ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

ASSESSMENT OF DRIVERS' COMPREHENSION OF TRAFFIC CONTROL DEVICES (THE CASE OF ADDIS ABABA)

BY TOLESSA GUDETA BEDADA

A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for Degree of Masters of Science in Civil Engineering (Road and Transportation Engineering)

Advisor: Bikila Teklu Wodajo (PhD)

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M.Sc. Thesis on

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DECLARATION

I declare that this thesis entitled "ASSESSMENT OF DRIVERS' COMPREHENSION OF TRAFFIC CONTROL DEVICES (THE CASE OF ADDIS ABABA)" is my original work. This thesis has not been presented elsewhere for assessment and award of any degree or diploma, and all sources of material used for the thesis have been duly acknowledged.

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ABSTRACT

Traffic control devices provide essential information to road users for their safe and efficient maneuvering on the road. The driving behavior of drivers in Addis Ababa City is rarely in compliance with the traffic control devices. There is no literature on drivers' compliance towards traffic control devices in Addis Ababa city. The main objective of this research is to identify which drivers' personal characteristics played prominent roles in drivers' understanding of traffic control devices and to investigate the driver compliance to signalize and two-way stop control intersections. To study driver's comprehension of traffic control devices in Addis Ababa, Churchill to Stadium segment and Semien Mezagjah TWSC intersection were selected. They consisted of four traffic signalized intersections namely Eliana, Tracon, EBC, and Harambe, and also have speed limit sign, No entry, road marking, No parking sign, No U-turn sign, and No left turn. Data collection was done using a questionnaire and video recordings. 385 drivers were interviewed to determine factors affects driver's compliance of traffic control devices and video recording of four traffic signalized intersection and one two-way stop-controlled intersection at peak hours on Tuesday and Wednesday in the morning and afternoon to determine the correlation between traffic volume and violation rate of signalized intersections. Chi-square test was used to identify factors affecting driver's compliance of traffic control devices while Correlation analysis was used to describe the relationship between traffic volume and violation rate at the signalized intersection. Gender, age, educational background, driving experience, and type of vehicle driven were found as dominant factors affecting drivers' comprehension of traffic control devices. All variables were found statistically significant at 95% of significance to predict driver's compliance with traffic control devices. Correlation analysis suggests that right turn on red (no stop) violation rate and right turn volume are correlated positively (r=0.905). This indicates that as of right turn volume increases, the right turn on red (no stop) violation rate increases. Running on red light rate and through, left-turn traffic volume, total violation rate and total traffic volume were found negatively correlated with r=-0.74 and r=-0.841 respectively. This indicates that as of traffic volume increases, the violation rate decreases. In addition, reasons for noncompliance with traffic control devices are most likely related to the personal reason of drivers.

Key words: Compliance, Traffic control device, Chi-square, Right turn on red, Peak hours.

LIST OF ABBREVIATIONS

ADT-Average Daily Traffic

AADT-Average Annual Daily Traffic

AM-After Meridian

Df-Degree of freedom

EBC-Ethiopian Broad Casting Corporation

ECA-Economic Commission for Africa

FHA-Federal Highway Administration

G.C-Gregorian Calendar

GNP-Gross National Product

MUTCD-Manual of Uniform Traffic Control Device

PM-Post Meridian

r- Correlation Coefficient

RNOR-Right Running on Red

RTOR-Right Turn on Red

RTVOL-Right Turn Volume

SPSS- Statistical Package for Social Science

THLTVOL-Through and Left Turn Volume

TOTVIOL-Total Violation

TOTVOL-Total Volume

TWSC-Two-way Stop-controlled

UNECA- United Nations Economic Commission for Africa

CHAPTER ONE

INTRODUCTION

1.1 Background

Traffic control devices are a vital element of the highway environment. They are important for traffic safety on the highway. They provide information about the highway to road users, so they can operate their daily life safely along a highway or street. Traffic control devices include a sign, signal, marking, or other device used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, private road open to pedestrian facility, public travel or shared-use path by authority of a public agency or official having jurisdiction, or, in the case of a private road open to public travel, by authority of the private owner or official having jurisdiction. Traffic control devices at and in advance of intersections are of remarkable importance. Enough traffic signing and marking must be provided to give the user important information but not so much as to distract the user, thereby negatively affecting safety. Drivers are limited in their ability to read and understand information on traffic signs as a function of their speed and the amount of time to view and process the information on signs; information on signs beyond that limit is simply not read(FHA 2009).

According to MUTCD (2009) there are five basic criteria of traffic control devices; fulfill a need, command attention, convey a clear, simple meaning, command respect from road users, and give adequate time for response. Traffic signs, traffic signals, and pavement markings are designed with dedicated colors, shapes, and sizes based on the different functions they perform. They regulate, guide, and warn road users about road conditions. Uniformity of design helps drivers to understand quickly the messages of traffic control devices. Consistency is important for driver attention, visualization, respect, and recognition and for proper reaction to the devices.

Drivers are often in situations where there is a great deal of potential information in the roadway environment. It is not possible to fully attend to and process all this information. The driver must be able to glance at the traffic control devices and determine rapidly whether the information is relevant and should be retained and acted upon. Depending on driver needs and driving conditions, all devices are possible sources of relevant information, so the driver must first take in, and process the information at a deep level before it can be decided whether it is relevant.

This takes time and a level of mental thinking that may not be available to the driver under conditions of high information load or stress. The appropriate action to be taken should not require a significant amount of thinking and time of deciding, especially if the action must be taken quickly e.g. yield to oncoming traffic or turn within a very short distance onto a cross street (Dewar et al.1997).

Compliance in road safety is the act of respect to rules guiding the usage of the roads by road users. The main objectives of these rules are; to avoid conflicts among road users; prevent events that are undesirable to the road users; and mitigate the effects of the undesirable event (Southgate, and Mirrlees-Black 19991;Zaal 1994). A high compliance rate will lead to improving road safety which will, in turn, minimize the destruction of human and material resources required for economic growth and development.

Traffic control device's comprehension is critical for effective driving, responses to warnings, and way-finding. While a lot of research effort was undertaken in the world, there has been no study to assess the driver's comprehension of traffic control devices in Ethiopia has been reported to date. This paper investigated the efficiency of the traffic control devices in Addis Ababa along Churchill to the Stadium by measuring their comprehension by the driver population-based on using direct observation/video survey and questionnaires the survey distributed to a sample of drivers representing various socio-demographic groups in Addis Ababa.

1.2 Statement of the Problem

Traffic has been one of the most important parts of our daily lives as people spend more time in traffic thereby forcing drivers and other road users to face a higher risk of the traffic accident. The economic burden of road crashes has been put at between one and three percent of the Gross National Product (WHO 2011).

The United Nations Economic Commission for Africa (UNECA 2009) report also showed that Ethiopia has one of the world's worst crash records with 170 fatalities per 10,000 vehicles. The UNECA (2009) report showed that, despite having a very low road network density and vehicle ownership, the country (Ethiopia) has been cited as the worst example in road crash.

High road traffic crashes statistics in Addis Ababa are attributed to different complex risk factors such as driver and pedestrian behavior, traffic rules and regulations, and vehicle and road conditions. The Ministry of Infrastructure, Roads Authority (2005) report showed that problems related to the road itself were only responsible for about 1 to 3 percent while the largest crashes were attributed to driver error, which accounted for 81 percent. Similarly, Tesema et al. (2005) in their study of road traffic crashes in Ethiopia reported that about 81 percent of the road traffic crashes countrywide are due to driver errors.

A general analysis of the cause of traffic accidents shows that majority is due to the driver's mistakes and traffic violations. Noncompliance problem appears to be concentrated in specific situations and/or with specific traffic control devices; exceeding the posted speed limit, not stopping at stop signs, not stopping at the right turn on red locations, violating the red signal, violating active railroad grade crossing signals, violating left-turn lane signals, traveling too fast for conditions, i.e., work zones (Pietrucha et al. 1989).

One major factor affecting safe driving is the comprehensibility of traffic control devices by drivers (Yakut 2006). However, it is worthy to note that the traffic control devices cannot serve their intended purposes effectively if the information encoded in the devices is not properly understood by the driver. The increased numbers of traffic control devices cause more confusion and misunderstanding of these devices and this might increase the number of traffic accidents (Al-omari et al. 2011).

Confusion, misunderstanding and lack of familiarity with traffic control devices may be attributed to the increasing age of the driving population, increasing the complexity of the driving task in urban areas, specialized traffic control devices utilized with priority transportation facilities, a limited explanation of traffic control devices a given in the driver education and licensing process and non-uniform and non-standard use of some traffic control devices (Womack et al. 1993).

Despite is fact, there has been no assessment made on the comprehension of traffic control devices among drivers in the Addis Ababa city. Hence, this noncompliance of drivers with traffic control devices increases the chance of occurrence of traffic crashes. This research is therefore motivated by the research gap on the areas and focuses on the way of the drivers understanding and compliance of traffic control devices.

1.3 Research Questions

This research conducted to answer the following questions.

- Does a driver's level of education have an influence on his comprehensibility of traffic control devices?
- Does the age and number of years driven have an influence on the traffic control devices comprehensibility?
- What is the main reason for the driver's noncompliance towards traffic control devices?
- Does driver non-compliance with traffic control devices is a significant problem?

1.4 Research Objectives

1.4.1 General Objective

The goal of this study is to investigate the level of understanding and compliance of traffic control devices among drivers with different socio-demographic characteristics in Addis Ababa.

1.4.2 Specific Objectives

The research has the following specific objectives:

- To identify which drivers' personal characteristics played prominent roles in drivers' non-compliance of traffic control devices,
- To investigate the driver compliance to traffic control devices at signalized and two-way stop control intersection,
- To identify the correlation between traffic signal vehicle volume and violation rate.

1.5 Scope of the Study

Because of different type and number of the traffic control device in Addis Ababa city, the study area of this research is Addis Ababa city. Due to budget and time constraints, a simple random approach has been followed to analyze the driver's comprehension of a traffic control device in the city. As a result, the research focuses on traffic control device found along Churchill to Stadium segment and TWSC intersection located at Semein Mezagjah and the scope of this research is limited to this area.

1.6 Limitation of the Research

This research has the following limitations;

- Difficulty to get traffic police for interviewing because they were engaged in different tasks,
- During data collection around some secured intersections they were challenges to get permissions from authorities to record a video,
- The researcher spends most of the time to extract video data by manual technique due to lack of software this affects the quality of data.

1.7 Significance of the Study

This study concerned with the assessment of traffic control device understanding among drivers in Addis Ababa. Emphasis should be given to examining, identifying and analyzing the effects of personal characteristics of drivers on understanding of traffic control device and level of compliance to traffic control devices. Therefore, the study may be significant for the following reasons.

- The study may be having some paramount importance to the government and authorities at the future to improved drivers' license exam and modification of traffic control device which confusing to drivers.
- Even though the study is foreseen to a very specific area in the country the results to be obtained from this research may be helpful to authorities devote special effort to improve drivers' comprehension of a traffic control device.
- The outcome from the study may be helpful to gain valuable data and information about the traffic control devices understanding among drivers within personal characteristics and to propose design solutions to improve the traffic safety solution in these locations.

1.8 Structure of the thesis

This study is comprised of five chapters.

Chapter one gives a brief overview of the general background of the study, statement of the problem, research question, general and specific objectives of the study, scope of the study, limitation of the research, significance of the study and structure of the thesis.

Chapter two deals with the literature review of relevant and important concepts of the traffic control device, classification of the traffic control device, characteristics of the traffic control device, problems with the traffic control device placement and installation, driver age, driving experience, driver compliance at stop signs, red signal and right turn on red (no stop).

Chapter three describes research methods, materials, and procedures including description of the study area, population, sample size determination, way of data collection, and procedure, data description, variables of the study, and methods of analysis.

Chapter four gives results and discussions of the results of the study

Chapter five deals with conclusions and recommendations. In this chapter the findings of this study were concluded.

CHAPTER TWO
LITERATURE REVIEW

2.1 Definition of Traffic Control Devices

Traffic control devices are one of the important features on a highway; it shows direction and gives the location of where you are, and what is ahead of you. They have clear and concise meanings. Signs, signals, pavement markings and other traffic control devices placed along highways and streets to move vehicles and pedestrians safely and efficiently. They are installed in key locations to guide traffic movement, control vehicle speeds and warn of potentially hazardous conditions. They also provide important information to drivers about detours and traffic delays (Federal Highway Administration safety 2004).

2.2 Classification of Traffic Control Devices

Traffic control devices are grouped into three categories. These are traffic signs, traffic signals, and roadway markings. A description of each categories can be found in the sections that follow.

2.2.1 Traffic signs

A traffic sign is any traffic control device that is intended to communicate specific information to road users through a word, symbol, and/or arrow legend. They do not include highway traffic signals, pavement markings, delineators, or channelization devices (MUTCD 2009). They shall be defined by their function as follows:

2.2.1.1 Regulatory signs

These signs give notice of traffic laws or regulations. They include the STOP sign, GIVE WAY etc, basically signs that assign the right of passage to merging roads or interceptions. The regulatory sign shall be installed at or near where the regulations apply. The regulatory sign shall clearly indicate the requirements imposed by the regulations and shall be designed and installed to provide adequate visibility and legibility in order to obtain the compliance (MUTCD 2009).

The drivers expected to be aware of many traffic regulations, such as the basic right of way at the intersections, and the state speed limit. Signs, however, should be used in all cases where the driver cannot expect to know the applicable regulation. Except for some special signs such as the stop and yield most regulatory signs are rectangular with the long dimension vertical. Some regulatory signs are square. These are primarily signs using a symbol instead of legend to impart information. The use of symbol signs generally conforms to international practices established at the 1971 United Nations conference on traffic safety. The background color of regulatory signs within a few exceptions is white while legends or symbols are black. In symbol signs, a red circle with a bar through it signifies prohibition of the movement indicated by the symbol (Roses, Prassas and Mcshane Third Edition).

2.2.1.2 Warning signs

Warning signs call attention to sudden condition on or an adjacent to a highway or street and to the situation that might not be readily apparent to road users. They alert road user to the conditions that might call for a reduced speed or an action in the interest of safety and efficient traffic operations (MUTCD 2009).

Most warning signs are diamond-shaped, with black lettering or symbols on a yellow background. A rectangular shape used for some arrow indications. A circular shape is used for railroad crossing warnings. The MUTCD specifies minimum sizes for various warning signs on different types of facilities.

The MUTCD indicates that warning sign shall be used only in the conjunction within an engineering study or based on the engineering judgment. While this is a fairly loose requirement, it emphasizes the need to avoid the over-use of such signs. Warning signs should be only to alert drivers conditions that they could be normally expected to discern on their own. When used warning must be placed far enough in advance of the hazard to allow drivers adequate time to perform the required adjustments. These signs generally provide information to drivers about impending conditions on the road. Thus, these signs seek to provide forehand advice about approaching conditions for drivers to prepare themselves vigilantly to respond adequately to the condition.

2.2.1.3 Guide (informatory) signs

The informatory signs show and inform route designations, destinations, directions, distances, services, and points of interest to the road users. They serve a unique purpose in that drivers who are familiar or regular users of a route will generally not need to use them; they provide critical information, however, to unfamiliar road users. They serve a vital safety function: a confused driver approaching a junction or other decision point is a distinct hazard (Roses, Prassas and Mcshane Third Edition).

The MUTCD provides guide-signing information for three types of facilities: conventional roads, freeways, and expressways. Guide signing is somewhat different from other types in that overuse is generally not a serious issue, unless it leads to confusion. Clarity and consistency of message is the most important aspect of informatory signing. Several general principles may be applied:

- If a route services a number of destinations, the most important of these should be listed.
- No guide sign should list more than three (four may be acceptable in some circumstances) destinations on a single sign. This, in conjunction with the first principle, makes the selection of priority destinations a critical part of effective guide signing.
- Where roadways have both a name and a route number, both should be indicated on the sign if space permits. In cases where only one may be listed, the route number takes precedence.
- Wherever possible, advance signing of important junctions should be given. This is more difficult on conventional highways, where junctions may be frequent and closely spaced. On freeways and expressways, this is critical, as high approach speeds make advance knowledge of upcoming junctions a significant safety issue.
- Confusion on the part of the driver must be avoided at all costs. Sign sequencing should be logical and should naturally lead the driver to the desired route selections.

2.2.2 Traffic signals

Traffic Signals are any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed (MUTCD 2009). The message in traffic signals is relayed through the use of colors, therefore, the meaning of the colors have been standardized.

The MUTCD defines nine types of traffic signals:

- Traffic control signals
- Emergency vehicle traffic control signals

- Traffic control signals for one-lane, two-way
- Traffic control signals for freeway entrance
- Traffic control signals for moveable bridges
- Lane-use control signals
- Flashing beacons
- In-roadway lights

The most common of these is the traffic control signal, used at busy intersections to direct traffic to alternately stop and move. Traffic control signals are valuable devices for the control of vehicular and pedestrian traffic when properly used. They assign the right-of-way to the various traffic movements and influence traffic flow. According to MUCTD (2009) traffic control signals that are properly designed, located, operated, and maintained will have one or more of the following advantages:

- They provide for the orderly movement of traffic.
- They increase the traffic-handling capacity of the intersection
- They reduce the frequency and the severity of certain types of crashes, especially right-angle collisions.
- They are coordinated to provide for continuous or nearly continuous movement of traffic at a definite speed along a given route under favorable conditions.
- They are used to interrupt heavy traffic at intervals to permit other traffic, vehicular or pedestrian, to cross.

2.2.3 Roadway markings

Markings on highways open to public travel have important functions in providing guidance and information for the road user. Major marking types include pavement and curb markings, delineators, colored pavements, islands, and channelizing devices. In some cases, markings are used to supplement other traffic control devices such as signals, signs, and other markings. In other instances, markings are used alone to effectively convey guidance, regulations, or warnings in ways not obtainable by the use of other devices. Roadway markings have limitations. Visibility of the markings can be limited by debris, snow, and water on or adjacent to the markings. Marking durability is affected by material characteristics, traffic volumes, location, and weather. However, under most highway conditions, markings provide important information while allowing minimal diversion of attention from the roadway (MUTCD 2009).

They serve a variety of purposes and functions and fall into three broad categories:

- Longitudinal markings
- Transverse markings
- Object markers and delineators

Transverse and longitudinal markings are applied to the roadway surface using a variety of materials, the most common of which is paint and thermoplastic. Reflectorizing for better night vision is achieved by mixing tiny glass beads in the paint or by applying a thin layer of glass beads over the wet pavement marking as it is placed. The latter provides high initial Reflectorizing, but the top layer of glass beads is more quickly worn. Object delineators and markers are small objects mounted reflectors. Delineators are small reflectors mounted on lightweight posts and when standard markings are not visible they are used as roadside markers to help drivers in proper positioning during inclement weather (Roses, Prassas and Mcshane Third Edition).

2.3 Characteristics of Uniform Traffic Control Devices

According to FHA (2000) traffic control devices have different characteristics;

I. Color:-Certain colors are used to trigger instant recognition and reaction; for example, STOP signs are always red. Similarly, signals at intersections must have the same sequence of red/yellow/green to communication stop/warning/go to drivers and pedestrians.

II. Night time visibility:-Traffic control devices are made visible under nighttime operating conditions by either being separately lighted or retro-reflectorized so that the light coming from vehicle headlamps is bounced off signs and other devices back to the eyes of drivers.

III. Daytime visibility:-Traffic control devices are designed with highly visible colors or a sharp contrast of messages against a background. Sometimes traffic control devices are lighted even for daytime viewing to draw the attention of drivers to their messages.

IV. Shape and size:-Signs have standard shapes and sizes to trigger instant recognition and reaction. For example, STOP signs have an octagonal shape of a particular size that no other sign is permitted to have. There are similar specifications for the shapes and sizes of many other traffic control devices for both permanent and temporary conditions.

V. Location:-Traffic control devices must be placed in locations that provide enough time for all drivers to make the appropriate safe maneuvers, such as entering or departing a road or stopping and turning to avoid conflicts with other vehicles and pedestrians.

2.4 Problems with Traffic Control Device, Placement and Installation

According to the FHA (2004) the main problems with the traffic control device, placement, and installation as follows:-

I. Use of an improper device:-Placing a yield sign where a stop sign is needed will result in an adequate amount of time and distance for drivers to react to another vehicle or pedestrian.

II. Improper placement:-A traffic control device at the wrong location may result in the device being seen too late by drivers to safely react (e.g., placing a properly designed sign too far around the bend of a sharp curve).

III. Wrong size:-Using a small warning or information sign may result in the inability of drivers to detect and comprehend the need to make safe maneuvers.

IV. Wrong color:-Using yellow or some other color for lane lines instead of white.

V. Wrong shape:-Using a diamond warning shape for a traffic regulation.

VI. Excessive installation of specific devices that often results in increasing driver disregard of their important messages.

VII. Failure to use traffic control devices at necessary locations. Traffic signs that may have controlled the movement of vehicles and pedestrians for years may no longer be effective in doing so.

VIII. Failure to warn or notify drivers and pedestrians of unexpected, potentially hazardous conditions. Neglecting to provide advance warning of an upcoming signal or stop sign over the top of a steep hill can result in inappropriate braking and steering maneuvers that result the collision are important messages.

2.5 Drivers Behavior

Several studies have attempted to use accident analyses to establish the relative importance of vehicle, road, and human factors as causes in road accidents. As it has been discussed worldwide studies such as those of the Organization of Economic Co-operation and Development, show that about 80-90% of the road traffic accidents are attributed to the fault of the driver. The United States Department of Transportation also reported that over 75% of vehicle crashes can be attributed to some type of human error (Hankey et al. 1999). The results clearly indicate the human element as the main cause. But an analysis of the road traffic process and its development in a historical perspective indicates that the question and consequently also the answer is improper. It is normally not the failure of a component but the failure of a system interaction that causes accidents. However, the problem remains also with the systems approach - how to decrease human errors in traffic. The common denominator of human mistakes seems to be lack of adequate information - from the road, the road environment, other road users and the vehicle.

Rumar (1982) noted that the information available in traffic is analyzed both from the point of view of the road user and the road and traffic engineer .Two factors govern why motorists observe or ignore Traffic control devices: the perceived reasonableness of the Traffic control devices and the perceived risk of punishment for violations. In assessing the strategy of driving, two main types of behavior were observed: adapting to traffic needs and expressing psychodynamic needs (Versace 1967).

Human error in driving can be broken down into four categories: slips, lapses, mistakes, and violations. Slips occur when a driver misreads a sign or turns on the headlights when trying to activate the wiper blades. Lapses happen when the driver has no clear recollection of the road just traveled. Mistakes might be underestimating the speed of an oncoming vehicle when overtaking or using the wrong lane in a roundabout. Violations are further separated into two sub-categories: unintended and deliberate. Unintended violations might include unknowingly speeding or forgetting to change the sticker on a license plate. Deliberate violations occur when driver emotions are involved, as in a race or impatience with slower drivers (Reason et al. 1990).

Reason et al. (1990) defined violations as deliberate (not necessarily reprehensible) deviations from the practices believed necessary to maintain safe operation of a potentially hazardous system.

Reason et al. (1990) also argues that people may error without violation and, reciprocally, may perform a violation that is not an error. Drivers will have their own interpretation of what is safe or unsafe, comfortable or uncomfortable, etc. for any given set of roadway conditions. These errors and violations are of high interest due to their likely cause of or influence on roadway crashes and/or safety issues. Based on a 50-item driver behavior questionnaire given to 500 subjects, the most significant violation, in terms of frequency, was unknowingly speeding. This is classified as an unintentional violation that poses a possible risk to others. This high frequency supports the argument that roadside signage may not be commanding the attention of drivers, calling for actions to improve the communication of that information.

Drivers adapt to traffic needs, such as complying with speed limits, to the extent they consider worthwhile and risk-free. Driving behavior is also gauged according to the psychodynamic needs of the moment. Drivers have been studied in a social context as well. Interviews were conducted to determine reactions to common driving situations. The behavior of other drivers was seen as a potential cause of danger in traffic: it appeared to markedly affect psychological reactions of motorists while driving. These results suggest that driving performance is not based solely on the physical environment, but also involves reactions to attitudes and motives that are inferred to exist in other drivers. Thus, it was concluded that driver education for deficient drivers could probably benefit from the application of social psychology theory (Knapper, and Cropley 1978).

2.6 Drivers Age

Some studies have been found that age does not affect comprehension of traffic control devices and even where there is some impact, there is no consensus concerning the trend of the impact. According to Hawkin et al. (1993) misunderstanding of over two-thirds of the signs that they tested were not related to age. The study by Ng and Chan (2008) stated that no significant differences among three age groups (18-27 years; 28-37 years; 38-57 years) in comprehension performance were observed in a survey done.

Some studies have shown that young drivers have an advantage in understanding traffic control devices. For example, Dewar et al. (1994) found that approximately thirty-nine percent of United State traffic control devices were better understood by young drivers both before and after modifications to some of the symbols. Possible reasons for the better compliance towards traffic control devices of younger drivers include: they may have passed the driving test relatively recently so they should have a fresh memory of the meanings of the traffic control devices; also, young people have generally better information processing capabilities as well as a better vision than old drivers (Vallesi et al. 2009). Hulbert et al. (1979) studied the understanding that over 3000 drivers had eight traffic signs in the U.S. and concluded that there were significant differences in comprehension among different age groups: comprehension level was 70% on average for young drivers (under 24 years), 79% for middle-aged drivers (between 24 and 50 years old) and 72% for the old group (over 50 years).

In Addis Ababa driver's in the age group, between18-30 are responsible for 39, 36, 27 and 32 percent of the fatal, serious, and slight and damage to property respectively during the specified period. Whereas those in the age group 31-50 had contributed 38,38, 27 and 42 percent of the fatal, serious, slight and damage to property respectively (Asrat 2015).

In summary, clear differences exist between different researcher regarding age-influence on driver understanding capabilities of traffic signs probably because of the differences in types of traffic control devices used, study methods, samples, definitions, and limitations.

2.7 Driving Experience

Some studies have used a definition from Simpson (2003), that driving experience can be taken as a number of years licensed. Study by Al-Madani (2002) reported that there was a small increasing trend of traffic control devices comprehension with years of driving and those with at least two decades of experience performed significantly better than those with at most five years of experience. However, as there might be a high correlation between experience and age, the effect of experience with age constraint involved was further explored in a follow-up. They only explored one age group and the results showed that experience had no significant influence when drivers were forty-five or older.

Ng and Chan (2008) proposed that actual years of active driving and hours of driving in the 12 months prior to the study should be additional measurement for driving experience, as there were situations where licensed drivers rarely drove after obtaining a driving license. Using the three different indicators, they concluded that comprehension level was not related to the factors of years of active driving and hours of driving in the past twelve months, but was found to be negatively relationships with years licensed.

2.8 Driver's compliance

The noncompliance problem appears to be within specific traffic control devices which are exceeding the posted speed limit, not stopping at STOP signs, not stopping at right turn on red (RTOR) locations and violating the red signal, violating left-turn lane signals, traveling too fast for conditions, i.e., work zones.

2.8.1 Not stopping at STOP signs

The options available for at-grade intersection control range from the right-of-way rule for extremely low volume of traffic to computerized signals for extremely high volumes of traffic. The majority of intersections that fall between these extremes use stop-sign control on the minor roadway. Low-volume intersections at which there is up to 500 averages daily traffic on at least one intersecting roadway account for literally millions of stop-controlled locations (Glennon 1978).

Traffic engineers apparently categorize behavior into four types. The first two comprise legal stops; voluntary full Stop which is stopping when there is no conflicting traffic, as distinguished from Stopped by Traffic. The other two would be illegal; Almost Stopped, and Non-Stopping (Box and Oppenlander 1976). There was much in the Behavioral / Social Sciences literature on this Feest (1968), Lebbon (2007), McKevlie (1986) and Trinkaus (1997) observed a voluntary full stop rate of only 15%, 4.6%, 24.1%, and 1% respectively. Voluntary full stop means fully stopped other than being stopped in order to yield to any other traffic.

Compliance (a full stop, whether you need to or not) is high when there is a lot of conflicting traffics, and low when there is little traffic. And in addition, if the sightline is good, compliance is lower. The results from 2830 observations at 66 intersections indicated that the violation rate decreases with increasing major-roadway volume and is significantly high ($p < 0.001$) up to the average-daily-traffic (ADT) level of 2000 and significantly low ($p < 0.001$) above the ADT level of 5000-6000. An interaction effect between minor-roadway sight distance and major-roadway volume results in a violation rate that is significantly higher ($P < 0.05$) when sight distance is unrestricted than it is when sight is restricted **(**Mounce 1981).

Several studies have documented low compliance at stop signs, characterized by failure to stop or to look adequately for oncoming traffic (McKelvie 1986; Pietrucha et al. 1989). A study by (Treat et al. 1979) stated that improper lookout to be the leading cause of crashes, accounting for nearly one-fourth of all investigated vehicle collisions. Carstens (1983) reported that improvements in stop sign visibility and installation of rumble strips at stop signs were not associated with crash reductions. Thus, although the ability of drivers to see stop signs is important, it is apparently not a major factor influencing driver behavior.

According to MUTCD stop sign is only tangentially related to the issue at hand, there is a lot of controversy about placing so-called unnecessary stops (e.g. placing stops on the busier road, or adding extra all-way stops). MUTCD guidance states flatly "STOP signs should not be used for speed control."

From literature, the general conclusion is that compliance isn't the problem, driver-error is. In short, the results of many previous studies suggest that accidents at two-way stop controlled intersections are more closely related to driver error, such as failure to accurately judge the speed of major roadway vehicles, than to roadway geometry, sight distance and driver compliance with traffic control devices (Stokes 2000).

2.8.2 Violating the red signal

In a signalized intersection the purpose of the amber interval is to alert approaching drivers that they will no longer have priority to cross the intersection. During this amber interval, they should either stop or clear the intersection. Crossing the stop line with a red light on is considered a serious traffic violation which might cause the most severe accidents. However, it is common practice for many drivers to cross a highway intersection at the beginning of the red light interval. The principal reasons for this obviously offensive and dangerous behavior are the avoidance of the discomfort caused by the deceleration due to braking action and by the subsequent loss of time and impetus, in conjunction with the very low probability, as all drivers are convinced that an accident would occur to them (Alexandros et al.1997).

The problem of poor driver compliance with traffic light signals was examined in terms of drivers who traverse the stop line after the termination of the yellow signal interval (red-runners) (Hulscher 1984). The data confirm that (red-running) is a significant motorist compliance problem, and its incidence is increasing because the deterrent effects of accident risk and penalty severity are low. It was concluded that a high level of police surveillance increases the perceived probability of detection, which is an effective deterrent**.**

Researchers concluded that driver observance of red signals should be improved by appropriate changes to signal timing, particularly the change interval (Hulscher et al. 1984). It was suggested that the most promising long-term countermeasure lies in a change of societal attitudes toward motivation, which is the primary factor influencing drivers' behavior (Hulscher et al.1984).

In the study regarding RTOR at twelve intersections referenced, it was found that 0.52 percent of the left-turning and straight-through vehicles observed run the red signal, more frequently at higher volume intersections and during peak traffic periods(Gordon 1987). In another study, many motorists were observed to violate a traffic signal with red, yellow, and green arrow right-turn controls if no serious "vehicular conflict" was obvious (Kraft et al 1973). In general, studies of driver behavior at signalized intersections have shown that increased enforcement leads to increased compliance. The presence of surveillance reduces the incidence of unsafe driver behavior.

Research showed that intensified police surveillance at signalized intersections led to more cautious driving (Gunnarson 1972). During periods of po1ice surveillance, average speeds dropped at 115 feet (35 meters) before the stop line for stopping drivers. Traffic signal violations dropped from 23 percent to 9.2 percent of the number of vehicles which were at 131-328 feet (40-100 meters) from the stop line when the signals changed to green-amber.

2.8.3 Not stopping at right turn on red (RTOR)

The right turn on red is a maneuver that allows a motorist who is facing a red light to turn right, unless specifically prohibited, after stopping and yielding to pedestrians, cyclists and cross-traffic. This definition does not include special phases that allow vehicles to turn right on a green arrow or with an exclusive right-turning bay (Dominique Lord 2002).

Factors which support the use of right turn on red are as follows: (Seward Cross)

- Prevents delay which is irritating to the motorist.
- Expedites the flow of traffic, thereby increasing intersection volume capacity and reducing congestion.
- Is not significantly hazardous, since accidents which involve vehicles turning right against the red signal comprise a small percentage of total accidents at signalized intersections.
- There occurs along major arterial routes with traffic signal progression in operation, the opportunity for vehicles turning right from the various side streets against a red signal indication to enter immediately into the green band of the main street progression.

In a Baumgaertner (1981) study, it was found that 64 percent of the vehicles observed did not come to a full stop before turning right on red; 2% of those did so unsafely. During the one year period following the implementation of RTOR in which the study was conducted, the percentage of non-stoppers rose from 47 percent to 70 percent. These results were compared with those found in a Virginia Highway Research Council study using similar procedures. In that study of 15 locations one month after the advent of RTOR, the compliance rate was found to be 3 percent. Also, in a study of 13 locations where RTOR had been allowed for a year or more, the rate was found to be 9 percent. RTOR behavior at 12 intersections in the Washington, D.C. metropolitan area was studied in 1987. For all right-turning vehicles, 7.6 percent were RTOR where the vehicle did not come to a full stop. The results of this study also indicated that this violation occurs more in off-peak traffic periods and the incidence is greater at low-volume approach legs (Gordon 1987).

2.9 Research Gap

There is no scientific literature identifying which drivers' personal characteristics played prominent roles in drivers' non-compliance of traffic control devices ,investigating the driver compliance to traffic control device at signalized and two-way stop controlled intersection and identifying the correlation between traffic signal vehicle volume and violation rate in Addis Ababa city.

Knowing the major factors contributes to drivers non-compliance towards traffic control devices, identifying which traffic control devices drivers mostly frequently violated, identifying the reasons of drivers fail to obey the devices and response of traffic police about drivers non-compliance of traffic control devices in order to improve traffic safety in the city. So**,** this study motivated by the research gap on the areas and focuses on the way of the drivers understanding and compliance of traffic control devices.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study Areas

Addis Ababa, with an area of 540 square kilometers is divided into 10 sub-cities and 117 woredas. The city is the capital city of Ethiopia and the diplomatic capital of Africa. Due to this, there are higher populations of humans and vehicles leading to road crashes. The city has five main gates, which are Ambo, Bishoftu (Kality), Dessie, Gojjam and Jimma gate. The annual average daily traffic (AADT) for freight vehicles estimated to be 10,725 for entering and 12,890 for leaving the city (Abel Kebede 2017).

The study by Tesema et al. (2005) noted that Addis Ababa holds about 60% crashes on average out of all crashes registered in Ethiopia. This is because the city has great traffic volume through its all gates. In addition to this, out of all the registered motor vehicles in Ethiopia, the city takes about 77% of it. This indicates the city has more car crashes. Statistical data from Addis Ababa police commission depicts that Addis Ababa is experiencing around 700 crashes per month and the costs of such fatalities and injuries due to traffic crashes have a great impact on various aspects of the society.

The study is conducted in Addis Ababa along Churchill to Stadium segment, and one two-way stop-controlled intersection located at Semien Mezagjah. It was selected randomly as study area because where the area of traffic control devices causes more confusion, have closest traffic signalized intersection, downhill grade, limited explanation and very vulnerable by a traffic accident. The segment has four traffic signalized intersection named as Eliana intersection. Tracon intersection, EBC intersection, and Harambe intersection, and also have speed limit sign, No entry, road marking, No parking sign, No U-turn sign, and No left turn. The Google earth image of these intersections taken from Google earth can be seen from the below figure 3.1 to figure 3.5.

3.1.1 Description of Eliana Signalized Intersection

The Eliana signalized intersection has four approaches namely, Piassa approach, Churchill approach, Atkilt Tera approach, and Wutma hotel approach. They were the steepest gradient intersection. The plan view of the intersection is shown below in figure 3.1.

Figure 3.1 Eliana Signalized Intersection

3.1.2 Description of Tracon Signalized Intersection

The Tracon signalized intersection has four approaches namely, Churchill approach, Berawih approach, Tikur Anbessa approach, and Fluhawa approach. The plan view of the intersection is shown below in figure 3.2.

Figure 3.2 Tracon Signalized Intersection

3.1.3 Description of EBC Signalized Intersection

The EBC signalized intersection has four approaches namely, Post Office approach, Berawih approach, Black Lion approach, and Ambassador approach. The Plan view of the intersection is shown below in figure 3.3.

Figure 3.3 EBC Signalized Intersection

3.1.4 Description of Harambe Signalized Intersection

The Harambe signalized intersection has four approaches namely, Stadium approach, Berawih approach, Fluhawa approach, and Ambassador approach. The plan view of the intersection is shown below in figure 3.4.

Figure 3.4 Harambe Signalized Intersection

3.1.5 Description of Semein Mazagjah Two-Way Stop Controlled Intersection

They have four approaches namely, Giorgis approach, Addisu Gebeya approach, Enkulal Fabrica approach, and Qecene Medanialem approach. Stop sign was installed at the Enkulal Fabrica approach and Qecene Medanialem approach direction. The plan view of the intersection is shown below in figure 3.5.

Figure 3.5 Semein Mazagjah Two-Way Stop Controlled Intersection

3.2 Research Approach

In this study the methods followed were designed in such a way that the main questions of the research be answered properly. To answer which factors contributing drivers non-compliance to traffic control device and interrelationship between traffic volume and violation rate. The research approach in this study involves both qualitative and quantitative approaches. The Qualitative data were obtained from two different questionnaires that were distributed to vehicle drivers and traffic police who were around the study area and willing to complete the questionnaires. Qualitative data from questionnaire were used to identify the factors affect the driver's non-compliance of traffic control devices. Primary data sources were collected through the interview-questionnaire of the drivers and video survey of the intersections. Quantitative data from observational/video surveys were used to predict the relationship between traffic volume and the violation rate of the signalized intersection.

3.3 Primary Data Collection through Questionnaires

3.3.1 Population

The populations that are considered in this study are drivers among (a) the employees of public institutions, (b) local people at shopping centers, local business owners and customers, and (c) professional drivers serving along the segment.

3.3.2 Sampling

The population of drivers in the city along the route is too large. Hence, for populations that are large, and particularly for those with unknown members amongst them, the sample size required to be taken into account is calculated as follows (Krejcie and Morgan 1970).

$$N=\frac{Z^2}{e^2}*p*(1-p)$$

Where: - N= sample size

Z= at a 95% confidence interval

P=degree of variability

e= precision rate

In this research a confidence interval of 95% (Z = 1.96) is used and since the variability is unknown, a degree of variability of 0.5 is used. A precision rate of 5% is selected. With these parameters, the number of sample size is, $N=\frac{Z^2}{e^2}*p*(1-p) = \frac{1.96^2*0.5*0.5}{0.05^2} = \frac{3.8416*0.25}{0.025} = \frac{0.9604}{0.025} = 384.16 \approx 385$.

3.3.3 Data Collection, procedures and methods of analysis

Questionnaires data for this study were collected starting from February 30, 2019 G.C to April 30, 2019 G.C for randomly selected weeks. The structured questionnaire paper was translated into the Amharic language in order to be easily understandable for drivers. Before starting the distribution of the questionnaire to the drivers they were asked whether they are voluntary to answer the questionnaire.

Data was collected for the following sections.

Section-I the socio-demographic characteristics of drivers

This questionnaire survey used includes the personal information made up of short answer questions designed to give detailed information about the drivers' demographic characteristics such as the age, gender, driving experience, and educational background.

Section-II Behavior the drivers conducted and other related variable

Driver behavior conducted with regards to road marking, stop signs, posted traffic sign and traffic signal.

Section-III Driver reason for non-compliance of the traffic control devices

Principal reason for drivers committed violation are categorized as; Device fault, personal case, enforcement, road blockage, and safe no risk.

The collected data was described as follows;

I. Age-is the age of driver's interviewed the questionnaire and it was categorized as;

- 18-24 years old
- 25-30 years old
- 31-40 years old
- 41-50 years old
- >51 years old

II. Gender- classified as male and female.

III. Educational Background- The education level attained by the drivers was classified as follow;

- < 12 grade level
- Diploma level
- Degree level
- Masters level
- PhD level

IV. Experience of the driver- this is numbers of the years the drivers have driven the vehicles and classified as <5 years, 5-10 years and >10 years.

V. Type of vehicles the drivers have driven-it was categorized as Car, Bus and Truck.

VI. Driver's response for non-compliance towards traffic control device categorized as;

- Never
- Sometimes
- Often
- Always

VII. Principal reason for non-compliance- Different kinds of literature were followed to make classifications driver's reason for non-compliance traffic control devices (Pietrucha et.al 1989). It was categorized as device fault, personal reason, enforcement, safe no risk, road blockage, and others.

The number of driver's non-compliance towards the traffic control device was the dependent variable for analysis in this study. For this research a number of independent variables were used. These were; Socio-demographic characteristics of drivers like age, gender, educational background, type of vehicle driven and driving experience.

After collecting the necessary information, data processing and interpretations was done using statistical package for social science (SPSS) and descriptive methods in the form of table, charts and graph. Statistical package for social science (SPSS) software used in order to determine the association between the variables. Chi-square test is used to test the independence of two categorical variables. The use of chi-square as a statistical tool was employed to test for hypothesis relating driver's characteristics. The null and alternative hypotheses for the testing where:

Null:-The driver characteristic and traffic control devices non-compliance are independent of each other.

Alternative:-Reject the Null hypothesis.

Where driver characteristics are; age, gender, educational background, type of vehicle driven and experience of driving. The expected cell frequencies were compared with the observed cell frequencies using the test chi-square, as estimated.

$$X^2 = \frac{\sum(O-E)^2}{E}$$

Where, X^2=chi-square calculated

O=observed frequency

E=Expected frequency

The calculated chi-square result was compared with the critical chi-square value (using the table) with (r-1)x(c-1) degree of freedom to make a decision regarding the acceptance or rejection of the null hypothesis, Kothari(2004).

If $X^2tab > X^2cal$, accept null hypothesis otherwise reject.

3.4 Primary Data Collection through Video Survey

3.4.1 Data requirement

All vehicles that pass through the selected intersections were considered in this study. A total of four signalized intersections and one two-way stop-controlled intersection were sampled for direct observation/video.

Data required from the signalized intersection;

- Right turn volume
- Through and left turn volume
- Total volume
- Red run volume
- Right turn on red
- Total violation
- Vehicle type

Data required from two-way stop-controlled intersection;

- Spot speed
- Sight distance
- Traffic volume
- Vehicle type
- The distance from the curb line to the center of the closest travel lane from the direction under consideration(dcl)

3.4.2 Sampling

The minimum sample of observation was determined using standard statistical estimating procedures which meet the desirable level of confidence and permitting error.

$$N=\frac{Z^2}{e^2}*p*(1-p)=\frac{1.96^2*0.5*0.5}{0.05^2}=\frac{3.8416*0.25}{0.025}=\frac{0.9604}{0.025}=384.16\approx 385.$$

3.4.3 Data Collection Procedures

Video cameras were used to record video data of vehicle movement at each approach of intersections. Video capturing techniques is preferred over the manual collection because it:

- provides a permanent, easily-review record and show the traffic conditions at any time
- has better accuracy than manual methods; and
- enables to capture a larger sample of the total number of vehicles.

Observations were carried out on Tuesday and Wednesday at peak times for two hours in the morning and afternoon. Traffic counts on Monday morning peak hour and a Friday afternoon peak hour may show high volumes and are not used in the analysis. Data collection for five intersections was performed on April 16, 2019, G.C and April 17, 2019, G.C. The video was captured by being on the high rising building floor and roof which found around the study intersections at each approaches. Video cameras were installed in front of the signalized light and stop signs. Behavior of every vehicle that passes through the study leg was recorded. Traffic volumes were counted of 15 minute time intervals per approach for 2 hr. While counting traffic, all approaches were monitored for traffic violations. For signalized intersection vehicles entering the intersection on green, red, and yellow were counted by the number of left turning, straight through and right turning vehicles.

For Stop sign intersection first determine if the study vehicle arrived as a single vehicle or was part of a queue (line) of vehicles waiting at the Stop sign. Next, decide if the study vehicle made a voluntary full stop (a stop is defined as a complete, however brief, cessation of movement), was stopped by vehicular or pedestrian cross traffic or did not stop at all before entering the intersections. Next identify if the study vehicle turns left or right, or continues straight through the intersection. Lastly, note if the study vehicle were a car, bus or a truck.

Thus, recorded violations represented total counts, while hourly volumes were obtained by expanding the 15 min of sample counts for each approach.

3.4.4 Data Description

3.4.4.1 Signalized intersection data description

The non-compliance problem occurred at the signalized intersection categorized as run red and right turn on red (no stop).

- Run red is when the vehicle crossing the stop line with a red light on, it was a serious traffic violation which might cause the most severe accidents. Most of the time if the leading vehicles violate the red signal; the following drivers encouraged to make the offence as well.
- Right-turn on red (no stop) is the number of vehicles to not full stop before making a right turn on red and not yield to all vehicles and pedestrians in the intersection. They never to be used in conflict with pedestrian indications except where pedestrian-storage channelization places an island between the right-turn vehicle and the pedestrian.

3.4.4.2 Two-way stop-controlled data description

For compliance data of two-way stop-controlled intersection by categorizing driver action as not stopping, practically stopped, stopped by traffic (forced stop) and voluntary full stop. Categories not stopping and practically stopped represent total and partial noncompliance while stopped by traffic and voluntary full stop represent compliance with the traffic control device.

Spot speed was used to determine the vehicle speed percentiles, which are useful to calculate the sight distance of the intersection. Ewing (1999) for a spot speed study at a selected location, a sample size of at least 50 and preferably 100 vehicles is usually obtained. In this research, it was considered 100 vehicles for spot speed determination at TWSC by using the stopwatch method. Traffic counts conducted on Tuesday and Wednesday at peak hours. The reason the stopwatch method used is it was the least expensive. Speed percentiles are used to determine effective and adequate speed limits. The two-speed percentiles most important to understand are the 50th and the 85th percentiles. According to Homburger et al. (1996) the 85th percentile is the speed at which 85% of the observed vehicles are traveling at or below. In other words, the 85th percentile of speed is normally assumed to be the highest safe speed for a roadway section. According to the handbook of simplified practice for traffic studies (2002), the following formula was used to find the exact speeds for the 50th percentile of speed and the 85th percentile of speed.

$$SD = \frac{PD - Pmin}{Pmax - Pmin}(Smax - Smin) + Smin$$

Where, SD=speed at P_D,

P_D=Percentile desired,

Pmax=higher cumulative percent,

Pmin=lower cumulative percent,

Smax=higher speed and

Smin=lower speed.

Vehicle type:-for simplicity and labour saving reasons traffic composition it was considered from three types of vehicles: cars, buses, and trucks.

Sight distance:-length of roadway visible to the drivers. AASHTO criteria were used in order to check the intersection sight distance.

$$d_{STOP} = 18ft + dcl$$

Where, d_{STOP}= distance of vehicle on stop-controlled approach from collision point (ft), dcl=the distance from the curb line to the center of the closest travel lane from the direction under consideration (ft)

$$d_{min} = Smaj*tg$$

Where, d_{min} =minimum sight distance for vehicle approaching on major road (m)

Smaj= design speed of major approach (m/sec)

tg=average gap accepted by minor road approach to enter the major road approach(sec)

Check whether d_{act} is greater than d_{min}, we calculated d_{act} using similarity of triangles.

3.4.5 Variables of the study

Dependent variable

Non-compliance rate is the variables depend on other factors that are measured in this study. For traffic signal intersection the non-compliance rate was running the red signal (run red) and Right-turn-on-red (no stop). Running the red signal is the number through and left-turning vehicles entering the intersection past the near curb after the onset of the red signal indication and the Right turn on red is the number of right-turning vehicles not coming to complete stop during the red signal indication.

Independent variable

Variables that was stable and unaffected by other variables. In this study the independent variables for traffic signal intersections;-right-turn volume, through and left-turn volume and total volume.

3.4.6 Methods of Analysis

To determine whether driver non-compliance at signalized intersection was a problem, study the relationship between the volume and violation rate using correlation analysis. In order to interpret the strength of relationships between variables, the strength of the association is described by a correlation coefficient (Dowdy and Weardon 2003). The strength of the association is described by a correlation coefficient- r which is;

r = 0 - 0.2 low, probably meaningless

r = 0.2 - 0.4 low, possible importance

r = 0.4 - 0.6 moderate correlation

r = 0.6 - 0.8 high correlation

r = 0.8 - 1 very high correlation

The bivariate correlation the procedure was subject to a two-tailed test of statistical significance at the level of 95% significance, $p<0.05$.

3.5 Secondary data collection

The distance from the curb line to the center of the closest travel lane from the direction under consideration and spot speed study length at the two-way stop-controlled intersection were measured using roller meter.

CHAPTER FOUR
RESEARCH ANALYSIS AND DISCUSSION

4.1 Descriptive analysis of driver's non-compliance toward traffic control device

This part describes the frequency of the respondents and analysis of driver's questionnaires by using tables, percentage and chi-square analysis methods.

4.1.1 Descriptive results of respondents

Out of 385 questionnaires distributed to the drivers' 350 questionnaires were responded with a return rate of 90.91%. Table 4.1 shows the frequency and percentage of different categorical variables. From the total drivers interviewed 88 percent and 12 percent was male and female respectively. Regarding the age of drivers 6.86%,33.14%,36%,17.14% and 6.86% were the drivers categorized under the age of 18-24,25-430,31-40,41-50 and >51 respectively. Based on educational background about 51.14% of the respondents have grade twelve education levels or less, 19.43% have a diploma, 24% have a bachelor's degree and 5.43% have a master's degree. From the respondents 61.71% had less than five years drive experience, 24 % had five up to ten years of drive experience and 1.43% had greater than ten years of the drive experience. Based on the type of vehicle they have driven 76.57%, 14.86%, 8.57% have driven the car, truck, and bus respectively.

Table 4.1 General respondent rate

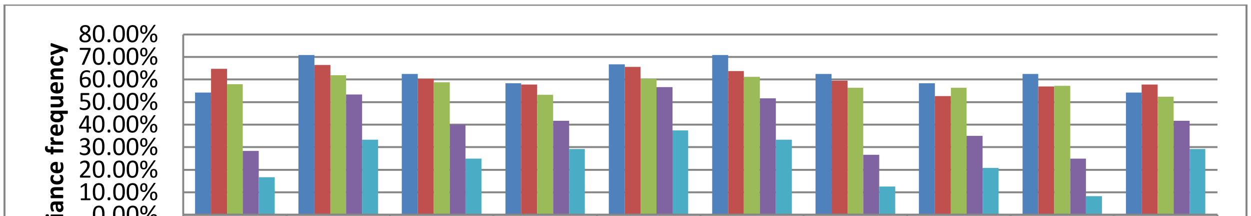
Variables	Category	Frequency	Percent
Gender	Male	308	88%
	Female	42	12%
Age	18-24	24	6.86%
	25-30	116	33.14%
	31-40	126	36%
	41-50	60	17.14%
	>51	24	6.86%
Educational Background	<12	179	51.14%
	Diploma	68	19.43%
	Bachelor degree	84	24%
	Master degree	19	5.43%
Driving Experience	<5	216	61.71%
	10-5	84	24%
	>10	50	1.43%
Type of vehicle drive	Car	268	76.57%
	Bus	30	8.57%
	Truck	52	14.86%

4.1.2 Major factors contributing driver non-compliance to traffic control device

This section focuses on the identification and analysis of major factor contributes to driver's non-compliance to traffic control devices.

4.1.2.1 Drivers factors by Age

Figure 4.1; below elaborates the age distribution of the drivers and its effects on the driver's non-compliance towards traffic control devices. When drivers' violations were compared by their age category, those drivers with an age 18-24 years old had higher non-compliance except for road marking signs. For instance,70.83%(red signal),62.5%(right turn on red),58.33%(No left turn sign),66.67%(stop sign),70.83%(speed limit sign),62.5%(roundabout yield sign),58.33%(No entry sign),62.5%(No parking sign) and 54.17%(No U-turn sign) were higher violation percentile of the drivers within the 18-24 years age category. Correspondingly, the drivers did not follow the directives of road markings were those drivers within the age of 25-30 years old. Generally, as the age of drivers increase the violation percentile was decreased for a red signal, right turn on red (no stop), No left turn sign, stop sign, speed limit sign, roundabout yield sign, No entry sign, No parking sign, and No U-turn sign but irregular patterns for road marking. However, this study discovered 62.08%,60.52%,57.54%,40% and 24.58% of the drivers violated the traffic control device within the age of 18-24,25-30,31-40,41-50 and >51 years old respectively.



	Road marking	RONR	RTOR(no stop)	No left turn sign	Stop sign	Speed limit sign	Roundabout yield sign	No entry sign	No parking sign	No U-turn sign
18-24	54.17%	70.83%	62.50%	58.33%	66.67%	70.83%	62.50%	58.33%	62.50%	54.17%
25-30	64.66%	66.38%	60.34%	57.76%	65.52%	63.79%	59.48%	52.59%	56.90%	57.76%
31-40	57.94%	61.90%	58.73%	53.17%	60.32%	61.11%	56.35%	56.35%	57.14%	52.38%
41-50	28.33%	53.33%	40.00%	41.67%	56.67%	51.67%	26.67%	35.00%	25.00%	41.67%
>51	16.67%	33.33%	25.00%	29.17%	37.50%	33.33%	12.50%	20.83%	8.33%	29.17%

Figure 4.1 Driver's non-compliance frequency based on age category

Chi-square test was conducted to observe age participation in traffic control device violation.

Table 4.2 Chi-square test result of driver's age and violation

Age	Observed violation	Expected violation	Observed non violation	Expected non violation	Total observed	Df	Critical X^2	Calculated X^2
18-24	15	13	9	11	24	4	9.488	15.866
25-30	70	62	46	54	116			
31-40	72	67	54	59	126			
41-50	24	32	36	28	60			
>51	6	13	18	11	24			

By considering a 5% level of significance, the critical chi-square value is 9.488. The calculated chi-square values of all the traffic control devices evaluated were larger than the critical value indicating that there are reasons to believe that the variables are dependent. According to the table**,** the null hypothesis of independence between the age of the driver and compliance of the traffic control device is rejected at p-value<0.05. It is evident that compliance is highly related to the age of the driver. Since X^2cal is greater than X^2tab, reject the null hypothesis, meaning that the characteristics i.e. age of driver and traffic control devices compliance is dependent on each other.

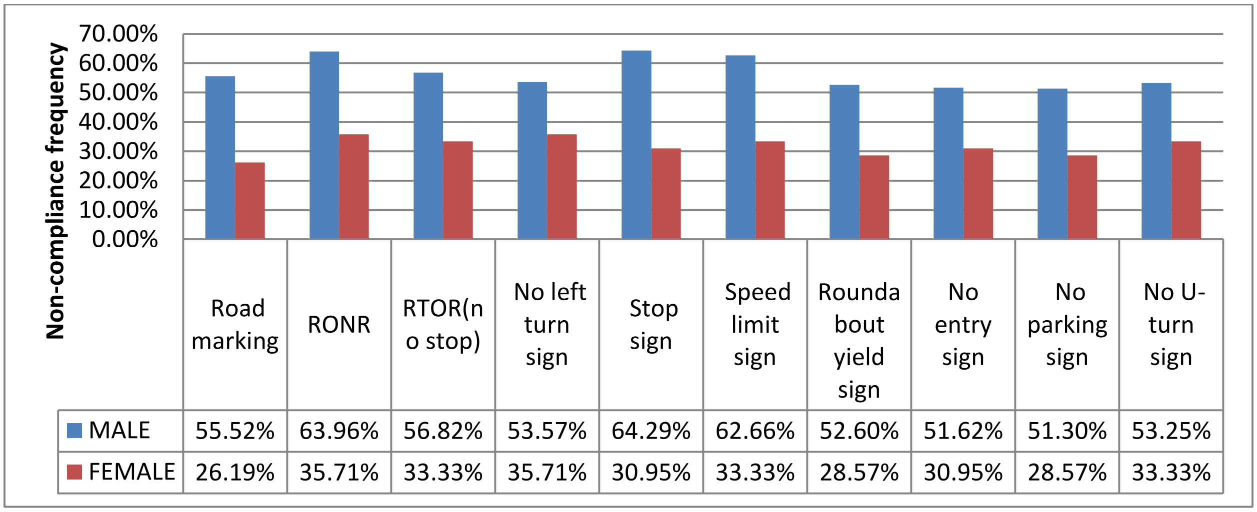
Table 4.3 Non-parametric tests for association of driver's age and non-compliance frequency

Age	Non-compliance frequency				Statistics	
	never	sometimes	often	always	Chi-square	p-value
18-24	9	10	4	1	23.23	0.026
25-30	46	47	21	2		
31-40	54	55	16	1		
41-50	36	22	2	0		
>51	18	5	1	0		

From the analysis, associations between age and violation frequency were found and it is statistically significant at 5% significance level (p=0.026<0.05). It is concluded that driver's age and violation rate are not independent. They are statistically related.

4.1.2.2 Drivers factor by gender

Figure 4.2 below shows male drivers were more non-compliance towards stop sign (64.29%) and less non-compliance towards No parking sign (51.3%) out of total male driver's respondents. Similarly, female respondents were more non-compliance towards RONR (35.71%), and No left turn sign (35%), and less non-compliance towards road marking (26.19%) out of total female respondents. Generally, male drivers were more non-compliance than female drivers.



	Road marking	RONR	RTOR(no stop)	No left turn sign	Stop sign	Speed limit sign	Roundabout yield sign	No entry sign	No parking sign	No U-turn sign
MALE	55.52%	63.96%	56.82%	53.57%	64.29%	62.66%	52.60%	51.62%	51.30%	53.25%
FEMALE	26.19%	35.71%	33.33%	35.71%	30.95%	33.33%	28.57%	30.95%	28.57%	33.33%

Figure 4.2 Driver's non-compliance frequency based on gender

In the association analysis of the gender of the respondents and the comprehension of the selected traffic control devices, the result is given below in table 4.4, and table 4.5. By considering a 5% level of significance, the critical chi-square value is 3.843. The calculated chi-square values were greater than the critical value. Consequently, in agreement with the below analysis, the chi-square test result confirms that the presence of statistically significant difference among male and female drivers in non-compliance towards traffic control device in the city at the probability level of p (0.011) and with chi-square value of 11.157. Meaning, the more the probability level approaching to 0.011 and the chi-square value greater than the critical value of 95% confidence interval i.e., 3.843, show the presence of significant effects between the drivers gender and non-compliance toward traffic control devices.

Table 4.4 Chi square result of driver's gender and non-compliance frequency

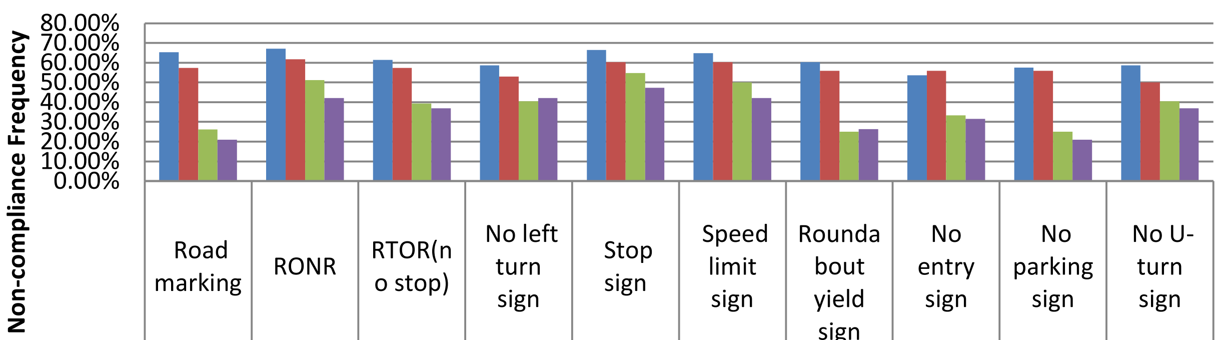
Gender	Observed violation	Expected violation	Observed non violation	Expected non violation	Total	Df	Critical X2	Calculated x2
Male	174	165	134	143	308			
Female	13	22	29	20	42	1	3.843	9.6899

Table 4.5 Non-parametric association of gender and non-compliance frequency

Age	Non-compliance frequency				Statistics	
	never	sometimes	often	always	Chi-square	p-value
Male	134	127	43	4	11.157	0.011
Female	29	12	1	0		

4.1.2.3 Drivers factor by Educational background

Figure 4.3, below shows <12 grade (67.04%), and diploma (61.76%) educational level were committing high non-compliance towards running the red light. Similarly, the degree (54.76%), and master (47.37%) levels violated stop sign device. This study noted that 61.4%, 56.76%, 38.57%, and 34.74% of the drivers violated the traffic control device within the educational level of <12, diploma, degree, and master's respectively. Among the four categories of educational background those drivers with <12 school level of education is responsible for the largest share of violation of traffic control device (61.4%) than other education level and those drivers with master's, education level is lesser participant in traffic control device violation (34.74%) than others. Accordingly, as the driver's education level increased the driver's non-compliance towards traffic control device decreased.



	Road marking	RONR	RTOR(no stop)	No left turn sign	Stop sign	Speed limit sign	Roundabout yield sign	No entry sign	No parking sign	No U-turn sign
<12	65.36%	67.04%	61.45%	58.66%	66.48%	64.80%	60.34%	53.63%	57.54%	58.66%
diploma	57.35%	61.76%	57.35%	52.94%	60.29%	60.29%	55.88%	55.88%	55.88%	50.00%
degree	26.19%	51.19%	39.29%	40.48%	54.76%	50.00%	25.00%	33.33%	25.00%	40.48%
master	21.05%	42.11%	36.84%	42.11%	47.37%	42.11%	26.32%	31.58%	21.05%	36.84%

Figure 4.3 Driver's non-compliance frequency based on educational background

In table 4.6, and table 4.7, the association using chi-square was tested for the association of education level of drivers in non-compliance towards traffic control device was tested and showed an association. Since p-value (0.038) <0.05 and calculated chi-square (15.091)>critical chi-square (7.815), we shall reject the null hypothesis. The null hypothesis of independence between the educational background level of the drivers and distribution of violation of traffic control device is rejected at p-value<0.05. It is evident that the non-compliance of the traffic control device is related to the educational background of the drivers.

Table 4.6 Chi square results of driver's educational background and non-compliance frequency

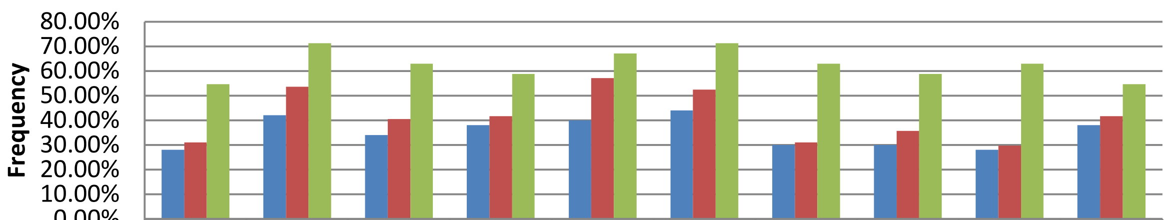
Educational background	Observed violation	Expected violation	Observed non violation	Expected non violation	Total	Df	Critical X2	Calculated x2
<12	110	96	69	83	179	3	7.815	15.091
Diploma	39	37	29	31	68			
Degree	32	45	52	39	84			
Master	7	10	12	9	19			

Table 4.7 Non-parametric associations of educational background and non-compliance frequency

Educational background	Non-compliance frequency				Statistics	
	never	sometimes	often	always	Chi-square	p-value
<12	69	84	23	3	17.751	0.038
Diploma	29	26	12	1		
Degree	52	25	7			
Master	12	5	2			

4.1.2.4 Drivers factor by Experience of driving

Figure 4.4, depicts that drivers <5, 5-10, and >10 driving experience years were committing violation of running the red light/speed limit sign(71.3%), stop sign(57.14%) and speed limit sign(44%) respectively. However, drivers whose experiences were less than 5 years represented an average of 62.55% non-compliance towards traffic control device. This indicates they are more violators than other categories. Similarly, finding indicated that drivers whose experiences were greater than 10 years indicated an average of 35.20% of non-compliance frequency. Generally, as driving experience increased the non-compliance frequency decreased and vice versa.



	Road marking	RONR	RTOR(no stop)	No left turn sign	Stop sign	Speed limit sign	Roundabout yield sign	No entry sign	No parking sign	No U-turn sign
>10	28.00%	42.00%	34.00%	38.00%	40.00%	44.00%	30.00%	30.00%	28.00%	38.00%
5.-10	30.95%	53.57%	40.48%	41.67%	57.14%	52.38%	30.95%	35.71%	29.76%	41.67%
<5	54.63%	71.30%	62.96%	58.80%	67.13%	71.30%	62.96%	58.80%	62.96%	54.63%

Figure 4.4 Drivers' non-compliance frequency based on driving experience

Table 4.8, and Table 4.9 indicates that the calculated χ 2 statistics, for 2 degrees of freedom is 17.921 which was greater than the critical chi-square value (5.992). Additionally, it indicates that the significant value (0.000) is less than the critical p-value of 0.05. This suggests that the null hypothesis is rejected. From the analysis, associations between the driving frequency and violation frequency were found and it is statistically significant at a 5% significance level ($p=0.00<0.05$). It is concluded that driver's experience and violation rate are not independent. They are statistically related.

Table 4.8 Chi square result of drivers experience and non-compliance frequency

Driver Experience	Observed violation	Expected violation	Observed non violation	Expected non violation	Total	Df	Critical X2	Calculated x2
>10	18	27	32	23	50			
5-10	35	45	49	39	84			
<5	135	116	81	100	216	2	5.992	17.921

Table 4.9 Non-parametric association of driving experience and non-compliance frequency

Driver Experience	Non-compliance frequency				Statistics	
	never	sometimes	often	always	Chi-square	p-value
>10	32	16	1	1	27.477	0
5-10	49	31	3	1		
<5	81	93	40	2		

4.1.2.5 Drivers factor by type of vehicle driven

This variable has three categories. Among the three categories, Car and Trucks drivers are responsible for the largest number of non-compliance with average values of 60.04%, and 34.81% respectively. Similarly, the bus drivers were the least non-compliance to the traffic control device (28.33%).

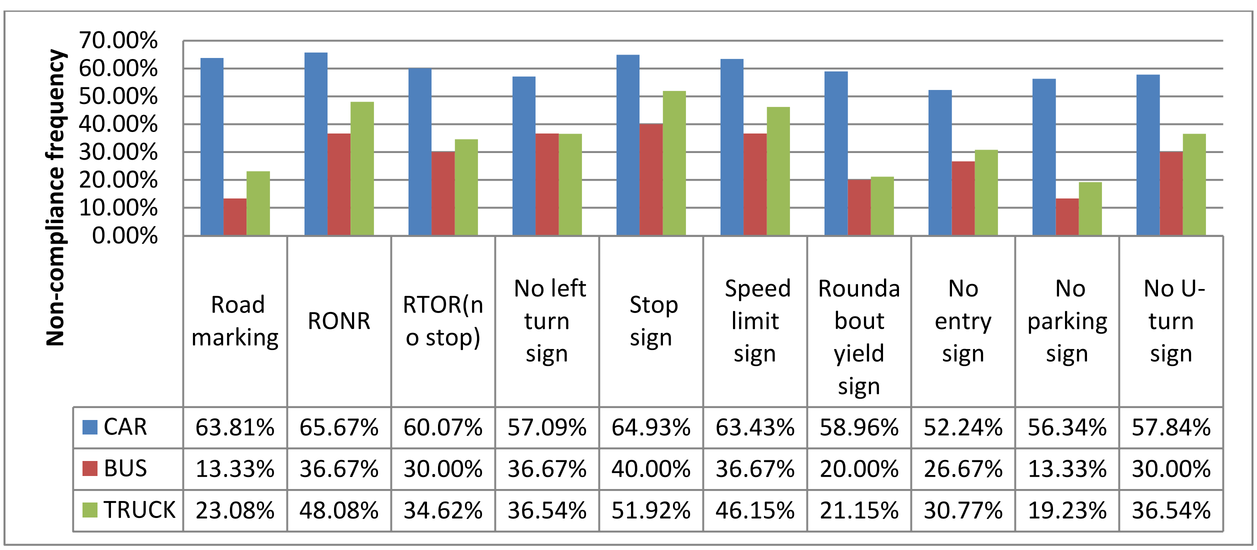


Figure 4.5 Driver's non-compliance frequency based on type of vehicle driven

Table 4.10, and Table 4.11 shows the calculated χ 2- value of 18.696 for two df and a critical χ 2- value of 5.992 at 0.05 alpha level. Since the calculated χ2- value is greater than the critical χ2- value and p=0.001<0.05, the null hypothesis, i.e. the type of vehicles drivers driven were related to non-compliance of the traffic control device.

Table 4.10 Chi square result of type of vehicle driven and non-compliance frequency

Type of vehicle	Observed violation	Expected violation	Observed non violation	Expected non violation	Total	Df	Critical X2	Calculated x2
Car	161	157	107	125	268			
Bus	8	16	22	14	30			
Truck	18	28	34	24	52	2	5.992	18.696

Table 4.11 Non-parametric association of type of vehicle driven and non-compliance frequency

Type of vehicle	Non-compliance frequency				Statistics	
	never	sometimes	often	always	Chi-square	p-value
Car	107	116	41	4	23.88	0.001
Bus	22	6	2	0		
Truck	34	17	1	0		

4.2 Drivers non-compliance reason of traffic control devices

Figure 4.6; provide a summary of the frequency of the violation and the principal reason for committing violation for each device. While drivers gave very specific reasons for each category, the main principal reason was categorized into five.

Device fault answer includes;

- Defective device,
- Yellow is short, and
- Bad sign placement.

Safe no risk includes;

- Low cross street traffic

- Good sight

Personal reason includes;

- I am impatient
- Confused
- Unaware of sign
- I am in a hurry
- Don't see sign

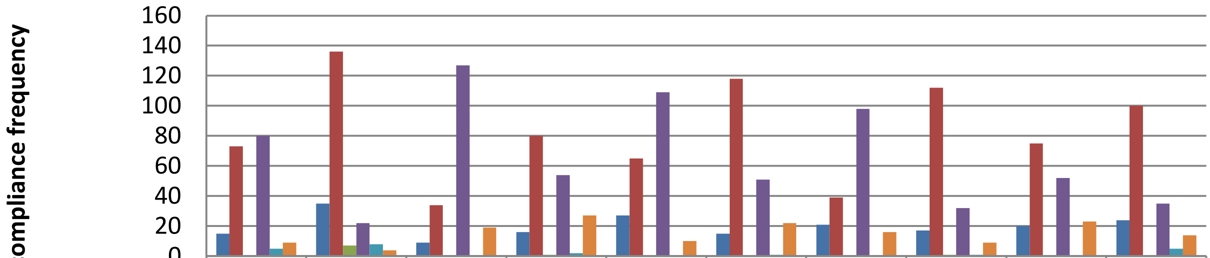
Enforcement category answer includes;

- I check for the police first

As we have seen from figure 4.6, the reason for drivers violates the traffic signal by running the red indication, 4.15 percent of the drivers cited impatience or being in a hurry as a reason for not complying. Interestingly, 10.38 percent of drivers believed it was safer to run the red than risk, while 16.51% of the respondents feel that device error. Similarly, reasons cited for not coming to a complete stop at RTOR locations, 67.2 percent said they did not come to a full stop making a right turn on red at intersections where the cross-street traffic volume is low and/or there are no sightline obstructions.

The reasons motorists fail to come to a complete stop at STOP signs, 51.66 percent said that they do not come to a full stop at a stop-controlled intersection because of the cross-street traffic volume is low and for there are no sightline obstructions. From figure 4.6, we were also noted that 44.44%, 65.12%, 44.12% and 56.18% of the drivers who admitted to violating no left turn, no entry, no parking, and no u-turn restrictions respectively said they do so as being lost or confused about directions as their reason for noncompliance.

Similarly, reasons cited by drivers relative to "exceeding" advisory speeds, 57 percent felt the advisory speeds are set too low to be meaningful and reason for committing roundabout yield sign violation(56.32%) is safe no risk. Generally, Running on red was among the most frequently violated, and while 60.57% percent of drivers admitted to committing the violation. Most of the reasons given for violating traffic control devices were perceived risk and personal reasons.



	Road marking	RONR	RTOR(no stop)	No left turn sign	Stop sign	Speed limit sign	Roundabout yield sign	No entry sign	No parking sign	No U-turn sign
Device error	15	35	9	16	27	15	21	17	20	24
Personal case	73	136	34	80	65	118	39	112	75	100
Road blockage	0	7	0	1	0	0	0	1	0	0
Safe no risk	80	22	127	54	109	51	98	32	52	35
enforcement	5	8	0	2	0	1	0	1	0	5
Others	9	4	19	27	10	22	16	9	23	14

Figure 4.6 Driver's non-compliance reason of traffic control device

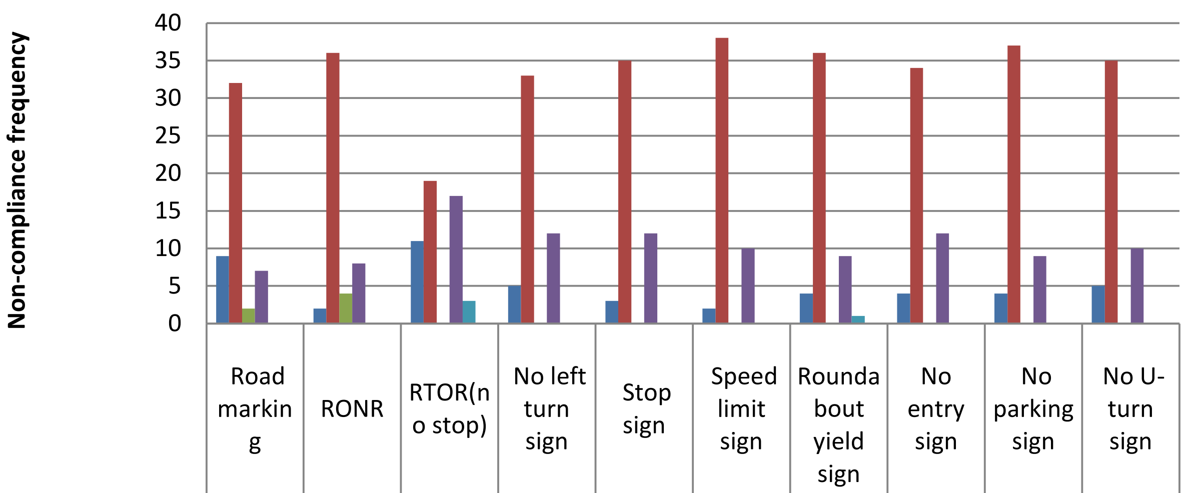
4.3 Descriptive of traffic police interview

A total of 55 questionnaires were distributed for traffic police and 50 questionnaires were returned back with a complete answer for each question. From Table 4.12, 26%, 32%, 32% and 10% of traffic police strongly agree, agree, disagree and strongly with the statement of age and gender of drivers have an influence on traffic control device comprehensibility respectively. Most of the respondents agree with education level and number of years driven (58%), mode of drivers training (64%) and type of vehicles driven (54%) have an influence on the compliance to the traffic control device. Similarly, 76 percent replied agree with increased traffic enforcement would increase driver compliance with traffic control devices.

Table 4.12 Traffic police questioners respond about driver's non-compliance

General questions	Are you agree with this statement?			
	Strongly agree	agree	disagree	Strongly disagree
The age and gender of drivers have an influence on traffic control device comprehensibility	13	16	16	5
The education level and number of years driven have an influence on the compliance to the traffic control device.	12	17	11	10
The mode of drivers the training they have an effect on the compliance to the traffic control device.	12	20	12	6
The type of vehicles driven has an effect on the compliance to the traffic control device.	8	19	17	6
Increased traffic enforcement would increase driver compliance with the traffic control devices.	20	18	6	6

In figure 4.7 below, averagely 67% of traffic police said drivers committing violation of traffic control device is due to personal reason. Similarly, 21.2% said due to safe no risk.



	Road marking	RONR	RTOR(no stop)	No left turn sign	Stop sign	Speed limit sign	Roundabout yield sign	No entry sign	No parking sign	No U-turn sign
Device error	9	2	11	5	3	2	4	4	4	5
Personal case	32	36	19	33	35	38	36	34	37	35
Road blockage	2	4								
Safe no risk	7	8	17	12	12	10	9	12	9	10
enforcement			3				1			
Other										

Figure 4.7 Traffic police response to drivers' reason of non-compliance.

4.4 Drivers non-compliance of two-way stop control intersection

Drivers on conflicting approaches must be able to see each other in time to assess whether an impending hazard is imposed and to take appropriate action to avoid an accident. Thus sight distances must be analyzed to ensure that they are sufficient for drivers to judge and avoid conflicts. To check sight distance first we calculated the spot speed. For a spot speed study, 100 vehicles were sampled using the stopwatch method. Traffic counts conducted on a Tuesday and Wednesday. According to the handbook of simplified practice for traffic studies (2002), the spot speed study length recommended for traffic stream average speed less than 11.76m/sec is 26.82 meters.

I) From Addisu Gebeya to Giorgis direction

Table 4.13 shows out of a hundred vehicles ninety car, two truck, and seven buses were counted for spot speed study.

Table 4.13 Stopwatch spot speed study data

Elapsed time(sec)	Spot Speed(m/sec) for 26.82m	Car	Bus	Truck	Total
3	10.00	3			3
4	7.50	14			14
5	6.00	24		1	25
6	5.00	24	2		26
7	4.29	16	2	1	19
8	3.75	3			3
9	3.33	6	1		7
10	3.00	1			1
11	2.73		1		1
13	2.31		1		1

A frequency distribution table is the simplest way to determine speed percentiles. From table 4.14 second column shows the number of vehicles recorded at each speed. The cumulative frequency is the total of each of the frequencies added together row by row from lower to higher speed. The fourth column is the cumulative percentile calculated by running the percentage of the cumulative frequency.

Table 4.14 Frequency distribution

Speed	Frequency of vehicles	Cumulative frequency	Cumulative percentile	Speed percentile
2.31	1	1	1%	
2.73	1	2	2%	
3.00	1	3	3%	
3.33	7	10	10%	
3.75	3	13	13%	
4.29	19	32	32%	50TH
5.00	26	58	58%	
6.00	25	83	83%	85TH
7.50	14	97	97%	
10.00	3	100	100%	

The study shows the 50th percentile or median speed was between 4.29 m/sec and 5 m/sec, and the 85th percentile of speed was between 6m/sec and 7.5 m/sec.

For 50th percentile of speed= (50-32)*(5-4.29)/(58-32)+4.29=4.782m/sec

For 85th percentile of speed= (85-83)*(7.5-6)/(97-83)+6=6.214m/sec

Therefore, the 85th percentile speed was used to be highest safe speed for this roadway section.

II) From Giorgis to Addisu Gebeya direction

Table 4.15 shows that from the total hundred vehicles counted along this road approach eighty-three, eleventh, and six were a car, truck, and bus considered respectively.

Table 4.15 Stopwatch spot speed study data

Elapsed time(sec)	Spot Speed(m/sec) for 26.82m	car	Bus	Truck	Total
3	8.33	1			1
4	6.25	1			1
5	5.00	3	1		4
6	4.17	14			14
7	3.57	20	1		21
8	3.13	33	2		35
9	2.78	9	5		14
10	2.50		1	1	2
11	2.27		1	4	5
12	2.08			1	1
13	1.92		1		1
14	1.79			1	1

Table 4.16 Frequency distribution

Speed	Frequency of vehicles	Cumulative frequency	Cumulative percentile	Speed percentile
1.79	1	1	1%	
1.92	1	2	2%	
2.08	1	3	3%	
2.27	5	8	8%	
2.50	2	10	10%	
2.78	14	24	24%	50TH
3.13	35	59	59%	
3.57	21	80	80%	85TH
4.17	14	94	94%	
5.00	4	98	98%	
6.25	1	99	99%	
8.33	1	100	100%	

From table 4.16 the study shows the 50th percentile or median speed was between 2.78and 3.13 m/sec and the 85th percentile of speed was between 3.57m/sec and 4.17 m/sec.

For 50th percentile of speed= (50-32)*(5-4.29)/(58-32)+4.29=4.782m/sec

For 85th percentile of speed= (85-83)*(7.5-6)/(97-83)+6=6.214m/s

According to AASHTO basic rules drivers on conflict approaches must see each other in time to assess whether the hazard is imposed and to take appropriate action to avoid an accident. Sight distance must be analyzed to ensure that they are sufficient for drivers to judge.

Minimum sight distance for a vehicle approaching on the major (uncontrolled) street from Addisu Gebeya to Giorgis major road approach=Smaj*tg=6.214m/sec*7.5sec=46.605m, where AASHTO recommends tg=7.5sec for typical conditions.

Minimum sight distance for a vehicle approaching on the major (uncontrolled) street from Giorgis to Addisu Gebeya major road to approach=Smaj*tg=3.78m/sec*7.5sec=28.35m

Distance of vehicle approaching on a STOP controlled approach from collision point=18ft+dcl or 5.486m+dcl, where dcl is the distance measured from the curb line to the center of the closest travel lane from the direction under consideration and it was measured using roller meter. The distance from curb line to the center of vehicle approached from Giorgis was 6.75m and the distance from curb line to the center of vehicle approached from Addisu Gebeya was 17.75m.

Distance of stopped vehicle from Giorgis=5.486+6.75=12.236m

Distance of stopped vehicle from Addisu Gebeya =5.486+17.75=23.236m

The actual distance of the vehicle from major to the collision point was determined using the similarity of the triangle as follows: where distance from driver position to the sight obstruction was measured using roller meter.

Actual distance of vehicle from Giorgis = (7.75*12.236)/(12.236-6.75)=17.286m

Actual distance of vehicle from Addisu Gebeya = (10.25*23.236)/(23.236-17.75)=43.413m

From the above results, the actual distance of vehicles was greater than the minimum sight distance required for a vehicle this indicates that there was no sight obstruction from the direction analyzed.

Table 4.17 below noted that 67.77 percent of the drivers were found to be non-compliant with the stop-control among this car (66.03%), bus (0.87%) and truck (0.87%) while 32.23 percent of drivers were found to be in compliance to the stop-control signs at a two-way stop control intersections among this car (30.59%), bus (1.00%) and truck (0.64%).

Table 4.17 Qecene Medanaliem to Semein Mazegjah minor road compliance data

Day	Non-compliant			Compliant		
	Car	Bus	Truck	Car	Bus	Truck
Morning	709	9	8	328	9	5
Afternoon	733	10	11	340	13	9

Table 4.18 below noted that 67.75 percent of the drivers were found to be non-compliant with the stop-control among this car (64.74%), bus (1.7%) and truck (1.31%) while 32.25 percent to drivers were found to be in compliance to the stop-control signs at a two-way stop control intersections among this car (28.76%), bus (1.72%) and truck (1.77%) along Qechene Medanaliem to Semein Mazegjah road section.

Table 4.18 Enkulal Fabrica to Semien Mazegjah minor road compliance data

Day	Non-compliant			Compliant		
	Car	Bus	Truck	Car	Bus	Truck
Morning	704	16	11	307	16	14
Afternoon	700	22	18	318	22	25

Generally, from table 4.17 and 4.18 shows 67.76 percent of the driver's non-voluntary to a stop and 32.24 percent of the drivers voluntary to a stop-controlled intersection.

4.5 Drivers non-compliance towards signalized intersection

Traffic volume at Eliana intersection

This intersection is located at the center of the city and has a steep gradient as a result of this the number of violations is higher since it is more difficult either to stop or to restart moving a vehicle. The traffic count was done for 2hr starting from 1:30 AM up to 3:30 AM and 10:00 PM up to 12 PM for two days on Tuesday and Wednesday on each approach. Accordingly, traffic volume and violation rate were high during 2:15 AM up to 2:45 AM and 11:00 PM up to 11:30 PM. The average result is summarized in figure 4.8

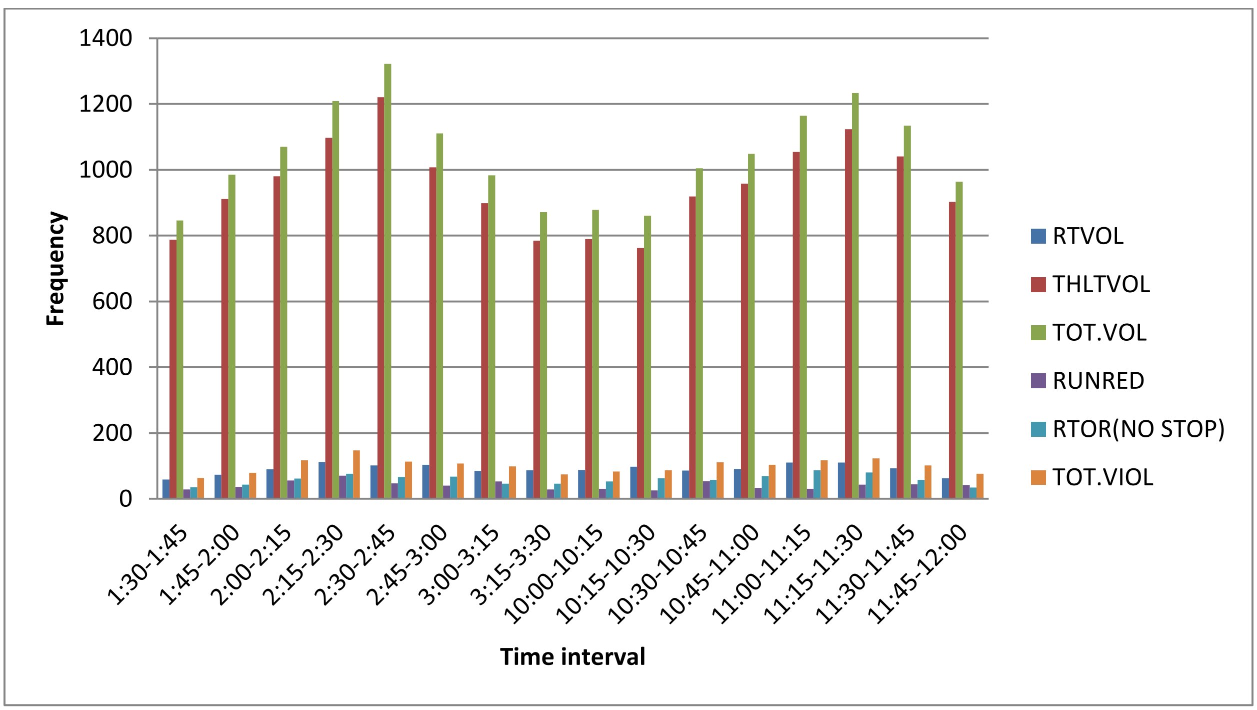


Figure 4.8 Traffic volumes within 15 minute interval at Eliana Intersection

They have four approaches. Figure 4.9 below shows that Piassa and Churchill approach had the highest traffic volume with both morning and afternoon peak period. Accordingly, the afternoon peak period traffic volume is found to be higher than the morning peak period. However, drivers passed on the Piassa approach had highest violation of red light due to the downhill of the grade. Similarly, Atikilty tera approach had highest right turn on red (no stop) and total violation rate.

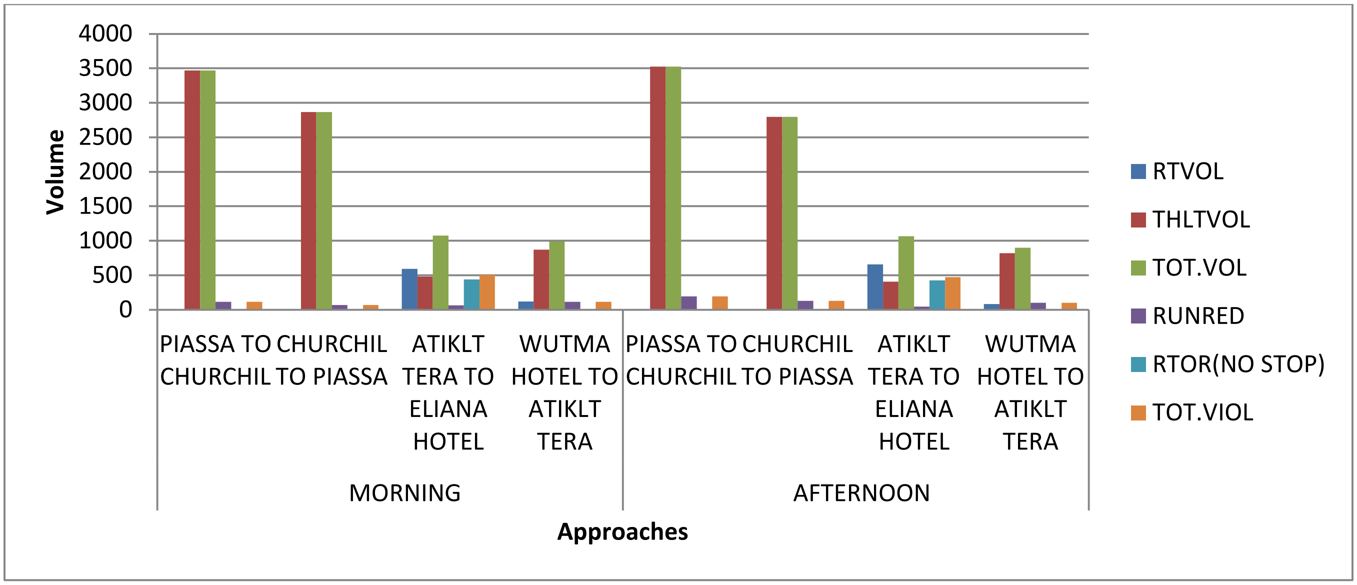


Figure 4.9 Traffic volumes per approaches at Eliana intersection

In the following figure 4.10, car divers were committing higher violation towards red-light running and right turn on red (no stop). However, the bus drivers were the least violators.

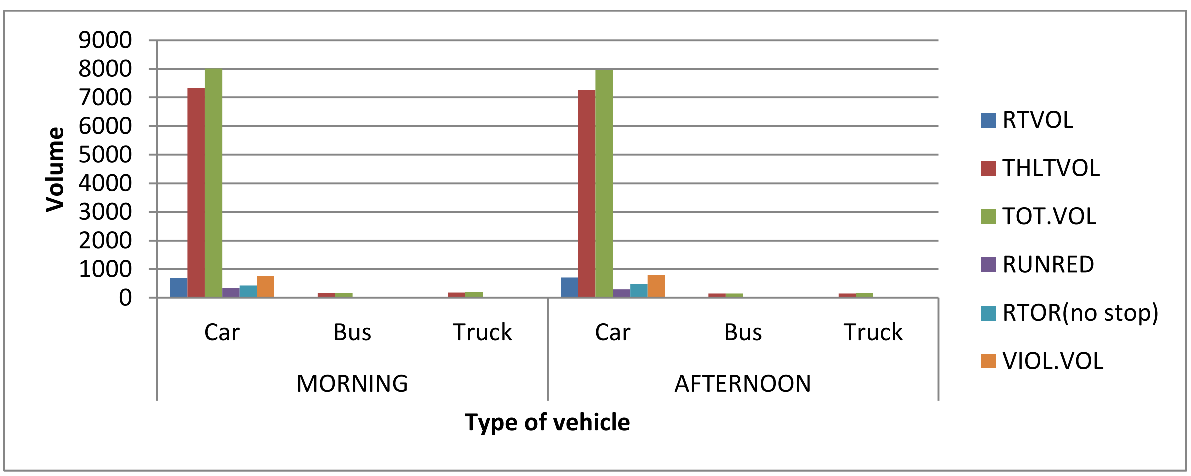


Figure 4.10 Traffic volumes by vehicle composition at Eliana Intersection

Traffic volume at Tracon intersection

The intersection has four legs and traffic count was done for 2hr morning and afternoon on Tuesday and Wednesday for each approaches. As per the Figure 4.11, the higher violation was occurred from 2:00 up to 2:45 in the morning and 11:00 up to 11:30 in the afternoon.

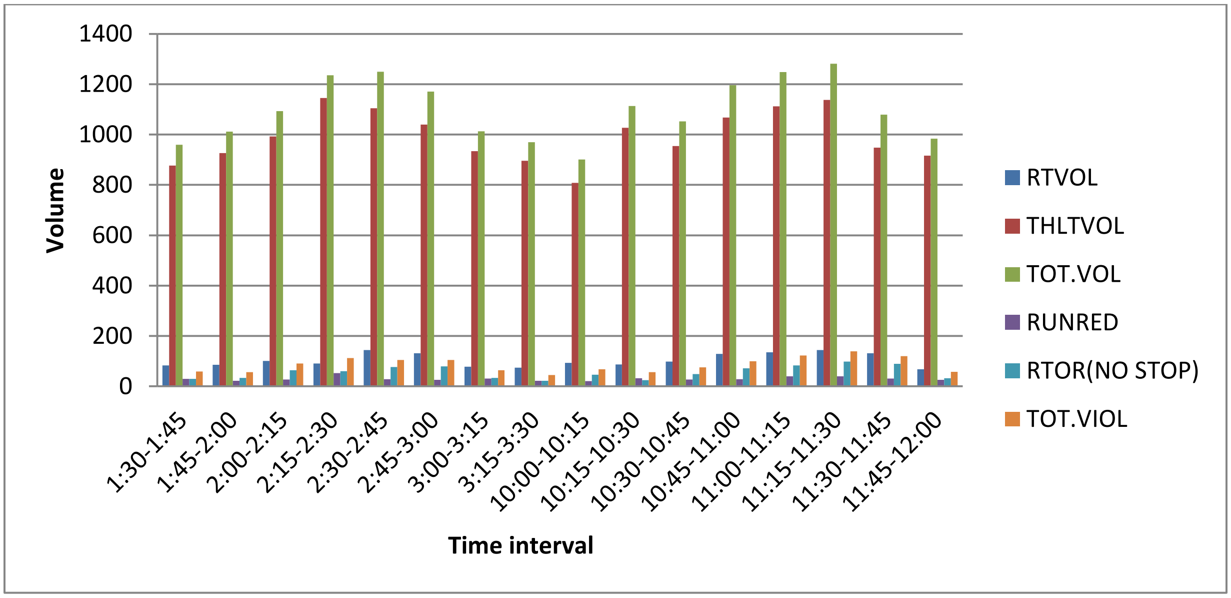


Figure 4.11 Traffic volumes by 15 minute time interval at Tracon Intersection

According to Figure 4.12, the Churchill approach had higher running on red than other approaches and Berawih approach had higher right turn on red (no stop) and total violation than other approaches. However, Fluhwa approach approaches had a lower violation rate than others.

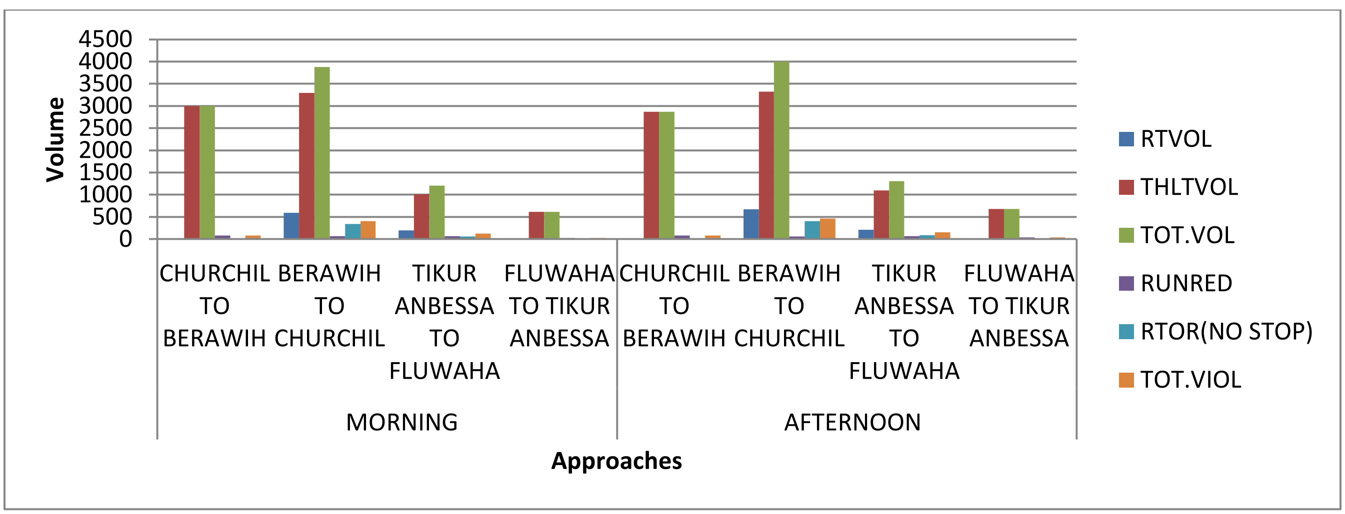


Figure 4.12 Traffic volumes per approaches at Tracon intersection

In the following figure 4.13, there are three types of vehicle compositions at Tracon intersection. Cars and truck drivers had a large percentage of running on the red and no stop than other vehicle drivers.

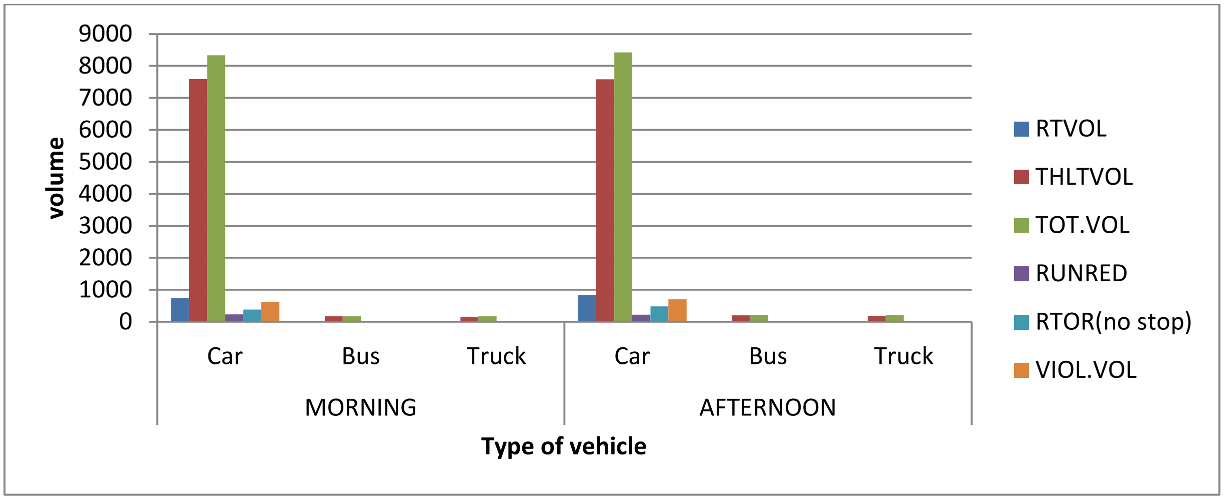


Figure 4.13 Traffic volumes by vehicle composition at Trackon Intersection

Traffic volume at EBC intersection

This intersection is located at the center of the city and has a high traffic volume. The traffic count was done for 2hr starting from 1:30 AM up to 3:30 AM and 10:00 PM up to 12 PM for two days on Tuesday and Wednesday on each approach. Accordingly, traffic volume and violation rate was high during 2:15 AM up to 2:45 AM and 11:00 PM up to 11:30 PM. The average result is summarized in figure 4.14.

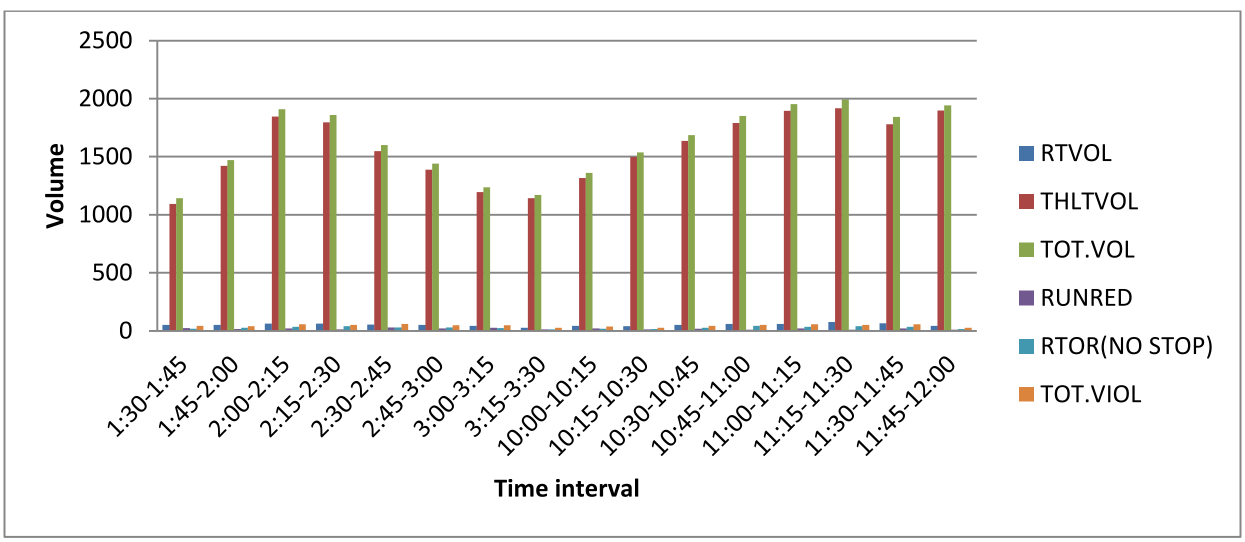


Figure 4.14 Traffic volumes by 15 minute time interval at EBC Intersection

Figure 4.15, shows the Post Office approach had the highest running on red volume with both morning and afternoon peak periods than other approaches. Similarly, the Black lion hospital approach had higher right turn on red (no stop) and total violation volume than other approaches. However, the Berawih approach had lower total violation volume than other approaches.

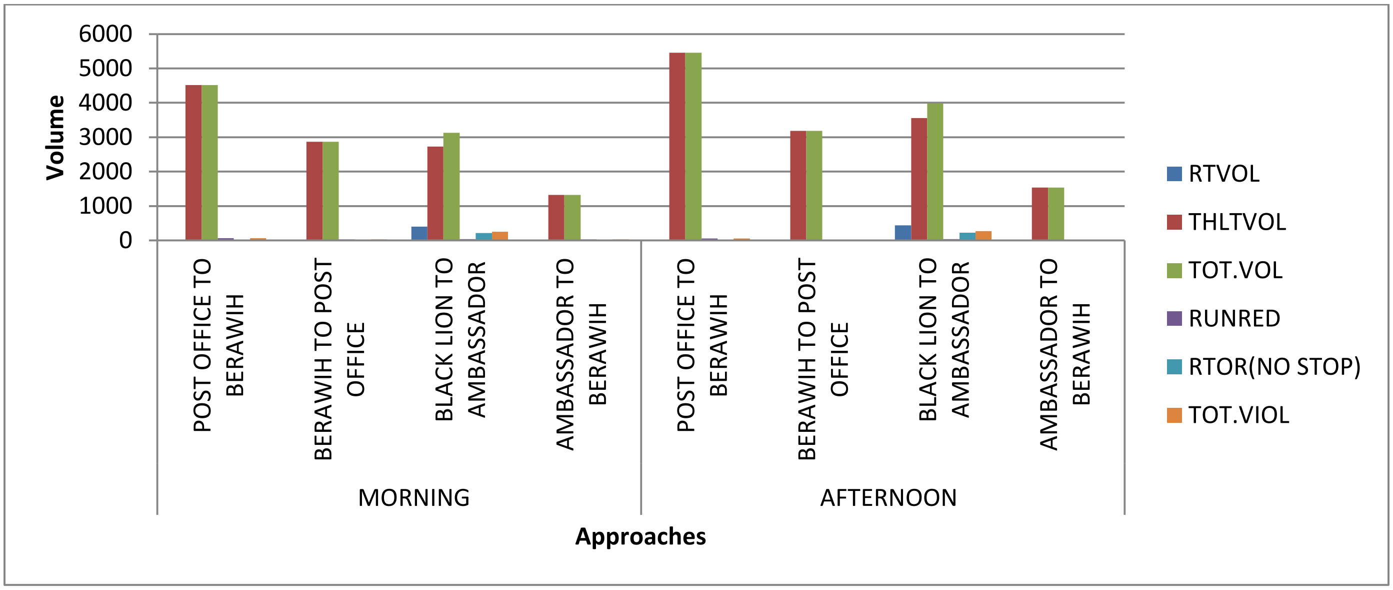


Figure 4.15 Traffic volumes per approaches at EBC intersection

Figure 4.16, below shows that there are different types of vehicle compositions at EBC intersection. Cars and truck drivers had a large percentage of violations than other vehicles drivers.

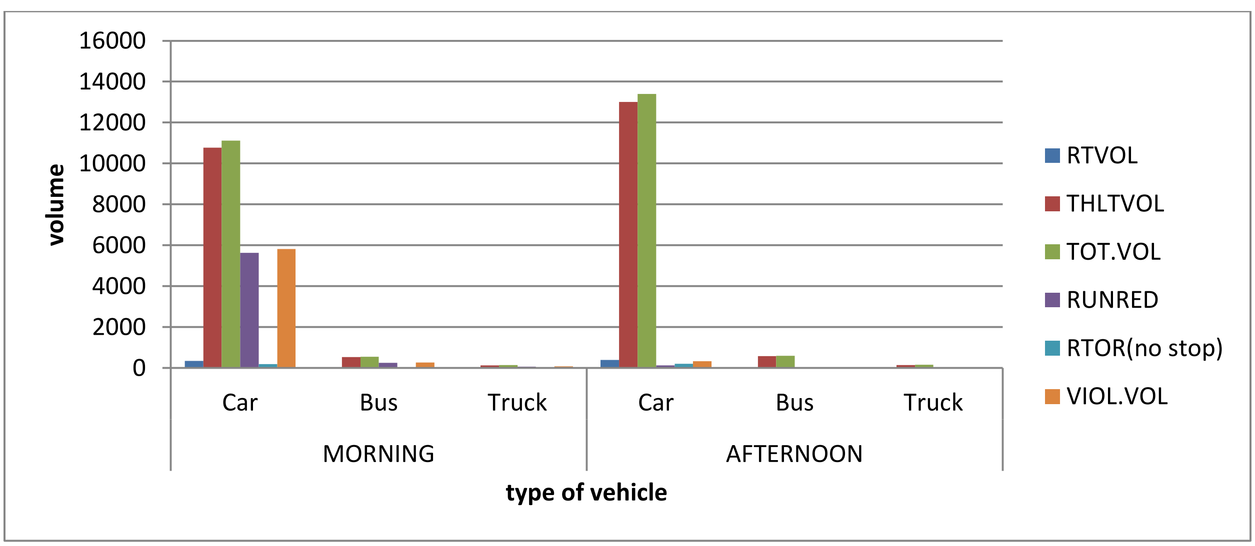


Figure 4.16 Traffic volumes by vehicle composition at EBC Intersection

Traffic volume at Harambe intersection

This intersection has four approaches. The traffic count was conducted for two hours of each peak time in the morning and afternoon for two days on Tuesday and Wednesday. As shown in figure 4.17, below mostly the drivers committing the violation towards red light and right turn on red was 2:00 up to 2:45 in the morning and 11:00 up to 11:30 in the afternoon.

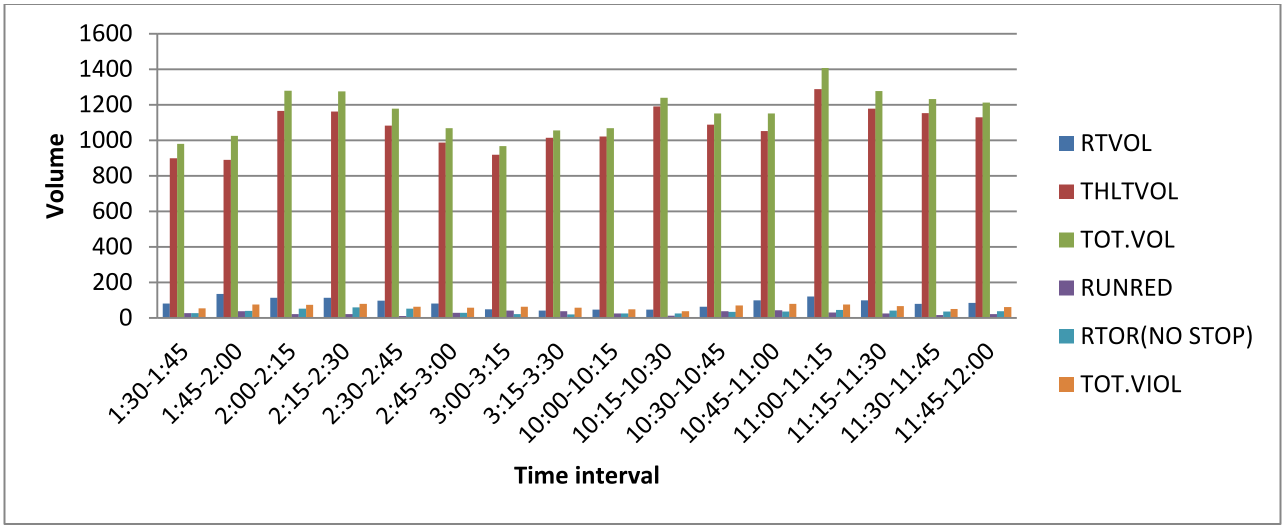


Figure 4.17 Traffic volumes by 15 minute time interval at Harambe Intersection

Figure 4.18 below shows, among the four approaches, Ambassador to stadium approach had higher running on the red than other approaches and Berahawi to Flawuha Approach had a higher right turn on red (no stop) violation and a total violation rate than other approaches.

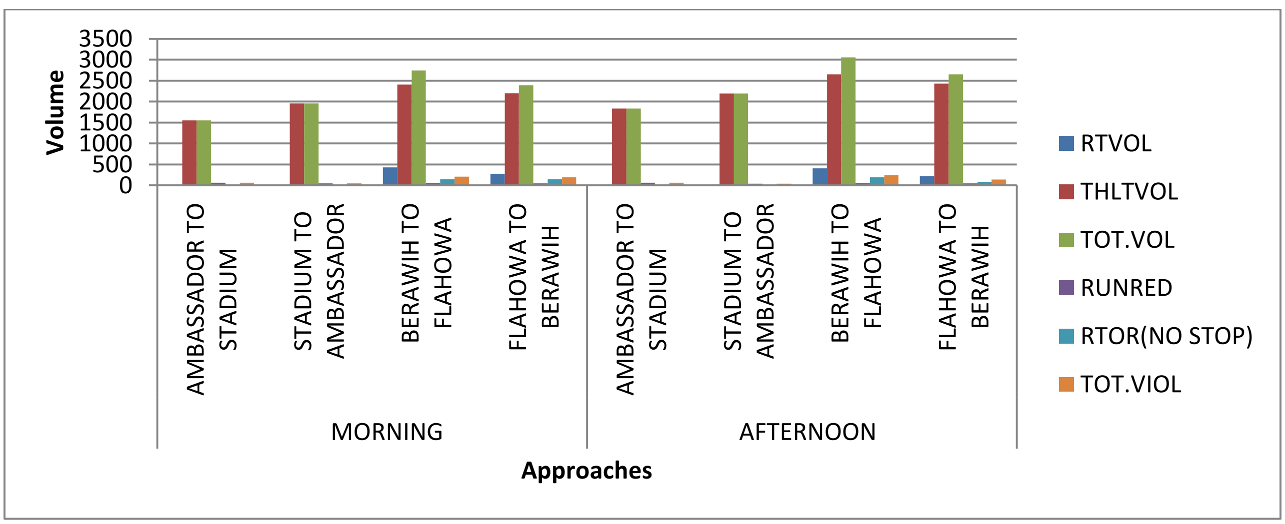


Figure 4.18 Traffic volumes per approaches at Harambe intersection

From figure 4.19, among different types of vehicle compositions cars drivers had higher non-compliance towards red light and right turn on red other than other vehicle drivers.

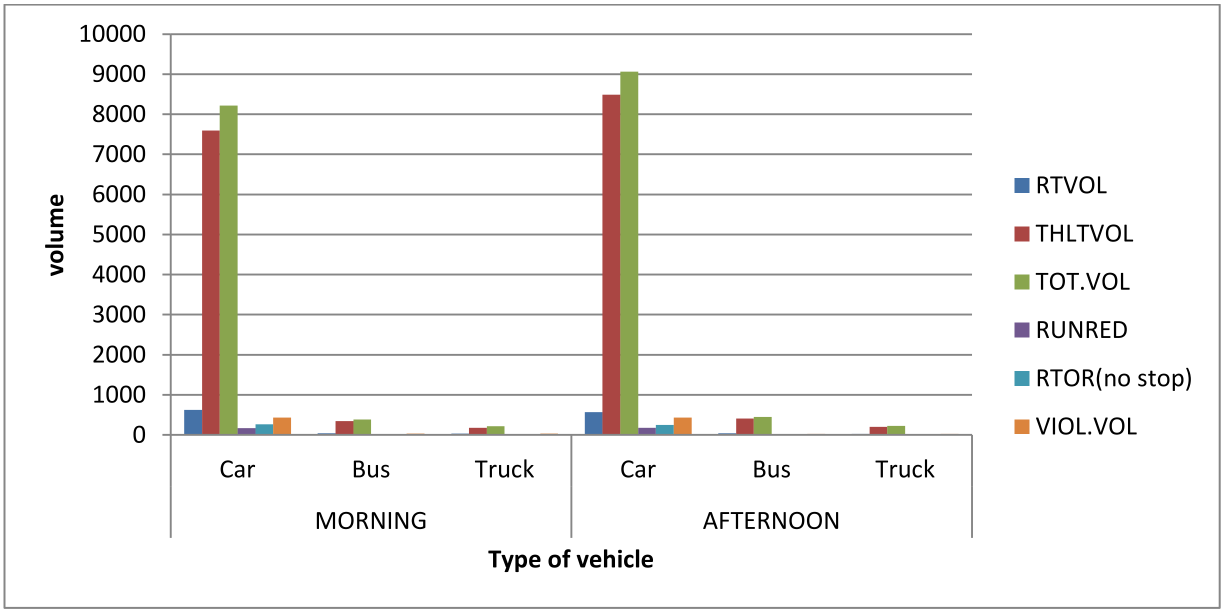


Figure 4.19 Traffic volumes by vehicle composition at Harambe Intersection

4.5.1 Correlation analysis between traffic volume and violation rate of signalized intersection

The statically treatment of the study included the determination of the correlation between volume and violation rate. Table 4.19 and table 4.20 below shows that EBC intersection has the highest traffic volume than other intersection but has the lowest run red and right turn on red (no stop) rate because they have lower right turn volumes. Eliana intersection has lowest traffic volume than other intersections but has the highest run red rate because they were the steepest grade. Tracon intersection has highest right turn on red rate than other intersection because they have higher volume right turn volumes.

Table 4.19 Traffic volumes per hour

Intersection Name	RTVOL	THLTVOL	`TOT.VOL
Eliana Intersection	362	3809	4170
Tracon Intersection	418	3972	4389
EBC Intersection	209	6290	6467
Harambe Intersection	335	4304	4592

Table 4.20 Violation rate per 100 vehicles

Intersection Name	RUNRED	RTOR(no stop)	TOT.VIOL
Eliana Intersection	2.07	2.17	4.24
Tracon Intersection	1.21	2.23	3.44
EBC Intersection	0.71	1.09	1.81
Harambe Intersection	1.05	1.44	2.49

In following table 4.21, the correlation coefficient between right turn volume and right turn on red (no stop) is r = 0.905. This indicates a relatively very high positive correlation relationship between the two variables. A very high correlation positive relationship would yield a correlation between 0.8 and 1. The correlation coefficient between: through, left turn volume versus running on the red light and total volume versus total violation rate are -0.74 and -0.841 respectively.

This indicates a relatively high negative correlation relationship between the two variables. A high correlation negative relationship would yield a correlation between 0.6 and 0.8.

Table 4.21 Pearson correlation table for violation versus volume

Correlated variables	RTVOL	THLTVOL	TOTVOL
	RTOR(no stop)	RUNRED	TOTVIOL
Pearson coefficient	0.905	-0.74	-0.841

CHAPTER FIVE

CONCLUSIONS AND RECCOMENDATIONS

CONCLUSIONS

From the study analysis and results obtained in the previous chapter the following conclusions are drawn:

- The Comprehension of the traffic control device by drivers is an important factor in order to enhance maximum safety on the roads. Traffic control device as a means of communication are used in providing necessary information about the road and its environment to road users especially the drivers.
- Driver's characteristics i.e. age, gender, educational background, driving experience, and type of vehicle driven was tested if each of the factors significantly affects driver's compliance with traffic control device. As a result age, gender, educational background, driving experience, and type of vehicle driven were found as factors affecting a driver's compliance with the traffic control device.
- From the study young drivers (18-24 years) compliance towards the traffic control device significantly less well than older drivers. They were mostly committing violations towards red light and speed limit signs. However, middle-aged drivers (31–50 years) are as good as older ones. The association between the driver's age and violation of traffic control devices was found statistically significant at a 5% significance level ($p=0.026 < p=0.05$).
- Male drivers demonstrate poorer compliance of traffic control device in comparison to female drivers. Male and Female drivers were found mostly violate the red light due to long queues, drivers are waiting for long periods, the number of violation increases: the higher the discomfort (the less the green period time available and the higher the waiting time), the greater the number of red signal violations. The association between the driver's gender and violation of traffic control devices was found statistically significant at a 5% significance level ($p=0.011 < p=0.05$).

- Education had a significant effect on the compliance of the traffic control device as observed in the result. Among the four categories of educational background those drivers with lower level of education (<12) were found not as good as with a higher level of education drivers by compliance of the traffic control device. It was evident that the non-compliance of the traffic control device is related to the educational background of the drivers. Since p-value (0.038) <0.05 and calculated chi-square (15.091)>critical chi-square (7.815).
- Driving experience was a valuable factor to predict compliance performance for a traffic control device. Generally, it can conclude from the result that the better experience drivers had a high compliance rate than less experienced drivers. The associations between the driving frequency and violation frequency were found and it is statistically significant at a 5% significance level (p=0.00<0.05).
- Cars were found that the higher violator of traffic control devices other than traffic compositions. Since the calculated χ 2- value of 18.696 for two df and a critical χ 2- value of 5.992 at 0.05 alpha level and p=0.001<0.05, the type of vehicles drivers driven were related to non-compliance of the traffic control device.
- The most principal reason for violating the traffic control device were due to personal reason consisted of answers such as "I am in a hurry", "I am impatient" and "it's a habit" , etc. and consideration as "safe no risk".
- According to traffic police interview 58 percent was agrees with the age, educational level, number of years and gender of drivers have an influence on traffic control device comprehensibility and 42 percent was disagree with the statement. 64 percent was agree with the mode of drivers the training they have an effect on the compliance to the traffic control device and 36 percent was disagree with the statement. 54 percent was agree with the type of vehicles driven has an effect on the compliance to the traffic control device and 46 percent was disagree with the statement. 76 percent was agree with increased traffic enforcement would increase driver compliance with the traffic control devices and 24 percent was disagree with the statement.
- From the outcome of the study 67.76 percent of the driver's non-voluntary to a stop and 32.24 percent of the drivers voluntarily to stop at the two-way stop-controlled intersection.

- When correlated with right turn volumes, the right turn in red (no stop) violation rate had positive significant correlations (r=0.905) for all approaches combined. These results may be attributed to a lesser risk of conflict events (low traffic volume levels), better sight distances on approaches, and possibly lower enforcement levels at peak hours.
- The run-red violation rate was highest during the afternoon peak hours. It was also found that these high rates occurred for mostly low traffic volumes intersection and steep gradient. The main cause of a red signal run is to avoid the discomfort of the braking and stopping actions. Relatively high negative correlations(r=-0.74) indicated that as the through and left-turn traffic volumes increased, the run red violation rate decreased.
- Right turn is the maneuver concentrating the highest red signal violation rate; right turn on red violation almost two times the red violation. Drivers can check the road during their right-turning crawling and (practically equating the red signal to a stop sign) cross the stop line when the conflicting stream is free.
- With all violations combined, total violation resulted in the highest negative significant correlations (-0.841) with total traffic volumes and the highest rates occurred on low traffic volume intersection.

RECCOMENDATIONS

- Education would be one of the most effective ways to improve this situation. It is recommended that authorities devote special effort to improve drivers' comprehension of traffic control devices. Drivers' license exams should be improved, and traffic control devices that are confusing to drivers should be redesigned or modified. Education programs about traffic control devices should be initiated at schools, universities, and other governmental and non-governmental institutes. This is achievable by the proper use of educational materials such as posters, handbooks, campaigns, use of public media like radio and television, seminars and talk shows.
- Engineering improvements might be consider include removing unnecessary informational or regulatory control, devices adjacent to intersection approaches, better signal timing and network progression, lighted intersections, and intersection geometric improvements. Not all of these improvements are applicable for every signalized intersection; therefore, the traffic engineer must use professional judgment. It is also recommended that signalized intersections be monitored periodically for driver noncompliance levels. As traffic volume conditions change, further intersection improvements may be justified.
- Efforts should be made to inform the driver, local police, and local traffic engineers that driver noncompliance is a problem and should be addressed. Improvements such as higher enforcement levels at low traffic volume intersections, stiffer violation penalties, and educating the public of what constitutes a traffic signal violation should be considered.

These recommendations should be implemented or pursued through the collaboration of traffic-safety officials, law-enforcement agencies, and transportation professionals.

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APPENDIX A
Interview Questions for Drivers (English)

Interview Questions for Drivers

Part I) Demographic & Socioeconomic Characteristics:

1. Age ☐ 18-24 years ☐ 31- 40 years

☐ 25 – 30 years ☐ 40-50 years

☐ More than 51 years

2. Gender ☐ male ☐ female

3. Educational level: ☐ <12 ☐ Diploma ☐ Degree ☐ Master ☐ PhD

4. Job: ______

5. Residence: Urban: ____ Rural: ____

6. License Type: Private ____ Public ____ Heavy Vehicle ____

7. Driving Experience a)<5 ☐ b)5-10 ☐ c)>10 ☐

8. Modes of training: (A)Formal training (training by accredited driving schools)____________

(B)Informal training(learning through a friend or relative)__________

Part II) Behavioral study

9. What type of vehicle do you drive most often? Car_____ Bus_____ Truck _____

10. Do you practice driving every day?

(a)Yes ☐ (b) No ☐

11. How often do you drive the vehicles? (a)A few times a year (b) A few times a month

(c) A few times a week (d) Once a day (e) Several times a day

12. Did you involved in accident/s?

(a)Yes ☐ (b) No ☐

If yes, how many times? ____

13. Do you use mobile phone while you are driving?

(a)Yes ☐ (b) No ☐

14. Please indicate your level of compliance with regard to traffic control devices (tick √ where appropriate)

Drivers non compliance behavior	Have you ever conducting this behavior?			
	never	sometimes	often	always
Not following the directives of road marking				
Non-compliance towards the red signal				
Non-compliance towards the right turn on red				
Non-compliance towards the No left turn sign				
Violating the stop sign				
disobeying the speed limit sign				
Violating the roundabout yield sign				
Violating the No entry sign				
Violating the No parking sign				
Violating the No U-turn sign				

15. Please indicate your reason of non-compliance with regard to traffic control devices (tick √ where appropriate)

Drivers non compliance behavior	Reason for non compliance					
	Device error	Personal case	Enforcement	Road blockage	Safe no risk	Other (specify)
Not following the directives of road marking						
Non-compliance towards the red signal						
Non-compliance towards the right turn on red						
Non-compliance towards the No left turn sign						
Violating the stop sign						
disobeying the speed limit sign						
Violating the roundabout yield sign						
Violating the No entry sign						
Violating the No parking sign						
Violating the No U-turn sign						

16. Which type of the traffic control device mostly made confusion?

----

17. What do you recommend as a countermeasure for the non-compliance of traffic control device?--

APPENDIX B
Interview Questions for Traffic Police (English)

Interview Questions for Traffic Police

1. Please indicate your level of agreement with regard to drivers compliance of traffic control devices (tick √ where appropriate)

General questions	Are you agree with this statement?			
	Strongly agree	agree	disagree	Strongly disagree
The age and gender of drivers have an influence on traffic control device comprehensibility				
The education level and number of years driven have an influence on the compliance to traffic control device.				
The mode of drivers training they have an effect on the compliance to traffic control device.				
The type of vehicles driven has an effect on the compliance to traffic control device.				
Increased traffic enforcement would increase driver compliance with traffic control devices.				

2. Please indicate your level of agreement with regard to drivers reason of non- compliance of traffic control devices (tick √ where appropriate)

Drivers non compliance behavior	Reason for noncompliance					
	Device error	Personal case	Enforcement	Road blockage	Safe no risk	Other (specify)
Not following the directives of road marking						
Non-compliance towards the red signal						
Non-compliance towards the right turn on red						
Non-compliance towards the No left turn sign						
Violating the stop sign						
disobeying the speed limit sign						
Violating the roundabout yield sign						
Violating the No entry sign						
Violating the No parking sign						
Violating the No U-turn sign						

3. What safety problems are associated with driver noncompliance to traffic control device?

----

4. Which type of traffic control device the drivers mostly violating? ---------------------------------

5. What are your enforcement practices relative to each traffic control device?---------------------

----

6. What do you recommend as a countermeasure for the non-compliance of traffic control device?

APPENDIX C
Interview Questions for Drivers (Amharic)

Interview Questions for Drivers

I. **<u>አጠቃላይ መረጃ ስለሹፌሮች</u>**

1. ዕድሜ ☐ 18-24 ☐ 31-40 ☐ >51
☐ 25-30 ☐ 40-50

2. ፆታ ☐ ወንድ ☐ ሴት

3. የትምህርት ደረጃ ☐ < 12 ☐ ዲፕሎማ ☐ ድግሪ ☐ ማስተርስ ☐ ፒኤችዲ

4. ሥራ----------------------

5. የሚኖሩበት ቦታ፡ አ/አበበ ውስጥ ☐ ከአ/አበበ ውጭ ☐

6. የመንጃ ፍቃድ አይነት፡ የሕዝብ ☐ የጭነት ☐ አውቶሞቢል ☐

7. ስንት ዓመት አሽከረክራለህ/ሽ? < 5 ☐ 5-10 ☐ >10 ☐

8. በምን መልኩ ነው የተለማመዱት? አሽከርካሪ ማሰልጠኛ ውስጥ ☐ በጓደኞችዎ በኩል ☐

II. **<u>የማሽከርከር ሁኔታ</u>**

9. ብዙግዜ ምን አይነት መኪና ነው የሚነዱት?

የቤት/ታክሲ ☐ ☐ ስ ☐ ዕቃ ጭነት

10. ሁል ጊዜ ልምምድ ያደርጋሉ? አዎ ☐ አላደርግም ☐

11. ምን ያህል ግዜ መኪና ታሽከረክራለህ/ሽ?

☐ በዓመት ውስጥ ትንሽ ግዜ ☐ በሳምንት ውስጥ ትንሽ ግዜ
☐ በወር ውስጥ ትንሽ ግዜ ☐ በቀን አንዴ ☐ በቀን ብዙ ግዜ

12. ሲያሽከረክሩ አደጋ አድርሰው ያውቃሉ? አዎ ☐ አላውቅም ☐

መልስዎ አዎ ከሆነ ምን ያህል ግዜ ---

13. እያሽከረከሩ የሞባይል ስልክ ያዋራሉ አዎ ☐ አላዋራም ☐

14.በተዘጋጁ ሳጥኖች ውስጥ ምርጫዎትን ራይት (✓) በማድረግ ይተባበሩን

የሹፌሮች ሁኔታ	እነኝህን ተግባር ፈፅመው ያውቃሉ?			
	በጭራሽ	አንድ አንዴ	ብዙ ግዜ	ሁል ግዜ
Road marking /zebra, shoulder lane" ምልክት ያለመክበር				
"Red signal" ቀይ መብራት መጣስ				
"Right turn on Red sign" ቀይ መብራት ሲበራ ማለፍ የተፈቀደ ቦታ ላይ አለማለፍ				
" No left turn sign" ምልክት ያለማክበር				
" stop sign" ቁም ምልክት ያለማክበር				
"speed limit sign" የፍጥነት ወሰን ምልክትን ያለማክበር				
" Roundabout yield sign" ምልክት ያለማክበር				
"No entry sign" (መግባት ክልክል ነው) ምልክት ያለማክበር				
"No parking sign" ምልክት ያለማክበር				
"No U-turn sign" ምልክት ያለማክበር				

15.በተዘጋጁ ሳጥኖች ውስጥ ምርጫዎትን ራይት (✓) በማድረግ ይተባበሩን

የሹፌሮች ሁኔታ	የማያከብሩበት ምክንያት ምንድን ነዉ?					
	በመብራቱ/ በምልክቱ ችግር	በራሴ ችግር	አደጋ አያመጣም ብዬ	ትራፊክ ፖሊስ አስገድዶኝ	መንገድ ተዛግቶ	ሌላ (ያብራሩ)
Road marking /zebra, shoulder lane" ምልክት ያለመክበር						
"Red signal" ቀይ መብራት መጣስ						
"Right turn on Red sign" ቀይ መብራት ሲበራ ማለፍ የተፈቀደ ቦታ ላይ አለማለፍ						
" No left turn sign" ምልክት ያለማክበር						
" stop sign" ቁም ምልክት ያለማክበር						
"speed limit sign" የፍጥነት ወሰን ምልክትን ያለማክበር						
" Roundabout yield sign" ምልክት ያለማክበር						
"No entry sign" (መግባት ክልክል ነው) ምልክት ያለማክበር						
"No parking sign" ምልክት ያለማክበር						
"No U-turn sign" ምልክት ያለማክበር						

16. አብዛኛውን ግዜ የትኛው የትራፊክ መቆጣጠሪያ ምልክት ነው የሚያወዛግብዎ?-------------------------------

17.ሹፌሮች የትራፊክ መቆጣጠሪያ ምልክት እንዲያከብሩ ምን መደረግ አለበት ብለው ያስባሉ?--------------

APPENDIX D
Interview Questions for Traffic Police (Amharic)

Interview Questions for Traffic Police

1.በተዘጋጁ ሳጥኖች ውስጥ ምርጫዎትን ራይት (✓) በማድረግ ይተባበሩን፤፤

አጠቃላይ ጥየቄ	በእነዚህ ዓርፍተ ነገር ይስማማሉ?			
	በጣም እስማማለው	እስማማለዉ	አልስማማም	በጣም አልስማማም
የሹፌሮች ፆተ እና ዕድሜ የትራፊክ መቆጣጠሪያ ምልክትን የማገናዘብ ችሎታቸዉ ላይ ተፅኖ አለዉ				
የሹፌሮች የትምህርት ደረጃ እና ብዙ ዓመት የማሽከርከር ልምዳቸዉ የትራፊክ መቆጣጠሪያ ምልክትን የማክበር ችሎታቸዉ ላይ ተፅኖ አለዉ				
ሹፌሮች የሚለማመዱበት ሁኔታ የትራፊክ መቆጣጠሪያ ምልክትን የማክበር ችሎታቸዉ ላይ ተፅዕኖ አለዉ				
ሹፌሮች የሚያሽከረክሩት የመኪና አይነት የትራፊክ መቆጣጠሪያ ምልክትን የማክበር ችሎታቸዉ ላይ ተፅዕኖ አለዉ				
የትራፊክ ቁጥጥር መጠንከር ሹፌሮች የትራፊክ መቆጣጠሪያ ምልክትን በደንብ እንዲያከብሩ ያደርጋል				

2.በተዘጋጁ ሳጥኖች ውስጥ ምርጫዎትን ራይት (✓) በማድረግ ይተባበሩን፤፤

የሹፌሮች ሁኔታ	ሹፌሮች የማያከብሩበት ምክንያት ምንድን ነዉ?					
	በመብራቱ/ በምልክቱ ችግር	በራሴ ችግር	አደጋ አያመጣም ብዬ	ትራፊክ ፖሊስ አስገድዶኝ	መንገድ ተዛግቶ	ሌላ (ያብራሩ)
Road marking /zebra, shoulder lane" ምልክት ያለመክበር						
"Red signal" ቀይ መብራት መጣስ						
"Right turn on Red sign" ቀይ መብራት ሲበራ ማለፍ የተፈቀደ ቦታ ላይ አለማለፍ						
" No left turn sign" ምልክት ያለማክበር						
" stop sign" ቁም ምልክት ያለማክበር						
"speed limit sign" የፍጥነት ወሰን ምልክትን ያለማክበር						
" Roundabout yield sign" ምልክት ያለማክበር						
"No entry sign" (መግባት ክልክል ነው) ምልክት ያለማክበር						
"No parking sign" ምልክት ያለማክበር						
"No U-turn sign" ምልክት ያለማክበር						

3. ሹፌሮች የትራፊክ መቆጣጠሪየ ምልክትን ባለማክበራቸዉ ምን አይነት የጥንቃቄ ችግር (safety problems) ሊየስከትል ይችላል ብለው ያስባሉ?--

4. የትኛዉ የትራፊክ መቆጣጠሪየ ምልክት ነዉ ብዙ ግዜ ሹፌሮች የሚጥሱት?-------------------------------------

5. እየአንድአንዱን የትራፊክ መቆጣጠሪየ ምልክት ሹፌሮች ሲጥሱ ምን አይነት እርምጃ ነዉ የምትወስዱት?--

6. ሹፌሮች የትራፊክ መቆጣጠሪየ ምልክትን እንዲያከብሩ ምን መደረግ አለበት ብለው ያስባሉ?

APPENDIX E
Compliance Data of Signalized Intersections within 15 Min Interval

Table E-1: Traffic Count Data of Eliana Intersection within 15 min interval

Day	Eliana Intersection						
	Time	RTVOL	THLTVOL	TOT.VOL	RUNRED	RTOR(no stop)	TOT.VIOL
Tuesday Morning	1:30-1:45	68	785	853	21	45	66
	1:45-2:00	83	1029	1112	28	51	79
	2:00-2:15	91	980	1071	50	63	113
	2:15-2:30	106	1125	1231	99	68	167
	2:30-2:45	103	1308	1411	61	70	131
	2:45-3:00	102	1047	1149	50	72	122
	3:00-3:15	98	951	1049	68	60	128
	3:15-3:30	87	799	886	32	57	89
Tuesday Afternoon	10:00-10:15	81	788	869	22	41	63
	10:15-10:30	89	765	854	24	54	78
	10:30-10:45	78	930	1008	72	52	124
	10:45-11:00	92	977	1069	37	78	115
	11:00-11:15	125	1068	1193	31	103	134
	11:15-11:30	101	1176	1277	49	76	125
	11:30-11:45	107	1057	1164	40	68	108
	11:45-12:00	64	898	962	54	39	93
Wednesday Morning	1:30-1:45	49	789	838	35	25	60
	1:45-2:00	64	793	857	44	35	79
	2:00-2:15	89	980	1069	61	59	120
	2:15-2:30	118	1068	1186	42	85	127
	2:30-2:45	99	1133	1232	32	63	95
	2:45-3:00	105	967	1072	31	62	93
	3:00-3:15	71	846	917	37	31	68
	3:15-3:30	87	770	857	25	35	60
Wednesday Afternoon	10:00-10:15	95	791	886	38	65	103
	10:15-10:30	106	760	866	26	70	96
	10:30-10:45	93	908	1001	36	63	99
	10:45-11:00	89	939	1028	30	61	91
	11:00-11:15	95	1041	1136	30	70	100
	11:15-11:30	119	1070	1189	37	84	121
	11:30-11:45	79	1024	1103	47	48	95
	11:45-12:00	60	906	966	31	29	60

Table E-2: Traffic Count Data of Tracon Intersection within 15 min interval

Day	Tracon Intersection						
	Time	RTVOL	THLTVOL	TOT.VOL	RUNRED	RTOR(no stop)	TOT.VIOL
Tuesday Morning	1:30-1:45	88	958	1046	40	44	84
	1:45-2:00	106	1023	1129	20	53	73
	2:00-2:15	103	1111	1214	32	71	103
	2:15-2:30	67	1224	1291	45	55	100
	2:30-2:45	147	1136	1283	26	81	107
	2:45-3:00	117	1065	1182	28	74	102
	3:00-3:15	89	942	1031	33	48	81
	3:15-3:30	60	913	973	18	9	27
Tuesday Afternoon	10:00-10:15	73	751	824	20	26	46
	10:15-10:30	64	988	1052	23	24	47
	10:30-10:45	88	978	1066	23	45	68
	10:45-11:00	127	1122	1249	22	74	96
	11:00-11:15	140	1147	1287	33	89	122
	11:15-11:30	151	1170	1321	50	112	162
	11:30-11:45	151	964	1115	29	104	133
	11:45-12:00	80	938	1018	24	38	62
Wednesday Morning	1:30-1:45	77	796	873	19	14	33
	1:45-2:00	64	830	894	25	15	40
	2:00-2:15	98	875	973	22	57	79
	2:15-2:30	114	1065	1179	59	65	124
	2:30-2:45	142	1073	1215	31	72	103
	2:45-3:00	145	1015	1160	24	84	108
	3:00-3:15	68	926	994	28	20	48
	3:15-3:30	89	878	967	27	35	62
Wednesday Afternoon	10:00-10:15	113	864	977	22	67	89
	10:15-10:30	109	1066	1175	40	25	65
	10:30-10:45	108	931	1039	32	52	84
	10:45-11:00	131	1013	1144	34	69	103
	11:00-11:15	131	1078	1209	46	78	124
	11:15-11:30	136	1105	1241	30	85	115
	11:30-11:45	111	933	1044	33	74	107
	11:45-12:00	56	894	950	27	27	54

Table E-3: Traffic Count Data of EBC Intersection within 15 min interval

Day	EBC Intersection						
	Time	RTVOL	THLTVOL	TOT.VOL	RUNRED	RTOR(no stop)	TOT.VIOL
Tuesday Morning	1:30-1:45	48	1063	1111	26	15	41
	1:45-2:00	28	1471	1499	22	18	40
	2:00-2:15	44	1876	1920	18	31	49
	2:15-2:30	55	1696	1751	18	24	42
	2:30-2:45	53	1586	1639	36	30	66
	2:45-3:00	45	1396	1441	23	25	48
	3:00-3:15	33	1186	1219	26	18	44
	3:15-3:30	31	1169	1200	11	15	26
Tuesday Afternoon	10:00-10:15	27	1359	1386	22	10	32
	10:15-10:30	24	1541	1565	13	12	25
	10:30-10:45	40	1824	1864	25	22	47
	10:45-11:00	66	1934	2000	8	50	58
	11:00-11:15	48	2048	2096	23	30	53
	11:15-11:30	43	1852	1895	15	24	39
	11:30-11:45	45	1874	1919	28	29	57
	11:45-12:00	26	1896	1922	11	14	25
Wednesday Morning	1:30-1:45	52	1124	1176	23	21	44
	1:45-2:00	74	1369	1443	9	33	42
	2:00-2:15	78	1817	1895	26	40	66
	2:15-2:30	69	1898	1967	6	54	60
	2:30-2:45	54	1508	1562	24	30	54
	2:45-3:00	58	1382	1440	16	31	47
	3:00-3:15	51	1205	1256	26	27	53
	3:15-3:30	23	1117	1140	15	9	24
Wednesday Afternoon	10:00-10:15	56	1276	1332	19	25	44
	10:15-10:30	57	1454	1511	12	18	30
	10:30-10:45	60	1446	1506	13	28	41
	10:45-11:00	55	1645	1700	9	37	46
	11:00-11:15	68	1744	1812	21	37	58
	11:15-11:30	109	1980	2089	6	56	62
	11:30-11:45	87	1682	1769	13	41	54
	11:45-12:00	62	1899	1961	8	19	27

Table E-4: Traffic Count Data of Harambe Intersection within 15 min interval

Day	Harambe Intersection						
	Time	RTVOL	THLTVOL	TOT.VOL	RUNRED	RTOR(no stop)	TOT.VIOL
Tuesday Morning	1:30-1:45	70	855	925	30	24	54
	1:45-2:00	131	909	1040	45	44	89
	2:00-2:15	116	1177	1293	30	56	86
	2:15-2:30	102	1193	1295	24	50	74
	2:30-2:45	86	1098	1184	11	44	55
	2:45-3:00	80	990	1070	18	19	37
	3:00-3:15	51	966	1017	46	20	66
	3:15-3:30	40	1007	1047	33	17	50
Tuesday Afternoon	10:00-10:15	35	1055	1090	23	20	43
	10:15-10:30	53	1197	1250	13	27	40
	10:30-10:45	57	1072	1129	34	30	64
	10:45-11:00	88	1058	1146	36	19	55
	11:00-11:15	126	1267	1393	32	44	76
	11:15-11:30	98	1195	1293	26	37	63
	11:30-11:45	73	1220	1293	18	28	46
	11:45-12:00	70	1142	1212	21	32	53
Wednesday Morning	1:30-1:45	92	942	1034	24	30	54
	1:45-2:00	139	871	1010	28	34	62
	2:00-2:15	110	1154	1264	14	46	60
	2:15-2:30	125	1129	1254	17	67	84
	2:30-2:45	106	1067	1173	9	61	70
	2:45-3:00	82	982	1064	40	38	78
	3:00-3:15	44	872	916	36	22	58
	3:15-3:30	43	1020	1063	40	23	63
Wednesday Afternoon	10:00-10:15	56	988	1044	25	29	54
	10:15-10:30	41	1185	1226	10	24	34
	10:30-10:45	70	1102	1172	39	38	77
	10:45-11:00	111	1046	1157	50	53	103
	11:00-11:15	113	1308	1421	28	45	73
	11:15-11:30	99	1161	1260	24	46	70
	11:30-11:45	85	1086	1171	12	42	54
	11:45-12:00	98	1115	1213	23	44	67

APPENDIX F
Compliance Data of Signalized Intersections by Approaches

Table F-1: Traffic Count Data of Eliana Intersection by approaches

Eliana Intersection							
Day	Approach	RTVOL	THLTVOL	TOT.VOL	RUNRED	RTOR(no stop)	TOT.VIOL
Tuesday Morning	Piassa to Churchil		3560	3560	109		109
	Churchil to Piassa		2984	2984	63		63
	Atiklt Tera to Eliana Hotel	643	523	1166	81	486	567
	Wutma Hotel to Atiklt Tera	95	957	1052	156		156
Tuesday Afternoon	Piassa to Churchil		3623	3623	124		124
	Churchil to Piassa		2765	2765	80		80
	Atiklt Tera to Eliana Hotel	686	407	1093	47	511	558
	Wutma Hotel to Atiklt Tera	51	864	915	78		78
Wednesday Morning	Piassa to Churchil		3374	3374	118		118
	Churchil to Piassa		2745	2745	71		71
	Atiklt Tera to Eliana Hotel	540	442	982	48	395	443
	Wutma Hotel to Atiklt Tera	142	785	927	70		70
Wednesday Afternoon	Piassa to Churchil		3424	3424	267		267
	Churchil to Piassa		2831	2831	177		177
	Atiklt Tera to Eliana Hotel	625	411	1036	45	340	385
	Wutma Hotel to Atiklt Tera	111	773	884	123		123

Table F-2: Traffic Data Count of Tracon Intersection by approaches

Tracon Intersection							
Day	Approach	RTVOL	THLTVOL	TOT.VOL	RUNRED	RTOR(no stop)	TOT.VIOL
Tuesday Morning	Churchil to Berawih		3213	3213	78		78
	Berawih to Churchil	569	3551	4120	77	352	429
	Tikur Anbessa to Fluwaha	208	999	1207	66	83	149
	Fluwaha to Tikur Anbessa		609	609	21		21
Tuesday Afternoon	Churchil to Berawih		2829	2829	60		60
	Berawih to Churchil	660	3358	4018	59	416	475
	Tikur Anbessa to Fluwaha	214	1147	1361	71	96	167
	Fluwaha to Tikur Anbessa		724	724	34		34
Wednesday Morning	Churchil to Berawih		2784	2784	87		87
	Berawih to Churchil	611	3030	3641	61	327	388
	Tikur Anbessa to Fluwaha	186	1019	1205	61	35	96
	Fluwaha to Tikur Anbessa		625	625	26		26
Wednesday Afternoon	Churchil to Berawih		2909	2909	103		103
	Berawih to Churchil	681	3294	3975	59	399	458
	Tikur Anbessa to Fluwaha	214	1041	1255	61	78	139
	Fluwaha to Tikur Anbessa		640	640	41		41

Table F-3: Traffic Data Count of EBC Intersection by approaches

EBC Intersection							
Day	Approach	RTVOL	THLTVOL	TOT.VOL	RUNRED	RTOR(no stop)	TOT.VIOL
Tuesday Morning	Post Office to Berawih		4556	4556	71		71
	Berawih to Post Office		2937	2937	34		34
	Black Lion to Ambassador	337	2647	2732	35	176	211
	Ambassador to Berawih		1303	1303	40		40
Tuesday Afternoon	Post Office to Berawih		5695	5695	57		57
	Berawih to Post Office		3408	3408	15		15
	Black Lion to Ambassador	319	3649	3968	51	191	242
	Ambassador to Berawih		1576	1576	22		22
Wednesday Morning	Post Office to Berawih		4474	4474	66		66
	Berawih to Post Office		2791	2791	19		19
	Black Lion to Ambassador	459	2806	3265	39	245	284
	Ambassador to Berawih		1349	1349	21		21
Wednesday Afternoon	Post Office to Berawih		5224	5224	49		49
	Berawih to Post Office		2958	2958	9		9
	Black Lion to Ambassador	554	3455	4009	28	261	289
	Ambassador to Berawih		1489	1489	15		15

Table F-4: Traffic Data Count of Harambe Intersection by approaches

Harambe Intersection							
Day	Approach	RTVOL	THLTVOL	TOT.VOL	RUNRED	RTOR(no stop)	TOT.VIOL
Tuesday Morning	Ambassador to Stadium		1638	1638	61		61
	Stadium to Ambassador		1951	1953	53		53
	Berawih to Flahowa	402	2374	2584	73	133	206
	Flahowa to Berawih	272	2232	2325	50	141	191
Tuesday Afternoon	Ambassador to Stadium		1900	1900	60		60
	Stadium to Ambassador		2207	2207	35		35
	Berawih to Flahowa	370	2598	2968	57	156	213
	Flahowa to Berawih	226	2501	2727	51	81	132
Wednesday Morning	Ambassador to Stadium		1460	1460	66		66
	Stadium to Ambassador		1965	1965	37		37
	Berawih to Flahowa	458	2443	2901	46	164	210
	Flahowa to Berawih	281	2169	2450	39	157	196
Wednesday Afternoon	Ambassador to Stadium		1774	1774	66		66
	Stadium to Ambassador		2169	2169	40		40
	Berawih to Flahowa	449	2698	3147	56	225	281
	Flahowa to Berawih	220	2350	2570	49	96	145

APPENDIX G
Compliance Data of Two-Way Stop-Controlled Intersection

Table G-1: Qechene Medanaliem to Semein Mazagjaha minor road traffic volume at two-way stop-controlled intersection

Day	Driver behaviors	Type of vehicles	Movements		
			Left	Straight	Right
Tuesday Morning	Not Stopping	Car	113	43	95
		Bus			
		Truck			
	Practically Stopped	Car	308	79	102
		Bus	3	3	2
		Truck		2	2
	Stopped by traffic(forced stop)	Car	61	31	35
		Bus	1		
		Truck		2	1
	Voluntary full stop	Car	109	36	46
		Bus	1	1	1
		Truck	1		
Tuesday Afternoon	Not Stopping	Car	102	26	95
		Bus		1	1
		Truck			
	Practically Stopped	Car	335	85	113
		Bus	3	1	4
		Truck		1	5
	Stopped by traffic(forced stop)	Car	61	28	44
		Bus	1		
		Truck		1	
	Voluntary full stop	Car	112	35	53
		Bus	2	2	1
		Truck		2	
Wednesday Morning	Not Stopping	Car	96	14	103
		Bus			
		Truck			1
	Practically Stopped	Car	292	79	93
		Bus	2	2	5
		Truck	4	2	5
	Stopped by traffic(forced stop)	Car	60	38	46
		Bus	4		
		Truck	1		
	Voluntary full stop	Car	101	37	55
		Bus	3	3	4
		Truck		1	4

Day	Driver behaviors	Type of vehicles	Movements		
			Left	Straight	Right
Wednesday Afternoon	Not Stopping	Car	127	24	88
		Bus			2
		Truck			4
	Practically Stopped	Car	295	86	90
		Bus	1	4	3
		Truck	1	4	7
	Stopped by traffic(forced stop)	Car	66	36	56
		Bus	3	1	2
		Truck			3
	Voluntary full stop	Car	101	38	50
		Bus	8	4	1
		Truck	6	2	4

Table G-2: Enkulal Fabrica to Semein Mazagjaha minor road traffic volume at two-way stop-controlled intersection

Day	Driver behaviors	Type of vehicles	Movements		
			Left	Straight	Right
Tuesday Morning	Not Stopping	Car	99	81	13
		Bus		1	1
		Truck	1		1
	Practically Stopped	Car	232	232	55
		Bus	2	6	4
		Truck	2	4	1
	Stopped by traffic(forced stop)	Car	70	71	21
		Bus			1
		Truck	2	2	
	Voluntary full stop	Car	72	66	26
		Bus	1	12	3
		Truck	2	1	1
Tuesday Afternoon	Not Stopping	Car	86	84	19
		Bus	3	1	
		Truck	5		1
	Practically Stopped	Car	230	224	54
		Bus	7	8	3
		Truck	5	7	2
	Stopped by traffic(forced stop)	Car	68	66	31
		Bus	2	4	0
		Truck	2	3	1
	Voluntary full stop	Car	67	64	27
		Bus	6	9	1
		Truck	7	8	0
Wednesday Morning	Not Stopping	Car	101	73	15
		Bus			1
		Truck	3	3	1
	Practically Stopped	Car	222	226	59
		Bus	10	5	1
		Truck	1	4	1
	Stopped by traffic(forced stop)	Car	54	44	25
		Bus	3	1	0
		Truck	5	1	3
	Voluntary full stop	Car	68	67	29
		Bus	4	6	0
		Truck	1	6	4

Day	Driver behaviors	Type of vehicles	Movements		
			Left	Straight	Right
Wednesday Afternoon	Not Stopping	Car	77	61	13
		Bus	1	1	0
		Truck	2	1	2
	Practically Stopped	Car	246	246	60
		Bus	7	9	3
		Truck	3	3	4
	Stopped by traffic(forced stop)	Car	60	61	23
		Bus	4	1	2
		Truck	6	6	0
	Voluntary full stop	Car	63	67	38
		Bus	7	2	6
		Truck	3	8	5