onto its side or roof. Any vehicle can be involved in rollover crash, but cars with a high center of gravity such as SUVs (Sport Utility Vehicles) are especially prone to this type of crash. Often caused by sharp turns at high speed, rollover crashes can lead to serious injuries including spinal cord injuries and brain trauma.

- **Head-on collisions** often have poor outcomes because of the speed involved when the collision takes place. The typical cause of head-on collisions is when one vehicle inadvertently strays into the path of an oncoming vehicle. However, the root cause sometimes lies in a steering overcorrection after veering to the side of the road as opposed to the center (IRAP, 2014). The likelihood of head-on collision is at its greatest on roads with narrow lanes, sharp curves, and no separation of lanes of opposing traffic and high volumes of traffic. Crash severity, measured as risk of death and injury, and repair costs to vehicles, increases as speed increases. Therefore, the roads with the greatest risk of head-on collision are busy single-carriageway roads outside urban areas where speeds are highest (European Road Assessment Program, 2008).

Contrast this with motorways, which rarely have a high risk of head-on collision in spite of the high speeds involved, because of the median separation treatments such as cable barriers, Concrete step barriers, Jersey barriers, metal crash barriers, and wide medians (European Road Assessment Program, 2008).

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

- **Single car crashes** - Crashes involving only one vehicle are also common. They occur when a vehicle strikes objects such as poles, trees, fire hydrants, and walls. In some cases, they may involve pedestrians and other innocent bystanders. Single car collisions can result in driver and passenger injuries, pedestrian injuries, and often extensive property damage.
- Side-impact collisions - Side-impact collisions can cause grave injuries. Often called "T-bone" or "broadside" collisions, side impact crashes occur when the side of a vehicle is impacted. It can be impacted by the front or rear of another vehicle or in some cases a fixed object. Vehicle damage is often severe and drivers or passengers on the impacted side of the vehicle usually sustain far worse injuries than they would in another type of crash.

The mix of people using a road network can vary significantly between countries. Although vehicle occupants typically account for the majority of road deaths in high-income countries, in low-income and middle-income countries many road users are motorcyclists, bicyclists and pedestrians (WHO, 2013). The suitability of the road infrastructure provided for each of the road users is also variable. Such differences are reflected in crash statistics. Recognizing that the mix of road users can vary between countries and that different road users have different infrastructure needs, a separate star rating is produced for each of the four road user types that account for the majority of road use worldwide:

i. Vehicle occupants;
ii. Motorcyclists;
iii. Bicyclists; and
iv. Pedestrians.

The Star Rating methodology is based on the types of crashes that account for a large proportion of road deaths and serious injuries for each road user, as shown in Table 2-2 below. Three key potential outcomes are not included in the table: a sideswipe crash; rear-end motorway crashes away from junctions; and a recovery (that is, where a crash is initiated but a crash does not actually occur). These outcomes are not explicitly included in the iRAP Star Rating methodology as they either do not account for a significant number of deaths or serious injuries and/or because infrastructure solutions (such as for sideswipe crashes and rear-end mid-block crashes on motorways) are difficult to model. Nevertheless, sideswipe crashes and recoveries were taken into account during the development of the ‘external flow risk factors’ for fatality estimations because they can have a bearing on the relative proportion of crash types that occur on a road. As further evidence-based research and/or engineering solutions for these crash types becomes available over time, their inclusion in future iRAP models will be considered by the iRAP global technical committee (iRAP, 2014).
Table 2-1: Crash types included in the Star rating models of iRAP

<table>
<thead>
<tr>
<th>Vehicle Occupant</th>
<th>Motor Cyclist</th>
<th>Bicyclist</th>
<th>Pedestrian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run-off road</td>
<td>Run-off road</td>
<td>Travelling along the</td>
<td>Walking along road</td>
</tr>
<tr>
<td></td>
<td></td>
<td>road</td>
<td></td>
</tr>
<tr>
<td>Head -on</td>
<td>Head -on</td>
<td>Intersections</td>
<td>Crossing road</td>
</tr>
<tr>
<td>Intersection and access points</td>
<td>Intersection and access points</td>
<td>Run- off road</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moving along the road</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Common Types of Roadside (on shoulder) Vehicle Crashes**

These are examples of three types of accidents that often occur on the shoulder of the road:

- A car parking on the shoulder of the road in the dark fails to utilize hazard lights, causing an unsuspecting driver exiting the highway to collide with the stationary car.
- A car is appropriately stationed on the shoulder of the road, visible to all motorists due to the use of hazard lights, when a negligently driven vehicle barrels into the stationary vehicle.
- A pedestrian walking on the shoulder of the road is struck and killed by a negligent motorist.
- A car exits using the shoulder of the road, but due to faulty maintenance and construction of that part of the road, there is a dangerous drop off that causes the car to lose control and collide with the concrete median (Andzois, 2017).

**2.5 Regressions models**

Regression is a statistical method that allows us to summarize and study relationships between two continuous (quantitative) variables:

- One variable, denoted as x is called the predictor, explanatory, or independent variable
- The other variable denoted by y, is called the response, outcome or dependent variable

**Deterministic (functional) relationship:** Under deterministic relationship, the equation exactly describes the relationship between the two variables; and

**Statistical relationships:** The relationship between the variables is not perfect. In this relation, there are many different outcomes. The plots are scatter and some trends are not deterministic. Some other examples of statistical relationships might include:
✓ Height and weight — as height increases, you would expect weight to increase, but not perfectly.
✓ Alcohol consumed and blood alcohol content — as alcohol consumption increases, you would expect one's blood alcohol content to increase, but not perfectly.
✓ Vital lung capacity and pack-years of smoking — as amount of smoking increases (as quantified by the number of pack-years of smoking), you would expect lung function (as quantified by vital lung capacity) to decrease, but not perfectly.
✓ Driving speed and gas mileage — as driving speed increases, you would expect gas mileage to decrease, but not perfectly.

There are two types of regression based on the number of independent variables: Simple linear regression and multiple regressions. In simple linear regression, a single independent variable is used to predict the value of a dependent variable. In multiple linear regressions, two or more independent variables are used to predict the value of a dependent variable. In statistical modeling, regression analysis is a set of statistical processes for estimating the relationships among variables.

Regression analysis is a form of predictive modeling technique, which investigates the relationship between a dependent (target) and independent variable(s) (predictor). This technique is used for forecasting, time series modeling and finding the causal effect relationship between the variables. For example, relationship between rash driving and number of road accidents by a driver is best studied through regression (Analytic Vidya, 2015).
CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study Area

Bole sub city is one of the ten administrative divisions of Addis Ababa. With a total area of 122.08 Km$^2$ a total population of 328,900 and density 2,694.1.

![Location of the Bole Sub city](www.addisababa.gov.et, 2018)

The study area includes, Bole airport entry road, African avenue, Cameron street, Ghana street, Cape Verde street, Megenagna-salitemihret road, Hayat -Goro, Summit -Tsehay Real Estate, Ethio -China Street, CMC-Summit, Sealitemihret- CMC, Jacrose -Salite miheret, Hayat -Jacrose, Saris Abo -Bole Bulbula, Goro -Summit Square, Djibouti Street, Gabon Street, Namibia Street & Rwanda Street all the paved roads of Bole sub city, excluding the roundabout. Figure 3-2 (A, B and C) depicts location of study routes.
A, Gotera – Wollo sefer route

B, Multiple routes in the Sub city
Data was taken for the years from 2013/2014 to 2016/2017. The traffic surveys, which were used to calculate the AADT of each road, were conducted for the first seven days of the months of June-August 2017 representing the rainy season and September to November 2017 representing the dry season; using ERA surveying techniques (ERA, 2013).

According to ERA, the traffic count should have to be conducted for seven consecutive days:–

i) The counts on week days were for 12 hours day time and the night traffic was assumed based on previous studies in this Sub city and the traffic survey for weekends was also conducted from 12 hours day time from 6:00 am morning to 6:00 pm evening.

ii) The 7-day counts had been repeated for both rainy and dry seasons. Please refer to ERA, Flexible Pavement Design Manual for further details.

### 3.2 Data Collection

The traffic crash data was collected from Addis Ababa Police Commission Bole Sub city Police Department. Traffic count was conducted on 19 different roads located in bole sub city. In addition to the traffic count filed measurement of the parking lane width and median width of 19 roads were also conducted. Please refer to Figures presented on Appendix D, which shows on site
measurement and sample of data recorded on ledger by Addis Ababa Police Commission Bole Sub city Police Department.

### 3.3 Data Analysis

The traffic count was conducted from September 1-November 30, 2016 for dry season and from June 1-August 30, 2017 for rainy season. The data was converted to AADT in such away:

- On five days of the week, the counting times are between 6:00 AM morning and 6:00 PM evening. On two days of the week (one week day and one weekend day), the counting times are 12 hours. The 12-hour counts are used to establish night factors.
- The average of the two-day night factors is used to adjust the 12-hour counts of the other days by converting to 24-hour counts. The average of the 7 days’ counts is considered as average daily traffic (ADT) of the subject quarter. The quarterly ADT is then converted to annual average daily traffic (AADT) using seasonal adjustment factor.

\[
\text{Night factor for weekdays} = \frac{\text{Day traffic}}{\text{Night traffic}} \tag{a}
\]

\[
\text{Night factor for weekends} = \frac{\text{Day traffic}}{\text{Night traffic}} \tag{b}
\]

\[
\text{ADT} = (\text{Average of 7 days count} * \text{night factor}) \tag{c}
\]

The second paragraph on page 45 of ERA Flexible Pavement Design Manual, it is clearly stated that traffic growth rate can be related linearly to anticipate growth of Gross Domestic Product (GDP). This is normally preferable since it explicitly takes into account changes in overall economic activity (ERA Flexible Pavement Design Manual, 2013).

The World Bank had reported that, Ethiopia’s economy experienced strong, broad-based growth averaging 11% a year from 2005/06 to 2015/16 (World Bank, 2018). Therefore, the traffic growth rate was assumed 11%, which is Ethiopian GDP. Based on this assumption and the traffic count the dry season and rainy season’s traffic count was used to calculate the seasonal factor. Finally, AADT, which is the only traffic parameter in this study, has been calculated by applying the economic formula stated by ERA Flexible Pavement Design Manual (ERA, 2013). Which is presented as below:-

\[
\text{AADT}_{m1} = AADT_{mo} (1 + i)^n \quad \text{Where, AADT}_{m1} \text{ is the estimated traffic, AADT}_{mo} \text{- initial traffic and i- traffic growth rate or GDP and n- number of years.}
\]
3.4 Crash Trend in Bole Sub city

A traffic crash is classified as any accident involving motor vehicles, which results in an event that is considered to be in contrast of expected, intended, or routine operation. Such incident is very common in our country as most of the developing countries. Due to lack of integrated data recording system, it is very common some of the crash data might be missed. The data collected from Bole sub city police department also suffers from the same problem under reporting.

According to the police report from September 2013 to September 2017, the following chart developed and traffic crash trend of Bole sub city can be drawn accordingly:

![Traffic crash trend of Bole sub city from 2013/2014 to 2016/2017](image)

Figure 3- 3 Traffic crash trend of Bole sub city from 2013/2014 to 2016/2017

The number of death decrease from 2013/2014 to 2016/2017. Fifty one deaths were registered at the police commission in 2013/2014, in 2014/2015 the number decrease to 46 and 2015/2016 to 43. In 2016/2017, the number of death dramatically decrease to 27.

The number of heavy crash and light crash totally increase from 2013/2014 to 2016/2017. The property damage only has the worst figure of all crashes. It increases from 280 to 2649 from 2013/2014- 2016/2017.
3.5 Model Development

3.5.1 Model Selection
Choosing the correct linear regression model can be difficult. However, it is very crucial part of the statistical modeling procedures.

The most common criteria’s applied to select the most appropriate models are *(Ezra G.and Reuben A.Ipinyomi, 2009)* Akaike information criterion (AIC), Schwarz information criterion (SIC) and coefficient of multiple determination (R²).

Studies shows that the AIC and SIC are applied when we want parsimony (simplest model with least assumptions and variables) but with great explanatory power. While R² is used when we need better predictive power *(Ezra G.and Reuben A.Ipinyomi, 2009)*.

The coefficient of determination (R²) is a measure of the variation of the dependent variable that is explained by the regression line and the independent variable. It is used when we work with variables that are specifically under experiment along with other variables that affect the response in order to avoid biased results. It is very appropriate mechanism in the scientific world.

Generally, models with higher adjusted R-squared values are preferred over the lower ones. The adjusted R-squared value is statistics that is designed to solve the key problem with R-value, which increase as a predicator number increase.

For this research Statistical model for exponential, polynomial, logarithmic, power and linear scale were incorporated to test which function will define the dependent variable to acceptable range. Furthermore, the relationship of each explanatory variable was tested one by one with the mentioned statistical functions. The one with R-squared value closer to one or best fit the model is then selected to develop the relationship between the pavement surface temperature (dependent variable) and the two explanatory variables latitude and maximum air temperature. Please refer to Appendix E for the scatter plot of each parameter with maximum pavement surface temperature and for detail graphical analysis of the Model selection.
All the functions were developed using the Accident data taken from Addis Ababa police commission Bole sub-city Police department, data from field measurement for Median and Parking Lane width.

Table 3-1 presents different functional scales used to select the model. The table shows the relation between the Median width and Accident per Annual Average Daily Traffic and the relation between Parking Lane width and Accident per Annual Average Daily Traffic is best explained with polynomial function. The best fit is the polynomial function with degree Six, which gives the R-squared value of 0.7699 for Median width and 0.334 for Parking Lane width. However, the statistical software can only model up to degree three. Therefore, the model selected in this research is the Polynomial function with power of three.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Linear</th>
<th>Polynomial</th>
<th>Exponential</th>
<th>Logarithmic</th>
<th>Power</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X¹</td>
<td>X²</td>
<td>X³</td>
<td>X⁴</td>
<td>X⁵</td>
<td>X⁶</td>
</tr>
<tr>
<td>R²</td>
<td>0.6214</td>
<td>0.6221</td>
<td>0.6394</td>
<td>0.6581</td>
<td>0.7699</td>
<td>0.7699</td>
</tr>
<tr>
<td>(Accident/</td>
<td>AADT vs Median)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.3247</td>
<td>0.334</td>
<td>0.334</td>
<td>0.334</td>
<td>0.334</td>
<td>0.334</td>
</tr>
<tr>
<td>(Accident/</td>
<td>AADT vs Parking Lane)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The combined effect of the two parameters on Accident per Annual Average Daily Traffic can be further elaborated with the following table:

Table 3- 2 Relation of each parameter with Accident per Annual Average Daily Traffic

<table>
<thead>
<tr>
<th>Independent Parameters</th>
<th>(Parking Lane width)(^1)</th>
<th>(Parking Lane width)(^2)</th>
<th>(Parking Lane width)(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Median width)(^1)</td>
<td>0.6825</td>
<td>0.6800</td>
<td>0.6770</td>
</tr>
<tr>
<td>(Median width)(^2)</td>
<td>0.6854</td>
<td>0.6833</td>
<td>0.6800</td>
</tr>
<tr>
<td>(Median width)(^3)</td>
<td>0.6718</td>
<td>0.6708</td>
<td>0.668</td>
</tr>
</tbody>
</table>

From Table 3-2 the combined R-squared value for the Parking Lane width decrease as the polynomial degree increase where as for the Median width combined R-squared value increase and then decrease with increasing polynomial degree. Generally, Median width best explains the Accident per Annual Average Daily Traffic when it is Quadratic and the Parking Lane width best explains the Accident per Annual Average Daily Traffic when it is on linear scale.
3.5.2 Available Models
Continuous variables, by comparison, can assume an infinite number of values in an interval between any two specific values. They often include fractions and decimals.

Ordinary Least Square (OLS) is always the starting point of modelling. The OLS assumptions are-

- The dependent variable (y) is linear and continuous
- The error term has mean of zero, i.e. the differences between the estimated dependent variable (yhat) and the observed (actual) dependent variable (y) sums to zero (Σ(yhat-y) = 0)
- The independent variables are not correlated with each other (no multicollinearity)
- The independent variable are exogenous, i.e. they are not themselves dependent variables
- All other models are because of violating some of the OLS assumptions. These include Logit and Probit model.

3.5.1.1 Logit and Probit Models
Logit & Probit Model is applicable when the dependent variable is continuous but in binary category (Charles Jumbe et al., 2014).

In such cases, linear regression model is not appropriate because the dependent variable is not continuous (also homoscedasticity & normality assumptions are violated).

The difference between the Probit & Logit lies in the assumption that the researcher makes about the error term. The Probit is assumed as normal distribution of errors and the Logit is assumed as logistic distribution of errors.

3.5.1.2 Linear Model
Linear regression is a statistical tool for evaluating the relationship of one or more independent variables (x) to single continuous dependent variables (y). Regression analysis characterizes the relationship between the dependent and independent variables by looking determining the extent, direction and strength of the association (Charles Jumbe et al., 2014).
The goal of linear regression is to find if change in one variable x causes change in another variable y, holding all other relevant factors fixed. Correlation is rarely enough to conclude. Therefore, need to hold other factors constant (Charles Jumbe et al., 2014).

The population model is linear parameter

\[ y = \beta_0 + \beta_1 x_1 - \ldots - \beta_k x_k + u \] (1)

The dependent variable (y) is linear and continuous. The error term has mean of zero, i.e. The differences between the estimated dependent variable (yhat) and the observed (actual) dependent variable (y) sums to zero (\( \Sigma (yhat - y) = 0 \)). The independent variables are not correlated with each other (no multi co linearity). The independent variable is exogenous, i.e. they are not themselves dependent variables (Charles Jumbe et al., 2014).

Multiple linear regression model is a model that associates one continuous dependent variable to two or more independent variables (Charles Jumbe et al., 2014).

There are two types of regression models: - Deterministic and statistical

✓ **Deterministic (functional) relationships**: deterministic relationship the equation exactly describes the relationship between the two variables.

✓ **Statistical relationships**: in which the relationship between the variables is not perfect. In this relation, there are many different outcomes. The plots are scatter and some trend they are not deterministic.

For this study Statistical model is developed using the field data and Stata–se13.

### 3.5.3 Merits of Stata and its application to develop the model

Stata is a powerful statistical package with smart data-management facilities, a wide array of up-to-date statistical techniques, and an excellent system for producing publication-quality graphs. The word Stata is not an abbreviation but rather a corruption of the word Statistics. Stata is fast and easy to use.

There are numerous comparable statistical packages such as SPSS, R, SAS, Matlab, Eviews, etc. Stata’s main strengths are handling and manipulating large data sets i.e. millions of observations, and it has ever growing capabilities for handling panel and time-series
regression analysis. The most recent (2014) version is Stata 13 and with each version, there are improvements in computing speed, capabilities and functionality. It now has flexible graphics capabilities (Charles Jumbe et al., 2014).

Table 3- 3 merits of Stata /Se-13(Charles Jumbe et al., 2014).

<table>
<thead>
<tr>
<th>Stata/SE-13</th>
<th>Maximum Number of Variables</th>
<th>Maximum Number of Regressors</th>
<th>Maximum Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>32,767</td>
<td>10,998</td>
<td>2,147,583,647</td>
</tr>
</tbody>
</table>

As it is presented in Table 3-3 the merits of, Stata includes capacity to analyze maximum number of variables with maximum number of regressors and maximum number of observations.

Table 3- 4 Stata input data

<table>
<thead>
<tr>
<th>Route Name</th>
<th>Accident/AADT</th>
<th>Median</th>
<th>Parking Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bole air port</td>
<td>0.000010</td>
<td>5.8</td>
<td>3</td>
</tr>
<tr>
<td>Africa Avenue ( Airport Road )</td>
<td>0.000032</td>
<td>2.9</td>
<td>3</td>
</tr>
<tr>
<td>Cameron Street</td>
<td>0.000025</td>
<td>2.4</td>
<td>3</td>
</tr>
<tr>
<td>Ghana Street</td>
<td>0.000040</td>
<td>1.4</td>
<td>0</td>
</tr>
<tr>
<td>Cape Verde Street</td>
<td>0.000040</td>
<td>1.4</td>
<td>3</td>
</tr>
<tr>
<td>Megenagna -SealiteMihret</td>
<td>0.000045</td>
<td>1.4</td>
<td>3</td>
</tr>
<tr>
<td>Hayat Roundabout-Goro</td>
<td>0.000032</td>
<td>0.9</td>
<td>3</td>
</tr>
<tr>
<td>Summit Roundabout-Tsehay real estate</td>
<td>0.000032</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>Ethio -China Street</td>
<td>0.000033</td>
<td>0.9</td>
<td>3</td>
</tr>
<tr>
<td>CMC-Summit</td>
<td>0.000033</td>
<td>0.9</td>
<td>2.5</td>
</tr>
<tr>
<td>SealiteMihret- CMC</td>
<td>0.000035</td>
<td>0.9</td>
<td>3</td>
</tr>
<tr>
<td>Jacrose -Salite Mihret</td>
<td>0.000035</td>
<td>0.9</td>
<td>3</td>
</tr>
<tr>
<td>Hayat -Jacrose</td>
<td>0.000040</td>
<td>0.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Saris Abo -Bole Bulbula</td>
<td>0.000045</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>Route Name</td>
<td>Accident/AADT</td>
<td>Median</td>
<td>Parking Lane</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------</td>
<td>--------</td>
<td>--------------</td>
</tr>
<tr>
<td>Goro -Summit Square</td>
<td>0.000045</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>Djibouti Street</td>
<td>0.000035</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>Gabon Street</td>
<td>0.000050</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>Namibia Street</td>
<td>0.000050</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>Rwanda Street</td>
<td>0.000050</td>
<td>0.4</td>
<td>0</td>
</tr>
</tbody>
</table>

Using the input data presented in Table 3-4 data collected as an input for Stata/Se-13 assuming accident per AADT as Y-variable median $X_1$ (m), parking lane width (m) $X_2$, and constant coefficient the output from the strata i.e. the model and the figure will be presented as below:

$$Y = -2.41 \times 10^{-6} \times X_1 - 8.06 \times 10^7 \times X_2 + 0.000044$$

The statistical analysis ANOVA for the developed model. An ANOVA test is a way to find out if the model results are significant. This helps to figure out which hypothesis to accept and which one to reject.

The statistical analysis of the model is tabulated and presented with the following table 3-5 below. Please refer to appendix C for all the data and STATA output.
Table 3- 5 Statistical Analysis output ANOVA analysis

<table>
<thead>
<tr>
<th>Confidence interval (%)</th>
<th>P-Value for F-test</th>
<th>Explanatory variables and constants</th>
<th>P-Value for t-test</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.9</td>
<td>0.0001</td>
<td>Parking lane width</td>
<td>0.001</td>
<td>insignificant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Median width</td>
<td>0.099</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>99.5</td>
<td>0.0001</td>
<td>Parking lane width</td>
<td>0.001</td>
<td>insignificant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Median width</td>
<td>0.099</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>0.0001</td>
<td>Parking lane width</td>
<td>0.001</td>
<td>insignificant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Median width</td>
<td>0.099</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>97.5</td>
<td>0.0001</td>
<td>Parking lane width</td>
<td>0.001</td>
<td>insignificant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Median width</td>
<td>0.099</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>0.0001</td>
<td>Parking lane width</td>
<td>0.001</td>
<td>insignificant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Median width</td>
<td>0.099</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>0.0001</td>
<td>Parking lane width</td>
<td>0.001</td>
<td>significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Median width</td>
<td>0.099</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

3.5.4 Validation of the model

After the model is developed, it is necessary that predicted accident cases from our analysis of data should be verified for having a confidence with real accident data. We verified an accident prediction model developed and selected for Bole sub city using parking lane, median & AADT for verification.
The result showed that R of model by road types were all statistically meaningful. Besides, we verified actual accident data and estimation by statistical method using minimum root square error (Root Mean Square Error; MS).

There are 3 types of statistical test used to test validity of the model.

1. F-test: measures the overall significance of the model.
   - The null hypothesis (NH) for the test will be \( 0 = \beta_1 = \beta_2 = \ldots = \beta_k \) i.e. that the coefficients are equal to zero implying that there is no relationship between the dependent variable and the independent variables.
   - The alternate hypothesis (AH) \( \beta_l \neq 0 \), i.e. none of the coefficients is equal to zero.
   If the NH is accepted, it implies that there is no relation between the dependent and independent variables even if the coefficients are not zero.
   If the NH is rejected, i.e. the F-statistic is valid, then the overall model is valid and we can go ahead and check the other two tests (R\(^2\) and t-statistic):

   From our Stata which present the F-test output at the top right we can read that, for 90% confidence interval where \( \alpha = 10\% \) the, F test is significant at 10% & the F-statistics is 0.0001 means it is probability of exceeding 10% is 0.01%. This implies that we reject the null hypothesis and accept the alternative hypothesis. Here we assure that the model is overall significant, so we can go ahead for the next two test of validation.

2. R\(^2\)-test
   R\(^2\) measures the proportion of the variation in the dependent variable (Y) that is being explained by the independent variables(s).
   The major problem is that R\(^2\) is sensitive to the number of independent variables included in a regression model. The greater the number of independent variables the higher the R\(^2\) is likely to be, i.e. the more the independent variables we add (even if they are not valid), the bigger the R\(^2\) becomes. This problem arises because R\(^2\) does not take into account the number of degrees of freedom, i.e. R\(^2\) is given by the following formula:
\[ R^2 = \frac{\text{Regression of squares (SSR)}}{\text{total sum of squares (SST)}} = \frac{\sum(\hat{Y}_i - \bar{Y})^2}{\sum(Y_i - \bar{Y})} \quad (3) \]

To solve this problem, when testing the validity of a regression model we use the Corrected or Adjusted \( R^2 \) (denoted as) \( \bar{R}^2 \) which takes degrees of freedom into account as given in the following formula:

\[ \bar{R}^2 = 1 - (1 - R^2) \frac{(n-1)}{(n-k-1)} \quad (4) \]

Where \( R^2 \) is coefficient of determination, \( n \)=sample size, \( k \)-number of independent variables.

<table>
<thead>
<tr>
<th>R^2</th>
<th>Adjusted R^2</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6825</td>
<td>0.6428</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Table 3- 6 Analysis result of accident predictive model by STATA/Se-13

So far, the model has satisfied the two validity tests but still one test of significance is remaining the t-test.

3. T-test

Because the model shows significance in the above two tests it is possible to proceed with the third and final test, t-test. It is a test of significance for individual explanatory variables \( X_1, X_2 \) and the constant term. The t-statistic is found by coefficient (unstandardized) divided by the standard error.
CHAPTER FOUR
RESULT & DISCUSSION

4.1 Traffic count and filed measurement results

The following tables will present the summarized output of field traffic count and field measurement of parking lane and median width.

Table 4- 1 Traffic parameter data from field study

<table>
<thead>
<tr>
<th>Route Name</th>
<th>Median width (m)</th>
<th>parking Lane width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bole air port</td>
<td>5.8</td>
<td>3</td>
</tr>
<tr>
<td>Africa Avenue (Airport Road)</td>
<td>2.9</td>
<td>3</td>
</tr>
<tr>
<td>Cameron Street</td>
<td>2.4</td>
<td>3</td>
</tr>
<tr>
<td>Ghana Street</td>
<td>1.4</td>
<td>0</td>
</tr>
<tr>
<td>Cape Verde Street</td>
<td>1.4</td>
<td>3</td>
</tr>
<tr>
<td>Megenagna–Sealite Mihret</td>
<td>1.4</td>
<td>3</td>
</tr>
<tr>
<td>Hayat Roundabout-Goro</td>
<td>0.9</td>
<td>3</td>
</tr>
<tr>
<td>Summit Roundabout-Tsehay real estate</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>Ethio-China Street</td>
<td>0.9</td>
<td>3</td>
</tr>
<tr>
<td>CMC-Summit</td>
<td>0.9</td>
<td>2.5</td>
</tr>
<tr>
<td>SealiteMihret-CMC</td>
<td>0.9</td>
<td>3</td>
</tr>
<tr>
<td>Jacrose-Salite Mihret</td>
<td>0.9</td>
<td>3</td>
</tr>
<tr>
<td>Hayat–Jacrose</td>
<td>0.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Saris Abo-Bole Bulbula</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>Goro-Summit Square</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>Djibouti Street</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>Gabon Street</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>Namibia Street</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>Rwanda Street</td>
<td>0.4</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 4-2 Sample on site seven days traffic count

<table>
<thead>
<tr>
<th>Expected peak hour</th>
<th>Days of count</th>
<th>Route No.</th>
<th>Route Name</th>
<th>Cars</th>
<th>Land Rover (&lt;27 seats)</th>
<th>Large Bus (&gt;27 Seats)</th>
<th>Mini Bus (&lt;27 seats)</th>
<th>Small Truck &lt;3.5 Trucks</th>
<th>Medium Truck 3.5-7.5 Tons</th>
<th>Heavy Truck 7.5-12 ton</th>
<th>Truck &amp; Trailer &gt;12 ton</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 am-6:00 pm</td>
<td>1-Jun</td>
<td>1</td>
<td>Africa Avenue (Airport Road)</td>
<td>1077</td>
<td>416</td>
<td>317</td>
<td>332</td>
<td>219</td>
<td>298</td>
<td>144</td>
<td>138</td>
<td>2941</td>
</tr>
<tr>
<td></td>
<td>2-Jun</td>
<td></td>
<td></td>
<td>708</td>
<td>299</td>
<td>141</td>
<td>190</td>
<td>141</td>
<td>127</td>
<td>44</td>
<td>92</td>
<td>1742</td>
</tr>
<tr>
<td></td>
<td>3-Jun*¹</td>
<td></td>
<td></td>
<td>717</td>
<td>295</td>
<td>152</td>
<td>187</td>
<td>104</td>
<td>117</td>
<td>46</td>
<td>78</td>
<td>1696</td>
</tr>
<tr>
<td></td>
<td>4-Jun*</td>
<td></td>
<td></td>
<td>1154</td>
<td>548</td>
<td>326</td>
<td>369</td>
<td>209</td>
<td>305</td>
<td>190</td>
<td>148</td>
<td>3249</td>
</tr>
<tr>
<td></td>
<td>5-Jun</td>
<td></td>
<td></td>
<td>981</td>
<td>518</td>
<td>190</td>
<td>221</td>
<td>138</td>
<td>158</td>
<td>142</td>
<td>99</td>
<td>2447</td>
</tr>
<tr>
<td></td>
<td>6-Jun</td>
<td></td>
<td></td>
<td>1019</td>
<td>398</td>
<td>198</td>
<td>217</td>
<td>83</td>
<td>165</td>
<td>143</td>
<td>89</td>
<td>2312</td>
</tr>
<tr>
<td></td>
<td>7-Jun</td>
<td></td>
<td></td>
<td>999</td>
<td>427</td>
<td>237</td>
<td>217</td>
<td>126</td>
<td>159</td>
<td>178</td>
<td>124</td>
<td>2467</td>
</tr>
</tbody>
</table>

¹ * The yellow cells represent weekends
Table 4-3 Traffic parameter data from field study

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa Avenue (Airport Road)</td>
<td>14,942.00</td>
<td>9,303.00</td>
<td>14,002.00</td>
<td>12,616</td>
<td>10,239</td>
<td>7,487</td>
<td>4,932</td>
<td>12,875,000</td>
</tr>
<tr>
<td>Ethio China Street</td>
<td>729.00</td>
<td>508.00</td>
<td>692.00</td>
<td>624</td>
<td>506</td>
<td>370</td>
<td>244</td>
<td>636,364</td>
</tr>
<tr>
<td>Gabon Street</td>
<td>369.00</td>
<td>246.00</td>
<td>349.00</td>
<td>314</td>
<td>254</td>
<td>186</td>
<td>123</td>
<td>320,000</td>
</tr>
<tr>
<td>Cape Verde Street</td>
<td>2,827.00</td>
<td>2,007.00</td>
<td>2,690.00</td>
<td>2,425</td>
<td>1,968</td>
<td>1,439</td>
<td>948</td>
<td>2,475,000</td>
</tr>
<tr>
<td>Djibouti Street</td>
<td>65.00</td>
<td>46.00</td>
<td>62.00</td>
<td>55</td>
<td>45</td>
<td>33</td>
<td>22</td>
<td>56,497</td>
</tr>
<tr>
<td>Cameron Street</td>
<td>2,054.00</td>
<td>1,505.00</td>
<td>1,963.00</td>
<td>1,176</td>
<td>954</td>
<td>698</td>
<td>460</td>
<td>1,200,000</td>
</tr>
<tr>
<td>Rwanda Street</td>
<td>1,716.00</td>
<td>1,236.00</td>
<td>1,636.00</td>
<td>9,720</td>
<td>7,889</td>
<td>5,769</td>
<td>3,800</td>
<td>9,920,000</td>
</tr>
<tr>
<td>Ghana Street</td>
<td>1,441.00</td>
<td>1,030.00</td>
<td>1,373.00</td>
<td>784</td>
<td>636</td>
<td>465</td>
<td>306</td>
<td>800,000</td>
</tr>
<tr>
<td>Namibia Street</td>
<td>1,624.00</td>
<td>994.00</td>
<td>1,519.00</td>
<td>882</td>
<td>716</td>
<td>523</td>
<td>345</td>
<td>900,000</td>
</tr>
<tr>
<td>Megenagna-SealiteMihret</td>
<td>4,421.00</td>
<td>2,501.00</td>
<td>4,101.00</td>
<td>15,482</td>
<td>12,566</td>
<td>9,188</td>
<td>6,052</td>
<td>15,800,000</td>
</tr>
<tr>
<td>SealiteMihret-CMC</td>
<td>5,601.00</td>
<td>3,146.00</td>
<td>5,192.00</td>
<td>2,128</td>
<td>1,727</td>
<td>1,263</td>
<td>832</td>
<td>2,171,429</td>
</tr>
<tr>
<td>Jacros-Salite Mihret</td>
<td>4,930.00</td>
<td>2,741.00</td>
<td>4,565.00</td>
<td>2,800</td>
<td>2,272</td>
<td>1,661</td>
<td>1,094</td>
<td>2,857,143</td>
</tr>
<tr>
<td>Goro-Summit Square</td>
<td>3,121.00</td>
<td>1,693.00</td>
<td>2,883.00</td>
<td>6,337</td>
<td>5,143</td>
<td>3,760</td>
<td>2,477</td>
<td>6,466,667</td>
</tr>
<tr>
<td>Ayat Roundabout-Goro</td>
<td>3,256.00</td>
<td>1,881.00</td>
<td>3,027.00</td>
<td>641</td>
<td>520</td>
<td>380</td>
<td>251</td>
<td>654,206</td>
</tr>
<tr>
<td>Summit Roundabout-Tsehay real estate</td>
<td>2,098.00</td>
<td>1,148.00</td>
<td>1,940.00</td>
<td>513</td>
<td>416</td>
<td>304</td>
<td>200</td>
<td>523,077</td>
</tr>
<tr>
<td>Bole airport Roundabout</td>
<td>5,633.00</td>
<td>3,343.00</td>
<td>5,251.00</td>
<td>1,960</td>
<td>1,591</td>
<td>1,163</td>
<td>766</td>
<td>2,000,000</td>
</tr>
<tr>
<td>Ambasel Hotel Roundabout</td>
<td>1,507.00</td>
<td>837.00</td>
<td>1,395.00</td>
<td>1,257</td>
<td>1,020</td>
<td>746</td>
<td>491</td>
<td>1,282,570</td>
</tr>
<tr>
<td>Wollo Sefer Roundabout</td>
<td>3,013.00</td>
<td>1,770.00</td>
<td>2,806.00</td>
<td>2,528</td>
<td>2,052</td>
<td>1,500</td>
<td>988</td>
<td>2,579,850</td>
</tr>
<tr>
<td>Bole Michael Roundabout</td>
<td>3,366.00</td>
<td>1,936.00</td>
<td>3,128.00</td>
<td>2,818</td>
<td>2,287</td>
<td>1,672</td>
<td>1,102</td>
<td>2,875,899</td>
</tr>
<tr>
<td>----------------------------</td>
<td>--------------------</td>
<td>--------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Bob Marley Roundabout</td>
<td>5,400.00</td>
<td>3,792.00</td>
<td>5,132.00</td>
<td>4,623</td>
<td>3,752</td>
<td>2,744</td>
<td>1,807</td>
<td>4,718,386</td>
</tr>
<tr>
<td>Jacros Roundabout</td>
<td>5,175.00</td>
<td>2,879.00</td>
<td>4,792.00</td>
<td>216</td>
<td>175</td>
<td>128</td>
<td>84</td>
<td>220,000</td>
</tr>
<tr>
<td>Salite Mihrete Roundabout</td>
<td>6,259.00</td>
<td>3,727.00</td>
<td>5,837.00</td>
<td>5,259</td>
<td>4,268</td>
<td>3,121</td>
<td>2,056</td>
<td>5,366,567</td>
</tr>
<tr>
<td>EDNA Mall Round about</td>
<td>7,757.00</td>
<td>4,477.00</td>
<td>7,210.00</td>
<td>6,495</td>
<td>5,272</td>
<td>3,855</td>
<td>2,539</td>
<td>6,628,909</td>
</tr>
<tr>
<td>Olympia</td>
<td>2,799.00</td>
<td>1,550.00</td>
<td>2,591.00</td>
<td>2,334</td>
<td>1,895</td>
<td>1,385</td>
<td>913</td>
<td>2,382,178</td>
</tr>
<tr>
<td>CMC Roundabout</td>
<td>7,858.00</td>
<td>4,521.00</td>
<td>7,302.00</td>
<td>6,578</td>
<td>5,339</td>
<td>3,904</td>
<td>2,572</td>
<td>6,713,495</td>
</tr>
<tr>
<td>Summit Roundabout</td>
<td>7,300.00</td>
<td>4,150.00</td>
<td>6,775.00</td>
<td>6,104</td>
<td>4,954</td>
<td>3,622</td>
<td>2,386</td>
<td>6,228,968</td>
</tr>
<tr>
<td>Ayat Round about</td>
<td>3,813.00</td>
<td>2,190.00</td>
<td>3,543.00</td>
<td>3,192</td>
<td>2,591</td>
<td>1,894</td>
<td>1,248</td>
<td>3,257,452</td>
</tr>
<tr>
<td>Ayat Zone 5 Round about</td>
<td>1,876.00</td>
<td>1,029.00</td>
<td>1,735.00</td>
<td>1,563</td>
<td>1,269</td>
<td>928</td>
<td>611</td>
<td>1,595,168</td>
</tr>
</tbody>
</table>

The above Tables from 4-1 to 4-3, shows the results of the Traffic survey, Accident report of Bole Sub city for the past 4 years and the field measurement results of median and parking lane widths.
4.2 Result Interpretation

From the correlation analysis, it was found that Median width had the highest correlation with the Accident per Annual Average Daily Traffic. This was achieved by applying different statistical analysis for exponential, polynomial, logarithmic, power and linear scale.

The $R^2$- value for the linear scale was determined to be 0.6214. For logarithmic function $\ln(\text{Median})$ the $R$- value was determined to be 0.5742 and the exponential functions gives $R$-value of 0.5814. The polynomial function generally increases from 0.6221 to 0.7699 for degree two to degree six. From this analysis it was determined that Median had good relation.

The relation between the other parameter Parking Lane width and Accident per Annual Average Daily Traffic is not as strong as that of Median width. The strongest correlation was recorded for polynomial function of degree two to six, where the R-value was recorded to be 0.334 and the weakest relation was determined for Exponential function, where the R-value was recorded to be 0.2277.

After each variables correlation was determined the combined effect was then analyzed. From the combined analysis, it was confirmed that there is good correlation between Parking Lane width when it was linear and that of Median Width When we use Polynomial functions of higher degree.

As it is presented in Table 3-1 the R-square value varies for each function. The R-square value for linear function was determined to be 0.6214. This implies that the Median width will explain the Accident per Annual Average Daily Traffic to 62.14%. On the other hand, refereeing the same table the linear function of the Parking Lane width is 0.3247 implying that the Parking Lane width will explain the Accident per Annual Average Daily Traffic to 1.96%.

When we come to the second function, i.e. polynomial function the R-square value was 0.6221 for second degree, 0.6394 for third degree, 0.6581 for fourth degree, 0.7699 for degree five and 0.7699 for degree six. The R-square value generally tends to increase when we go from lower degree polynomial function to higher degree function. From these results we can infer that the capacity of the Median width to explain the Accident per Annual Average Daily Traffic increase from 63.94% to 76.99%.

Page | 45
Referring the same table and function the values of R-square for Parking Lane width was found to be 0.334. This implies that the capability of the Parking Lane width to explain the dependent variable is 33.4% in second to the sixth degree polynomial function. From the table polynomial function of degree six provides the best fit for each explanatory variable.

The third function that was incorporated in the study was Power function. The result shows that the Median width explains the dependent variable to 58.18% while, the Parking Lane width does not explain the dependent variable this is because power function does not work for Zero values.

The fourth function is logarithmic function. When the data was subjected to this function in STATA analysis the results presented in Table 3-1 were found. The R-square value for the Median width was 0.5742 which implies that the parameter explains the Accident per Annual Average Daily Traffic to 57.42% while, the Parking Lane width does not explain the dependent variable this is because Logarithmic function does not work for Zero values.

From Table 3-1 the fifth and last function was exponential function. For this function the Median width explains the Accident per Annual Average Daily Traffic to 58.14% and Parking Lane width explains the Accident per Annual Average Daily Traffic by 22.77%.

Table 3-2 presents the combined effect of these two parameters, which is basic to determine which function to use in the final stage of model development. It presents a polynomial function up to third degree. Even though the six-degree polynomial function provides the best fit we recall the capability of the modeling software STATA (SE13), only enables us to develop a model up to third degree.

Moreover, from Table3-2. The Median width best explains the dependent variable when it is quadratic. Again, from the same Table the R-square value of Median width value increase from 0.6825 to 0.6854 and the decreases to 0.6748 when we go from first degree polynomial to cubic polynomial function. For the Parking Lane width, the R-value decrease from 0.6825 to 0.677 when we go from the first degree to third degree. Generally, there is good relationship between the Median width and Accident per Annual Average Daily Traffic when it is quadratic and when
the Parking Lane width is linear. Based on this the model was developed and presented in the paper as equation (2): -

\[ Y = -2.41 \times 10^{-6} \times X1 - 8.06 \times 10^{-7} \times X2 + 0.000044 \]

(2)

Where,

- \( Y \) – Accident per Annual Average Daily Traffic
- \( X1 \) – Median width(m)
- \( X2 \) – Parking Lane width(m)

After the development of the model the next step is to determine the degree to which the model corresponds to the real system i.e. validation of the model. From the validation process it is verified that the numerical results obtained from quantifying hypothesized relationship between variables shows that there is significant relationship between the dependent variable (Accident per Annual Average Daily Traffic) and the explanatory variables (Median width and Parking Lane width).

Table 3-6, which is presented under sub section 3.5.4 above shows that the R-square value was 0.6825. Moreover, the P-value for each variable tests the null hypothesis. In this regard, only at 90% confidence interval where \( \alpha = 0.1 \), the probability of P-value to be greater than \( \alpha \) is zero. But for the other confidence intervals the significance level for the Parking Lane width which is 9.9% is greater than their significance level.

Regression coefficients represent the mean change in the predictor variable while holding the other parameters constant. As we can refer from the model the relationship between Accident per Annual Average Daily Traffic and Median width is quadratic.

The value of a coefficient for Median width is \(-2.41\times10^{-6}\). This shows that for every increment in Median width it is expected that the Accident per Annual Average Daily Traffic to increase by \((-2.41\times10^{-6})^2\). As it is presented with equation 2, the relation between Parking Lane width and Accident per Annual Average Daily Traffic is linear with coefficient of \(-8.06\times10^{-7}\) this implies for every increment of the Parking Lane width we expect the Accident per Annual Average Daily Traffic to increase by \((-8.06\times10^{-7})^1\).
Generally, from Table 3-5 above for the six confidence intervals the $R^2$ is 0.6825 i.e. 68.25%, this means the independent variables (Median width and Parking Lane width) are explaining 68.25% the variation in Accident per Annual Average Daily Traffic. Moreover, from Table 3-5, above at the significant level (alpha) 10%, the P value is less than the chosen significance level for confidence intervals 99.9 %, 99.5%, 99%, 97.5% and 95% hence here the null hypothesis is rejected. Therefore, the correlation is insignificant for these confidence intervals. This substantiates that there is a statistically meaningful relation existed between the explanatory variables and the dependent variable. On the other hand, the remaining 31.75% is attributed to variables not included in the model. This is normal because it is impossible to include all the independent variables in the regression model.

As it is presented with equation (2), the correlation between the median width, which is represented by $X_1$, is negative with power function of degree -6. The rate of accident occurrence will decrease as the width of median increase and vice versa. This result is the same as previous researches conducted by (FHWA, 1993), which states that accident rates do decrease with increasing median width.

This is meaningful because these medians will provide vehicular safety, pedestrian safety and increase operational efficiency. When we say vehicular safety it implies crash reduction by traffic turning left, head on, cross over traffic and headlight glare. Pedestrian safety is achieved by providing refuges for pedestrians crossing the high way. Medians help traffic flow well by removing turning traffic from through lanes. A roadway with properly designed medians can carry more traffic, which can reduce the need for additional through lanes; by doing so the operational efficiency of traffic flows will be increased.

The correlation of the other parameter parking lane width from the developed model show that there is a negative correlation between accident per AADT and parking lane width. Moreover, the relation can be represented by power function of negative six degree. This implies, the crash occurrence will decrease as the parking lane width increase and vise versa.

Previous studies suggest that, field observations do not suggest a major safety problem related to narrower parking lanes. It may be that many of the unforced encroachments on adjacent lanes are made in situations in which the driver is aware that no conflicting vehicles are present.
The findings of this study also have the same outcome with the one conducted by (Douglas, 1990), which concludes that where travel lanes were narrowed to create space to relieve the traffic, there were large decreases in crash rates. Narrower lanes may result in increases in some specific accident types, such as same-direction sideswipe collisions (Douglas, 1990).

The width of the travel lane does not only influence the comfort of driving and operational characteristics of a roadway, but is also an important parameter affecting the road crash frequency as well as crash severity. For any functional classification of roadway, whether it is an arterial road or a local road, and for any environment of the roadway, whether it is an urban road or a rural road, when the lane width reduces, the probability of crashes increases drastically. For example, a study which looked at safety risks on a two-lane undivided highway, found that when the lane width was increased from 2.75 meter to 3.65 meter, the probability for head-on or other related crashes was reduced by fifty percent (50%) (Zegeer C.V etal., 1988).

When the traffic volume is higher and the lane width is less, the probability for crashes, especially crashes like head-on or run-off the road, are greater. For example, in a multi-lane rural highway where the average annual daily traffic volume is greater than 2,000, the probability for a crash on a narrow lane i.e. 9 feet (2.75 meters) increases by more than thirty percent (30%) (Zegeer C.V etal., 1988).

By implementing the model, the estimated crash occurrence for seven selected streets in Bole sub city is illustrated in figure 4-1 below to show the relation between median width parking lane width and crash occurrence.
Figure 4-1 Predicted traffic crash occurrence.

As we can read from figure 4-1 the median width provided in the sub city are 0, 0.4, 0.9, 1.4, 2.4, 2.9 to 5.8 m. the parking lane width in some streets were 0 on the others it was 2.5 m and 3m wide.

Generally, the model depicts that as the parking lane width and median width increase the traffic crash occurrence reduces. On reality in some of the streets the crash occurrence is zero this might be due to miss report & under reporting however in our model the predicted crash will never be zero, the streets are always suitable to traffic crash; which will alert the designer to consider the safety impact of parking lane & median width design.

The only traffic parameter employed in this study, which is the traffic volume (AADT) has a direct& positive relationship with the traffic crash occurrence. Increase in the average annual traffic volume had increased the traffic crash. This is supported by previous researches on of these is the result by (Persaud and Dzbik 1993), which states that the relation between the accident frequency (accident severity) and volume (AADT) and is nonlinear.

Furthermore, the accident severity is always expressed as accident per number of vehicles. Generally, the accident severity will increase as the number of the vehicles increase, which
further is influenced by level of service and vehicular speed. However, the relation between vehicular speed and level of service with accident severity is beyond the scope of this thesis.
4.3 Engineering Solutions to Enhance Traffic Safety related to median and parking lanes

The existing crash severity data in Bole sub city shows that Megenagna –Salitemihret road is the one with overall high rate of traffic accidents. Followed by Rwanda Street and Africa Avenue. Based on the assessment on the existing traffic crash severity the following traffic engineering treatments are proposed:

4.3.1. Providing appropriate median

Studies show that the location of median openings has a direct relationship to operational efficiency and traffic progression. The assessment shows that the medians in Bole sub city were used as space where vehicles await for both left turning and merging. Some of these were painted & raised medians.

Studies shows that raised medians have the following benefits (Redmon, 2013):-

- Have been found to reduce motor vehicle crashes by 15 percent;
- Decrease delays (>30 percent) for motorists;
- Have resulted in increase in capacity (>30 percent) of roadways;
- Have been shown to reduce vehicle speeds on the roadway;
- Provide space for landscaping within the right-of-way;
- Provide space to install additional roadway lighting, further improving the safety of the roadway;
- Provide space to provide supplemental signage on multi-lane roadways; and
- Can be less expensive to build and maintain than paved medians.

It was expected that the median lanes/strips would: improve traffic progression on the major road passing through towns with unlimited access, as vehicles turning to numerous destinations can wait for proper gaps on the median strip, improve individual pedestrian/cyclists crossings across the main road, decrease and unify speeds of individual cars.

Generally, medians make the road safer by minimizing the number of potential conflict points the corridor user must monitor at a single time.

To assure efficient traffic operations, full median openings should only be at locations, which are thoughtfully placed along the corridor. If median locations are properly spaced when signalized,
traffic will flow at efficient and uniform operating speeds (FDOT, 2014). Full median openings should be limited to the following situations:

- Signalized intersections or those expected to be signalized intersections that conform to the adopted median opening spacing interval, or are separated from neighboring median openings so they will not interfere with the deceleration, queuing or sight distance of the full opening.
- Divided roadways where the traffic volume provides numerous opportunities for left-turns and crossing maneuvers from the intersecting access connection to be made with little or no delay.
- Median barriers are also used to prevent overtaking and to eliminate head-on crashes.

**4.3.2. Providing appropriate lanes (Driving and Parking Lanes)**

A range of engineering measures is needed to encourage appropriate speed and make hazards easily perceptible. These measures include:

- Provision of appropriate lane for slow-moving traffic and for vulnerable road users;
- Lanes for overtaking, as well as lanes for vehicles waiting to turn across the path of oncoming traffic;
- Better highlighting of hazards through road lighting at junctions and roundabouts;
- Improved vertical alignment;
- Advisory speed limits at sharp bends;
- Regular speed-limit signs; and
- Introducing additional lane improves the flow of vehicles as a result of eliminating jamming the flow by turning vehicles.
CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Summary & Conclusion
 The study developed a statistical model investigated the effect of road cross sectional elements on road traffic crashes and injury severity in Bole Sub city of Addis Ababa. Road geometric elements of median width and parking lane width were included in the study with traffic parameter AADT.

 Thirty-one streets, which are located in the Sub city, were incorporated. Out of these 31 streets, 19 were selected to achieve the objective of the study and establish the relationship in model.

 The correlation between the parking lane width, median width and traffic accident can be expressed with power function

 In this research, a 12-hour count was used to estimate the average annual daily traffic of each street.

 Traffic crash data of four years, which was collected from the Addis Ababa City Government Police Commission Bole Sub city Police department, was used. From the data, the age constituent, road user constituent, gender constituents of fatalities, heavy & light crash were assessed.

 Assessing the existing situation in the Sub city, generally men are more vulnerable to traffic accident than female. When we consider the age group constituent of traffic accident age group from 31-50 are the most vulnerable age groups. Among road user’s passengers and pedestrian were the most vulnerable groups.

 Based on the aforementioned data, multiple linear regression models was developed to investigate the effect of median width, parking lane width and average annual daily traffic on road traffic crash severity.
Based on the model, it is concluded that both the median width and parking lane width had a positive impact on road traffic accident reduction. However, the traffic parameter has a negative impact. The wider the median and parking lane width, the lesser the traffic accident occurrence and vice versa.

As the AADT increase, crash severity will increase. Moreover, the correlation between volume and crash severity can be expressed with polynomial function of degree six.
5.2 Recommendations
This research had examined the impact of median width and parking lane width on the traffic crash occurrence. Based on the study the following recommendation had been outlined:

- It is recommended that the designers and authorizes consider that they must provide adequate parking lane in order to increase the operational efficiency of the traffic network.

- It is recommended that adequate parking facilities be provided for the following types of vehicles: Private cars, Courier vehicles, Delivery / service vehicles and Bicycles separately.

- The importance of parking must be kept in perspective in the overall planning assessment of the city.

- Because in this study only the Addis Ababa City administration Police Commission Report was used, it is recommended that multiple data from different concerned bodies including insurance companies’ hospitals and traffic agencies should be incorporated.

- More geometric and traffic parameters should be included to increase the accuracy of the model.

- In this study, only four years’ period data were used; therefore, it is recommended that the study period should be increased and crash location information be provided with more explanatory facts.
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Appendix A: Accident
Appendix B: AADT
Appendix C: Stata Output
Appendix D: Picture of Field measurement and Data Sample
Appendix E: Model Selection Scatter Plots