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

ASSESSING THE EFFECT OF DIGITAL COUNTDOWNS AT SIGNALIZED INTERSECTION IN ADDIS ABABA

By:

Yared Abraha Mesele

A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of

The Requirements for the Degree of

Master of Science

In

Road and Transport Engineering

Research Advisor: **Bikila Teklu Wodajo (PhD.)**

October 2019

Addis Ababa, Ethiopia.

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UNDERTAKING

I, the undersigned, certify that this research work titled "**Assessing the effect of digital countdowns at signalized intersection in Addis Ababa**" is my original work performed under the supervision of my research advisor **Dr. BikilaTeklu** and has not been presented elsewhere for assessment and for a degree in any other university. All sources of materials used for this thesis have also been duly acknowledged.

Signature: ________________

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Place of Undertaking: Addis Ababa, Ethiopia.

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ABSTRACT

Signalized intersections are important elements of urban road networks, and their efficiency and safety significantly impact the performance of the entire roadway network. There are different educational, enforcement and engineering measures that are attempted to improve safety and efficiency at a signalized intersection. A traffic signal countdown timer is an engineering device that displays the remaining time, typically in seconds, of the current signal phase. Because of the difference in drivers behavior from place to place, different previous studies associated with the effects of signal countdown has different outcome, and this study tries to assess the effect of signal with countdown on intersection safety and efficiency on the selected intersections located in Addis Ababa. For this research matter, the researcher selected six intersections in Addis Ababa, three with a countdown timer and the rest three without countdown timer.

Data collection was done using video recording and driver's attitude survey from the end-users. To measure intersection safety and efficiency startup lost time, red light violation, dilemma zone, and the driver's decision were identified. Startup lost time was estimated and found that the red signal countdown helped to reduce the startup lost time. Green signal countdown (GSC) and Red signal countdown (RSC) affects the red light violations by increasing violations at the end of red and decrease at the end of yellow. The presence of signal countdown enlarged the range of type II dilemma zone at the onset of yellow. A binary logistic regression model is developed to study the effect of significant factors on driver's decision making; and distance, approach speed, remaining time, and signal conditions were found statically significant to predict driver's probability to stop or cross the intersection after onset of yellow. In signal with countdown, the driver's decision to cross is smaller than the intersection without countdown. From the driver's attitude survey, it was found signal with countdown is the most recommended in order to reduce traffic crashes and to maximize traffic efficiency by improving driver's decision making. Additionally, it is found that the most dominating reasons of red light violation in signal with countdown are to save time, if there is no traffic police, inadequacy of allocated green time and carelessness towards crash.

Keywords: *Countdown, Dilemma zone, Drivers behavior, Red Light Violation, startup lost time*

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA:	Analysis of variance
D:	Distance from the stop line
DZ:	Dilemma zone
EBC	Ethiopia Broadcasting Corporation
G:	Approach grade
GSC:	Green signal countdown
HCM:	Highway capacity manual
L:	Intersection length
MC:	Movement of vehicle from conflicting direction
MUTCD:	Manual on uniform traffic control device
PCU:	Passenger car unit
PRT:	Perception reaction time
RE:	Drivers response
RLV:	Red light violation
RSC:	Red signal countdown
RT:	Remaining yellow time
Sec	Second
SC:	Signal condition
SULT:	Startup lost time
V:	Approach speed at onset of yellow.
Veh:	Vehicle
VI:	Vehicle in front of the target vehicle
VT:	Vehicle type

CHAPTER ONE: INTRODUCTION

1.0 Background

Signalized intersections are important elements of urban road networks, and their efficiency and safety significantly impact the performance of the entire roadway network. Thus, the application of innovative approaches to manage traffic at signalized intersections with a high level of safety and efficiency is crucial. Traffic signal countdown timers are innovative practices that have the potential to resolve certain operational issues at the signalized intersection. A traffic signal countdown timer is a device that displays the remaining time, typically in seconds, of the current signal phase. The purpose of using these devices is to provide the driver with specific information regarding a pending change in traffic signal indication at intersection. Countdown timers are thought to have the potential of improving capacity, reducing right-angle crashes, and easing driver anxiety while in queue (Kidwai et al, 2005). Signal countdown timers are expected to help drivers with better decision-making processes.

Though signal without countdown systems play an important role in controlling traffic flow, they do experience significant lost time, and hence capacity reduction, at the transition points. Because the actual transition point is completely unpredictable in many without countdown signal locations, drivers that are caught in the dilemma zone may make judgment errors about whether they should go or stop. Therefore, intersection safety and capacity could potentially be enhanced among drivers by providing additional warning about the onset of the transition.

Signal countdown timers are widely used in East Asian countries and have provided some useful operational and safety benefits; however, the application of the device in North America is small. A green-phase countdown timer can serve as a mounting warning about the imminent termination of the right of way and can arguably reduce red-light running and other potential conflicts. When implemented during the red phase, a countdown timer may also ready vehicles for the approaching onset of the green phase and reduce startup lost time.

The purpose of this research is to address the effect of signal countdown on intersection safety and efficiency by comparing with signalized intersections without countdown. Past research, projects, and papers were reviewed with an emphasis on signal design features and effects on traffic, as well as strengths and weaknesses associated with the use of signal countdown timers. This research has selected six intersections in Addis Ababa. Three intersections are equipped with countdown timers and the other three without countdown.

1.1 Statement of the Problem

Countdown timers are considered to have the potential of improving capacity, reducing right-angle crashes, and easing driver anxiety while in queue.

From some previous findings Like (Long et al, 2013, Sabyasachi Biswas, 2017), it is evident that signal countdown timers were found to be associated with reduced Startup Lost Time, Dilemma Zone, Red light violations, and improved drivers decision making. There are also some other research works and manuals (MUTCD, 2003), which contradicted these findings. The key reason behind these inconsistent findings could be the difference in traffic conditions and driver behaviors among the countries, even from one city to another.

The Engineering study conducted in Ethiopia, Addis Ababa to evaluate their effect on intersection efficiency and safety prior to installations of these countdown timers is low. Due to the difference in driver's behavior from place to place signal type and signal design parameters (startup lost time, inter-green time, length of dilemma zone, and duration of yellow time) developed for other cities should not be used for Addis Ababa. As a result, the intention of the research is to assess the effect of signal countdown on intersection safety and efficiency in Addis Ababa.

1.2 Research Questions

- What is the effect of digital signal countdown in the traffic stream?
- Is there any red-light violation at the end of the red phase?
  - With count down and
  - Without countdown signal intersections.
- Is there any violation at the end of the green phase?
  - With count down and
  - Without countdown signal intersections.
- How much is the dilemma zone in the intersection?
  - with countdown and
  - Without countdown signal intersections.

1.3 Objective of the study

1.3.1 General Objective

The general objective of the study is to assess the effect of signal countdown on intersection safety and efficiency by comparing with signalized intersections without countdown.

1.3.2 Specific Objective

- To analyze startup lost time with and without countdown on the selected intersections in Addis Ababa.
- To assess the red-light violation at signalized intersection with and without countdown
- To describe the driving behavior at signalized intersection with and without countdown
- To assess the reasons for red light violation for both countdown and without countdown.

1.4 Scope, Scientific Contribution, and Limitation of the Study

1.4.1 Scope of the study

This research has used Addis Ababa city as study area. Due to budget and time constraint, the study was subjected to six signalized intersections. Three with signal countdown and the remaining three intersections are without countdown on them. During the study only one approach had been used and the study is limited to the intersection safety and efficiency measured by startup lost time, red light violation, dilemma zone and driver decision making only.

1.4.2 Scientific Contribution of the Study

Assessing the effect of signal countdowns at selected signalized intersection in Addis Ababa will have the following importance:

Theoretically it helps to:

- ✓ Improve our understanding on the benefits of signalized intersection for drivers in Addis Ababa,
- ✓ Find how different parameters affect drivers decision making at the onset of yellow,
- ✓ Know the associations between signal type and parameters of intersection safety and efficiency,
- ✓ Know the preference or understanding of drivers towards signal type its effect on safety and efficiency,

Practically to:

- ✓ Use applicable signal type (signal with countdown or without countdown) by understanding and characterizing the stochastic nature of driver's behavior in order to improve safety and efficiency,
- ✓ Quantify Startup lost time at Addis Ababa's signalized intersections to be used in signal timing,
- ✓ Identify the dominant parameter in driver's decisions making at local conditions and can make different interventions towards maximizing of intersection safety and efficiency.

1.4.3 Limitation of the study

The study has not been incorporated

- Effect due to pedestrian movement
- Effect due to pavement distress
- Effect due to Motorcycle and bicycles
- Effect due to Weather condition
- Gradient for SULT, RLV, and DZ

1.5 Structure of the thesis

This study is organized in five chapters. Chapter one briefs an overview about the general background of the study, statement of the problem, research questions, objectives of the study, scope significant and limitation of the study. Chapter two deals with reviews literature relevant to the study subject. Chapter three explains the method of the study including a description of the study area, research procedure, data requirement, sample size determination and study design, data collection and extraction, data analysis and research materials. Chapter four describes details of the data analysis and discussion of the results obtained during the study period. Finally, conclusion and recommendation have been presented.

Graphical representation for the structure of the research

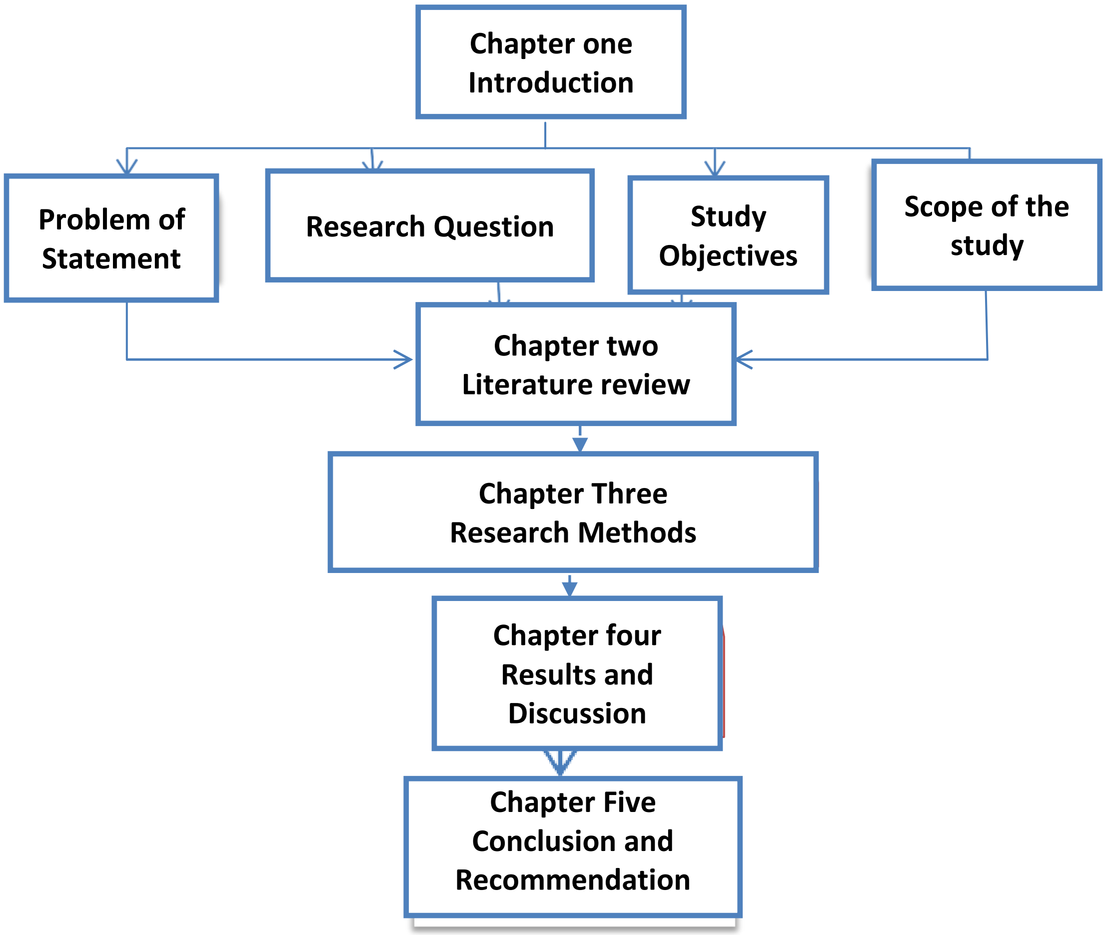

Figure 1 Structure of the thesis

CHAPTER TWO: LITERATURE REVIEW

2.1. Terminologies Related to Signalized Intersection

It is important to discuss several traffic engineering terms and concepts related to the concept of signalized intersection. Although this section may not be comprehensive, it should serve to provide a working knowledge of the terms being used through the rest of this document.

Intersection: - An intersection is a location where two or more roads carrying traffic streams in different directions cross.

Signalized intersection: - A traffic control signal (traffic signal) shall be defined as any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed (FHWA, 2004).

Cycle: A signal cycle is one complete rotation through all of the indications provided.

Cycle length: Cycle length is the time in seconds that it takes a signal to complete one full cycle of indications. It indicates the time interval between the starting of green for one approach till the next time the green starts.

Interval: Thus it indicates the change from one stage to another. There are two types of intervals change interval and clearance interval. Change interval is also called the yellow time indicates the interval between the green and red signal indications for an approach. Clearance interval is also called all red is included after each yellow interval indicating a period during which all signal faces show red and is used for clearing the vehicles in the intersection (FHWA, 2004).

Green interval: It is the green indication for a particular movement or set of movements. This is the actual duration the green light of a traffic signal is turned on.

Red interval: It is the red indication for a particular movement or set of movements. This is the actual duration the red light of a traffic signal is turned on.

Phase: A phase is the green interval plus the change and clearance intervals that follow it. Thus, during the green interval, non-conflicting movements are assigned to each phase. It allows a set of movements to flow and safely stop the flow before the phase of another set of movements start (HCM, 2010).

Green signal countdown timer (GSC):- is a device, which shows the remaining time during the green phase of the signal cycle (Hongyun Chen, 2009).

Red signal countdown timer (RSC):- device that provides information to the drivers about the remaining time left in the red phase.

2.2 Overview of Signalized Intersections

With the rapid increase of car ownership and the commuting demand that is generated by the speedy urbanization, serious traffic problems, emerge for cities. Intersections, as the nodes for connecting the links, are important for the operation of an entire urban road network, thus have attracted researchers to explore the related traffic phenomena, especially those that occur at a signalized intersection. Intersection is an area embraced within the persistence or connection of lateral curb lines, or of none, the lateral boundary line of a roadways of two highways that join one another at or approximately at, right angles, or the area within which vehicles traveling on different highways that join at any other angles might come in to conflict (MUTCD, 2003).

Traffic shall be defined as pedestrians, bicyclists, ridden or herded animals, vehicles, streetcars, and other conveyances either singularly or together while using any highway for purposes of travel (Roess et al, 2011). Traffic control signals can attract the attention of a variety of road users, including those who are older, those with impaired vision, as well as those who are fatigued or distracted, or who are not expecting to encounter a signal at a particular location (MUTCD, 2003) Traffic control signals are valuable devices for the control of vehicular and pedestrian traffic. They assign the right-of-way to the various traffic movements and thus greatly influence traffic flow. Traffic control signals that are properly designed, located, operated, and maintained will have one or more of the following advantages (MUTCD, 2003):

- They provide orderly movement of traffic
- They increase the traffic-handling capacity of the intersection if:
    1. Proper physical layouts and control measures are used, and
    2. The signal operational parameters are reviewed and updated (if needed) on a regular basis to maximize the ability of the traffic control signal to satisfy current traffic demands

They reduce the frequency and 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.

Traffic control signals are often considered a solution for all traffic problems at intersections. This belief has led to traffic control signals being installed at many locations where they are not needed, adversely affecting the safety and efficiency of vehicular, bicycle, and pedestrian traffic (MUTCD, 2003).

Traffic control signals, even when justified by traffic and roadway conditions, can be poorly designed, ineffectively placed, improperly operated, or poorly maintained. Improper or unjustified traffic control signals can result in one or more of the following disadvantages (MUTCD, 2003):

- Excessive delay;
- Excessive noncompliance of the signal indications;
- Increased use of less adequate routes as road users attempt to avoid the traffic control signals; and
- Significant increases in the frequency of collisions (especially rear-end collisions).

2.2.1. Signal Countdown Timer

Traffic Signal Countdown Timers are clocks that digitally display the time remaining for a particular signal indication for red, yellow, or green. They provide real-time information to drivers to improve decision making and vehicle control. Drivers at a signalized intersection waiting for right of way the information makes the driver alert of an oncoming signal change (Mohammad Rabiul Islam, 2014).

Signal control systems are intended to regulate traffic passing through intersections safely and efficiently. Even if Signal without Countdowns plays an important role in controlling traffic flow, they do experience significant lost time, and hence capacity reduction, at the transition points. The transition points, where the signal light turns from green to red and from red to green, are necessary to allow drivers to respond to changes in right-of-way assignment. (Hongyun Chen, 2009). Because the actual transition point is completely unpredictable in many signals without countdown, drivers that are jammed in the dilemma zone may make judgment errors about whether they should go or stop. Therefore, intersection safety and capacity could potentially be enhanced among drivers by providing additional warning about the onset of the transition. Signal countdown timers are widely used in the world and have provided some useful operational and safety benefits. Past research, projects, and papers were reviewed with an emphasis on signal design features and effects on traffic, as well as strengths and weaknesses associated with the use of signal countdown timers. Signal countdown devices are designed to provide drivers with the remaining time before status change (e.g., yellow to red) on vehicular signal indications. The basic assumption is that drivers will apply this information to make better decisions on the proper time to enter the intersection.

2.2.2. Headway

The term headway refers to the time headway, in the context of this document. It can be defined as the time elapsed between two successive vehicles to pass a given point on the roadway. A special case of headway called the "first headway" exists at signalized intersections. Because there is no vehicle in directly front of the first vehicle in a standing queue on a red indication, the headway of the first vehicle (i.e., first headway) is defined as the time lapse between the onset of the green indication and the time when the front axle of the vehicle passes the stop line. The discharge or departure headways of a traffic stream are usually highest at the beginning of green for the first few vehicles due to the perception reaction time (PRT) of the first few drivers. It is also assumed that the saturation headway will be reached by the fourth (HCM, 2010) or fifth (Roess et al., 2011) vehicle in the queue and vehicles will continue to process at the saturation flow rate until the last vehicle of the queue is processed, as shown in Figure 2

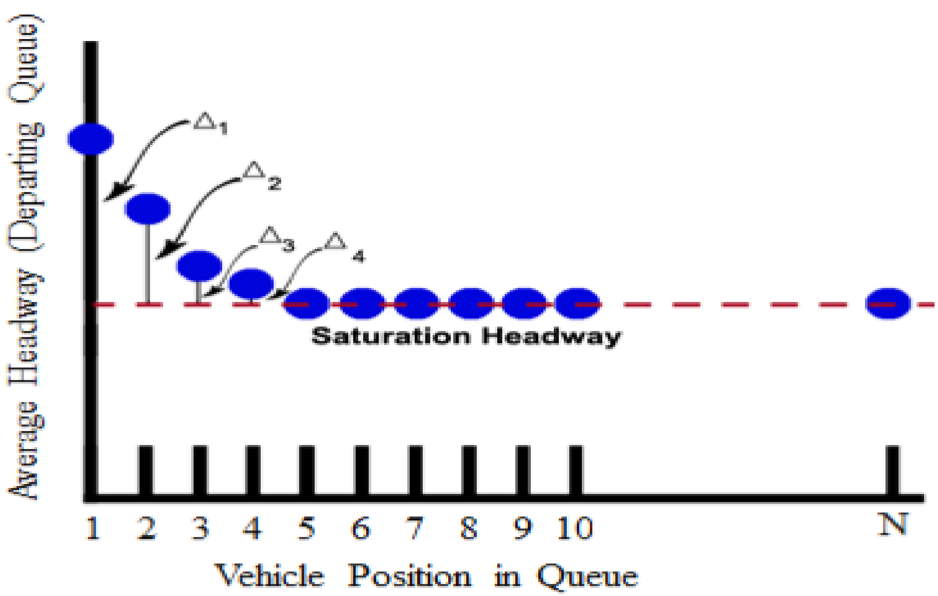

Figure 2 Headway

Red signal countdown (RSC) is clearly visible to the first four or five vehicles in a standing queue waiting to respond to the green indication. Thus, headways between the vehicles responding to RSC, as the queue starts moving at the end of the red indication are expected to be lower than that of a traditional signal. This reduction in headways has the potential to increase capacity at signalized intersections.

2.2.3. Startup Lost Time (SULT)

It is defined as the sum of the extra time required over the minimum headway (at saturation flow) at the beginning of green indication and signalized intersection. The Traffic Signal Timing Manual defines startup lost time as the additional time, in seconds, consumed by the first few vehicles in a queue at a signalized intersection above and beyond the saturation headway due to the need to react to the initiation of the green phase and to accelerate to a steady flow condition (S. P. Calıskanelli, et.al, 2017).

Start-up lost time is one of the parameters which may show the effect of different driver behaviors of different signal type. (HCM, 2010) Recommends that the minimum discharge headway be calculated, is the average headways for the fifth through last queued vehicles. This approach implies that the first four vehicles affect all of the start-up lost time and it indicates that start-up lost time is generally about 2.0 sec/cycle. Start-up lost time can affect by Vehicle type and gradient, Pedestrians in the intersection, Perception/reaction time which varies from driver to driver, Psychological factors and violated vehicles in the intersection.

(Roger p. Roess et al., 2011) Stated that, if a saturation headway for the data has been established as h s/veh, then the lost time component in each of the first four headways is (h_i - h), where h_i is the total observed headway for vehicles 1 to 4 in the queue.

The startup lost time is the sum of these increments. Both saturation flow rate and startup lost time are observed for a given lane during each signal cycle. The calibrated value for use in analysis would be the average of these observations.

Note that saturation conditions are said to exist only between the fifth headway and the headway of the last vehicle present in the standing queue when the signal turns green.

Only the headways occurring between these limits can be used to calibrate the saturation flow rate. The first four headways in each queue will be used subsequently to establish the startup lost time. The Saturation headway for the lane in question is the average of all observed headways representing saturated conditions.

2.2.4. Dilemma Zones (DZ)

Dilemma zones (DZ) are the areas upstream of a signalized intersection where drivers have difficulty deciding whether to stop or go through when presented with yellow indication. Depending on how they are produced at signalized intersections, DZ is classified into two categories: Type I and Type II. Type I DZ results from the inadequate design parameters (Gazis, et al., 1960), whereas Type II DZ results purely from driver's indecision to stop or go through the intersection (Zeeger, 1978). And he defined that the beginning of dilemma zone Type II is the distance beyond which 90 percent of all drivers would stop if presented with a yellow indication and the end of the zone is the distance within which only 10 percent of all drivers would stop. Type I dilemma zone deal with the period of time during a driver either proceeds through the intersection if it is too close to stop line or stop if too far to the stop line. Failure to provide adequate yellow and red clearance time produces a type I dilemma zone. This problem can address by the selection of appropriate yellow change and red clearance intervals.

Type II dilemma zones are associated with driver behavior and this can address by the proper design of the detection system and the appropriate selection of controller timing parameters. (Tom Urbanik et al, 2007).

The Type II dilemma zone has also been defined as the observed travel time to the stop line. (Chang et al. 1985) found that 85 percent of drivers stopped if they were more than 3 seconds from the stop line, regardless of their speed.

Approach Speed is an important transportation consideration because it relates to safety, time, comfort, convenience, and economics.

2.2.5. Red Light Violation

Violation is a situation when the vehicle travels past the solid stop line or its equivalent location on the intersection approach after the light has turned red (Bams Boneson and Karl Zimmerman, 2004).

(Jeevitha Devalla et al., 2015) said that the long waiting time at red light has other negative impacts as well. The resultant delay gives rise to frustration and stress, as well as the carelessness of drivers to signal changes. These situations also tend to contribute to different traffic violations whereby drivers disregard the traffic signals, leading to the occurrence of red light violation.

2.2.6. Driver's Behavior

The effects of signal countdown on the driving behavior are different from country to country, even from one city to another. The presence of signal countdown affects driving behavior and consequently influences the safety at signalized intersection. The approach speed during the phase transition is the major factor behind driver's decision to stop before or proceed through intersection, accelerating/decelerating behavior and key determinant of risk exposure to motorists and other road users (Jeevitha Devalla.et.al. 2015).

2.3. Previous Studies on the Effect of Signal Countdown

The purpose of applying the devices is clear to assist drivers in the current state of signal control. However, the application of the countdown device has also brought some attention to its safety and operational characteristics. A research institute within Taiwan's Ministry of transportation by (Chen et al. 2007) has done a study on the safety of the countdown device of the 187 intersections that had the timers installed, those locations that shows remaining time on green lights have double the number of crashes, with a 33 % increase in the number of injuries. However, those sites with red signal countdown can reduce both the number of total crashes and injuries by half. Installing a red-time countdown device has a positive impact, while the green one increases the probability of crashes occurring at intersections. There could be several explanations; however, the main reason is the diversion of the driver's attention from the intersection. When a driver decides to pass through a green light, he or she tends to focus more on the countdown time as opposed to what is happening on the road, especially during the last few seconds. For example, the driver in the previous vehicle might decide to slow down and stop at the intersection, while the trailing vehicle driver wants to speed up to pass through the intersection. According to (Chiou and Chang 2010) green countdown time can increase the travel time and limit the traffic capacity. Fewer vehicles could jump the intersections during the fixed green time, and delay would increase largely, especially in peak hours. Because the green-time countdown device had negative effects on both safety and efficiency, the local police administration is considering dismantling or shutting off the devices in the near future. However, the installation of red-time countdown devices has some benefits. The observed driver behavior is different from the green countdown device. If a driver is at a red signal, more attention is paid to the road conditions than the signal indications. Also, it would help drivers to reduce delay time by knowing when to anticipate the beginning of green. A research study done by (M. R Ibrahim et al, 2008) used six intersections, three with countdown timers and three without those timers. The countdown timer has little effect on initial delay but does have a significant effect on headway. The discharge headway had a high variance for the same car positions in different cycles for several intersections; however, it has no significant effect on the travel time to stop line, especially for the first few vehicles. The traffic signal violation rate for countdown versus no-countdown configurations was also compared. For the countdown case, the drivers crossed the stop line during red time in 24 out of 88 cycles. For the non-countdown case, 22 out of 90 cycles were violated. Therefore, the rate of violation is 30 percent for countdown and 24 percent for non-countdown. The increased violation rate would certainly increase the chances of crashes occurring.

(Panos Papaioannou et al, 2014) stated that the percentage of the violations of the early start for the signal with the Countdown Signal Time device was observed to 24% whereas the respective percentage for the signal without the Countdown Signal Time installation was less than 1%. (Mohammad Rabiul Islam, 2014) stated that the presence of countdown timer reduced drivers' reaction time at the onset of green. Drivers who decided to go through the intersection were 2.5 seconds in the absence of the GSC, whereas it was 2.0 seconds when GSC was present. Similarly, the influence for drivers who chose to stop was 5 seconds and 4.5 seconds in absence and in presence of GSC respectively. This leftward shift in presence of GSC suggested an improvement in driver's stopping behavior.

The mean deceleration rate with GSC was 10.69 ft/sec2 and 9.19 ft/sec2 without GSC. This implies the deceleration rate of GSC is higher than without GSC.

(Moore and Hurwitz, 2013) studies 11 signalized intersection with timer to develop a model the entire type II DZ, and the result ranging from 1.0 to 6.0 seconds in 0.5 seconds intervals to ensure that driver behavior on dilemma zone. They found that nearly 100% of the drivers proceeded through the intersection when presented the yellow signal at a distance of 2 seconds or less and stopped at a distance of 6 seconds or more.

Most of the drivers go through the intersection for equal or less than 2 seconds after red light onset and stop at the intersection after equal or greater than 4.5 seconds onset of red light. Therefore, the area under the curve between a red light equal to 2 and 4.5 seconds was divided by the difference in (4.5-2.0 = 2.5 seconds) to estimate the overall increase in the probability to stop resulting from the presence of GSC. The overall increase in the probability was found to be 13.10%. That is, the presence of GSC is expected to increase driver's probability to stop in the DZ by 13.10%. (Chang et al., 1985) also suggested that DZ-II is located between 2.5 to 5.5 seconds upstream from the intersection.

As per the (Red Light Running Guideline, 2004), the red-light running can decrease when: Approach speed decrease, yellow interval duration increase but not exceed 5.5 second, approach delay decrease, approach grade increase and if there is short travel through the intersection. And it concludes that 98% of drivers are entered the intersection within 4.0 s after the start of red (i.e., end of yellow).

At the same time, the handbook tries to address the reason that drivers involved in red-light related crash and some generalization are listed under.

Table 1 Factor Caused to Red-Light Running

Cause Category	**Cause of Red Running**
Unnecessary delay	Disregard for red (unnecessary delay)
	Judged safe due to low conflicting volume
Incapable of stop	Downgrade steeper than expected
	Speed higher than posted limit
	Unable to stop (yellow seemed too short)
Inattentive	Unexpected, first signal encountered
	Distracted and did not see the traffic signal
	Not distracted, just did not see signal
	Confusing signal display (looked at wrong signal

(Kidwai et al. 2005) conducted a study in Malaysia by considering three intersections having no countdown timers and four intersections with countdown timers. They observed that countdown timers have no impact on the saturation flow, thus having no significant effect on intersection capacity. However, these timers reduced RLVs by 50 percent.

(Lum and Halim, 2006) in Singapore observed that the number of drivers who decided to stop during the amber time had increased 6.2 times after green signal countdown timer installation and the RLVs reduced by 65 percent within 1.5 months since its installation. However, GSC lost its initial effectiveness after 7.5 months under high traffic flows as RLVs bounced back to almost the same amount as it was before the signal countdown installation.

In 2003, Singapore Land Transport Authority collaborated with the Nanyang Technological University (NTU) to install a countdown timer along Rocher Road near Bug is Junction as a trial. Over a period of one year, the number of vehicles running the red light was reduced during the first four months. The red-time countdown device had a positive influence on the safety performance. However, some motorists behave differently when they approach the intersections during the green countdown time. The countdown timer may result in a greater likelihood of rear-end collisions at traffic junctions. The countdown devices also were tested over an eight-month period in Abilene, Texas, USA. The results were not satisfactory, and the devices have been uninstalled for a long time.

In Thailand, (Limanond et al. 2009) studied an intersection for two days - once when the timer was operating and another when it was switched off. SULT was observed to reduce in the presence of timer and the effect on saturation headway was insignificant. (Sharma et al. 2009) also noted that the presence of timers could reduce SULT and increase the discharge rate during the last half of the green. (Chiou and Chang 2010) studied the effect of GSC and RSC at four different time periods in Taiwan- before its installation, and 1.5 months, 3 months and 4.5 months after its installations. Early start ratios of the leading vehicles waiting in different waiting areas were found to reduce initially but returned to the same level before Red Signal Countdown Timer (RSC) installation for both peak and non-peak hours indicating poorer safety condition over the long run. At the end of 4.5 months after the installation, RSC was found to be associated with reduced SULT, discharge headway during peak hours as well as the cumulative start-up delay. It was also observed that RSC reduced the red-running ratio and number of vehicles ejecting to cross the intersection, but it extended the dilemma zone by approximately 28m. Consequently, drivers found it difficult to decide between stopping and proceeding through the intersection. (Limanond et al. 2010) studied an intersection during the non-peak hours and observed that while the presence of timer led to the reduction in SULT for through movement, it also reduced saturation flow, thus jeopardizing the effectiveness of timers. Green Signal countdown (GSC) reduced the number of RLVs at the starting of the red phase by 50 percent. In (China, Ma et al. 2010) concluded that GSC helped to eliminate the dilemma zone (DZ) and reduced RLVs. (Long et al. 2011) carried out a study in China at four urban intersections and concluded that timers' presence encouraged the drivers for entering the intersection late, which in turn could lead to hazardous RLVs. (Harshitha et al. 2012) has conducted a study at an intersection in Chennai and concluded that under the heterogeneous condition, no-timer case followed conventional headway distribution though it had increased headway values towards the end of the queue. On the other hand, the presence of a timer case observed steady discharge headway similar to the stabilized minimum discharge headway of the no-timer case. Thus, these timers considerably reduced the SULT and delays, resulting in a more efficient intersection. (Liu et al. 2012) in China observed that countdown timers significantly affected the SULT of both through and protected left-turn movements, but it has little effect on saturation headways. The reduction in saturation headways due to timers' presence was statistically significant for through movements, but not for left-turn movements. The timers resulted in headway compressions at the end of each queue. (Raksuntorn 2012) studied thirty-two signalized intersections in Thailand and observed that countdown timers do not have any effect on the saturation headway, but total SULT was reduced by 33 percent resulting in an increase in the capacity of signalized intersection. (Sharma et al. 2012) carried out another study in Chennai and found that the presence of timers reduced SULT. It was also observed that the presence of timers resulted in the reduction of the percentage of RLV cycles and mean RLVs per RLV cycle at the starting of red. (Long et al. 2013) observed that the presence of timers assisted drivers to make a better decision and helped to reduce dangerous driving maneuvers during the transition period. In 2007 China has conducted a study on the effectiveness of signal countdown and based on the study they decide to uninstall the signal countdown due to four operational problems that have been identified.

First, the critical problem of the device is that it can only accurately display the time remaining for a particular phase in intersections with fixed time traffic signals.

Second, the countdown device has been phased out among domestic big and medium-sized cities. Traffic actuated or traffic responsive signals, which are able to change time according to reveling traffic, are employed in more and more in these cities.

The third problem is that the countdown device increases the risks of potential crashes and thus decreases safety, which is not consistent with the original design purpose.

Last but not least, recent research results showed that the regular green flash plus the yellow time is sufficient for drivers to make judgments to safely cross the intersection. The green flash is generally three seconds long and signals the end of the green time and the upcoming red time, thus alerting drivers to slow down their vehicles.

(Hongyun Chen et al, 2009) conducted a study effect of installing signal countdown and it is found that the red time countdown device has a positive influence on safety and delay but increases the travel time and decreases the capacity and the rest of signal components have a negative impact on safety, travel time, capacity and delay.

(Rijavec et al. 2013) in Slovenia found that red and/or amber running violation rate is higher when the countdown display is turned off. (Zhang et al. 2013) studied two intersections in China and observed that RSCs reduced the first headway of discharged vehicles and fluctuations of vehicular headways while they were in the queue. The capacity of the through movement was increased by 5 to 10 percent after the installations of the GSC, but it did not influence the order of the vehicle attaining saturation headway.

As per (Sabyasachi Biswas, 2017), the value of SULT was significantly higher when RSCs were switched off. The reason is that when drivers were waiting in the queue during red, the timer information (the number of seconds remaining for the signal to become green) helped them to prepare early. This led to a reduction in the perception-reaction time of drivers to accelerate, which ultimately resulted in a lower SULT in the presence of RSC and he observed that the number of cycles where RLVs occurred during the initial 10 s of red phase increased in the absence of GSC. This is due to the fact that drivers could adjust their speeds when approaching the intersection with the aid of countdown timer.

On the other hand, RLVs during the last 10s of red phase decreased when the RSC was off. This shows that many drivers used RSC information to make early start decisions, which might have increased the percentage of cycles with RLVs during the last 10 s of red phase.

And he founds that small cars with signal countdown crossed the stop line at a higher speed during the amber time as compared to the condition without timer (i.e., 15.55 vs. 16.63m/s) and this finding was statically significant at 95% confidence level. This shows that the presence of timer encouraged drivers of small Car to cross the stop line at higher speed. Similarly, the value of type I dilemma zone in the presence of countdown is smaller when compared to the absence of countdown timer (i.e. 7.86 vs. 11.15m). He also found that type II dilemma zone is located between 4 to 5.76se when timer on condition and 2.17 to 5.34 seconds when countdown off condition.

To identify the most dominant parameter on the driver's decision making (Qiang Yang, 2012) developed a binary logistic regression model. Binary logistic regression is used to predict binary response variable based on the predictor variables. The mathematical concept of regression is to express the relationship between the outcome variable and predictor variables in terms of logit: the natural logarithm of odds. And the equation for probability of stop was:

$$\ln\frac{p}{1-p} = -0.145 + 0.083D - 0.07V - 1.266C \qquad (1)$$

Where,

D = distance to the stop line,

V= velocity at onset of yellow and

C= signal condition (1 for countdown and 0 for without countdown).

And he concludes that the presence of countdown timer didn’t lead to drivers to better decisions or safer behaviors.

2.4. Summary of Literature Review

The signal countdown device is a warning enhancement system within the transition phase of a traffic signal and allows drivers to anticipate and identify the exact point of the signal change, green to red or red to green. The objective of the device is to inform the driver’s current signal status so that installing the device might have some effects on decreasing delays and increasing safety. However, based on real-world data, the anticipated safety and operational benefits were not realized. Based on previous findings, it is evident that there are studies where signal countdown timers were found to be associated with reduced SULT, DZ, and RLVs. There are some other research works, which contradicted these findings. The key reason behind these conflicting findings could be the difference in traffic conditions, driver behaviors, and level of enforcement among the countries, even from one city to another.

The research will try to address the effect of signal countdown at signalized intersections by comparing with signalized intersections without countdown in Addis Ababa.

CHAPTER THREE: RESEARCH METHODS

3.1 Description of the Study Area

Six intersection approaches in Addis Ababa have been selected for the research. These intersections have heterogeneous traffic flow condition. Three intersections are equipped with countdown timers and the other three without countdown.

Figure 3: Study area

3.1.1 Study Location

The following selected intersections are located in Addis Ababa,

- Signalized intersections with countdown located at:
  1. Eliana
  2. Tracon(Tikur Ambesa)
  3. EBC(from piazza side)
- Signalized intersection without countdown
  1. Shola-2
  2. Stadium
  3. EBC(from Biherawi)

These intersections are selected according to the following criteria,

1. They have no advanced traffic calming on the Road approach.
2. Vehicular arrivals are observed at most yellow onset.
3. No blockage of view between the video camera and traffic light.
4. They have low pedestrian intervention on the intersection.
5. There is no vehicular access on the approach

3.1.2 Description of Intersections

The Detailed Description of the study area is presented in the following table;

Table 2: Intersection Detail

Characteristics	Intersection No. 1	Intersection No. 2	Intersection No. 3	Intersection No. 4	Intersection No. 5	Intersection No. 6
Location	Stadium	EBC(Post Office)	Eliana Hotel	Tracon (Tikur Anbessa)	Shola-2	EBC(Post Office)
Targeted Approach	From Leghare	From Biherawi	From Piazza	From Piazza	From Lem Hotel	From Piazza
Targeted Movement	Through	Through	Through	Through	Through	Through
No. of Lane	3	3	4	3	3	3
Cycle Length(S)	187	118	152	164	149	159
Green Time(S)	71	38	40	45	30	38
Yellow Time	3	3	3	3	3	3
Timer Condition	Off	Off	On	On	Off	On
Approach Width(M)	10.5	10.5	12	10.5	9	10.5
Approach Grade (%)	-1.4	1.86	-5.3	-5.4	3.9	-2.7
Intersection Length	93	38	38	35	40	38
Pavement Quality	Good	Good	Good	Good	Good	Good
Parking/Loading Unloading	No	No	No	No	No	No
Pedestrian Interaction	Low	Low	Low	Low	Low	Low
Vehicular Access	No	No	No	No	No	No

3.2 Research Procedure

The research is carried out dividing into three major categories. The detail research procedure is presented in the following figure.

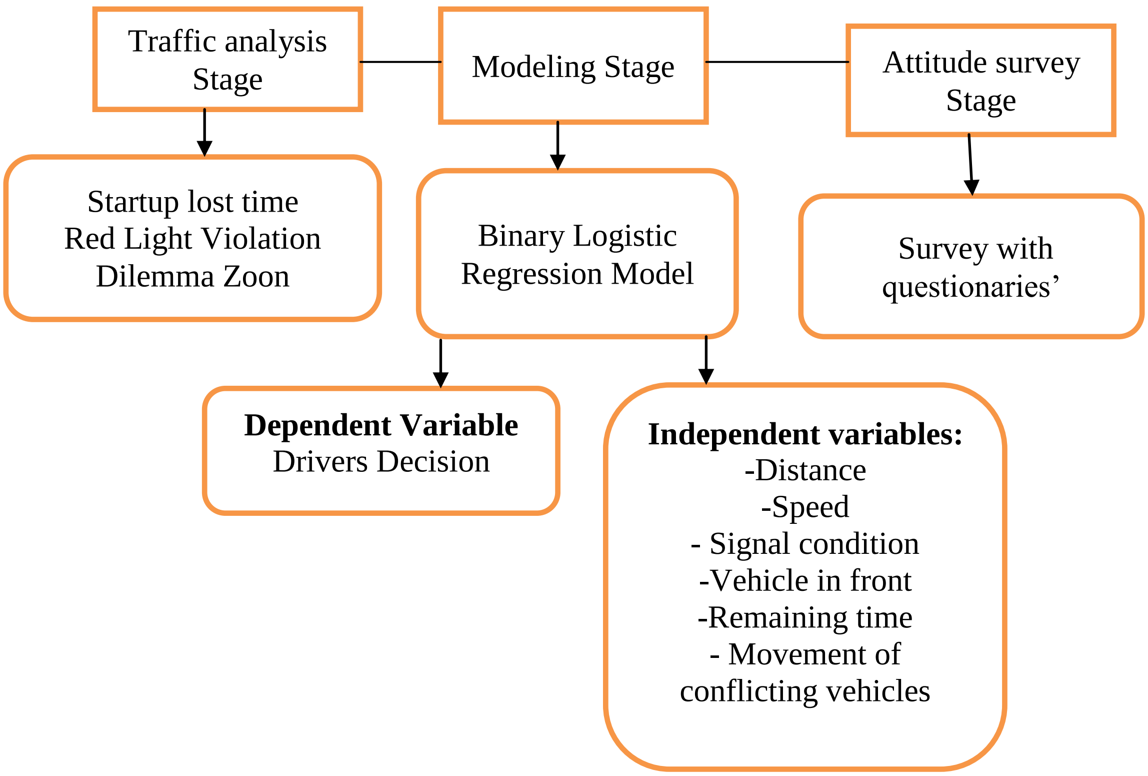

Figure 4: Research Procedure

The research is done according to figure 4: which contains three major tasks the first one is traffic analysis stage of the research in order to analyze and compare the effect of countdown timers in the signalized intersection performance and traffic activity using the following traffic efficiency and safety-related parameters; Startup lost time (SULT), red light violation and dilemma zone. The second stage of the research which includes modeling with binary logistic regression model with the dependent variable being drivers decision and the independent variables being vehicle type, vehicle In front, remaining time, distance from the stop line, approach speed movement of conflicting vehicle. Finally, expert and non-expert opinion on the effect of countdown timers in signalized intersection is assessed using questionnaires. The questionnaire is to investigate drivers' understanding and preference towards traffic signal countdown and to validate the finding by modeling and traffic analysis.

3.3 Study Design

Several researches were reviewed to find the parameters that are used to study the effect of countdown timers in signalized intersections.

Assessing the effect of signal countdown at signalized intersections by comparing with signalize intersections without countdown in Addis Ababa city covered the following.

- Signalized Intersection
- Signal countdown
- Vehicles
- Dilemma zone
- Drivers decision making
- Red light violation
- Startup lost time

In order to identify the factors that dominantly affect intersection safety and efficiency of signalized intersections, a statistical significance test has been conducted.

3.4 Data Requirement

Data required for this research was listed as follows;

- Headway between the vehicles that began moving after a stop as the signal turned green on the basis of the rear bumpers of the successive vehicles through the stop line.
- Vehicle composition data.
- Vehicle Approach Speed (m/s): the distance covered per time taken
- Vehicles location during onset of yellow: measured from the stop line
- Drivers response towards traffic signal: cross or stop
- Late stopping/violated vehicles during the onset of yellow for each cycle
- Early started vehicles at the end of red
- No. of lane
- Road width
- Approach grade
- Intersection length
- Green, Red and Yellow time
- Attitude of the end-user

3.5 Sample size determination

As per the discussion in section 3.1.1 above, six intersections have been selected among the signals in the city. Among the six intersections, three of them are signals with countdown and the remaining three being without countdown. To recall namely

Figure 5: Eliana Intersection

Figure 6: Tracon Intersection

Figure 7: EBC. Intersection from Piazza

Figure 8: Shola -2 Intersection

Figure 9: Stadium Intersection

Figure 10: EBC. Intersection from Biherawi

Sample size for Attitude survey

Sample size for assessing the driving behavior through questionnaire with a 95% confidence level and standard deviations = 0.5. The minimum number of respondents where

$$\boldsymbol{n} > \left(\frac{\boldsymbol{z\sigma}}{\boldsymbol{\varepsilon}}\right)^{\mathbf{2}} = \left(\mathbf{1.96} * \frac{\mathbf{0.5}}{\mathbf{0.05}}\right)^{\mathbf{2}} \quad > \mathbf{385\ respondents} \tag{2}$$

Where: n= sample size required for the study

Z (1.96) = critical value for the 95 percent confidence level, the amount of uncertainty that one can tolerate.

σ (0.5) = proportion of driver's expected to have the basic knowledge about the problem because the Morgan table value recommended 50 percent for the value of '$\boldsymbol{\varepsilon}$' 0.05 = margin of error that can be tolerated.

Sample Size for Model

According to Samuel B. Green (1991), the minimum sample size for regression is

N=50+8m. (3)

Where: N= Sample size required for regression

m= number of predictors =9

N>=122 because a larger sample size has the potential of eliminating unexpected bias on the response variable; for this study, the researcher adopted 613 samples.

The same sample was adopted for approach speed and Dilemma zone.

Sample Size for Startup Lost Time

Different studies adopted different sample sizes. According to the study by (Calıskanelli et al, 2017) adopts 323start up lost time values for 8 intersections in all directions and recorded for one hour at peak hour. For this study, greater than 400 vehicles and greater 30 numbers of cycles per intersection were adopted. Generally, startup lost time was conducted over 1517 vehicles from 107 cycles at signalized intersections with countdown and 1669 vehicles from 102 cycles were adopted for signalized intersection without countdown.

Sample Size for Red Light Violation

A sample size of 100 vehicle samples was used by different stats Departments of Transportation (1998) and academic researches by (Cruzado, 2010). For the case of this research, the researcher adopted 177 cycles for six intersections.

3.6. Data Collection

3.6.1. Primary Data Collection

Primary data was collected at the intersections with videotaping at a vantage point to record traffic operation and signal phasing change by using a video camera. The video field was mounted on a nearby building. The location of the stop line and distance upstream of it were marked to determine the exact distance of the vehicle from the stop line at the onset of yellow. The duration of the study was selected to capture as many cycles as possible along with the fluctuations in demand. During the onset of the yellow phase, the position of all the vehicles in the visible area in terms of distance from the stop line and the time to reach the intersection along with its nature of decision. The geometrical and signal related data were collected at field by measuring recording and counting.

Data collection was held in March 2019 from 8:00 AM – 11:00 AM and 5:00 PM – 6:00 PM for six days during the weekdays and weekends starting March 4, 2019 to March 15, 2019. And it was conducted at the absence of traffic police on the intersection to avoid driving behavioral change. Cycles with presence of traffic police in the intersection were canceled. Driver attitude survey data was also taken parallel to video data collection. In this attitude survey, drivers who participated in design, evaluation or implementation of traffic stream were well engaged. Before going to collect the whole data for this study, pilot study was conducted and analyzed on data from 20 respondents which is 5% of the sample size. After pilot study, the whole data for this study was collected and were checked for out of range values. Responses which are not much with the intended target were canceled.

3.6.2 Secondary Data

The secondary data were collected from different organizations and studies including:

- ✓ Approach grade: from Addis Ababa city roads authority
- ✓ Intersection length: from Addis Ababa city roads authority
- ✓ Sample size from different literatures.

3.7. Data Extraction

Only one straight through lane away from curbs on each intersection was selected to minimize the effect of roadside friction on driver behavior.

3.7.1 Extraction for SULT

As per HCM (Highway Capacity Manual, 2010), SULT is estimated by adding the time difference between saturation headway and headways of the first four vehicles in the queue. Vehicle headway can be defined as the difference of passage time between the front or rear bumper of successive vehicles over the stop line. But if the front bumper is used, the headway of the subject vehicle depends mainly on the characteristics of the preceding vehicle. For large preceding vehicles, a longer headway results for the subject vehicle (i.e. a passenger car following a bus has a longer headway than that of a bus following a passenger car). This condition gives misleading results because a passenger car should have a smaller headway than a bus due to its small size and easy maneuverability. However, if the researcher adopted the rear bumper the measured headway depends essentially on the length and characteristics of the subject vehicle. Longer vehicles probably results in longer headways.

Therefore, for this research, the headway was measured from the back (rear bumper) of the leading vehicle to back (rear bumper) of the following vehicle for each vehicle type.

Start-up lost time can affect by vehicle type, illegal parking, pedestrian in the intersection, perception/reaction time towards green time which varies from driver to driver and violated vehicles in the intersection.

To minimize the effect of illegal parking and pedestrian, the researcher tries to select intersections with approximately no illegal parking and low pedestrian volume on the intersection. And to minimize the effects of violated vehicles on the intersection, a cycle with violated vehicles in the intersection was rejected. Vehicles which started moving from their positions during the red light (considered as RLVs at the end of a red phase in the present study) and bicycles were not considered in the calculation of SULT.

3.7.2. Extraction for RLV

There are two type of red light violation, red light violation at the end of yellow (start of red) and at the end of red (start of green). Red light violation at the start of red refers to the red light runners who travel through the intersection during the red phase just after the yellow phase becomes off. On the other hand, red light violations at the end of the red phase indicate the instances when vehicles, waiting in the queue during the red phase, crossed the stop line or waited at the edge of the intersection for the green phase to start by occupying the zebra crossing location. The safety implications of these two violations are entirely different in nature. The red light violation at the starting of red can induce severe injury/fatal angle crashes and red light violation at the end of red results to interrupt pedestrian movements along zebra crossing during the vehicular red phase and thus exposing the pedestrians to higher risk.

From 177 recorded cycles the researcher tries to extract a number of vehicles who had the chance to violate within the onset of yellow and late stopping vehicles in each cycle, vehicles cleared from the intersection within yellow. Vehicles which started movement or cross the stop line during the red light/end of red with its remaining red time was also extracted for each vehicle type.

3.7.3 Extraction for DZ and Driver Decision

The data was extracted from the recorded video manually by using video playback technique. As the signal turned yellow, the exact time was recorded. At the same time, the vehicle nearest to the stop line was identified and as the target vehicle and its distance to stop line and the time taken was also recorded. The driver's decision and the exact crossing time of the target vehicle for those who decide to cross were recorded. Generally, for the case of driver’s decision the following parameters were extracted from the video:-

- Distance from stop line (D)
- Approach Speed (V)
- Remaining yellow time (RT)
- Vehicle type (VT)
- Vehicle in front of the target vehicle (VI) during the onset of yellow

- Movement vehicle from conflicting direction (MC)

3.8. Data Analysis

Statistical toolbox called Mini tab 18 is used mainly for the data analysis purpose. one-way ANOVA is used to compare the difference in the means of the parameters used in with or without countdown timers.

As per HCM (Highway Capacity Manual, 2010), SULT is estimated by adding the time difference between saturation headway and headways of the first four vehicles in the queue and it was determined as follows.

$$\mathbf{SULT} = \sum_{\mathbf{i=1}}^{\mathbf{4}} (\mathbf{hi} - \mathbf{hs}) \qquad (4)$$

Where hi is the total observed headway for vehicles 1 to 4 in the queue. And h_s is the average saturation headway (sec) in the queue.

The dilemma zone was analyzed using a graphical representation of the probability of vehicles stopped with its allocated distance.

For the case of red light violation, cycles which had the chance to violate during red light per cycle was analyzed. And mean RLV per RLV cycle has been estimated for both the end of yellow and end of red. Since there were very few heavy vehicles in the observation, the impact due to vehicle type doesn't consider for this study.

Binary logistic regression model was developed to study the effect of significant factors on signalized intersections with and without countdown timers for the dependent variable driver's decision. The driver's decision type is a binary dependent variable Y, where Y= 0 denotes a decision to stop and Y= 1 a decision to cross the intersection. Independent variables include, vehicle distance from the stop line (D), approach velocity at onset of yellow (V), Intersection length (L), type of vehicle (VT), Remaining yellow time (RT), Vehicle in front of the target vehicle during onset of yellow (VI), Movement of vehicle from conflicting direction (MC), approach grade (G), and signal condition (SC). The driver's decision can then be modeled by the following:

$$\mathbf{Logit}(\mathbf{P}) = \boldsymbol{\beta 0} + \boldsymbol{\beta 1 D} + \boldsymbol{\beta 2 V} + \boldsymbol{\beta 3 RT} + \boldsymbol{\beta 4 VT} + \boldsymbol{\beta 5 VI} + \boldsymbol{\beta 6 MC} + \boldsymbol{\beta 7 SC} + \boldsymbol{\beta 8 L} + \boldsymbol{\beta 9 G} \qquad (5)$$

Where, p is the probability of a decision to stop or cross (Y=1 or 0), logit (p) is the natural logarithm of the odds ratio, and βis are model parameters. The researcher uses VI= 1 for no vehicle in front, and 0 for the presence of a vehicle in front, MC= 1 for no movement of vehicle from conflicting direction and 0 is for the presence of vehicles from conflicting directions, and SC = 1 and 0 denotes countdown and without countdown respectively.

- ✓ Coefficient value > 0 indicates an increase in the logit of the response variable with an increase in the predictor variable.
- ✓ Coefficient value < 0 indicates a decrease in logit of response variable with an increase in predictor variable and
- ✓ When coefficient value = 0 there is no relationship between logit of response variable and predictor variables.

Requirement for binary Logistic Regression:

- ➢ The dependent/outcome to be binary
- ➢ No influential value or outlier in the predictor
- ➢ Not to be highly correlated(multicollinearity) among predictors
- ➢ Linearity of independent variable and the log odds.

Stepwise selection criterion was designed to find the most prudent set of predictors that are most effective in predicting the dependent variable. This is used to produce a predictive model that is accurate because it excludes variables that do not contribute to explaining differences in the dependent variable and useful in finding relationships that have not been tested before. The order of the variables can be used as a measure of relative importance.

For the case of interpretation, the researcher adopted the odds ratio along with the regression coefficient (e^{β}) to represent the constant effect of the predictor.

Where: Odds ratio >1 indicates predictors associated with increased risk of outcome.

Odds ratio < 1 indicates predictors associated with decreased risk of outcome.

Odds ratio = 1 indicates no association predictor and the outcome.

Odds ratio is the change in the odds of success and can be found by (odds ratio- 1)*100%.

To determine whether the model does fit the data or not goodness of fit tests has been used. If the P- value for the goodness of fit test is lower than the chosen significance level, the predicted probabilities deviate from the observed probabilities in the a way that the model does not predicted. Hosmer-Lameshow test is commonly used to measure the goodness of fit where the null hypothesis of the test is: Ho- model fit the data well. It is expected to obtain a higher P value than the significance level in order to get the best-representing model. Because it does not depend on number of trials per row in the data as the other goodness of fit tests, this test is more trustworthy indicator of how well the model fit the data.

The attitude surveys were analyzed by using excel for all respondents and experts separately. This attitude survey is used to fill the gap that cannot discover by video and to cross-check the result due to video and the end-users attitude towards the effect of countdown on intersection safety and efficiency. Some of them are: to check whether the displayed information is understood by the driver or not, drivers decision making on countdown, to know the recommended signal type and to rank the reason for red light violation.

3.9. Research Materials

- Microsoft Word for text writing
- Microsoft Excel for analysis and data manipulation plot
- Minitab 18 for statistical analysis
- Video to JPG Converter to analyze it better frame by frame

CHAPTER FOUR: RESULTS AND DISCUSSION

To analysis, the effects of signal countdown, several measures of effectiveness related to intersection efficiency and safety were identified. While start-up lost time was examined for studying the effect of these signalized countdowns on intersection efficiency, red-light violations (RLVs) and dilemma zone (DZ) were considered for safety-related evaluation.

4.1 Effect on Traffic Efficiency

In this subsection of the research startup lost time will be discussed in its effect and magnitude in signalized intersections.

4.1.1 Startup Lost Time (SULT)

One of the major parameters being SULT is compared between the intersections with and without signal countdown timers. SULT refers to the lost time at the beginning of a green phase. When the signal turns green after the red phase, the actual headways of the first few vehicles were observed to be longer than the saturation headway due to the perception-reaction time and time taken for acceleration. It is the resultant sum of the reaction time, vehicle acceleration, and any delay caused by distraction. And this lost time results in capacity reduction. As per HCM (Highway Capacity Manual, 2010), SULT is estimated by adding the time difference between saturation headway and headways of the first four vehicles in the queue.

Before analyzing the SULT difference for both countdown and without countdown the descriptive statistics of parameters that can affect SULT were checked as shown below and in the appendix.

As we can see from the table 3 below the vehicle composition is the same for both countdown and without countdown, this indicates the variance of SULT due to vehicle type is insignificant.

Table 3: Percentage of Heavy Vehicle for SULT

Signal condition	vehicle type	vehicle No.	Total	%ge
Countdown	passenger car	1462		96%
	heavy vehicle	55	1517	4%
without countdown	passenger car	1600		96%
	heavy vehicle	69	1669	4%

To check if the SULT data comes from normal distribution Minitab software is used and the following result was obtained.

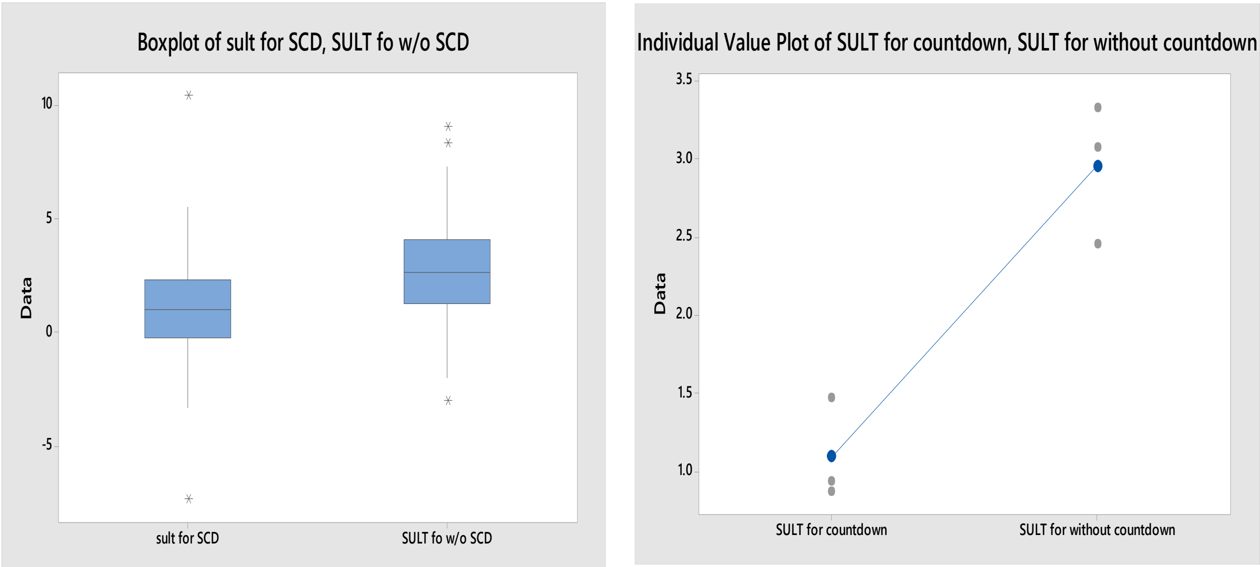

Figure 11: Box plot and Individual value plot for SULT

The box plot in figure 11 shown the data in the middle of the box for box signal with countdown and without countdown indicates a balanced concentration of data.

At the same time, the individual value plot shows a significant difference in SULT for countdown and for without countdown.

Startup Lost Time Comparison between Countdown and Without Countdown

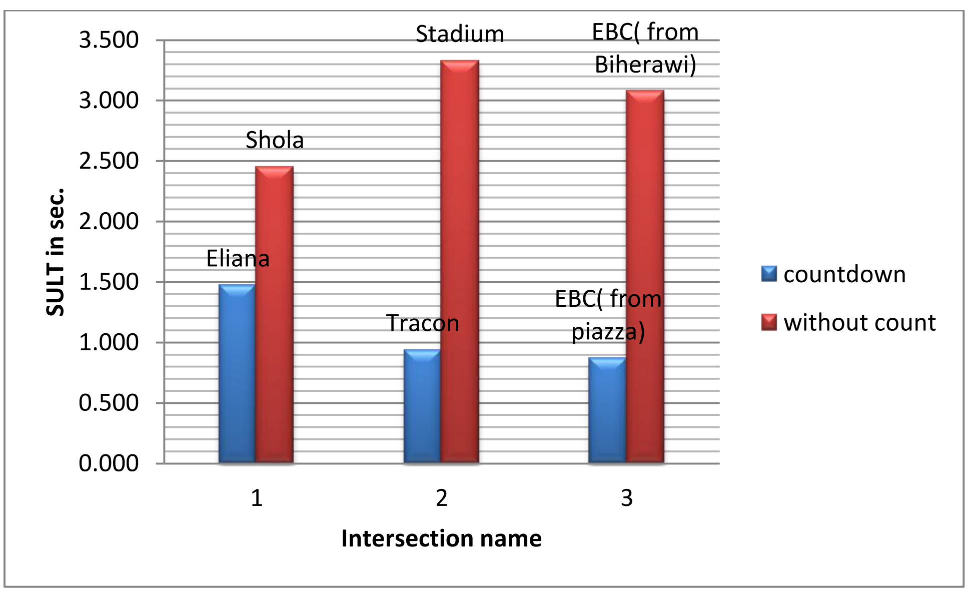

Figure 12: Startup Lost Time for Both Countdown and Without Countdown

Figure 12 presents the value of Startup Lost Time is higher at intersections without a red signal countdown. At Shola-2 intersection, SULT value is 2.45 second per cycle and the value of SULT of Stadium and EBC (from Biherawi direction) intersections are 3.33seconds per cycle and 3.08 second per cycle respectively. The result is found to be relatively higher with an average value of 2.95 seconds per cycle which is greater than that used in signal design in the highway capacity manual 2 second per cycle of startup lost time is recommended (HCM, 2010). However, SULT values of signalized intersections with red countdown are relatively small. The values at Eliana, Tracon and EBC (from paisa) intersections are 1.47, 0.94 and 0.87 seconds per cycle respectively. The result of SULT for countdown is found lower than the one which is being used in signal design in the highway capacity manual. And as we can see in the appendix from one way ANOVA, the mean startup lost time of signal with countdowns and signal without countdowns are significantly different with 95% confidence interval. It is not only the first vehicle that experiences lost time but the entire queue, as the delay incurred by the startup lost time is the cumulative function.

This finding is consistent with the previous studies (Limanond et al., 2009, 2010; Raksuntorn, 2012; Sharma et al., 2012; Biswas et al., 2017). The reason is that when drivers were waiting in the queue during red, the timer information (the number of seconds remaining for the signal to become green) helped them to prepare early. This leads to a reduction in the perception-reaction time of drivers to accelerate, which ultimately resulted in maximizing the operational efficiency of the intersection in the presence of RSC.

4.2 Effect on Traffic Safety

The extracted data from the video were also used to evaluate the effect of signal countdown on vehicular violation, dilemma zone and driver's decision at signalized intersections. Reductions of Dilemma zone and Red light violation can improve intersection safety and reduce the number of rear-end and right-angle crashes.

4.2.1 Effect on Red Light Violations (RLVs)

Red light violation can occur at the end of the yellow (start of red) phase and at the end of the red (start of green) phase. Red light violation at the end of yellow refers to the red late stopping vehicles that travel through the intersection during the red and red-light violations at the end of the red phase indicate the early started vehicles during the red phase.

The following shows the variability in red light violation of intersections with and without countdown timers.

Violation at the end of yellow

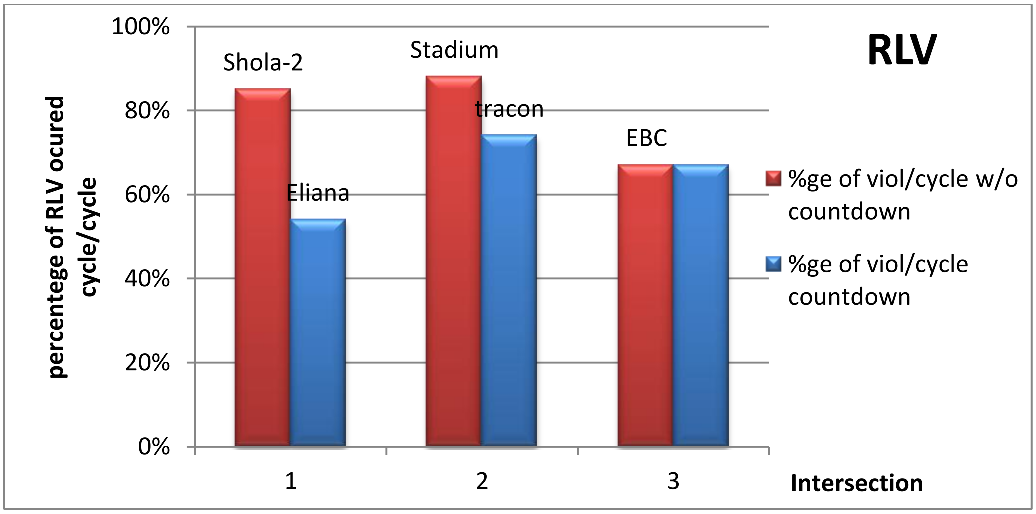

Figure 13: Red Light Violation

From the above figure 13, it can be observed that 54 to 74 percent of the cycles have Red light violations for these intersections with countdown. And 66 to 88 percent of the cycles had Red light violations for theses intersections without countdown. Even though, the percentage of red light violations occurred in each cycle of both countdowns and without countdown is high, but the occurrence at without countdown is relatively greater than at countdown. The red light violation in signalized intersection with countdown and without countdown is significantly different with 95% confidence interval as per one way ANOVA analysis shown in the appendix.

Generally, RLV at the end yellow for both with countdown and without countdown is tabulated below.

Table 4: Difference in Red Light Violation at the End of Yellow

Violation at the end of yellow		
	With Countdown	Without Countdown
Number of cycle	93.00	84.00
Number of RLV Occurred	58.00	71.00
Percent of RLV cycle/cycle	62%	85%

Table 4: indicates that in intersections with countdown drivers cross the stop line/ late stopping during red time in 58 cycles out of 93 cycles (62%) and for intersections without countdown drivers cross the stop line in 71 cycles out of 84 cycles (85%). This indicates that even both results are shocking RLV is relatively higher for intersection without countdown. The increased violation rate would certainly increase the chances of crashes occurring.

This result concedes with the finding obtained by (Sharmae et al., 2012) and contradicts with (M.R Ibrahim et al., 2008). This probably due to the fact that drivers had enough time to diced either to clear the intersection or to stop in expectation of the red phase. But drivers in intersection without countdown had no prior information about the amber and red phase which resulted in the last second attempt to pass.

Other criteria which was considered to evaluate the effect of signal with countdown is mean RLV per RLV cycle which represents the average number of vehicle violated over all the cycles having at least one red light violation in that cycle (Sharma et al.2012).

Table 5: Mean RLV/RLV Cycle at the End of Yellow

	Countdown	without Countdown
No of vehicle violated	92.00	137
No. of cycle with RLV	58.00	71
No. of mean RLV /RLV cycle	1.59	1.93

The above table 5: show that the mean RLV/RLV cycle of signal with countdown is slightly smaller than the signal without countdown. This implies that the tendency of RLV in signal with countdown decreases because the information at the end of green makes drivers to safe stop decision. It was also considered vehicle entry time for the above red runners in order to know how much of them are enter the stop line with red time after onset of yellow. The figure shown below is a vehicle entry time chart that represents vehicle crossing frequency against the vehicle entry time.

Vehicle Entry Time after the Onset of Yellow for those who decided to Cross

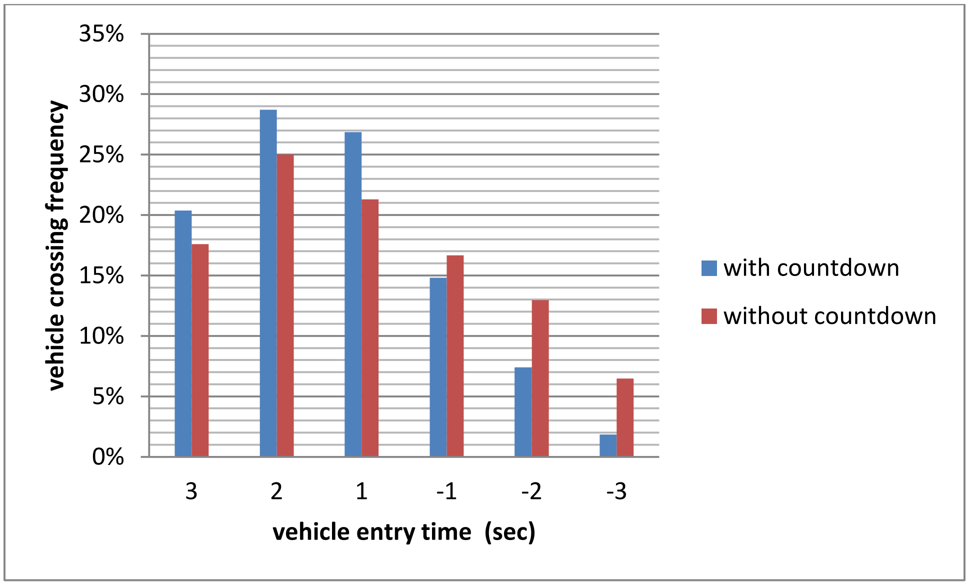

Figure 14: Vehicle Entry Time after the Onset of Yellow (Sec)

The figure 14: shows that after the onset of red (the negative entry time) at intersection without countdown, the frequency of vehicle crossed the stop line is higher than that of intersection with countdown (i.e. 36% of the violated vehicles are crossed the stop line after onset of red for without countdown and 26% for with countdown). This strengthens the conclusion that the information displayed at the end of green makes drivers to decide safely. But the time taken to clear the intersection as shown in the appendix depends on intersection length and approach speed.

Violation at the end of red

The figure below shows the difference in percentage violation in signalized intersection with and without countdown timers.

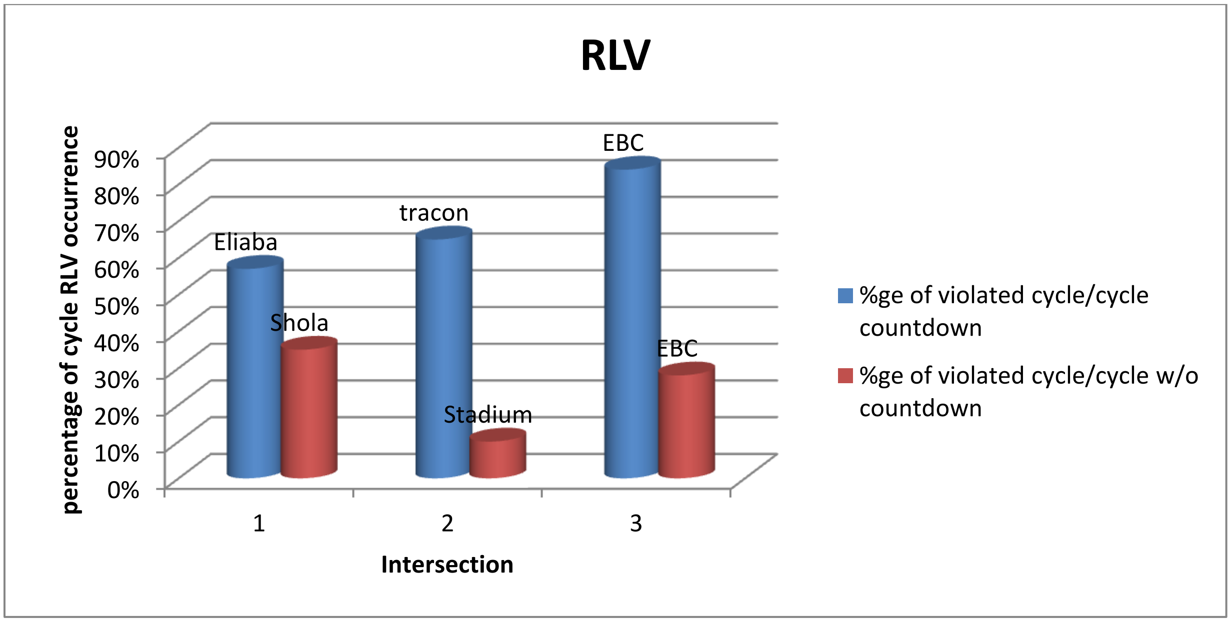

Figure 15: Percentage RLV difference

From the above figure 15: it can observe that the percentage difference is greater in signalized intersection with countdown timers, as will be described in the following.

Table 6: Violation at the end of red

Violation at the end of red		
	with count sown	without countdown
Number of cycle	111.00	106.00
Number of RLV Occurred	74.00	25.00
Percent Of RLV cycle/cycle	67%	24%

From the above table 6: and figure 15: the percentage of the cycles that have red-light violations for countdown intersections are ranged from 57 to 84. And 10 to 35 percent of the cycles had RLVs for theses intersections without countdown. That means for countdown intersection drivers cross the stop line/start early during red time in 74 cycles out of 111 cycles (67%) and for intersections without countdown drivers cross the stop line in 25 cycles out of 106 cycles (24%). the rate of RLV (early start) is relatively higher in signalize intersection with countdown than signalized intersection without countdown. similar results were obtained by (Sharma et al.,2012) at intersection Chennai, India and by (Sabyasachis Biswas 2017) in India institute of technology. This result indicates that digital countdown timer enabled the drivers, standing in the queue during red phase, to see the time remaining for the green phase to come and this movement of drivers ahead of stop line during final stage of red phase resulting in more occurrences of RLVs and increase the pedestrian risk but used to reduce SULT. It is evident that from the table 7: below the mean RLV/RLV cycle is relatively similar for both signal condition.

Table 7: Mean RLV/RLV Cycle at the End of Red

	Countdown	without Countdown
No. of vehicle started Early	82	26
No. of cycle with RLV	74.0	25.0
No. of mean RLV /RLV cycle	1.11	1.04

As we can see from the appendix in the presence of countdown, vehicles start to move 2.5 seconds per cycle early than the onset of green. But in the absence of countdown vehicles starts movement with 0.77second per cycle.

4.2.2 Effects on Dilemma zone

DZ can be determined based on the probability of drivers' decision to stop the vehicles at stop line during the amber phase. (Zegeer 1978) defined DZ type II as an area/distance starts where 90 percent of vehicles will stop and ends where only 10 percent of the vehicles will stop when they see a yellow indication. And this has been represented in terms of length and time.

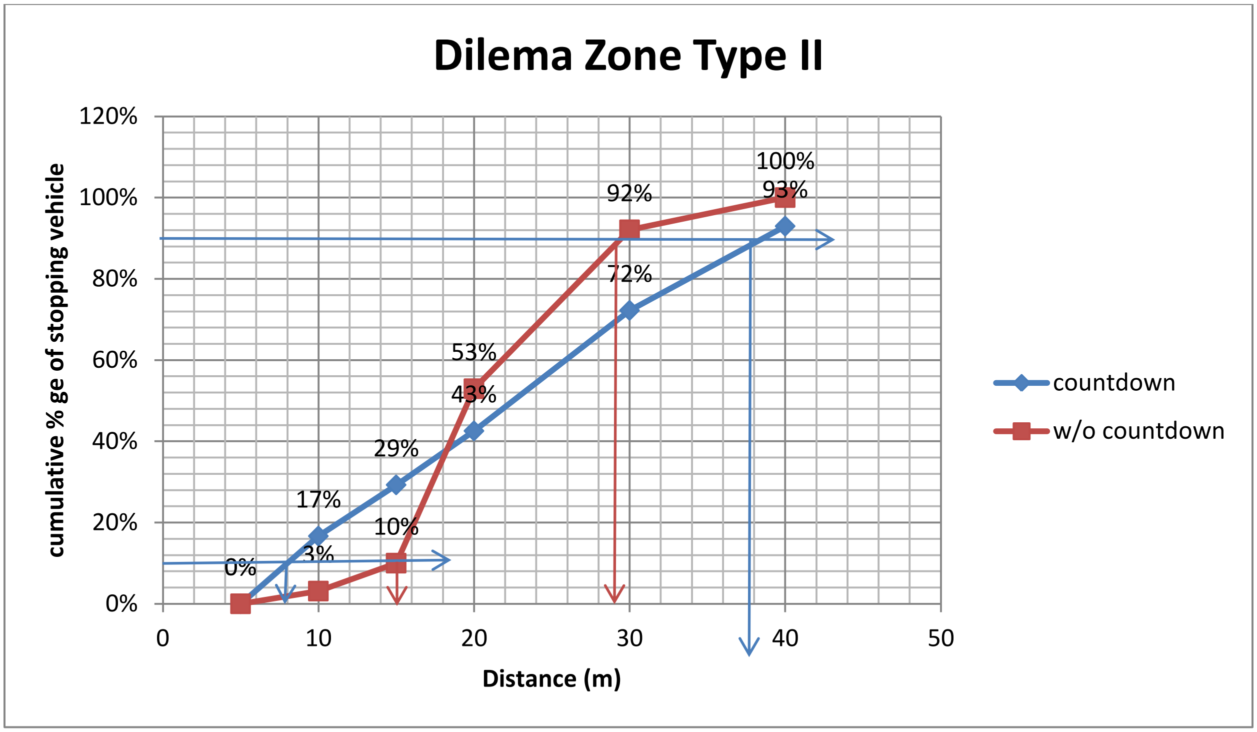

Figure 16: Type II DZ for intersections with and without countdown

Because of the average approach speeds of drivers at intersection with countdown is relatively higher than the speed at intersection without countdown (6.22m/s Vs 4.95m/s); the researcher summarizes the DZ for both countdown and without countdown case. And it was found between 8 m to 38.8 m for countdown intersection and between 15 m to 29.5 m for without countdown. Additionally, as it is shown in the figure below the DZ In terms of time was between 2.8 seconds to 6.2 seconds for a countdown and between 3.4 seconds to 5.8 seconds at without countdown. The values of type II DZs estimated were found to be almost consistency with the finding by other researchers like 2.86 s - 5.34 s (Sabyasachi Biswas, 2017) and 2.5–5 s (Zegeer, 1977)

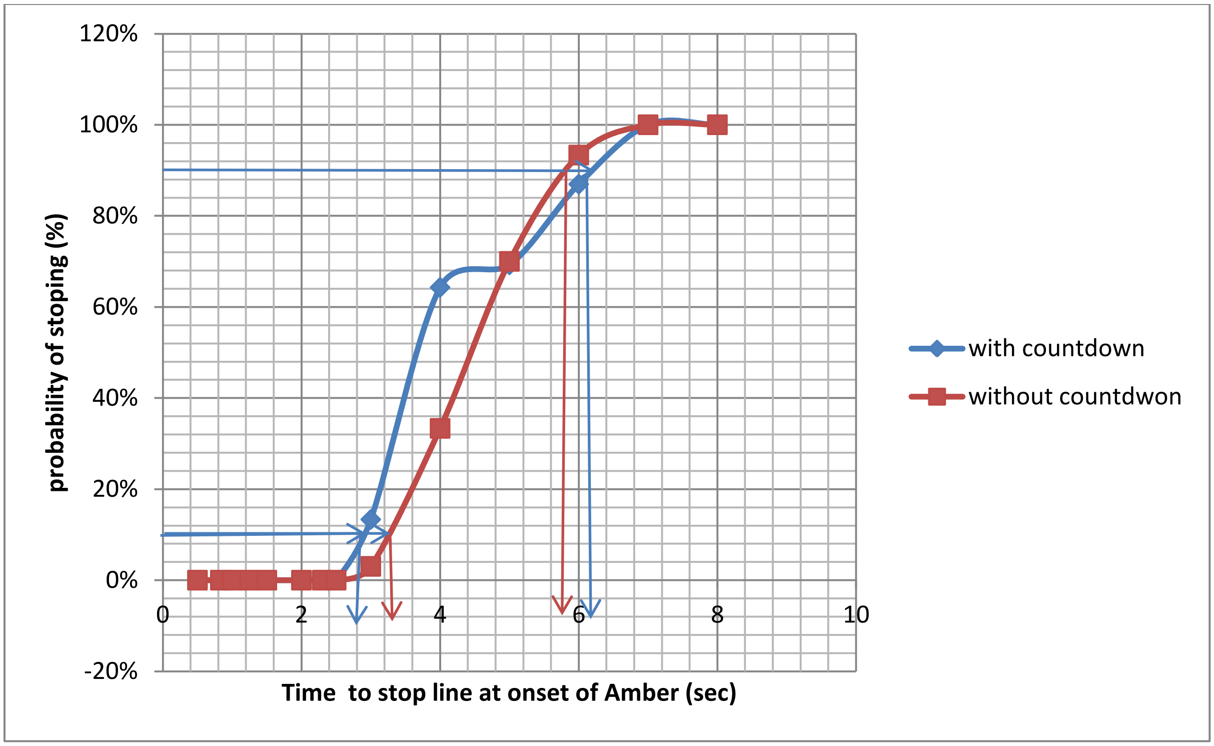

Figure 17: Type II DZ for intersections with and without count down in time

In this DZ study, it is found that most of the drivers go through the intersection if the time to stop line is equal or less than 2.8second, and most of them stop at the intersection if the time to stop line is equal or greater than 6.2 second in the presence of countdown. But at intersection without countdown, most of drivers go through the intersection if the time to stop line is equal or less than 3.4sec and stopped at a distance of 5.8 seconds or more.

4.2.3 Binary Logistic Model

The driver's decision to stop or to cross is coded as either 0 or 1 for the driver's decision at the end of yellow. Decision to stop depends on other independent variables which will be described below. A binary logistic regression model was developed due to the fact that the dependent variable has only two responses to stop or go.

A logistic regression model studies the association between a categorical dependent variable and a set of independent (explanatory) variables. The name logistic regression is used when there are only two responses such as 0 or 1.

Dependent Variable

- Drivers Decision/ Reaction towards signal (RE)

Independent variables

- Distance from stop line (D)
- Approach Speed (V)
- Remaining yellow time (RT)
- Intersection length (L)
- Approach grade (G) (negative for downward and positive for upward)
- Vehicle type (VT) (1 for car, 2 for minibus, 3 for bus and 4 for truck)
- Vehicle in front of the target vehicle (VI) (0 if there is vehicle, 1for no vehicle)
- Movement from conflicting direction (MC) (0 if there is vehicle, 1for no vehicle)
- Signal condition (SC) (0 for without countdown, 1 for countdown)

Requirement for Binary Logistic Model

1. **Binary outcome**

Binary logistic regression requires the dependent variable to be binary. Driver’s decision to stop has two outcomes. Hence, a binary variable is suitable to indicate the decision.

2. **No Influential value (outlier)**

There should not be an outlier present in the data set or *any extreme values* should be removed from the data. From the ***Grubbs test result*** shown below, we can see that the p-value of all continuous predictors is greater than the significant level (0.05) which indicates there is no outlier at 5% of the level of significance.

Table 8: Grubbs' Test result

Variable	N	Mean	StDev	Min	Max	G	P
D	613	21.982	11.629	5.000	40.000	1.55	1.000
V	613	5.610	2.540	1.667	15.000	3.70	0.124
RT	613	2.5318	0.7845	0.0000	3.0000	3.23	0.733
L	613	45.918	19.864	35.000	93.000	2.37	1.000
G	613	-1.760	3.614	-5.400	3.900	1.57	1.000

3. **No Multicollinearity**

Multicollinearity (binary regression assumes that there is little or no Multicollinearity in the data) Multicollinearity occurs when the independent variables are too highly correlated with each other. We can check Multicollinearity by correlation coefficients. To check it using correlation coefficients, simply throw all your predictor variables into a correlation matrix and look for coefficients with magnitudes of 0 .80 or higher. If your predictors are Multicollinearity, they will be strongly correlated. As we can see in the table below the entire coefficient of correlation matrix are less than, 0.8 so it can be concluded that there is no Multicollinearity problem.

Table 9 Correlation Matrix between Independent Variables

	RE	D	V	VT	RT	VI	MC	L	G
D	-0.694								
V	0.534	-0.190							
VT	0.031	-0.069	-0.007						
RT	0.479	-0.463	0.232	0.098					
VI	0.426	-0.454	0.316	0.001	0.292				
MC	0.267	-0.369	0.071	0.079	0.222	0.114			
L	0.059	-0.109	-0.073	-0.005	-0.004	-0.035	0.110		
G	0.055	-0.163	-0.226	-0.022	0.073	-0.070	0.115	0.101	
SC	-0.078	0.178	0.249	0.031	-0.067	0.087	-0.137	-0.479	-0.787

4. **Linearity of independent variable and log-odds**

The linearity between continuous predictor and the logit of the outcome is checked by visually inspecting the scatter plot between each predictor and logit value. The scatter plot shows that there is no significant evidence of nonlinearity relationship. All independent variables are linearly associated with the driver's decision outcome in the logit scale.

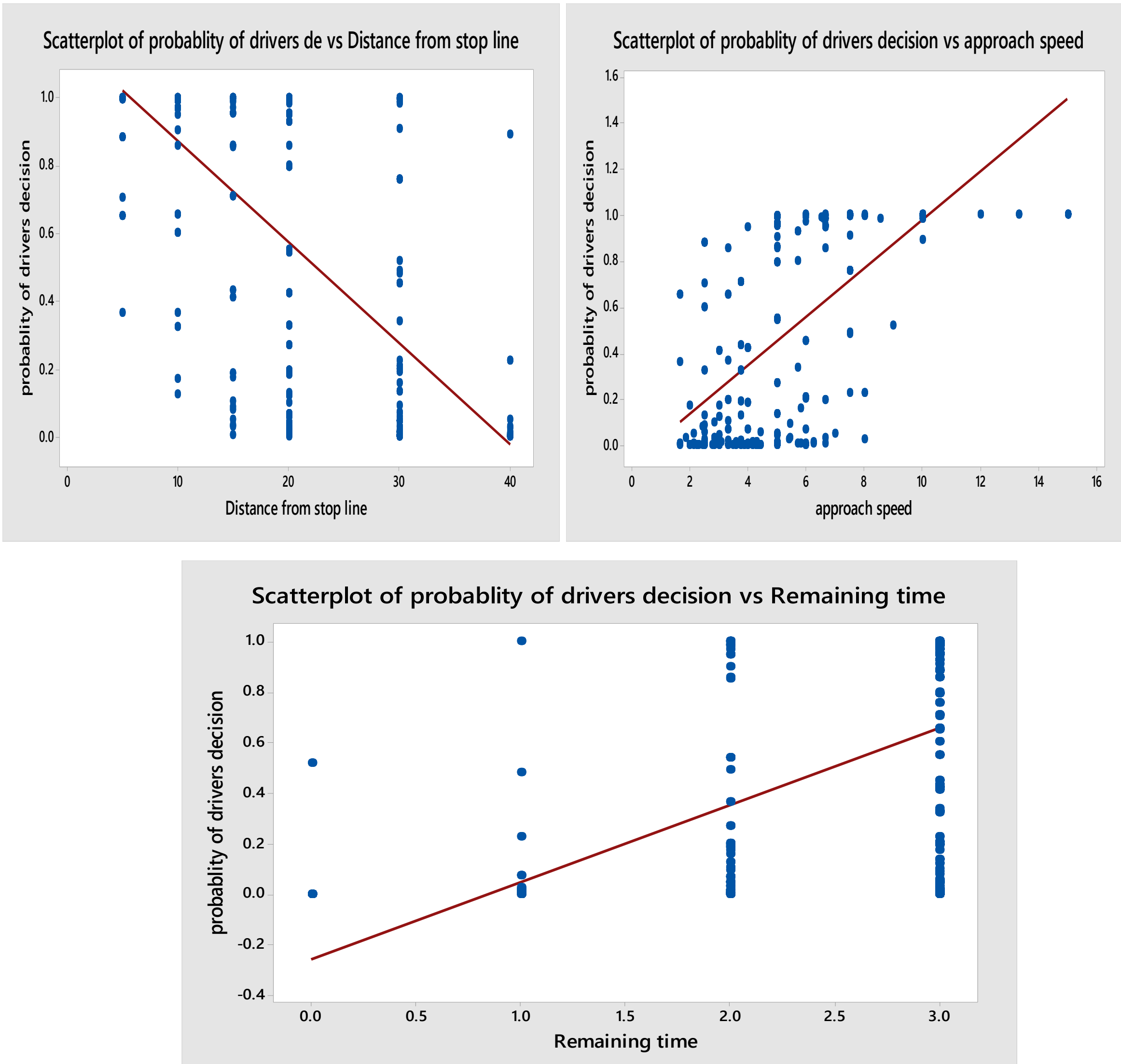

Figure 18: Probability of Drivers Decision VS Each Continuous Predictor

Regression Analysis

To run the regression, stepwise model selection techniques were used to screen out predictors not associated with the response. From the stepwise selection table below vehicle type, movement of vehicle from the conflicting direction, length of the intersection, approach grade and vehicle in front of the target vehicle are not eligible for the stepwise mode because its p-value is greater than the significance level (0.05).

Table 10 Stepwise Selection of Terms

Candidate terms: D, V, VT, RT, VI, SC, MC, L, G

	Step 1		Step 2		Step 3		Step 4	
	Coef	P	Coef	P	Coef	P	Coef	P
Constant	-4.233		0.538		3.99		4.10	
D	0.1900	0.000	0.3389	0.000	0.3167	0.000	0.3211	0.000
V			-1.553	0.000	-1.538	0.000	-1.662	0.000
RT					-1.162	0.001	-1.189	0.000
SC							1.151	0.005

As the coefficient table 10 shown below all p- values are less than the significance level (.05), this indicates there is a significant association between the response and the predictors. And the variance inflation factor (VIF) is small; this indicates that the predictor variables are not strongly correlated with each other.

Table 11 Coefficients

Term	Coef	SE Coef	VIF	P-Value
Constant	4.10	1.21		0.00
Distance from stop line (D)	0.3211	0.0363	2.46	0.00
Approach speed (V)	-1.662	0.190	2.80	0.000
Remaining yellow time (RT)	-1.189	0.341	1.08	0.000
Signal condition (SC)	1.151	0.413	1.18	0.005

The final Regression Equation for the probability of driver's decision to stop is

$$P(0) = \exp(Y')/(1 + \exp(Y')) \qquad (6)$$

$$Y' = 4.10 + 0.3211\,D - 1.662\,V - 1.189\,RT + 1.151\,SC$$

Where:

D= Distance from the stop line (m)

V= Approach speed at onset of yellow (m/s)

RT= Remaining time (sec)

SC= Signal condition (countdown=1 or without countdown=0)

4.2.3.1 Model Interpretation

Distance from the stop line has a positive effect on driver's decision to stop, with the coefficient of 0.321; the probability to stop will increase as the distance from the stop line increases.

Vehicular approach speed has a negative impact on the driver's decision to stop, with a coefficient of 1.662, which makes the probability to stop will decrease as the approach speed increase.

Remaining time has also a negative impact on drivers' decision to stop with a 1.189 coefficient value which makes the probability of driver's decision to stop decreases as the remaining time increases.

From the regression coefficient, we have clearly understood that Signal condition, has a positive effect on drivers' decision to stop with 1.151 coefficient value meaning that the drivers have a very high tendency to stop if the signal is with countdown timer.

From the table below, it can show that parameters with odds ratio greater than 1 indicates that the event is more likely to occur as the predictor increase. An odds ratio less than 1 indicates the event is less likely to occur as the predictor increase. Distance from the stop line and signal conditions are positively associated with the outcome but the approach speed and remaining time are negatively associated.

Table 12: Odds Ratios

	Odds Ratio	95% CI
Distance from stop line	1.3786	(1.2839, 1.4803)
Approach speed	0.1897	(0.1308, 0.2752)
Remaining yellow time	0.3045	(0.1562, 0.5938)
Signal condition	3.1611	(1.4076, 7.0990)

For intersection with countdown timer (SC=1), the equation can be:

$$Y' = 5.251 + 0.3211\,D - 1.662\,V - 1.189\,RT \tag{7}$$

And for cases without countdown timer (SC=0), we have:

$$Y' = 4.10 + 0.3211\,D - 1.662\,V - 1.189\,RT \tag{8}$$

Subtracting Eq. (8) from Eq. (7):

Odds ratio = exp (1.15) = 3.16, this indicates that given the same vehicle location, approach speed and remaining time at the onset of yellow, the odds ratio of stopping at intersection with countdown timer is 3.16 times that of intersections without countdown. That is, at intersection without countdown, drivers are 3.16 times more likely to cross than stop after the onset of yellow, which may potentially result in more red light violation.

To check the percentage change of drivers decision to stop by distance it is calculated by (odds ratio- 1)* 100% which is as the distance from the stop line increase by 1 meter the odds of drivers decision to stop increases by 37.8%. Using the same simple equation as above, it is found that the odds for drivers decision reduces by 81% and 70% as approach speed and remaining time increases by one m/s and second respectively.

Table 13: Goodness-of-Fit Tests

Test	DF	Chi-Square	P-Value
Deviance	608	191.53	1.000
Pearson	608	344.59	1.000
Hosmer-Lemeshow	8	4.84	0.775

As it is shown in the above table the Hosmer- Lemeshow goodness of fit test gives a p-value of 0.775 which is greater than the significance level (0.05). This shows that the model fits the data well.

4.3 Attitude Survey

To investigate drivers' understanding and preference towards traffic signal countdown and to validate the finding by modeling and traffic analysis an attitude survey was conducted over 387 drivers including drivers who are participated or involved in design; evaluation and implementation of traffic stream are selected randomly. The questioner incorporates personal information of the respondents, attitude towards signalized intersection in both countdown and without countdown and reasons for red light violation. During the study, it was tried to incorporate age distribution, sex, driving experience, driver's vehicle type, and educational level.

The educational level was aimed to investigate the preference and knowledge of each representative about signalized intersection in Addis Ababa. Among the respondents, 26% of them were participated or involved in designing, evaluating or implementing traffic stream. From the total respondents, 60% of them are adults (18-35 years).

Drivers Response by Category

Table 14: Drivers Response by Category

Category	Drivers Response for Each Question			
	Most Exposed to Crash		Used to Facilitate Traffic	
	Countdown	Without Countdown	Countdown	Without Countdown
Education Level				
1)Elementary	0%	8%	8%	1%
2)Secondary	6%	16%	20%	2%
3)Preparatory	2%	13%	13%	3%
4)Diploma	4%	20%	16%	4%
5)BSC	9%	11%	16%	4%
6)MSC& Above	4%	7%	9%	3%
Experts	10%	16%	21%	5%
Total	**25%**	**74%**	**82%**	**18%**
Driving Experience (Year)				
1)0-4	10%	31%	35%	8%
2)5-8	10%	20%	24%	6%
3)9-12	3%	10%	10%	2%
4)>12	3%	12%	13%	2%
Total	**26%**	**74%**	**82%**	**18%**
Driver's Vehicle Type				
1) Car	14%	38%	42%	10%
2) Minibus	9%	21%	25%	6%
3) Bus	1%	7%	7%	1%
4) Truck	1%	8%	8%	1%
Total	**26%**	**74%**	**82%**	**18%**

From the above table 14: and appendix, the categorical variables like educational level, driving experience, and driver's vehicle type are consistent with the overall result, which is in all category signals with countdown are used to lower the probability of exposing to crash, increase traffic efficiency, and increase probability of start early. And signal with countdown is the most preferable by mentioned categories.

Driver's Attitude and Preference to Wards Signal

Table 15: Results from Respondent's Attitude and Preference

No	Question	Choose	No. of Respondents	Percentage (%)
1	Which type of signal more exposed to traffic crashes?	1) countdown	98	26%
		2) without countdown	285	74%
		total	**383**	
2	More important signal type to facilitate traffic	1) countdown	308	82%
		2) without countdown	68	18%
		total	**376**	
3	In which type of signal most drivers start early?	1) countdown	210	55%
		2) without countdown	30	8%
		3) both	72	19%
		4) never	72	19%
		total	**384**	
4	Which signal type creates frustration?	1) countdown	86	23%
		2) without countdown	235	62%
		3) both	9	2%
		4) never	50	13%
		total	**380**	
5	In which signal drivers urgently decelerate?	1) countdown	212	55%
		2) without countdown	175	45%
		total	**387**	
6	In which signal drivers urgently accelerate	1) countdown	255	67%
		2) without countdown	127	33%
		total	**382**	
7	Most recommended signal type	1) countdown	277	74%
		2) without countdown	42	11%
		3) flashing without countdown	54	15%
		total	**373**	

No	Question	Choose					
		1)Strongly agree	2)Agree	3)Neutral	4)Disagree	5)Strongly disagree	total
1	The information displayed by countdown is understood by drivers	143 38%	157 42%	29 8%	43 12%	1 0%	**373**
2	Signal countdown assists decision making	154 41%	161 43%	19 5%	38 10%	5 1%	**377**
3	Signal without countdown assists decision making	40 11%	107 29%	58 15%	157 42%	13 3%	**375**

No	Reasons for RLV at	Rank				
1	**Countdown**	1	2	3	4	5
	To save time	108	90	41	16	19
	Because inadequate green time	47	36	74	42	17
	Because absence of traffic police	77	99	46	36	26
	Problem in signal design	30	33	32	36	65
	Difficult to stop within yellow	42	17	44	75	64
	Total	274	217	284	200	243
2	**without Countdown**					
	To save time	74	76	61	27	25
	Because inadequate green time	46	41	82	40	17
	Because no traffic police	65	67	55	63	29
	Problem in signal design	32	33	11	38	84
	Difficult to stop within yellow	86	55	45	37	39
	Total	263	226	279	198	262

4.3.1. Interpretation of the Attitude Survey

From the respondents, drivers' attitude on signalized intersection is discussed as follows.

- 74 percent of the total respondents conclude that signalized intersections without countdown are exposed to traffic crash. And around 26% of the respondent said signal with countdown is exposed to traffic crash which is consistence with the result found through video because the information displayed by countdown makes driver to decide safely and resulting in reduction of crash.

- Among the surveyed drivers, 82% chooses signal with countdown to facilitate traffic flow and 18% of them said that signal without countdown is best to facilitate traffic flow in the intersection.
- More than half of the respondent mentions that most drivers are urgently accelerating at signalized intersection with countdown to escape the red time. From this, it can understand that, if the vehicle cannot clear the intersection within the yellow and all-red time it can cause to traffic crash.
- Out of the total respondents, 74% of them recommended signalized intersection with countdown.
- Most of the drivers understand the function of yellow time, that is used to prepare the driver to stop in the stop line or to cross the intersection if it is difficult to stop at stop line but 16% of them are misunderstood this and they believe that yellow should always be used for crossing the intersection.
- 55% of drivers are initiated to start early when the intersection is with countdown and 8% started early at signal without a countdown. This indicates that red light violation at the end of red is much higher than the intersection without countdown.
- 41% and 28 % of the drivers had violated at intersection without countdown and with countdown respectively. This shows red light violation at the end of yellow is relatively higher in signal without countdown.
- 62% of the respondents are frustrated when the intersection is without countdown. From this, it can understand that frustrated drivers are exposed to traffic crash.
- 80% of the respondents are agreed on the information displayed at signalized intersections are easily under stable by drivers.
- About 84% of the respondents/drivers agree on the importance of signal with countdown for decision making in order to reduce crashes due to RLV and DZ.
- More than half of the respondents are disagreed on the importance of signal without countdown for decision making. This indicates drivers cannot decide to stop or cross the intersection safely resulting in high red-light violations and enlarging the range of dilemma zone.

- The reasons for red light violations for both countdown and without countdowns are ranked below.

Table 16: Reasons for RLV

Rank	Reasons for RLV at signal with countdown	Reasons for RLV at signal without countdown
1ST reason	To save time	Difficulty to stop within yellow time
2nd reason	Because of the absence of traffic police	To save time
3rd reason	Inadequacy of allocated green time	Inadequacy of allocated green time
4th reason	Difficulty to stop within yellow time	because of the absence of traffic police
5th reason	Problem in signal design	Problem in signal design

From table 16: the major leading reasons for red light violations are to save time in countdown intersection, and because of difficult to stop at stop line during yellow time is the main reason in signal without countdown. This indicates that the violations in signal with countdown are not by the displayed information they originated from carelessness to crash and gap in enforcement, but the reason of RLVs in signal countdowns are mainly because of difficulty to stop due to lack of prior information. The red light violation at signal with countdown can be treated by engineering measures through modifying (signal operation, and intersection geometry), by public awareness campaign like (educate drivers on red light- running hazards to stimulate a voluntarily in the driver's behavior, use media to open communication between officials and public, and provide advance warning that additional enforcement is being implemented to improve traffic safety), through enforcement like (traffic police and red light camera).

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In Addis Ababa, signal countdowns are being installed at several major intersections with Low understanding to their impacts on intersection safety and efficiency. This is the first study which focused on the effect of signal countdown based on driver's behavior.

SULT was conducted to evaluate the effect on traffic efficiency and It was observed that the presence of signal countdown, drivers Startup lost time reduced significantly at all the selected locations due to the tendency of early starting of vehicles (utilizing the time-related information provided by RSC) while standing in the queue during the red phase. Therefore, it is evident that the presence of RSC was related to reduce SULT.

To evaluate the impact of signal countdown timer on traffic safety, DZ, RLV at end of red and end of yellow and driver's decision were observed. The presence of signal countdown leads to higher RLVs during the end of red. This indicates that it enabled the drivers, standing in the queue during the red phase, to see the time remaining for the green phase to come and resulting in occurrences of crash during the end of RSC. But at the end of green/yellow lower RLVs were observed. As the respondents conclude that the reasons for RLVs for signal countdown are because the assumption that time can be saved by red-light running and the absence of traffic police encourages to red light violation. These reasons are not due to the signal information; those are most likely related to the low level of awareness or carelessness towards crashes and because of the gap in enforcement and implementation of the law. The information displayed makes drivers decide to stop safely and enhancing traffic safety due to the presence of GSC. While approaching the intersection without countdown resulting in very late stopping and the occurrence of crashes will increase and as per the respondents the main reason to red light violations are ranked as first because of no prior information to decide, it is difficult to stop within yellow time. Second most of them assume red light violation is time saving.

In the presence of GSC effects on type II dilemma zone were examined and it was observed that the range of type II DZ increased on the presence of GSC. In the presence of GSC, most of drivers are go through the intersection if the time to stop line is less than 2.8 seconds or 8m far but for signal, without GSC most drivers go through the intersection if the time is less than 3.4 seconds or 15 meter far from the stop line.

The driver's stop/go decisions were also modeled by logistic regression model, and approach speed, distance from the stop line, remaining yellow time and signal condition were found statistically significant to predict driver's decision making to cross or stop after the onset of yellow.

Results of the model suggest that:

- Holding the remaining constant, Distance from the stop line has a positive effect on driver decision to stop; the probability to stop will increase as the distance from the stop line increase.
- Holding distance from the stop line constant, Vehicular approach speed has a negative impact on the driver's decision to stop; the probability to stop will decrease as the approach speed increase.
- Remaining time has also a negative impact on drivers' decision to stop: holding distance from stop line constant probability of driver's decision to stop decreases as the remaining time increases.
- When the signal is without countdown drivers are more likely to cross the intersection after the onset of yellow.
- At 95% confidence level, Hosmer- Lameshow goodness of fit test significant P-value for driver's decision to stop/ go is 0.775. This indicates that the developed model is corrected and predicts the data well.

Generally, signal countdown has an effect on both traffic safety and efficiency. GSC has a significant positive effect on road traffic safety in terms of reduced red-light violations during the end of the green/yellow phase and maximizes the driver's decision to stop or cross safely. And the presence of RSC was responsible for reduced startup lost time, but it resulted in a higher propensity of RLV during the end of the red phase. This conclusion is similar to the respondents understanding and preference that countdown can maximize the intersection safety and efficiency by facilitating the traffic flow and reducing traffic crash.

5.2 Recommendation

Depending on the results of the study the Researcher recommends signal with a countdown with the following points to add its own positive effect on the intersection safety and efficiency.

- Education (making awareness creation) and enforcement (like red light camera and officer) of traffic law have to be implemented for drivers on crossing during the red light phase to reduce crashes.
- It should be focused on the design of inter-green time or clearing time by considering the early started drivers and late stopping drivers to give the required time between the end of green of a signal group and the beginning of green of a conflicting signal group. This can reduce the number of Red light violations at the end of the red phase and to clear the intersection safely.
- The intersection should be geometrically compacted in order to reduce the clearing time and enhance traffic safety.
- Future research or studies should be conducted on the influence of interference with pedestrian/bicycle and with vehicles in adjacent lanes, which are ample at intersections in Addis Ababa. In addition, this study focused on the effects of signal countdown in one approach straight - through lanes but the effect might be different for turning movement so it is better to study in all directions and all movements to generalize this finding and it is better to consider the geometrical factors such as Grade and curve radius on SULT, RLV and DZ. Moreover, Cost-effectiveness of signal countdown should also be considered before appreciating this device.

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Appendix

Startup Lost Time Analysis Result

Vehicle Composition in Each Intersection

Table 17 Vehicle composition for SULT

location				Eliana Hotel	
vehicle type		no. of vehicle	total	%ge of composition	
passenger car	Car	378	472	80%	96%
	Minibus	74		16%	
heavy vehicle	Bus	10		2%	4%
	Truck	10		2%	

location				Tracon/Tukur Ambesa	
vehicle type		No. of vehicle	total	%ge of composition	
passenger car	Car	455	563	81%	98%
	Minibus	93		17%	
heavy vehicle	Bus	8		1%	2%
	Truck	7		1%	

location		EBC from Tracon			
vehicle type		no. of vehicle	total	%ge of composition	
passenger car	Car	394	482	82%	96%
	Minibus	68		14%	
heavy vehicle	Bus	10		2%	4%
	Truck	10		2%	

Location		Shola			
vehicle type		no. of vehicle	total	%ge of composition	
passenger car	Car	543	605	90%	96%
	Minibus	39		6%	
heavy vehicle	Bus	7		1%	4%
	Truck	16		3%	

Location		Stadium			
vehicle type		no. of vehicle	total	%ge of composition	
passenger car	Car	623	697	89%	96%
	Minibus	45		6%	
heavy vehicle	Bus	11		2%	4%
	Truck	18		3%	

location				EBC from Biherawi	
vehicle type		no. of vehicle	total	%ge of composition	
passenger car	Car	299	367	81%	95%
	Minibus	51		14%	
heavy vehicle	Bus	8		2%	5%
	Truck	9		2%	

The vehicle composition for each intersection is almost the same; hence the impact on SULT due to vehicle type is negligible.

Computation of SULT

Table 18 Sample for SULT

Location	Shola
Sum of saturation Headway	909.0
No of saturation headway	429
average saturation headway (s/veh)	2.119
Avg. saturation flow rate for this lane (veh/hr/lan	1699.010
The 1st four vehicles for SULT	
average h	SULT= havg- h2.07
2.98	0.864
2.98	0.858
2.56	0.445
2.47	0.350
SULT (sec/cycle)	2.517

Location	Tracon
Sum of saturation Headway (s)	798
No of saturation headway (veh)	395
average saturation headway (s/veh)	2.020
Avg. saturation flow rate for this lane (veh/hr/lan	1781.955
The 1st four vehicles for SULT	
average h	SULT= havg- h2.02
1.95	-0.07
2.55	0.53
2.45	0.43
2.04	0.02
SULT (sec/cycle)	0.93

From table 18 it can understand that the startup lost time for Shola is more than two times the startup lost time of Tracon as a result, the saturation headway of Shola is less than Tracon.

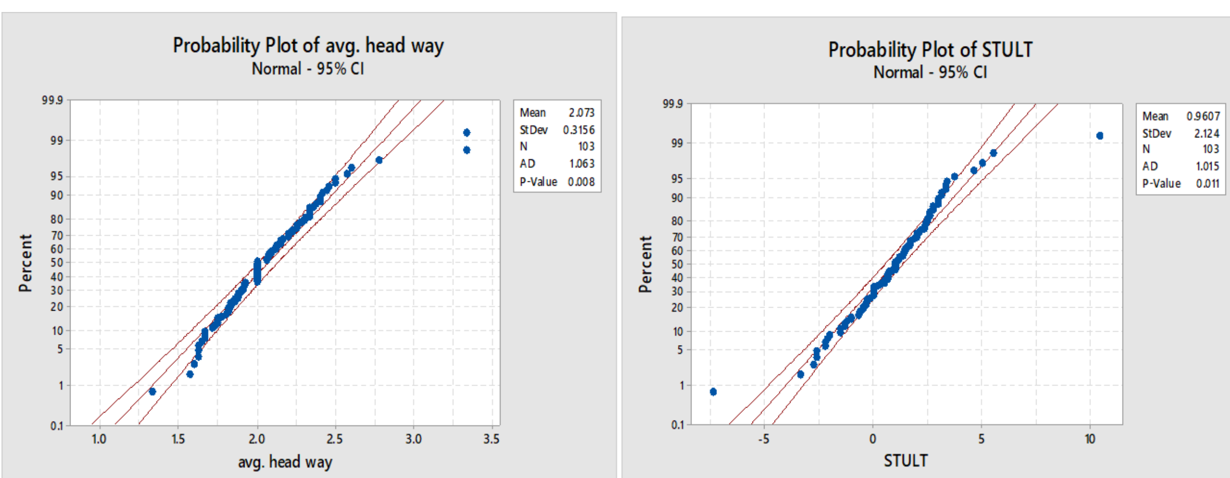


Figure 19: Probability plot of average headway and SULT for signal with countdown

According to figure 19, the probability plot shows the headway and SULT data's come from normal distribution.

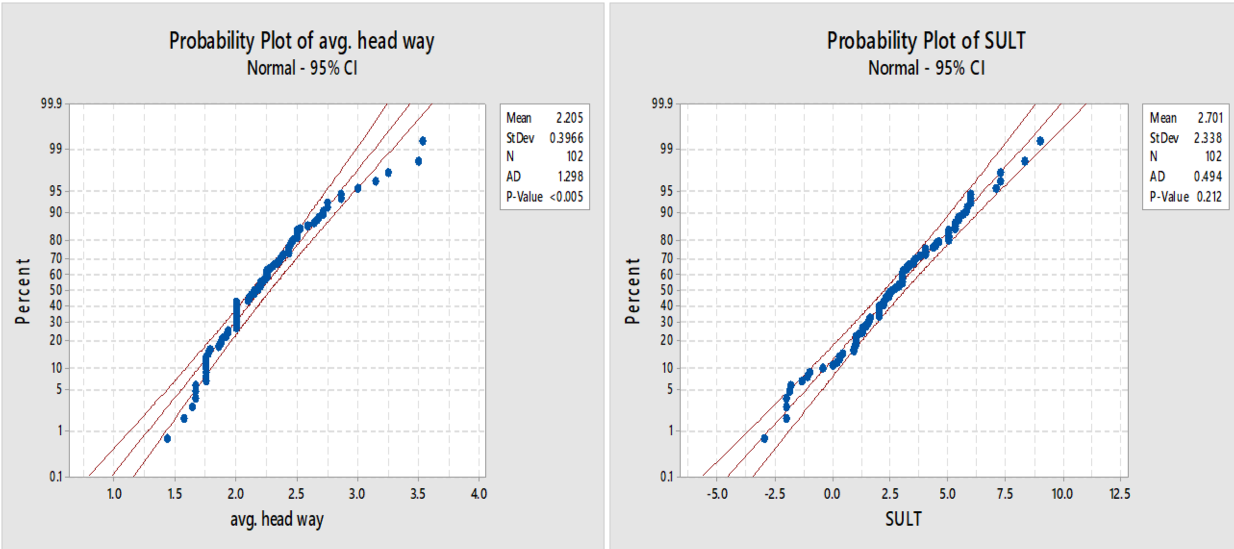


Figure 20: Probability Plot of Average Headway and SULT for Signal without Countdown

From Figures 19 and 20 the probability plot of SULT for both countdown and without countdown shows approximately straight line and this indicates that the data is from a normal distribution.

One-way ANOVA: SULT for countdown, SULT for without countdown

Table 19 One Way ANOVA for SULT

S		R-sq	R-sq(adj)	R-sq(pred)
0.395626		89.22%	86.53%	75.75%
Factor	N	Mean	StDev	95% CI
SULT for countdown	3	1.091	0.330	(0.457, 1.726)
SULT for without countdown	3	2.950	0.452	(2.316, 3.584)

One way ANOVA can understand that the mean startup lost time of signal with countdown and signal without countdown are significantly different at 0 .05 significance level.

Red light violation

Sample of RLV at the End of Yellow

Table 20: Sample of RLV for Countdown at the End of Yellow

location	Eliana hotel	Tracon
Target movement	↑	↑
No of violated vehicle	43	38
No. of cycle	50	31
No. vehicle violated /RLV cycle	1.59	1.65
No. of cycle violation	27.00	23
Percentage of violation /cycle	54%	74%

Table 21: Sample of RLV for Without Countdown at End of Yellow

Location	Shola	Stadium
Target movement	↑	↑
No of violated vehicle	65	68
No. of cycle	46	32
No. vehicle violated /RLV cycle	1.67	2.43
No. of cycle violation	39	28
Percentage of violation /cycle	85%	88%

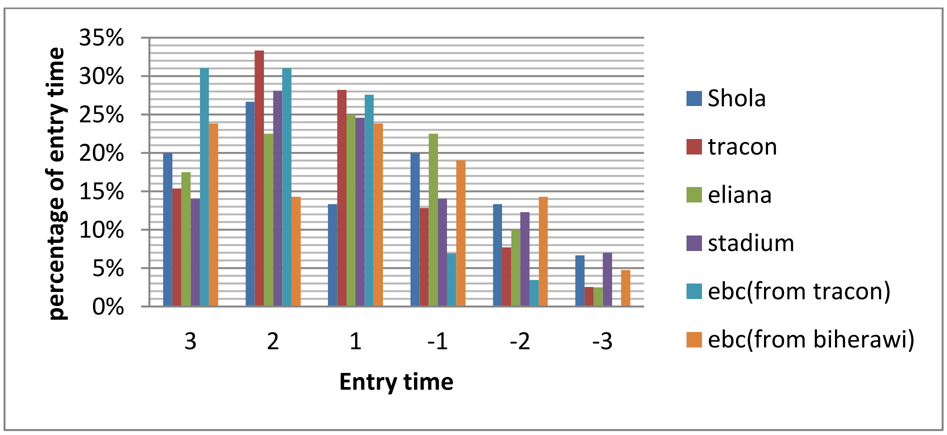


Figure 21: Vehicle Entry Time after Onset of Yellow for Each Intersection

The negative sign indicates vehicle entry time to the intersection during red phase.

Vehicle Clearing Time for Each Intersection

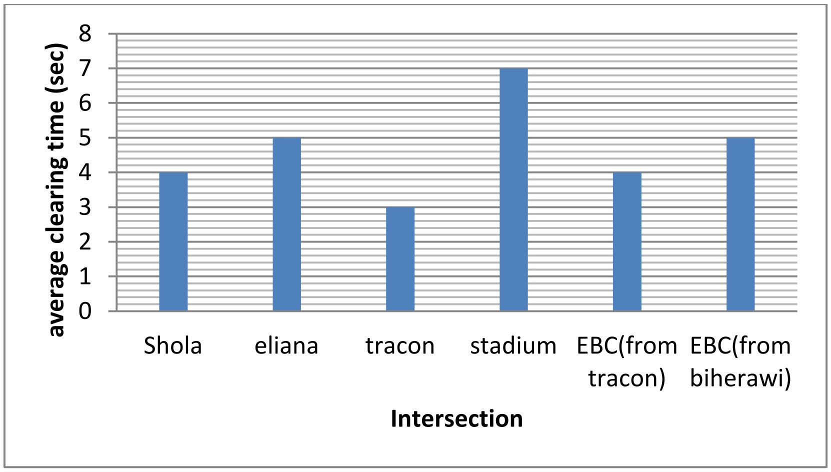


Figure 22: Average Clearing Time for Each Intersection

One-way ANOVA: RLV for countdown, RLV for without countdown

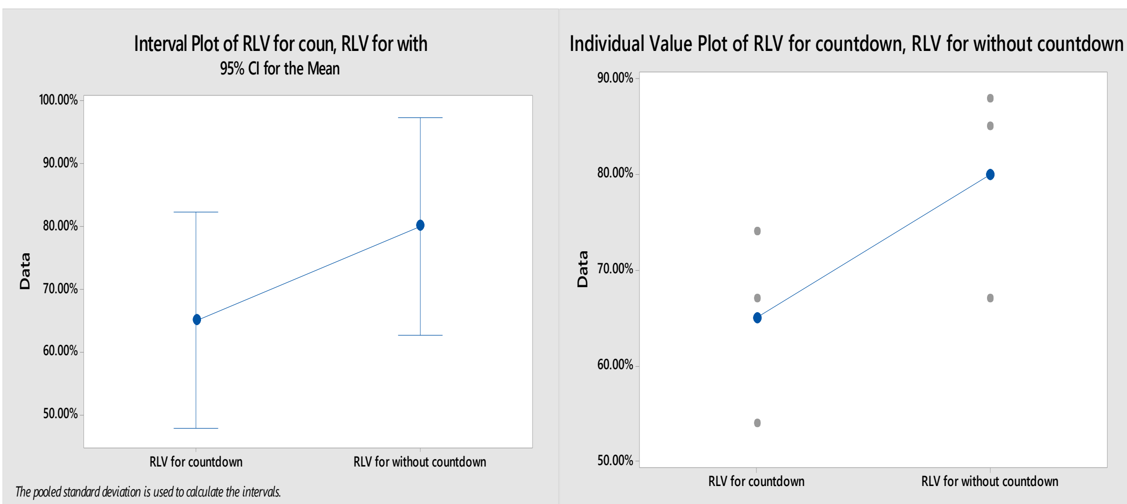


Figure 23: One Way ANOVA for RLV at End of Yellow

Table 22: Two-Sample Equivalency Test:

RLV for Countdown and Without Countdown

Null Hypothesis	DF	T-Value	P-Value
Difference ≤ 0.9	3	-11.940	0.999
Difference ≥ 1.1	3	-14.214	0.000

Red light violation at the end of yellow time for both countdown and without countdown is significantly different with P-Value is 0.999. It cannot claim equivalence.

Sample of RLV at the end of Red

Table 23: Sample of RLV for countdown at the end of red

Location	Eliana	Tracon
Target movement	↑	↑
No. of vehicle Early started	28	23
No. of cycle	49	31
No of vehicle violated /RLV cycle	1.00	1.15
No. of cycle with violation	28	20.0
Percentage of violated cycle/cycle	57%	65%
sum of remaining time	72	69.00
avg. remaining time(s)/vehicle	2.57	3.00
avg. remaining time(s)/cycle	1.47	2.23
Percentage of small car violated	75%	83%
Percentage of minibus violated	25%	17%

Table 24: Sample of RLV for without countdown at the end of red

Location	Shola-2	Stadium
Target movement	↑	↑
No. of vehicle Early started	17	4
No. of cycle	46	42
No of vehicle violated /RLV cycle	1.06	1.00
No. of cycle with violation	16.0	4.0
Percentage of violated cycle/cycle	35%	10%
sum of remaining time	59.00	9.00
avg. remaining time(s)/vehicle	3.47	2.25
avg. remaining time(s)/cycle	1.28	0.21
Percentage of small car violated	82%	25%
Percentage of minibus violated	18%	75%

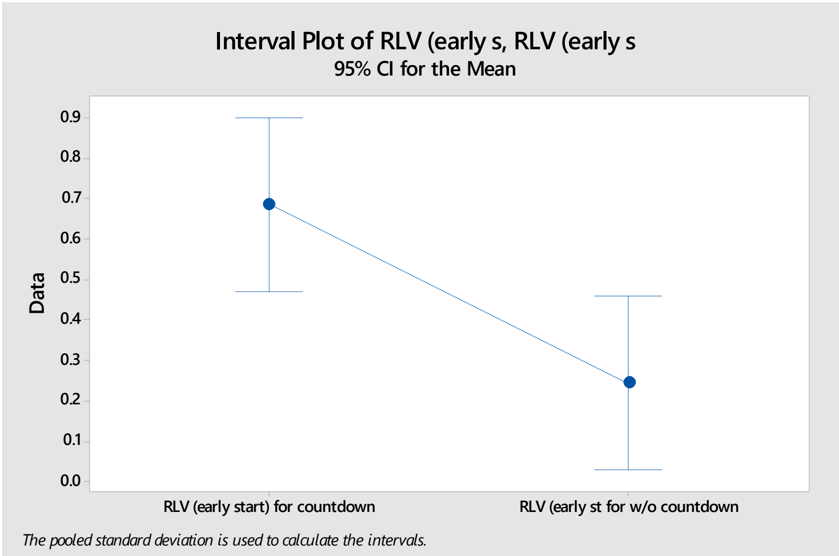


Figure 24: One way ANOVA of RLV (early start) for countdown and without countdown

Two-Sample Equivalence Test: RLV (early start) for both countdown and without countdown

CI is not within the equivalence interval. It cannot claim equivalence with p-value of 0.987.

Table 25: Average Time of Early Start

Countdown			With Countdown		
Eliana	2.57se/veh	1.47sec/cycle	3.47sec/veh	1.28sec/cycle	Shola
Tracon	3se/veh	2.23sec/cycle	2.25sec/veh	0.21sec/cycle	Stadium
EBC	2.98se/veh	2.9sec/cycle	3sec/veh	0.83sec/cycle	EBC

Table 25: shows that in the presence of countdown most vehicles start to move 2.5 seconds per cycle early than the onset of green. But in the absence of countdown vehicles starts movement with 0.77second per cycle.

Dilemma Zone

Table 26: Approach Speed for Each Intersection

Signal condition	Countdown			without Countdown		
Intersection	Tracon	Eliana	EBC(from piazza)	Shola-2	Stadium	EBC(from Biherawi)
Average speed for each intersection	6.6	5.8	6.2	5.38	5.08	4.4
Average approach speed	6.2m/s			4.95m/s		

Table 26: shows that the vehicles approach speed with signal countdown is higher during the yellow time as compared to signal without countdown (i.e., 6.2 vs. 4.95 m/s) and this finding is statically significant at 95% confidence level with p-value of 0.86 as shown in table 27 below.

Two-Sample Equivalence Test: speed for with countdown or without countdown

Table 27: Two- sample Equivalence test for speed

Variable	N	Mean	St.Dev	SE Mean
speed for with countdown	316	6.2239	2.9848	0.16791
speed for without countdown	297	4.9569	1.7405	0.10100

Difference: Mean (speed for with countdown) – Mean (speed for without countdown)

Null Hypothesis	DF	T-Value	P-Value
Difference $\leq$ 0.95	512	1.6177	0.053
Difference $\geq$ 1.05	512	1.1073	0.866

The greater of the two P-Values is 0.866. **It cannot claim equivalence.**

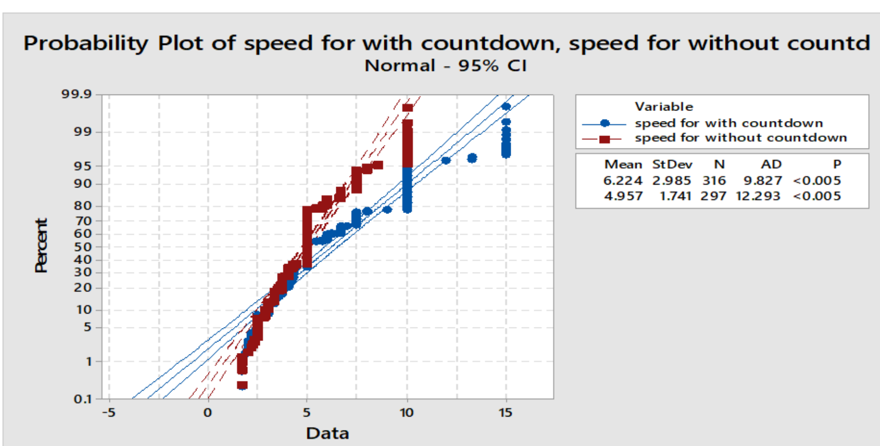


Figure 25: probability plot of speed for both signal condition

Once checked the statistical significance of approach speed then the observed results of the dilemma zone are discussed below.

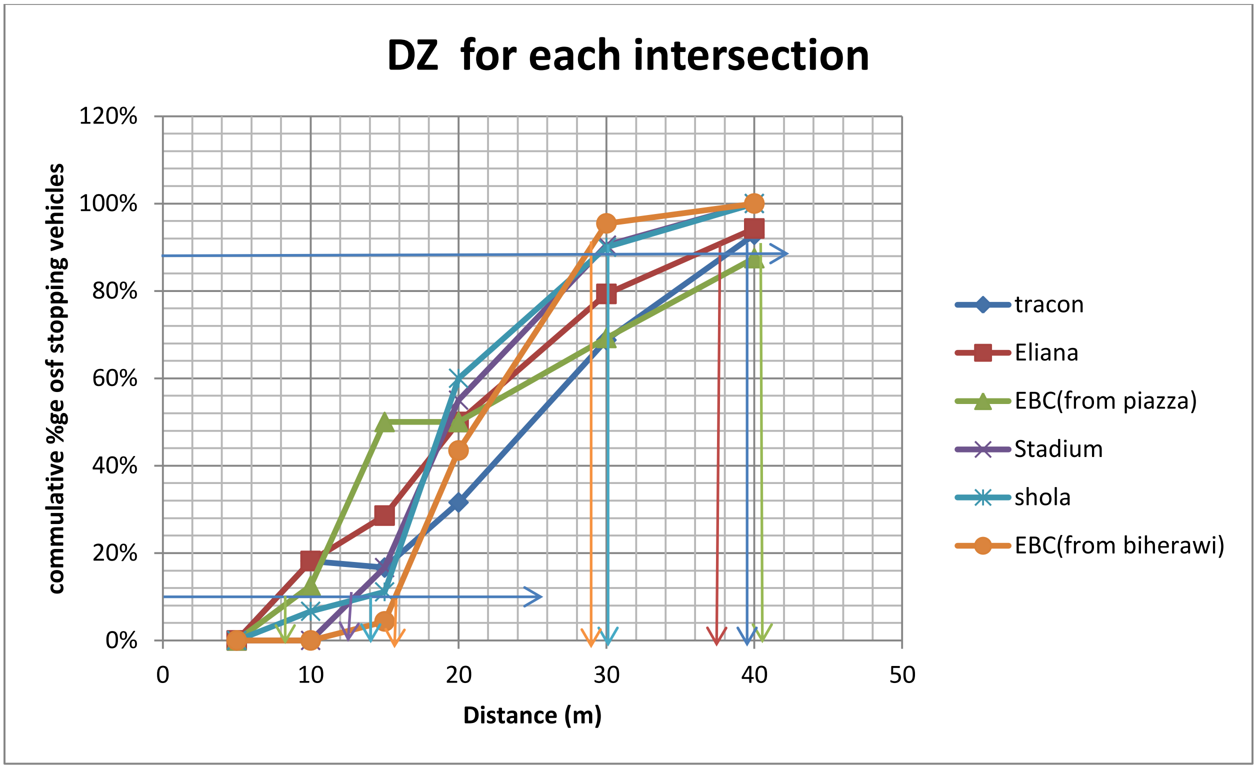


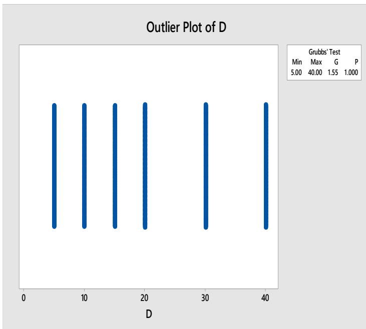
Figure 26 DZ Type II for each Intersection

From the above figure 26: it is observed that Dilemma zone for signalized intersection with countdown (between 8m to 39m for Tracon, between 8m to 37m for Eliana Hotel and 9m to 41m for EBC) and for the intersection without countdown (13.5m to 30m for Stadium between 15m to 30m for Shola and between 15.8m to 29m for EBC (from Biherawi)).

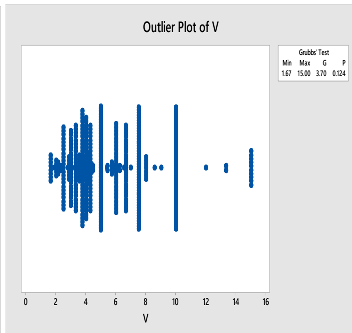
Binary logit regression

Outlier Test for Distance from stop line, Approach speed, Remaining time, intersection length, and approach grade.

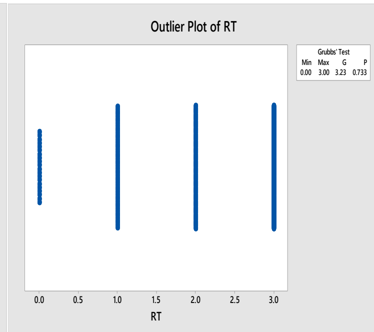
*** NOTE * the following figures shows that no outlier at the 5% level of significance**



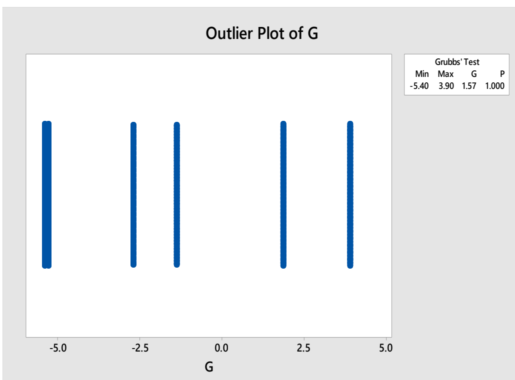
Outlier test for distance



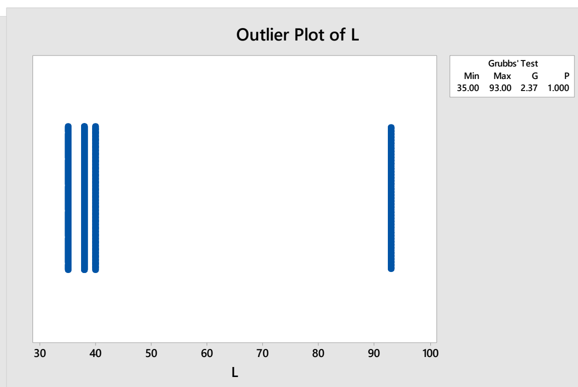
Outlier test for speed



Outlier test for remaining time



Outlier test for grade



Outlier test for intersection length

Figure 27 Outlier test for continuous predictors

Attitude Survey

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

QUESTIONNAIRE

Dear Respondents;

As part of my **M.Sc** study in Road and transport at **Addis Ababa Institute of Technology (AAIT)**, Now, I am undertaking a research study in the title, "**Assessing the effect of signal countdown on intersection** efficiency and safety**: at selected areas in Addis Ababa"**.

The research is conducted for the partial fulfillment of the **masters of Science** in Road and Transport Engineering.

Your response will be kept strictly confidential. Only I and my academic supervisor will access the information you give me and will be exclusively used for the research. Therefore, I request to complete the questionnaire genuinely to enable me to finalize the research.

Thank you very much for your time and cooperation, and looking forward to receive your response early.

Please choose your best answer and explain in the space provided if any.

1. Gender

   1) Male 2) female

2. Age

   1) 18-35 2) 36-60 3) above 60

3. Educational background

   1) Elementary 2) secondary 3) preparatory 4) college
   5) BSC 6) MSc. and above

4. Driving Experience in year

   1) 0-4 2) 5-8 3) 9-12 4) above 12

5. Which type of vehicle do you drive?

   1) Car 2) Minibus 3) Bus 4) Truck

6. Which type of signal do you think more exposed to traffic crash like rear-end and right-angle collision?

   1) Signal with Countdown 2) Signal without countdown

7. Which type of signal do you think more important to facilitate traffic flow or to reduce start lost time?

1. Signal with Countdown 2) Signal without countdown

8. In which type of signal, drivers impose to urgently decelerate at start of yellow?
   1) Signal with Countdown 2) Signal without countdown
9. In which type of signal, drivers impose to urgently accelerate at the start of yellow?
   1) Signal with Countdown 2) Signal without countdown
10. What type of signalized intersection do you recommend?
    1) Signal with Countdown 2) Signal without countdown
    3) Signal without countdown with flashing at the end of red

Why? --

11. What is the use of amber phase/ yellow light?
    1) To cross the intersection 2) To stop safely at stop line
    3) To cross when difficult to stop at the stop line and to leave drivers in the intersection
12. In which type of signal do you start your vehicle and cross the stop line before the start of green light?
    1) Signal with Countdown 2) Signal without countdown
    3) Both in countdown and without countdown 4) Never start
13. Have you ever violated a red light at the end of the yellow light of signalized with countdown?
    1) Yes 2) No
14. If you say yes for Q13, how often do you violate?
    1) Always 2)Usually 3) Sometimes
15. Have you ever violated a red light at the end of the yellow light of signalized without countdown?
    1) Yes 2) No
16. If you say yes for Q 15, how often do you violate?
    1) Always 2) Usually 3) Sometimes
17. Which type of signal creates a frustration on you?
    1) Signal with Countdown 2) Signal without countdown 3) Both 4) None

Why--

18. What is your attitude towards countdown signal?

Please indicate the level at which you agree by putting a tick (✓) here under the table provided.

No	Description	1)Strongly agree	2)Agree	3)Undecided	4)Disagree	5)Strongly disagree
19	The information displayed on signal countdown is correctly understood by drivers					
20	Signal countdown can assist my decision making to cross or to stop at signalized intersection					
21	Signal without countdown can assist my decision making to cross or to stop at signalized intersection					

22. Rank the following possible reasons for violating a red light at signalized intersection with countdown.

----1. To save time

----2. Because allocated green time is not adequate

----3. Because there is no traffic police

----4. Because I think signal facility design is not reasonable

----5. Because difficult to stop safely within the given yellow phase.

If any additional or unmentioned idea ____

23. Rank the possible reasons for violating a red light at a signalized intersection without countdown.

----1.To save time

----2. Because allocated green time is not adequate

----3. Because there is no traffic police

----4. Because I think signal facility design is not reasonable

----5. Because difficult to stop safely within the given yellow phase.

If any additional or unmentioned idea ____

በአዲስ አበባ ዩኒቨርስቲ የሲቪል እና ኢንቫሮመንታል ምህንድስና ትምህርት ክፍል

<u>የድህረ ምረቃ ትምህርት ፕሮግራም ማሚያ መጠይቆች</u>

ይህ መጠይቅ በአዲስ አበባ ዩኒቨርስቲ ለድህረ ምረቃ የትምህርት ፕሮግራም(Msc) የመመረቂያ ጽሁፍ ማሚያ ወይም ግብአት እንዲሆን የተዘጋጀ ሲሆን መጠይቁ "Assessing the effect of digital count down on signalized intersection: at selected areas in Addis Ababa" በሚል ርዕስ የተዘጋጀ ነው፡፡ይህ መጠይቅ በአዲስ አበባ የሚገኙ ቆጣሪ ያላቸው የትራፊክ መብራቶች በትራፊክ ፍሰት እና ደህንነት ላይ የሚያመጡትን ተጽእኖ ለማጥናት የተዘጋጀ ነው ፡፡

"ውድ የሆነ ሰዓትዎን ሰጥተው ይህን መጠይቅ ስለሚሞሉ በቅድሚያ አመሰግናለሁ"፡፡

<u>**እባክዎን ትክክለኛ ነው ብለው የሚያስቡትን መልስ ይምረጡ/ ይስጡ፡፡**</u>

1. ጾታ

   1) ወንድ 2) ሴት

2. ዕድሜ

   1) ከ18-35 2) ከ36-60 3) ከ60 በላይ

3. የትምህርት ደረጃ

   1) አንደኛ ደረጃ(1-8) 2) ሁለተኛ ደረጃ (9-10) 3)ፕሪፓራቶሪ(11-12)
   4)ዲፕሎማ 5) ዲግሪ 6) 2ኛዲግሪ እና በላይ

4. የማሽከርከር ልምድ

   1) 0-4 2) 5-8 3) 9-12 4) ከ 12 በላይ

5. ምን አይነት መኪና ያሽከረክራሉ?

   1) የቤት መኪና 2) ሚኒባስ 3) አውቶብስ 4) ከባድ መኪና

6. ለትራፊክ አደጋ (የኋላ መኪና ከፊት መኪና እና ከተቃራኒ አቅጣጫ ከሚመጣ መኪና ለሚፈጠር ግጭት) የበለጠ የሚያጋልጥ የትኛው ዓይነት የትራፊክ መብራት ነው?

   1) የሚቆጥረው(countdown) 2) የማይቆጥረው(without countdown)

7. የትኛው ዓይነት የትራፊክ መብራት የትራፊክ ፍሰትን ወይም የሥራ ክንውን ውጤታማነትን ያፋጥናል ብለው ያምናሉ?

   1) የሚቆጥረው(countdown) 2) የማይቆጥረው(without countdown)

8. ቢጫ የትራፊክ መብራት ሲበራ የትኛው ዓይነት የትራፊክ መብራት አሽከርካሪዎች በአስቸኳይ ፍጥነታቸው እንዲቀንሱ ያደርጋል?

1) የሚቆጥረው 2) የማይቆጥረው

9. ቢጫ የትራፊክ መብራት ሲበራ የትኛው አይነት የትራፊክ መብራት, አሽከርካሪዎችን በአስቸኳይ ፍጥነታቸው እንዲጨምሩ ያደርጋል?

1) የሚቆጥረው 2) የማይቆጥረው

10. ምን ዓይነት የትራፊክ መብራት ቢኖሩ ብለው ይመክራሉ?

1) የሚቆጥረው 2)የማይቆጥረው 3)የማይቆጥረው በቀይ መጨረሻ ላይ flashing ምልክት ያለው

ለምን? ---

11. ቢጫ የትራፊክ መብራት ለምን የሚጠቅም ይመስልዎታል?

1) ለመሻገር 2) ለመቆም 3) መቆም በሚከብድበት ስዓት ለመሻገር እና ውሰጥ የገባ እንዲወጣ

12. በየትኛው የትራፊክ መብራት ዓይነት አረንጓዴ መብራት(Green light) ከመጀመሩ በፊት መኪናዎን ከቆምበት ማሽከርከር ይጀምራሉ?

1) በሚቆጥረው 2) በማይቆጥረው 3) በሁለቱም 4) አልንቀሳቀስም

13. በሚቆጥረው የትራፊክ መብራት ላይ ቀይ መብራት(Red light) በበራበት ጊዜ መንገዱን አቋርጠው/ጥሰው ያውቃሉ?

1) አዎ 2) አላቅም

14. ለጥያቄ ቁ.13 መልስዎ አዎ ከሆነ ምን ያህል ጊዜ መብራት አቋርጠው/ ጥሰው ያውቃሉ?

1) ሁልጊዜ 2) አብዛኛውን ጊዜ 3) አልፎ አልፎ

15. በማይቆጥረው የትራፊክ መብራት ላይ ቀይ መብራት(red light) በበራበት ጊዜ መንገድን አቋርጠው/ጥሰው ያውቃሉ?

1) አዎ 2) አላቅም

16. ለጥያቄ ቁ. 15 መልስዎ አዎ ከሆነ ምን ያህል ጊዜ ቀይ መብራት አቋርጠው/ጥሰው ያውቃሉ?

1) ሁልጊዜ 2) አብዛኛውን ጊዜ 3) አልፎ አልፎ

17. ምን ዓይነት የትራፊክ መብራት እርስዎን በጣም ያበሳጫል/ያሰለቻል?

1) የሚቆጥረው 2) የማይቆጥረው 3) ሁለቱም 4) ከሁለቱም ውጭ

ለምን?---

18.በሚቆጥረው የትራፊክ መብራት ላይ (signal countdown) አጠቃላይ እይታዎ ምን ይመስላል?

ቁጥር	መግለጫ	1)በጣም እሰማማለሁ	2)እስማ ማለሁ	3)አሳብ የለኝም	4)አልስማማ ም	5)በጣም አልስማማም
19	በሚቆጥረው የትራፊክ መብራት ላይ ያለውን መረጃ ሾፌሮች በትክክል ይረዱታል?					
20	የሚቆጥረው የትራፊክ መብራት ያለበት መገናኛ ላይ የመሻገር እና የመቆም ውሳኔዎትን ይደግፋል?					
21	የማይቆጥረው የትራፊክ መብራት ያለበት መገናኛ ላይ የመሻገር እና የመቆም ውሳኔዎትን ይደግፋል?					

22. በሚቆጥረው የትራፊክ መብራት (countdown) ላይ ቀይ መብራት በርቶ አሽከርካሪዎች ጥሰው እንዲያቋርጡ የሚያደርጓቸው ምክንያቶች በደረጃ ያስቀምጡ፡፡

------1 ጊዜ ለመቆጠብ

------2 ምክንያቱም ለመሽጋገሪያ የተሰጠው አረንጋዴ ጊዜ በቂ ስላልሆነ

------3 ትራፊክ ፖሊስ በቦታው ስለሌለ

-------4. ምክንያቱም የትራፊክ መብራቱ ዲዛይን ምክንያታዊ አይደለም ብዬ ስለማስብ

------5. ብጫ የትራፊክ መብራት ሲበራ ማቆም ስለሚከብድ

ተጨማሪ ምክንያት ወይም ያልተጠቀሰ ሃሳብ ካለዎት

____

23. በማይቆጥረው የትራፊክ መብራት (without countdown) ላይ ቀይ መብራት በርቶ አሽከርካሪዎች ጥሰው እንዲያቋርጡ የሚያደርጓቸው ምክንያቶች በደረጃ ያስቀምጡ፡፡

-----1 ጊዜ ለመቆጠብ

------2 ምክንያቱም ለመሽጋገሪያ የተሰጠው አረንጋዴ ጊዜ በቂ ስላልሆነ

------3 ትራፊክ ፖሊስ በቦታው ስለሌለ

------4. ምክንያቱም የትራፊክ መብራቱ ንድፎች ምክንያታዊ አይደለም ብዬ ስለማስብ

-----5. ብጫ የትራፊክ መብራት ሲበራ ማቆም ስለሚከብድ

ተጨማሪ ምክንያት ወይም ያልተጠቀሰ ሃሳብ ካለዎት

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Drivers Response by Category

Table 28: Drivers Response by Category

Category	Drivers Response for Each Question						
	Most Recommended Signal			Initiate To Start Early			
	Countdown	Without Countdown	Flashing Without Countdown	Countdown	Without Countdown	Both	None
Education Level							
1)Elementary	5%	1%	2%	2%	1%	3%	1%
2)Secondary	20%	1%	1%	13%	3%	2%	5%
3)Preparatory	13%	2%	1%	9%	1%	3%	2%
4)Diploma	13%	3%	5%	13%	2%	4%	5%
5)Bsc	16%	3%	2%	12%	1%	5%	2%
6)MSC& Above	6%	2%	4%	6%	1%	2%	3%
Experts	18%	5%	5%	6%	1%	6%	5%
Total	**74%**	**11%**	**15%**	**55%**	**8%**	**19%**	**19%**
Driving Experience (Year)							
1)0-4	32%	5%	6%	22%	2%	8%	10%
2)5-8	21%	4%	6%	18%	8%	4%	5%
3)9-12	8%	2%	2%	8%	1%	2%	2%
4)>12	13%	1%	0%	7%	1%	5%	2%
Total	**74%**	**11%**	**15%**	**55%**	**11%**	**19%**	**19%**
Driver's Vehicle Type							
1) Car	35%	8%	10%	28%	5%	9%	10%
2) Minibus	26%	2%	2%	15%	2%	7%	5%
3) Bus	5%	1%	2%	6%	2%	2%	2%
4) Truck	7%	1%	1%	6%	1%	1%	1%
Total	**74%**	**11%**	**15%**	**55%**	**11%**	**19%**	**19%**

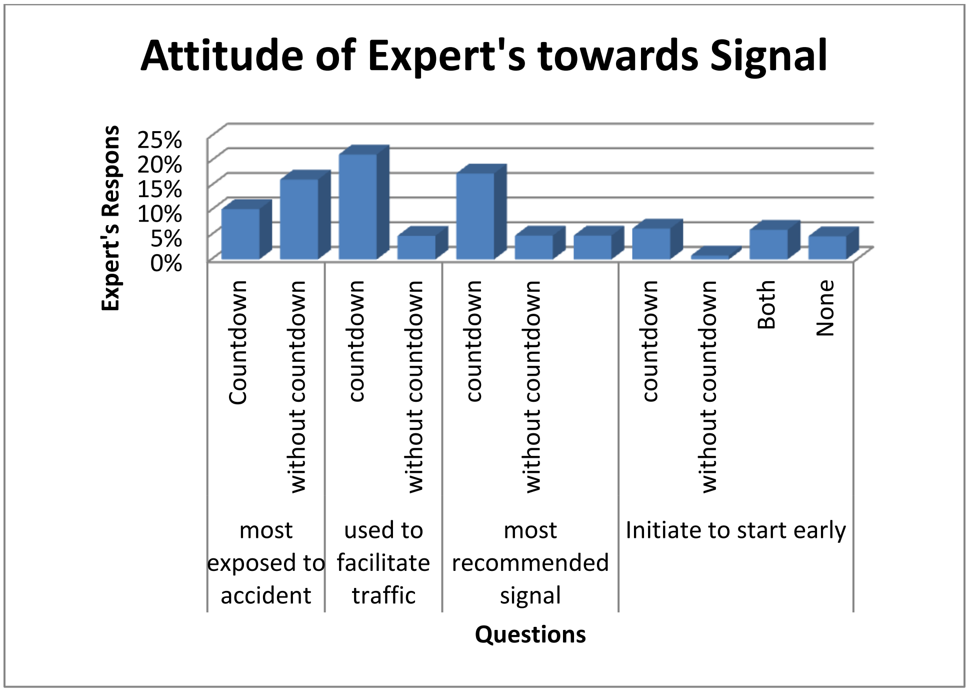

Figure 28: Attitude of Experts towards Signal