COLLEGE OF SOCIAL SCIENCE

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GIS-Based Identifications of Road Traffic Accident Hotspots and Hazardous Bus Stops: a Case Study of Yeka Sub-city, Addis Ababa

A Project Submitted to Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Art in Geography and Environmental Studies

(GIS, Remote Sensing, and Digital Cartography)

By

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This is to certify that the project prepared by Robel Ayichew, entitled: GIS-Based Identifications of Road Traffic Accident Hotspots and Hazardous Bus Stops: a Case Study of Yeka Sub-city and submitted in partial fulfillment of the requirements for the Degree of Master of Arts in Geography and Environmental Studies (specialization in GIS, Remote Sensing, and Digital Cartography) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

Approved by the Examining Committee

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Chairman or Graduate Program Coordinator Signature Date

DECLARATION

I certify that this project is originally prepared by me, has not been presented for a degree in any other universities and all reference sources used for this project task have been properly acknowledged.

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Abstract

Nowadays, the main negative impact of road transportation systems is the loss of property, injuries, and deaths in road traffic accidents. Ethiopia hosted an average of 13 fatalities and 37 people for disability per day, from this Addis Ababa shares 10 % of fatality and 26 % of disability. In Addis Ababa city 70 percent of pedestrian deaths occurred when walking for crossing a road. There is a strong relation between road traffic accidents and pedestrian accumulators, especially, bus stops. The primary objective of this study was to assess road traffic accidents to identify black spots and hazardous bus stops in Yeka Sub-city administration (which is the second leading sub-city by road traffic accident after 2017). The data collection techniques of this study were questionnaires, interviews, and field observation. The primary data collected from questionnaires distributed to 60 city bus drivers (by using a simple random sampling technique) and 5 key informants. In addition to this Global Positing System (GPS) were used to collect x,y coordinates of bus stops and uncollected fatal accidents in 2019; whereas the secondary data were collected from Yeka sub-city police commission (non-spatial data) and Addis Ababa transport program management office (the spatial data). The applications of GIS such as interpolation and kernel density functions, buffering were used to produce a continuous surface, magnitude per unit area proximity respectively. The analysis was done using Arc GIS 10.3 and 10.5 software and Microsoft excel. 97% of all traffic accidents caused by male drivers, and Mondays, Thursdays, and Fridays which were more frequent traffic accident registered days. Inapt use of steering and driving closely were the primary causes of a road traffic accident and 52 percent of fatal accidents were caused by failure to give pedestrian priority. Ferencay Kela, Megenagna, Wesen Grocery, Aboare, Kara Akababi, Yeka Michael, and Gurd Shola were identified hotspot areas. Kokebe Tsibah, Lamberet Terminal, Ayat-Tafo entrance; CMC St. Michael, Yeka Sub-city Administration Roundabout, and Ferencay Biret Dildiy were hazardous/unsafe bus stops. The researcher recommended that special inspection and priority should be given for those identified black spots sites and hazardous bus stops. Traffic management agency and other concerned bodies should construct overpasses or bridge, fence, and relocation activities over those hazardous/unsafe bus stops.

Key Words: Road Traffic Accident, Fatal Crash, Black Spots/Hotspot, Buffer, Kernel Density

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Acronym and Abbreviations

ATPMO	Addis Ababa Transport Programs Management Office
GIS	Geographic Information Systems
GPS	Global Positioning System
KDE	Kernel Density Estimation
NNH	Nearest Neighborhood Hierarchical
FGDs	Focused Group Discussions
RTA	Road Traffic Accident
RTAs	Road Traffic Accidents
TMA	Traffic Management Agency
WHO	World Health Organization

CHAPTER ONE

1. Introduction

1.1 Background of the study

The economic growth and development of any country depend upon its transportation infrastructure and network systems, like road, rail, and air distributions and connectivity. These roads have vital importance to the movement of people and goods over the surface of the land. A good network of roads is important to increase economic performance as it provides connectivity between rural and urban areas. Accompanying this, road safety is an equally important aspect. It plays a key role in sustainable and efficient transportation development. The adverse impact of modern road transportation systems is injury and loss of life due to road accidents. While the road accident situation is improving in the high-income industrialized countries, most developing countries are facing a worsening situation (Ghosh, Sanjay.etal.2004).

Globally a road traffic accident has been increased from the 1999 year records 750,000-880,000 people fatality to 1.3 million people after. Recent statistical figures prove that each year nearly 1.3 million people die as a result of a road traffic crash. More than 3000 deaths each day and more than half of these people are 20-50 million more people sustain non-fatal injuries from a crash. These injuries are an important cause of disabilities worldwide. Ninety percent of road traffic deaths occur in low and middle-income countries, which own approximately 54% of the world's vehicles. Unless immediate and effective action is taken, road traffic deaths are predicted to become the seventh leading cause of death in the world by 2030, resulting in an estimated 1.9 million deaths each year (United Nations, 2018).

In Africa, the number of road traffic injuries and deaths has been increasing over the last three decades. According to the 2015 Global status report on road safety, the African region had the highest rate of fatalities from road traffic injuries worldwide at 26.6 per 100 000 population for the year 2013. A recent study found that the rate could be closer to 65 deaths per 100 000 inhabitants in 2018. With the rapid rise of motorization and urbanization in Africa, action must be taken to reduce accidents and protect societies (WHO, 2018).

Road injuries are the 7th leading cause of death in males in sub-Saharan Africa. They are the 13th leading cause of death in females, compared with the 18th globally. The road injury death rate for females in Western sub-Saharan Africa is more than twice the global average and almost five times the rate in Western Europe. Four countries (Nigeria, Ethiopia, South Africa, and Sudan) together account for half the road injury death toll of sub-Saharan Africa (Bahalla, et al.2014). Like many African countries, Ethiopia is facing several road safety crises. Each year more than thousands of road users are killed and the majority of them are economically active (Ethiopian Federal Police Commission 2017). According to the Ethiopia federal police commission in Ethiopia in the past eleven-year (beyond 2008) on average 9.16% growth rate of road traffic accidents were registered. Similarly the road network coverage and motorized vehicles have grown on average around 10.4% and 9.34% respectively (Ethiopian Federal Police Commission 2017).

According to the Ethiopian Federal Police Commission, the number of people killed increased from 4,500 to 5,118 while a record number of close to 41,000 traffic accidents were registered during the 2017/18 fiscal year. The commission also indicated that Ethiopia's rate of traffic incidents in2017/18 fiscal year has registered a 6 % increase as compared with the previous year (2016/17). The work of Kalu, (2017) shows that road traffic accidents in Addis Ababa are problems which need urgent attention as it has been damaging consequences on the health and economic development of the city. Therefore, immediate preventive action should be taken to mitigate the increasing number of road traffic accidents which are the main causes of fatalities and injuries in roads and bus stop areas. Some studies (Long Tien Truong and Sekhar Somenahalli, 2011) have shown that there is a strong relation between pedestrian-vehicle crashes and pedestrian accumulators, especially, bus stops.

To identify road traffic accident hotspot locations and unsafe bus stops GIS is a great tool. Around the globe, accident hotspots can be identified by using a variety of techniques such as accident density, accident frequency, and accident rate, and accident severity indexes. Currently, GIS has become a leading tool for road safety activity, mainly in identifying black spot sites. GIS combines spatial attributes with geostatistical analysis to present hotspot results in an easy way (KaluHabte 2017).

This research is intended to show the spatial and statistical analyses of traffic accidents mainly identify hot spots and hazardous bus stops in the Yeka sub-city.

1.2 Statement of the problem

Road Traffic accidents are an occasion for the death of millions and causing destruction of the property leading to socio-economic crises throughout the world particularly in third world countries. Road traffic crashes now represent the eighth leading cause of death globally. The road traffic accident problem is getting worse. Deaths from road traffic crashes have increased to 1.35 million a year. That is nearly 3700 people dying on the world's roads every day. One of the most heart-breaking statistics in the WHO report is that road traffic injury is the leading cause of death for people aged between 5 and 29 years. This implies that the impact it has on human, physical, and financial capital, is huge posing challenges to national development (WHO, 2018).

Road traffic accidents are a preventable cause of fatality and disability around the world and the adverse impacts worse in economically weak countries like third world countries. Road safety is one of the big problems worldwide since it picks public life and endangers its socio-economical aspects of the country. To maintain this challenge countries take an intervention action accordingly. One of the most cost-effective road safety interventions is to identify and take a countermeasure to eliminate so-called black spots or crash hotspots along the roads (Ghosh, Sanjay et al.2004).

The city of Addis Ababa has taken the lion's share of road accidents. Recently, road traffic crashes and particularly pedestrian crashes have become a challenging problem within the city. Walking is the main mode of transportation in Addis Ababa, accounting for about 60% of daily trips beside this the pedestrian injuries account for about 85% of total injury crashes (Gebresenbet & Aliyu, 2019). Even though the government has been trying to improve the safety of the road network and road safety programs and campaigns made by mass media on the national and local levels the issue still devastates many lives. There are also some signs of progress in improving access to Post-crash care to reduce the consequences and severity of injury once a crash occurs. But still, the crash cases are increasing rather than reducing (National Road Traffic Safety Council of Ethiopia 2015). In Ethiopia, based on the Federal Police Commission's annual police crash statistical report of 2018, approximately 3820 fatal crashes occurred and resulted in 5118 people death. Of those, Addis Ababa accounts for 12% (456) of fatal crashes.

Based on the Addis Ababa police commission 2019 report a total of 29,448 traffic accidents occurred in Addis Ababa and from this 458 were fatal, 1875 severe injury, 1115 slight injury, and 26,000 property cases. There is an increasing trend of 0.4 percent of fatality from 2018 to 2019. According to this report, Yeka sub-city is the second-largest fatal case registered sub-city next to Bole sub-city which accounts for 68 and 83 fatal cases respectively (Addis Ababa Police Commission, 2019)

Many studies have been conducted for analyzing traffic accidents in Addis Ababa. Most previous studies are based on the report data analysis without mapping and identifying the spatial location of the accident site. In the last 10 years, very few studies have applied GIS to understand the case, and hotspot areas of RTA in Addis Ababa but none of all below did not consider bus stops that are the most pedestrian generator places. For example, Kalu (2016) studied GIS-based spatial analysis & prediction of traffic accidents in Addis Ababa case of Gulele sub-city, Mahlet (2016) studied the assessment of reported road traffic crash in Addis Ababa case of Kolfe Keranyo sub-city, Efrem (2019) investigated about GIS-based road traffic accident black spot assessment in Addis Ababa in case of Kirkos Sub-city, Dawit (2016) studied about the road traffic accident and safety evaluation in Addis Ababa case of Bole Sub City. With exception of some sub-city including the Yeka sub-city, almost all sub-cities are studied by the researchers on the issue of GIS-based identification of traffic accident hot spots. But none of these were devoted to identifying hazardous bus stops at the sub-city level. So this study fills this gap by identifying hazardous bus stops in the Yeka sub-city level.

The absence of pedestrian signals and facilities including crosswalk at bus stops leads to pedestrians or bus users crossing the road on midblock from either behind or in front of the bus to board or alight a bus. These unsafe conditions frequently result in auto-pedestrian collisions which result in road traffic accidents. Identifying and ranking bus stops in high auto-pedestrian crash sites which resulted in fatal accidents is extremely helpful to develop an effective evidence-based intervention. Road traffic accidents should be analyzed spatially in the GIS environment with their occurrence of time, type, severity, and locations. The focus of this study is. This study was done in the Yeka sub-city which is never studied yet on the topic of GIS-based analysis of road traffic accident hot spots and dangerous bus stops. This study was done using 3 years (2017-2019) of traffic accident data with available constructed bus stop coverage in Yeka sub-city.

1.3 Objectives of the study

1.3.1 General Objective

The general objective of this study was to identify road traffic accident hotspot areas and hazardous/unsafe bus stops in the Yeka sub-city.

1.3.2 Specific Objective

- Explore the spatiotemporal distribution of fatal accidents in the study area,
- Identify the underlying factors contributing to a road traffic accident in Yeka sub-city,
- Showing the most traffic accident (black spot) locations in Yeka sub-city,
- Identify hazardous bus stops in Yeka sub-city.

1.4 Scope of the Study

The scope of this study is limited to analyzing, identifying, and mapping RTA hot spots and hazardous bus stops. To conduct this kind of research spatial data with its attribute are necessary. The study is conducted in Addis Ababa city, delimited to Yeka sub-city administration which is one of the leading traffic accident record sub-city in Addis Ababa city administration. The study included 3 years' (2017-2019) road traffic accident data and constructed bus stops.

1.5 Significance of the study

Previously, no GIS-based studies were undertaken to show hazardous bus stops in the Yeka sub-city administration. Hence, the current study will be of paramount importance as listed below.

The study will be offering valuable insight to concerned authority especially for road transport authority and traffic management. It will be helpful to give insights to drivers mainly city bus drivers relating to road traffic accident exposure in and around the bus stop area. It will help to gain valuable data and thematic map information about the hot spots, dangerous bus stops. The study will help to show the RTA trend, cause, and impact of RTA in the sub-city, which in turn, could help to develop countermeasures that could reduce the frequency and severity of RTA in the Yeka sub-city. The researcher believes that this study will be helping to do an evidence-based intervention and improve access to post-crash care and to assist decision-makers in identifying and ranking bus stops in high fatality areas. The study will be used as a reference to the researchers who want to conduct future detailed studies on RTA and related issues. Finally, the information generated from this study has been disseminated to promote awareness and participation among the professionals and bus drivers to mainly those found in Yeka sub-city.

1.6 Limitations of the study

By considering things, this study has been limited in time and area coverage. Accordingly, to conduct the study on the issue of road traffic accident hotspots and hazardous bus stops in Addis Ababa city administration would be wide and it needs more budget and long progress. Hence, the study has been limited to identifying road traffic accident hotspots and hazardous bus stops in Yeka sub-city of Addis Ababa city administration. Due to the absence of collected x, y fatal accident co-ordinates prior to 2017 the study was limited to three years of fatal data (2017-2019. In addition to this, the researcher has considered a limited number of representatives of sample respondents in interviews and questionnaires in order to supplement the spatial data executed by using the Arc GIS tool. Besides, to accomplish the desired work successfully possible efforts were exerted to follow scientific standards and requirements to overcome the above constraints.

1.7 Organization of the paper

The study has five chapters. The first chapter includes an introductory part which consists of an introduction, statement of the problems, research questions, and objective of the study. The second chapter discussed the review of related literature regarding definition and concepts of road traffic accident (RTA), global and local trend of RTA, causes of RTA occurrences, economic and social impacts of RTA, definition, and concept RTA black spot an unsafe/ dangerous bus stops by expanding the role of GIS for identifying road traffic accident and dangerous bus stops. The third chapter presented about data collection method, source of data, data analysis method research design, and methodology. The fourth chapter assessed the data discussion and presentation part. The fifth chapter included a conclusion and recommendation.

1.8 Definition of Basic Terms

The definitions of some basic terms are varying from one country to another. Because of the variety of context and concept of basic terms/ words should be clearly defined in the first chapter to avoid incomprehensibility of their usage in the study. Accordingly, the researcher clearly defines those terms in the lines of this research context and the United Nations (UN) standard (United Nations 2018).

Road infrastructure: road network facilities and equipment which including the network, parking spaces, stopping places, draining system, bridges, and footpaths

Road traffic accident: any accident involves personal injury occurring on the public highway (including footways) involving at least one road vehicle or a vehicle in collision with a pedestrian or infrastructure object and which becomes known to the police within 30 days.

Road traffic crash: a collision or incident that may or may not lead to injury and death, occurring on a public road and involving at least one moving vehicle on the road.

Fatal accident: an accident involving at least one fatal casualty.

Fatal injury/ casualty: a death occurring within 30 days of the road traffic crash

Serious injury: a serious injury as an injury that results in any of the following:

Death, significant disfigurement, dismemberment, Fracture, loss of a fetus, permanent loss of use of a body organ, member, function, or system, permanent consequential limitation of use of a body organ or member, a significant limitation of use of a body function or system or a non-permanent injury preventing you from performing your daily activities for not less than 90 days within the 180 days immediately following your accident

Slight accident: Accident in which at least one casualty suffers slight injuries but no fatal or serious injuries

Road transport: a type of transport that used to move goods and/or passengers using a road vehicle on a given road network (United Nations 2018).

A bus stop: is a designated place where buses stop for passengers to get on and off the bus (United Nations, 2018).

Hot Spot Analysis (Getis-Ord Gi*) is a tool to identify statistically significant spatial clusters of high values (hot spots) and low values (cold spots) of accidents.

Kernel Density is a tool to Calculate accident magnitude-per-unit area from a point using a kernel function to fit a smoothly tapered surface to each point.

A buffer is a tool that Creates buffer polygons around input features to a specified distance

Erase: Creates a feature class by overlaying the Input Features with the polygons of the Erase Features (Arc GIS tool help description)

CHAPTER TWO

Review of Related Literature

2.1 Introduction

This chapter explores the theoretical and conceptual framework of the study that used to provide background information and current state road traffic accident and hazardous bus stops. The theoretical and conceptual framework explains the path of the project. The theoretical framework provides concepts, factors, trends, prior and existing road traffic accident (RTA) statistics, and conditions in road traffic accidents. On the other hand, the conceptual framework provides a comprehensive understanding of road traffic accident phenomena. The conceptual framework presents an integrated way of looking at a problem under study. Interestingly, it shows the series of actions the researcher intends to carry out in a research study (Liehr & Smith, 1999). Accordingly, the researcher explains how the road traffic accident problem would be explored and identified.

2.2 Theoretical framework

2.2.1 Concept of Road Traffic Accident

An accident is a sudden phenomenon or happening unexpectedly by chance or probability. Road traffic accidents are any vehicle accidents occurring on a public highway. It includes collision between vehicles and animals, vehicles and pedestrians, or vehicles and infrastructures. Single vehicle accidents, which involve a single vehicle, which means without other road users, are also enclosed (Fora, 2017). Alebachew (2019) cited the definition given by Alister and Simon, stating that an accident involves personal injury occurring on the public highway (including footways) involving at least one road vehicle or a vehicle in collision with a pedestrian and which becomes known to the police within 30 days. In this respect, road traffic accidents can be defined as abrupt phenomena that happened on the road that open to public traffic; resulted in fatal or injury either slight or serious injury of road users and at least one vehicle will be involved. So RTA is defined as a crash between vehicles and pedestrians, vehicles and animals, and vehicles with infrastructures and buildings.

2.2.2 Road traffic accidents and development

Road traffic accidents can adversely affect economic development just like communicable diseases such as HIV/AIDS, tuberculosis, and malaria and thus should be considered as a development issue. Some scholars argue that as income per capita increases and is able to enhance the disposable income of households, the number of vehicles increases on the road of the countries that experience such events. For example, researchers find that at very low levels of income road traffic fatalities per (100,000) persons increase with income given that motorization goes up to a certain threshold, after which countries seem to be able to invest in safety measures (including modern cars) and possibly in measures that could bring behavioral changes to reduce traffic fatalities. Poor road infrastructures may be due to resource scarcity or misuse, lack of sound road safety regulations and weak enforcement of road traffic laws, the increment in the number of vehicles which is not accompanied by adequate improvements in infrastructure and road safety legislation leads to a mismatch between public expenditure required to accommodate an increased number of vehicles and increase private expenditure on vehicles. This discrepancy, in turn, leads to high road traffic accidents which could be carefully understood with the development trend (Eshbaugh et al. 2012)

Traffic fatalities rapidly increase as countries reach a middle-income level where people are able to buy vehicles but governments are not able to improve road infrastructure and enforce traffic laws that accommodate the ongoing large number of vehicles. From then on, road traffic fatalities decline as countries approach a high-income level and invest huge resources to improve and develop infrastructure that could accommodate a growing number of vehicles (Anbarci, Escaleras and Register 2006).

Based on the 2006-2015 road traffic accident data in Ethiopia, on average road traffic injuries are increasing from time to time where Oromia regional state is the major contributor to total fatalities that occurred in the past decade. On the other hand, Addis Ababa city administration is found as a major contributor to serious and slight injuries as well as property damages. The report confirms that male road users who are in their productive age group are disproportionately affected by road traffic injuries. Human errors (mainly drivers' behavior and actions) are found as the major cause of road traffic accidents in Ethiopia (Amanuel, 2017).

2.2.3 Road traffic accident statistics

The degree of road traffic accidents are divided into four groups: fatal, severe injury, slight injury, and property cases. With respect to the assertion of the road traffic accident statistics, the fatal accident statistics are more complete and reliable than the non-fatal accident data due to fatal accident information is vital to enforce the law and carry out prosecutions. Road traffic injuries are a worldwide problem affecting all sectors of society (Alebachew, 2019).

Road accidents are one of the major causes of death, injury, and disability all over the world both in developed and developing countries. With a broad estimate, in every one minute, two people are killed and 95 people are severely injured or permanently disabled in traffic accidents worldwide. Traffic accident-related deaths and injuries result in not only substantial economic losses but also serious physical and mental sufferings. Developing countries are much more affected by traffic accidents than in developed countries. According to the world health organization (WHO) statistics, 75% of deaths resulted from traffic accidents occurring in developing countries, although they own only 32% of the motor vehicles in the world (The et al., 2004).A recent statistical figure shows that each year nearly 1.3 million people die as a result of a road traffic crash. More than 3000 deaths each day and more than half of these people are twenty to fifty million more people sustain non-fatal injuries from a crash (United Nations 2018).

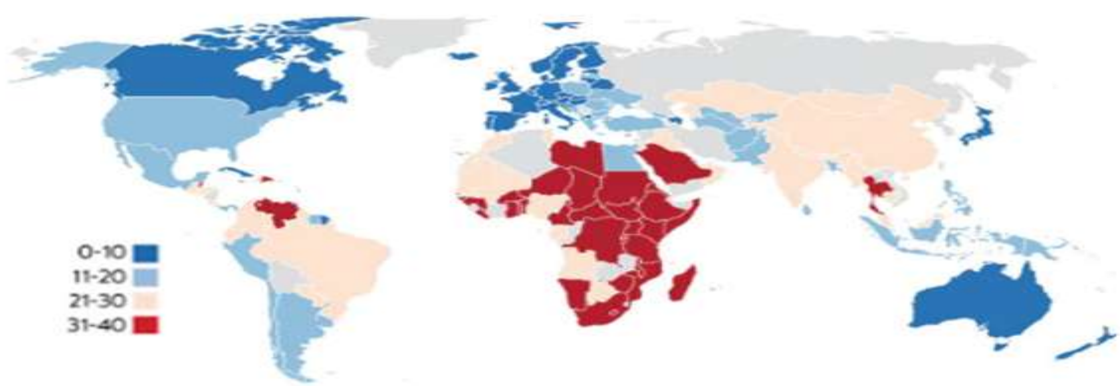

Figure 2. 1 Road traffic accident by country (per 100,000 people)
Source: World Health Organization (2018)

2.2.4 Cause of Road traffic accident

The rapid growth of private vehicles has led to many negative effects, such as congestion, noise, air pollution, and traffic accidents. The causes of traffic accidents are road, the driver, the road user, vehicle, and environmental factors. According to Ruman, K (1985), studies from the American and British reports; accidents occurred 57% due to driver factor, 27% due to the combined roadway and driver factor, 6% combined vehicles and derived factor,3% a combination of the road, drivers, vehicles,2% vehicle factor,1% combined of vehicle and road user factor. Most research findings confirmed that 70% to 80% of all road traffic accidents are the result of human error. However, there is no common agreement among scholars on the term human error; and is often controversial. It doesn't satisfactorily describe that a large number of injuries and deaths that occur on the road as the result of driving errors while abilities to do so are impaired by alcohol or drugs, lack of experience, lack of distribution of attention, etc. Road network in Africa is expanding fast, and similarly, maintenance standards are improved resulting in the safety standard of the road. However, in Ethiopia, due to lack of training in the subject area, the contribution of roads and environment to traffic accidents is underestimated (Atsbeha, 2014).

2.2.5 Risk Factors

Road traffic crash results from a combination of factors related to the components of the system comprising roads, the environment, vehicles, and road users, and the way they interact. Some factors may not appear to be directly related to road traffic injuries. Some causes are immediate, but they may be underpinned by medium-term and long-term structural causes. Identifying the risk factors that contribute to road traffic crashes is important in identifying interventions that can reduce the risks associated with those factors. Risk factors in road accident models play to improve overall model fit and reduce the amount of unexplained variation and provide a means for evaluating the effectiveness of alternative safety measures (Geurts & Wets, 2003). The following risk factors are elaborated for explaining accident involvement and accident severity.

- Course of the accident: vehicle maneuver, driver action
- Traffic conditions: traffic volume, dynamics, speed regulation
- Environmental conditions: light condition, road surface condition, road geometry

- Human conditions: driver age, occupant age, driver sex, driver condition (alcohol, fatigue, illness), seating position, seat belt use
- Vehicle conditions: vehicle mass, vehicle size (Geurts & Wets, 2003).

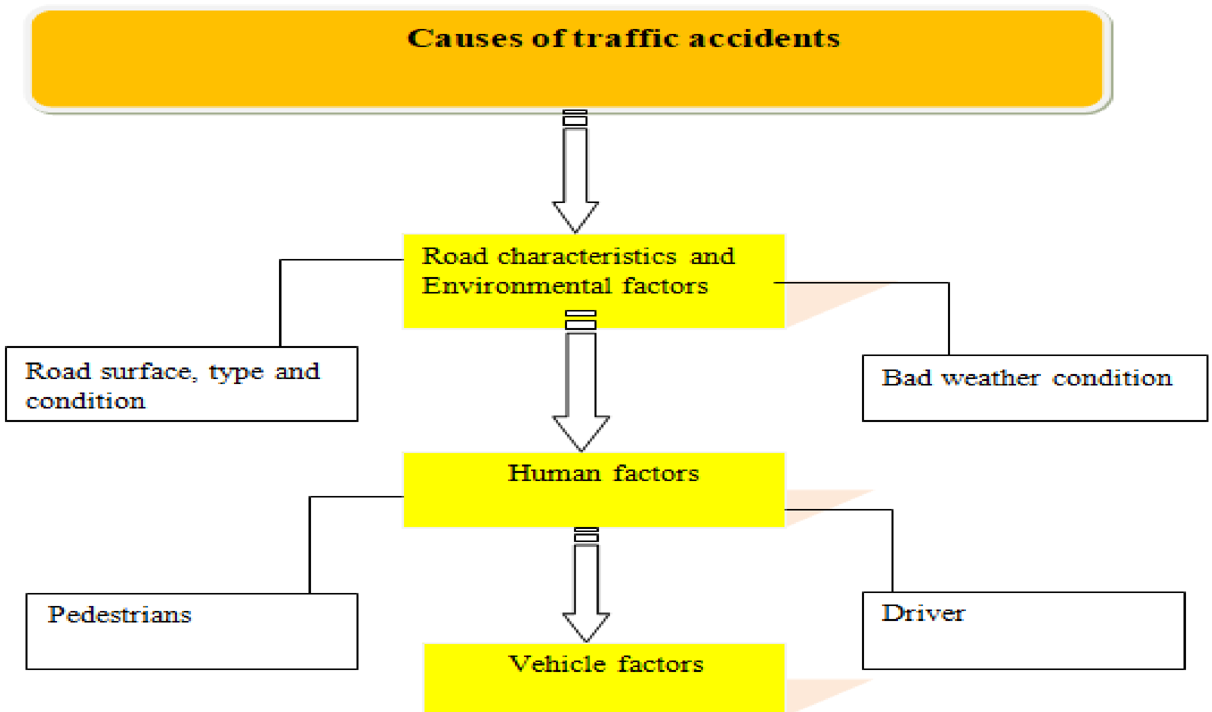

Figure: 2.2 Causes of road traffic accident Source: (Geurts & Wets, 2003)

The main cause of accidents and crashes are due to human errors. Some of the common behavior of humans which results in an accident is over speeding, distractions to driver, drunken driving, red light jumping, avoiding safety gears like Seat belts and helmets, non-adherence to lane driving, and overtaking in a wrong manner various national and international researchers have found these as most common behavior of road drivers, which leads to road traffic accidents (Ajit and Ripunjoy, 2004).

Over Speeding

Over speeding means that travels too quickly, that exceeds a speed limit. Most of the fatal accidents occur due to overspeeding.. If given a chance man is sure to achieve infinity in speed. But when we are sharing the road with other users we will always remain behind some or other vehicles. An increase in speed multiplies the risk of accident and severity of injury during accidents. Faster vehicles are more prone to accidents than slower ones and the severity of accidents will also be more in case of faster severity of accident will also be more in case of faster vehicles. The higher the speed results in the greater risk. At high speed, the vehicle needs greater distance to stop i.e. braking distance. Running late is one of the most common reasons people use for driving too fast. The hothead of being late to work or school can cause a driver to disregard the speed limit. A vehicle moving at high speed will have a greater impact during the crash and hence will cause more injuries. Speeding is a common problem for new drivers, especially teenagers. One of the reasons for this is inexperience. New drivers often don't realize just how dangerous speeding is. Sometimes Drivers may fail to observe posted speed limits and danger signs that settle on the road network (Ajit, and Ripunjoy, 2004).

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Fig: 2.3 Speed caused accident photograph in Addis Ababa Source: TMA media

Drunken Driving

Drinking and driving exacerbation both the risk of a crash and the likelihood that death or serious injury will result. When a driver drinks their judgment is affected. Additionally, a drunk driver may try to get home as fast as possible to avoid detection. Drinking is the biggest cause that reduces a driver's reaction time and increases the likelihood of an accident. Alcohol concentration decreases the reaction time of the human body. For every increase of 0.05 blood alcohol concentration, the risk of accident doubles (Ajit, G. and S. Ripunjoy, 2004).

Distraction to Driver

Distracted driving is a major cause of car-related injuries and deaths. In fact, it's estimated that roughly 25% of motor vehicle accident fatalities are a result of distracted driving worldwide. Distractions could be outside or inside the vehicle. Human beings do not perform two tasks at the same time. It will switch between one task and another. The major distraction causes are lost in thought, Cell phone use, outside person objects or events which share 62%, 12%, 7% of distraction to driver causes respectively (Ajit, and Ripunjoy, 2004). The major causes of distraction to drivers are listed below.

1. Lost in thought –62%
2. Cell phone use – 12%.
3. Outside person, object, or even – 7%.
4. Other occupants – 5%
5. Using or reaching for a device brought into the car – 2%
6. Eating or drinking – 2%.
7. Adjusting audio or climate controls – 2%
8. Using devices/controls to operate the vehicle – 1%.
9. Moving objects – 1%
10. Smoking-related– 1%.

Red Light jumping

Red Light jumping means a vehicle that crosses an intersection or red light traffic signals. It is a common sight at road intersections that vehicles cross without respect for the light. Frequently drivers speed up when they approach a yellow light. The main motive behind red light jumping is saving time. The common conception is that stopping at a red signal is a wastage of time and fuel. Studies have shown that traffic signals followed properly by all drivers save time and commuters reach their destination safely and timely. But it hampers his ability to judge the ongoing traffic and quite often crashes (Ajit, and Ripunjoy, 2004).

Avoiding Safety Gears like seat belts and helmets

Wearing Helmets and seat belts are necessary while driving as safety carefulness. Use of a seat belt in a four-wheeler is now mandatory and not wearing a seat belt invites a penalty, same in the case of helmets for two-wheeler drivers mostly bicycles and motorcycles. Wearing seat belts and helmets has been brought under law after proven studies that these two things reduce the severity of injury during accidents. Wearing seat belts and helmets doubles the chances of survival in a serious accident. Safety gears keep you intact and safe in case of accidents. Two-wheeler deaths have been drastically reduced after the use of helmets has been made mandatory. Because seat belts could avoid severe accidents, wearing helmets and seat belts are very necessary not only for drivers but also for the safety of the passengers who are traveling on 4-wheeler, motor bicycles, bicycles, cars, etc. Most of the fatal accidents all over the world are caused by head injuries. In general road traffic accidents have occurred as a result of the interaction of many different factors among which are road, human, and vehicle characteristics. Most investigations have revealed that 70% to 80% of all traffic accidents have occurred as the result of human error (Ajit, and Ripunjoy, 2004).

2.2.6 Preventive measures for road traffic accidents

Evangeline and Andrew, 2016 presented that road traffic accidents are the major cause of mortality among people aged 15–30 years in the world. World Health Organization (WHO) and the World Bank launched decadal action for road safety in 2011 with the goal of halving the number of injuries and deaths on the roads. Some of the preventive measures are listed below.

Implement safety-oriented infrastructures: - Infrastructure is the primary task to prevent road traffic accidents, especially for developing countries. Continuous improvement of hotspot locations and hazardous road areas. Implementation of safety facilities including roundabouts, bus stops and terminals, and rest areas.

Establish traffic culture: - Safety awareness should begin from childhood because childhood is a better way to impart awareness than adults. Enforce road safety campaigns and education; enhance road safety advertisement by promoting cooperation of diverse road safety-related institutions.

Strengthen Traffic National Policy: - Enforce control of illegal, non-registered vehicles and investigate repetitive accident cased vehicles. Strengthen local government authority traffic safety capacities; conduct road safety training and workshops to local government officers to share road safety-related policies.

Enhance safety regulations for transport service enterprise and upgrade accident response systems: -conduct traffic safety assessment to transport service enterprises both government and private enterprises that have caused traffic accidents and fatalities. Reward and provide incentives to high-performance enterprises.

Increasing parking supply: On-street parking is a major problem for traffic congestion and accidents. Strengthening public parking is important to minimize on-street parking that affects traffic flow and safety (Evangeline and Andrew, 2016).

2.2.7 Road traffic accident condition in Ethiopia

Road transportation has become a common mode of transportation in Ethiopia. More than 90% of the overall transportation system is operated by road transportation. In Ethiopia, road transport safety became a big challenge due to the increased traffic flow as well as a situation in which vehicles and pedestrians were using the same roadside and other underlying factors. On-street crashes continued to be the most outlined problem of the road transportation system in Ethiopia, even if the government has undertaken a major effort in road development. In addition to this, the road infrastructure lacks inclusive safety considerations. One can easily observe and understand the defect within the road segment of the road network due to a lack of appropriate safety considerations during planning the design and construction. Ultimately, these conditions result in exacerbating the severity of traffic accidents. Moreover, driver and pedestrian-related cases are also the biggest problems, underlying causes like speeding, improper stopping, lack of attention, using mobile phones, the influence of drugs, improper turning, violation of traffic laws, ignoring priority of way are the major cases to road traffic accidents (Alamirew and Alemayehu, 2019).

Based on the 2019 national report in Ethiopia 4592 fatality, 7407 serious injury, 5949 slight injury cases occurred, of total accidents 86 percent were on pedestrians. In addition to this 870 million birr were lost. Road traffic accident problems are a current issue in Ethiopia which needs urgent attention as it has damaging consequences on the health and economic development of the country. Based on the 2019 Addis Ababa annual road safety report in Ethiopia road traffic accident cases for an average of 13 fatalities and 37 people for disability per day, this Addis Ababa shares 10 % of fatality and 26 % of disability in the country level. In general, the number of vehicles and traffic flow increases at a higher rate, traffic accidents rise rapidly. According to federal police commission statistics after 2008 Ethiopia has lost over 40,000 people due to fatal crash (Transport Program Management Office (TPMO), 2019).

2.2.7.1 Road traffic accident condition in Addis Ababa

Addis Ababa is Ethiopia’s largest city, according to a global population review in 2019, its population in the near future is expected to grow to exceed 6.5 million residents and nearly 25,000 road crashes happen per year. In the city of Addis Ababa, road traffic accidents and fatalities have risen as the size of the population and the number of vehicles has increased. The number of road fatalities in Addis Ababa has increased incessantly from 395 in 2007 to 480 in 2019. Most of the casualties have occurred on pedestrians. This is due to a combination of very high pedestrian activity and very low levels of pedestrian safety protection. Based on the 2017 annual road safety report of Addis Ababa 82 percent of road deaths were occurred on pedestrians and from this 70 percent of pedestrian deaths occurred when walking for crossing a road. Walking is the dominant mobility model in Addis Ababa for an estimated 70% of the population, with public transport the dominant mode for 26%, and private motorized transport the dominant mode for 4% of the population. From all of the cases, one of the headache problems is that most road traffic injuries and fatalities cases are castrates young population mainly young men, causing serious social and economic effects on their ménage and society. The impact of road traffic accidents is a serious health problem on the victim's side. Reducing this preventable burden of death, disability, and property damage is a prior issue of the Addis Ababa city government. (Addis Ababa transport office, 2018)

There are four main government authorities and agencies, which have a responsibility to control and sustain road safety and traffic flow in the city. Those are the Addis Ababa Traffic Management Agency (ATMA) which is responsible for deciding, improve and control road utilization; the Addis Ababa Transport Authority (AATBO); the Addis Ababa City Roads Authority (AACRA) which is responsible for the construction and maintaining the road infrastructure; Addis Ababa Police Commission which is responsible for traffic management, enforcement, accidents investigations, and accident recording; and Transport Programs Management Office (TPMO). But unfortunately, there is a poor interconnection between them to describe the city's road safety status in order to plan, monitor, and execute interventions (Kalu, 2017).

Currently, the city is on the way to implementing the road safety implementation plan in collaboration with city agencies and partners. The number of vehicles has more than doubled in the past five years. From 2014 to 2017, the city population and the number of registered vehicles increased by 7.1% and 119% respectively. The annual population growth rate is 2.4%. Women make up 53% of the population. Addis Ababa has been standing to reduce road traffic accident cases. The city spent 13 years developing safety strategies and three years on an implementation plan. Though, road crashes in the city are a major public health concern. More than 450 people die every year on the roads, with pedestrians being the most vulnerable group (Addis Ababa transport office 2018). No days in Addis Ababa that is free from road traffic accidents. On average one person will be dying, 10 people's disabling, and 27 properties damaging (Federal Police Commission, 2019).

Even though; the number of fatal road crashes dropped by 1.5% from 2017 to 2018, the number of fatalities slightly increased (from 477 to 478 and an increment (0.4%) in terms of fatality cases in the year 2018 to 2019. Based on the 2019 report 29448 traffic accidents occurred; from this case 458 (1.6%) fatal cases, 1875(6.4%) serious injury cases,1115 (3.4%) slight injury cases and 26000(53%) is property damage. Relative to sub-city level Gulele, Addis Ketema, and Lideta were the list three sub-cities that traffic fatality rate was very low which accounts for 18, 20, and 22 cases respectively. On the other hand, Bole, Yeka, Nifas Silk Lafto, and Kolfe sub-cities recorded higher fatality rates; accounts for 83, 68, 66, and 65 fatal cases respectively. Kolfe and Nifas Silk were the leading sub-cities in terms of serious injury. In all sub-cities, the trends of traffic accidents were increased. In 2019 a total of 1125 additional traffic accident cases were registered compared to the 2018 year, which is a 4 % increase in total accident cases (Addis Ababa police commission, 2019).

Table 2.1: Traffic accident statistics of Addis Ababa sub-city (2019)

Sub-city	Fatal	Serious injury	Slight injury	Property damage	Total
Lideta	22	121	67	1436	1646
Kirkos	29	166	92	3671	3958
Gulele	18	44	124	1109	1295
Yeka	68	128	69	3078	3343
Bole	83	374	102	6123	6682
Kolfe	65	256	134	1955	2410
Addis Ketema	20	174	28	1124	1346
Arada	28	170	9	2207	2414
Nifasilk	66	286	341	3742	4435
Akaki	59	156	149	1555	1919
Total	458	1875	1115	26000	29448
Percentage	1.60%	6.40%	34%	53%	

Source: Addis Ababa Police Commission report 2018-2019 fiscal years

Table: 2.2 Traffic accident statistics of Addis Ababa city (2018 - 2019)

Accident Type	2018	2019	Difference in number	Difference in percent
Fatal	456	458	+2	0.40%
Serious injury	1902	1875	-27	1%
Slight injury	1050	1115	+66	6%
Property damage	24915	26000	+1085	4%
Total	28323	29448	+1125	4%

Source: Addis Ababa Police Commission report 2018-2019 fiscal years

All tables show that except for serious injury there was a positive trend in all cases of RTAs. The overall traffic accident condition was escalated in the 2018-2019 year in all sub-city levels. The level of increments was between 25 % to 151%. Yeka sub-city was the second leading large number of RTA sub-cities next to Bole. In general, in the year 2018 and 2019, there was a rapid change of traffic accident increment in Addis Ababa city level which records a total case of 97 percent of increscent from the 2018 traffic accident report.

Table 2.3 Addis Ababa Police Commission report

Sub-city	Initial year road traffic accident(2018)	Plan for reduction to 2019		2019 proposed accident	2019 actual registered accident	Difference relative to 2018	
		Percent	Number			Number	Percent
Lideta	1020	20%	204	816	1646	626	61%
Kirkos	2632	20%	526	2106	3958	1326	50%
Gulele	624	20%	124	500	1295	671	108%
Yeka	1500	20%	300	1200	3343	1843	123%
Bole	2700	20%	540	2160	6682	3982	147%
Kolfe	1212	20%	242	970	2410	1198	99%
Addis Ketema	732	20%	144	588	1346	614	84%
Arada	1189	20%	238	950	2414	1225	103%
Nifas Silk	1768	20%	354	1414	4435	2667	151%
Akaki	1536	20%	307	1229	1919	383	25%
Total	14913	20%	2979	11933	29448	14535	97%

Source: Source: Addis Ababa Police Commission report 2018-2019 fiscal years

2.2.7.2 Working towards Road Safety Improvement in Addis Ababa

Addis Ababa city administration is working on measurements to overcome the transport challenges in general and road traffic problems in particular. To develop the way and capacity of handling the challenges, the Addis Ababa city transport office has been restructured and established a Traffic Management Agency (TMA) in the year 2015, under the missions of ensuring safe and acceptable traffic flow in Addis Ababa city. To provide minimum traffic accidents the TMA properly controls 50 intersections out of 403 total intersections on 475 kilometers of road length. But recently 353 intersections are requiring interventions. To provide a reliable traffic system the TMA takes major interventions through geometrical improvement, providing off-street parking, proper road markings, signs, and priority for selected users at traffic signals (Addis Ababa traffic management agency, 2019).

However, the TMA still has no confidence that all roads are designed and built with all road user considerations. Some roads lack minimum road user rules. Lack of standards, on-street parking, absence of bus and taxi stations, faded hence outdated road marking and proper design is among the gaps. For developed road infrastructure, evidence-based countermeasures based on careful study of crash data is a good system to identify the root cause of traffic accidents. According to TMA, to avoid traffic accidents that might result in slight, serious, and fatal accident evidence-based scientific researchers/studies in different areas of traffic are essential tools (Addis Ababa traffic management agency, 2019).

2.2.8 Identification of Accident Black spots

The locations of places where the accidents are occurring more frequently were marked as the black spots. Black spot identification is basically planned to explore the location of accidents by distinguishing risky areas and accident-prone locations of accident occurrence and to break down basically reasons attributing for the same in order to guarantee road transport well being. The identification and analysis of accident black spots help in identifying the stretches where accidents are more and these spots reduce road safety in general. The spot on the road where traffic accidents frequently occur is termed as black spot (Ezgi, 2014)

Road intersections are often accident black spots. It is important to distinguish between accidents occurring at intersections or on links (the sections of road between intersections) as the factors contributing to the accidents and possible treatments are generally very different for each. Whilst in many cases the location will be clear, there will be accidents near intersections that might fall into either category. In such cases, depending upon the quality and extent of data, it is desirable to examine the factors contributing to the accident in order to establish whether the features of the intersection were important and if so to classify the accident accordingly as an intersection accident. Generally, accidents that occur within 30 meters of an intersection can be regarded as 'intersection' accidents (Thakali et al., 2015).

One of the key criteria for black spot identification is the length of years of crashes to be used. Elvik (2008) demonstrated that a suitable period of data for identifying hazardous road locations (Bus stops and others) is between 3 to 5 years. However, a 3 years period is, frequently used. Efrem (2019) have cited the work of Rokytova (2000) and (Geurts and Wets, 2003) in his thesis paper that different countries can use expected time limit extent for black spot analysis in respect to the level of accident existed repeatedly with the specified number and relative severity in the specified period. Two or three year analysis periods are more appropriate

In the British black spot area defined as at least five injury accidents should be reported in three years. Thus, in Bangladesh black spot is defined as having more than 10 injury accidents in a year (Geurts and Wets 2003).

In Germany, a location is considered a black spot if a large number of accidents occur on a very small section of a road network, i.e. if a certain number of accidents is reached or exceeded on the one-year and/or three-year map (Mitiku, 2018).

Table 2.4: Accident black spot time consideration

Source of data	**Critical count of accident**	**Length of period**
1-Year map	5 Similar type	12 Months
3-Year map	5 Injury accidents	36 Months
3-Year map	3 Serious/ fatal injury accidents	36 Months

Source: German road and transport research association, 2006 cited in Mitiku Dinsamo (2018).

In most developed countries, black spots sites are defined as the locations where there are 12 accidents in 3 years per 300-meter radius (Guo, et al. 2003). In the Czech Republic, the black spot identification criteria are 250m long road sections that are considered as black spots on a way that at least 3 road accidents with injuries or fatal case occurred within 1 year or at least 3 road traffic accidents with injuries of the same type occurred within 3 years or at least 5 road accidents of the same type occurred within 1 year (Rokytova, 2000).

When we see the overall definitions of road traffic accident black spots that are presented by several scholars it was theoretically unsatisfactory, hence there is no clear boundary about whether black spots should be defined in terms of the expected number of accidents or in terms of the recorded number of accidents. In conclusion, from a more theoretical point of view, black spots can be defined as any location that has a higher expected number of accidents than other similar locations, as a result of local risk factors. (Elvik, 2007).

Efrem, (2019) presented that there are various alternatives to delineate black spots based on road traffic accidents. Basically most recent (1 to 3-year period) is normally used for black spot analysis and is generally enough to identify hazardous locations. Using this there are several methods that are adopted to classify and identify the road segment as a black spot area. Some of the well-known methods are illustrated below (Efrem, 2019).

A. Critical crash rate factor method: the critical crash rate method has been a widely used technique in traffic accident analysis. In this method, the observed crash rate at a site is compared with a critical crash rate unique to each site. The critical crash rate for a site is a function of the average crash rate of a reference group associated with the site, the traffic volume of the site, and a desired level of confidence. This method labels a particular location as a black spot if the car crash rate on this location is higher than the average. Since traffic crashes are random occurrences and can be considered rare events, it is not possible to identify hazardous locations simply on the basis of the number of car collisions or accident

B. Number of accidents (crash frequency) method: This method counts the number of crashes that have occurred at a given location (along a roadway section or at an intersection) over a specified time period, typically three to five years. The results are ranked from highest to lowest crash frequency. This is the simplest method that uses the number of car crashes or accidents at a location to identify its safety performance. Locations with more than the expected number of accidents are categorized as hazardous locations.

C. Accident density method: The accident density is calculated from the number of accidents per unit length for a segment of the road. Segments with more than the expected number of accidents are categorized as black spot locations.

D. Accident rate (Crash rate) method: This method uses accident numbers divided by vehicle exposure to provide rates such as accidents per million entering vehicles per spot location and accidents per million vehicle-miles for segments of the roads. Locations with higher than expected rate are categorized as hazardous locations.

E. Severity index method: is defined as the number of persons killed per 100 accidents. The concept of this method is that the number of fatal and/or injury accidents at a location or segment of a road is given greater weight than property damage-only accidents.

There are various approaches that are aimed at identifying and mapping hotspots. One of the well-known approaches is using statistical crash models. This approach focuses on relating crashes as a function of potential variables such as road characteristics, traffic level, and weather factors using historical records and subsequently uses these models to identify relatively high-risk sections. The other alternative approach is a geostatistical technique. This technique differs from the previous approach by considering the effects of unmeasured confounding variables through the concept of spatial autocorrelation between the crashes event over a geographical space (Lloyd, 2010).

2.2.9 Application of GIS for Road Traffic Accident

GIS applications have the ability to analyze various planning problems such as collecting, managing, analyzing, retrieving, modeling, and presenting spatial data. The growing problems of road traffic accidents require effective planning and treatment. The role of GIS as an analytical tool provides a major influence in providing solutions to solve road traffic accident problems. This capability makes it easier for planners to make decisions more effectively and efficiently (Evangeline Muthoni, Andrew Imwati, 2016)

Geographic data usage plays an important role in several fields. In our day to day studies, we used several data that have spatial information. Usage of spatial data required data clarity and manipulation of them correctly. In this way, GIS has a critical role. GIS is a tool that provides collection, storage, manipulation, query, analyzing, and visualization of spatial data. The occurrence of accidents at the same place or nearby places is the indicator of the location of accidents. Traffic accidents should be analyzed with their coordinates. With the help of spatial analysis tools, high crash occurrence areas will be clearly identified. In order to understand the causes of accidents and improve traffic safety, hot spot analyses have an important role (Lloyd, 2010).

GIS has an important tool in road traffic planning and management. Since traffic jams location is a spatial process, so GIS is an efficient and effective tool to handle and solve the problems. Traffic management and planning operators may apply the application of GIS in many ways to locate the optional route to road users, for effective traffic signal control, to give specific information to drivers and passengers, to generate databases on traffic accident-prone areas, and to compute accident severity index. It is also used for accident mapping and reporting systems.

This system may be used in actual-time traffic accident recording, analyzing, visualization, and finally apply the report and management system of the accidents through delineations of the nearest suitable facilities and emergency services (Evangeline Muthoni, Andrew Imwati, 2016).

To prepare the data as much as suitable for the GIS environment the concerned body or traffic police should be reporting the georeferenced data and all things that happened there(accidents and incidents). Then the GIS experts may store the recorded data in a database. The database may contain datasets like district, accident types, clinic/hospital access, and road networks. After preparing all observed data it is possible to apply GIS applications for a further advanced process like trend analysis, modeling, and overall visualization. The final map may help to locate and visualize the issues for the concerned bodies like traffic managers to properly decide decisions. It is also used to understand the hot spot areas for a traffic accident and ultimately the planners and decision-makers may select the appropriate suitable location for service sectors in relation to road networks. This system is also very important to do web GIS for traffic accident problems. With the aid of geospatial technologies like global positioning systems we can record the location for web mapping purposes and this is very crucial for data sharing among different government sectors (Evangeline and Muthoni, 2016).

2.2.10 GIS-based Analysis of Accident Black Spots

Crashes occurring spatially close together may be the products of locations with higher levels of conflicting volumes, such as intersections or inappropriate infrastructure designs, such as lack of pedestrian crossings, etc. Identifying high probability crash areas is an important issue of traffic safety programs. (Ezgi, 2014)

There are many accident hot spot analysis techniques such as KDE, Network KDE, Black Spot Analysis, Moran's I Index, and Getis-Ord GI* statistics. Hot Spot Analysis (Getis-OrdGi*) is a geoprocessing tool to identify statistically significant hot spots. This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). It creates a new output feature class with a z-score, p-value, and confidence level bin (Gi_Bin) for each feature in the input feature class. The z-scores and p-values are measures of statistical significance which tell you whether or not to reject the null hypothesis. The critical z-score values when using a 95 percent confidence level are -1.96 and +1.96 standard deviations. The uncorrected p-value associated with a 95 percent confidence level is 0.05. If the z-score is between -1.96 and +1.96, the uncorrected p-value will be larger than 0.05, and we cannot reject the null hypothesis because the pattern exhibited could very likely be the result of random spatial processes.

Table: 2.5.The critical p-values and z-scores for different confidence levels

Z-score (Standard Deviations)	P-value (Probability)	Confidence level
< -1.65 or > +1.65	< 0.10	90%
< -1.96 or > +1.96	< 0.05	95%
< -2.58 or > +2.58	< 0.01	99%

Source: Arc GIS software (Arc map) help tool

Moran's I, Getis-Ord GI* statistics, and KDE all use zone data, on the other hand, Nearest Neighbor Hierarchical (NNH) and Black Spot methods use point data. The Kernel Density tool calculates the density of features in a neighborhood around those features. It can be calculated for both point and line features (Lloyd, C. D, 2010).

Identification of an accident hotspot area in a road network is usually simplified into a task that detects concentrations of point events in route. Several methods will be (have been) proposed, mainly includes spatial autocorrelation methods and kernel density methods

2.2.10.1 Kernel Density Methods

The kernel density tool calculates the density of features in a neighborhood around those features. Greater values of the search radius parameter produce a smoother, more generalized density raster. Smaller values produce a raster that shows more detail. Only the points or portions of a line that fall within the neighborhood are considered in calculating density. If no points or line sections fall within the neighborhood of a particular cell, that cell is assigned no data. The kernel density methods divide the total area into grid cells and calculate the density of point features in and around each output raster cell. To run the calculation, a mathematical equation, called a kernel function, is applied to each accident point. A kernel function is a weighting function that is used to estimate variable density within a given radius depending on its distance to the accident point. The Kernel density calculations are dependent on accurate distance and area calculations. It is recommended that in most cases the geodesic method should be used because it takes into account the curvatures of the spheroid. On the other hand, the planer method may be appropriate if the analysis is to be performed in a local area with a projection that accurately maintains the correct distance and area (Kalu,2017).

GIS is a very effective tool for analyzing accident black spots. Its advantage is that it can present both the geographical positions of the accidents and the information about the accident details. Hazardous locations can be identified using one of the following criteria (Ahmed, 2017).

An accident with Casualties: all the accidents with victims will be selected from the accident database and analysis will be done on it to identify whether it fulfills black spot features. Accident Cost: using a specific cost amount as standard caused by road accidents and analysis is done on it to display it as a hazardous location on a map.

Number of People Involved in an Accident: The number of people involved in an Accident may be used as an indicator for a black spot.

Accidents Involving Pedestrians: pedestrians are the most endangered group in a traffic accident and more pedestrian causality in an accident implies how hazardous the location is and the work needed to improve its infrastructure.

Night Time Accidents: as these kinds of accidents increase, it demonstrates the need for fixing defective traffic lights and to improve the sight on the road. At the same time, it will indicate how vulnerable the location is for accidents.

Peak Hours Accidents: the increase in these accident types is used to show the number of people using the road at peak hours (morning and afternoon). Accordingly, it will clearly present the location as a candidate for a black spot and for an immediate mitigation measure to be taken (Ahmed Kalid, 2017)

2.2.10.2 Types of Cluster Analysis (Hot Spot) Methods

Several types of cluster analysis have been developed as cluster routines typically fall into several general categories

- Point locations are the most intuitive type of cluster involving the number of incidents occurring at different locations. Locations with the most number of incidents are defined as ‘hot spots’.

- Hierarchical techniques are like an inverted tree diagram in which two or more incidents are first grouped on the basis of some criteria (e.g., nearest neighbor). Then, the pairs are grouped into second-order clusters. The second-order clusters are then grouped into third-order clusters, and this process is repeated until either all incidents fall into a single cluster or else the grouping criteria fails.

- Partitioning techniques, frequently called the K-means technique, partition the incidents into a specified number of groupings, usually defined by the user. Thus, all points are assigned to one, and only one, group.

- Density techniques identify clusters by searching for dense concentrations of incidents.

- Risk-based techniques identify clusters in relation to an underlying base ‘at risk’ variable, (Ezgi, 2014).

2.2.11 Time-based distribution of accident hot spots

High speed is a major factor causing serious accidents. The expected congestion during peak hours decreases the mean speeds significantly, which may reduce serious accidents (note: the bumper-to-bumper traffic conditions may increase property damage only accidents, on the other hand). Lack of traffic causes more speeding at night time, which in combination with improper lighting and visual issues may increase serious accidents. While it is technically possible to do an hourly traffic accident analysis, if there is not enough number of accidents for every hour, it may be more meaningful to divide the accidents (and hot spots) into basic categories such as morning and evening peak periods, noon off-peak period, nighttime period. The cut-off limits for these periods must be selected based on the local traffic flow characteristics in an urban region. The expected number of hot spots would be proportional to the total duration of the defined perio0d (Ezgi, 2014).

2.2.12 spatial distribution of accident hot spot

The distribution of traffic accidents is not spatially random over a region. Land use that affects directly the trip generation and trip distribution, as well as vehicle kilometers, traveled. For this reason, there is expected to be higher traffic volume in CBD and in densely urbanized areas. If there were no impact of land use on the formation of hotspots, dividing the urban region into zones would result in a distribution of hot spots proportional to the geographical area of the zones. If the observed numbers of hot spots in zones are more or less than the expected values, it suggests that factors related to the zones may affect traffic safety in that zone. Also, pedestrian activities are expected more in CBD and urban zones, where cultural, commercial, governmental, and residential facilities are mostly seen; as a result, more pedestrian accidents are expected in these regions. In the city center, due to traffic signalization, speed limit, and traffic congestion, vehicles are expected to have lower speeds contrary to outer urban zones (Ezgi, 2014).

2.2.13 Bus stops

A bus stop is a place and sign on a bus route that is used for the waiting, boarding, and alighting of bus passengers. Bus stops typically include the street and curb space, sidewalk area, shelter, and associated amenities for bus passengers. There are four general placement types for bus stops on the road network:

A. Nearside – the bus stop is located in advance of an intersection, before the crosswalk, in the direction of travel. The advantage of this location is that red-light dwell time can overlap with passenger boarding and alighting dwell time. However, it increases the risk of conflicts with vehicles making right turns.

B. Far side – the bus stop is located immediately beyond an intersection, past the crosswalk, in the direction of travel. The advantage of this location is traffic signals create gaps in traffic flow for buses to re-enter traffic.

C. Mid Block – the bus stop is located between intersections.

It creates less pedestrian congestion than the other two bus stop locations. It increases mid-block crossing for pedestrians and walking distance for people crossing from intersections (Chao Wang et al. 2016).

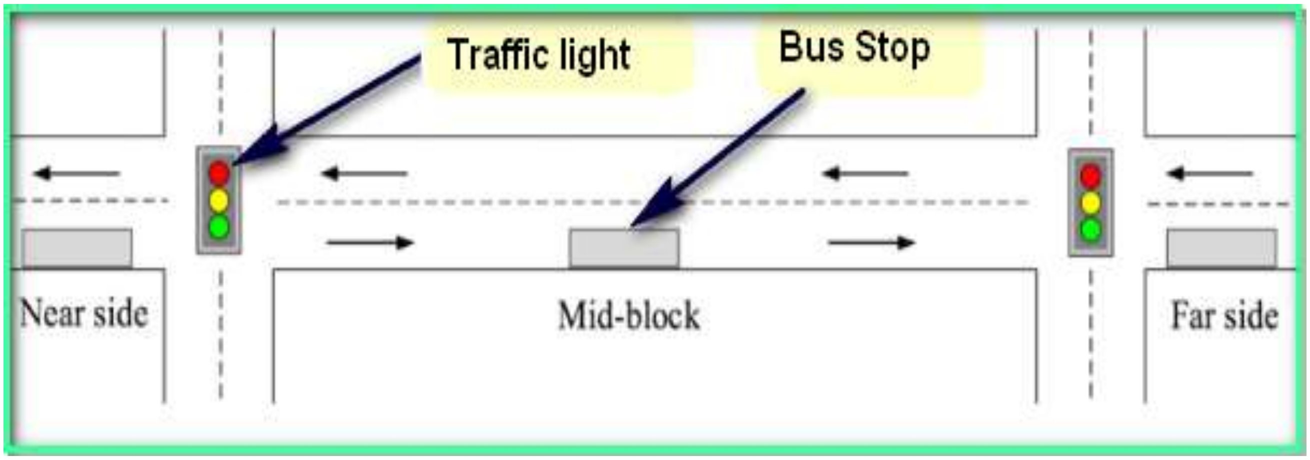


Figure: 2.4 Bus Stop locations Source: *Chao Wang et al.* 2016

2.2.13 Bus Stops in Addis Ababa

In Addis Ababa city the bus stops are constructed with regular intervals of 300-600 meters based on the accessibility and number of passengers. Mostly those bus stops are used by three government transport enterprises (Sheger express city bus, Anbessa city bus, and public employee bus) and other private and enterprise buses (Lonchin, Higer). But in some places these bus stop sites are reserved by automobiles, minibusses, and lorry vehicles and this resulted in bus driver obstruction or for accidents when they stop on superimpose position. Bus stops should be located where they are expediential to use and the safety of passengers and other road users has been considered. In addition to this, the bus stop normally located conveniently to points where most passengers require to board and alight the bus. A bus customer normally tends to cross the road from either in front of or behind the bus as crosswalks to board or alight. Especially after alighting in front of the crosswalk is a risky action that mostly pedestrian-vehicle crashes occur by side or lateral vehicles. Hurry running and to cross when customers see the route bus also a big challenge. The bus stop is the first point of contact between the passengers and the bus services. Most studies suggested that it will safer if the bus stop will be located not less than 30 meters from the main road junction (Chao Wang et al. 2016).

The location of bus stops inquires a number of considerations; especially factors that affect the safety and suitability of passengers and road users. The spacing, location, design, and operation of the bus stop significantly influence the bus users and operators. Safety and easy access to the servicing buses are essential. In the condition of mixed traffic, the bus stop will be taken by other vehicle types and services, ultimately this condition leads to traffic accidents in and around the bus stop. Some bus stops locations are found to be hazardous, posing danger to other vehicles and may also cause traffic congestion. One method to locate the unsafe location of a bus stop is by applying Geographic Information Systems (GIS). KDE is used to determine the spatial patterns of dangerous bus stops with continuous surface density estimates of discrete events such as road traffic accidents by summing the number of events within a search bandwidth (Fitzpatrick, et al 2005). This analysis is dependent on 3 years (2017-2019) of fatal accident data and bus stop coverage in the Yeka sub-city. However, due to the lack of isolated fatal data that involved bus users, this project used inclusive fatal data for identifying dangerous/unsafe bus stops.

2.2.14 Considered aspects of bus stop

The bus stop may be affected by: Proximity to adjacent junctions; Proximity to pedestrian crossings or Zebra; Bends in the road; On-street parking; Existing accesses to residential and business area and, Footway or verge width. The bus stop should be located close to the junction of the roadside to maintain standards like visibility requirements and road safety. Junctions are intended to operate where vehicles often must share space with other road users and pedestrians. The coordination of the vertical and horizontal alignment of the junction should be given more emphasis to enhance safety and conformability as the bus stop zone is found in and around there. In most countries, 40 - 60% of the total number of accidents occurs at junctions. So identifying hazardous bus stops is a very important issue to enhance the efficient movement of all road users (Fitzpatrick, et al 2005).

2.2.15 Identifications of Hazardous Bus Stops

Due to Corona Various (COVID19) the loading standard of bus reduced by 50 percent of the previous loading standard. It was difficult to get proportional alighting and boarding passenger data. To fill this gap the researcher utilized pedestrian exposure at bus stops using fatal case collision frequency methods. An important feature of Arc GIS to execute distance on features is buffer. It enables to create of polygons around a fatal feature to a specified distance. Generating a Buffer zone around the bus stops in selected risk level areas is very important to search and identify fatal accidents in the vicinity of each bus stop. Considering a buffer radius is a very critical thing. To determine buffer radius we should know the standard or average distances of the near side and far side bus stops away from the intersection. If the bus stop near side and far side distance from the intersection is 23-45 meter 30-meter searching radios are recommended beyond this it may increase the likelihood of capturing fatal accidents that may not involve transit system users and their related activity and may fall around another bus stop at the same intersection. But 30-100 meter distance may be used for severity index analysis. Generally, a small buffer size might exclude some crashes associated with bus customers, while a greater buffer size might capture crashes that do not involve bus users. Fatal crashes within a 30-100 meter searching radios recommended to computing the severity index of bus stops. (Srinivas S. Pulugurtha and Vinay K. Vanapalli, 2008). A weight of 1.5 should be given to those within 50 meters as they are near to the bus stop. The bus stop severity index

$$SI_{\text{bus stop}} = 1.5 * SI_{50} + SI_{50-100}$$

SI 50 = severity index of all fatal case crash within a 50-meter network buffer of the bus stop SI 50-100 = severity index of all fatal case crashes within a 100-meter network buffer but excluding 50-meter network buffer of the bus stop. (Long Tien Truong and Sekhar V. C. Somenahalli 2011)

Euclidean buffers are the more common type of buffer and work well when analyzing distances around features in a projected coordinate system which are concentrated in a relatively small area (such as one UTM zone). Another method to show the hazardous/unsafe bus stops is the interpolation technique and kernel density method that shows the concentration of accidents map. In kernel density determining the cell size, the searching radius is a critical thing. The range between 30 to 150 meters is appropriate for the generation of an accident concentration map. To calculate the percentages of auto-pedestrian collisions in the vicinity of a bus stop dividing the number of fatal accidents at a bus stop by the total number of fatal accidents at all selected bus stops and then multiplying it by 100 (Srinivas et al,2008).

2.3. Conceptual framework Research design

The conceptual framework is intended to provide an appropriate way for the study. The study highly dependent on the field survey method hence, the traffic accident data collection process requires a field survey. Space, time, and frequency of RTA occurrences are however considered as major criteria to identify RTA black spots. The fatal accidents were used for black spot map generation because of the slight and serious injury coordinate data that was not collected during the incident. It is a difficult task to collect three years of injury point coordinates. RTA black spot is a single place that exhibits one or more (fatal case) RTA occurrences in one year.

Developing collision concentrations is extremely helpful in identifying high RTAs (fatal case) concentration areas. This can be done using the Kernel density and Inverse Distance Weighted (IDW) interpolation map. Generating a Buffer zone around the bus stops in selected risk level areas is very important to search and identify fatal accidents in the vicinity of each bus stop. To determine buffer radius we should know the standard or average distances of the near side and far side bus stops away from the intersection. If the bus stop near side and far side distance from the intersection is 23-45 meters, 30-meter searching radios are recommended. But 30-100 meter distance may use for severity index analysis. In general, the conceptual framework depicts that diagrammatic representation of road traffic accident as shown below in figure below 2.5.

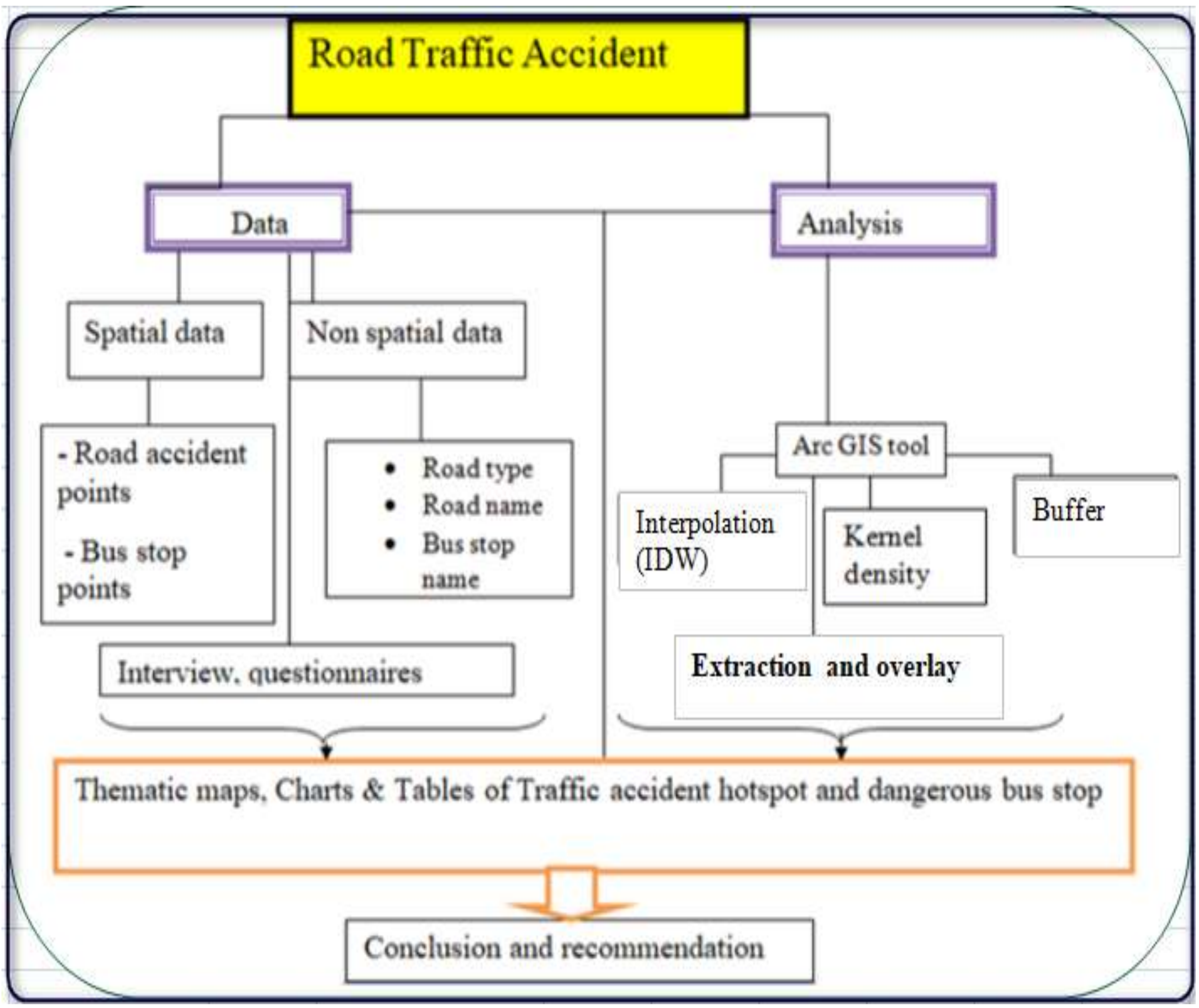


Figure 2.5: Conceptual framework

CHAPTER THREE

Research Methodology

3.1 Introduction

This chapter explores the general systems of analysis appropriate to this study. The research methodology is used to provide the methods of the study. It includes descriptions of the study area, sources and tools of data collection, data types and sources of data, the research method, data analysis, and interpretation.

3.2 Descriptions of the Study Area

Addis Ababa is the capital city of Ethiopia and the largest city in Ethiopia which covers 540 square kilometers. The city has over 553,938 registered vehicles and accounts for about 59 percent of national total vehicles (Addis Ababa transport office 2018). From 2014 to 2017, the city population and the number of registered vehicles increased by 7.1% and 119% respectively. The annual population growth rate is 2.4%. The number of females is slightly higher than the male population. Women share 53% of the population (Addis Ababa transport office, 2017). There are 10 sub-cities in Addis Ababa city administration. It is costly and time-consuming to collect all traffic accidents in all sub-cities. Therefore, specific study sites should be selected (Addis Ababa city government 2017).

For this study, Yeka sub-city selected as a study place because it was one of the second top sub-cities in the number of traffic accidents in 2018. Moreover, no study conducted on this topic so far in the sub-city. Yeka sub-city is geographically found in the north-eastern part of Addis Ababa, having dynamic topography. The eastern limits extend along the road from Lambert terminal via Taffo to Debre Berhan and the western extent extends along in Kebena River. The total area of the Yeka sub-city is 85.98 km2 and 4,284.9 people live in one km2. Based on the CSA population projection for the year 2016, Yeka Population is estimated to be 424,217. There are some bureaus, agencies, offices, and educational colleges and universities which are found in the sub-city are Road and Transport Bureau (Lamberet terminal), Ministry of Mining and Energy, Ethiopian Civil Service University, Kotebe Metropolitan University, Ethiopian Athletics Federation and, Ethiopia Leadership Institution. There are also 15 orthodox, eight Muslim, and 16 protestant religious institutions (Addis Ababa city government 2017).

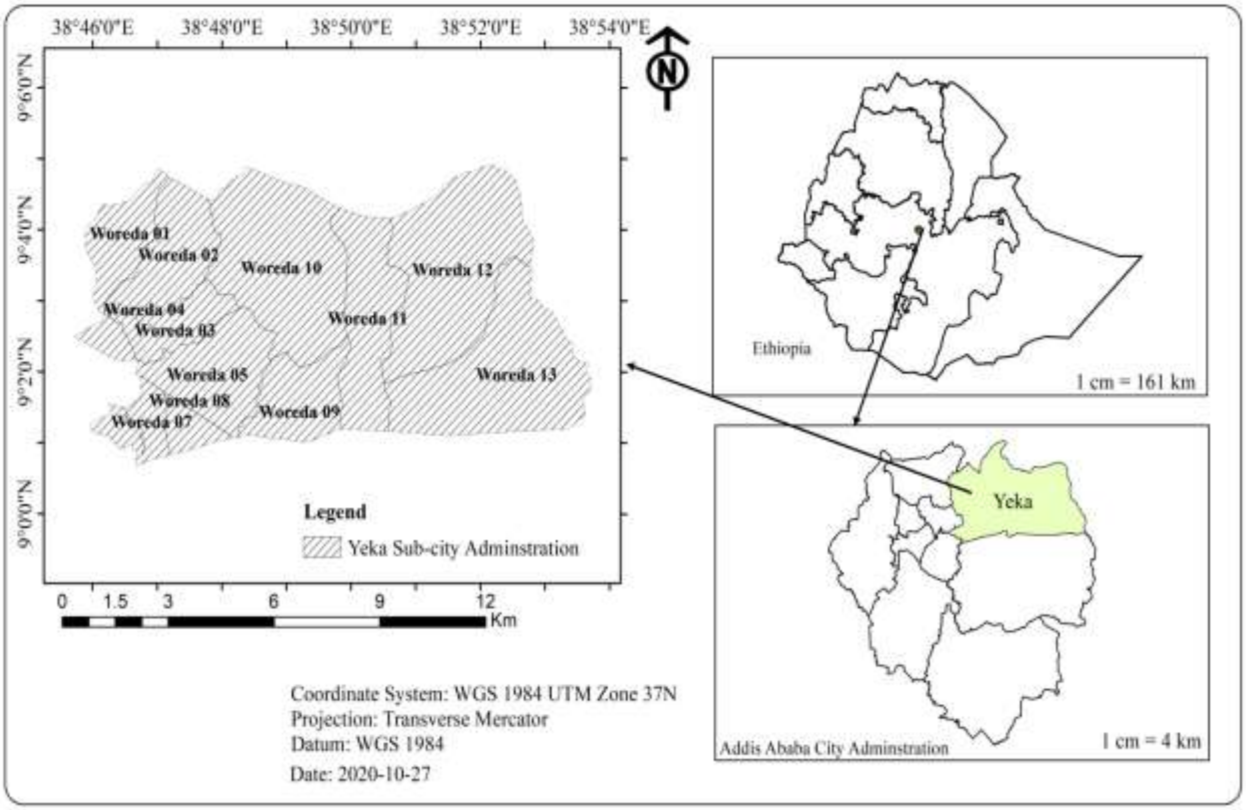


Figure 3.1: Study area map Source: Compiled by the researcher

3.2.1 Topography

Based on DEM value Yeka sub-city characterized by relatively high elevation on the northern part and low elevation on the south part. The topography is undulating and forms a plateau in the northern parts of the sub-city. Generally speaking, the altitude of the Yeka sub-city ranged from 2344 meters to 3048 meters above sea level which has a range of 704 meters. The highly elevated land exists in the north while relatively lower elevation exists in the South. The elevation is an indicator that enables to understand the relief of an area, here is mapped below.

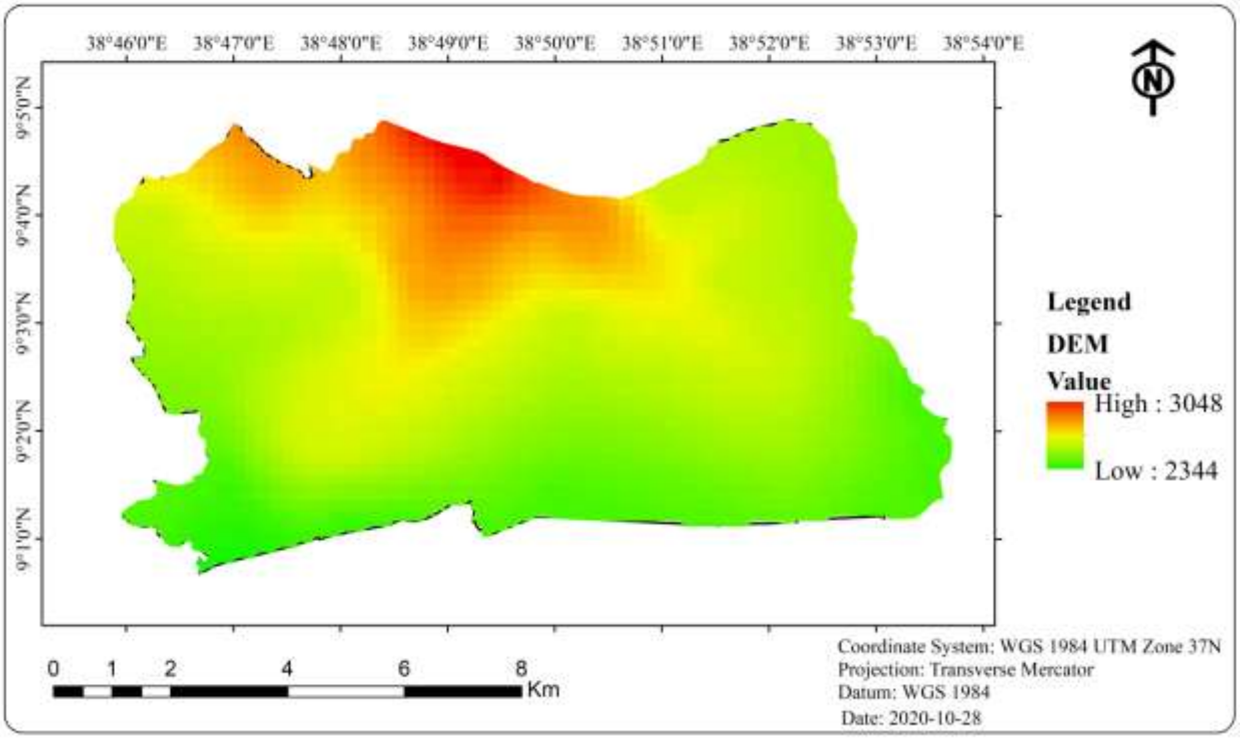


Figure 3.2: DEM value of Yeka Sub-city

3.2.2 Yeka sub-city land coverage and its administration division

Yeka sub city is the third largest sub city next to Bole and Akaki Kaliti. It covers 8744 hectares (87km2) and this shares about 16.5 percent of Addis Ababa city. Yeka sub-city has 14 administrative districts but the most well structured and formerly planned districts are 13. This study also used 13 districts; the one that district 14 is included in district 13 because of the absence of a well-known demarcation boundary shape file as it's the newly added district. Among all districts, 12 has the largest followed by district 13 and district 10 which constitutes 1468.78, 1437.76, and 1427.70 hectares respectively. District 6 and 4 are the smallest districts that share 100.2 and 107.6 hectares respectively (Addis Ababa city government 2017).

3.2.3 Yeka sub-city road infrastructure

The road is a very important infrastructure and use as an indicator of the level of development of a particular area. A Road network is the geographical expression of roads with line features. The road network provides the means to travel through the city.

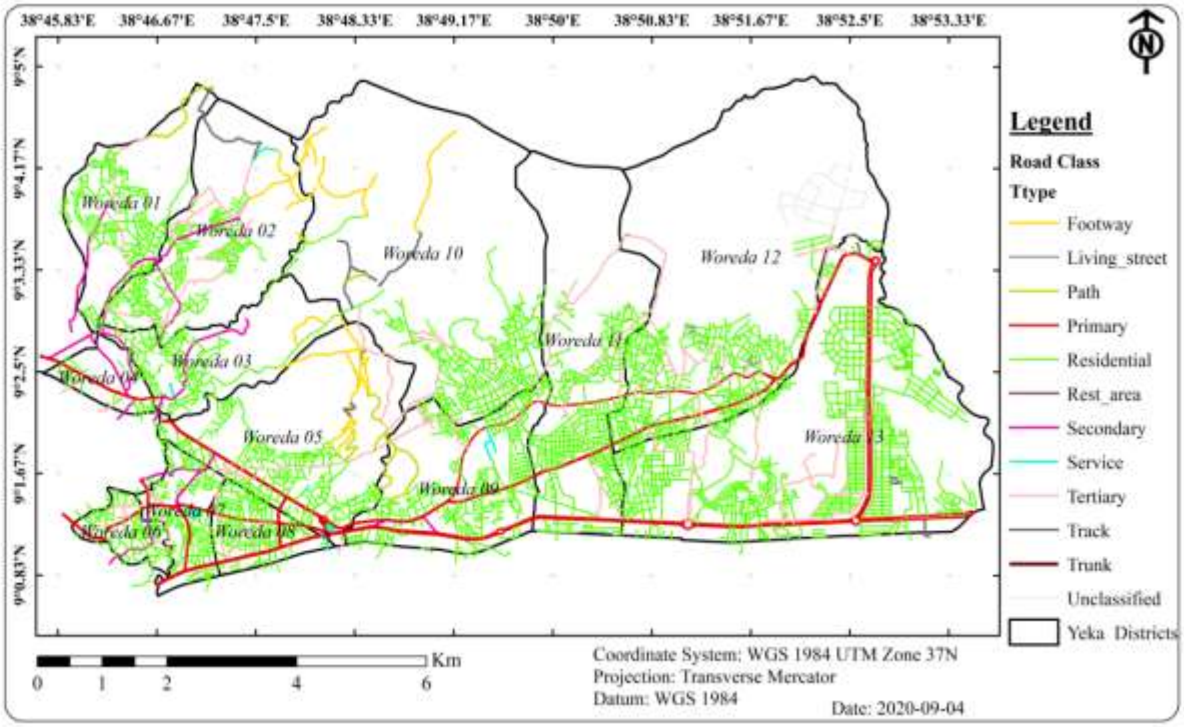


Figure 3.3: Yeka Sub city road network map Source: Downloaded from DIVA GIS

Yeka sub-city has a 615.54-kilometer long road network which covers a 6.63 square kilometer area of the sub-city. Cobblestone and asphalt are the largest road surface type which is 269.5 km and 120 km long respectively (AACRA 2018).

3.3 Research design

Research design is a plan to answer the research question. It is a procedure for collecting and analyzing data. The research design is intended to provide an appropriate framework for a study. To capture the trends and details of the situation the researchers used a combination of both qualitative and quantitative data to yield a more complete analysis. The study was highly dependent on the field survey method hence; the traffic accident data collections process requires a field survey. A longitudinal study was employed using the data obtained from the Yeka sub-city traffic Police Commission and Addis Ababa Transport Programs Management Office (AATPMO) of road traffic accident (fatal case) data recorded in the past three years (2017-2019). The spatial and non-spatial data collection and process was done using Geospatial technology like GPS and GIS software. The data collection, analysis, and method of presentation are explained below.

Table: 3.1 Research matrixes

Objectives	**Research method**			**Data Source**
	Data collection methods	Data analysis /interpretation	Display	
Objective1: To explore spatiotemporal distribution of fatal accidents in the study area,	Primary and Secondary data	Quantitative and Qualitative method Using Arc GIS10.5 and Excel	Table Chart Map	Yeka sub city police commission and Addis Ababa Transport Programs Management Office
Objective 2: To identify the underlying factors contributing to road traffic accident in Yeka sub-city,	Secondary data used	Quantitative and Qualitative method Using Arc GIS10.5 and Excel	Table chart Map	Yeka sub city police commission
Objective 3: To show the most traffic accident (black spot) locations in Yeka sub-city,	Primary and Secondary data used	Quantitative and Qualitative method Using Arc GIS10.5 and Excel	Table Chart Map	Yeka sub city police commission and Addis Ababa Transport Programs Management Office

Objective 4: To identify hazardous bus stops in Yeka sub-city	Primary and secondary data	Quantitative and Qualitative method Using Arc GIS10.5 and Excel	Table Figure Map	GPS based data collection, Addis Ababa Transport Programs Management Office, Questionnaire

3.4 Research method

The research method is a strategy used to implement the study plan. The research method employed different approaches to achieve its objectives, accordingly this study applied mixed methods (combinations of the survey, interview, quastionneriy, and secondary data analysis). Both qualitative and quantitative methods and a combination of primary and secondary sources with spatial and non-spatial data were applied. The qualitative data supported the quantitative data analysis and results. The result obtained is triangulated since the researcher utilized the qualitative and quantitative data types in the data analysis

3.5 Sources and tools of data collection

To make the result more reliable the researcher used both primary and secondary data sources. The primary data source includes; structured questionnaires (for bus drivers), interviews (key informant), and GPS (to collect bus stops). The key informant interviews were conducted with road transport experts, traffic controls, and traffic polices. Multiple (alternative) based questions were presented to the respondents. Secondary data sources were used to explore and investigate road traffic accidents in the Yeka sub-city. To get a detailed conception, the researcher used published and unpublished documents, books, articles, reports, and previous studies. The researcher collected both spatial and non-spatial data of RTAs (fatal accident co-ordinates). Spatial data were collected from Addis Ababa Transport Programs Management Office (ATPMO) while the non-spatial data collected from Addis Ababa and Yeka sub-city police commission, Addis Ababa transport authority, transport programs management office, and traffic management office. The data that collected from ATPMO and Addis Ababa and Yeka sub-city police commission included those variables such as:

- Accident causes
- Accident district
- Total number of people involved in the accident
- The type of vehicles which caused the injury
- Number of victims
- Nature of accidents (fatality, injury and slight/property damage),
- Victim age and sex
- Light condition (Noon, Evening)
- Vehicle driver relation (Personnel, owner, friend's, family)
- Driver profile(age, education, experience, sex)
- Vehicle Code and type
- Time, date, month, and year and location of the accident were included.
- Weather condition

The data collected for the study was arranged in ways that help for analyses and retrieval in excel and Arc GIS environment.

3.6 Sampling techniques

There are ten sub-cities in Addis Ababa. The study employed purposive sampling techniques to select Yeka sub-city because Yeka sub-city is one of the leading sub-cities in terms of RTA after 2017 next to the Bole sub-city. In order to supplement the result that executed by using Arc GIS 10.5 software, the researcher selected 60 bus drivers (for questionnaire) to include driver's perception about unsafe bus stops on their operating route line and 5 interviewers as key informants. This questionnaire confirms the fact of Arc GIS output and population perception of unsafe/hazardous bus stop. The bus stop is constructed on four principal arterial streets of Yeka sub-city which runs from Ferencay Gurara via Jammed to Megenagna, Ayat Tsebel to Megenagna, Yeka Abado to Megenagna, and Taffo via Ayat to Megenagna. There are 30 and above bus drivers on each route. Then using a simple random sampling method the researcher selected 15 respondents (half of the total drivers on the route) from each route with a total of 60 respondents in all four routes. The adoption of a simple random sampling method could be based on the fact that the sample population (drivers) is homogeneous in which they operating on the same route. Therefore sample of one may a representative of the drivers regardless of the size of the population (drivers).

3.7 Data analysis and interpretation

The collected data were checked and edited in excel format, then coded and saved as CSV format to do so in Arc GIS software. This study combined spatial and geostatistical and statistical analysis of traffic accidents by relating their geographical location with attributes of accidents. Since traffic accidents are geographic data, so GIS is the right and key tool to demonstrate such events. GIS makes the analysis simple, accurate, reliable, and easy to understand. To determine hot spot areas the researcher applied the more recommended traffic accident hot spot determination criteria which are, the black spot criterion is that junctions or 250m long road sections that are considered as black spots on condition that at least 3 road accidents with injuries occurred within 1 year or at least 3 road accidents with injuries or fatal of the same type occurred within 3 years. Hazardous bus stops were selected using buffers with considerable and recommended searching radius.

GIS is a computer system that is designed to capture, store, manipulate, analyze, manage, and present geographically referenced data. Hot Spot Analysis (Getis-OrdGi*), Kernel Density Estimation (KDE), and buffer function was applied to identify hot spot areas and hazardous bus stops. To identify dangerous bus stops buffering with a considerable searching distance from hot spot sites was done. The GIS-based analysis of hotspots and hazardous bus stops were done by using a geo-processing model and spatial selection method. The overall workflows were as shown in figure 3.4 below.

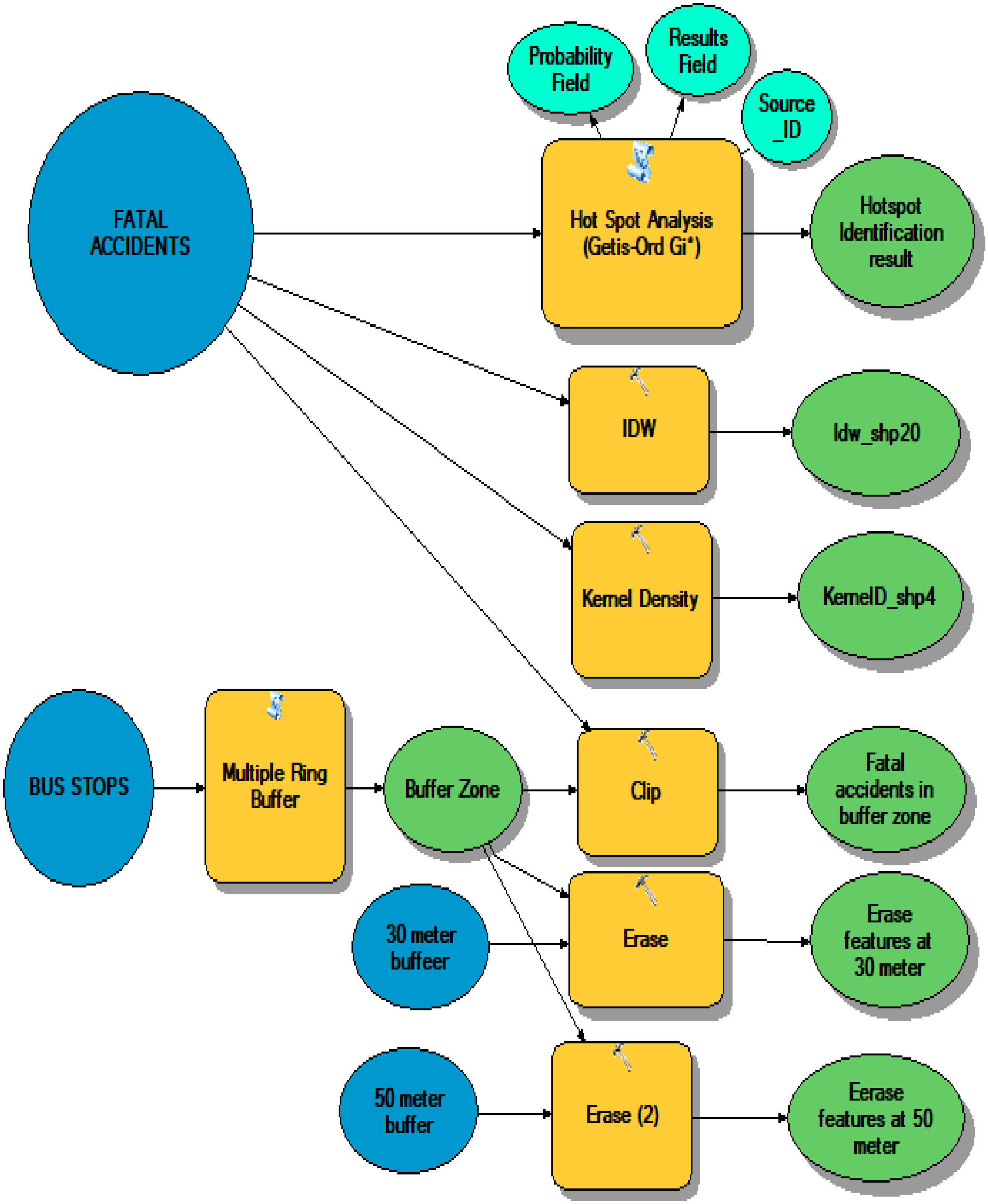


Figure 3.4: Hot spot analysis and hazardous bus stop identification process

CHAPTER FOUR

Result and Discussion

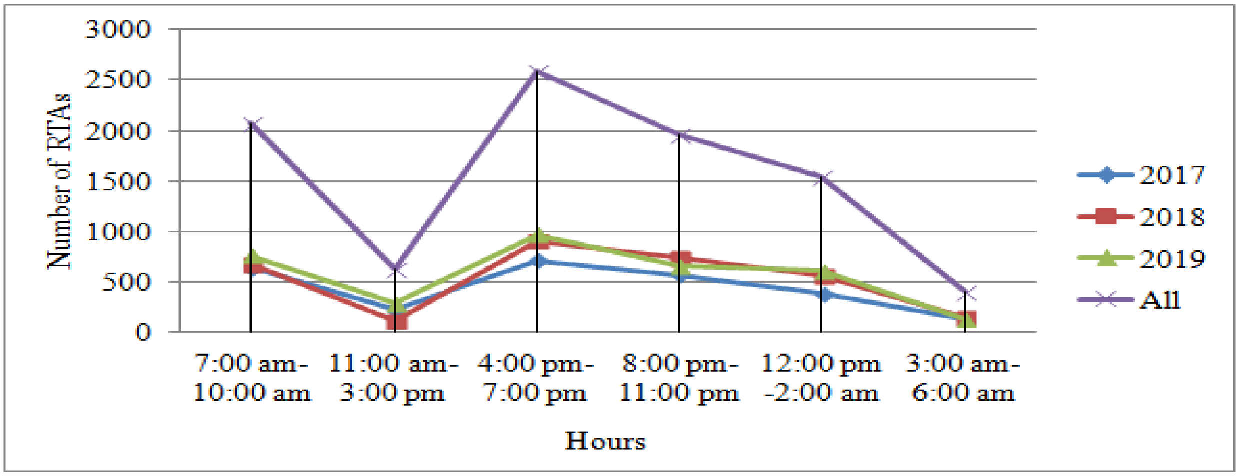
4.1 Introduction

This chapter presents the empirical finding of this study and it incorporates statistical and spatial analysis (presented in tables, figures, and maps). For this study, 156 fatal, 480 injuries, 8583 property case road traffic accidents were collected and included in the database from the year 2017 to 2019 in the Yeka sub-city. Out of 156 fatal case traffic accidents, only 139 fatal cases were geo-coded on the road network and located exactly within the study area. The spatial analysis was based on 139 fatal accidents.

4.2 Spatiotemporal Variation and Distributions of Road Traffic Accidents (RTAs)

4.2.1 Time Variation of Road Traffic Accidents

The road traffic accident phenomena have varied within 24 hours of a day. Most of the crashes on the study road network occurred during the afternoon peak (4:00 pm-7:00 pm) hour and morning rush hours where the volume of traffic and the road user was high. Figure 4.1 shows that the occurrences of road traffic accidents vary each year with a high and a low number of road traffic accidents. Most numbers of crashes were recorded in three-time intervals. Those are 7:00 am-10:00 am, 4:00 pm to 7:00 pm and 8:00 pm to 11:00 pm the highest road traffic accident registered times, and on the other hand times from 3:00 am to6:00 am, 11:00 am - 6:00 pm and 12:00 pm-2:00 am a comparatively low number of accidents were recorded.



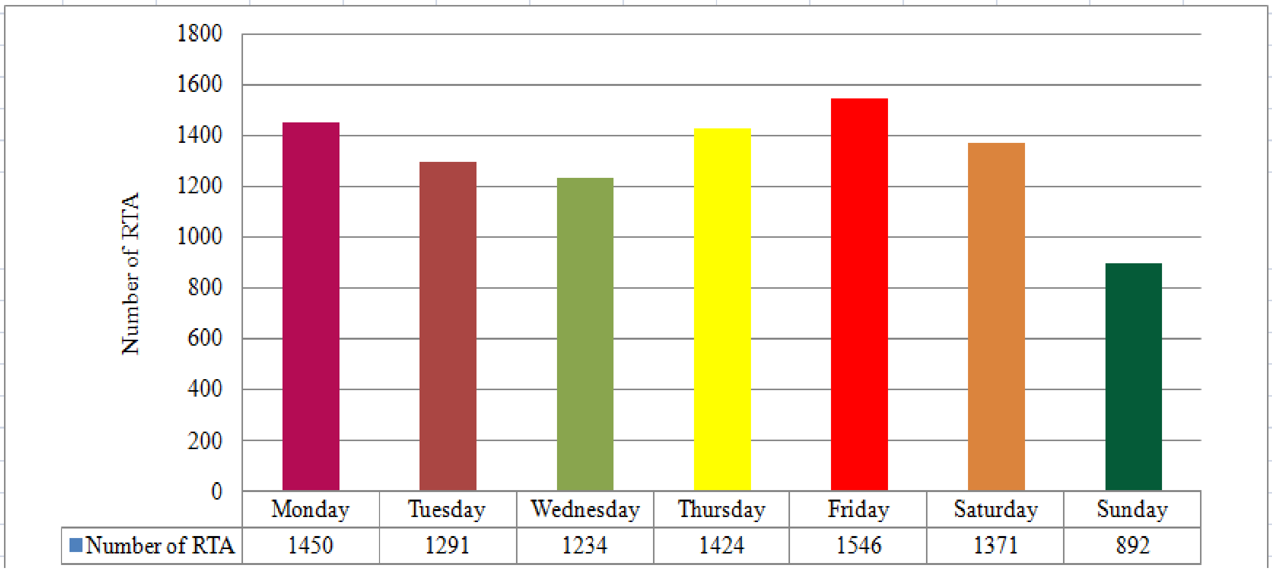
Source: Compiled from Yeka Sub-city Traffic Police Commission RTAs data (2017-2019)

Figure 4.1:- Temporal variation road traffic accident (RTA)

In general, most road traffic accidents have occurred in the afternoon especially from 4:00 pm to 7:00 pm. At this time there are two conditions, the first one is there are mass commuters who return back to their home and result in congestion which causes traffic accidents. The next condition is in the nighttime most controls and traffic policies may come back home and the drivers transgress traffic rules which lead to traffic accidents. Similar to this result, Alebachew, (2019) have discussed that RTAs commonly occur between 3 P.M to 6 P.M and contribute to the majority of RTA occurrences in Addis Ababa.

4.2.2 Daily Variation of Road Traffic Accidents

The variation of a road traffic accident is presented in hours, days of the week, month, and year. The weekly temporal variation of RTA is the difference in the number of accidents within the week of the day. Figure 4.2 shows the disparity of road traffic accidents based on the week of the day. The result shows that Fridays, Mondays, and Thursdays were the more frequent traffic accident registered days than others. Except for Fridays and Mondays, almost all days of the week have been under similar RTA accident occurrence. The little variation shows are 17%, 16%, and 15 % of RTA occurred on Fridays, Mondays, and Thursdays respectively. Comparatively the least RTAs have occurred on Sundays and Wednesdays. Figure 4.2shows daily variations of road traffic accidents in the Yeka sub-city

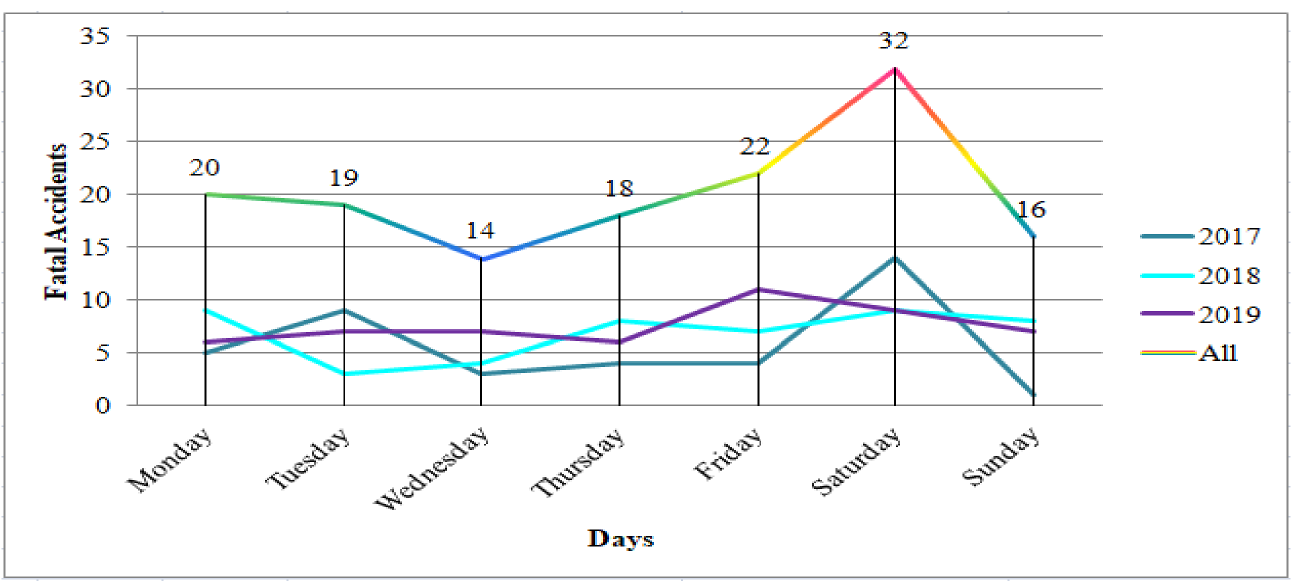


Source: Compiled from Yeka Sub-city Traffic Police Commission RTAs data (2017-2019)

Figure 4.2: Daily variations of road traffic accidents

4.2.3 Daily Variations of Fatal Accidents

Fatal accidents are the worst end result of severe RTA. The line chart in figure 4.3 below shows fatal accidents over the days of the week. Saturdays are the leading fatal case accident day followed by Fridays and Mondays. The minimum numbers of fatal accidents and other RTAs took place on Wednesdays and Sundays. Saturdays are the most dangerous days of the year, because there are more drunk drivers and market based pedestrians on the road than other days.



Source: Compiled from Yeka Sub-city Traffic Police Commission RTAs data (2017-2019)

Figure 4.3: Daily variations of fatal accidents in Yeka sub city (2017-2019)

4.2.4 RTAs Condition in three years (2017-2019) in Yeka sub-city

The study shows that the road traffic accident trend has increased from 2650 accidents in 2017 to 3427 accidents in 2019. In particular, fatality accidents have increased from 40 fatal cases in 2017 to 68 fatal case crashes in 2019. Figure 4.4 below shows that the number of RTAs was in the increasing trend from year to year.

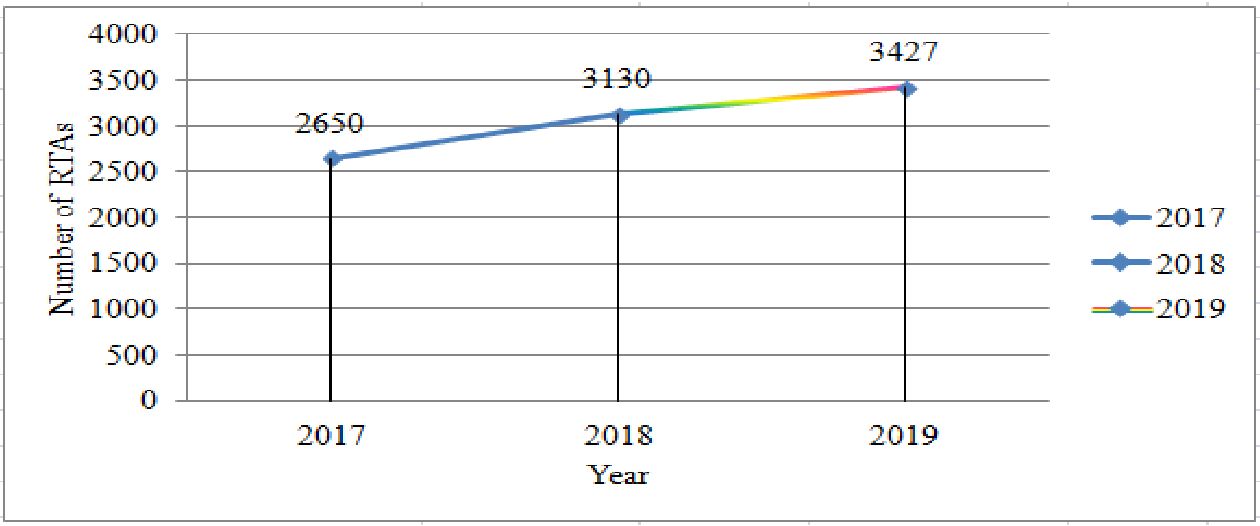


Figure 4.4: RTAs increasing trend in Yeka sub city (2017-2019)

Source: Compiled from Yeka Sub-city Traffic Police Commission RTAs data (2017-2019)

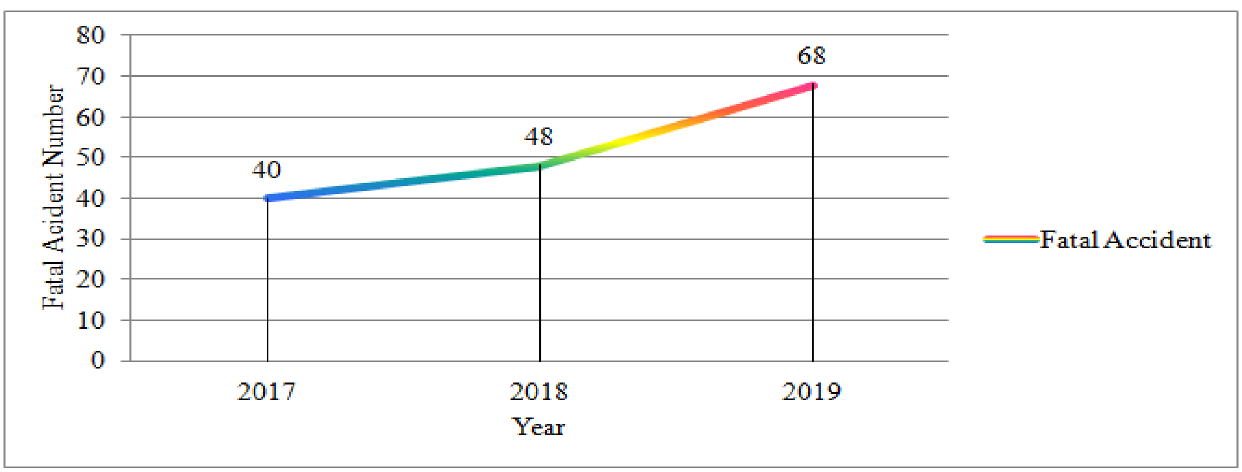


Figure 4.5: Yearly variations of fatality accident

Source: Compiled from Yeka Sub-city Traffic Police Commission RTAs data (2017-2019)

Figure 4.5 above shows a total of 156 people were killed in RTAs during 2017–2019 in the Yeka sub-city administration. The statistical result of this study shows that every one-week three-person has been killed due to RTA in Yeka sub-city.

4.3 Underlying Factors of RTAs

4.3.1 Driver gender and RTA condition

Even though there is a higher proportion of male drivers against female drivers, male drivers. Considering the absolute number of male drivers were involved more in RTAs in Yeka sub-city. It shares 97% of all traffic accidents were registered in male drivers. In a very similar result, Efrem (2019) has concluded that male drivers are the main contributors to RTAs than females in Kirkos sub-city also. However, based on this cannot be concluded as it is due to the different proportions of male against female drivers

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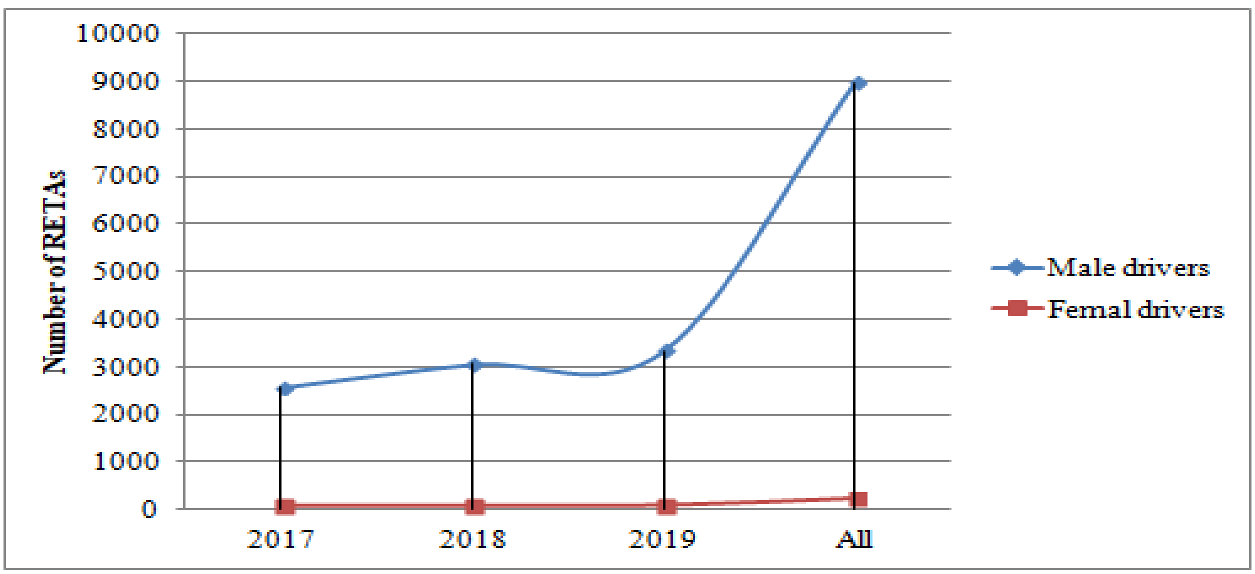
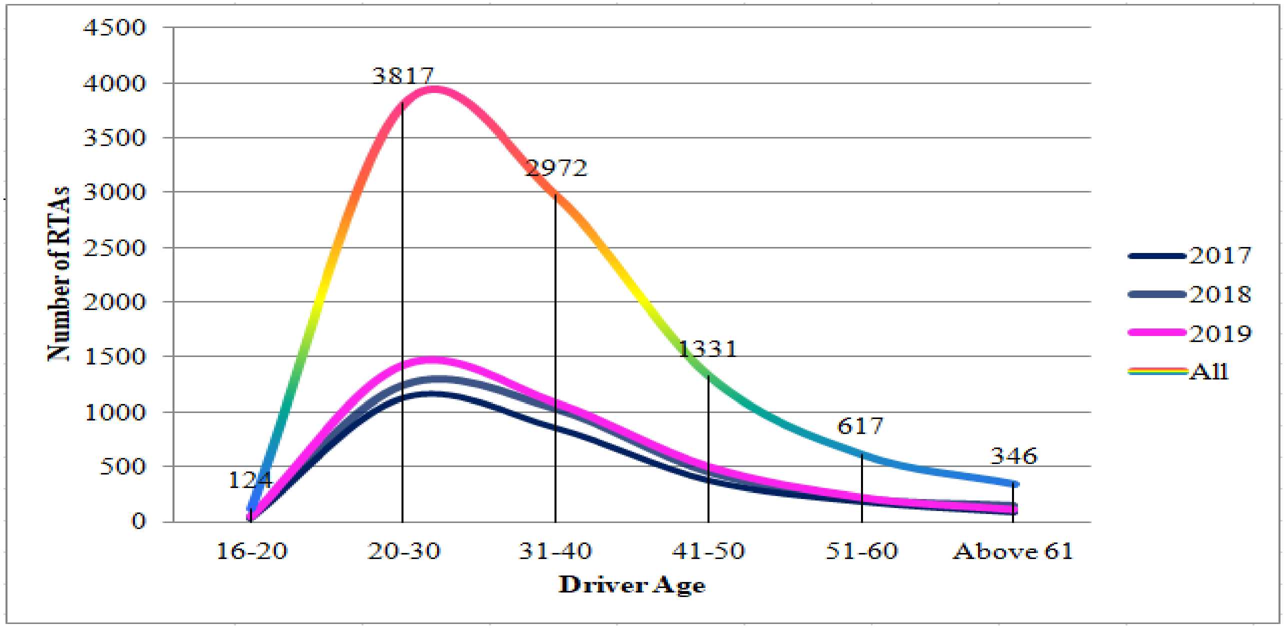


Source: Compiled from Yeka Sub-city Traffic Police Commission RTAs data (2017-2019)

Figure 4.6: Drivers sex and RTA in Yeka sub city (2017-2019)

4.3.2 Drivers Age and RTA

The higher number of accidents was imperiled by younger people in the age group of 20-30 years. The drivers whose ages were from 20-30 have more sensitive to road traffic accidents for the last three years. The following line chart shows there were a number of accidents that occurred by younger drivers age group of 20-30 years followed by adults ages 31-40. This is due to the fact that the age of drivers affects their driving character, astuteness, patience, and perspicacity.



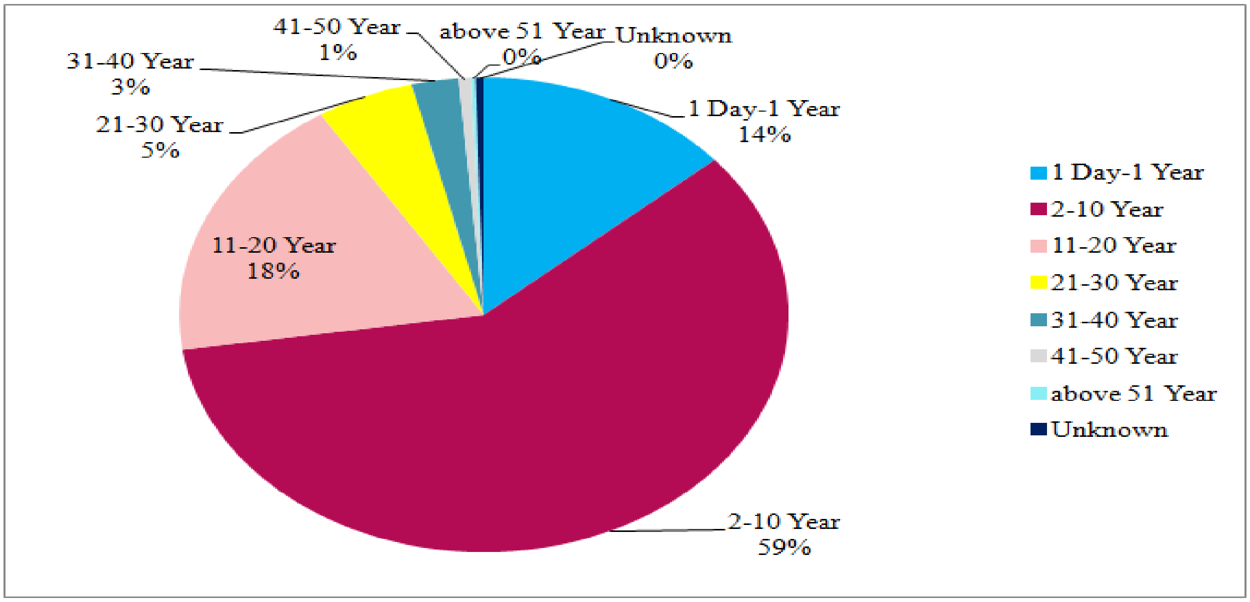
Source: Compiled from Yeka Sub-city Traffic Police Commission RTAs data (2017-2019)

Figure 4.7: Driver age and RTA

The age group under the sphere of traffic accident influence was 18-30 followed by 31-40 and 41-50. This analysis confirms that the age of drivers has a greater prejudice over the occurrence of road traffic accidents. Similarly; a study conducted by Mitiku (2018) indicated that the magnitude of drivers' sufferers in RTAs reached maximum levels between 18-30 years. Aged drivers are more careful about traffic safety than youth below 50 years old. It is possible that aged drivers have more experience and probably much more responsibility than youths. In addition, it is also possible to say that youth behaviors towards traffic safety are poor due to peer groups' suggestions and influence on driving style.

4.3.3 Drivers Experience and RTA Condition

The pie chart figure 4.10 below shows the association between driving experience and RTA condition. In fact, driving experience serves as an indispensable role in RTA. Figure 4.8 below shows that 59 % of all accidents have occurred by the drivers who had 2-10 year experience followed by 11-20 year experience which shares 18 %. In addition to this 14 % of drivers triggers road traffic accidents before celebrating one year of driving experience which means drivers with less than 1-year experience. In general road traffic accident has been decreasing with an increase in the driving experience



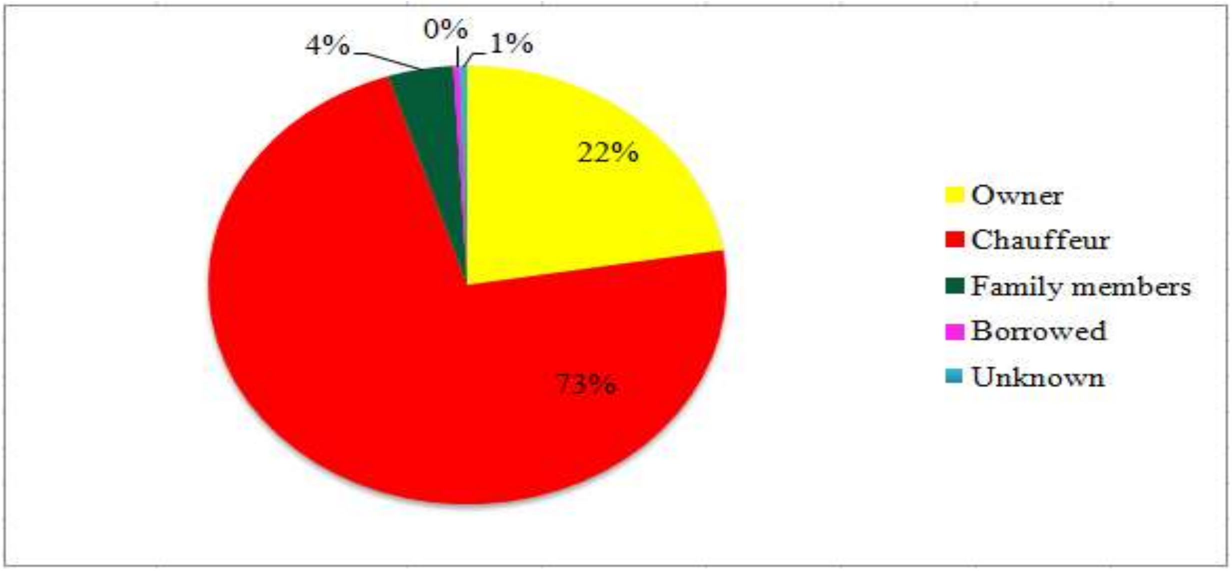
Source: Compiled from Yeka Sub-city Traffic Police Commission RTAs data (2017-2019)

Figure 4.8: Driving experience and RTA

4.3.4 Vehicles driver relationship

Vehicles driver relationship defines the property/ownership conditions of the vehicles. In this study, there are five main vehicle driver relations. These are owner-driver, chauffeur, member of the family, borrowed (from friends), and unknown. The result shows that chauffeur drivers were engaged in frequent RTA in the study area. The vehicle driver relationship with RTA conditions in Yeka sub-city shows that 73% of chauffeur, 22% of owner-drivers, and 4 % of family member drivers are primarily attributed to RTAs. To understand the reason behind this the researcher asked road staff as traffic polices.

One of selected traffic police of Yeka sub-city-states that: *"Relatively ownership relationship with the vehicle one driver somehow underlines carefulness. I hope the reason that the low incidence of accidents caused by family member drivers and own drivers is mainly related to a strong sense of ownership feeling, belongingness, and responsibility. As I saw most of the chauffeur are young and requires additional business after complete their duty and very hurry for that but unfortunately they trigger a road traffic accident".*



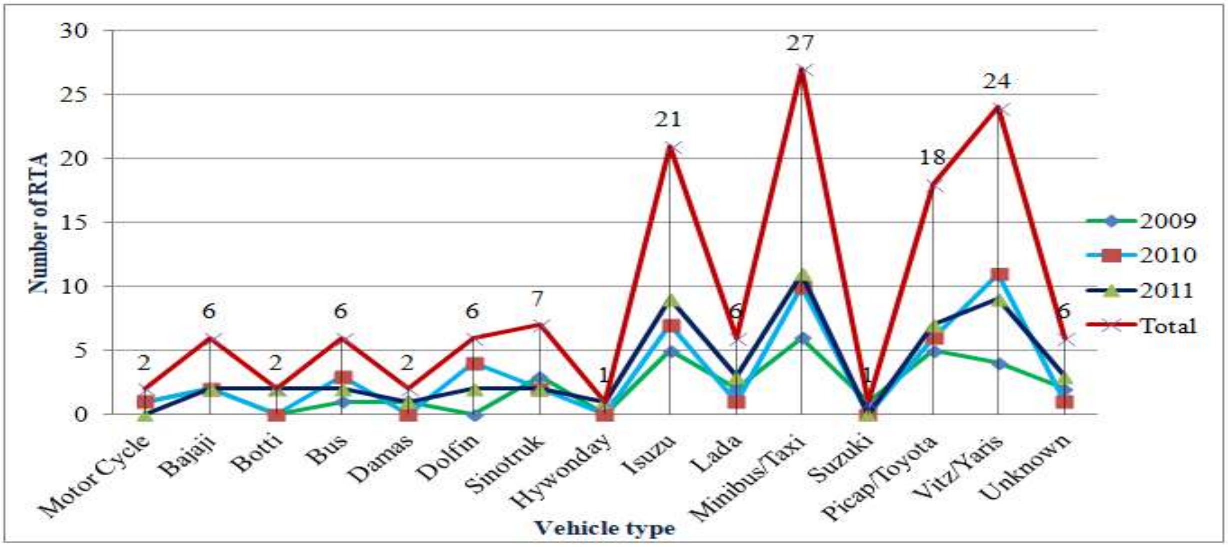
Source: Compiled from Yeka Sub-city Traffic Police Commission RTAs data (2017-2019)

Figure 4.9: Vehicles driver relationship

Actually, accidents occurred by owners were not small which is a large number (2067) next to personnel. Similar results of the Addis Ababa transport office (2018) report show that the majority of RTAs have occurred by chauffeur next to owners; hence transportation is a vast industry that large numbers of people hire as a driver.

4.3.5 RTAs by Vehicle Type in Yeka sub-city (2017-2019)

The line chart figure 4.10 below shows the type of vehicles that caused fatal accidents in the Yeka sub-city (2017-2019). Accordingly, Taxis (Minibuses), Vitz/Yaris, and Isuzu rank one to three based on their shares 20%, 16%, and 14% respectively.

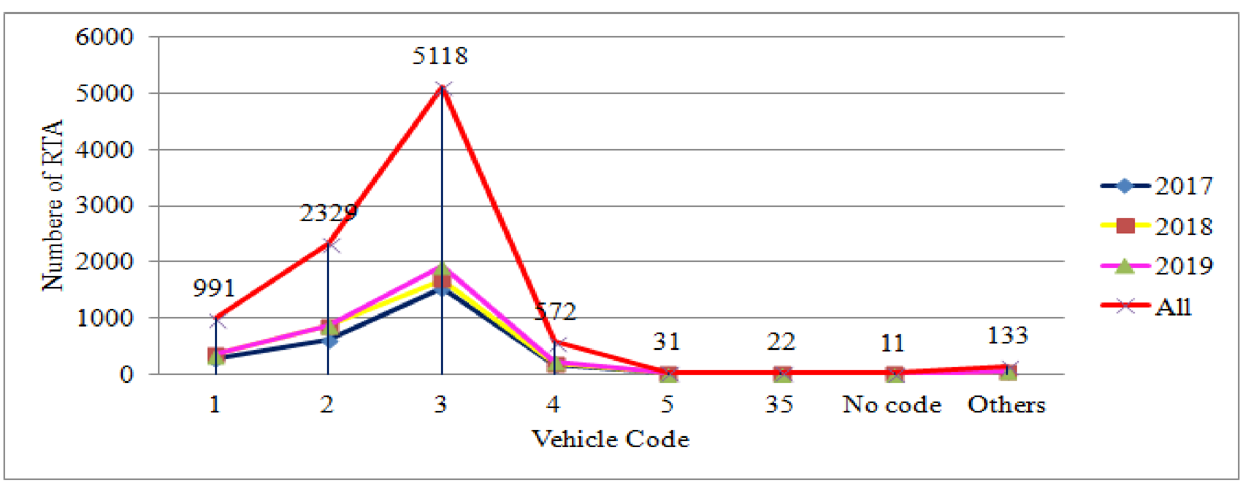


Source: Compiled from Yeka Sub-city Traffic Police Commission RTAs data (2017-2019)

Figure: 4.10: Type of involved vehicles in fatal accident in Yeka sub-city (2017-2019)

4.3.6 RTAs by vehicles code

As shown in figure 4.11 below 5118 (56%) of road traffic crashes were caused by vehicle code three. On the other hand code, 2 ranked 2nd and code 1stood 3rd rank by accident frequency share of 25 % and 11% respectively. The representations of codes are as follows 1 = Taxi, code 2= private vehicles, code 3 = business vehicle, code 4=government vehicles, code 5= Red Cross vehicles, code 35= aid organization vehicles and others (UN = .United Nation, AU= Africa Union, CD=Diplomat and transit code vehicle).



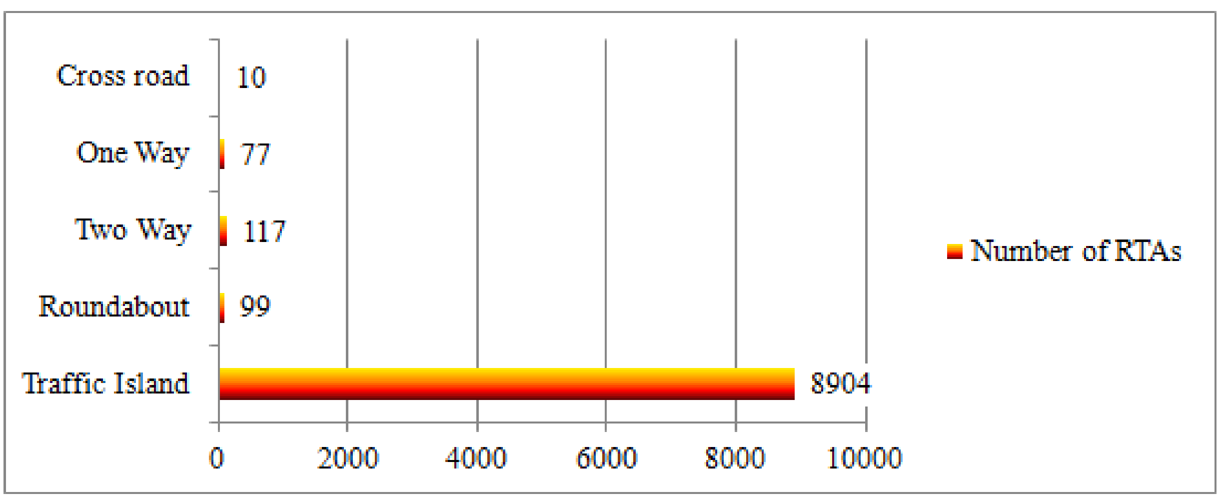
Source: Compiled from Yeka sub city police commission traffic accident data (2017-2019)

Figure 4.11 RTAs by vehicles code

One of the transport controls at Megenagna expressed his perception on road traffic accident and vehicle code relation: "I know most of the registered vehicles in Addis Ababa city have vehicle code 3, so the more the vehicle code type results in the frequent mode of the accident will present but other contributing factors are common. For example, when you see Taxi/Minibuses it generates a high number of trips within one day, this maneuvers results for driver tiredness, and then RTA may occur; hence, the more the trip distance the more incidents may happen." Kalu (2017) presented his thesis result that most fatal, damage and serious crashes were caused by vehicle Plate code three. In general, most of the crashes were caused by vehicle code three, one, two, and four in descending order.

4.3.7 RTA Condition by Variation of Road Characteristics

Variation of road characteristics has a significant factor in determining the occurrences of RTA in a given place. A total of 8904 RTAs occurred in traffic island sections of the roads. Figure 4.12 below clearly shows the presence of several different portions of road division. The result confirms that the highest accidents were recorded in the roads that are divided by traffic Islands followed by two ways and one-way road division. This is because traffic island roads coverage all of the traffic movements in the principal, sub principal, and collective street that leads to RTA.

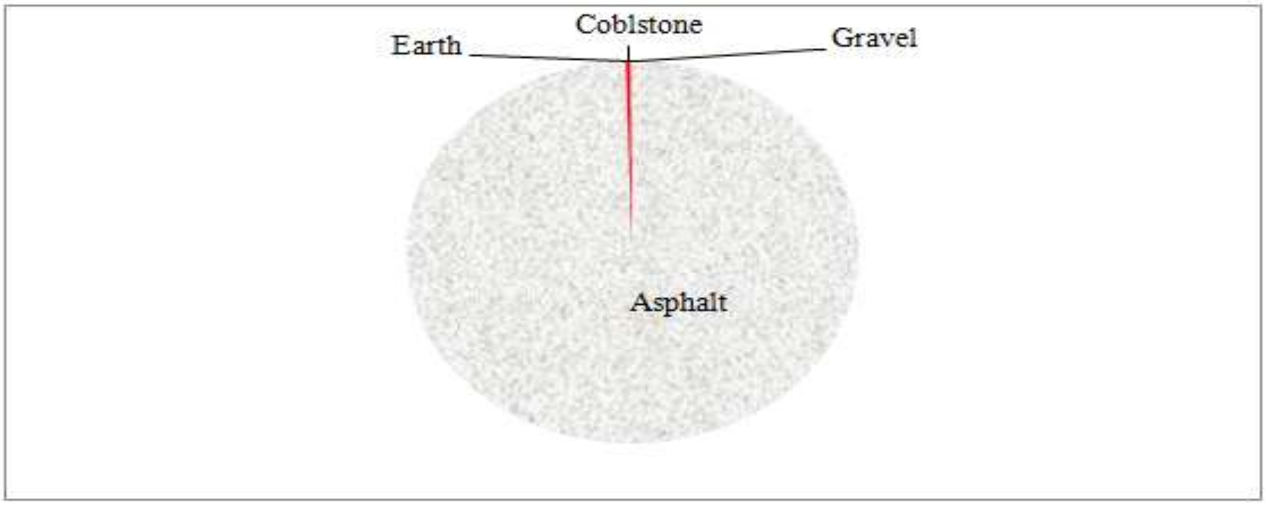


Source: Compiled from Yeka sub city police commission traffic accident data (2017-2019)

Figure 4.12: RTA by variation of road characteristics in Yeka sub-city (2017-2019)

4.3.8 RTA and Road Surface in Yeka sub-city (2017-2019)

Road surfaces are categorized into different types including asphalt, cobblestone, gravel, and earth. The analysis confirms that almost all of the RTAs happened on the asphalt road surface in the Yeka sub-city (2017-2019). The figure below shows the highest road traffic accidents were recorded on the asphalt surface type. Secondly, a small portion of RTA occurred on community roads, especially in the cobblestone road surface type. This is due to larger traffic flows found on principal asphalt roads than others.

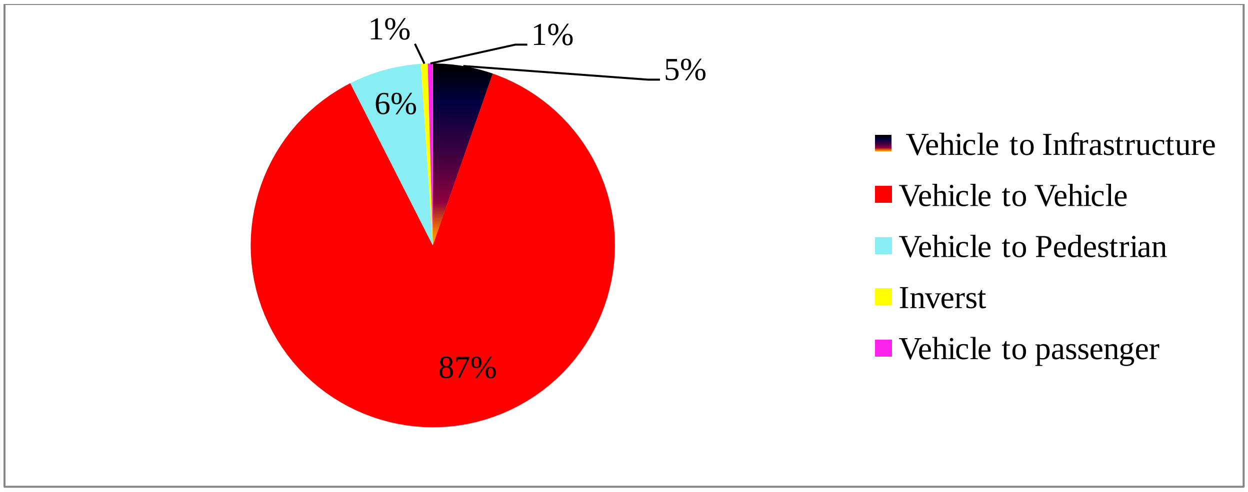


Source: Compiled from Yeka sub city police commission traffic accident data (2017-2019)

Figure 4.13: RTA and road surface characteristics in Yeka sub-city (2017-2019)

4.3.9 Accident Condition Based on Collision

Accident conditions may be dividing indifference, but for this purpose, this accident condition tells us the assigned vehicle collision status. As indicated in figure 4.14 below 87% of the total accidents are resulted from a vehicle-to-vehicle collision which is the leading accident collision type followed by vehicle to pedestrian which shares 6 %.

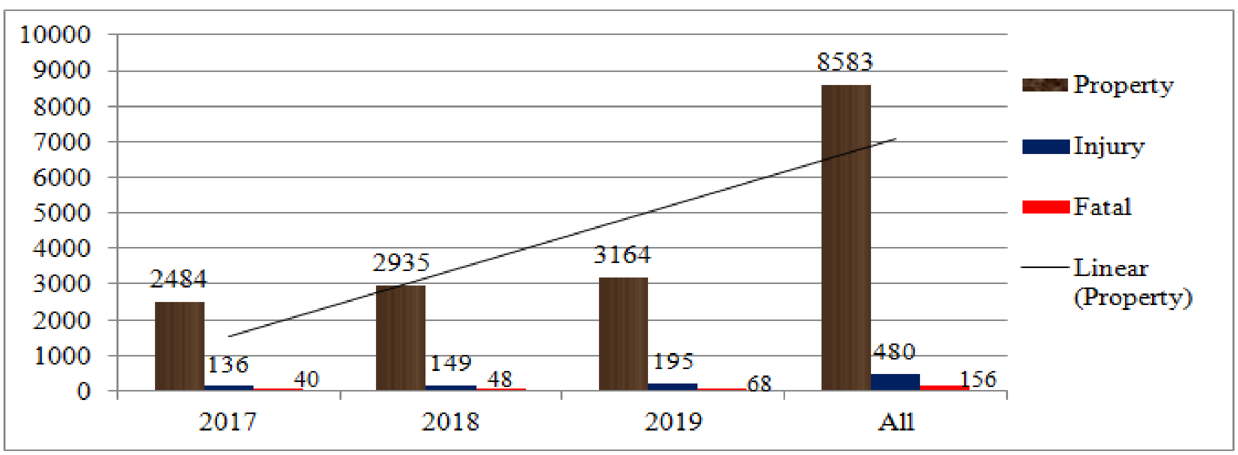


Source: Compiled from Yeka sub city police commission traffic accident data (2017-2019)

Figure 4.14: Accident condition

4.3.10 RTA by Type of Accident

RTAs may cause property damage, injury, and fatal accident. 93% of the total crashes were property damage. On the other hand, 5 % and 2 % of the total accidents were injuries, fatal crashes cases respectively.

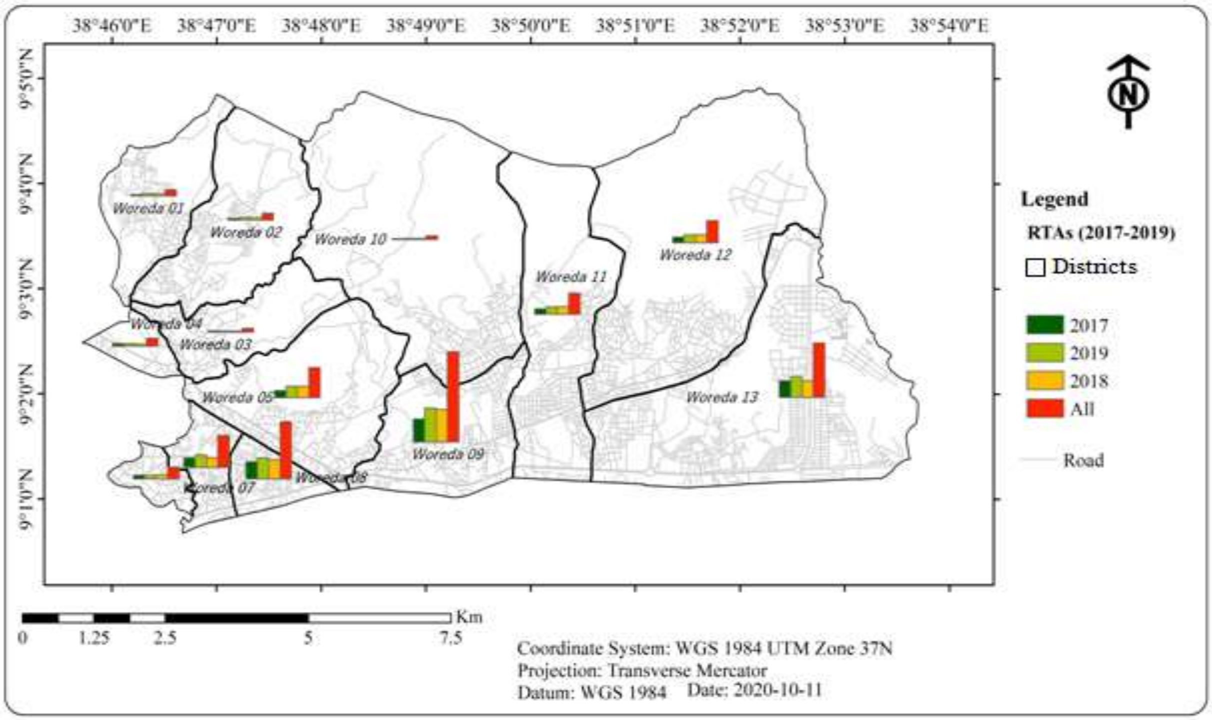


Source: Compiled from Yeka sub city police commission traffic accident data (2017-2019)

Figure 4.15: Traffic accident by type

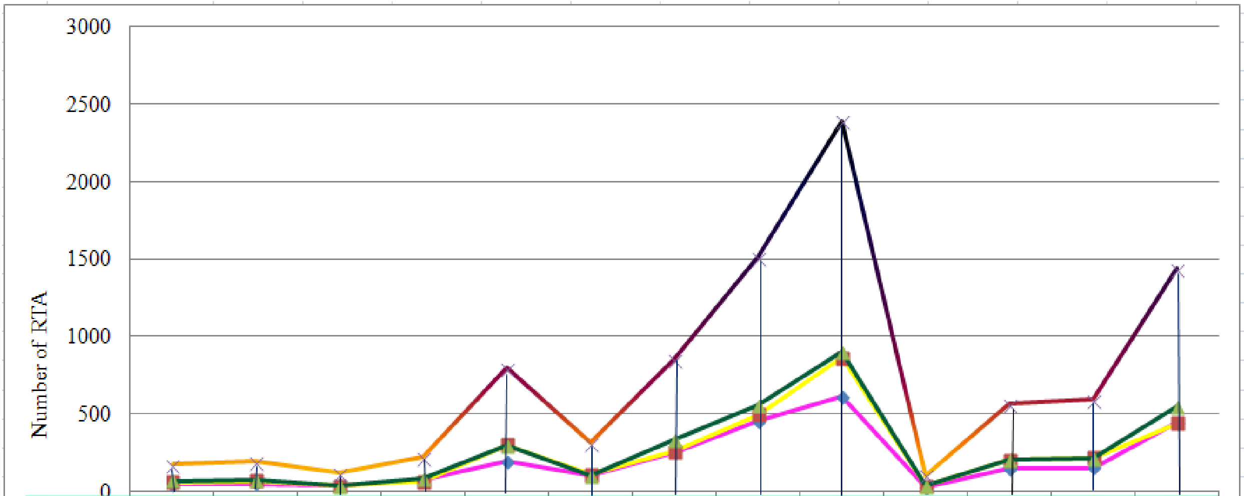
4.3.11 Number of RTA in Districts of Yeka sub-city (2017-2019)

Yeka sub-city has 14 administrative Woredas but the most well structured and formerly planned Woredas/districts are 13. This study also used totals of 13 districts because all accidents that occurred in district 14 were registered in district 13. This is because of the absence of a well-known demarcation boundary shapefile as it's the newly added district in 2018 for administration purposes. Figure 4.21 below shows RTAs in each district (2017-2019) by column/bar graph. We can understand that the longest bar is the higher rates.



Source: Compiled from Yeka sub city police commission traffic accident data (2017-2019)
Figure 4.16 RTAs in districts of Yeka sub-city (2017-2019)

The summary report testifies that more road traffic accidents were concentrated in district 9 (26%), district 8 (16%), district 13 (16%), and district 7(9%).On the other hand, spatial districts that have maximum fatal accidents were district 13, 9, and 12 was hosted maximum numbers of fatal crashes which share 19 %, 16%, and 16 percent of the total accidents respectively. Comparatively the minimum number of RTA has occurred in district 10 (1%), district 3 (1%), and district 1(2%).



Districts	1	2	3	4	5	6	7	8	9	10	11	12	13
2017	43	48	39	72	190	97	253	450	613	23	143	148	441
2018	58	66	33	60	297	109	257	495	864	35	203	216	437
2019	67	70	36	77	299	101	330	553	904	33	200	209	548
All	169	186	111	213	791	313	847	1506	2390	101	557	585	1439

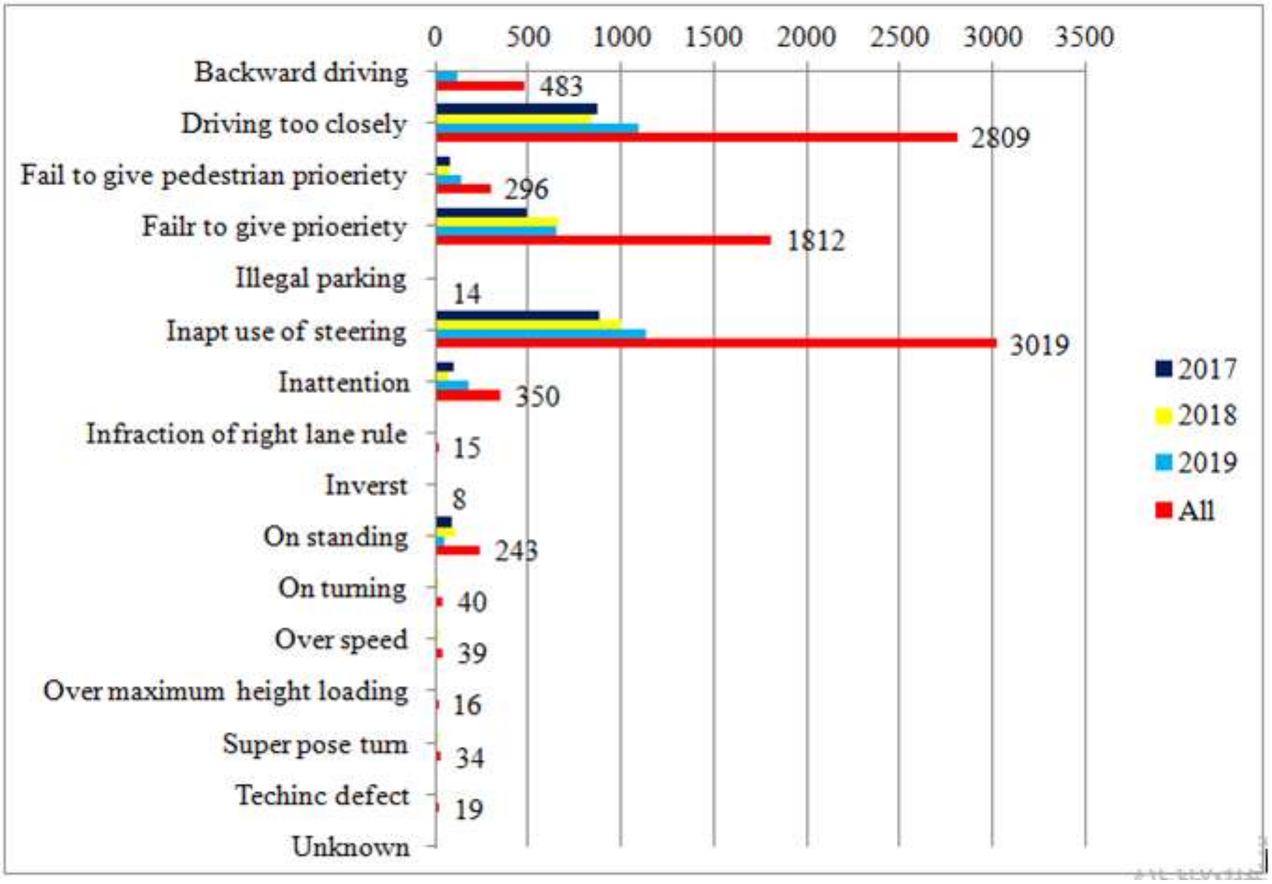
Source: Compiled from Yeka sub city police commission traffic accident data (2017-2019)

Figure 4.17: RTAs statistics in districts of Yeka sub-city (2017-2019)

4. 3 Causes of RTA

The finding of the study revealed that the most frequent and common causes of RTAs in Yeka sub-city administration were inapt use of steering which includes (steering to left, steering to the right) was the primary cause of RTAs. In addition to this, the frequently observed causes of RTAs were driving closely (31%), failing to give priority (20%), backward driving (5%), and failing to give pedestrian priority (3%) of the total causes of RTAs. In a similar case, the result of the Addis Ababa transport office (2018) report shows that the most commonly reported causal factor for fatal crashes was not giving priority to pedestrians followed by the carelessness of drivers, inappropriate use of the wheel, and suspected alcohol use. One of the key informants among traffic policies in Yeka sub-city reported that " *Inapt use of steering, failure to keep driving distance (driving too closely) and failure to give pedestrian priority are frequent causes of RTAs that I observed frequently. In addition to this over speed and failure to give pedestrian priority in connection with pedestrian negligence when using roads are the primary causes of fatal accidents."*

Figure 4.18 below presents the frequent cause of RTAs in Yeka Sub-city. We can easily understand that the longest clustered bar is the frequent causes for RTAs



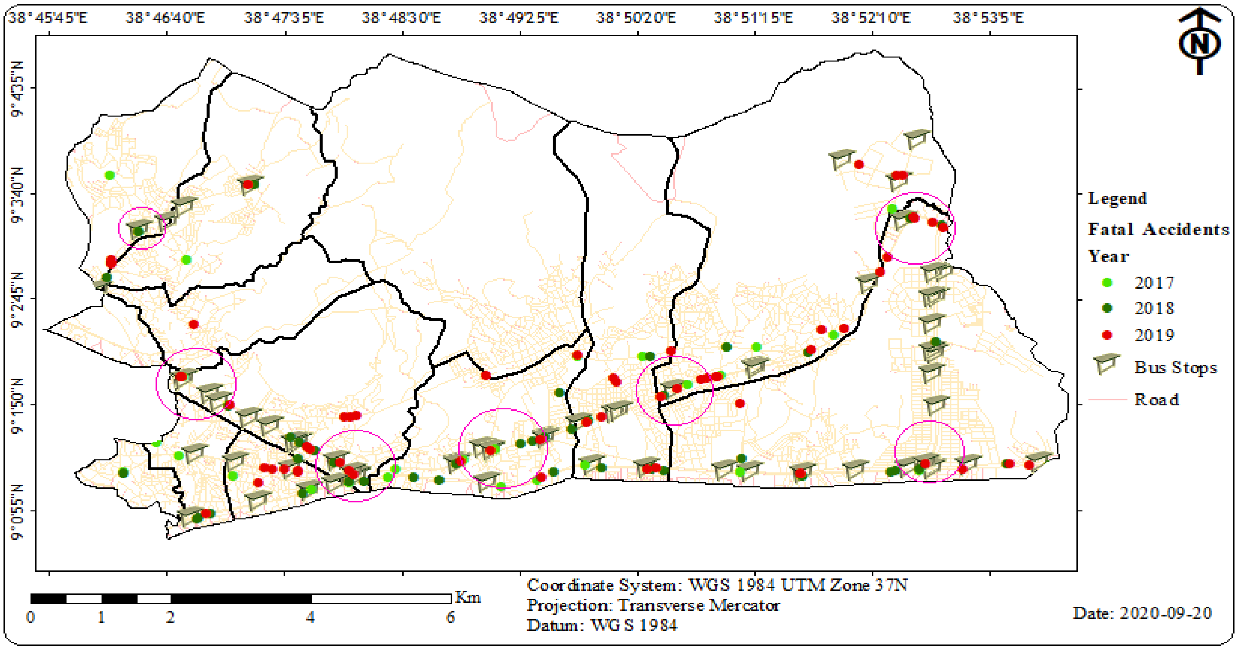
Source: Compiled from Yeka sub city police commission traffic accident data (2017-2019)

Figure 4.18: Causes of RTA

4.4 GIS-Based Analysis of Road Traffic Accident

4.4.1 Spatial Distributions of Fatal Accidents and Bus stops

Dangerous bus stops are ranked using the number of fatal case accidents in the vicinity. To explore fatality locations and bus stops it is important to overview the bus stop coverage and fatal accident points together. A total of 156 fatal case road traffic accidents have been recorded from 2017-2019 in Yeka sub-city administration. Due to the absence of some specific information, only 139 fatal accidents are considered in this study. The level of frequency had been increasing from 41 fatal cases in the year 2017 to 68 in 2019. Most numbers of fatal accidents happened in the principal arterial (primary) streets. The bus stops are mainly on primary road type; hence almost all accidents occurred on primary roads. Figure 4.18 below shows that the circle icon on the map high fatal accident within and around bus stops. All maps of this section are compiled by using Addis Ababa Transport Program Management Office fatal data source (2017-2019)



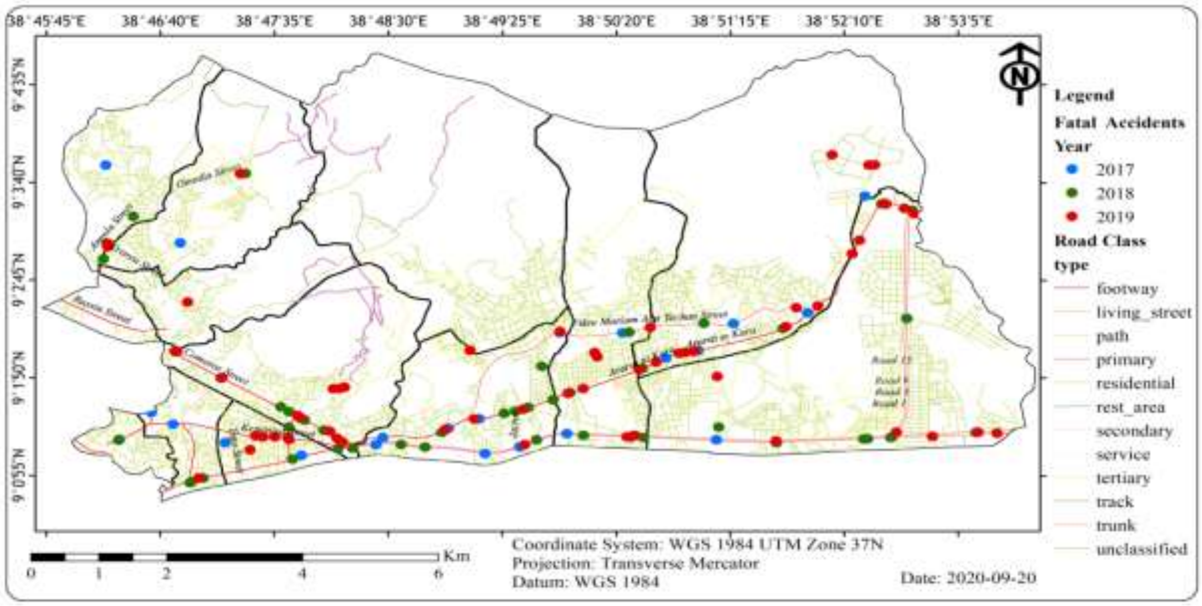
Source: Compiled from AATPMO fatal case accident data 2017- 2019).

Figure 4.19: Spatial distributions of fatal accidents and bus tops

Based on figure 4.19 above shows that three to five fatal accidents occurred near to the bus stop. So identifying fatal accident concentrations is extremely helpful in identifying dangerous bus stops using Kernel Density and Proximity Analysis (buffer). The circle icon on the map shows expected hot spot and hazardous bus stop places.

4.4.2 Spatiotemporal Distributions of Fatal Accidents

The fatal case of road traffic accidents has a temporal condition that everything happens someplace and occurs at some point in time. The Spatiotemporal distributions analysis can answer questions of whereby when. Most GPS based fatal accident points and field observations show that a majority of accidents occurred in arterial streets where a large volume of traffic flow is presented.

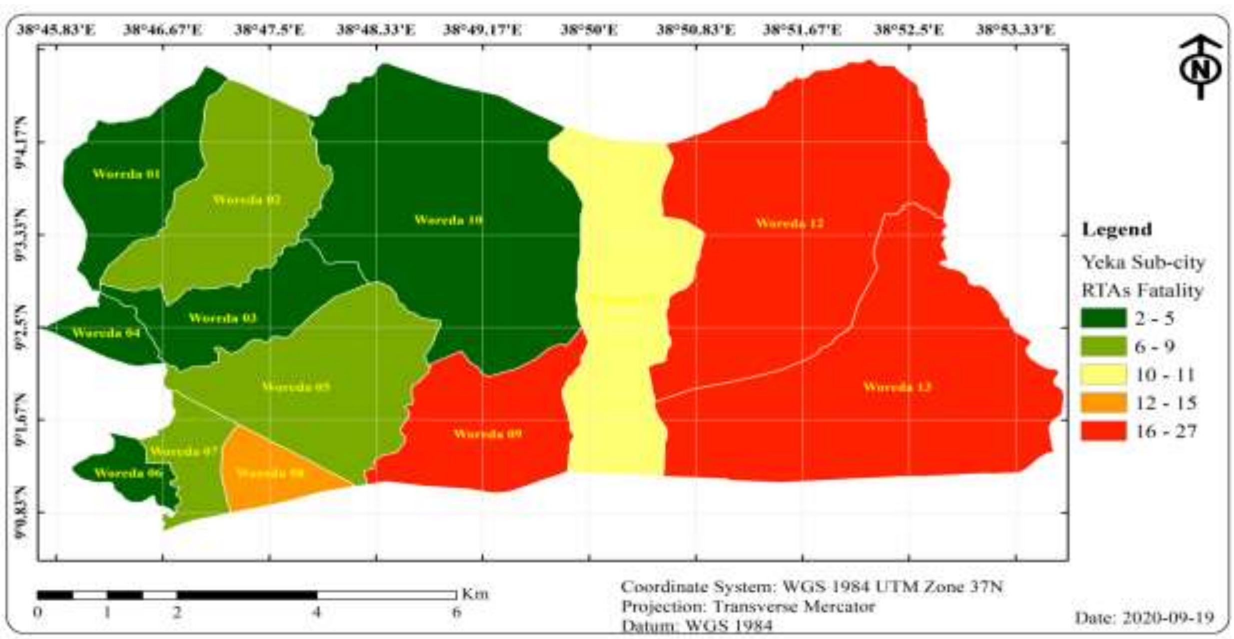


Source: Compiled from AATPMO fatal case accident data 2017- 2019).

Figure 4.20: Spatiotemporal distributions of fatal accidents

4.4.3 Mapping RTAs in Districts

The sub-city of Yeka has 13 structured districts/Woredas. Figure 4.27 below shows that the highest numbers of fatal crashes were found in districts 13, 9, and 12.



Source: Compiled from AATPMO fatal case accident data 2017- 2019)

Figure 4.21: District level fatal accident concentration

Each of the districts/woredas as shown in figure 4.21 above have their own characteristics. For instance, the read shaded sections show the highest road traffic accident(fatal) concentration weredas whereas the lively green shaded colors indicate the lower fatal accident concentration area. The researcher observed that Woreda 13 and 12 have found in the peripheral area of the sub-city that hosts low number of vehicles and low congestion but the vehicles move above the posted speed and sudden road traffic accidents trigger. On the other hand, woreda 9 has a central area of the sub-city that hosts a large number of vehicles per day.

4.4.4 Hot Spot Analysis (Getis-OrdGi*)

Getis-OrdGi statistics identify the place as a hot spot or cold spot using weighted overlay features. It creates a new output feature class with a z-score, p-value, and confidence level bin (Gi_Bin) for each feature in the input feature class. The z-scores and p-values measure statistical significance which tells about whether to reject the null hypothesis. The critical z-score values when using a 95 percent confidence level are -1.96 and +1.96 standard deviations. The p-value associated with a 95 percent confidence level is 0.05. If the z-score is between -1.96 and +1.96, the p-value will be larger than 0.05, and we cannot reject the null hypothesis because the pattern exhibited could very likely be the result of random spatial processes. In this paper, the weighted overlay features to be evaluated was the number of victims each year. To be organized the most appropriate spatial relationship parameter must be completed according to the data type. To execute a realistic model the researcher used the fixed distance band method which works well for point data. It is the default option used by the Hot Spot Analysis (Getis-OrdGi*) tool.

The Getis-Ord local statistics are calculated as

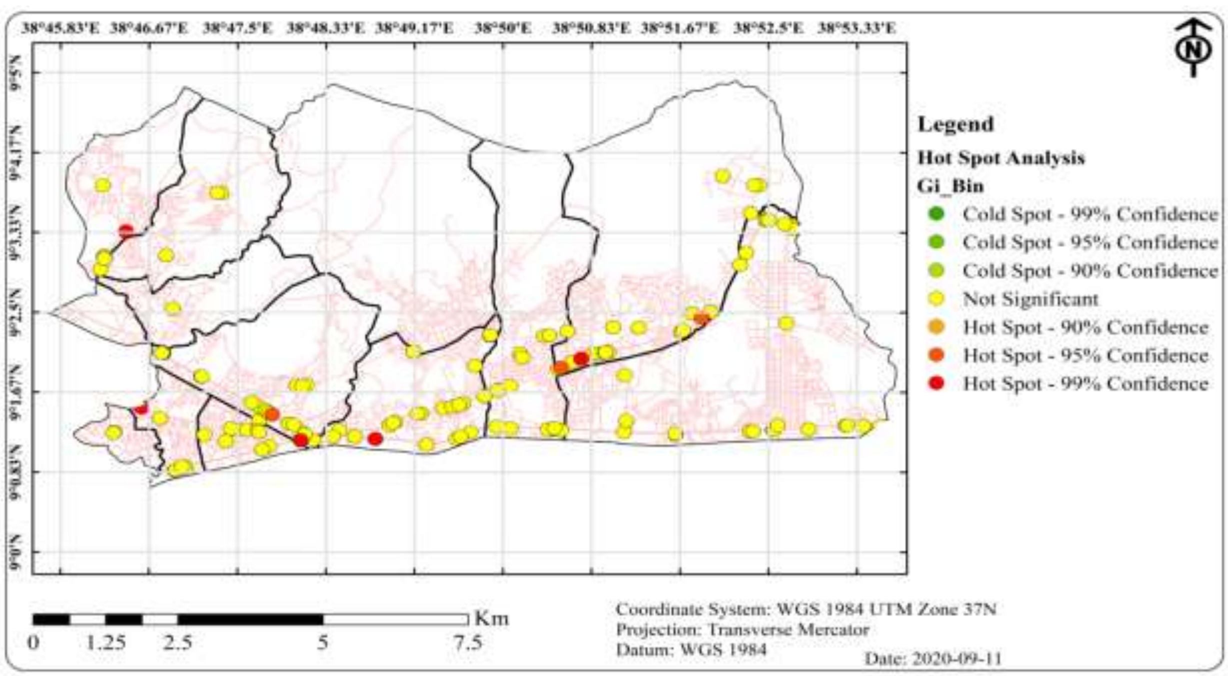
$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j} \right)^2 \right]}{n-1}}} \qquad (1)$$

Where Xj is the attribute value for feature j, wi is the spatial weight between feature I and j,n is equal to the total number feature of features and :

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} \quad (2)$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2} \quad (3)$$

The null hypothesis stated that there are no statistically significant spatial clusters of high values (hot spots) and low values (cold spots). The z-scores and p-values are measures of statistical significance that determines whether or not to reject the null hypothesis, feature by feature. When the p-value is very small, it means it is very unlikely to accept the null hypothesis. The researcher selected a 90 percent confidence level because the hotspot (spatial cluster) concentration has shown at a 90 % confidence level. The critical z-score values when using a 90 percent confidence level are -1.65 and +1.65 standard deviations.



Source: Compiled from AATPMO fatal case accident data 2017- 2019)

Figure 4.22: Spatial Statistics of RTAs

The results in the below table show that there was evidence to reject the null hypothesis, which was the spatial clusters exist among traffic accidents at a 90% confidence interval because the Z score is greater than 1.65 and the p-values are smaller than 0.10 in some accidents with high severity index that clustered and spatially correlated. This shows there is a statistically significant spatial structure in the data. Based on this Megenagna, Frensay Kela, Wesen grocery, Kara akababi, Abarie, around Yeka Michael Church were statistically significant hotspots identified by Hotspot Analysis.

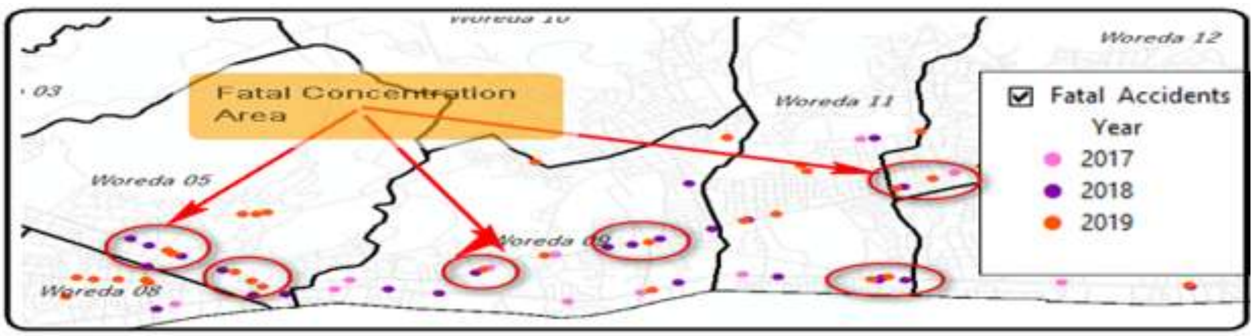
Table 4.1: Statistically significant hot spots

No.	GiZS core	GiP Value	Gi_Bin	Location name	Remark
1	4.609587944	4.03468E-06	3	Frensay_Kela	Hotspot
2	3.585821874	0.000336018	3	Megenagna	Hotspot
3	3.584629498	0.000337557	3	Wesen_grocery	Hotspot
4	3.583793401	0.00033864	3	Abarie	Hotspot
5	2.560918443	0.010439586	2	Kara_akababi	Hotspot
6	2.561157052	0.010432418	2	Yeka_Michael_Church	Hotspot
7	1.538958726	0.123814373	0	Gurd_Sholla	Not significant
8	1.53735847	0.124205551	0	Meri	Not significant
9	1.536178857	0.12449452	0	Salite_Mihret	Not significant
10	0.515421112	0.606258785	0	Yeka_Micheal	Not significant
11	0.516145047	0.605753109	0	English Embassy	Not significant
12	0.516115914	0.605773456	0	Kokeb_Tsiba_School	Not significant
13	0.515886715	0.605933535	0	Lamberet	Not significant
14	0.514853412	0.60665546	0	Yeka_Abado	Not significant
15	0.514853412	0.60665546	0	Sara_Ampule	Not significant
16	0.518404398	0.604176149	0	Frensay_Abo	Not significant

Source: Compiled from AATPMO fatal case accident data 2017- 2019)

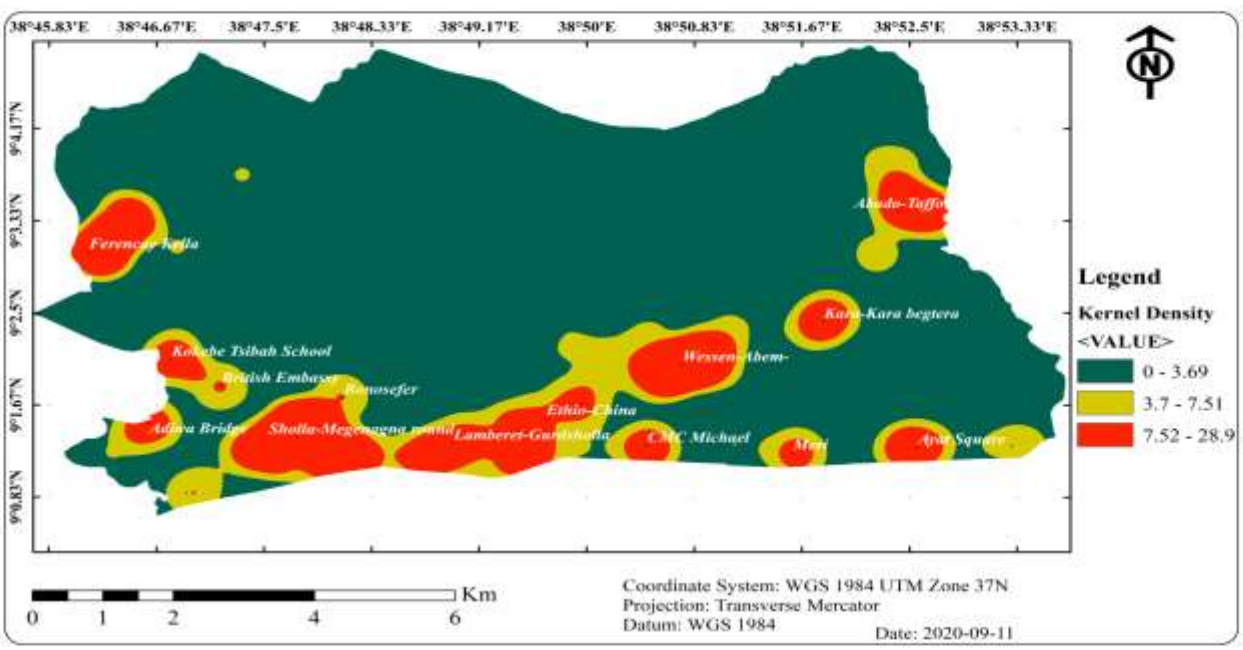
4.4.5 Kernel Density Estimation of Fatal Case RTAs

Kernel density analysis is used to calculate a magnitude-per-unit area from point or poly-line features using a kernel function to fit a smoothly tapered surface to each point or poly-line. The population field is the count or quantity to be spread across the landscape to create a continuous surface. Values in the population field may be integer or floating point. Accordingly the input field is the number of fatal accidents. Figure 4.23 shows below the number of accidents that occurred in the last three years. The repetitive occurrences of fatal accident results for high kernel density value. The surface value is highest at the location of the point and diminishes with increasing distance from the point, reaching zero at the search radius distance from the point.



Source: Compiled from AATPMO fatal case accident data 2017- 2019)

Figure 4.23: Fatal accident concentration site



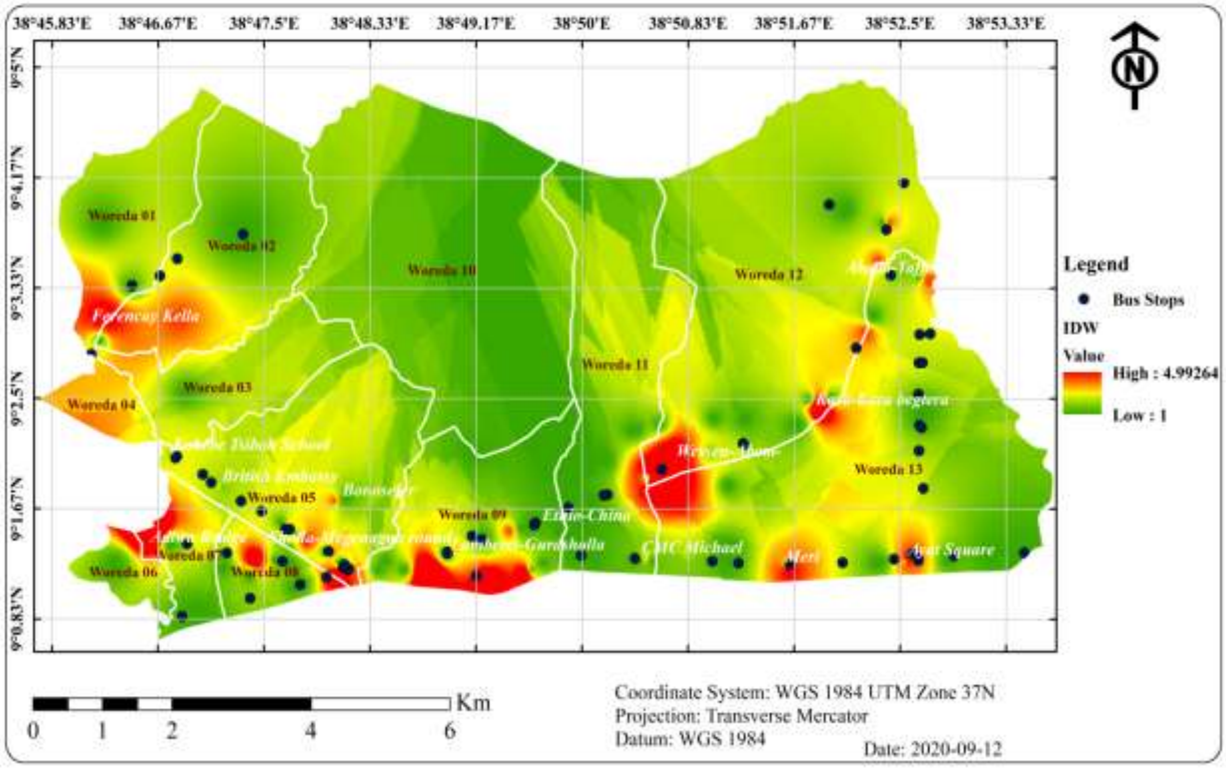
Source: Compiled from AATPMO fatal case accident data 2017- 2019)

Figure 4.24: Kernel density analysis of fatal accidents

Figure 4.24 below shows the density of RTAs in the Yeka sub-city administration. The Kernel density spatial analysis method identified the highest density of fatal accidents at the location of Ferencay Kella, Kokebe Tsibah School, Adiwa Bridge, Sholla-Megenagna, Zerihun Building, British Embassy, Bonosefer, Lamberet, Gurdsholla, Ethio-China, Hillside School, Wessen-Abem, Kara-Kara begtera, Abado-Taffo, CMC Michael, Meri, Ayat Square, and Ayat Bono Wuha. In the past three years, the highest number of fatal accidents have occurred and registered in these locations.

4.4.6 Fatal Severity Prediction using IDW

Interpolation functions used to produce a continuous surface from sampled fatal accident points. It enables us to predict unknown values of road traffic accident point data. The continuous surface representation of a raster dataset represents magnitudes of fatality over space. The researcher applied deterministic interpolation methods that predict surfaces based on the surrounding measured values. It used to produce collision concentration maps with overlaid bus stops. It interpolates a raster surface from points using an inverse distance weighted technique. Based on this the IDW interpolation result detects fatal case traffic accident hotspots and most vulnerable locations like Kokebe Tsibah School, British Embassy, Ferencay Kella, Adawa Bridge, Sholla-Megenagna, Zerihun Building, Bonosefer, Lamberet, Gurdsholla, Ethio-China, Hillside School, Wessen-Abem, Kara-Kara begtera, Abado-Taffo, CMC Michael, Meri and Ayat Square. Figure 4.31 shows the spatial distributions of bus stops along with black spot areas.



Source: Compiled from AATPMO fatal case accident data 2017- 2019)

Figure: 4.25 Spatial Distributions of bus tops over interpolated surface

When we roughly see the interpolated map there are a number of bus stops that appeared in high crash zones. Those are Kokebetsibah school, Shola Federal Court, Megenagna terminal, Wessen grocery, Kara, Yeka Abado Mskelegna, Ayat Square, Meri, and Gurd shola.

The collision concentration map in 4.32 shown below divided into four risk-level areas. These are no-risk level (0-1 fatal accident per unit area), low-risk level (2–5 fatal accident per unit area), medium-risk level (6–7 fatal accident per unit area), and high-risk level (8–10 fatal accident c per unit area).

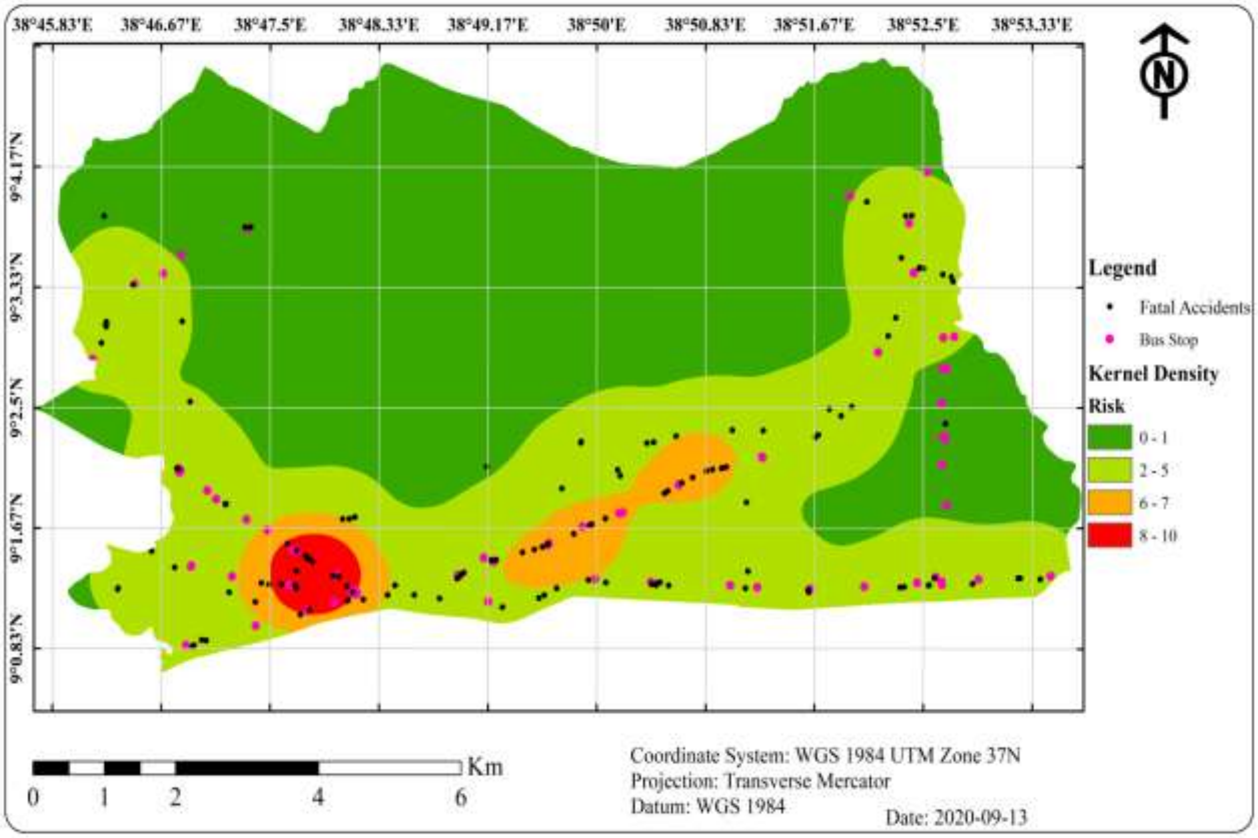


Figure: 4.26 Spatial Distributions bus tops over Kernel density surface

Based on map risk concentration the following bus stops were identified as high risk and medium risk level. The bus stop that appears at a red color considered as high risk level and vice versa.

Table 4.2 Spatial Distributions bus tops over interpolated surface

No.	Bus Stop Name	Risk Level
1	Megenagna Terminal	High risk level
2	Sholla Federal Court	High risk level
3	Shola Gebeya	High risk level
4	Lemhotel	High risk level
5	Yeka health center	High risk level
6	Megenagna Bethlehem Plaza	High risk level
7	Yeka Sub city Iterance	High risk level

8	Lamberet Terminal	Medium risk level
9	Ethio-China	Medium risk level
10	Hillside school	Medium risk level
11	Wessen Michael	Medium risk level
12	Wessen Grocery	Medium risk level

Source: Compiled from AATPMO fatal case accident data 2017- 2019)

4.4.7 Buffer generation around the bus stops

An important and prior feature of the Buffer tool is the method of the parameter which determines how buffers are constructed. There are two basic methods for constructing buffers, Euclidean and geodesic. Geodesic buffers are those that account for the actual shape of the earth (an ellipsoid, or more properly, a Geoid). It advisable if the input features are dispersed (cover multiple UTM zones, large regions, or even the whole globe). So in this case it not functional for this paper. The next and most important method of buffering is Euclidean which measures distance in a two-dimensional Cartesian plane, where straight-line or Euclidean distances are calculated between two points on a flat surface. Euclidean buffers are the most common type of buffer and situated when analyzing distances around features in a projected coordinate system that are concentrated in a relatively small area (such as one UTM zone).In this case, the researcher study area is Yeka sub-city which is found in UTM zone 37 and covers is 85.98 km square. So the researcher used the Euclidean method for buffer analysis. To do so a multiple ring buffer was generated at specified distances (30, 50, and 100meter) around each bus stop. As shown below figure fatal accidents have been captured in the generated buffer zone based on the vicinity of each bus stop. As stated in the literature hazardous bus stops identified when different radiuses were used to extract the number of fatal accidents. The researcher produces the 30-100 meter radius severity. A 30-meter radius is the most severe than others followed by a 50-meter searching radius. Fatal case crashes (auto-pedestrian crash) within a 30 –100-meter searching radios recommended to computing the severity index of hazardous bus stops. The researcher was generated multiple ring buffers using model builder as shown in figure 4.33.

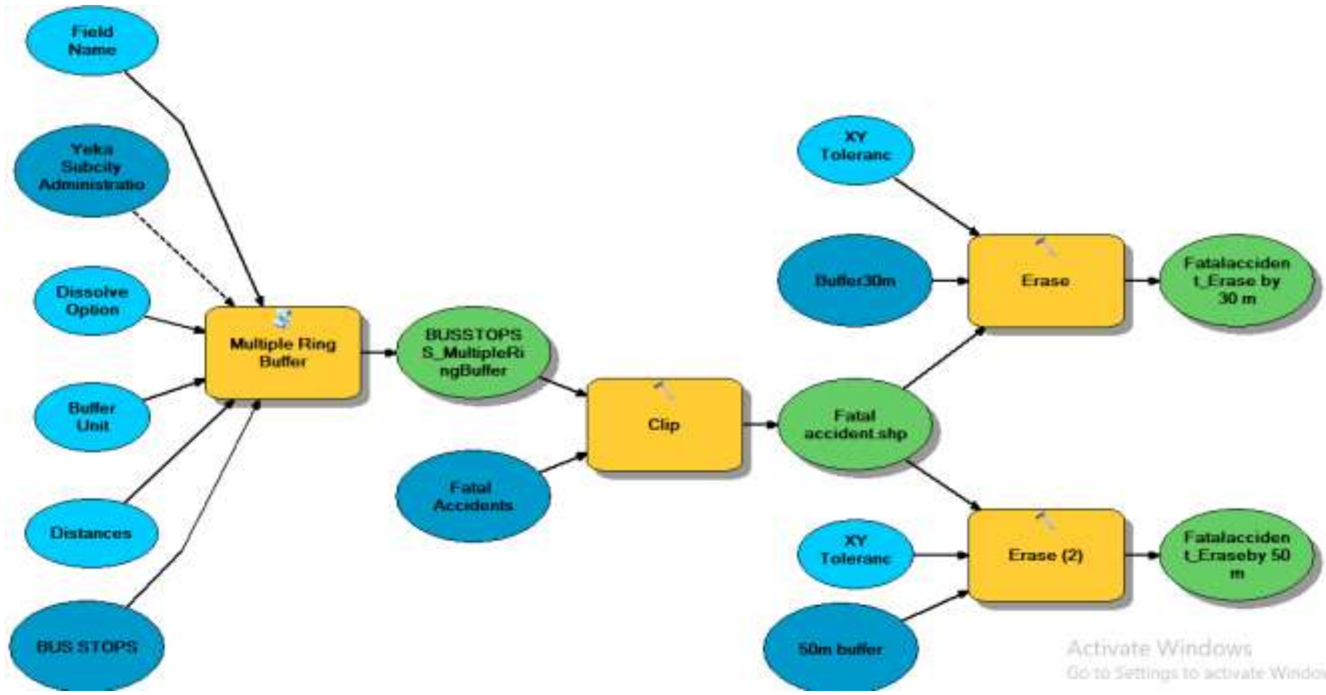


Figure 4.27: Multiple ring buffer generation

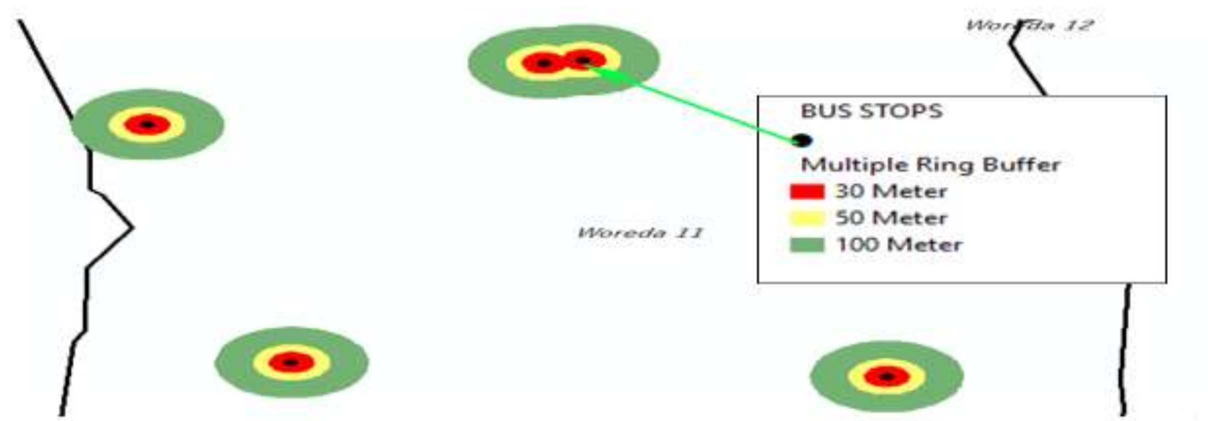


Figure 4.28: multiple ring buffers output

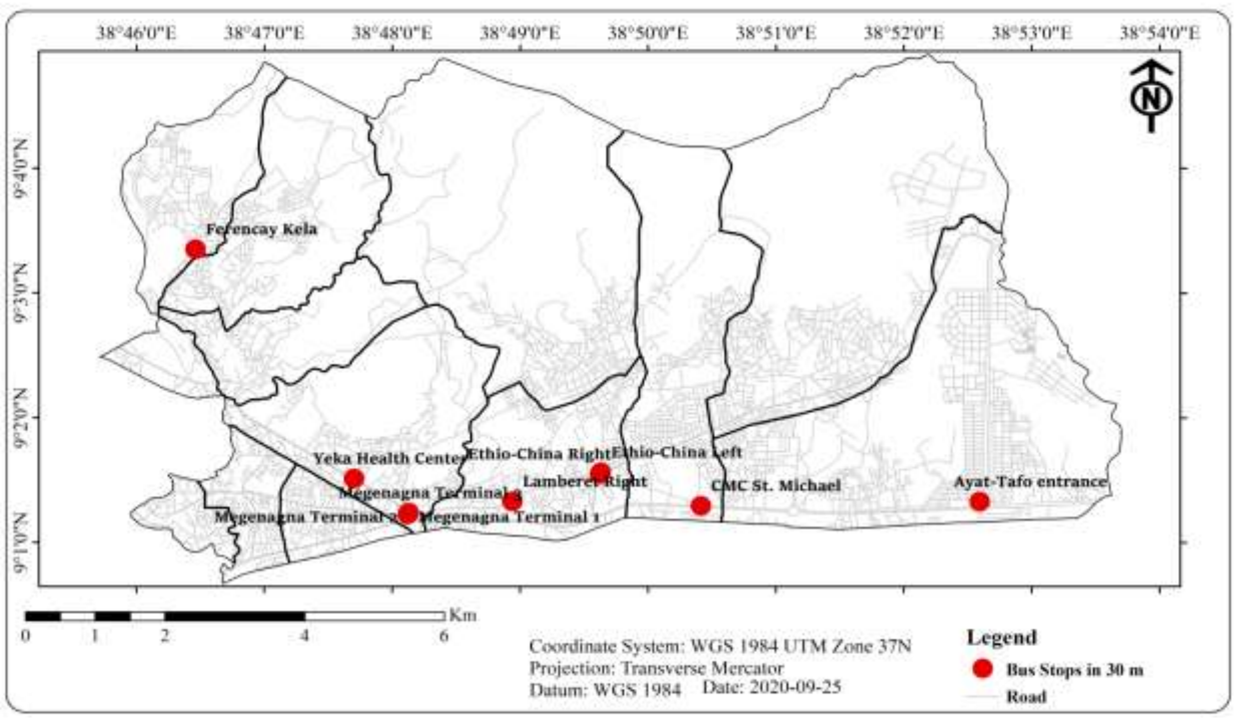
As shown in table 4.4 below hazardous bus stops were generated by using analysis tools (buffer, erase, and clip) within 30 meters and 30-50 meter searching radius.

Table 4.3: Hazardous bus stops in 30 meter radius

NB. Left side and right side road direction was referenced from Megenagna to all directions

N	X	Y	Name
1	478248	997120	Megenagna Terminal 1,2and 3
2	475207	1001037	Ferencay Kela
3	477478	997646	Yeka Health Center
4	479747	997310	Lamberet Right
5	481014	997737	Ethio-China Left
6	480999	997712	Ethio-China Right
7	482447	997243	CMC St. Michael
8	486439	997306	Ayat-Tafo entrance

Source: Compiled from AATPMO fatal case accident data 2017- 2019)



Source: Compiled from AATPMO fatal case accident data 2017- 2019)

Figure 4.29: Hazardous bus stop map in 30-meter radius

Field observations show that the yellow line strips were restricted for mass transport stops but other vehicles reserved as parking and the coming buses were boarding and alighting in improper place which leads to the crash. In addition to this, there were no pedestrian facilities like zebra, pedestrian signals near bus stops except Yeka health center.

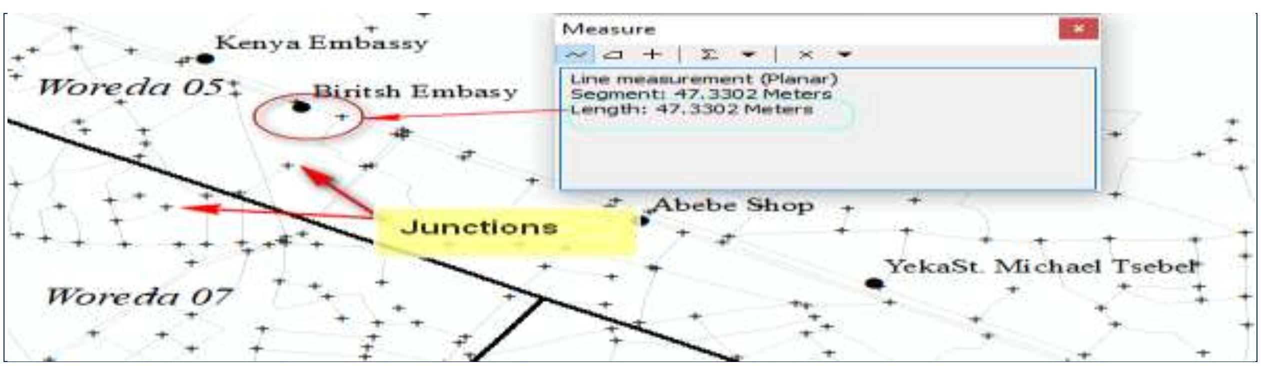
Table 4.4: Hazardous bus stop at 30-50 meter

No	X	Y	Name
1	477629	996876	Lem Hotel
2	478265	997155	Megenagna Diaspora Square
3	484676	997156	Meri
4	479743	997331	Lamberet Left
5	478032	997343	Yeka Sub-city Administration Gate
6	480239	997498	Lamberet Terminal Right
7	480240	997507	Lamberet Terminal left
8	475834	998640	Kokebe Tsibah Left Side
9	475854	998662	Kokebe Tsibah Right Side
10	476806	1001754	Ferencay Biret Dildiy

Source: Compiled from AATPMO fatal case accident data 2017- 2019)

4.4.8 Mapping Hazardous Bus Stops

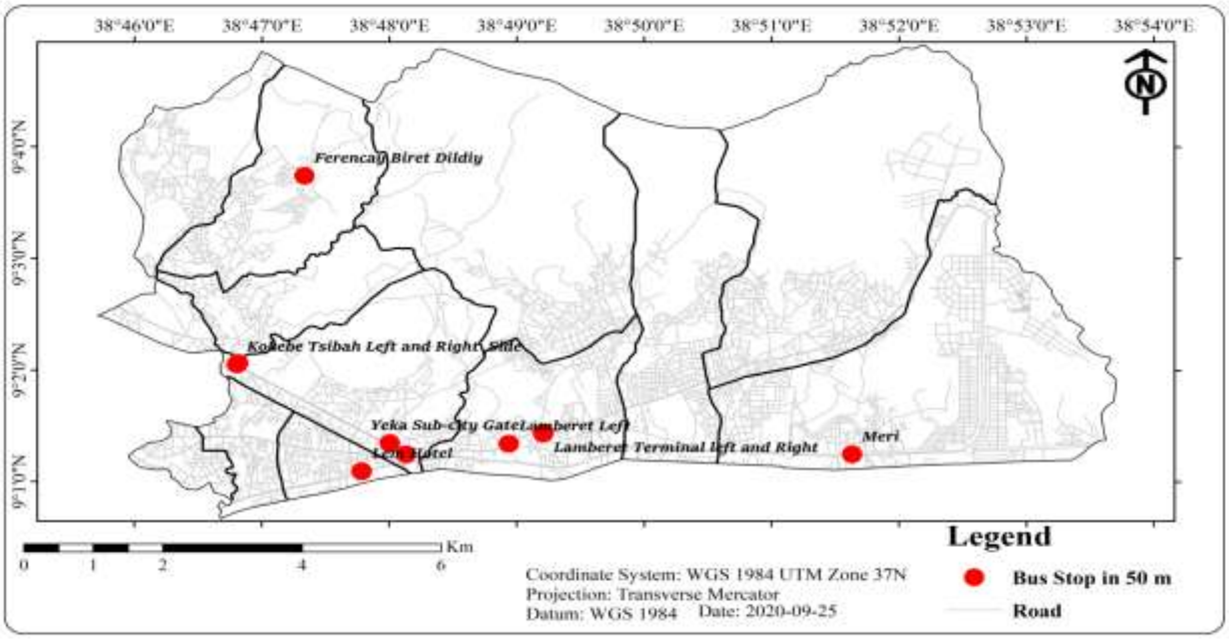
Two different hazardous maps were generated. The Differences in the results produced indicated that the number of fatal cases estimated is sensitive to the considered searching radius. Most far side and near side bus stops are constructed such that they are 30 to 100 meters away from intersections. For example, the British Embassy bus stop the nearside and fireside distance is 20 and 47 meters respectively as shown in figure 4.30 below.



Source: Compiled from AATPMO fatal case accident data 2017- 2019)

Figure4.30: Junctions and bus stop location

To improve the accuracy and reliability of the prioritization of a hazardous bus stops analysis tool (buffer, multiple buffers) was used. After producing multiple buffers clip and erase function was applied. Clip function used to create a new feature class also referred to as study area or area of interest (AOI) that contains a geographic subset of fatal crashes, whereas erase function was used to display fatal accidents near to bus stop at a different radius.



Source: Compiled from AATPMO fatal case accident data 2017- 2019)

Figure: 4.31: Hazardous bus stops in 50 meter radius

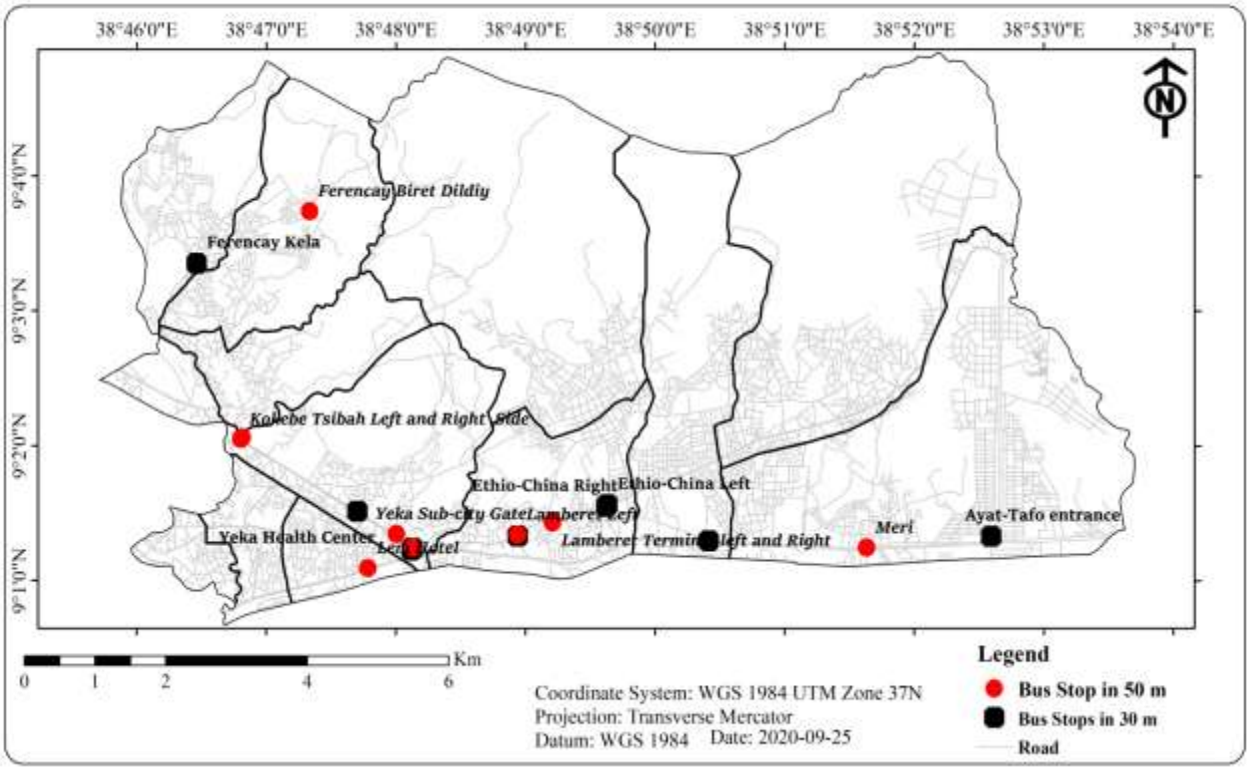
By using the selection by attribute function the following bus stops are classified as dangerous. In this case, the target layer was bus stops and the source layer was a fatal accident which was occurred in and around bus stops. A total of 14 bus stops in the hotspot location were identified. Table 4.6 below shows the top 10 unsafe bus stops with at least two fatal cases. The bus stop severity index is defined 0-50 meters away from bus stops unsafe bus stops are ranked based on their severity indices as shown below.

Table 4.5 Hazardous bus stops using severity index

No	X	Y	Bus Stop Name	Fatal accident crashes		SI	Rank based on severity
				50 meter	50-100 meter		
1	475854	998662	Kokebe Tsibah Left and Right Side	2	2	5	1
2	479743	997331	Lamberet Left and Right Side	2	1	4	2
3	486439	997306	Ayat-Tafo entrance	2	1	4	2
4	479743	997331	Lamberet Left and Right Side	2	1	4	2
5	482447	997243	CMC St. Michael	1	2	3.5	5
6	484676	997156	Meri	2	0	3	6
7	478032	997343	Yeka Sub-city Administration Entrance	2	0	3	6
8	476806	1001754	FerencayBiretDildiy	2	0	3	6
9	478262	997143	Megenagna Terminal 1-3	1	1	2.5	8
10	475207	1001037	FerencayKela	1	1	2.5	8
11	477478	997646	Yeka Health Center	1	0	1.5	11
12	478265	997155	Megenagna Diaspora Square	1	1	2.5	12
13	477629	996876	Lem Hotel	1	1	2.5	12
14	481014	997737	Ethio-China Left and Right	1	1	2.5	12

SI= Severity Index *Source: Compiled from AATPMO fatal case accident data 2017- 2019)*

The result shows that some bus stops has been extremely high severity indices, such as stop Kokebe Tsibah Left and Right Side, Lamberet Left and Right Side, Ayat-Tafo entrance, CMC St. Michael, Yeka Sub-city Administration Roundabout, and Ferencay Biret daily. Figure 4.38 below shows hazardous bus stops in both 30 and 50-meter searching radius.

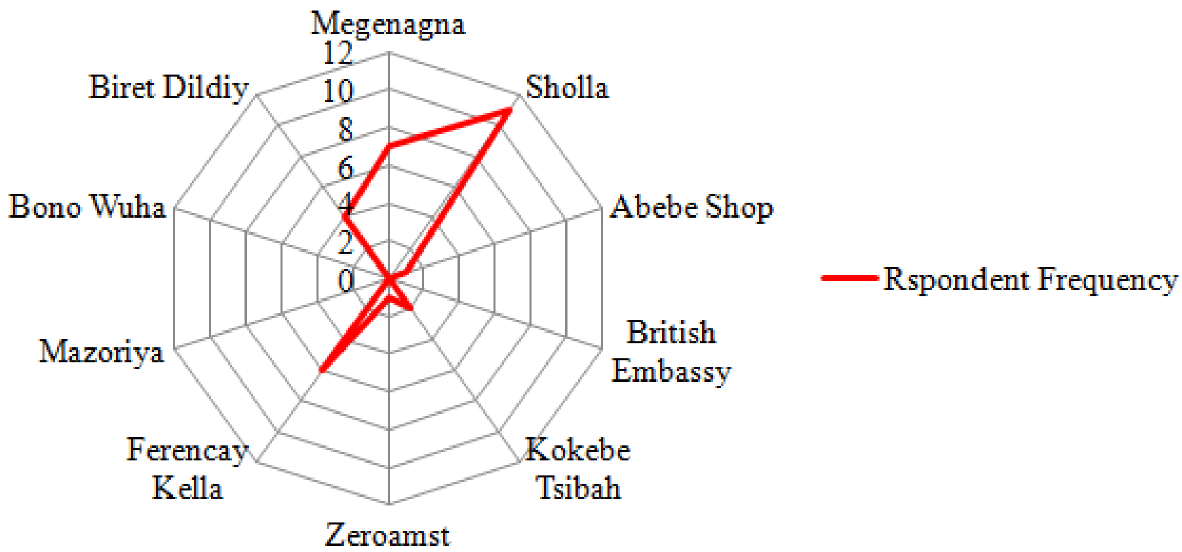


Source: Compiled from AATPMO fatal case accident data 2017- 2019)

Figure: 4.32: Hazardous bus stop maps in 30-50 meter radius

4.4.9 Unsafe Bus Stops Based on Drivers Point of view

To include driver’s perception about unsafe bus stops on their operating route line bus stop questionnaire was prepared. The questionnaire was disseminated in four major route lines (Megenagna –YekaAbado, Megenagna - Hayat Tsebel, Megenagna – Ferencay Gurara, and Hayat Roundabout –Taffo). All figures below demonstrate that the colored trace polygon and the line show unsafe bus stops in that route based on the driver's point of view.



Source: Compiled from questionnaires

Figure: 4.33 unsafe bus stops in Megenagna to Ferensay route

As shown in figure 4.33 above Megenagna, Sholla, Ferencay Kella and Biret Dilidiy were unsafe/hazardous bus stops inMegenagna to Ferensay route

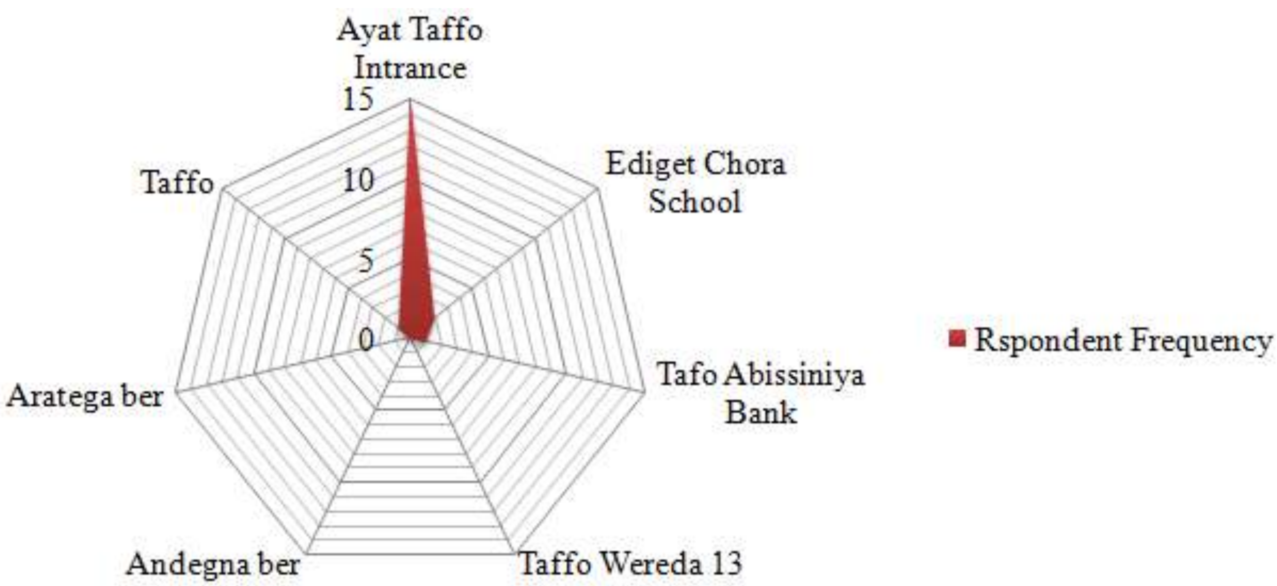
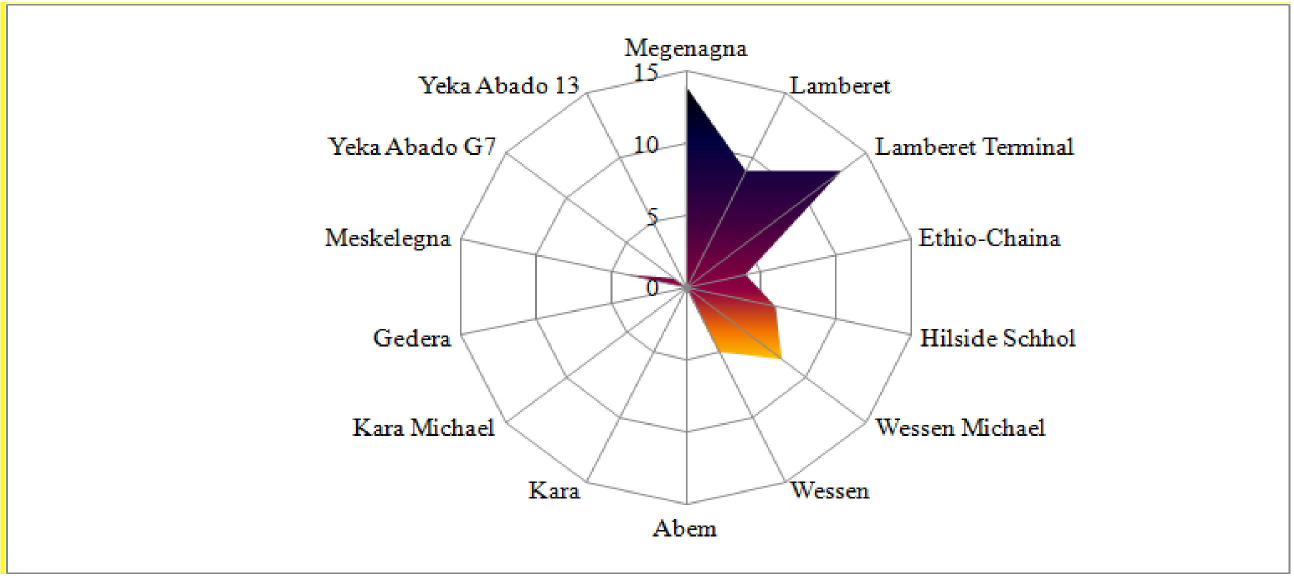


Figure: 4.34 unsafe bus stops in Ayat - Taffo route *Source: Compiled from questionnaires*

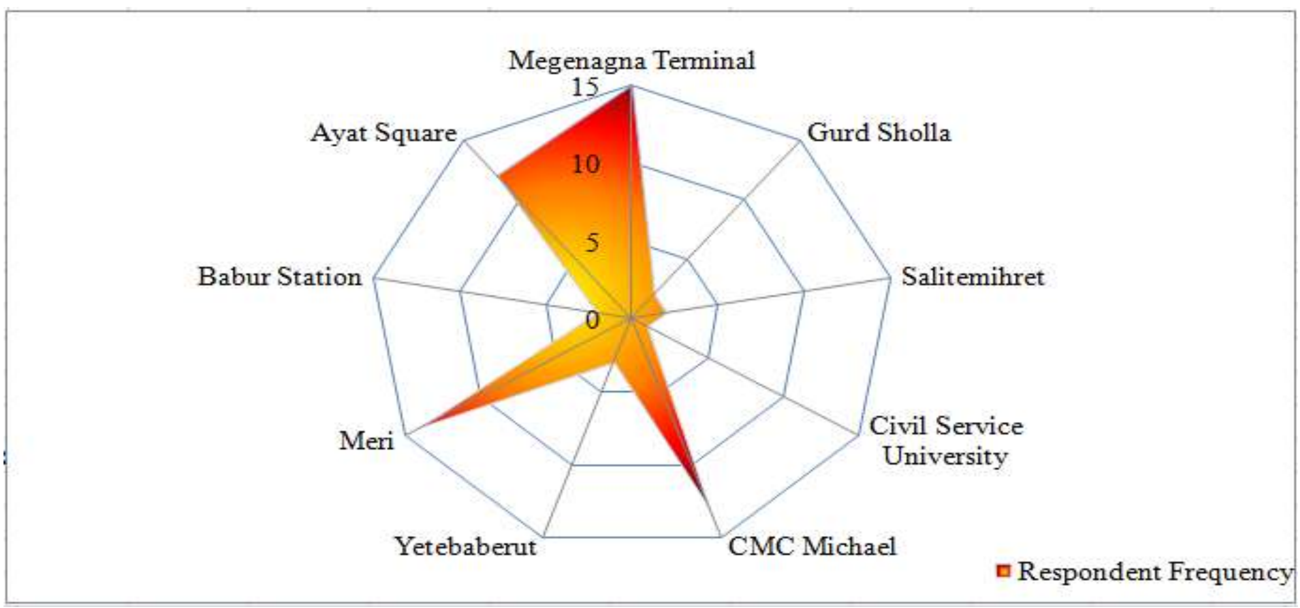
As shown in figure 4.34 above Ayat-Taffo interance is hazardous bus stop based on drivers point of view



Source: Compiled from questionnaires

Figure: 4.35 unsafe bus stops in Megenagna to YekaAbado route

As shown in figure 4.35 above Megenagna, Lamberet, Lamberet terminal Hillside School, Wesen Michael, and Wesen grocery were hazardous bus stops.



Source: Compiled from questionnaires

Figure: 4.36 Unsafe bus stops in Ayat to Mgenagna route

CHAPTER FIVE

Conclusion and Recommendations

5.1 Conclusion

In this project, road traffic accident hotspots/black spots and hazardous bus stops of the Yeka sub-city have been discussed. Using the Geographical Information System (GIS) black spot and the hazard bus stop was displayed on the crash locations map. Bus stops location points and fatal case accident points were the two essential spatial data used to interpolate this project output.

The statistical analysis of this study revealed that Traffic accidents were increased

time to time (2017- 2019) and recorded 156 fatal cases, 480 injury cases, and 8583 property damage cases in Yeka sub-city level. District 13, 9, and 12 hosted maximum numbers of fatal crashes. The result of the data indicated that 97 % of road traffic accidents were registered by male drivers whose age ranges between 20-30. Inapt use of steering which includes (steering to left, steering to the right) was the primary cause of RTAs. Driving with talking mobile, negligence of road users, failure to give priority, Unable to give pedestrian priority were the major contributing factors based on pedestrian and driver point of view. Most road traffic accidents have occurred in the afternoon especially afternoon peak hours 4:00 pm -7:00 pm. Taxis (Minibuses), Vitz/Yaris, and Isuzu were the frequent fatal accident cause vehicles.

Dangerous bus stops are ranked using the number of fatal case accidents in the vicinity. Bus-stop coverage was overlaid on the fatal accident concentration map to identify high-collision/hazardous bus stops. 30, 30- 50 meter and 100 buffer radius were generated to extract fatal accidents in the vicinity of high-collision bus stops. Hazardous bus stops were then ranked using hotspot concentration, kernel density, and collision frequency method.

The spatial clusters exist among traffic accidents at 90% confidence. Accordingly, FrensayKela, Megenagna, Wesen Grocery, Abarie, Kara Akababi, Yeka, Michael Church, and Gurd Shola were hotspot areas. The result shows that some bus stops are associated with extremely high severity indices, such as Kokebe Tsibah Left and Right Side, Lamberet Left and Right Side, Ayat-Tafo entrance, CMC St. Michael, Yeka Sub-city Administration Roundabout, and Ferencay BiretDildiy.

Moreover, the Questionnaire was disseminated in 4 major route lines (Megenagna –YekaAbado, Megenagna - Hayat Tsebel, Megenagna - FerencayGurara, and Hayat –Taffo). They confirmed that Megenagna, Ferencaykella, Ferencay biretdildiy, Megenagna, Sholla, Ayat-taffo, entrance,lamberet ,lamberet terminal, Wessen, Hillside school right side were unsafe bus sto

5.2 Recommendations

The primary input of such a project is highly dependent on spatial data(X, Y coordinates of accidents, and bus stop point data), but the data storage system of Addis Ababa and Yeka sub-city police commission was limited by attribute data. Hence, it is recommended to use a comprehensive (both spatial and non-spatial) database system which is useful to record and provide data in detail and in a specific manner. Primarily training should be provided to traffic police officers on how to collect XY coordinates using GPS to correctly record incidents locations. Ultimately, the data will be very helpful and easy to transport-related investigations.

This project has identified hazardous bus stops on a sub-city level (only Yeka sub-city). So the available concerned stakeholder, institutions, and governmental agencies/authorities such as TMA, AACRA, TPMO, and ATPMO should perform continuous investigation and assessment to relocate unsafe bus stops at the city level.

Special awareness creation programs should be organized especially for the drivers of ages from 20-30 which were frequently involved in RTAs.

Minibusses/Taxi and Vitz /Yaris were involved more frequently in RTAs than other vehicle types. Therefore, it is recommended that special inspection and media campaigns should be performed.

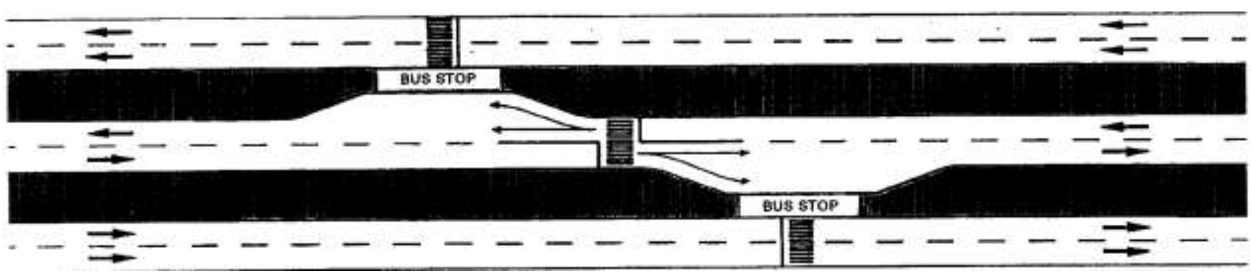
The traffic management agency should prepare hazard bus stop maps at the city level to regulate and create awareness.

Road crash injury is largely preventable and predictable; there are some common prone areas at the district level in which the prevalence of road casualties was higher. Those are districts 8, 9, and district 13, so special attention should be given to those districts with regard to RTAs campaigns.

To enhance a safer bus transit system. prioritization must be give for sensitive bus stops like Megenagna Terminal 1,2and 3, FerencayKela, Yeka Health Center, Lamberet Right, Ethio-China Left, Ethio-China Right, CMC St. Michael, Ayat-Tafo entrance.

Traffic behavior at bus stops is extremely complex; during the site visit, the researcher observed that most hazardous stops are constructed under on-line design and this has had a significant impact on congestion and accident occurrence. Hence, some improvements have been needed.

For example, Yeka Sub-city main gate bus stops are constructed under on-line(on the curb) configuration but it will be better if off-line configuration.



Off line bus stops are better in a high number of pedestrian sites like Megenagna.

The TMA controls and traffic polices should be tighten at identified hazardous bus stops and inspect its effectiveness.

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APPENDIXES

Bus stops data

No	X	Y	Bus Stop Name
1	478248	997120	Megenagna Terminal
2	478316	997084	Megenagna Terminal
3	478319	997092	Megenagna Terminal
4	478253	997128	Megenagna Terminal
5	478262	997143	Megenagna Terminal
6	478326	997100	Megenagna Terminal
7	474621	1000082	Janmeda Zero 5
8	475207	1001037	FerencayKela
9	475609	1001173	FerencayMazoriya
10	475859	1001413	BonoWuha
11	476806	1001754	FerencayBiretDildiy
12	475834	998640	KokebeTsibah Left Side
13	475854	998662	KokebeTsibah Right Side
14	476226	998410	Kenya Embassy
15	476349	998298	BiritshEmbasy
16	476776	998039	Abebe Shop
17	477073	997898	YekaSt. Michael Tsebel
18	477492	997652	Yeka Health Center
19	477415	997650	Sholla Federal Court
20	478032	997343	Yeka Sub-city Administration Roundabout
21	478265	997155	Megenagna Diaspora Square
22	478010	996984	MegenagnaBetelihem Plaza
23	477372	997204	Shola Gebaye
24	477629	996876	Lem Hotel
25	476906	996688	HayahuletTuristNigd
26	475929	996437	WehaLimatMirtZerDierijit
27	475984	497445	Adiwa Roundabout
28	476001	997451	Signal Condomnum Right
29	475998	997443	Signal Condomnum Left
30	476572	997318	Balderas
31	475231	997877	Abuare Roundabout Indian School
32	479743	997331	Lamberet Left
33	479747	997310	Lamberet Right
34	480104	997552	Lamberet Ararat Hotel

35	480239	997498	Lamberet Terminal Right
36	480240	997507	Lamberet Terminal left
37	481014	997737	Ethio-China Left
38	480999	997712	Ethio-China Right
39	481484	997947	Hilside School
40	482002	997961	Wesen Michael left
41	482154	997993	Wesen Michael right
42	482833	998479	Wesen Grocery
43	484004	998841	Abeam Hotel Left
44	484013	998827	Abeam Hotel Right
45	485633	1000170	AbadoSt.MichaelMesalemiya
46	486129	1001182	Abado Sara Ampol
47	486065	1001816	YekaAbadoMeskelegna
48	485243	1002165	YekaAbado G-7
49	486317	1002468	Yekaabado Project 13
50	480165	996996	Gurdsholla
51	481672	997282	Civilservice University
52	482439	997264	CMC St. Michael
53	483559	997202	CMC Yetebaberut
54	483937	997177	CMC Apartment
55	484676	997156	Meri
56	485436	997185	Ayat roundabout Apostholic Church
57	486177	997233	Hayat Train Station
58	486524	997241	Ayat roundabout Right
59	486440	997303	Ayat roundabout Left
60	487040	997279	AyatTsebelTebe Engineering building
61	488050	997319	AyatTsebel entrance
62	486439	997306	Ayat-Tafo entrance
63	486524	997241	TafoEdiget Chorea High School
64	486540	998218	TafoEdiget Chorea High School Left Side
65	486536	998738	TafoAbissinia Bank
66	486574	999058	Tafo Wereda13 Health Center
67	486540	999097	Tafo Wereda13 Health Center Right Side
68	486528	999525	TafoMebratHayil
69	486586	999964	TafoAndegnaBer
70	486534	999962	TafoAndegnaBer
71	486546	1000410	TafoArategnaBer
72	486546	1000357	TafoAmanuaelAndegnaBer

Fatal Accident Data

FID	ID	X	Y	Location_N	Accident	Year
1	5	475180.5	1001024	Frensay_Kela	6	2009
2	6	478191.2	997007.1	Megenagna	5	2009
3	8	483029.8	998576.7	Wesen_grocery	5	2009
4	9	475445.8	997637.6	Abarie	5	2009
5	18	485111.3	999360.3	Kara_akababi	4	2009
6	24	484657.8	997115.1	Meri	3	2009
7	25	480361.9	996926.2	Gurd_Sholla	3	2009
8	29	480873.9	997041.7	Salite_Mihret	3	2009
9	39	477635.9	997541.2	Yeka_Micheal	2	2009
10	43	476475.1	998238.6	English_Embassy	2	2009
11	46	475822.8	998685.8	Kokeb_Tsiba_Timhirt bet	2	2009
12	63	479822	997364.6	Lamberet	2	2009
13	70	485956	1001376	Yeka_Abado	2	2009
14	71	486223.5	1001249	Sara_Ampule	2	2009
15	72	475871.8	1000565	Frensay_Abo	2	2009
16	85	483499.7	998709.2	Sunshine_Menoriya	1	2009
17	87	486336.2	997201.5	Ayat	1	2009
18	102	475766.4	997432.9	Adew_Dildiye	1	2009
19	103	474776.8	1001910	Eyesus_Betekristian	1	2009
20	113	484019.6	999173.2	Karalo	1	2009
21	114	480275	997526.5	Lamberet_Menaheriya	1	2009
22	123	481461.9	999017.9	hana_mariam_Mewcha	1	2009
23	124	482388.5	999013.2	Kotebe_college	1	2009
24	129	478856.9	997204.5	Israel_Embassy	1	2009
25	139	481568	997272	Civil_Service	1	2009
26	146	476530	997116	Dinberua_Hospital	1	2009
27	148	478753.3	997081.4	Yared_Hospital	1	2009
28	154	477658.3	996892.8	Admas_University	1	2009
29	155	483584.5	999178.4	Koteb_Gebriel	1	2009
30	156	481615	997978.2	Hillside_Timhirt Bet	1	2009
31	170	474975	997168	Meles_Foundation	1	2009
32	174	483769.8	997166.2	Sumit_Roundabout	1	2009
33	2	479480.2	997036.6	Gurd_Shola	5	2010
34	9	482682.1	998402	Wossen_Grocery	4	2010
35	10	477701.3	997505.1	Yeka_Michael_Church	4	2010
36	15	486347	997207.6	Ayat_Adebabay	3	2010

37	33	480643	997622	Ethio_China_College	2	2010
38	36	474808.4	1000518	France_Embassy	2	2010
39	44	475816.5	998701.4	Kokebe_Tsiba_School	2	2010
40	55	477477	997649.6	Yeka_Tena_Tabiya	2	2010
41	57	478412.3	997021.5	Zerfeshewal_School	2	2010
42	58	481197	998435.9	02_Tena_Tabiya	1	2010
43	60	476015.3	996421.4	22_Mazoria_Cafe	1	2010
44	76	482514.8	997206.7	Altad	1	2010
45	87	485937.6	997177.8	Ayat_Babur_Tabiya	1	2010
46	88	487594	997292.5	Ayat_Bono_Wuha	1	2010
47	90	486574.3	999260.2	Ayat_Gebriel	1	2010
48	91	488189.9	997277.1	Ayat_Mekedonia	1	2010
49	92	485997.3	997182.5	Ayat_Menoria_Betoch	1	2010
50	102	476482	998232	British_Embassy	1	2010
51	107	482537.6	997233.9	CMC_Michael	1	2010
52	114	479725.1	997292.5	Elfora	1	2010
53	117	481122.3	997166.9	Ethiopian_Management_Institute	1	2010
54	118	475180.5	1001024	Ference_Kela	1	2010
55	119	474739.6	1000291	Ferenciy_Bridge	1	2010
56	125	476209.5	996501.2	Getahun_Besha_Building	1	2010
57	139	476835	1001766	Gurara_Adebabay	1	2010
58	143	481606.4	997976.7	Hillside_School	1	2010
59	144	483805.8	997385.1	ICMC_Hospital	1	2010
60	159	484752.6	999088.6	Kara_Daget	1	2010
61	171	482482	999026	Kotebe	1	2010
62	172	480997.7	997727.1	Kotebe_Awash_Bank	1	2010
63	173	483584.5	999178.4	Kotebe_Mesalemiya	1	2010
64	178	477527.9	996832.1	Lem_Hotel	1	2010
65	189	478195.7	997011.5	Megenagna	1	2010
66	194	484657.8	997115.1	Meri_Central_Hotel	1	2010
67	198	480808.7	997659.3	Mining_Minister	1	2010
68	202	474966.2	997154.6	Nigat_Kokeb_School	1	2010
69	203	482692.5	997201.3	Nile_Petrolum	1	2010
70	219	481812.5	997239.3	Salite_Mihret	1	2010
71	223	481364.1	997857.8	Science_and_Technology	1	2010
72	228	477470.1	997385.8	Shola_Gebeya	1	2010
73	236	486655.9	1001133	Tafo_Adebabay	1	2010
74	245	486203.7	1001241	Yeka_Abado_Condominium	1	2010
75	246	477701	997505	Yeka_Menafesha	1	2010
76	247	477352.3	997734.6	Yeka_Restaurant	1	2010

77	248	477984.1	997330.1	Yeka_Sub_City_Office	1	2010
78	250	479125.8	997082.8	Yerer_Hospital	1	2010
79	256	476038.5	996440.5	Zerihun_Building	1	2010
80	1	486103	1001914	YekaAbado	2	2011
81	2	486420	997295	Ayat	2	2011
82	3	483223	998658	Kara Sunshine	2	2011
83	4	481978	998672	Edir Mad Megbiya	1	2011
84	5	484790	999119	Kara	1	2011
85	6	480206	997523	Lamberet	1	2011
86	7	477092	997215	SumeyaMusque	2	2011
87	8	482879	998507	Wesen	2	2011
88	9	486017	1001910	AbadoCondomnium	1	2011
89	10	483308	998677	Sunshine	2	2011
90	11	478184	997190	Dispora Roundabout	1	2011
91	12	477601	997581	ShollaSt.Micheal	1	2011
92	13	481807	998053	Sunshine	1	2011
93	14	476757	1001765	Ferencay	1	2011
94	15	477264	997215	Sholla	1	2011
95	16	478264	997121	Megenagna	1	2011
96	17	485878	1000613	Zoble Park	1	2011
97	18	478295	998073	Bono Sefer	1	2011
98	19	482634	998376	Wesen	1	2011
99	20	474809	1000559	France Embassy	3	2011
100	21	477457	997202	Seaft driving trainning	1	2011
101	22	485771	1000381	YekaSt.Michael	1	2011
102	23	481465	999033	Zerohulet	1	2011
103	24	487904	997279	Ayat	1	2011
104	25	477474	997170	Seaft driving trainning	1	2011
105	26	475815	998693	KokebeTsibah	1	2011
106	27	474797	1000526	France Embassy	2	2011
107	28	485473	1002089	Abado	1	2011
108	29	484947	999446	Kara	1	2011
109	30	482456	997217	CMC St. Michael	1	2011
110	31	480922	997691	Laberet	1	2011
111	32	478123	998047	Bono Sefer	2	2011
112	33	485262	999476	Kara Begtera	1	2011
113	34	482015	998600	EdirMegbiya	1	2011
114	35	483784	998259	Legejila	1	2011
115	36	478073	997312	Megenagna	2	2011
116	37	474806	1000501	Ferencay Embassy	2	2011
117	38	480949	997079	SalisaSalitemihret	1	2011

118	39	476900	996993	TabotMaderiya	1	2011
119	40	475796	998689	KokebeTsibah	1	2011
120	41	480142	998715	KotebeKidanemihret	1	2011
121	42	486248	1001249	Gedera	1	2011
122	43	475982	999543	YekaWereda 03	1	2011
123	44	482796	999104	Kotebe College	1	2011
124	45	476146	996508	Lex Plaza	1	2011
125	46	486680	1001074	Tafo Roundabout	2	2011
126	47	484648	997142	Meri	1	2011
127	48	483435	998694	Kara	1	2011
128	49	476982	997234	SumeyaMusque	1	2011
129	50	483448	998699	Sunshine	2	2011
130	51	486268	1001238	Sara ampol	1	2011
131	52	486538	1001163	Tafo Roundabout	1	2011
132	53	486953	997222	Ayat	1	2011
133	54	482572	997241	CMC St. Michael	2	2011
134	55	477644	997543	Kara St.Michael	1	2011
135	56	476488	998239	Britsh Embassy	1	2011
136	57	478218	998049	Bono Sefer	1	2011
137	58	479781	997341	Lamberet terminal	1	2011
138	59	481586	997967	Hillside School	1	2011
139	60	487622	997294	Ayatbonowuha	1	2011