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**SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING**

**Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle  
Shared – Space Intersection**

**(Case Study of Saris Adey Ababa Intersection)**

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

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ADDIS ABABA UNIVERSITY  
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IMPROVING LEVEL OF SERVICE OF LIGHT TRAIN, PEDESTRIAN AND  
MOTORIZED VEHICLE SHARE - SPACE INTERSECTION  
(CASE STUDY OF SARIS ADEY ABABA INTERSECTION)

By Anteneh Zemedkun

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University  
in Partial Fulfillment of the Requirements for the Degree of Master of Science in  
Civil and Environmental Engineering  
(Road and Transport Engineering Stream)

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## DECLARATION

I certify that research work titled “Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection” is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

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## ABSTRACT

Providing of mass transport such as electric train in urban area is the best method to solve many transport problems such as safety, congestion, delay, free from air pollution, shortage of transport system supplies and others. However, provision of mass transport like urban light railway transit in congested city becomes a major cause for different problems such as excessive delay and queue formation and low performance of roads specially at grade crossing intersections and roundabouts that will be shared by pedestrian, light rail way and Motorized vehicle along the LRT. Accordingly, the main Cause for the problems are due to the light rail way builds parallel with center/median of road alignment and fragmented of the road area by fence, at grade crossing intersections become more congestion due to they were designed and build by considering only motorized vehicle and pedestrian without considering the new provided LRT, high concentration of U turns traffic due to lack of U turns in other locations and Un-controlled and high concentrated pedestrian crossing activities. Performance evaluation of the intersection under current traffic conditions was done during peak periods. The performance evaluation indicated that the approach delays of the intersection become over twelve minutes during peak periods.

This research deals about improving the Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space at grade signalized Intersection, Case study Saris Adey Ababa at grade Signalized Intersection by propose alternative solution for the identified problems causes and to see if an acceptable performance can be achieved with-out provision of under pass and over passes (grade separation). In order to achieve this goal necessary data were collected at the study intersection. Formerly VISSIM simulation software was used to for designed and modeling.

During the study Fixed Traffic Signal control with calibrated saturation flow, Transit Signal Priority, installation of Pedestrian fence and signals and diverting U turns to other locations are considered as alternative solutions. Performance evaluation such as maximum and average queue length, travel time, intersection delay and level of service was used as Comparing criteria under current and future traffic conditions. The best options for the study area are Fixed Traffic Signal control and Transit Signal Priority. Since, diverting U turns on other locations and provision of pedestrian signal were applied simultaneously with Fixed Traffic Signal control and Transit Signal Priority.

Related to selecting the best alternative from Fixed Traffic Signal control and Transit Signal Priority. Fixed traffic signal control has less intersection delay of 72.9 sec/veh for vehicles however; it has additional delay on Tram and main traffic flow directions. On the other hand transit Signal Priority has higher intersection delay 79.9 sec/veh and additional approach delay on the opposite direction from Tram way but it has less approach delay for main approaches vehicles and for Trams. Transit Signal Priority with green extension and Red Truncation are preferred to be applied.

**Key words: Shared - spaced intersection, Transit Signal Priority, Congestion, VISSIM**

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## **Acronyms**

AACRA Addis Ababa City Roads Authority

CBD Central Business District

ERA Ethiopian Road Authority

FHWA Federal Highway Administration

HCM Highway Capacity Manual

LOS Level of service

LRT Light Rail Transit

LRV Light rail vehicle

MUTCD Manual on Uniform Traffic Control Devices

PHF Peak-hour factor

V/c Demand to capacity ratio

Xc Demand to capacity ratio

PCU Passenger Car Unit

TRRL Transport Research Record Laboratory

VISSIM "Verkehr In Städten – SIMulationsmodell"

(German for "Traffic in cities - simulation model")

## CHAPTER ONE: INTRODUCTION

### 1.1 Background

In order to improve urban mobility, Ethiopian Railway Corporation has started a light rail transit project in Addis Abeba. The project is 34.25 kilometers long in total. From Ayat Village to Torhailoch, the east-west line of the two train lines travels 17.4 km, passing through Megenagna, Meskel Square, Legehar, and Mexico Square. Menelik II Square, Merkato, Lideta, Legehar, Meskel Square, Gotera, and Kaliti are all on the 16.9 km long north-south route. However, two lines share a 2.7 km-long track. The elevated portion that crosses from Meskel Square to Mexico Square and on to Lideta is known as the common track. Including this one underground station (beginning station), 12 grade crossing stations, and 9 elevated stations, the North to South Corridor has a total of 22 stops (Rediet., 2018). Besides to this, the LRT corridor crossing 3 roundabout and 2 main four leg intersections namely Sebategna and Adeyabeba intersections.

Following to the provision the LRT in the city transport system, it has brings many advantages such as no emersion or environmentally friend due to usage of electric power and less noise disruption, high capacity of passenger mobility, low operating/life cycle cost, low travel time, high safety, creating new work opportunities for employers. On the other hand due to the LRT is implemented on the existing road situations i.e space and traffic management system and not well integrated with existing road network, negative impacts also observed including fragmentation of road segment at grade crossing stations, additional delay around at grade crossing intersections, roundabouts and LRT stations due to concentrated/cumulative pedestrian crossing activity, high vehicle operating and travel cost, risk of safety on pedestrian during crossing activity.

There are many research were done related to the impact of the new provided LRT system on the adjacent roads, study done in 2014 by Eskinder Nigussie in Torhailoch to Ayat study areas showed that additional delay at roundabouts increases as LRT crossing frequency increases. Moreover, pedestrians getting on and off the LRT vehicle at ground stations interrupted traffic movement (Eskindr, 2014). A consequent study done by Demelash Berhane Mengesha et al.: analyze the LOS and Additional delay of Menilik to kaliti LRT section using three scenarios of i.e considering both light rail vehicle (LRV) and pedestrian crossing, without LRV crossing and in absence of pedestrians. As per the assessment it find out that LOS F and D at the Sebategna and Adey Abeba intersections at both light rail vehicle (LRV) and pedestrian crossing scenarios and related to an additional delay analysis, from the three scenarios an average additional delay due to LRV crossing have been 1.46 sec./veh and 1.51 sec./veh for Sebategna and Adey Ababa intersections respectively, while an average additional delay due to pedestrian crossing shown to be 13.22 sec./veh and 5.37 sec./veh for Sebategna and Adey Ababa intersections respectively (Demelash, 2019). On the other hand a study done by Rediet Firdu G/Tsadik in Addis Ababa East – West LRT corridor grade crossing in Sealite Mehert and CMC roundabouts shows that signalized roundabout is a solid and effective alternative to improving the additional delay expected on existing Sealite Mehert and CMC roundabouts. (Rediet., 2018)

As mentioned above, previous studies predict that the introduction of the LRT line will cause additional delay and quantifies the effects of LRT at grade intersection in terms of LOS and Delay. In addition to this the previous study also show that signalized roundabout is a solid and effective alternative to improving the additional delay expected on existing Sealite Mehert and CMC roundabouts. Unlike to the previous studies this study assesses the alternative signal controlling systems on Light Train, Pedestrian and Motorized Vehicle Shared - Space Intersection. The objective of this study is to evaluate the performance of selected grade crossing signalized intersection under existing traffic conditions and to improve it with alternative signal controlling system designs. The alternative solution proposed will be Actuated Signalized intersection with Transit Signal Priority (TSP) strategy (Green Extension and Early Green/Red Truncation) traffic signal controlling logic.

## 1.2 Statement of the Problem

Now a day's traffic congestion at those shared – Space at grade crossing intersections become threat in the city economy growth by limiting the mobility of the road user and increase delay and fuel consumptions.

Due to unbalance of demand and supply in the transport system of Addis Ababa city, provision of the mass transport mode by urban light railway transit would solve many problems related to the transport systems. However, at grade crossing intersections which are crossed by the Light Train become very congested from day to day due to the fact that those intersections was designed and build without considering the new provide LRT that will share the available road geometry and crossing time and fragmentation of the road corridor that would lead to concentration of vehicles and pedestrian at junctions beyond the capacity of the intersections.

In connection to this, there are researches done up to date on at-grade LRT shared - spaced grade crossing intersections and indicates significant problems with respect to traffic congestion. Such as following to the provision of the LRT line will causes additional delay at grade crossings to adjacent road traffic (yilikal, october 2013). And also another assessment find out that LoS F and D at the Sebategna and Adey Abeba intersections at both light rail vehicle (LRV) and pedestrian crossing scenarios and an average additional delay due to pedestrian crossing shown to be 13.22 sec./veh and 5.37 sec./veh for Sebategna and Adey Ababa intersections respectively (Demelash, 2019). A further study shows signalized roundabout is a solid and effective alternative to improving the additional delay expected on existing Sealite Mehert and CMC roundabouts (Rediet., 2018)

As shown in the above, researches are focused on evaluation of the current existing traffic condition and LoS at those grade crossing shared spaced intersections and proposing per-time signalized roundabout with considering of light train arriving at green phase of the through movement. However, improving of traffic condition and LoS for shared spaced signalized intersection has never been evaluated before by actual arrival time of light train with actuated traffic signal system that will be controlled by transit signal priority strategy for forecasted traffic demand on the available geometric condition with considering the three main road users of

pedestrian, LRT and Motorized vehicle and accordingly the problem yet not optimize even if the traffic pre-timed signal control system were provided by the city administration which is not currently operated.

Hence, to improve the traffic flow and LoS in those shared - spaced signalized at grade crossing intersections with actual arrival frequency of light train, it is important to assess the possible causes of congestion in the intersections, the performance of the intersections, future traffic demand of the intersections, current traffic condition, actual light rail operation condition and LoS after pre-timed traffic signal is provided and possible remedial alternative measure to be implemented to improve the traffic flow and LoS in order to make the traffic flow smooth and effective.

### **1.3. Objectives of the Study**

#### **1.3.1. General Objectives**

The General objective of the research is to improve LoS in the shared- spaced signalized intersection (case study in Saris Adey Abeba unsignalized intersection).

#### **1.3.2. Specific Objectives**

The specific objectives of this research are:

- a. To identify the effect of LRT, pedestrian and motorized vehicle interaction on the LOS of the shared - space intersection.
- b. To evaluate the level of service (LOS) and performance of the shared - spaced at grade signalized intersection for the current traffic condition.
- c. Evaluate the performance of alternative solution by modeling projected future traffic scenario at the shared- spaced intersection for the next 5, 10 and 15 years using VISSIM Software.
- d. Evaluate the proposed remedial measures base on measures of effectiveness to optimize traffic flow and minimize the delay at shared – spaced intersections and recommend the best alternative to the existing at grade intersection.

### **1.4. Scope of the Study**

The study will focuses on identifying the effect of LRT, pedestrian and motorized vehicle on the isolated multi shared - spaced intersection performance, project the current counted traffic to the next 5, 10, and 15 years and obtain a geometric measurement of the selected intersection. Accordingly, the obtained data will be simulated/ modeled and analyze using VISSIM simulation software based on delays, queue length, travel time and LoS on the intersection. After the evaluation, assessing possible counter measures which will be used and evaluate the proposed remedial measures for the specified at-grade shared- spaced intersection for improving and optimizing the above specified criteria.

## 1.5 Significance of Research

- ❖ Recommend best solutions to reduce traffic jam at study area

Roads adjacent to the LRT, traffic jams become uncontrollable condition at grade junction and it has its own negative impact on the economy of city. Hence, improving capacity of at grade intersections, will improve the performance of the whole road system, which will reduce the negative impact of the congestion on the economy of city. This study focused on to improve the operational capacity of at grade crossing shared spaced intersection which is located inside the Addis Ababa North –South LRT corridor. Besides to this, it will assess the main causes of congestion the same. Finally as per the assessment efficient, economical and easy of applicable alternative solution which is Transit Signal Priority is suggested. Based on the causes identified, simple and low cost solutions such as Active Transit Signal Priority with Green Extension and Early green /Red Truncation with diverting U turns and installing pedestrian signals with fence are proposed as effective solution.

- ❖ Base Model for Other Traffic Scenarios

In this study at grade multi shared spaced intersection by LRT, vehicle and pedestrian, LRT has get a priority to cross the intersection prior to vehicle and pedestrian due to its high functional benefits. Similar to this scenario, BRT has introduced in the Addis Ababa city in which at grade multi shared spaced intersection by Bus, other vehicles and pedestrian, BRT will get a priority to cross the intersection prior to vehicle and pedestrian due to its functional benefits. Accordingly, the modeling and the assessment on this study will be used as a base model for improving at grade intersecting in case of BRT.

- ❖ Introduce a New Type of Traffic Control System

Transit Signal priority is a comparatively new type of signal controlling logic design which is differ from the conventional pre-timed signal design provide in the city. The preceding studies at LRT grade crossing are mainly focused on forecasting the effect of LRT and assessment the LOS at multi shared spaced grade crossing. Unlike to this, there are some studies in which introduced a new system of combining traffic control system with roundabout by considering the light rail will arrive at green phase of its parallel/through movement (Rediet., 2018). However, studies concerning on actuated signal design with actual light rail arrival frequency (parallel or opposing flow) are null. As a result, any new research on actuated signalized intersections with transit signal priority controlling logic will add to the existing body of knowledge.

## 1.6 Organization of the Study

This research is mainly classified into five main chapters. The first Chapter intends to introduce the underlying background science to the topic and why this study needed to be done and what other significances it will have apart from addressing problems pointed out in previous studies. The second chapter extends the effort to look on background science in detail by

reviewing vast previous studies in the area of the topic. Chapter three describes research methods used and materials including description of the study area, sample study design, data collection methodology, and design of signalized intersection with traffic control logic of transit signal priority strategy for Green Extension and Red Truncation/ Early Green methods. Chapter four deals with analysis and discussion, which carried out analysis to check the effectiveness of the proposed alternative solutions. The last chapter of the study is conclusion and recommendation on the effectiveness of the proposed solutions along with recommendation for future studies.

## CHAPTER TWO: LITREATURE REVIEW

### 2.1 Introduction

One of the traffic management techniques used in developing smart cities to improve the quality of service for customers of public transportation is to provide priority to public transportation vehicles at traffic signals. It is essential to ending the vicious cycle of traffic that constantly threatens to grow up cities. In that cycle, escalating private traffic causes public transportation to deteriorate in speed, dependability and appeal. As a result, transit reliability and speed suffer, and more people choose private vehicles instead of public transportation, which worsens traffic congestion and increases emissions and energy consumption. As traffic demand and urban networks expand, giving public transit priority would end the cycle and make it a more desirable method of transportation. Prioritizing transit through time in the form of Transit Signal Priority (TSP) is one substitute for prioritizing it over space for transportation (B.Moghimi.et.al, 2020). As per TCRP-Synthesis-83\_2010 stated that the provision of trip time reductions and enhanced on-time performance for bus and rail systems running in mixed traffic on urban streets is made possible in large part by transit preferred treatments. Streetcars and light rail transportation are both types of rail systems that run on public streets. Mainly there are two ways of treatments which are relating to both roadway segments and spot locations (intersections) and include the following:

#### 1. Roadway Segments

- Median transit way,
- Exclusive lanes outside the median area, and
- Limited stop spacing/stop consolidation.

#### 2. Spot Locations (Intersections)

- Transit signal priority (TSP),
- Special signal phasing,
- Queue jump and bypass lanes, and
- Curb extensions.

TSP is the most affordable and straightforward to execute of the listed transit treatments, but other treatments need more resources and physical space to be taken into account. In reality, transit agencies are more concerned in using their limited resources wisely, and TSP could meet those demands. However, following the initial installation, the influence of TSP will show more effective with the usage of thorough evaluation, continual performance monitoring, and adjustment (T.Kimpel.et.al, 2005).

From the above mentioned transit treatment methods transit signal priority method which is categorized in Spot Locations (Intersections) will be preferred or selected for further evaluation

and analysis at the selected case study intersection which is Saris Adey Abeba signalized intersection.

This Chapter provides an overview the Concepts of different Signal control and Transit Signal Priority, in addition to the factors that will affect the choice of Transit Signal Priority Type. It intends to look on several literatures written in the areas of this research and Section 2.2 will be discussing about Traffic Signal Control Operation Modes. Section 2.3 Alternative Improvement Methods at LRT Signalized Grade Intersection and review the previous study on each of the proposed improvement method used in different locations are discussed. This chapter's final section will try to show how this study would be useful while also pointing out any gaps in earlier studies.

## **2.2 Traffic Signal Control**

The traffic signal is switched using a traffic controller. Red, green, yellow, and red-clearance is the colors in the signal sequence. Cycle duration and green split are the two key factors that affect signal timing. A signal's cycle length is the number of seconds it takes for a signal to go through a complete cycle of indications. The length of the green interval plus the yellow interval plus the red-clearance interval is equal to one cycle. Additionally, it shows how long it will be till the next time the green starts after one approach. Green split indicates a signal traveling in a specific direction is the portion of the cycle that occurs when the signal in that direction is green. (TELKOMNIKA, 2014).

In the traffic signal intersections Traffic signals operate in either pre-timed or actuated mode or some combination of the two. Here, the three types of traffic signal operation and there relation with TSP is discussed as follow;

### **2.2.1 Pre - Timed Control**

Pre-timed traffic signal controllers allocate a set amount of green time to each signalized movement. Based on a number of variables, such as historical traffic volume counts, system limits, and pedestrian movements, the amount of green time given for each movement is determined. Interconnecting pre-timed controllers ensures a predetermined green band for progressive movement along the main roadway because steady green intervals are provided for each movement. A pre-timed signal system typically provokes a positive response because of the visible green band and the progressive movement felt. Where traffic signal frequency and spacing are advantageous, a pre-timed controller is typically installed at intersections with predictable traffic patterns or frequently saturated circumstances (M.Dobersek, 1998).

Pre-timed control is best used at closely spaced intersections with predictable traffic volumes and patterns throughout the day or week. These circumstances can frequently be observed in urban settings. Additionally, it works better at crossings that only require three stages. Pre-timed control has a number of benefits. Since the beginning and end of green are predictable, it can be utilized, for instance, to efficiently coordinate with nearby pre-timed signals. Additionally, since it is not depend on detectors, any issues brought on by detector failure cannot affect how it operates. Pre-timed control, on the other hand, is less effective at isolated intersections because

traffic arrivals are sporadic and cannot account for unforeseen fluctuations in traffic flows (XING.ZHENG, 2010).

Whether the transit is anticipated to pass through the signal at a green light is indicated by the TSP on the fixed time control logic. If this is the case, there is no other course of action; however, if the bus is anticipated to arrive at the stop line just after the end of the green, the green extension tactic will extend the green time until the transit vehicle can pass through or before the permitted maximum green, whichever comes first. The following phase or any other phases that clash are used to calculate the green time needed for an extension (if there are more than two critical phases). However, the TSP logic truncates the active green phase if the bus is at the signal while traffic from another approach is being handled after the minimum green – of that phase is satisfied. Applying TSP to the fixed-time control logic will significantly reduce bus latency, but it may lengthen the delay of the opposing phases. The fixed time signal control lacks compensation, making it incapable of recovering from disruptions like TSP. This contributes to the limitation of TSP application over the fixed-time control in many existing models (F.Dion.et.al., 2004).

### **2.2.2 Semi - Actuated Traffic Control**

Semi-actuated signal controllers give actuated movements a "window of opportunity." All movements, with the exception of the main street through movement, are typically considered actuated movements. The signal controller monitors every movement using detectors during the specified timeframe, and only offers service when there is demand. When an actuation movement is serviced, a varying amount of green permission from the copyright owner is allotted to it. Without permission, further reproduction is banned. Preview time, according on the current traffic volumes, between predetermined minimum and maximum levels. Any unused green time by the actuated motions is transferred through movements to the main street. As a result, there will be varying amounts of green time for main roadway through movements (M.Dobersek, 1998).

Only the smallest motions at an intersection are controlled by semi-actuated detection. The phases connected to the major-road through movements are "non-actuated" in operation. In other words, no detection information is sent to these phases. The controller is configured to remain in the non-actuated phase during this type of operation, maintaining a green indicator for the highest flow movements (normally the major street through movement). Minor movement phases are handled following a request for their assistance (XING.ZHENG, 2010).

### **2.2.3 Fully - Actuated Signal Control**

Fully-actuated control refers to junctions where all phases are actuated; as a result, it has to be detected whenever a vehicle moves through the intersection. Fully actuated control is best suited for isolated crossroads with daily variations in traffic demands and patterns. For low-volume periods when the system is running in a "free" (or non-coordinated) mode, the majority of contemporary controllers in coordinated signal systems can be set to function in a fully-actuated mode. Additionally, fully-actuated control can boost efficiency at intersections with smaller traffic volumes that are situated at the edge of a coordinated system and do not impede system

development. Another crucial junction control technique, fully-actuated control, has been employed to maximize green time allocation at the intersection of two arterials (XING.ZHENG, 2010).

Actuated signal control makes judgments based on traffic data collected by sensors integrated into the infrastructure, such as loop detectors, video detectors, or radar. Since the demand for traffic can occasionally change, actuated control better captures the real-time dynamic of the traffic system. In order to reduce slack time, cycle length, and total delay at junctions, the fully actuated signal control runs as quickly (snappy) as possible. (B.Cesme.et.al, 2012)

Any traffic-actuated control system can be adjusted to operate according to the present or anticipated traffic condition by utilizing at least three data resources, including the current phase state, the signal timing plan, and the detector output (Zheng, 2010).

## **2.3 Alternative Improvement Methods at LRT Signalized Grade Intersection**

### **2.3.1 Transit Signal Priority**

TSP modifies intersection traffic signal timing to give precedence to transit in a median transit way, exclusive bus lanes, or mixed traffic. TSP changes standard signal operation to better accommodate transit vehicles while maintaining overall signal cycle length and coordination. TSP differs from signal preemption (which is commonly used for emergency vehicles), in which normal signal functioning is disrupted by modifying the signal cycle length, thereby excluding the general traffic flow from the preemption call's coordination. When LRT trains operate in a separate ROW and cross an urban street, signal preemption is utilized; however, when LRT trains drive along a street and cross an intersecting street, the priority concept is employed (TCRP, 2010).

The TSP uses techniques of peer-to-peer communications between crossings. It leverages detection information to lessen uncertainty and gives requests for priority treatment in advance. This idea aims to accomplish three main things. First, more LRV service phase chances should be made available within the current signal phasing. The second is to establish a means of communication between intersections so that incoming trains can be sent information. The third objective is to service the train promptly while preserving coordinated signal operation and to prepare the junctions for the railway without further delaying vehicle or pedestrian traffic. (TCRP, 2010).

TSP has evolved along with the applications it has evaluated and put into use with the development of intelligent transportation technologies. TSP is a method of operating that, if possible, enables the running of buses, tramways, or streetcars past signalized crossings without stopping for red signal lights. It can be a successful technique for lowering transit vehicle and passenger delays at signalized crossings, cutting fuel use and vehicle emissions, preventing bus swarming, and greatly improving transit reliability, all of which lead to cheaper operating costs and passenger wait times (smaller transit fleet size) (B.Moghimi.et.al, 2020).

### **2.3.1.1 Key Components of TSP System**

As per TCRP-Synthesis-83\_2010.TSP systems may involve the interaction of four major elements, the transit vehicle, transit fleet management, traffic control, and traffic control management. These four sub-systems are then enhanced with four functional applications of vehicle detection, priority request generation (PRG), priority request server (PRS), and TSP control. Or more specifically:

- a. Detection - A system for delivering vehicle data to a device that is sent to a Priority Request Generator (e.g., location, arrival time, approach, etc.). They used to detect “check in “and “check out “of the transit vehicles. There are several methods of detecting and processing transit vehicle information, including GPS Detector, inductive Detector, Radio Frequency Detector and infrared Detector.
- b. Priority Request Generator/Server - A system for requesting priority from the traffic control system and, if necessary, triaging numerous requests.
- c. Priority Control Strategies - A software upgrade to a traffic control system (preferably more adaptable than pre-emption) that provides a set of "TSP Control Strategies" that fulfill the traffic jurisdiction's functional needs.
- d. TSP System Management – Incorporates traffic and transit TSP services in transit and traffic control administration, allowing users to specify settings, log occurrences, and generate reports.

### **3.2.1.2 Types of TSP Priority Approaches**

As detailed below, transit signal priority can be handled in a number of methods, including passive, active, and adaptive priority treatments.

#### **2.3.1.2.1 Passive Priority**

Passive priority operates indefinitely, based on information about transit routes and ridership trends, and does not necessitate the use of a transit detection / priority request generation system. Because dwell times are highly varied, the signal timing plan would account for operational parameters such as average dwell time at transit stations, or employ as short a cycle length as possible. Retiming, lowering cycle durations, or coordinating signals on a corridor are examples of operational enhancements to signal timing plans that can improve traffic flow and minimize transit trip time. It would be considered a passive tactic to simply time the crossing to minimize person delay rather than vehicle delay (TCRP, 2010).

With regard to passive TSP, the goal of signal configuration is to increase the likelihood that transit vehicles will arrive at the intersection within the green interval. Passive TSP, however, it is rigid and unable to change to the changing traffic and transit conditions. The rationale is because passive priority always gives transit a green light even if there is no transit vehicle present. In addition, it would delay other competing phases by giving bus-phases an ineffective

green light. When traffic congestion is low to moderate, transit frequencies are high, and transit journey times are predictable, passive priority is more effective. (A.Shalaby.et.al, 2006).

Since transit detection and communication equipment is not needed, passive priority is both affordable and simple to deploy. Preemption priority uses priority techniques in an abrupt manner, it should be noted. This is occasionally done to allow a specific vehicle (such as an ambulance) to pass through the traffic light by skipping phases or ending the pedestrian clearance time. (Khan, 2012).

There are many ways of implementing passive priority technics, establishing transit signal progression is one such passive prioritization technique. The signal timing plan in this application would take into account operational features like the typical dwell duration at transit stops or, given that dwell periods are extremely unpredictable, employ a cycle length as short as possible. (TCRP, 2010).

#### **2.3.1.2.1.1 Use of Passive Signal Priority at Grade Crossing**

##### **I. A Passive Transit Signal Priority Approach for Bus Rapid Transit System**

(Case study at Beiyuan - Wuyingshan intersection)

Because each bus has a different signal status as it enters the intersection and has a varied delay, buses typically arrive at intersections with fixed frequencies and depart at dramatically varying headways. Besides to this, one issue with current bus priority policies is that they give little consideration to variations in sequential bus delays at crossings. Bus headway variation and time table deviation may be primarily caused by the BRT system, the vastly improved travel time dependability of buses on links, and traffic signal control system. In this paper, a junction's cycle time, the number of Different Signal Status (DSS) when buses arrive at the intersection, and the departure frequency of a BRT bus line were represented numerically. By examining their impacts on the bus average delay and deviation of headways, the best number of DSS One was determined. On the other hand in this paper also presented a bus signal priority control strategies for different numbers of DSS. The Beiyuan- Wuyingshan intersection, which has a dedicated BRT lane, was chosen as the test site for the suggested plan. The findings of the high performance simulation program VISSIM confirm that the variables bus frequency, signal cycle, number of DSS, bus headway deviation, and bus delay exhibit strong correlations. The suggested signal priority tactics can greatly reduce average bus delay and bus headway deviation while barely affecting the delay of motor vehicles.

#### **2.3.1.2.2 Active Priority**

Active priority techniques provide a certain transit vehicle preferential treatment when detection and activation of a priority request. It can be either unconditional or conditional priority can be applied as an active strategy. Unconditional Priority provides priority for all transit vehicles equipped with detection, whereas conditional priority only provides priority if a transit vehicle meets some condition based on Automatic Vehicle Location and/or Automatic Passenger

Counter data such as if the transit vehicle is behind schedule or there are a certain number of passengers on-board (TCRP, 2010). Real-time data on the location and speed of transit vehicles should be gathered in an active priority system. Inductive loops, infrared, and radio-based systems, which are referred to as static detection or selective vehicle detection (SVD), are some common vehicle/bus detection approaches. It has been shown that active TSP is a superior strategy for enhancing transit efficiency, accommodating erratic arrival times, and making on-street transportation more dependable, quick, and affordable (R. Smith, May 2005).

### **2.3.1.2.2.1 Active Transit Signal Priority Strategies**

Generally there are different types of Transit Signal Priority strategies may be used such as:-

#### **a. A Green Extension Strategy**

When a TSP-equipped vehicle approaches, the technique extends the green time for the TSP movement. This tactic is only used when the approaching TSP enabled vehicle has a green signal. Green extension is one of the more successful kinds of TSP since it does not require additional clearance intervals while still allowing a transit vehicle to be served and considerably reducing the time spent waiting for an early green or special transit phase for that vehicle (TCRP, 2010). The TSP logic uses the maximum green extension as an input value. A maximum point or duration at which transit can be identified will be determined based on maximum green extension and bus speed. (P.Koonce.et.al., 2002).

#### **b. An Early Green Strategy**

It reduces the green period of previous phases to speed up the return to green (i.e. red truncation) for a movement where a TSP equipped vehicle has been spotted. This tactic is only used when the approaching TSP-equipped vehicle's signal is red (TCRP, 2010).

#### **c. Early Red or Green Truncation**

It is also one of the methods which will use as TSP tactics. In this tactics the transit vehicles that would arrive a few seconds before the start of green are allowed to pass. In order to make the signal cycle more quickly and give the transit vehicle that was waiting behind the traffic lights a green window sooner, green truncation shortens the green time of the conflicting or non-transit phases. This strategy benefits all buses stopped at a red signal, giving many people a tiny reward. (S.Altun.et.al, 2009).

The early red strategy is advised to be used at crossings with low to medium interruptible bus requests because it reduces the green of the conflicting phases while there are vehicles in the line, causing greater disruption to the conflicting traffic (B.Moghimi.et.al, 2020)

#### **d. Phase Rotation**

Phase Rotation is a TSP method that has only lately gained popularity in research. To coincide with the bus' arrival time and the green light, it modifies the ring barrier signal system's phase sequence. Typically, it converts a leading left phase into a lagging left phase or the other way around. Thus, when there is a left-turn phase in the ring barrier with more than two crucial phases, the phase rotation technique is applied. This model, for instance, presupposes that the initial signal timing design is set to leading left and lagging through. The phase rotation technique flips the order of the phases so that the through-phase leads and the left-turn phase lags, assuming that the bus is moving in the through-phase. Where bus volume is high, the impact of phase rotation is useless (P.Furth.et.al, 2010).

To give TSP, the order of the signal phases can also be "rotated" (i.e., phase-rotated). For instance, the left-turn phase for a northbound vehicle could typically be a lagging phase, which means it comes after the opposing through signal phase. In order to request the left-turn phase, a northbound left turning bus must arrive before the beginning of the green phase for the through traffic. The left-turn phase could be used as a leading phase with the phase rotation concept to hasten the transit vehicle's passage (TCRP, 2010).

e. Phase Insertion

Phase insertion is another method for giving transit vehicles green time. The logic is not flexible enough to handle a situation when the transit vehicle arrives in the middle of a red light, preventing the logic from applying other TSP tactics like Green Extension or Early Green. This tactic strategy is typically used when there are many turning movement phases. As an alternative, it brings about a brief green phase within a cycle. Since, the transit-phase obtains green time twice in a single cycle, it is sometimes referred to as Double Realization. For a left-turn phase at an intersection with a lot of bus requests, double realization is used. At a signalized intersection close to a significant bus terminal, the phase sequence employed was leading left – through movement – lagging left (for the second time), all of which were applied in one cycle. (P.Furth.et.al, 2010).

#### **2.3.1.2.2.2 Active TSP Priority Request Scenarios**

Currently, in the Active signal priority approaches the priority request is not only depends on the presence /approaches of the transit vehicle rather considering additional situations/factors as used to apply on applying priority logic.

a. Unconditional priority

Unconditional priority is issued each time a transit vehicle is detected, and can be very disruptive to opposing traffic. (TCRP, 2010).

b. Conditional priority

in this method applied When a transit vehicle meets a criterion based on AVL and/or APC data, such as if it is running late or has a specific amount of passengers on board, conditional priority only gives it priority. (TCRP, 2010)

### **2.3.1.2.2.3 Use of Active Priority at Grade Crossing**

#### a) Active Signal Priority for Light Rail Transit at Grade Crossings

(Case study San Diego Trolley system, in California)

Implement an active priority system of light rail transit (LRT) for highway–rail grade crossings. Railway detectors, train travel and dwell time predictors, priority request generators (PRG), and traffic signal controllers are the four main parts of the proposed priority system. The PRG uses a three-scheme conditional priority control technique in its capacity as the system's brain. The late LRT trains covered by Scheme I have a timing optimization model. This optimization model's is used to reduce intersection delays for late trains while at the same time minimizing effects on other traffic. The suggested model works with signal timings at many junctions and offers an optimum green band for an approaching train, in contrast to existing signal priority studies, which often concentrate on isolated intersections. In order to cover the anticipated train arrival period, the optimized green band would begin at the appropriate moment. An use of the suggested Scheme I technique results in significant intersection delay savings of 89.5 percent and 25.3 s/train for late trains, according to a case study based on the San Diego Trolley system in California. The impact on other traffic in the priority cycle is only 4.1 s/veh at the same time. When no priority is required, traffic delay savings for Schemes II and III are 32.5 percent and 52.0 percent, respectively. A simulation analysis verifies the system's advantages and the usefulness of the active priority system for upcoming field tests. (Mengli, 2008).

#### b) Average Duration and Performance of Actuated Signal Phases

This paper describes an approach for evaluating alternative detection designs for a signalized intersection. The models described in this paper can be used to determine the average phase duration and frequency of phase “max-out” as a function of the detector loop layout, detector unit timing, traffic demand, and approach speed. Layout and timing are described by the number of detectors on each approach served by the phase, detector location on each approach, detector length, and detector unit and controller time settings. The authors have used the concept of maximum allowable headway (MAH) to combine the many possible combinations of layout and timing variables into one representative quantity, which greatly simplifies the modeling process. The performance models were used to examine the sensitivity of intersection performance to a range of design values. In general, both phase duration and cycle length increase with higher demands or larger MAHs. Multi loop (i.e. two or more detection zones per lane) detector designs typically have larger MAHs than designs with one detector loop per lane. Phase duration and cycle length also increase for very low demand levels. In terms of performance, the

maximum green duration was found to have a contrary effect at higher flow conditions. Larger maximum greens were found to reduce delays to the phase in service by reducing the probability of max-out but they increased delays to drivers waiting for service.

c) Active Transit Signal Priority for Streetcars

Experience in Melbourne, Australia, and Toronto, Canada

Even though streetcar networks have a distinctive personality, operating in mixed traffic presents significant obstacles. Growing urban auto traffic has made these issues worse by increasing competition for scarce road space and time. In order to manage traffic systems better at a lower cost and increase the dependability, efficiency, and speed of on-street public transportation, active traffic signal priority (TSP) has been found. Although the use of TSP is expanding globally, only a small number of researches have looked at how it might be used to streetcar-based systems. In this paper, the TSP experience in Toronto, Canada, and Melbourne, Australia, was reviewed. These cities operate some of the largest and oldest streetcar-based TSP systems in the world. The TSP systems used in the two cities are discussed in this study, along with significant experiences. The effectiveness of the TSP is examined, and any flaws and problems found are evaluated. According to the review, there are many similarities between the TSP systems in the two cities, including their configuration for approach and request loop detection as well as stop line and cancel loop detection, the level of priority they offer, and how they target clearance phases for turning traffic at intersections. There are a few minor changes in how bunching trams and opposing tram motions are handled, and the Toronto scenario handles them better. Futures for TSP development are somewhat different in the two systems. Toronto is concentrated on system-wide TSP deployment and TSP algorithm progress, while Melbourne wants to make priority more dependent on the degree of lateness of trams and on the degree of traffic congestion experienced. (A. Shalaby, 2008).

### **2.3.1.2.3 Real-Time or Adaptive Strategies**

This strategy requires specialist equipment capable of optimizing signal timings in the field to respond to current traffic circumstances and transit vehicle location, and it accounts for both transit vehicle and general traffic arrivals at an intersection or sequence of crossroads (TCRP, 2010).

#### **2.3.1.2.3.1 Adaptive Signal Control Systems**

It is a strategy that considers the trade-offs between transit and other modes of transportation. By adapting the movement of the transit vehicle and the current traffic state, it is possible to make graceful adjustments to signal timing. In this system prioritizes traffic while also attempting to optimize specific traffic performance metrics. Adaptive Signal Control Systems assess traffic conditions in real time and alter control techniques accordingly. It is possible to consider human delay, transit delay, vehicle delay, and/or a combination of these factors when employing Adaptive Signal Control Systems. TSP would normally require early identification of a transit

vehicle to allow more time to alter the signals to provide priority while reducing traffic disruptions in order to take advantage of Adaptive Signal Control Systems (TCRP, 2010).

#### **2.3.1.2.3.2 TSP with Adaptive Signal Priority System**

*a. “Development and Evaluation of Adaptive Transit Signal Priority Control with Updated Transit Delay Model (Case study Edmonton, Alberta, Canada)”*

Modern techniques allow TSP plans to be dynamic (and optimal), as opposed to being predetermined, so that they can take into account current traffic circumstances. The term "adaptive TSP" refers to these dynamic designs. Current adaptive TSP techniques typically evaluate each proposed TSP plan using a performance index (PI), which is a weighted summation of all delays, with the weights reflecting the corresponding priority. The estimation of the delay, the setting of the weights, and the formulation of the optimization all affect how well an adaptive TSP performs. Three significant academic contributions are made in this context: (a) an improved bus delay estimation model based on advance detection; (b) a mechanism to dynamically adjust the PI weights to reflect the shifting necessity of TSP under various conditions; and (c) TSP optimization modeled as a quadratic programming problem with an improved solution. . Moreover, a full scale signal simulator called ASC/3 in VISSIM was used to create an adaptable TSP simulation platform. Depending on TSP occurrences, such as check-in, check-out, and numerous TSP requests, the best TSP plans were approved or refused. This work used a case study in VISSIM to demonstrate how the new adaptive TSP method, when compared to traditional active TSP strategies, might further decrease bus travel time while better balancing service on non-TSP approaches along a 7.4-km bus corridor in Edmonton, Alberta, Canada.

*b. Traffic Signal Optimization with Application of Transit Signal Priority to an Isolated Intersection.*

An effective control approach for enhancing transit performance in urban networks is transit signal priority (TSP). However, existing control systems have not yet provided satisfactory solutions to a number of TSP deployment-related issues, such as the impact of TSP on auto traffic and the provision of priority to transit vehicles travelling in opposing directions at traffic signals. The real-time, traffic-responsive signal control system presented in this research minimizes the detrimental effects on vehicle traffic while maintaining signal priority on conflicting transit routes. The suggested system assigns precedence to the transit vehicles based on their passenger occupancy while determining the signal settings that minimize the network's overall person delay. The system was put through a simulation test at a complicated signalised intersection in Athens, Greece, where there were a lot of buses travelling in different directions and there was a lot of traffic. Results revealed that the suggested strategy significantly reduced both the total number of people waiting at the intersection and the delay experienced by transit riders. (E.Christofa.et.al, 2011).

c. An Efficient Priority Control Model for Multi-Modal Traffic Signal

A model for multi-modal traffic signal priority control is presented in the study. The strategy is founded on a flexible implementation method and an analytical model that takes real-time vehicle actuation into account. The analytical model takes into account various modes' requirements in a connected car environment that operates in real-time. The approach offers a signal plan that minimizes the overall delay caused by weighted priority requests. The flexible implementation algorithm is created to ensure that the best signal schedule is used with the least amount of interference to regular vehicles. San Mateo, California, and Anthem, Arizona, are the two networks where the model has been evaluated in a simulation framework. The simulation trials demonstrate that the model is capable of reducing the average priority vehicle delay and travel times when compared to fully actuated control.

The outcomes of putting the priority framework into practice at the National Affiliated Connected Vehicles Test Bed in Anthem, Arizona, demonstrate the model's viability in the actual world. (Zamanipour, 2016).

#### **2.4 Gaps in the Previous Research**

Even if various studies have been done to predict the effects of the new provide median LRT, there is a limited research for improving the LOS and Capacity of the shared spaced at grade crossing. Previous studies done on the same LRT corridor and location have studied the effects of the LRT line on the existing traffic condition and these study have indicated that the introduction of the LRT line brings about additional delay and drops in level of service. (Demelash, 2019). On the other study done on the other LRT corridor proposed signalized roundabout as an alternative junction design by considering the light rail will arrive at green phase of parallel movement of vehicles at LRT grade crossing to improve the LOS and capacity of the junctions (Rediet., 2018). This study focuses on attempting to further improve and reduce these effects by considering a new tactic of actuated traffic signal control operation with TSP strategies at light train, pedestrian and vehicles shared spaced intersection with considering of actual arrival time of light train in any signal phase to represent the real operation condition.

## CHAPTER THREE: RESEARCH METHODOLOGY

### 3.1 Study Area

The proposed study area is Adey Ababa signalized intersection which is located in the Addis Ababa North – South LRT corridor. This intersection is at grade with LRT lines passing through the exclusive center line.

The characteristic of this intersection is the following.

- ❖ Surrounded by commercial and residential areas.
- ❖ At grade LRT crossing through Median
- ❖ It has two main and two sub main leg
- ❖ LRT station located near at median of main approach to the intersection
- ❖ High Passenger volumes entering and departing at the station.

In this study the selected at grade intersection is going to be studied as isolated intersection due to there is no near intersection or roundabout located around the study intersection that will affect the study intersection in traffic changes.



Figure 1 Addis Ababa Railway Station Network Diagram

### 3.2 Study Design

This research demonstrated the effectiveness of Transit Signal Priority (TSP) in improving the LRT corridor travel time in a simulated environment using real world data. Accordingly, comparisons of alternative transit signal priority approaches were analyzed. The alternative approaches were modeled using VISSIM simulation software and compared based on queue length, level of service, travel time and personal delay and total delay. The study framework will be as follows.

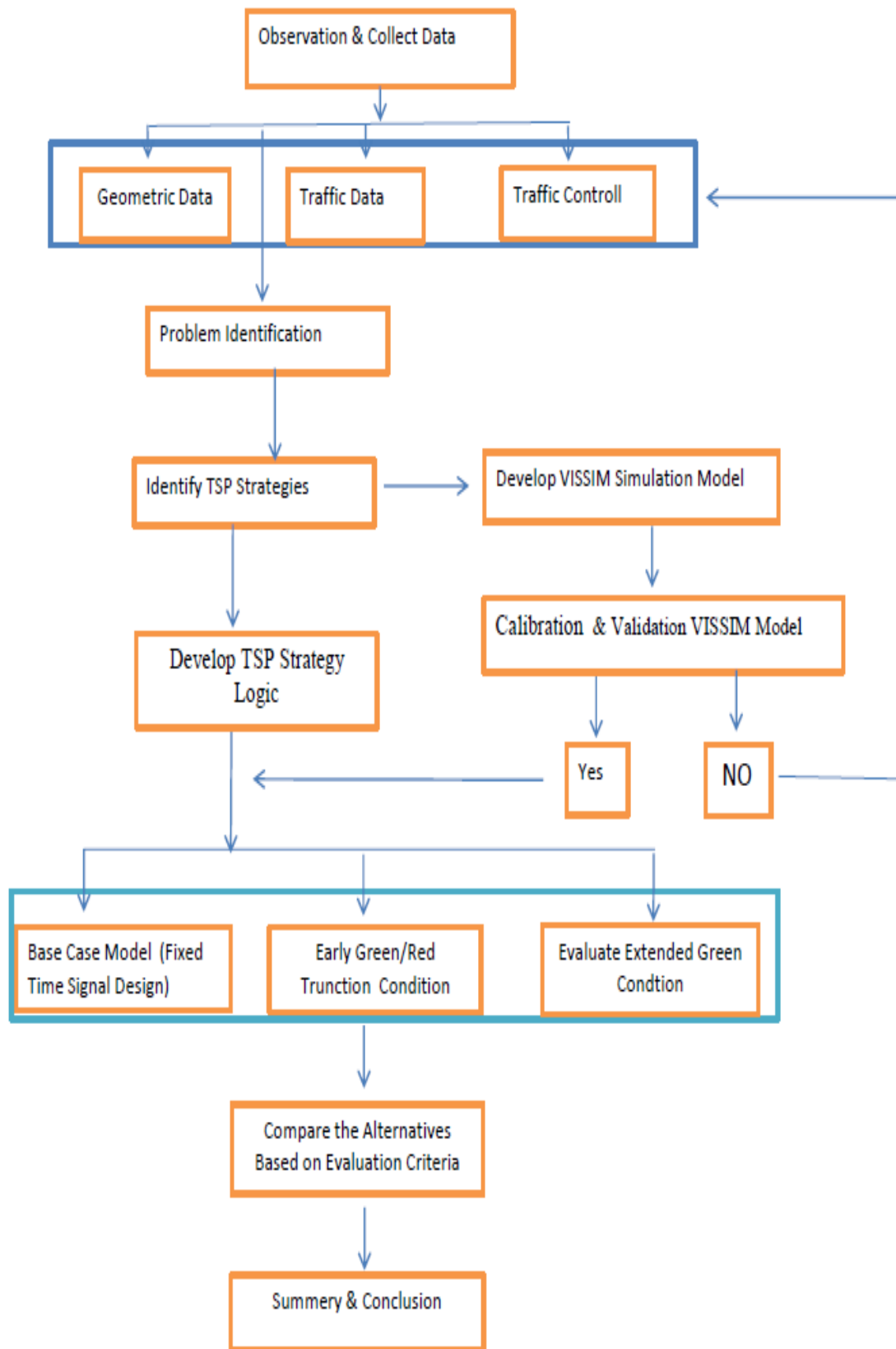


Figure 2. Study Design

### 3.3 Data Collection

#### 3.3.1 Geometric Data

Any traffic signal priority system's ability to operate is strongly influenced by the road geometry, making it one of the most important operational considerations. The surrounding land development has an impact on the geometry of the roads since it determines the quantity and placement of intersections as well as the locations of transit stops. Roadway geometry presents difficulties for the detecting technologies, such as the plane of vision (horizontal and vertical line of sight). (Falls Church, January 2003).

This paper concerns on improvement of at grade rail crossing intersection by comparing alternative traffic signal strategies in terms of LRT reliability and delay, average vehicle delay, queue length and LOS. AACRA and Google Earth maps are the methods used to collect Secondary data in the form of design documents.

Table 1. Geometric data for Adey Abeba Intersection

Description	Measurement
Number of legs	
Number of lanes along Major road (North-South)	3
Number of lanes along Minor road (East-West)	2
Angle of intersection (degrees)	90
Width of Entry and exit lanes	
North Approach	3.5m
South Approach	3.5m
East Approach	3.5m
West Approach	3.5m
Median Type	
North Approach	Separated
South Approach	Separated
East Approach	Un separated
West Approach	Un separated

Median width	11m
Grade	
North Approach	4.314%
South Approach	5.26%
East Approach	2.94%
West Approach	2.34%

### 3.3.2 Traffic Data

Because they fluctuate over time for each intersection or length of road, traffic volumes are an important consideration. The network frequently experiences limited conditions during peak hours, with increased levels of transit and general-purpose traffic as well. Since there is a higher demand for transportation during peak hours, it is essential for the transit operators to maximize the benefits from the traffic signal priority systems during this period. The effects of traffic signal priority systems are primarily influenced by the volume of traffic moving in the transit route's direction as well as the volume of traffic obstructing it. (Falls Church, January 2003).

#### 3.3.2.1 Traffic Condition

Adey Abeba at grade rail crossing intersection is surrounded by residential and commercial areas, which is very congested at morning and evening pick time. There are four legs (Two major and Two minor roads) directly joining this intersection from Saris, Kadisco, Addis Sefer and Biheretsige Sides. The peak morning and evening traffic is mainly comes from Saris and Kadisco major roads. At this intersection there is a signal control system installed to facilitate the intersection movement. However, currently the installed signal control device is idle. There is exclusive median LRT line crossing the intersection in both directions and a station at 42m away from the intersection on south bound/ Saris major road side. At the station, there are a lot of pedestrians; however there is no pedestrian signal to help with traffic. The station's pedestrian traffic is halted during morning rush hour, so traffic police stop in to help. Unauthorized pedestrian crossing (has no pedestrian fence) and U turns are also observed in which separately allowed U turn at the north bound side and uncontrolled turning in south bound (right side) of LRT grade crossing.



Figur 3. Traffic Condition of Adey Ababa Intersection

Due to there is no any traffic controlling system in the intersection the traveling speed of vehicle is generally low specially in the morning and night peak hours. According to Google Traffic Map as shown below in specific traffic condition on Thursday at 7:45 am. The lowest traffic speed is the approach from Saris approach and a better traffic flow on the remaining three approaches. As shown in the map the red black color indicate the most slow speed or near to stopped traffic condition and the other hand the red line indicate the traffic flow with less than 39 km/hr which is there is a congestion on the route.

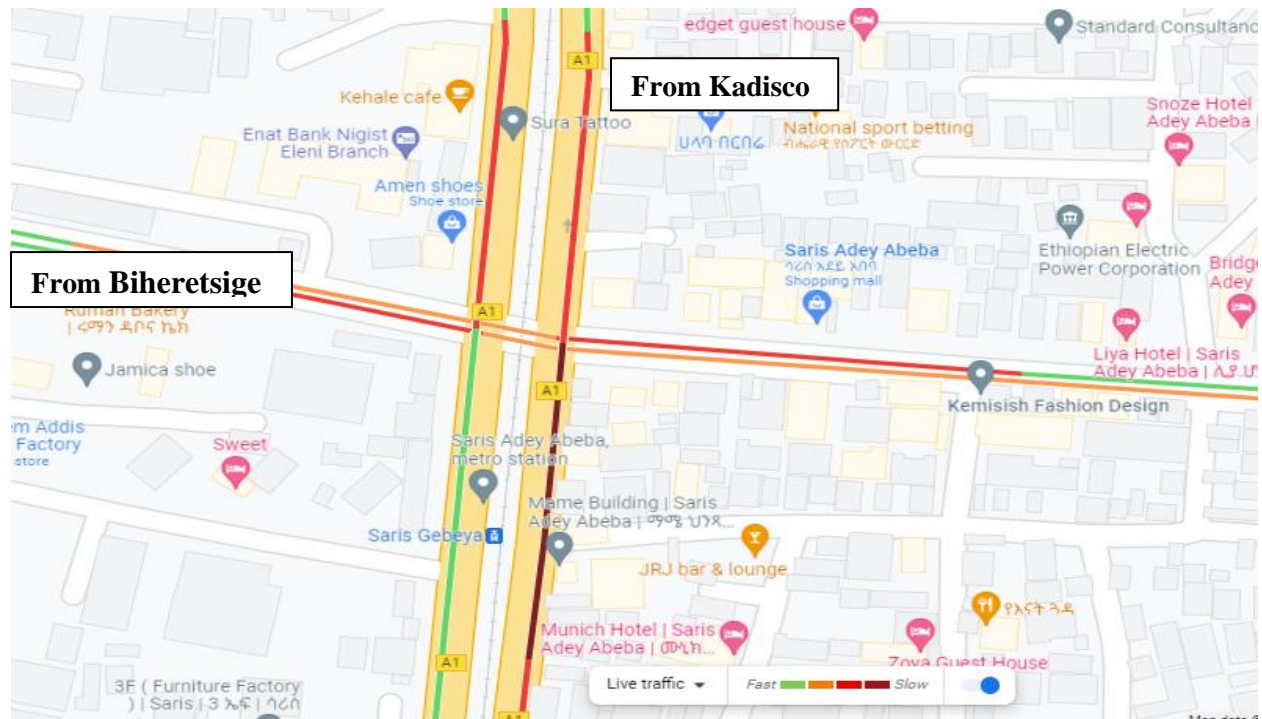


Figure 4. Typical Morning Pick Hour Traffic Flow, Adey Ababa Intersection (Map (Map G. T.))

### 3.3.3 Traffic Count

Inputs such as peak hour traffic and turning movement ratios are required in order to compare various types of junction designs in terms of queue length and delay. The maximum number of cars that can pass through a particular location on a roadway in a continuous 60-minute period is known as the peak hour volume (PHV). The geometrical elements of a roadway, such as the number of lanes, intersection signalization, channelization, and capacity analysis, are designed using PHVs. (Nicholas, 2009). This thesis uses video recording and hand counting to obtain data on peak hour traffic volume for traffic analysis. On a normal weekday (Tuesday), in good weather, the study area was videotaped for a total of 6 hours during morning peak hour, lunchtime off-peak hour, and evening peak hours in order to obtain peak hour volume. A traffic count for two hours is sufficient, according to MUTCD Intersection turning movement counts, to study turning movement traffic. (Mengli, 2008) (University, 2002).

In order to determine the number of days that the traffic counts should be done (minimal sample size) using the following equation

$$N = \left(\frac{Z\sigma}{d}\right)^2 \dots\dots\dots E.q (1)$$

Where

N = Minimum Sample Size

Z= number of standard deviations corresponding to the required confidence level, 1.96 for 95 percent confidence level

$\sigma$ = standard deviation

d= limit of acceptable error (% of the mean sample value)

In order to determine the standard deviation, it is necessary to review previous studies to estimate the traffic variation of the study area. Accordingly, a study done on the same study area by Berhanu G/Yohannes, estimates the AADT for seven days traversing through the intersection (Berhanu.G, 2016). From the estimated AADT Value the directional design hour volume (DDHV) can be determined using the following equation.

$$DDHV = AADT * K * D \dots\dots\dots E.q (2)$$

Where

K= proportion of daily traffic occurring during the peak hour, generally equals 0.12 for suburban and urban areas.

D= proportion of peak hour traffic traveling in the peak direction of flow.

Accordingly, the estimated DDHV for the study area is as follows in the table below, for K value of 0.12 and for D value of 1, since the AADT count was done for each direction of Adey Abebe intersection.

Table 2. Directional design hour volumes (veh/hr) for Adey Abeba Intersection

Location	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Adey Ababa Intersection	1504.08	1411.08	1015.44	1960.8	1384.32	1237.44	1148.64

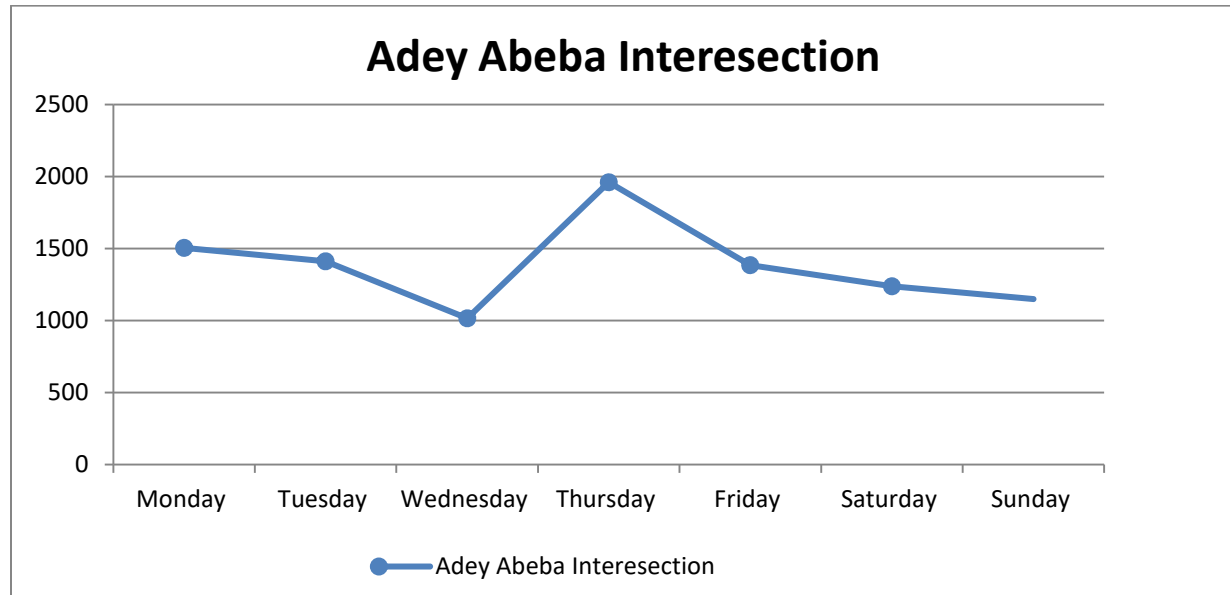


Figure 5. Daily DDHV (veh/hr) for Adey Abeba Intersection

Based on the above pick hour traffic variation of the study area, the standard deviation can be determined. And by assuming a normal distribution for 95% confidence interval and an error of 10% ( $0.1 \times 1433.16 = 143.3$ ) the minimum number of days that traffic must be counted is calculated as shown below.

Table 3. Minimum number of days to do traffic count

Study Area	Monday	Tuesday	Friday	$\sigma$	10 % Mean value	Z	N
Adey Abeba	1504.08	1411.08	1384.32	62.8	143.3	1.96	0.74

Thus, in order to determine the peak hour traffic data 1 day traffic count is enough at the study area.

Accordingly, the following traffic data were collected in February 8, 2023 in good weather condition. As per the collected traffic data the largest traffic flow occurs during morning peak hour, from 7:00AM to 9:00AM for the study area, specifically from 7:30AM – 8:30AM.,

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

7:45AM – 8:45AM, 7:00AM – 8:00AM and 7:15AM – 8:15AM for Kadisco, Saris, Bihere Tsige and Addis Sefer respectively.

Table 4. Collected Current traffic data at Adey Abeba Intersection

Count Period	Approaches	Traffic Movement				Total Traffic Volu. (ve/hr)	Veh/hr/lane	HGV %
		Through	Left Turn	Right Turn	U turn			
Morning Pick Hr 7:00 AM – 9:00AM	Saris	525	248	38	169	980	327	3
	Kadisco	696	285	89	248	1318	440	4
	Addis Sefer	126	270	173	0	569	285	2
	Bihere Tsige	118	450	24	0	592	296	2.5
Mid - Day (off Pick Period) 2:00 PM -4:00 PM	Saris	107	406	84	120	717	239	8
	Kadisco	617	183	83	240	1123	374	7
	Addis Sefer	135	127	101	0	363	182	3
	Bihere Tsige	245	148	27	0	420	210	2
Evening Pick Hr 5:00 PM – 7:00PM	Saris	121	589	98	203	1011	337	3
	Kadisco	328	846	98	313	1585	528	2
	Addis Sefer	58	90	25	0	183	92	1
	Bihere Tsige	70	132	49	0	251	126	1

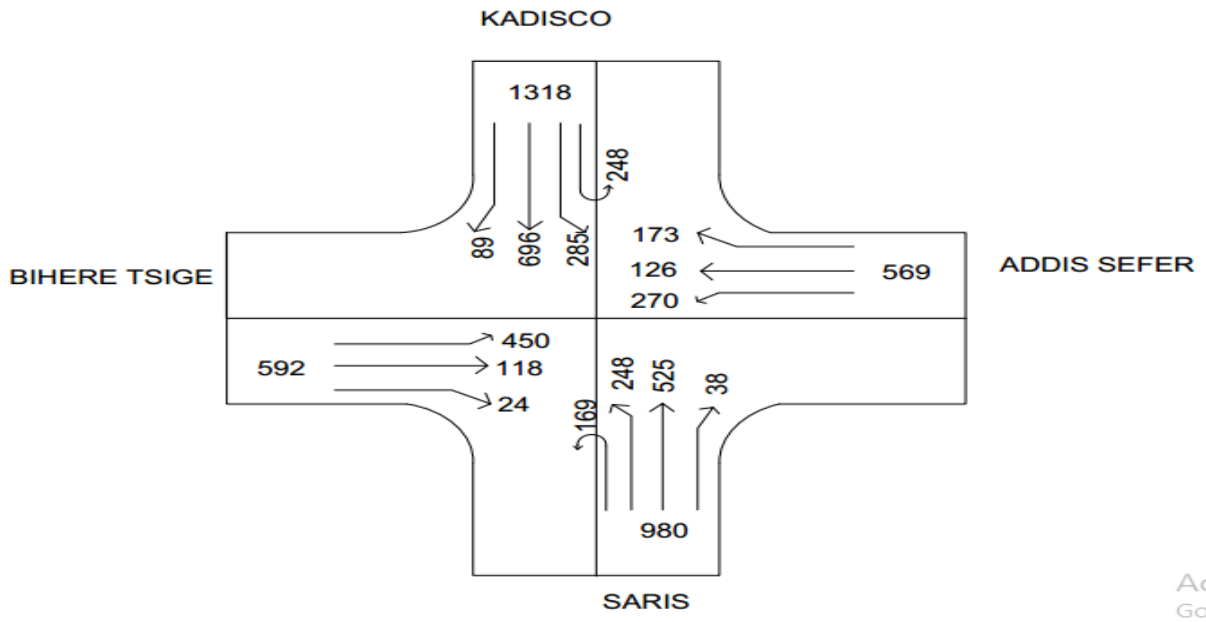


Figure 6. Vehicle Movement Distribution of the study area in morning peak hour  
Forecasting of Current Traffic as the Study Area

After current traffic data were collected as stated in the above table then current traffic will be forecasted for the next 5, 10 and 15 years. In order to determine the future traffic at the study area, traffic growth rate (i) should be calculated based on the pervious traffic history. However, there is no collected traffic history data at the study area. Accordingly, general traffic growth rate for the Addis Ababa city is used which is get from Addis Ababa City Traffic Planning and Management Office. The traffic growth rate used to forecast traffic volume is 6.6% and 6.8% for passenger car and heavy vehicles respectively. As per ERA Flexible Pavement Design Manual 2013, recommended to use this formula to forecast traffic volume as mention below.

$$ADT(m)_1 = ADT(m)_0 (1+i)^n \dots\dots\dots Eq. (3)$$

Where

ADT(m)<sub>1</sub> :- Forecasted Average Daily traffic volume for n years

ADT(m)<sub>0</sub> :-Current (base year) Average Daily traffic volume

n:- required forecasted number of year

i :- traffic growth rate

### 3.3.4 Speed Study

Due to the study area is at LRT grade crossing with rubber pavement surface, Speed study of the vehicles which cross this intersection is required in order represent speed variation. Vehicle approach speed at free flow speed condition and vehicle crossing reduce speeds are two required traffic speed data. Accordingly, in order to determine the required two traffic speed data, traffic

speed collected during off pick hours. The method used to collect the speed data is by using a stop watch as vehicles traverse a road segment of known length. The fundamental presumption used to calculate the minimal sample size for speed studies is that the speed distribution over a certain stretch of highway follows a normal distribution. (Nicholas, 2009). A pick hour and off pick hour data was analyzed to establish the representative value for pick hour approach and pick hour crossing speed and off pick hour approach speed and crossing speed respectively. Appendix A contains the raw data used for analysis.

Speed (Km/hr)	Frequency	Cumulative Frequ.	%cumulative Freq.
2	16	16	0.03
3	121	137	0.27
4	80	217	0.43
5	128	345	0.69
6	52	397	0.79
7	32	429	0.86
8	34	463	0.93
9	37	500	1.00

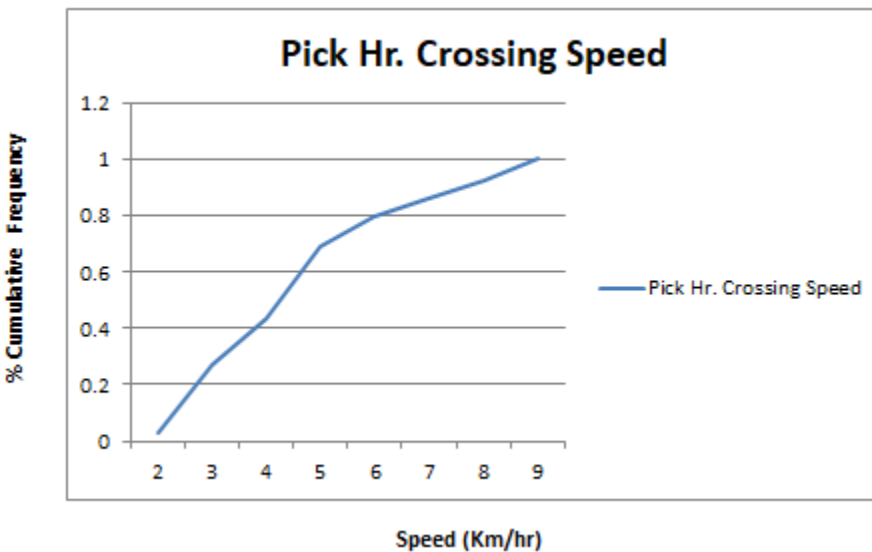


Figure 7. Observed crossing speed and Frequency at Adey Abeba Intersection in Pick Hour

Statically Parameters	Estimated Value	Statically Parameters	Estimated Value
Minimum Sample Size (N)	500	Maximum Speed (Km/hr)	9
85% Speed (Km/hr)	6	Minimum Speed (Km/hr)	2

Speed (Km/hr)	Frequency	Cumulative Frequ.	%cumulative Freq.
16-18	32	32	0.11
18-20	42	74	0.26
20-22	19	93	0.33
22-24	36	129	0.46
24-26	31	160	0.57
26-28	49	209	0.74
28-30	18	227	0.81
30-32	16	243	0.86
32-34	7	250	0.89
34-36	14	264	0.94
36-38	11	275	0.98
38-40	3	278	0.99
40-42	3	281	1.00

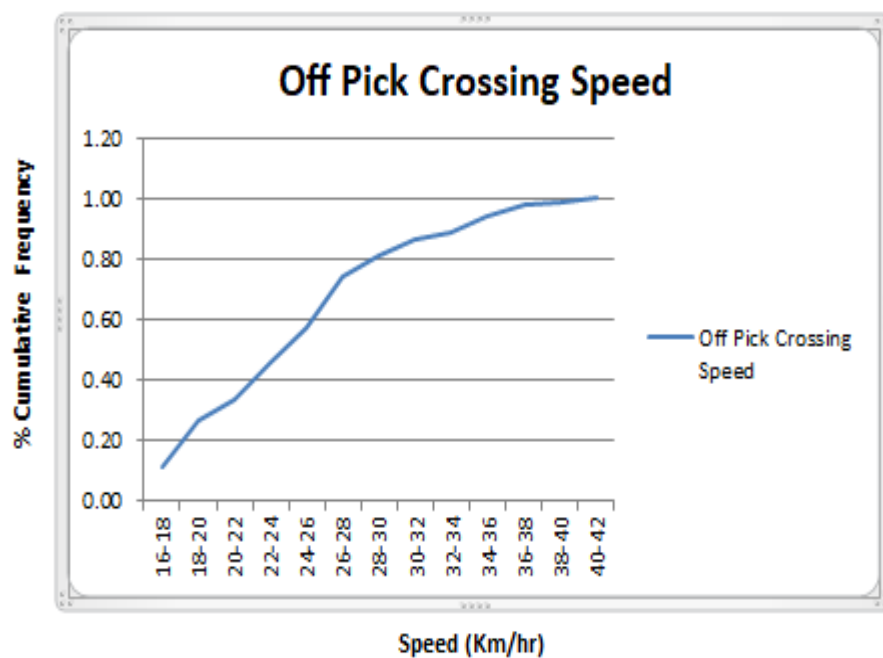


Figure 8. Observed crossing speed and Frequency at Adey Abeba Intersection in off Pick Hour

Statically Parameters	Estimated Value	Statically Parameters	Estimated Value
Minimum Sample Size (N)	281	Maximum Speed (Km/hr)	41
85% Speed (Km/hr)	31	Minimum Speed (Km/hr)	17

Speed (Km/hr)	Frequency	Cumulative Frequ.	%cumulative Freq.
32-34	3	3	0.01
34-36	21	24	0.09
36-38	25	49	0.18
38-40	36	85	0.30
40-42	29	114	0.41
42-44	35	149	0.53
44-46	20	169	0.61
46-48	8	177	0.63
48-50	34	211	0.76
50-52	28	239	0.86
52-54	12	251	0.90
54-56	14	265	0.95
56-58	8	273	0.98
58-60	6	279	1

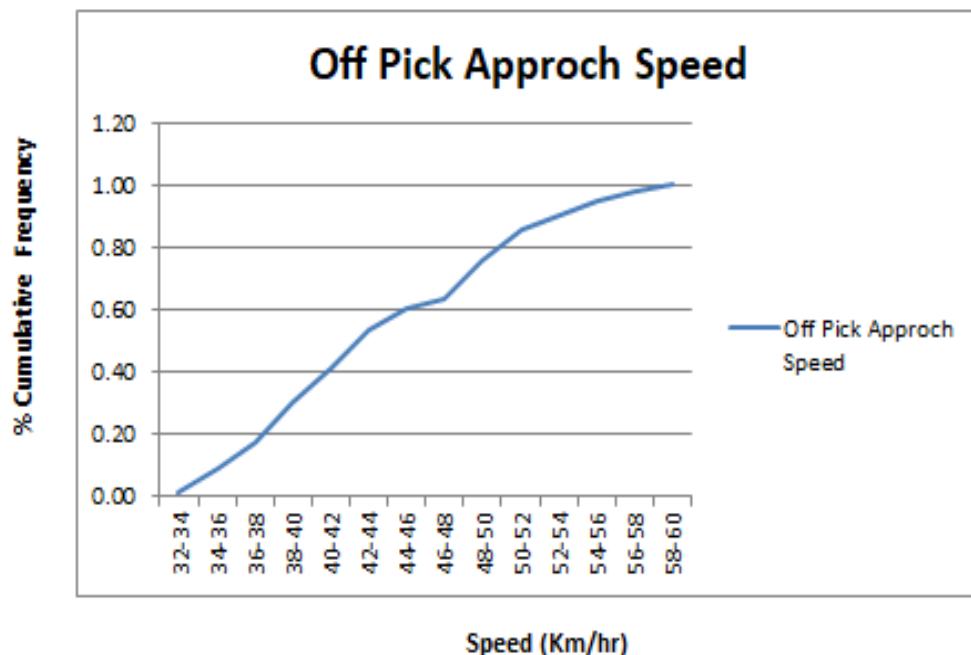


Figure 9. Observed Main Approach speed and Frequency at Adey Abeba Intersection in off Pick Hour

Statically Parameters	Estimated Value	Statically Parameters	Estimated Value
Minimum Sample Size (N)	279	Maximum Speed (Km/hr)	60
85% Speed (Km/hr)	48	Minimum Speed (Km/hr)	33

Speed (Km/hr)	Frequency	Cumulative Freq.	%cumulative Freq.
2	38	38	0.08
3	141	179	0.36
4	138	317	0.63
5	102	419	0.84
6	53	472	0.94
7	22	494	0.99
8	6	500	1.00

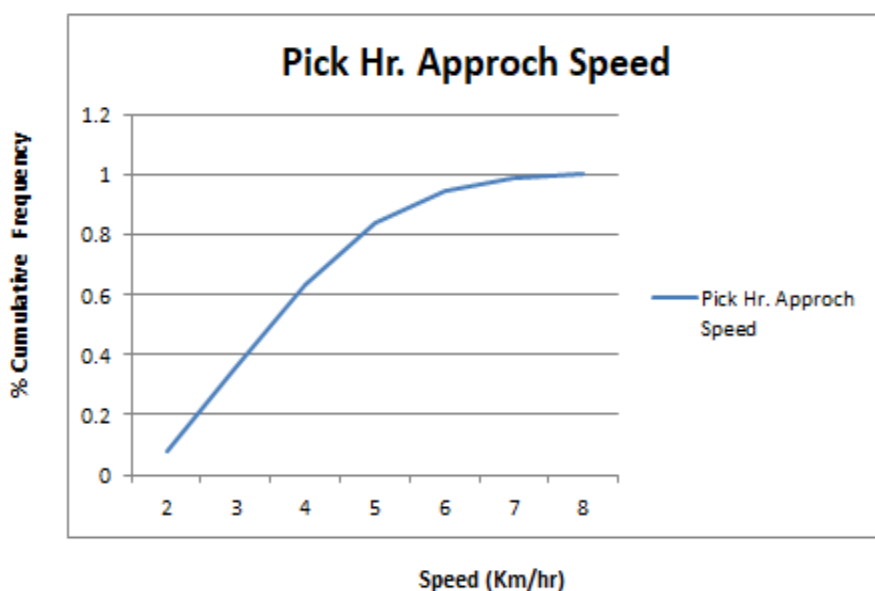


Figure 10. Observed Main Approach speed and Frequency at Adey Abeba Intersection in Pick Hour

Statically Parameters	Estimated Value	Statically Parameters	Estimated Value
Minimum Sample Size (N)	500	Maximum Speed (Km/hr)	8
85% Speed (Km/hr)	5	Minimum Speed (Km/hr)	2

### 3.3.5 Travel Time

Studies on travel times entail timing how long it takes cars to travel a certain stretch of road. Data on trip time is frequently presented as delay (i.e., time spent traveling over the amount of time allowed for uninterrupted, free flow) or as the average speed of links or zones. Delay is defined as additional time spent in the segment over that which would be spent in a free-flowing

scenario for travel. The 50<sup>th</sup> percentile speed of low volume traffic (about 1300 pc ph PI), or the posted limit or some logically lower value, may be used to establish the base free flow speed empirically. (Transportation, 2007).

The average speed technique is the approach taken to conduct the travel time study. Using this method, the test vehicle is driven at what the driver believes to be the average speed of the traffic stream the entire length of the test segment (Nicholas, 2009).

Travel time was determined for pick hour volume of Kadisco approach which has the highest traffic volume. In order to determine the travel time, the initial and destination time is recorded for the test vehicle traverses the proposed test section. The proposed test section is selected by considering the end queues length; the proposed test section for the study area is 834m long for north and south approaches.

Based on proposed test section of 834m (34m crossing and 800m approach length in both sides including maximum queue end) the travel time is determined for 85% which is 13.4 min.

Table 5. Travel time for Adey Abeba Intersection

Travel Time	Frequency	Cumulative Frequency	% Cumulative Frequency
6-6.5	3	3	0.006
6.5-7	4	7	0.015
7-7.5	12	19	0.040
7.5-8	33	52	0.111
8.5-9	20	72	0.153
9-9.5	59	131	0.279
9.5-10	27	158	0.336
10-10.5	42	200	0.426
10.5-11	29	229	0.487
11-11.5	35	264	0.562
11.5-12	60	324	0.689
12-12.5	43	367	0.781
12.5-13	28	395	0.840
13-13.5	16	411	0.874
13.5-14	9	420	0.880
14-14.5	12	432	0.889
15.5-15	15	447	0.895
15-15.5	11	458	0.910
15.5-16	21	479	0.921
16-16.5	7	486	0.950
16.5-17	11	497	0.980
17-17.5	3	500	1.064

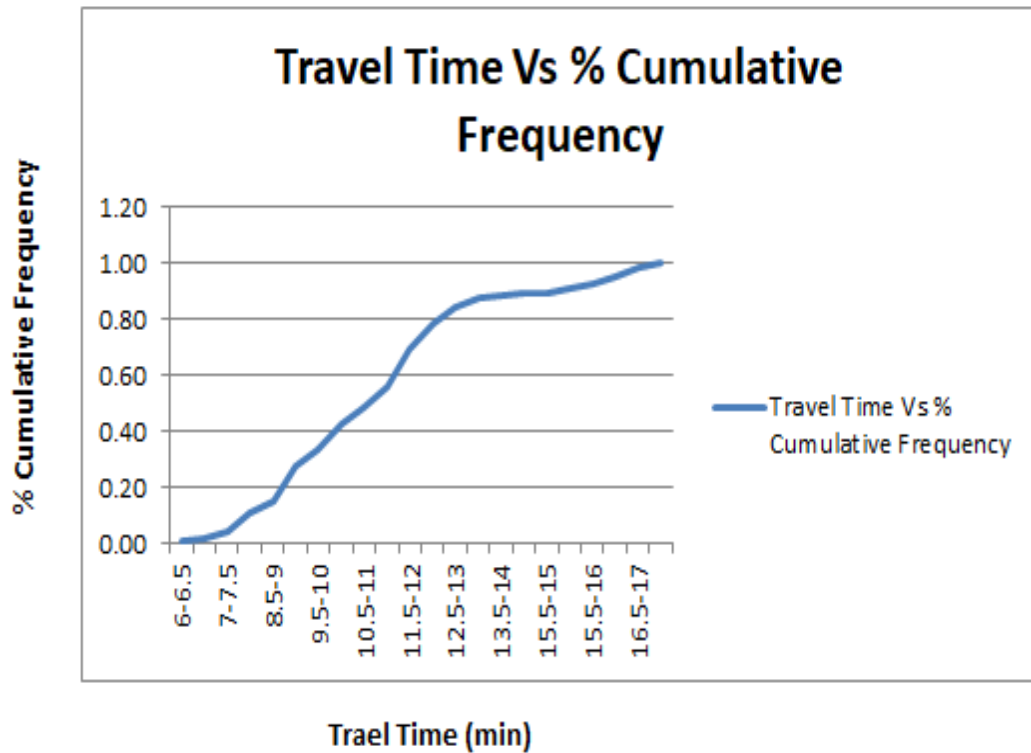


Table 6.Total delay at Adey Abeba Intersection

Location	Segment	Distance (L), (Km)	Ideal Free Flow Speed V (km/hr)	Calculated travel time (min), L/V	Total time T <sub>1</sub>	Median travel time (min) (T <sub>2</sub> )	Delay (min), T <sub>2</sub> - T <sub>1</sub>
Adey Abeba Intersection	Approach section	0.8	50	0.96	1.03	13.4	12.37
	Crossing section	0.034	30	0.07			

### 3.3.6 Pedestrians

In urban intersection, pedestrian crosswalks at legs restrict entry and departure capacity proportionately to the value of the pedestrian flow; hence pedestrian volume counts are required. The minimum signal timings at signalized junctions can be determined using these counts as well as crash analysis, capacity analysis, and other purposes (Nicholas, 2009).

*Manual on Uniform Traffic Studies* stated that in 15-minute intervals, pedestrian volume counts can be performed for the same amount of time as peak hour counts. (MUTCD, 2014)

Accordingly, pedestrian count data were done in the morning peak period for 1 hours. During site observation the main concentration of pedestrian is on the south and North bounds of the intersection due to there is no any available crossing section from North to South and vice verse however, there is LRT station at 48m away from the study area which used as a crossing and has less effect on the out flow and inflow. In addition to this, there is also uncontrolled cross walking in the intersection which has moderate effect on traffic flow of the intersection and included in the simulation model.

Table 7. Pedestrian count data

Approach	Pedestrian count data for both direction (ped/hr)	Number of interval per hr (3600/160)	Number of pedestrian arrival
Kadisco	410	23	15
Saris	390	23	14
Addis Sefer	180	23	7
Bihere Tsige	200	23	8

### 3.3.7 LRT Data

LRT data is the main input data in which this study is focused on improvement of the existing intersection due to inclusion of LRT system on the existing road geometry. In order to represent the existing condition and developing representative model the main LRT data are collected as shown below.

#### 3.3.7.1 Geometric Data

Due to difficulty of direct measuring the geometric data were collected from Google Earth maps as shown below.

Table 8. Geometric Data of LRT

Location or LRT line	Median of Major road in N-S direction
Number of LRT Lines in each direction	1
Width of LRT corridor	11m
Length of LRT Crossing	34m
Distance of LRT station away from LRT crossing in South Bound only	48m

#### 3.3.7.2 LRT Crossing Frequency

LRT crossing frequency (arrival interval) data is collected during pick period for each direction in normal condition as shown below:

Table 9.LRT Arrival Frequency

Direction	Arrival interval Frequency (min)	Speed (km/hr)	Length of LRT
North – South	5.13	24.1	30
	5.3	23.0	30
	3.24	27.0	30
	9.03	28.5	30
	20.8	31.4	30
	7.81	22.4	30
	4.86	27.0	30
	3.98	29.1	30
Average	7.517		
South –North	5.21	23.0	30
	6.9	27.0	30
	7.37	24.1	30
	8.5	22.6	30
	11.27	25.2	30
	12.69	26.2	30
	9.44	24.3	30
Average	8.74		

As shown in the above table the LRT has different arrival frequency in both north and south direction. However, the proposed improvement solution is active transit signal priority which control the traffic signal based on the current arrival time of LRT during the parallel and opposite vehicle movement instead of fixed arrival frequency of LRT.

### 3.3.7.3 Time difference arrival of LRT vehicles in opposite direction

As observed in pick period LRT vehicles in opposite direction arrive in a minimum of 1.38 min and a maximum of 10.89min.

Table time difference arrival of LRT vehicle in opposite direction

Table 10. Time difference arrival of LRT vehicle in opposite direction

Direction Of LRT Arrival	Recorder arrival time (min)	Arrival time gap of LRT Vehicle (min)
N	3.45	3.7
S	7.15	10.89
N	18.04	3.04
S	21.08	5.99
N	27.07	1.38
S	28.45	1.67
N	30.12	2.15
S	32.27	

### 3.3.7.4 Travel Time of LRT

In order to determine the tram speed a stopwatch was used. The tram speed was calculated by dividing the travel time of the tram to the distance it travels. As shown below the average tram speed is 25.1Km/hr but easy of analysis 25Km/hr was used in this thesis.

Table 11. Travel time of LRT

No.	Distance (M)	time (S)	Speed (Km/hr)
1	804	130	22.3
2	510	72	25.5
3	975	140	25.1
4	840	150	20.2
5	1970	250	28.4
6	560	78	25.8
7	600	72	30.0
8	485	60	29.1
9	895	180	17.9
10	440	66	24.0

11	560	72	28.0
Average Tram Speed (Km/hr)			25.1

### Delay in the Tram

During the analysis of the intersection due to there is a enough heady way between a trams the travel time of tram to cross the intersection was determined directly by dividing the intersection length 834m by average tram speed of 25km/hr. as per the VISSIM analysis Tram requires a travel time of 151.33Se and 143.14Se from north and south approach.

Count	SimRun	TimeInt	VehicleTravelTimeMeasurement	Vehs(All)	TravTm(All)	DistTrav(All)
40	1	0-3600	40: LANE	531	1.47	20.00
41	1	0-3600	41: LANE	531	1.47	20.00
42	1	0-3600	42: LANE	531	0.98	13.26
43	1	0-3600	43: tram north	7	151.33	834.00
44	1	0-3600	44: south tram	6	143.14	834.00

Figure 10. Travel time result for tram crossing Adey Ababa intersection shown a s below Table 12. Delay analysis for LRT

Location	Segment	Distance (L), (Km)	Ideal Free Flow Speed V (km/hr)	Calculated travel time (min), L/V	Total time T <sub>1</sub> (s)	Recorded travel time	Delay (sec), T <sub>2</sub> - T <sub>1</sub>
Adey Abeba Intersection	Approach section	0.8	25	1.92	120	151.3	31.3
	Crossing section	0.034	25	0.00136		143.14	23.14

### 3.4 Problem Identification

During data collection and observation at the study area there are three major problems identify as discussed below:

- a. Absence of Signal Control

It is observed that at the study area there is installed traffic light control system. However, the installed traffic light system is not operates at the study intersection and leads to high amount of

delay, congestion and formation of long queue of vehicle at the approach roads. In order to solve this gap a traffic police is assigned to facilitate the traffic operation of the intersection.

b. Uncontrolled/illegal pedestrian movement

Due to the provided LRT fragmented the area high amount of pedestrian is concentrated in the LRT stations and intersections. At the study area pedestrians illegally cross the intersection without keeping their crossing area and case for disruption on traffic flow

c. Demand of U- turns

As mention in the above the LRT fragments the area and most vehicles which have parallel movement with Light Rail way no chance to divert their travel direction in any section. Accordingly, in order to divert their travel direction vehicles forced to use intersections and roundabout as a diversion section. Hence, there is significant amount of U turns in the intersection will affect the efficiency of the intersection by blocking of through movement coming from opposite direction and left turn from the approach.

Table 13. Summarized Problem observed at study area

Problem Observed	Main Cause	Proposed Solution
❖ Congestion due to interlocking of vehicles from major and minor road	❖ Absence of Traffic Signal Control	❖ Provision of Adaptive signal control with TSP Logic
❖ Demand of U turns and affect the traffic flow at the intersection	❖ Absence of U turns in other area due to Fragment of area by LRT	❖ Re diverting U turns on other grade level location
❖ Traffic flow destruction by pedestrian	❖ Uncontrolled/illegal pedestrian movement	❖ Provision of pedestrian signal and fence

### 3.5 VISSIM Traffic Modeling

The investigation used the VISSIM microscopic simulation model. VISSIM was chosen because it can offer in-depth details on the detected effectiveness of measurement, it places a major emphasis on simulating transit, and it enables users to assess traffic signals using fixed time controllers or specifically defined controller logic. (Ova, 2001)

It is created by German business company, a microscopic, time step, and behavior-based simulation model, to simulate urban traffic and public transportation operations. Due to its capability to clearly represent a number of transportation modes, including as light rail and other kinds of public transportation, as well as various geometric and traffic control configurations, it is especially well suited for this study location. It has the capacity to simulate scenarios where LRT cars and conventional street traffic interact at grade crossings. Simulated data frequently

contains stochastic components (this means that the same input parameters do not lead to the same results each time in the simulation run.) This characteristic makes the simulation a selected simulation model tool since simulations are run numerous times with the provided set of input data and the average results of those runs are used to evaluate the intersection. (tewodros, 2019)

### 3.5.1 Modeling the Network

The first steps in VISSIM software is modeling the study area based on the collected data on the study area. There are two main categories which will be model in the software LRT network and Vehicular network.

#### 3.5.1.1 Background Image

In order to represent the actual condition of the study area the back ground image of the study area from Google earth scaled image will be inserted in the VISSIM software. Accordingly, the back ground image used in VISSIM software for modeling the study area is shown below.



Figure 11. Background Image for Adey Abeba Intersection

#### 3.5.1.2 Links and Connectors

In order to represent the actual geometric background of the intersection in VISSIM links and connectors are used. To build the four approaches of the intersection links are used to represent on the other hands by using connectors each links of the approaches are interconnected based on their movement direction as through, right turn and left turn. While using links and connectors inputs such as width, length, number of lanes and gradients should be adjusted as per the existing ground geometry.



Figure 12. Build background image in VISSIM by Links and Connectors on the study Area

### 3.5.1.3 Conflict Areas

In non-signalized intersection vehicles will tackle for many conflict routes which controls by yielding one vehicle to another vehicles and this make the intersection very congested and less capacity. In order to represent this condition In VISSIM conflict area is used to assign the right of way for vehicles that enter in the intersection in to get priority from other vehicles. Hence, based on the road hierarchy vehicles enter the intersection from main highway has the priority over vehicles enters the intersection from minor road. The vehicle on the road with red color have to stop and wait until the vehicle on the green area pass of get acceptable gap to pass the intersection as shown below. On the other hand train has priority over other any vehicles enters the intersection from both minor and major roads.. This condition was also implemented in

vehicle pedestrian conflict area. In this study area there was 61 conflict points between vehicles, train and pedestrian.

The right of way at crossings should be modeled using conflict areas rather than priority rules, according to the VISSIM user manual. Conflict zones are automatically displayed, are simpler to alter, and during simulation result in "more intelligent" driving behavior.

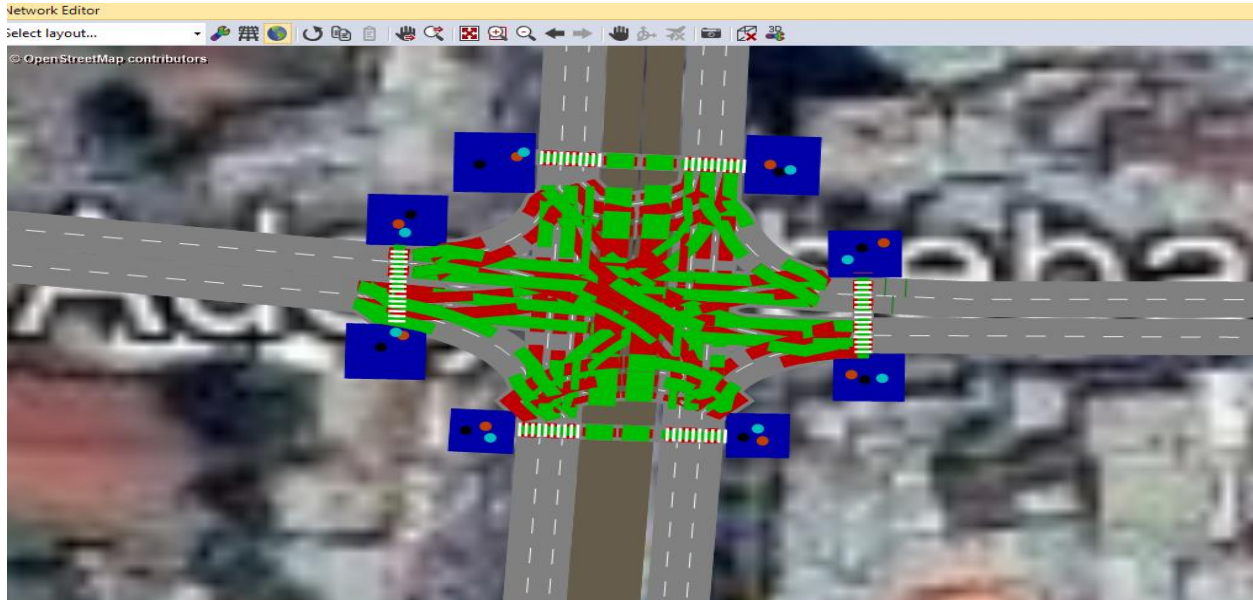


Figure 13. Conflict Area in the un-signalized study Area.

### 3.5.1.4 Reduced Speed Area

This is an area in which the vehicles will reduce their speed during turning crossing of the intersection. There are two types of speed which are approaching Speed and Crossing speed. Crossing speed distribution was used to model the reduced speed area of the study area. There was 14 speed reduced area in the study area.

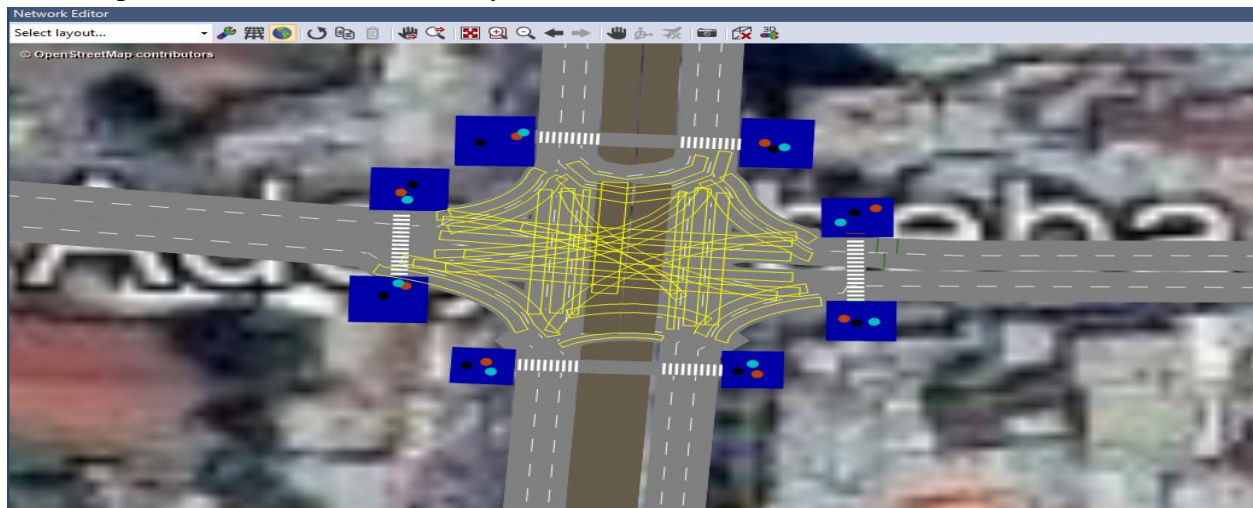


Figure 14. Reduced Speed Area in the Study Area

### 3.5.1.5 Vehicle Input and Vehicle Route

A traffic flow model is used to move vehicles through the network. For the simulation to be accurate, the traffic flow model must be of high quality. VISSIM utilizes the psycho-physical perception model created by Weidman (1974) as opposed to more straightforward models that provide a mainly constant speed and a deterministic car following logic. The fundamental idea behind this approach is that whenever a driver of a faster moving vehicle reaches his or her personal perception threshold of a slower moving vehicle, they begin to slow down. Until he starts to slowly accelerate again after crossing another perceptual threshold, his speed will drop below that of that vehicle because he cannot precisely gauge its speed. A slight and gradual acceleration and deceleration are seen. VISSIM uses distribution functions of the speed and distance behavior to account for the various driving styles. (VISSIM, 2017)

Based on traffic counts, the total number of cars that will arrive at each approach is input into the network. Both cars and heavy goods vehicles (HGV) have been used. Heavy trucks are represented by the second, whereas passenger automobiles are represented by the first. Vehicle routes are used to model the turning movement ratios.

### 3.5.1 6 Pedestrian Input

According on the count findings displayed in the data collecting section, pedestrians have been incorporated in the model. Crossings for pedestrians were constructed with their needs in mind. Determining a pedestrian's routes is another step in the modeling process. In this case, this step is straightforward because the only routes important to this study are those at pedestrian crossings. VISSIM recognizes three pedestrian types: men, women, and women with children. Additionally, default variables are offered to define walking patterns in line with the social force paradigm. (VISSIM, 2017). In order for pedestrians to follow a specific path when moving from one pedestrian area to another, pedestrian lanes and zones are drawn in the model. During VISSIM modeling of pedestrian due to walk way have 5m and zebra crossing have 3.5m width waiting area with size of 5m x 3.5m area was used as shown below in green color.

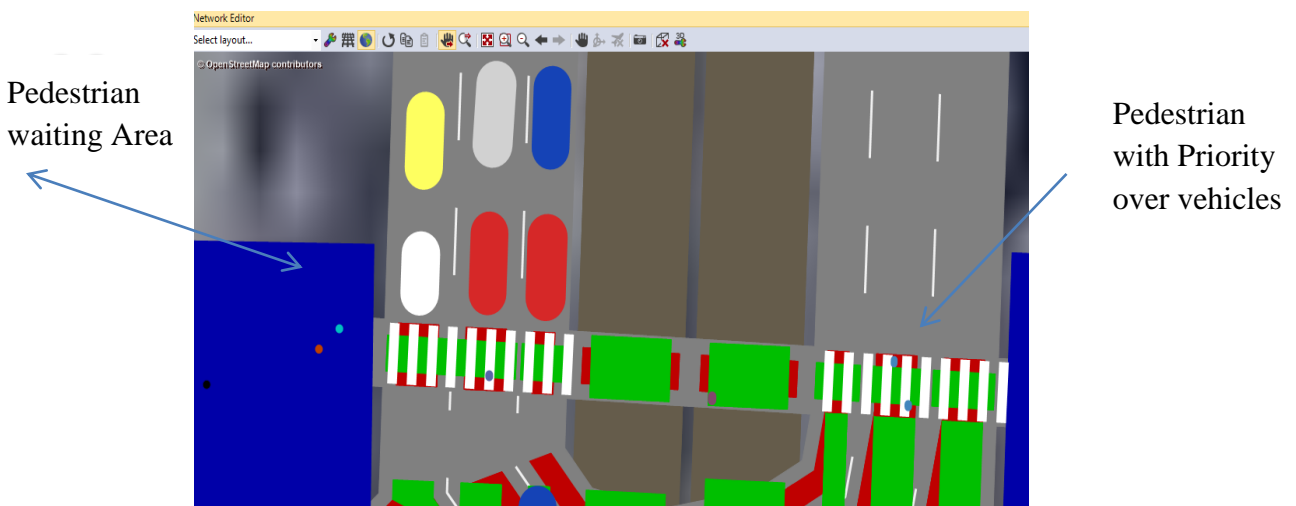


Figure 15. Pedestrian input in VISSIM Modeling

### 3.5.1.7 LRT Inputs

LRT line modeling was done, constructing dual LRT lines with 5.5m width for each LRT line and determining routes defining the kind, size, and speed of the LRT vehicle including the departure and frequency of crossing granting LRT vehicles priority at grade crossings.

According to the data gathered, the geometry of the LRT line was constructed with a grade crossing that was 34 meters wide and 5.5 meters rail way width in each direction. During LRT crossing the intersection average 25km/hr speed distribution is considered and LRT with 30m length is model in pick hour period for both north to south and south to north direction. LRT will get a full priority over the other vehicles at the intersection as per the green extension and red truncation of transit signal priority rule. As per the collected LRT arrival frequency period, different LRT arrival frequency was used for north and south approaches to represent the real site condition of the intersection. Accordingly, based on the real operation condition of the LRT arrival frequency period VISSIM simulation was done to analyze the effectiveness of the proposed TSP strategy with Green Extension and Red truncation/Early Green. Due to there is a LRT station 48m away from the intersection in the south bound the in check detector (Detector No.1) will be placed at 48m away from the station in both south and north bounds. On the other hand check out detector (Detector No. 2) will be provided at 64m (30m LRT length and 34m of crossing width) away from intersection in both directions. Hence, when the Light rail is detected by Detector No.1 during Green phase of the through movement Green Extension Strategy will be implemented based on the available green time until the detector No. 2 is detected. On the other hand if the light rail is detected by detector No. 1 during the opposing vehicles movement Red Truncation /Early Green will be implemented until detector No. 2 is detected (confirm Light rail is clearly out from the intersection).

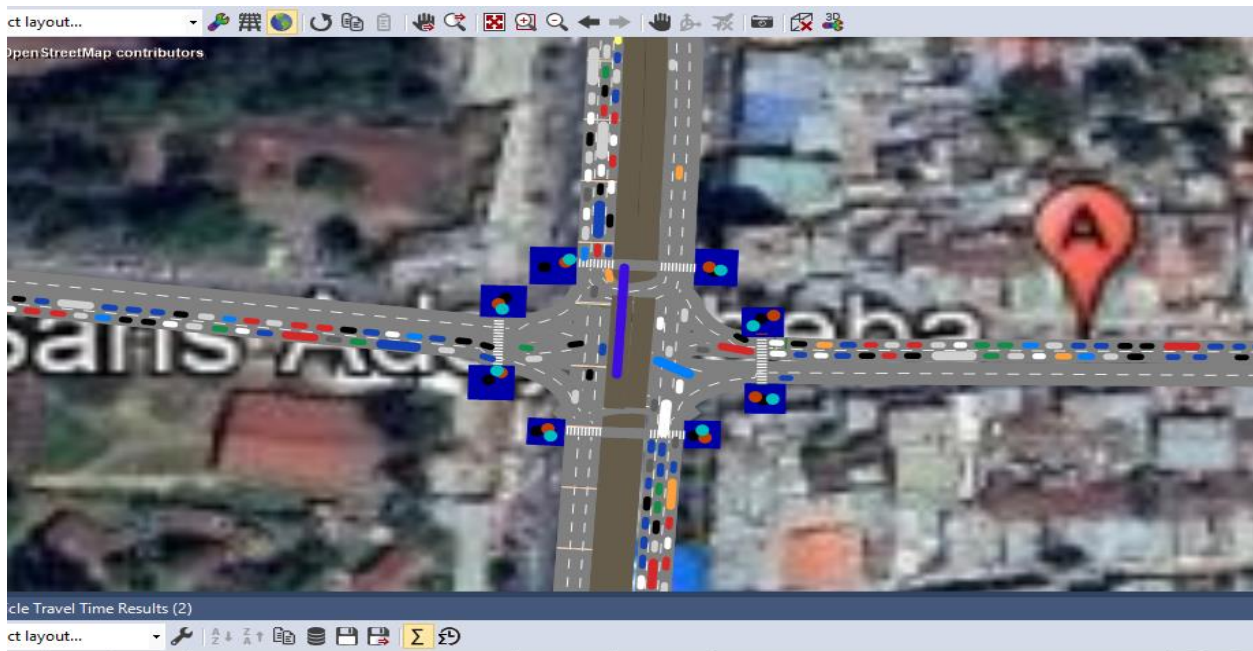


Figure 16. LRT Coming from kadisko with priority over vehicles

### **3.5.2 Traffic Signal Control**

Un-Signalized intersection modeling is required in order to represent the ‘base case’ condition before the improvement method of transit signal priority applied with Green Extension and Red Truncation/Early Green ‘after case’. In the study area there was a traffic signal control system which is not currently operated, hence in order to apply a transit signal priority the new traffic signal will be calculated for the collected traffic and model in VISSIM.

Therefore, it was crucial to simulate the signal control data as closely as possible and program the model to use a priority method.

In this study, the intersection in VISSIM was modeled using a Signal Control (SC) based technique. The study area signalized intersection has SC that includes different signal head groups attributed to different lane groups.

### **3.5.3 Signal Controller Logic**

An algorithm for actuated traffic signal control was created using the Vis VAP module. An easy-to-use tool for developing the program logic of VAP signal is Vis VAP (short for "Visual VAP"). PTV VISSIM can simulate programmable traffic actuated signal controls, whether they are stage-based or phase-based, thanks to VAP (vehicle actuated programming). VAP analyzes the control logic commands and generates the signal control directives for PTV VISSIM simulation runs or in the test mode. Actual detector variables are also taken from the simulation and put through the logic at the same time. A text file (\*.VAP) containing the VAP control logic is written in a straightforward programming language. VisVAP has the option of exporting it as well. The VAP signal data set (\*.PUA) can easily be generated manually in a text editor or exported using Vissig. The spectrum of applications includes everything from single junction controls to network or corridor controls to even VMS applications like variable speed control or the temporary usage of special lanes. In VISSIM the way used to control a signal controller for program actuated - coordinated signal logic by using a VAP (an English acronym for Vehicle Actuated Program) language which is signal state generator used. Once per second, the VAP polls data and provides traffic simulator with light status (VISSIM, 2017). For the purpose of studying Adey Abeba intersection, the VAP uses subroutine-based programming.

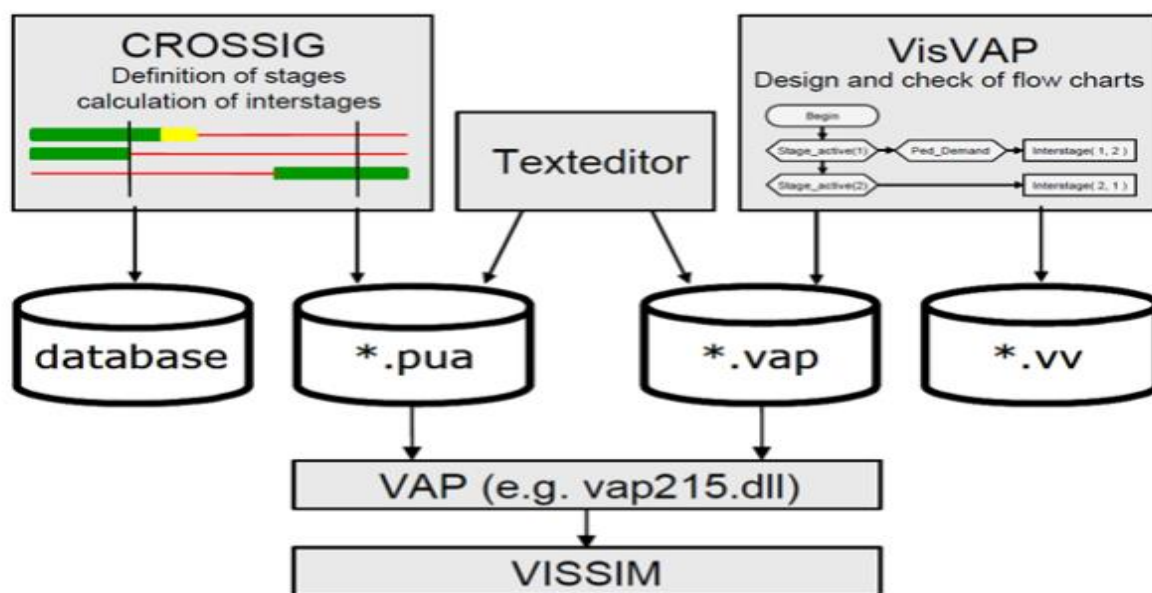


Figure 17. VIS VAP Steps in VISSIM model (source VISVAP Manual)

### 3.5.4 Signal Priority Logic

As mentioned in the literature review summarized in chapter 2 the proposed Transit Signal Priority (TSP) will be implemented in the two methods of Green Extension and Red Truncation (Early Green) in which they were most frequently employed. These tactics were also modified to take into account agency preferences, implementation needs, and geographical constraints. The least amount of disruption to coordinated traffic signal operations was the main focus of this study. The case study area, where the primary corridor (north and south bounds) are a major artery carrying large traffic volumes during peak hours, was particularly relevant for this aspect.

Additionally, deployment is intended for both green extensions and red truncation (early green) based on adding the remaining green time of the minimum required green time during early green and adding of required minimum green requirement on red truncation case. Therefore, the minimum required green time to clear out the LRT from the intersection used in modeling is 10sec.

In this study priority will be based priority logic of VAP on the individual detection of LRT in both checks in and checks out detection at the intersection.

These are the VISSIM detectors, which function in a manner similar to that of the 3M emitter and detector in the field. When the LRT approaches in the intersection detected and requested a priority the actual green time provided in first logic of signal will be adjusted to temporary green time based on the remaining green time that is compared with the required minimum green time for the LRT route takes that time from side streets to be distributed locally over the same cycle in the green extension case. If the LRT approach the intersection is detected and request priority, the red phase will be changed to green phase for the minimum required green time 10sec in order to enable the LRT clear the intersection in red truncation (early green) case and then the normal traffic control logic will be implemented.

The signal priority subroutine used for this model is provided as shows below

Program logic for Transit Priority in VISSVAP

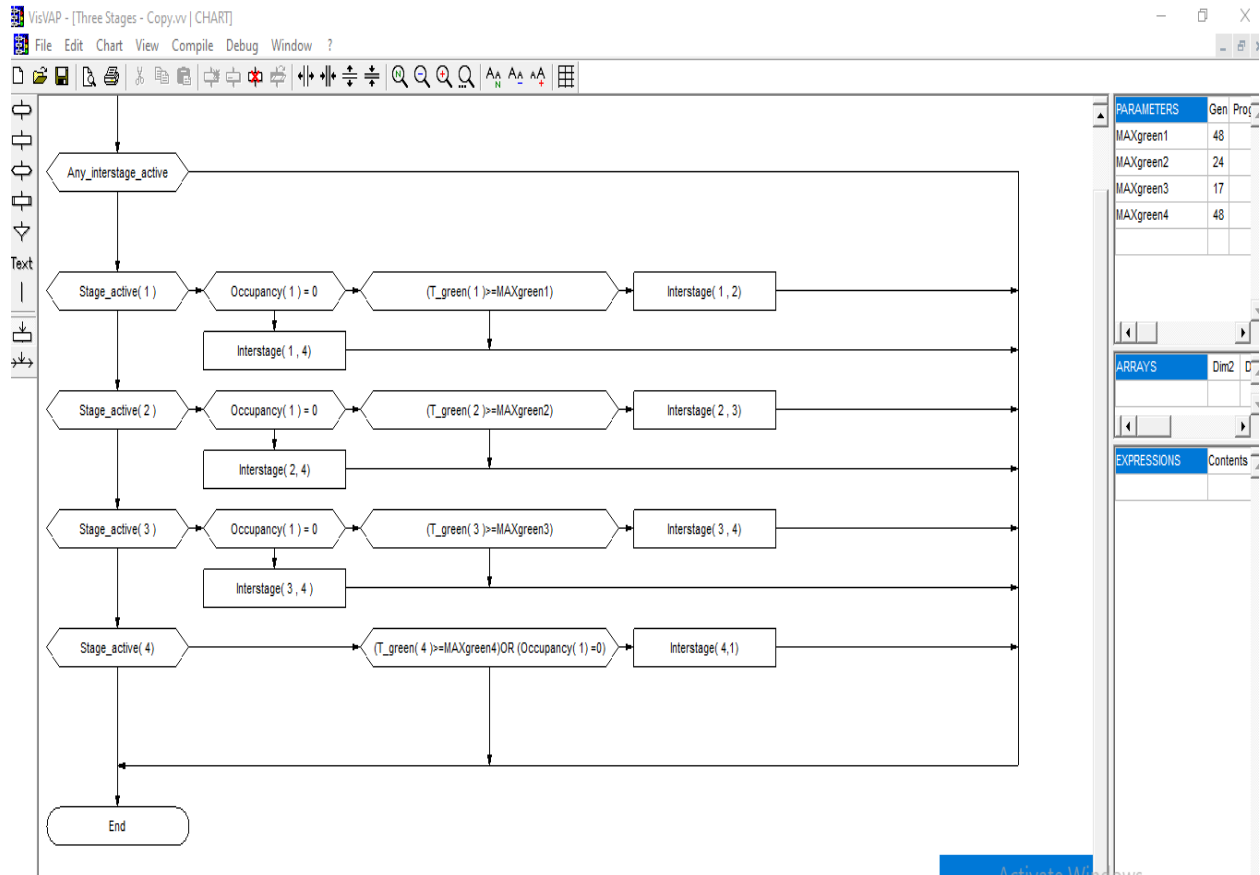


Figure 18. Program logic for Transit Priority in VISSVAP THE PUA FILE

```

$SIGNAL_GROUPS
$
A          1
B          2
C          3
D          4

$STAGES
$
STAGE_1    A
red        B C D
STAGE_2    B
red        A C D
STAGE_3    C
red        A B D
STAGE_4    D
red        A B C
    
```

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

---

\$STARTING\_STAGE

\$

STAGE\_1

\$INTERSTAGE

\$INTERSTAGE

INTERSTAGE\_number : 1  
length [s] : 48  
from stage : 1  
to stage : 2

\$

A	-127	0
B	6	127

\$INTERSTAGE

INTERSTAGE\_number : 2  
length [s] : 24  
from stage : 2  
to stage : 3

\$

B	-127	0
C	6	127

\$INTERSTAGE

INTERSTAGE\_number : 3  
Length [s] : 20  
from stage : 3  
to stage : 4

\$

C	-127	0
D	6	127

\$INTERSTAGE

INTERSTAGE\_number : 4  
length [s] : 28  
from stage : 4  
to stage : 1

\$

D	-127	0
A	10	127

\$INTERSTAGE

INTERSTAGE\_number : 5  
length [s] : 39  
from stage : 1

```
to stage : 4
$
A -127 0
D 6 127

$INTERSTAGE
INTERSTAGE_number : 6
length [s] : 19
from stage : 2
to stage : 4
$
B -127 0
D 6 127

$END
```

### 3.5.5 Simulation

Based on the required input data in the VISSIM such modeling the network, assign traffic signal control logic and traffic signal priority logic are ready the simulation is conducted based on simulation criteria for a minimum of 10min or 600sec. Accordingly, different output can be generated at the required location as per the user requirement and then the out puts are collected and analyzed the same.

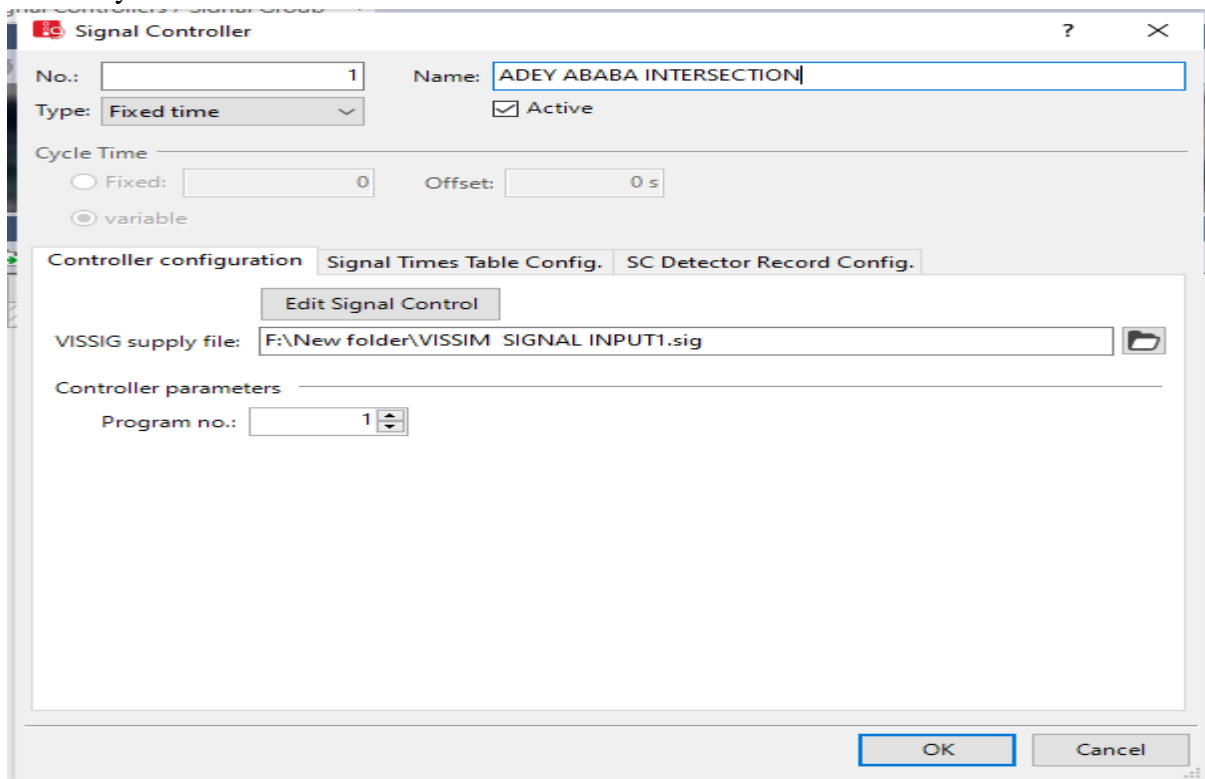
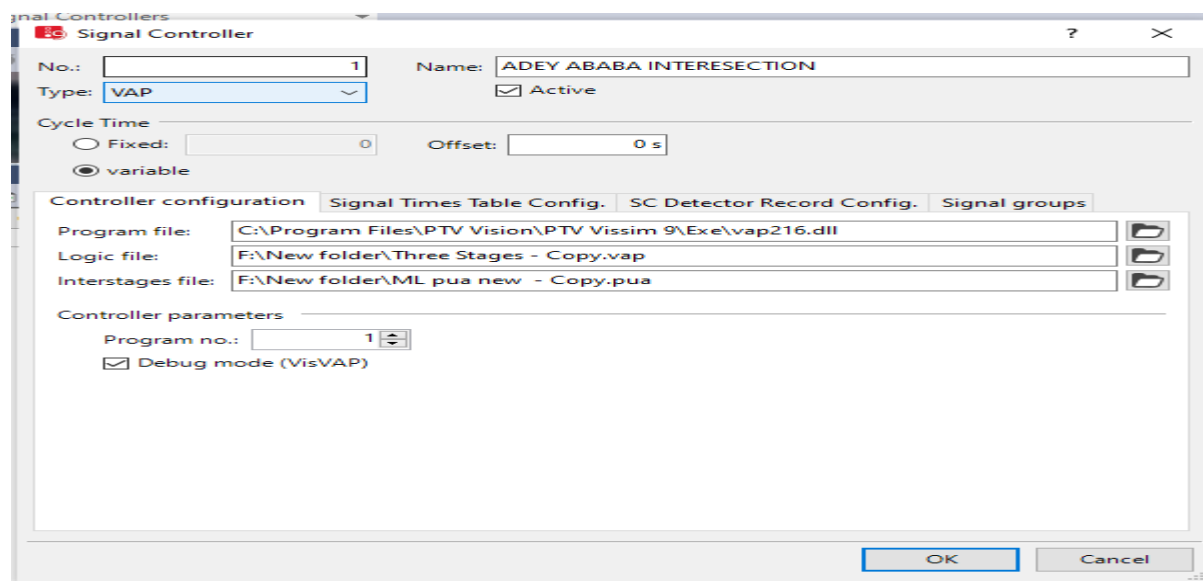


Fig 19. Fixed Traffic Signal control input in VISSIM



**Fig 20. Transit Signal Priority input in VISSIM simulation**

### **3.5.5.1 Simulation Scenario for Green Extension**

In order to analyze the Green Extension strategy simulation conditions are proposed based on the arrival frequency of the light rail and usages of the required Green Extension time (10se) for the study area when the light rail arrive at Green Phase of parallel movement of road side vehicles to LRT line (through movement of North and South Bound).

### **3.5.5.2 Simulation Scenario for Early Green/Red Truncation**

When the light rail is arrive at the red phase of the parallel movement of road side vehicles or crossing movement of road side vehicles to LRT line Early Green/Red Truncation strategy is implemented by initiating the green phase of the parallel vehicle movement.

### **3.5.6 Data Collection**

After simulation based on different scenarios, the required data which helps to evaluate the proposed optimization solution by measure of effectiveness (MOE) is generated from VISSIM software at the required location and conditions.

### **3.5.7 Model Calibration and Validation**

In order for the model to accurately depict the traffic environment being studied, model parameters must be quantified using data from the real world. The most important parameters which may need to be calibrated and may be site specific are vehicle and driver characteristics. Given the same traffic conditions, various drivers may act in different ways because driver behavior is not uniform. By using statistical distributions of behavior-related parameters, such as desired free-flow speed, queue discharge headway, acceptable gaps for lane changing and car following, and driver response to advance information and warning signs, the majority of microscopic models simulate stochastic or random driver behavior. (HCM, 2000)

Model validation is the act of ensuring that model findings accurately reflect the system that exists in the real world by comparing them to relevant data collected in the field. Model results can only be verified with measurable data gathered in the field. Queue length, travel time, delay, speed, density, and throughput are the most often utilized data for validation. (HCM, 2000)

In order to calibrate the VISSIM model to represent the real condition two parameters are used which are Approach free flow speed and crossing speed at LRT grade crossing (reduced speed area).

In VISSIM model, approaching free flow speed and LRT crossing speed were implemented by desire speed decision and reduced speed area respectively.

During Model validation the distance used in VISSIM model which was similar with distance used in delay calculation in real condition which is 834m. In VISSIM travel time was collected from north bound to south bound in link segment of 20m interval.

Accordingly, the required total travel time to cross Adey Abeba intersection from north bound to south bound is 12.66min as per VISSIM Simulation result. On the other hand the estimated ideal travel time required to cross the intersection with similar distance is 1.02min (table 14). Hence, delay on north to south bound at pick hour is 11.04min which is close to real condition delay 11.32 min. Therefore, the VISSIM modeled to represent the real condition is acceptable. The VISSIM out -put for travel time in 20m segment of the study area is attached in the Annex B Part.

Figure 19. Travel Time Vs Travel Distance

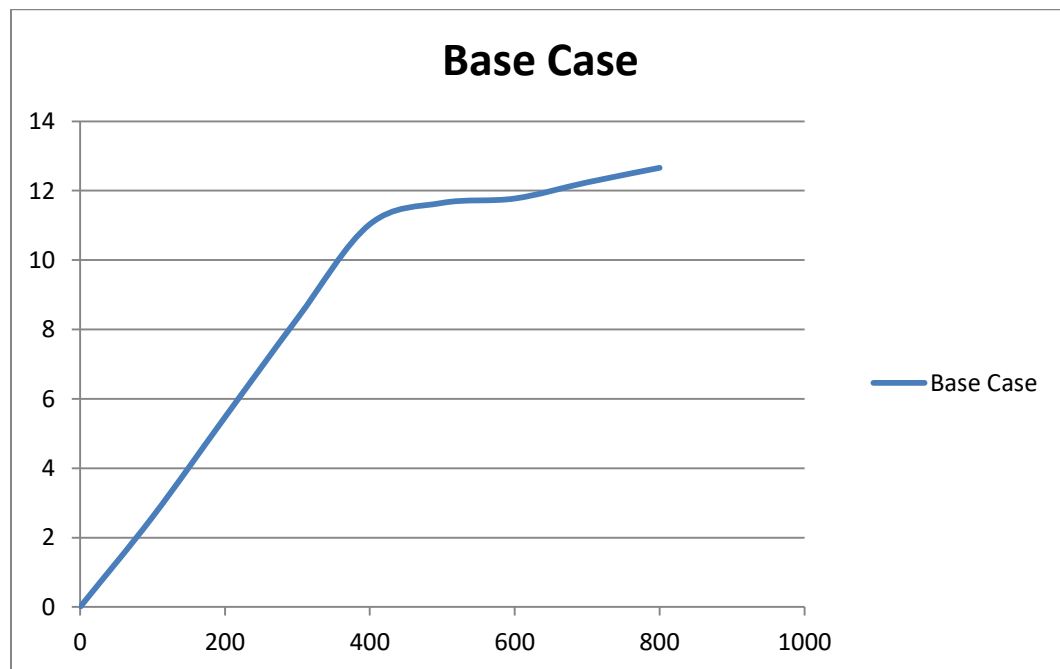


Table 14.

Delay Comparisons in Real Condition and VISSIM out put

APPROCH	Collected data from	Travel time (min)	Ideal Travel Time (min)	Delay (min)
North to South road segment	VISSIM	12.66	1.02	11.64
	Actual condition	13.4	1.02	12.38
	Error Accepted	0.74		0.74

Furthermore, as shown in the following figures traffic condition in VISSIM simulation model represents the traffic condition in the real world.



Figure 20. Morning pick hour traffic condition in real world

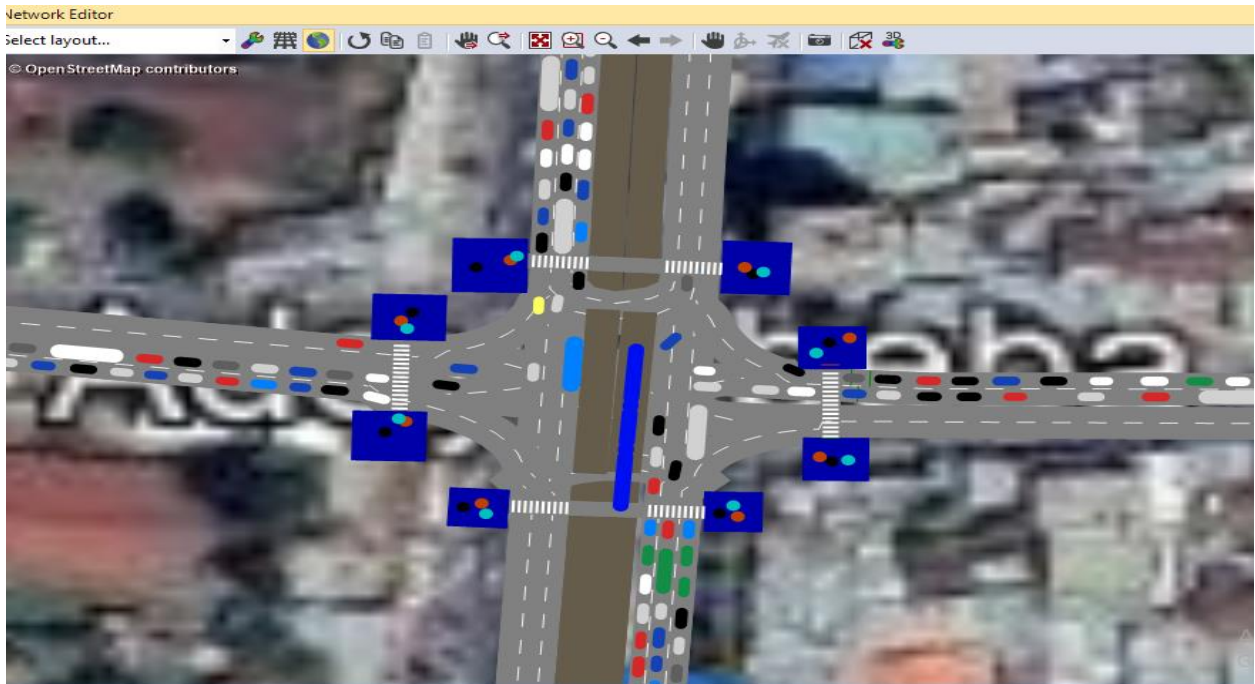


Figure 21. Morning pick hour traffic condition in VISSIM 9 simulation

### 3.6 Improvement Solution

In this topic the proposed improvement solution that can be implemented in the study area as per the observed problems will be discussed.

#### 3.6.1 Providing Pedestrian Fence and Signal

Hence, pedestrian are cross the intersection in uncontrolled/illegally way which need to be guided with street fence with pedestrian signal in order to manage it.

Minimum green time for pedestrian based on the requirement was determined and a separate phase was design and installed with vehicle signal. Based on the analysis the maximum green time required from the north approach.

In the VISSIM model's separate pedestrian signal head was installed in all approach.

#### 3.6.2 Diverting of U turns

In the north approach (Kadisco side) there is a separate 10m width crossing provided for only U turns in order to divert traffic flow from kadisco side as shown below.



Figure 22. Diverting of U- turn in other location as a solution

Accordingly, this U tern which is provided by the city administration will be diverted far away from the study area in order to minimize conflicting points at the intersection.

#### 3.6.3 Transit Signal Priority (TSP)

This section presents Transit Signal Priority (TSP) as improvement solutions that can be implemented at the study area in terms of Green Extension and Red Truncation/Early Green and the proposed improvement solution is based on identified problems that observed in the study area. The proposed solution is the other options before implementing of infrastructure solution such as underpass, over pass and realignment.

### 3.6.3.1 Base Case

In order to implement Transit Signal Priority (TSP) in terms of Green Extension and Red Truncation as an improvement solution for the study area the traffic signal (pre-timed) data is required as a base case. Accordingly, the traffic signal install in the study area is not currently operated and the new traffic signal design should be developed based on the current traffic volume and condition which will be the base for implementing the Transit Signal Priority (TSP) as a modification of the pre- time traffic signal.

#### 3.6.3.1.1 Traffic Signal Timing Design

High way capacity manual stated that there are three crucial decisions must be made in the difficult process of designing a traffic signal for operation: the type of signal controller to be utilized, the phase plan to be followed, and the distribution of green time among the various phases. (HCM, 2000).

The National Cooperative Highway Research Program (NCHRP) Report 812, the Signal Timing Manual, and the Highway Capacity Manual were both reviewed when designing the signal. This section provides a summary of the procedures used to establish the signal timing requirements.

##### i. Selection of Signal Controller

As discussed in the literature review summarized in chapter 2, among the three types of signal controller which are Pre-timed, semi-actuated or fully actuated traffic signals, fully actuated signal controller is selected for the study area due to transit signal priority approach is forced to give the priority for the selected route or vehicle in this case LRT Tramp when it is detected by the provided detector along the main route.

##### ii. Left Turn Traffic Determination

As per Highway Capacity Manual 2000, if one of the following conditions is satisfied the left turn movement should be protected

- ✓ The cross product of the opposing main line volumes and the unadjusted left turn exceeds the ensuing minimum values.
- ✓ Over 240 vehicles per hour (unadjusted) are turning left.
- ✓ On the approach, there are several lanes for left turns.

From the above mention criteria the 1st criteria is recommended based on the minimum value as mention below

Table 15. Minimum Cross-Product Values for Left Turn Protection Recommendation

Number of Through Lanes	Recommended Minimum Cross Product
-------------------------	-----------------------------------

1	50,000
2	90,000
3	110,000

Accordingly, based on the minimum recommended cross product value the requirement of left turn protection is determined for the study area as follow:-

Approach	Traffic Movement			No. of Opposing Lane	Vo/No	Vlt* (Vo/No)	Required Left turn Protection	Remark
	T	L	R					
Saris	525	248	38	2	348	86,304	Yes	$V_{LT} > 240$ Veh/hr
Kadisco	696	285	89	2	263	74,955	Yes	$V_{LT} > 240$ Veh/hr
Addis Sefer	126	270	173	1	118	31,860	Yes	$V_{LT} > 240$ Veh/hr
Biher etsige	118	450	24	1	126	56,700	Yes	$V_{LT} > 240$ Veh/hr

Where:-  $V_{LT}$ = left-turn flow rate, veh/hr

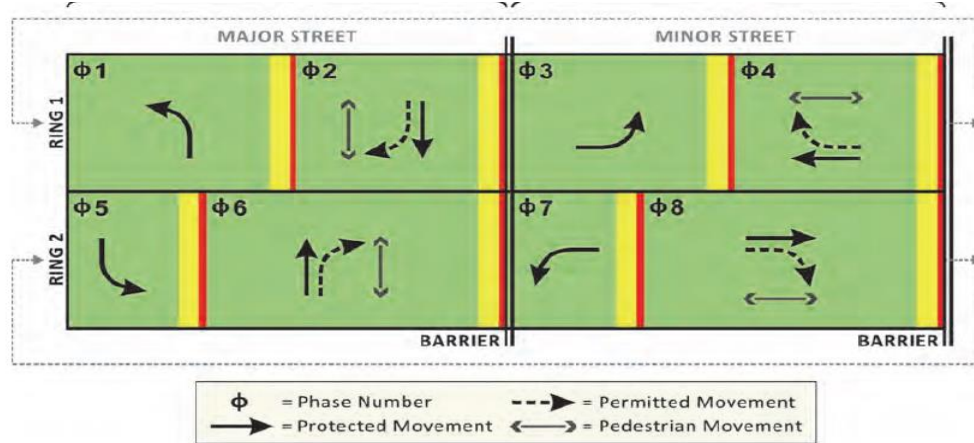
$V_0$ = opposing through movement, veh/hr

$N_0$  = number of lanes for opposing through

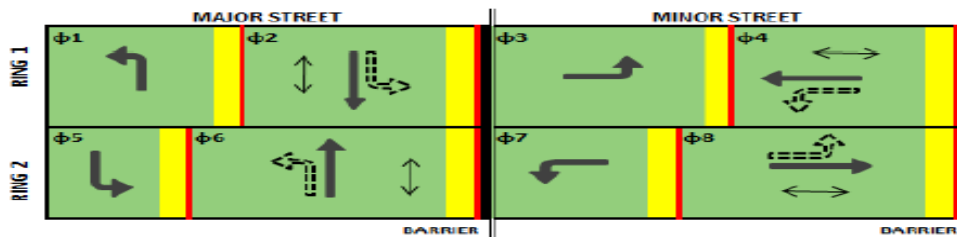
Therefore, as per the result all approaches of the study area left turn movement protection is recommended.

### iii. Phase Plan Design

The choice of an acceptable phase plan is the most important consideration in any design of signal timing. The numbers of phases to be used, as well as their implementation order, are included in the phase plan. Unless circumstances require more phases, straightforward two-phased control should be employed as a general rule. As the number of phases rises, the percentage of the cycle that is lost time typically increases as well since the change interval between phases adds to the cycle's lost time. (HCM, 2000)



Protected left turn phasing (NCHRP, 2015)



Protected – permitted Left turn phasing (HCM, 2000)

From different phase plan combination provided manuals the preferable phase plan combination will be selected based on the determined requirement of left turn protection number.

#### iv. Phase Sequence

Changing the order in which left-turn phases are provided may be useful in some situations, regardless of the kind of left-turn phasing that is used (relative to the through phases). The three possible sequences are lead-lead, lag-lag, and lead-lag. The lead-lead sequence, which initiates opposing left-turn phases before the through phases, is the most typical left-turn phase sequence. The following are some of the benefits of this sequence option:

- ✓ It gives unused time to the through movements, if a dual ring controller is used.
- ✓ Users react quickly to the leading green arrow indication.
- ✓ It minimizes conflicts between left-turn and through movements on the same approach, (NCHRP, 2015)

Accordingly from the above mention reasons, the lead-lead sequence is selected.

#### v. Determination of Yellow Interval

The following equation is provided by the Institute of Transportation Engineers (ITE) for calculating the yellow change interval. The formula determines how long it takes for a driver to decide whether to stop safely or keep going. The problem zone can be removed in this amount of time at the very least if the yellow is too short.

$$Y = t + \frac{1.47S_{85}}{2a+(64.4*0.01G)} \quad \text{E.q (4)}$$

Where

y = length of the yellow interval, s

t = driver reaction time, s (commonly 1s)

S<sub>85</sub> = 85<sup>th</sup> percentile speed of approaching vehicles, or speed limit, as appropriate, mi/hr

a = deceleration rate of vehicles, ft/s<sup>2</sup> (commonly 10 ft/s<sup>2</sup>)

G = grade of approach, %

64.4 = twice the acceleration rate due to gravity (32.2 ft/s<sup>2</sup>)

By using,

- ✓ the speed limit of the approach road is 50kph or 31.07 mph).
- ✓ approach grade from north and south 5.26% and 4.314% respectively

$$Y = 1 + \frac{1.47*(32.2)}{2*(10)+((64.4*0.01*(5.26))} = 3.024 \dots \dots \dots \text{E.q (5)}$$

The estimated yellow interval for the study area will be 4s

vi. Determining of All-Red

Similarly the following equation is provided by the Institute of Transportation Engineers (ITE) for calculating the all –red change interval. Before competing cars are given the Green, a vehicle that just legally entered the intersection on yellow must have enough time to cross the intersection and clear its back bumper past the far curb line (or cross-walk).

$$\text{All – Red} = \frac{P+L}{1.47 S_{15}} \quad \dots \dots \text{for significant pedestrian traffic} \dots \dots \text{E.q (6)}$$

Where

P = distance from the departure STOP line to the far side of the farthest conflicting crosswalk, ft

L = length of a standard vehicle, usually taken to be 18-20 ft

S<sub>15</sub> = 15<sup>th</sup> percentile speed of approaching vehicles, or speed limit, as appropriate, mi/hr

By taking  $L = 20\text{fi}$  ,  $P = 93\text{fi}$  (11.8fi lane +11.8fi lane +11.8 fi lane+ 11.8 fi lane + 36fi rail way +10ft cross walk) and  $S_{15} = 45\text{mi/hr}$  (50mil/hr - 5mi/hr)

$$All - Red = \frac{93+20}{1.47*45} = 1.71\text{sec} \dots\dots\dots\text{E.q (7)}$$

The required all –red interval is taken as 2 sec

vii. Estimating of Total Lost Time Per Cycle

According to HCM 2000, the total lost time per cycle recommended based on the street type as major and minor, number of phase and condition of left turn protection as shown below. (HCM, 2000). For the study area the total lost time of the cycle is use 16s by considering left turn protection.

Table 16. Recommended lost time per cycle by left turn phase protection type (HCM, 2000))

Major Street	Minor Street	Number of Phases	L(s)
Protected	Protected	4	16
Protected	Permitted	3	12
Permitted	Protected	3	12
Permitted	Permitted	2	8

viii. Proposed lane Assignment for the study area

The proposed lane assignment for the study area is protected left turn with permitted right turn for all approaches as shown in the figure below.

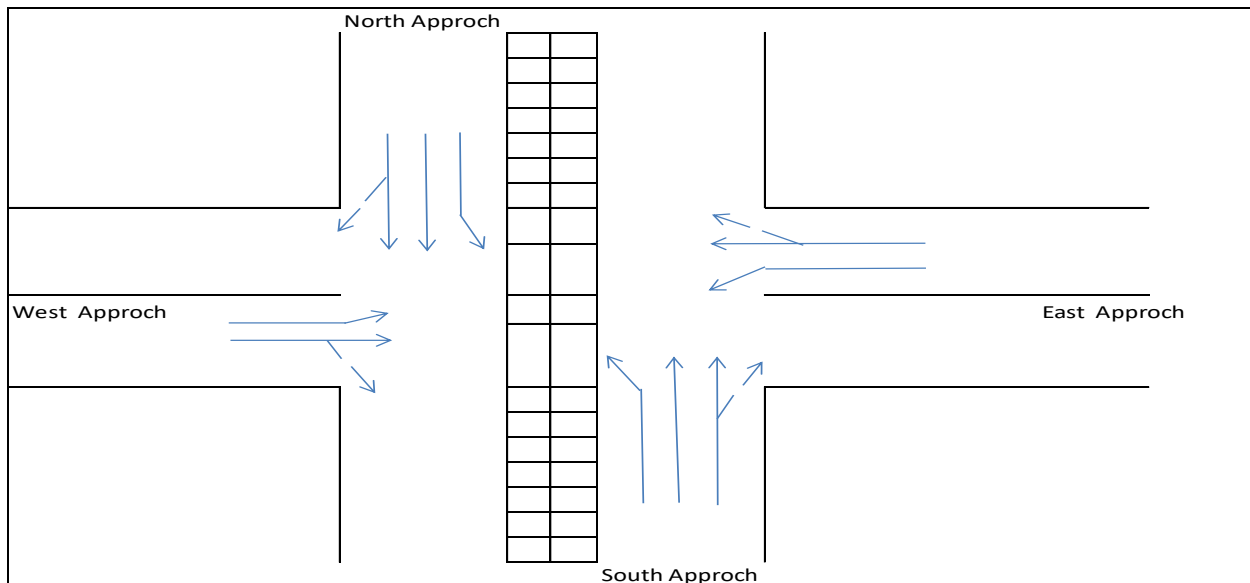


Figure 23. Proposed lane distribution for the study area

ix. Through Car Equivalents Determination

By using Exhibit C16-3 of the HCM 2000, left turn equivalency factor for the study area are determined as shown below and all left turns are considered as protected. Adjustment factor for Heavy good vehicle have also been made using a factor of 2. Due to the through vehicle shared its lane with right turn the total volume become through and right turn as shown below.

Table 17. Estimated vehicle demand per lane

Road Approach	Movement		No. lane for left turn	No. lane for through	No. vehicle for Left turn Veh/hr/lane	No. vehicle for Through Veh/hr/lane
	Left	Through /R.th				
Saris	248	563	1	2	248	282
Kadisco	285	785	1	2	285	393
Addis Sefer	270	299	1	1	270	299
Biheretsige	450	142	1	1	450	142

Table 17. Determined through Car Equivalents for Protected Left Turns

Road Approach	No. of Left turn vehicles	No. of Opposing Flow	$E_{LT}$ of protected Left turn	Through car Equivalent For Protected Left turn
Saris	248	393	1.05	261
Kadisco	285	282	1.05	300
Addis Sefer	270	142	1.05	284
Biheretsige	450	299	1.05	473

On the other hand right turn for all approaches are shared with the through movement through Car Equivalents for right turn will be determined based on the pedestrian volume per hour as per HCM 2000 manual as follows.

Estimated pedestrian volume at the study area

Road Approach	No. of pedestrian (ped./hr) on both direction	Recommended $E_{RT}$ factor	RT volume	Adjusted Right turn Volume
Saris	390	1.52	38	58
Kadisco	410	1.52	89	136
Addis Sefer	180	1.32	173	229
Biheretsige	200	1.32	24	32

x. Determination of Flow ratio for lane group i, (v/s)<sub>i</sub>

Based on the assumption that equivalent lane flow rates should be equalized across the approach, the base saturation flow rate for each of the defined lane groups in the intersection was calculated according to the HCM standard procedure (2010) using the approximate "through-vehicle-equivalents" used in the signal timing. According to the Highway Capacity Manual (2010), the saturation flow rate is calculated as follows:

$$S = (S_o)(N)(f_w)(f_{HV})(f_g)(f_p)(f_{bb})(f_a)(f_{LU})(f_{RT})(f_{LT})(f_{Rpb})(f_{Lpb}) \dots \text{E.q (8)}$$

Where:

S = Saturation flow rate for the lane group, veh/h

S<sub>o</sub> = base saturation flow rate, pc/hg/ln (1,900 pc/hg/ln, 1,750 pc/hg/ln, or locally calibrated value)

N = number of lanes in the lane group

f<sub>i</sub> = adjustment factor for prevailing condition i (w = lane width; HV = heavy vehicles; g = grade; p = parking; bb = local bus blockage; a = area type; LU = lane use; RT = right turn; LT = left turn; R<sub>pb</sub> = pedestrian/bicycle interference with right turns; and L<sub>pb</sub> = pedestrian/bicycle interference with left turns)

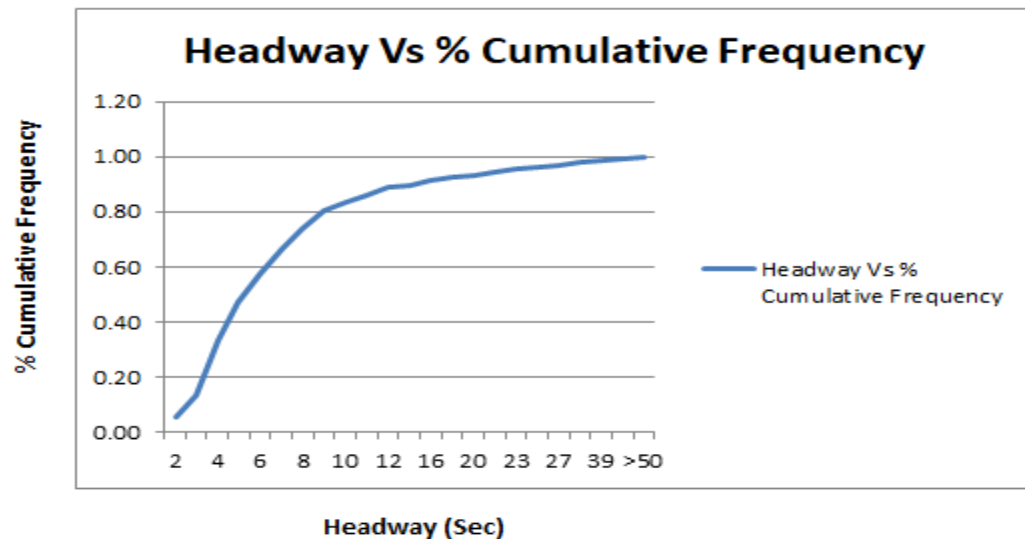
In order to determine the above mentioned factors there are assumptions and selected values which is used based on collected data such as

- ✓ Left turn are exclusive lanes and considered as a single lane group
- ✓ adjustment factor are assumed to be 1, for parking, effect of local bus, area type ,bicycle, pedestrian due to they are prohibited and has less effect at the study area
- ✓ Use base saturation flow rate, pc/hg/ln (1,900 pc/hg/ln)

However, base saturation flow (S<sub>o</sub>) was calibrated for the study area. As per the HCM Manual the average travel headway (h) for each approach was determined for pick hour traffics from 7:30am to 8:30am in order to get minimum headway.

Head way	Frequency	Cumulative Frequ	% Cumulative Frequency
2	28	28	0.06
3	38	66	0.13
4	96	162	0.33
5	69	231	0.47
6	49	280	0.57
7	45	325	0.66
8	37	362	0.74
9	30	392	0.80
10	17	409	0.84
11	10	419	0.86
12	15	434	0.89
13	4	438	0.90
16	9	447	0.91
19	7	454	0.93
20	3	457	0.93
21	4	461	0.94
23	5	466	0.95
24	3	469	0.96
27	5	474	0.97
36	5	479	0.98
39	3	482	0.99
48	3	485	0.99
>50	4	489	1

The average headway of the intersection was determined by selecting the minimum value of 85% headway of the north through approach as shown below. Accordingly base saturation flow determined from the minimum headway. The collected headway data is attached in the Annex D part.



From the above head way VS frequency distribution graph, the minimum headway of the intersection at 85% or >15% is 3.8sec.

$$S_o = \frac{3600}{h}$$

Where  $S_o$  = Saturation flow rate (veh/hr)

$h$  = Saturation Headway (S)

Therefore, from the above table the maximum base saturation flow rate is 947 veh/hr which is Kadisko approach.

Table 18. Base Saturation flow ( $S_o$ ) determination

Approach	Traffic flow	Pick 15min volume (a)	No. of lane (b)	Average Headway h sec (c)	Approach Base Saturation Flow $S_o$ fro approach
Saris	Through /RT	112	2	4.3	837
	Left	78	1	5.1	706
Kadisco	Through /RT	162	2	3.8	<b>947</b>
	Left	114	1	4.8	750
Addis Sefer	Through /RT	90	1	4.5	800
	Left	78	1	4.7	766
Bihertsige	Through /RT	46	1	8.1	444
	Left	130	1	4.6	783

Hence, the Saturation flow rate for the study area is calculated as follow based on the formula given in HCM 2000 (Exhibit 16-7 adjustment factor for saturation flow rate)

Table 18. Saturation Flow rates for Adey Abeba Intersection

Approach	Traffic flow	$f_w$	$f_{HV}$	$f_g$	$f_{LU}$	$f_{RT}$	$f_{LT}$	$S$	for protected	
									v	v/s
Saris	Through /RT	0.99	0.971	0.974	1	0.99	1	878	292	0.24
	Left	1							887	261
Kadisco	Through /RT	0.99	0.962	0.978	1	0.99	1	873	416	0.32
	Left	1							882	285
Addis Sefer	Through /RT	0.99	0.98	0.985	1	0.95	1	860	262	0.12
	Left	1							868	284
Biheretsige	Through /RT	0.99	0.976	0.988	1	0.99	1	895	150	0.163
	Left	1							904	345

xi. Critical v/s Ratio

The volume needed for the movement during the phase that demands the greenest time is known as the crucial phase volume. The key lane volume is the higher-volume left turn if there are two opposing lefts going during the same phase. (HCM, 2000)

There are 2 alternative phase plans are analyzed based on their critical V/S ratio to achieve the best phase plan for the study area with considering of all left turns are protected as follows.

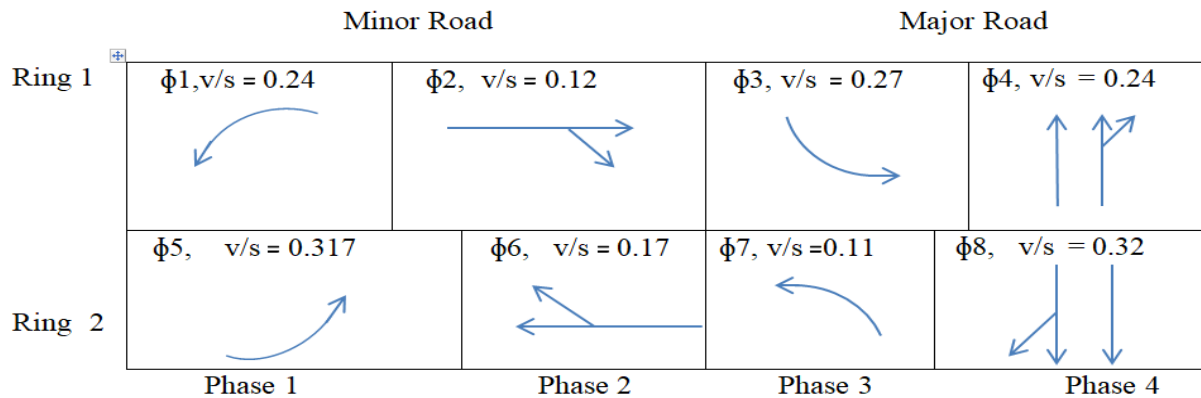


Figure 24. Alternative one phase plan diagram for all protected left turn

From the above alternative one phase plan determination of V/S ratio the maximum value is selected and sum up to determine the total phase V/s ratio as follow.

Ring No.	Major Road v/s ratio selected	Minor Road v/s ratio selected	Total Sum
Ring 1	0.411	0.36	
Ring 2	0.417	0.483	
Max. v/s ratio	<b>0.417</b>	<b>0.483</b>	<b>0.9</b>

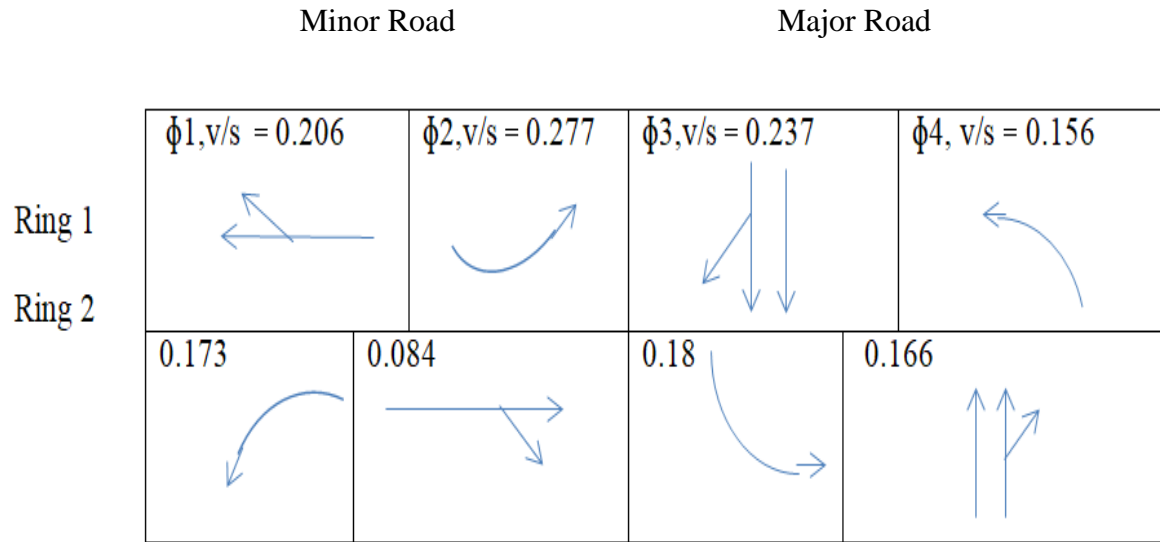


Figure 25. Alternative Two phase plan diagram for all protected left turn

Therefore, from the two possible phase plan alternatives the second phase has lower v/s ratio ( $0.876 < 0.9$ ) however in the alternative two phase plan during arrival of LRT all phases should be stop/red for the minimum required LRT crossing time on the other hand in the case of alternative one the through movement of north and south approach will not stop when their light is green even if LRT arrival, due to this reason and easy of complexity for operation alternative one is selected as a best phase plan for the study area to determination of the signal cycle length for the study area.

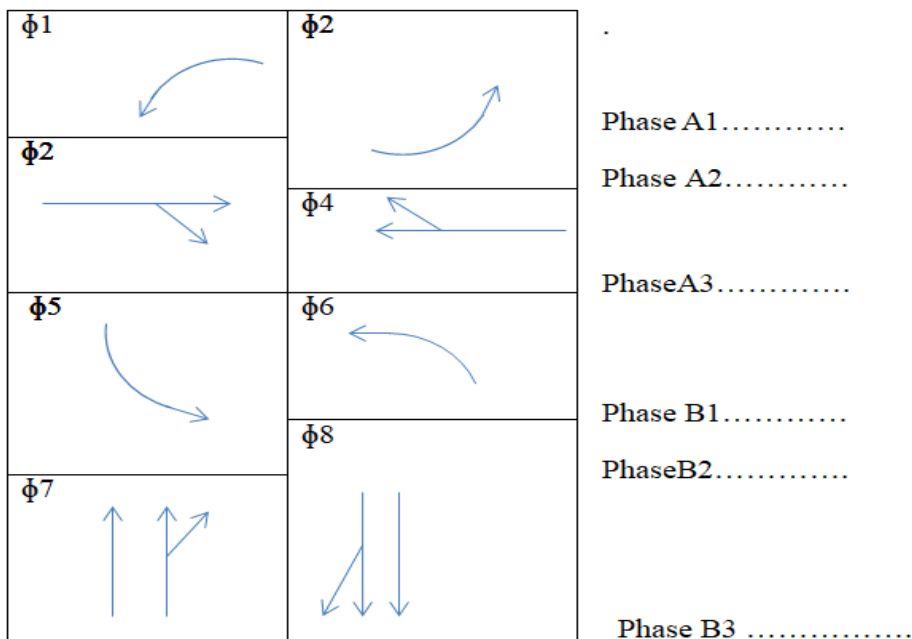


Figure 26. Ring diagram

Ring No.	Major Road v/s ratio selected	Minor Road v/s ratio selected	Total Sum
Ring 1	0.393	0.483	
Ring 2	0.417	0.257	
Max. v/s ratio	<b>0.417</b>	<b>0.483</b>	<b>0.9</b>

xii. Cycle Length

HCM 2000 provides the following equation to determine Cycle length

$$C_{\min} = \frac{LX_i}{[X_i - \sum_{n=1} \left(\frac{V}{S}\right) c_i]}$$

Where

C = cycle length (s);

L = Lost time per cycle (s);

X<sub>c</sub> = critical v/c ratio for the intersection

X<sub>i</sub> = v/c ratio for lane group i (note that target v/c ratio is a user- specified input with respect to this procedure; default suggested is 0.90);

(v/s)<sub>i</sub> = flow ratio for lane group i;

S<sub>i</sub> = saturation flow rate for lane group i (veh/h); and

G<sub>i</sub> = effective green time for lane group i (s).

On the other hand Equation B16-5 of HCM 2000 can be used to determine the minimum cycle time that will prevent oversaturation using the critical volume to capacity ratio X<sub>c</sub> = 1.00 and a desirable cycle length will be determined with X<sub>c</sub> = 0.75 however, the estimated v/s ratio (0.9) is high and make negative value, X<sub>c</sub> = 1.00 is used for determination of cycle length as follow.

$$C_{\min} = \frac{4 * 4 * 1}{[1 - 0.9]} = 160$$

Hence, the determined cycle length is 160sec.

Allocation of green time

In order to allocate the green time for each phase effective total green time is used as per (Nicholas, 2009).

G<sub>effe</sub> = C – L where G<sub>effe</sub> = Effective green time in the one cycle (160 sec)

C = Total one cycle time and L = Total lost time in one cycle (16 sec +8sec).

$$G_{\text{effe}} = 160\text{sec} - 16\text{sec} - 8\text{sec} = 136\text{sec}$$

Allocation of effective green time for each phase is determined as follows

$$G_{\text{efei}} = \frac{\left(\frac{v}{s}\right)}{\sum_{ci=1}^n \left(\frac{v}{s}\right)} .* G_{\text{effe}} .$$

Actual Green time for the cycle,

$$G_{\text{ac}} = G_{\text{efe}} + L - y - \text{all red} = 136 + 4 - 4 = 136$$

Calculated Green time for each phase

Phase No.	φ1	φ2	φ3	φ4	φ5	φ6	φ7	φ8
v/s <sub>total</sub>	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
v/s <sub>i</sub>	0.24	0.12	0.171	0.24	0.317	0.163	0.11	0.32
G <sub>ac</sub>	136	136	136	136	136	136	136	136
<b>Actual Green time allocated (sec)</b>	<b>39.0</b>	<b>32.0</b>	<b>26.0</b>	<b>39.0</b>	<b>47.0</b>	<b>24.0</b>	<b>17.0</b>	<b>48.0</b>

Allocation of Minimum Green Time

It is vital to allow for a minimum amount of green time at intersections where a sizable number of people cross so that they can do so safely. (Nicholas, 2009). or local practices If pedestrian timing requirements are necessary, the phase's minimum green time is calculated using Equation 16-2 of the HCM 2000. (HCM, 2000).

$$G_p = 3.2 + \frac{L}{S_p} + \left(0.81 \frac{N_{ped}}{W_e}\right) \text{ for } W_e > 3m$$

$$G_p = 3.2 + \frac{L}{S_p} + (0.27 * N_{ped}) \text{ for } W_e \leq 3m$$

Where,

G<sub>p</sub> = minimum green time (s)

L = crosswalk length (m)

S<sub>p</sub> = average speed of pedestrians (m/s), 1.2 m/s (HCM, 2000)

W<sub>E</sub> = effective crosswalk width (m)

3.2 = pedestrian start-up time (s), and

N<sub>ped</sub> = number of pedestrians crossing during an interval (p)

By considering 3.5m effective crosswalk width equation 1 is used to determine the required green time for pedestrian crossing.

The entire length of the vehicular green, yellow, and all-red intervals must be compared to the minimum pedestrian crossing requirement,  $G_p$ , in each phase.

Hence,  $G_p = G_{efe} + Y$

The following minimal pedestrian green times were calculated using this HCM 2000 equation, and they were contrasted with the total of the concurrent phases' amber and green periods.

Pedestrian volume in Pedestrian interval, number of pedestrian per hour divided by Number of intervals per hour.

Approach	Pedestrian volume in Pedestrian interval	Cross Walk length, L	Phase Number	Vehicle green + Amber & all red (s)	Pedestrian minimum green (s)	Requirement check
Saris	14	32m	ϕ8	54	33	Adequate
Kadisco	15	32m	ϕ4	45	34	Adequate
Addis Sefer	7	14m	ϕ2	32	17	Adequate
Biheretsige	8	14m	ϕ6	30	18	Adequate

### 3.6.3.2 Determination of Control Delay

The total control delay for each lane group is given as (HCM, 2000)

$$d_1 = d_{1i}PF + d_{2i} + d_{3i} \dots\dots\dots$$

Where,

$d_1$  = the average control delay per vehicle for a given lane group

PF = uniform delay adjustment factor for quality of progression

$d_{1i}$  = uniform control delay component assuming uniform arrival

$d_{2i}$  = incremental delay component for lane group  $i$ , no residual demand at the start of the analysis period

$d_{3i}$  = residual delay for lane group  $i$

#### Uniform Delay

$$d_{1i} = 0.5C * \frac{(1 - \frac{g_i}{c})^2}{1 - (\frac{g_i}{c})[\min(Xi, 1)]}$$

Where,

$d_{1i}$  = uniform delay (sec/vehicle) for lane group  $i$

C = cycle length (sec)

$g_i$  = effective green time for lane group i (sec)  
 $X_i$  = (v/c) ratio for lane group i

### Incremental Delay

Equation 15-3 calculated the incremental delay brought on by uneven arrival, individual cycle failures, and periods of prolonged oversaturation (together referred to as "random delay" and "oversaturation delay"). (HCM, 2000)

$$d_{2i} = 900T \left[ (X_i - 1) + \sqrt{[(X_i - 1)^2 + \left(\frac{8K_i I_i X_i}{C_i T}\right)]} \right]$$

Where,

$d_{2i}$  = incremental delay (sec/vehicle) for lane group i  
 $C_i$  = capacity of lane group i (veh/h)  
 $T$  = duration of analysis period (hr)  
 $k_i$  = incremental delay factor that is dependent on controller settings  
 $I_i$  = upstream filtering metering adjustment factor accounts for the effect of filtered arrivals from upstream signals (for isolated intersections,  $I=1$ )  
 $X_i$  = v/c ratio for lane group i

### Residual Demand Delay

$$d_{3i} = \frac{1800Q_{bi}(1 + U_i) * t_i}{C_i T}$$

Where,

$Q_{bi}$  = initial unmet demand at the start of period  $T_i$  vehicles for lane group i  
 $c_i$  = adjusted lane group capacity veh/h  
 $T$  = duration of analysis period (h)  
 $t_i$  = duration of unmet demand in  $T$  for lane group i (h)  
 $u_i$  = delay parameter for lane group i

Using these equations total control delay for each phase and average control delay of the study area is

$C = 160s$

$K = 0.5$  for pre-timed signals. (Nicholas, 2009)

$I = 1$  for isolated intersections. (Nicholas, 2009)

$PF = 1$  for isolated intersections. (Arrival type 3) (Nicholas, 2009)

$T = 10$  min (take quall to VISSIM simulation period in order to enable compare results)

$C = (g_i/C) * S$

Where:

$C_i$  = capacity (pcu/hour)

$g$  = Effective green time for the phase in question (sec)

$C$  = Cycle length (sec)

$s$  = Saturation flow rate (vhe/hour)

Table 19. Analysis Summary of Control Delay

Phase No.	$g_i$	$V$	$S$	$v/s$	$c_i$	$X_i (V/c_i)$	$d_{1i}$	$d_{2i}$	$d_{3i}$	$d_i$	$d_i * v_i$
1	36	284	878	0.24	192.6	0.59	109.35	28.6	0	135.8	38,567.20
2	48	150	887	0.11	259.2	0.57	112.22	31.52	0	142.3	21,345.00
3	25	300	873	0.32	134.3	0.98	54.33	0.89	0	62.2	18,660.00
4	18	292	882	0.171	96.75	0.94	57.71	2.51	0	66.2	19,330.40
5	34	473	860	0.12	177.65	1.09	48.5	3.59	0	49.5	23,413.50
6	27	355	868	0.24	142.76	1.11	53	5.24	0	65.7	23,323.50
7	36	261	895	0.163	196.2	1.07	55.5	3.59	0	59.1	15,425.10
8	49	416	904	0.317	269.8	1.1	50.99	4.39	0	57.65	23,982.40
<b>Sum</b>		<b>2531</b>								<b>Sum</b>	<b>184,047.10</b>

**Total Intersection Delay**

$$d_i = \frac{\sum_{A=1}^{An} daVa}{\sum_A Va} = \frac{184,047.1}{2275} = 80.89 \text{sec/veh}$$

**Proposed Signal Program**

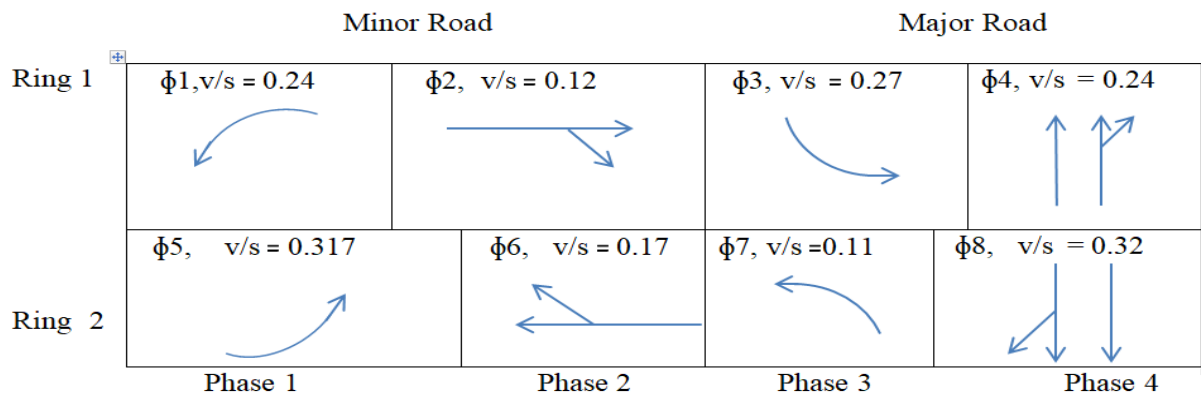


Figure 27. Ring Diagram for Adey Abeba Intersection

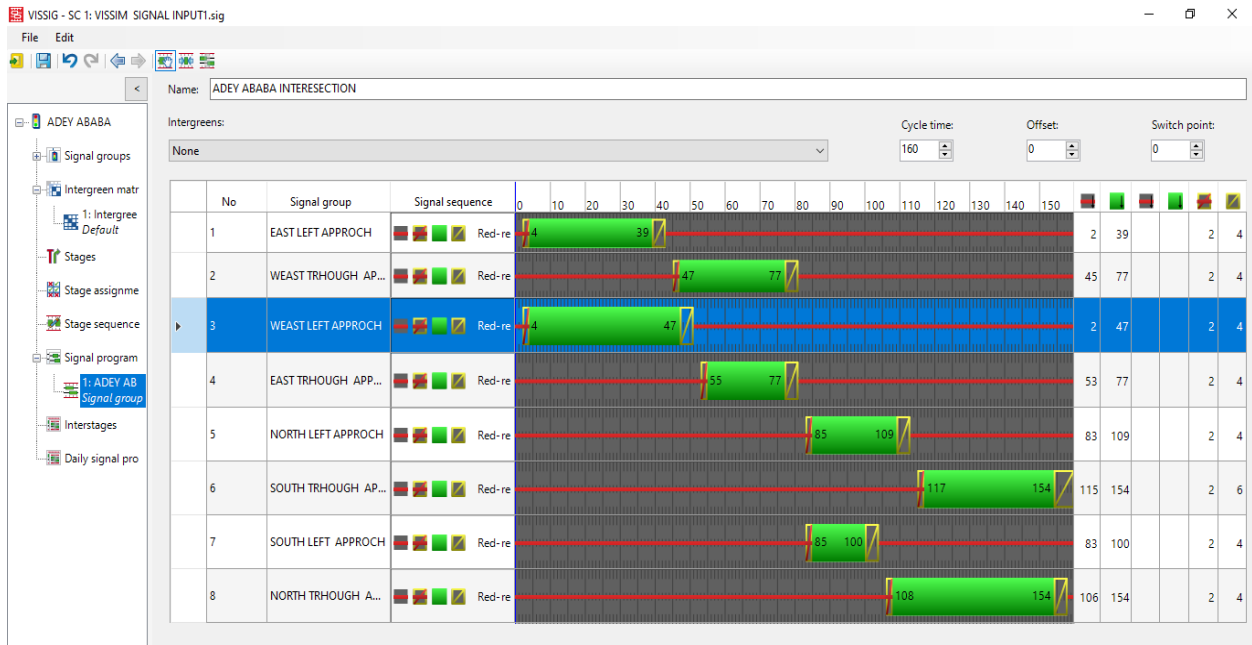


Figure 28. Signal Program for Adey Ababa Intersection in VISSIM Model

### 3.6.3.3 Green Extension

In this strategy the green extension will be applied if the LRT is detected during the green phase of the trough movement of North and south approach (a traffic flow parallel with the LRT movement) as illustrated in the figure below.

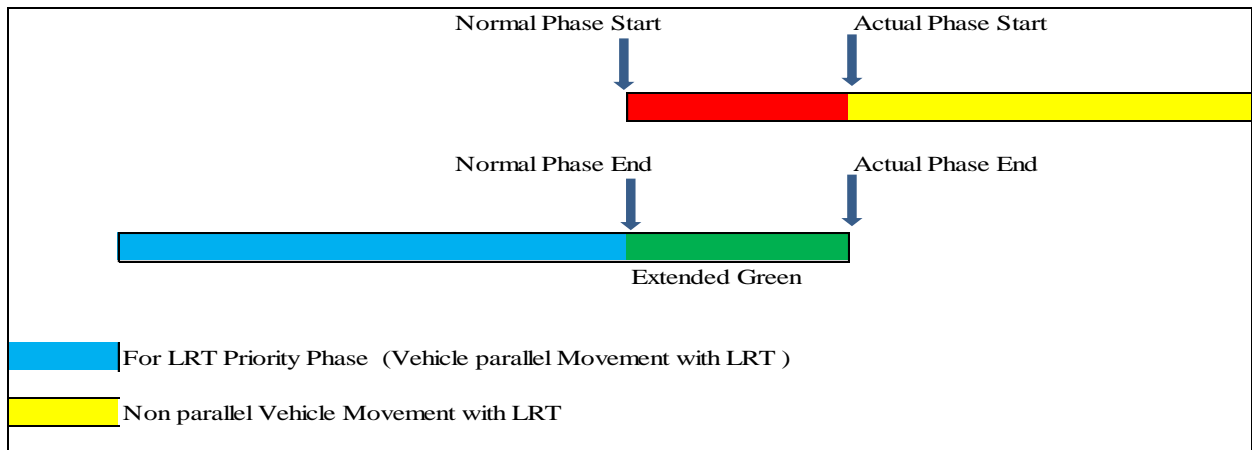


Fig. 32 Green Extension Demonstrations

In order to apply this strategy some parameters should be determine as follow.

- i. Estimating Minimum Green Extension Time

When traveling, LRT trains are given complete priority at level crossings, with traffic control systems forbidding any other movements. Traffic blockage time is the amount of time when

level crossings are closed to other traffic ( $T_b$ ). Its time is determined by the following factors: train speed, crossing width, and kind of traffic control system. (Berhanu.G, 2016)

$$T_b = T_c + T_{GC} + T_{GO}$$

Where:

TC is crossing time, = (Length of LRT train + Width of crossing)/ LRT speed

TGC is warning and gate closing time assumed to be 20 second (MTA and MUTCD, 2003)

TGO is gate opening and startup time assumed to be 10 second (MUTCD, 2003)

However, at the study area there is no any get opening (TGC) and get closing (TGO) only the required time for estimating minimum green time is the crossing time of LRT tram

$$T_b = (30m+34m)/ 25km/hr + 0+ 0$$

$$T_b = 64m/ 6.944m/s$$

$$T_b = 9.22sec \quad \text{Hence, take } T_b \text{ or (min. green time extension) to be 10sec}$$

ii. Detector Location

In order to implement transit signal priority strategies there must be check in and check out detector installed. These detectors used to identify the approaching and exiting of tram at the intersection of the study area. The checkout detector used to identify when the tram exiting from the intersection will be provided at  $L_{out} = 64m$  (34m intersection width and 30m tram length) away from the entrance of the intersection in order to continue the proposed signal phase.

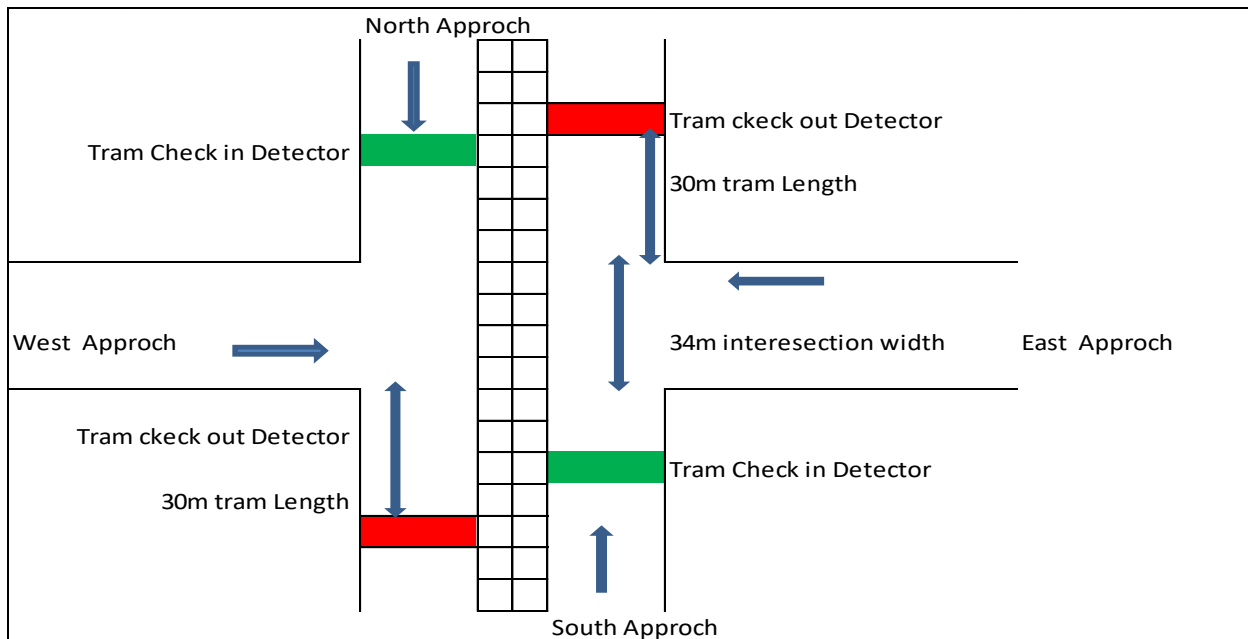


Figure 29. Provision Detector at the study Area

The location of check in detector will be determined based on the time requirement of the opposing vehicle enables to clear out from the long section of intersection. This minimum clearance time included yellow and all red interval of the opposing flow.

In section 3.6.3.1.1, Traffic Signal Timing Design the yellow interval of the proposed signal design is 4sec and the all –Red time 2sec.

$$L_{in} = V_{tram} * Clearance\ time$$

$$L_{in} = 6.95m/s * 6sec = 41.7m\ take\ 42m$$

Hence, considering sufficient clearance time the check in detector is provided at 48m away from the intersection.

In this optimization strategies Green Extension will be applied based on the remaining Green time

$$G_{extension} = | G\ available - G\ required / 10\ sec. |$$

If  $G\ available \geq G\ required / 10\ sec.$  no need of Green Extension

If  $G\ available < G\ required / 10\ sec.$  Green Extension will be requested

### 3.6.3.2 Early Green/ Red Truncation

In this strategy the early green/red truncation will be applied if the LRT is detected during the green phase of the opposing movement such as through movement of West and East approach, left turn from all approaches (a traffic flow transverse with the LRT movement) or Red phase of the parallel through movement with LRT (through movement of North and South) as illustrated in the figure below.

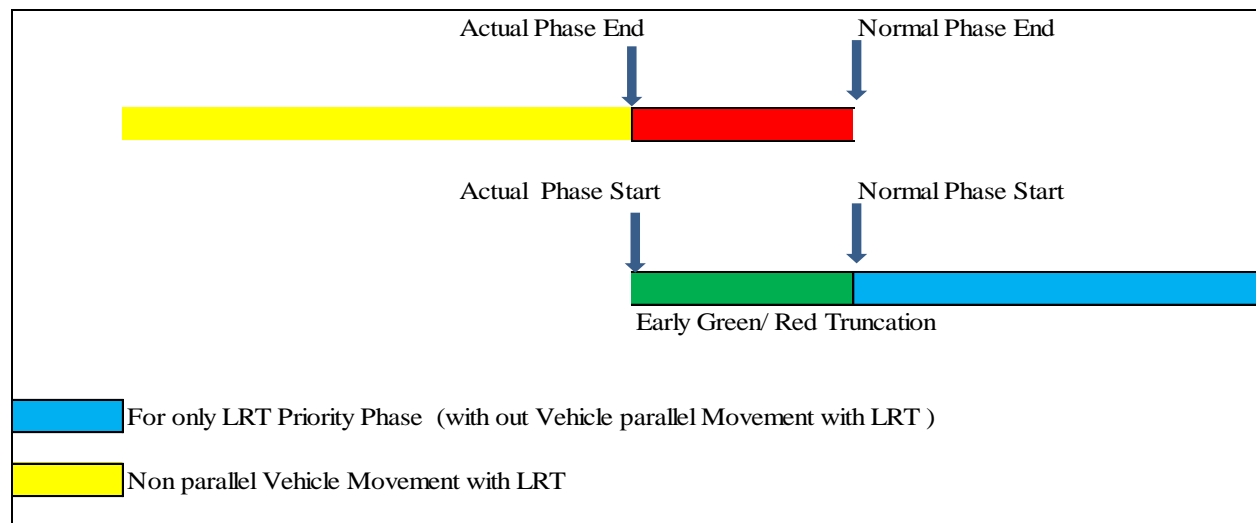


Figure 30. Red Truncation/Early Green Demonstration

### **3.7 Measurement of Performance (MOE)**

According to the HCM, any facility type that has a set procedure for determining capacity and service level also has performance metrics that may be calculated. Given a set of highway, traffic, and control circumstances, these measurements reflect the operational conditions of a facility. Examples of performance measurements that describe the flow conditions on a facility include travel speed and density on freeways, delay at signalized junctions, and walking pace for pedestrians. The key factor in determining the level of service is one or more of the mentioned performance measures. The service measure for each facility type is the phrase used to describe this LOS-determining metric. Delay is the service indicator for a signalized intersection. It is used to assess the quality of the service. (HCM, 2000)

## CHAPTER FOUR: RESULTS AND DISCUSSION

For the study area; Saris Adey Abeba light train Pedestrian and Motorized Vehicle Shared Spaced Intersection the proposed solutions based on identified problems were properly modeled in VISSIM 9 software and simulated accordingly. In this chapter analysis of results and discussion is provided. Hence, the performance measures as listed below on the study area are analyzed for the base condition and the proposed solution respectively. Finally the proposed solution is checked for the forecasted traffic of 5, 10 and 15 year.

- Travel Time
- Average and Maximum Queue Length
- Intersection Delay
- Level of Service (LOS)

### 4.1 Performance Evaluation for Adey Abeba light train Pedestrian and Motorized Vehicle Shared Spaced Intersection based on LOS

#### 4.1.1 Base Case Condition

The base condition is a condition with interaction of light train, Pedestrian and Motorized Vehicle with -out any traffic managements. In this condition the level service of the intersection is F. Maximum queue lengths of the study area is recorded up to 419m and average delay of an approach recorded up to 9.66 min/veh. The largest delay is observed on north approach which is coming from kadisko side with highest traffic flow and the recorded delay of the intersection is 8.1min. The analysis result on Table 21 shows the performance evaluation results of Adey Abeba light train, Pedestrian and Motorized Vehicle Shared Spaced Intersection.

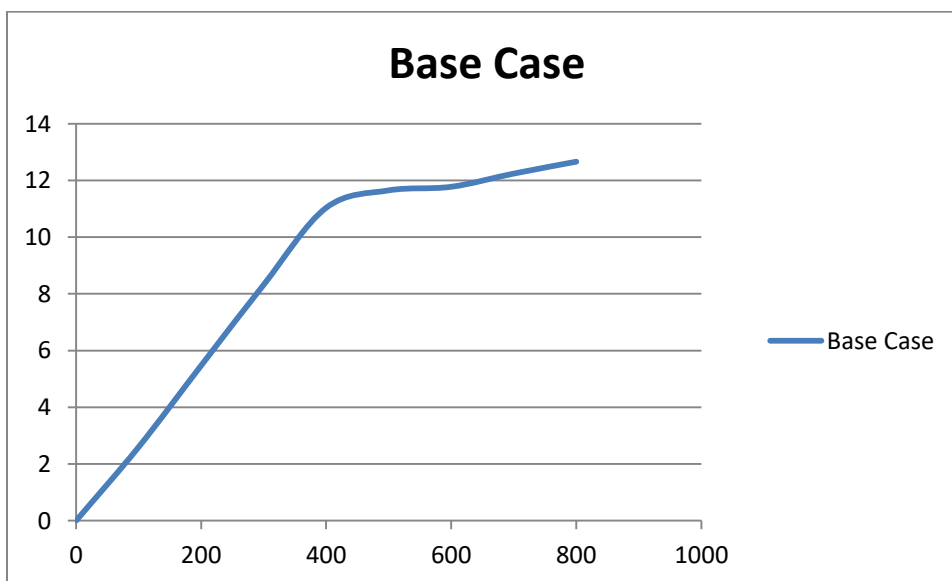


Figure 31. Travel time Vs Travel Distance result of Adey Abeba Intersection

Table 20. Performance Evaluation results of Adey Abeba Intersection in Base Condition

Approach	Traffic Movement	Traffic Volume	Max. Queue Length (m)	Aver. Queue Length (m)	Delay (min/veh.)	Approach Delay (min/veh)	Intersection Delay (min/veh)	Intersection Loss
Kadisco	Through	696	419	360	12.77	9.66	8.1	F
	Left	285			9.78			
	Right	89			7.86			
	U- Turn	248			8.23			
Saris	Through	525	413	341	8.51	9.05	8.1	F
	Left	248			5.61			
	Right	38			10.95			
	U- Turn	169			11.11			
Addis Sefer	Through	126	354	230	6.89	4.9	8.1	F
	Left	270			0.47			
	Right	173			7.2			
Bihere Tsigie	Through	118	422	356	9.2	8.8	8.1	F
	Left	450			12.58			
	Right	24			4.65			

#### 4.1.2 Installation of Fixed Traffic Signal

Installation of Fixed Signal Control in Adey Ababa intersection is based on the concept of north and south through and right turn vehicles will get green simultaneously with tram which approach from both north and south direction. On the other hand through with right turn of the remaining approaches and protected left turns of all approaches were getting green separately as per the design of fixed traffic signal. Hence, the VISSIM was analyzed without VISVAP (traffic signal controlling logic).

Table 22 shows the performance evaluation results of Adey Ababa intersection based on installation of fixed time signal control, the Intersection level of service is E. Intersection delay is 72.98 sec/veh which close to intersection delay determined in section 3.6.3.2 which is 80.89 sec/veh. The observed travel time along the major road controlled North approach is 12.66min.

Therefore, if fixed traffic signal control is installed on the existing intersection, travel time will be reduced by 78.9% (from 12.66min to 2.669min). Besides to this, the tram delay was increased due to provision of fixed traffic signal control which is 42.44sec and 41.54sec in North and South approach respectively that of base condition 31.3sec and 23.14sec for north and south approaches respectively. The VISSIM analysis results for the queue and delay on tram and vehicles were observed summarized in the table below.

Count: 8	SimRun	TimeInt	QueueCounter	QLen	QLenMax	QStops
1	1	0-3600	1	51.99	199.34	631
2	1	0-3600	2	13.79	71.24	102
3	1	0-3600	3	15.80	65.51	113
4	1	0-3600	4	31.03	113.38	435
5	1	0-3600	5	69.73	168.98	424
6	1	0-3600	6	286.12	407.08	1026
7	1	0-3600	7	20.76	94.17	178
8	1	0-3600	8	288.59	401.91	956

Figure 32. Max Queue Analysis for Fixed Traffic Signal Control for Adey Ababa Intersection

Count: 14	SimRun	TimeInt	DelayMeasurement	StopDelay(All)	Stops(All)	VehDelay(All)	Vehs(All)	PersDelay(All)	Pers(All)
1	1	0-3600	1: NT	80.29	1.26	91.26	605	91.26	605
2	1	0-3600	2: NR	79.90	1.22	88.85	77	88.85	77
3	1	0-3600	3: NL	81.31	1.19	90.29	276	90.29	276
4	1	0-3600	5: ST	59.56	0.97	69.20	511	69.20	511
5	1	0-3600	6: SR	60.05	0.90	66.96	29	66.96	29
6	1	0-3600	7: SL	71.56	1.02	80.92	251	80.92	251
7	1	0-3600	9: WT	48.86	0.79	54.81	96	54.81	96
8	1	0-3600	10: WR	58.70	0.76	63.63	21	63.63	21
9	1	0-3600	11: WL	87.72	1.11	96.60	425	96.60	425
10	1	0-3600	12: ET	49.22	0.80	54.82	49	54.82	49
11	1	0-3600	13: ER	60.61	0.91	67.09	67	67.09	67
12	1	0-3600	14: EL	44.61	0.83	51.40	225	51.40	225

Figure 33. Max Queue Analysis for Fixed Traffic Signal Control for Adey Ababa Intersection\

**Table 21. Performance Evaluation results of Adey Ababa Intersection with Fixed Traffic Signal**

Approach	Traffic Movement	Traffic Volume	Max. Queue Length (m)	Aver. Queue Length (m)	Delay (Sec/veh.)	Approach Delay (Sec/veh)	Intersection Delay (sec/veh)	Intersection Loss				
Kadisco	Through	696	199.34	51.99	91.26	90.13	72.98	E				
	Right	285			88.85							
	Left	89	407.08	286.12	90.29							
Saris	Through	525	113.8	31.03	69.2	72.36			72.98	E		
	Right	248			66.96							
	Left	38	401.91	288.59	80.92							
Addis Sefer	Through	126	65.51	15.8	54.82	57.77					72.98	E
	Right	270			67.09							
	Left	173	94.17	20.76	51.4							
Bihere Tsigie	Through	118	71.24	13.76	54.81	71.68	72.98	E				
	Right	450			63.63							
	Left	24	169.98	69.73	96.6							
Tram	North Approach	7			29.13	29.13			36	D		
	South Approach	6			42.91	42.91						

Table 52 Performance Evaluation results of Adey Ababa Intersection with Fixed Traffic Signal

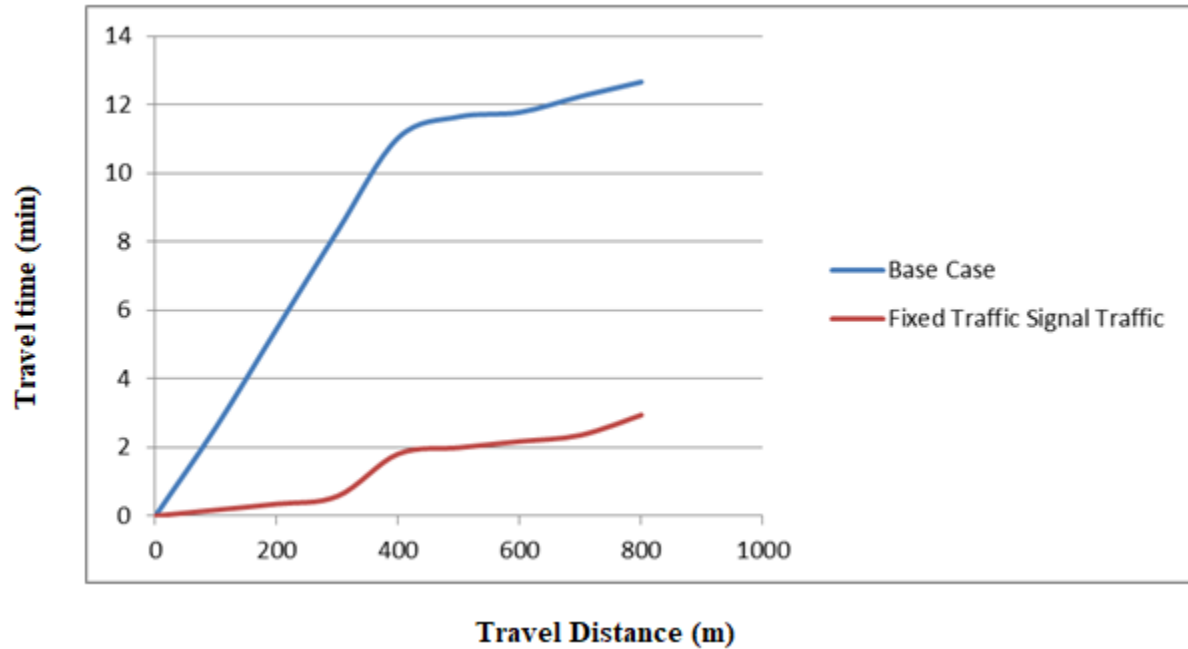


Figure 34. Travel Time- Distance Comparison of Fixed Traffic Signal with Base Case

#### 4.1.3 Provision of Transit Signal Priority Logic on Fixed Traffic

As stated in section 3.5.4 the fixed traffic signal control proposed for Adey Ababa intersection was modified to transit signal priority mode which includes green extension and red truncation by providing the traffic signal controller (PUA) file and traffic signal controller Logic VISVAP file.

Accordingly, Table 23 shows the performance evaluation results of Adey Ababa intersection based on installation of transit signal priority on fixed time signal control, the Intersection level of service is E. However, it shows that high amount of reduction of delay on North and South through movements and additional delay increment on other approaches opposite form tram direction. The overall intersection delay is 79.9 sec/veh. The observed travel time along the major road controlled north approach is 2.33 min. Therefore, if transit signal Priority signal control is installed on the existing intersection, travel time will be reduced by 81.65%. Besides to this, the tram delay due to provision of fixed traffic signal control is 7.82sec and 5.26sec in North and South approach respectively. And the tram travel time of 127.82sec and 125.26sec in North and South approach respectively. The VISSIM analysis results for the queue and delay on tram and vehicles were observed summarized in the table below.

Besides to this, in this analysis the queue and delay on tram and vehicles was observed as shown below.

Queue Results						
Select layout...						
Count: 8	SimRun	TimeInt	QueueCounter	QLen	QLenMax	QStops
1	1	0-3600	1	215.13	412.01	1980
2	1	0-3600	2	14.31	73.03	103
3	1	0-3600	3	15.11	84.35	113
4	1	0-3600	4	69.89	247.53	773
5	1	0-3600	5	46.64	168.93	413
6	1	0-3600	6	289.09	405.00	953
7	1	0-3600	7	16.14	92.91	170
8	1	0-3600	8	298.65	401.91	901

Figure 35. Maximum and Average Queue analysis of Transit Signal Priority in Adey Ababa Intersection

Table 22. Performance Evaluation results of Adey Ababa Intersection with Transit Signal Priority

Approach	Traffic Movement	Traffic Volume	Max. Queue Length (m)	Aver. Queue Length (m)	Delay (Sec/veh.)	Approach Delay (Sec/veh)	Intersection Delay	Intersection Los
Kadisco	Through	696	412.01	215.13	75.3	81.9	79.9	E
	Right	285			69.3			
	Left	89	405	289.09	103.5			
Saris	Through	525	92.91	16.14	52.2	89.6		
	Right	248			44.6			
	Left	38	401.91	298.65	172.99			
Addis Sefer	Through	126	84.35	15.11	68.6	66.46		
	Right	270			59.6			
	Left	173	247.53	69.89	71.2			
Bihere Tsige	Through	118	73.03	14.13	72.6	81.64		
	Right	450			60.72			
	Left	24	168.93	46.64	111.6			

Figure 36. Performance Evaluation results of Adey Ababa Intersection with Transit Signal Priority

Vehicle Travel Time Results						
Count: 56	SimRun	TimeInt	VehicleTravelTimeMeasurement	Vehs(All)	TravTm(All)	DistTrav(All)
47	1	0-3600	50	848	2.15	20.00
48	1	0-3600	51	847	2.19	20.38
49	1	0-3600	52	847	2.14	20.00
50	1	0-3600	53	846	2.13	20.00
51	1	0-3600	54	846	1.47	14.00
52	1	0-3600	55: TRAM NORTH	7	127.82	834.00
53	1	0-3600	56: TRAM SOUTH	6	125.26	833.69

Figure 37. Tram travel time analysis result under Transit Signal Priority in Adey Ababa Intersection

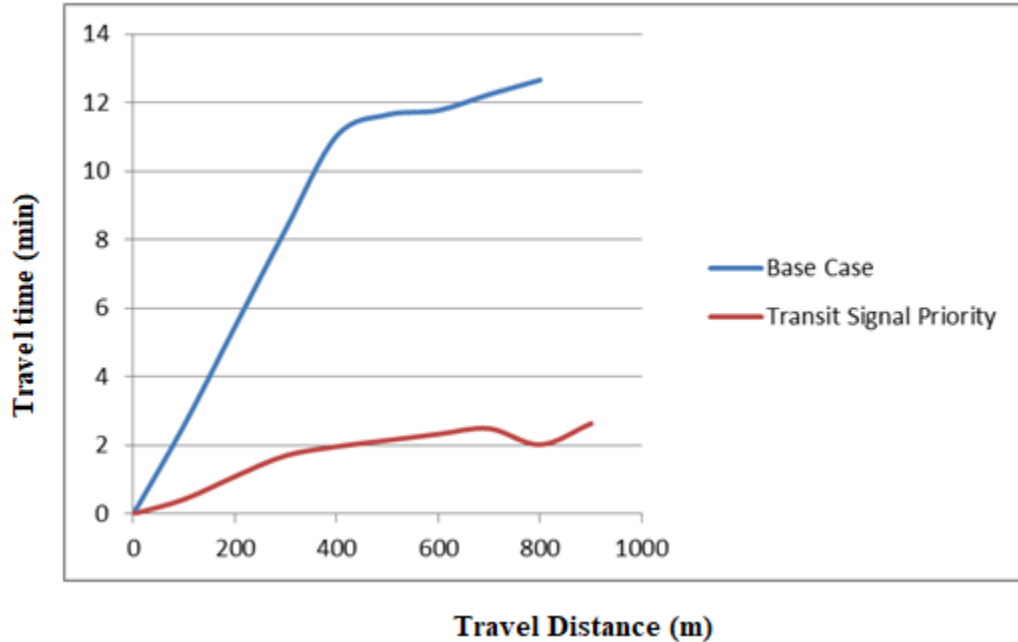


Figure 38. Travel Time- Distance Comparison of Transit Signal Priority with Base Case

## 4.2 Comparison within Alternatives under current traffic conditions for Adey Ababa Intersection

### 4.2.1 Performance Evaluation Based on Delay

Based on the proposed improving alternatives the following chart shows the effective reduction of intersection delay by providing of Transit Signal Priority, by 78.9% for vehicle. Similarly due to providing of fixed traffic signal on the intersection reduction of intersection delay observed, by 81.65% for vehicle from base condition. Regarding to tram, provision of fixed traffic signal has additional tram delay by 26.2% and transit signal Priority reduce the tram delay by 77.6% from base condition.

Therefore, provision of fixed traffic signal reduced more intersection delay for vehicles and additional delay on trams than provision transit signal priority.

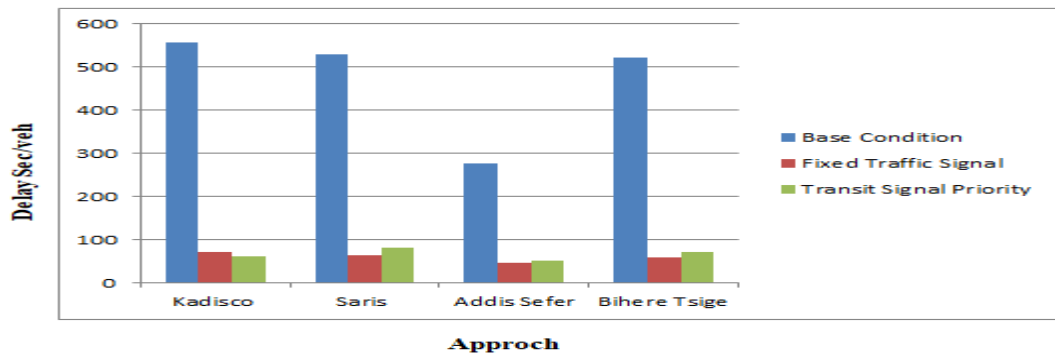


Figure 39. Delay comparison for proposed alternatives

### 4.2.2 Performance Evaluation based on Travel Time

From the proposed alternative improving solution, transit signal priority with green extension and red truncation provides the least travel time with 2.33min than that of fixed Traffic Signal 2.66min for the 834m intersection segment as shown below.

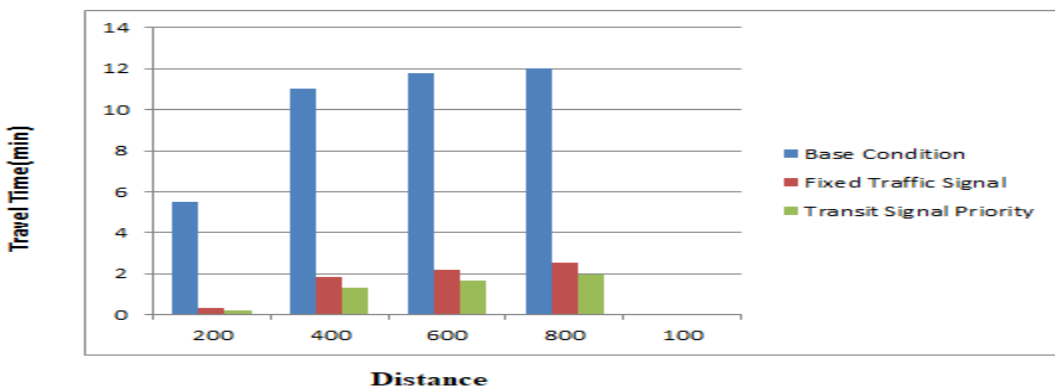


Figure 40. Travel Time Comparison of proposed alternatives

### 4.2.3 Performance Evaluation based on Average and Maximum Queue Lengths

From the Analysis result of simulation observed that the transit signal priority alternative has the lower maximum queue lengths on north and south approaches but has high maximum queue lengths on other approaches than fixed traffic signal. The analysis results are shown below.

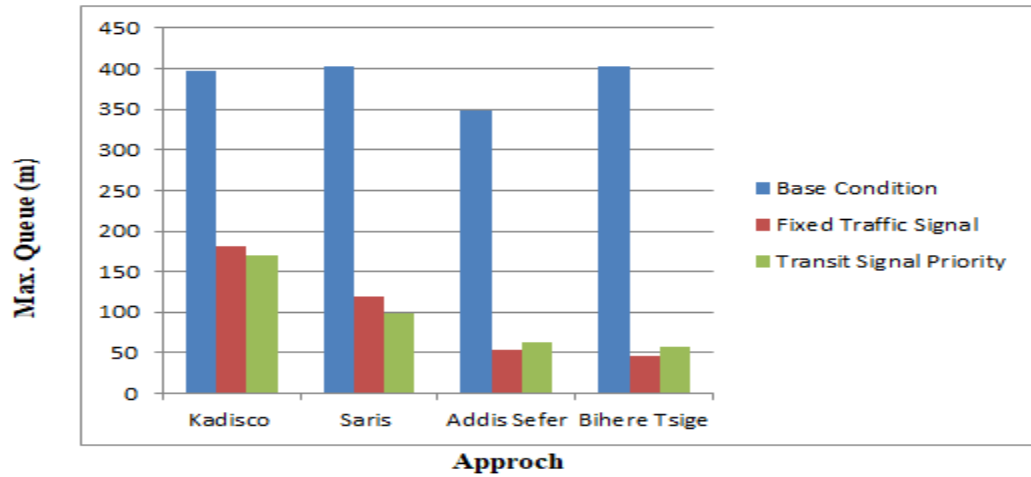


Figure 41. Maximum Queue Length for each Approach of Adey Ababa Intersection

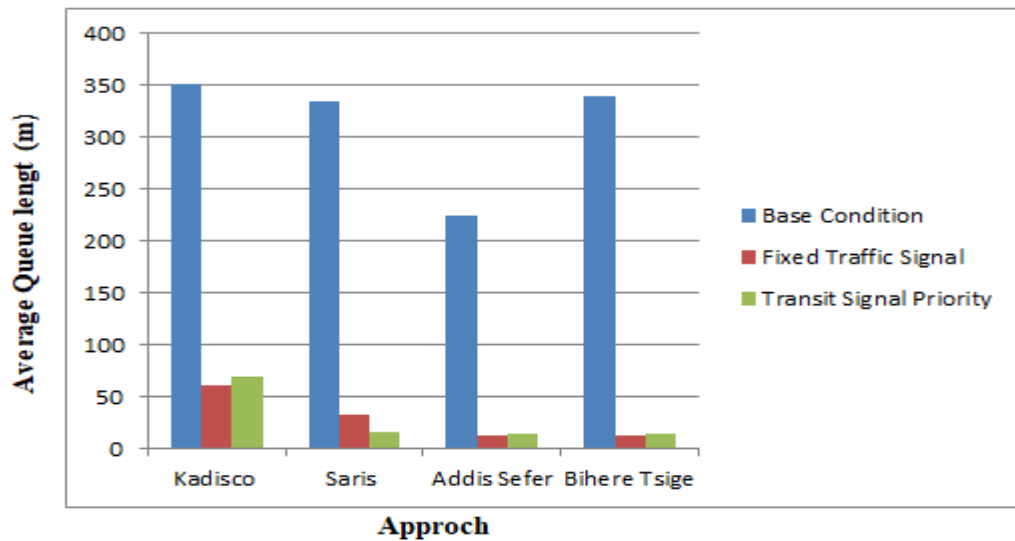


Figure 42. Average Queue Length for each Approach of Adey Ababa Intersection

### 4.3 Comparison of Improving Alternatives under Forecasted Traffic for Adey Ababa Intersection

As per the analysis results the best alternative for Adey Ababa intersection, based on current traffic condition is transit signal priority with Green Extension and Red truncation with delay reduction of north and south through approaches and tram. However, additional delay increment

observed on approaches which are opposite to tram way. In this section the performance of the proposed alternative solutions are going to analyzed and evaluated based on performance analysis measures under forecasted traffic conditions. In order to forecast future traffic a traffic growth rates that are used were prepared by CORE Consulting Engineers PLC based on demand elasticity and GDP growth rate. (Yilikal, October 2013) For the years of 2024-2040 an average growth rate of 6.6% and 6.8% is used for passenger cars and for heavy vehicles respectively. Traffic is forecasted for the next 5, 10, years and 15 years. Tables 54 to 57 show the forecasted traffic volumes of Adey Ababa Intersection.

Table 23. Year forecasted traffic for Adey Ababa Intersection

Adey Ababa Intersection		5 Years				
Morning Pick Hour Count Period	Approaches	Traffic Movement				Total Traffic Volu. (ve/hr)
		Through	Left Turn	Right Turn	U turn	
Heavy Vehicles	Saris	22	10	2	7	41
	Kadisco	39	16	5	14	73
	Addis Sefer	4	8	5	0	16
	Bihere Tsige	4	16	1	0	21
Passenger Vehicles	Saris	697	330	50	225	1303
	Kadisco	915	375	116	326	1733
	Addis Sefer	169	363	233	0	764
	Bihere Tsige	158	601	31.51	0	790
Total Vehicles	Saris	719	341	52	232	1344
	Kadisco	954	391	121	340	1806
	Addis Sefer	172	371	238	0	780
	Bihere Tsige	162	617	33	0	811

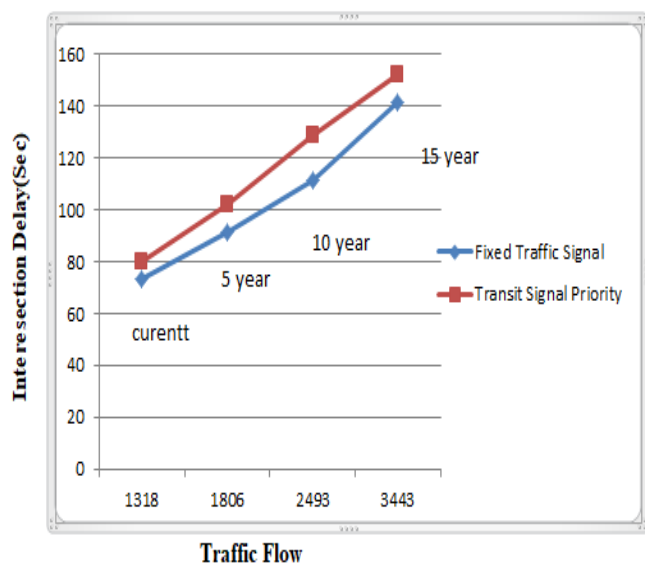
Table 24. Years forecasted traffic for Adey Ababa Intersection

Adey Ababa Intersection		10 Years				
Morning Pick Hour Count Period	Approaches	Traffic Movement				Total Traffic Volu. (ve/hr)
		Through	Left Turn	Right Turn	U turn	
Heavy Vehicles	Saris	30	14	2	10	57
	Kadisco	54	22	7	19	102
	Addis Sefer	5	10	7	0	22
	Bihere Tsige	6	22	2	0	29
Passenger Vehicles	Saris	962	455	70	310	1797
	Kadisco	1263	518	161	450	2391
	Addis Sefer	232	501	321	0	1055
	Bihere Tsige	217	829	43.47	0	1090
Total Vehicles	Saris	992	470	72	320	1854
	Kadisco	1316	540	168	469	2493
	Addis Sefer	237	511	328	0	1077
	Bihere Tsige	223	851	45	0	1119

Table 25. Years forecasted Traffic for Adey Ababa Intersection

Adey Ababa Interesection		15 Years				
Morning Pick Hour Count Period	Approaches	Traffic Movement				Total Traffic Volu. (ve/hr)
		Through	Left Turn	Right Turn	U turn	
Heavy Vehicles	Saris	42	20	3	14	79
	Kadisco	75	31	10	27	141
	Addis Sefer	7	14	9	0	30
	Bihere Tsige	8	30	3	0	41
Passenger Vehicles	Saris	1328	629	96	428	2482
	Kadisco	1743	715	222	621	3302
	Addis Sefer	321	692	444	0	1456
	Bihere Tsige	300	1145	60.03	0	1505
Total Vehicles	Saris	1371	649	99	442	2561
	Kadisco	1818	746	231	648	3443
	Addis Sefer	328	706	453	0	1487
	Bihere Tsige	308	1175	63	0	1546

Fixed traffic signal and Transit Signal Priority alternatives were evaluated for Adey Ababa Intersection under 5, 10 and 15 years forecasted traffic by using VISSIM software. The comparison analysis were done by using Travel time and intersection Delay for major road of north approach, which is the main approach that has pick traffic flow in the morning. Accordingly the analysis result discussed as follow.



Year	Veh/hr	Fixed Traffic	Transit Signal
0	1318	72.98	79.9
5	1806	91.5	101.2
10	2493	111.3	128.3
15	3443	141.2	152.3

Figure 43 . Comparison of alternatives under forecasted traffic with intersection delay

Based on the analysis of alternatives under forecasted traffic condition for Adey Ababa Intersection for performance evaluation of intersection delay as shown in the figure 60 Fixed Signal Priority has less intersection delay that of Transit Signal Priority for 5, 10 and 15 years of

forecasted traffic flow. An intersection delay for 15 year forecasted traffic is 130.1sec/veh for fixed traffic Signal Control and 140.5sec/veh for Transit Signal Priority. Hence both proposed improving alternatives has the same Los of E but due to fixed Traffic Signal Control has more delay on Tram than that of Transit Signal Priority, Transit signal Priority is the better alternative improving solution for Adey Ababa Intersection.

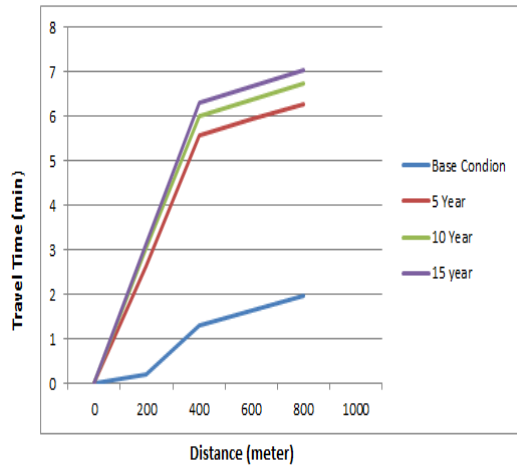


Figure 44. Travel time – Distance for Transit Signal Priority under Forecasted Traffic

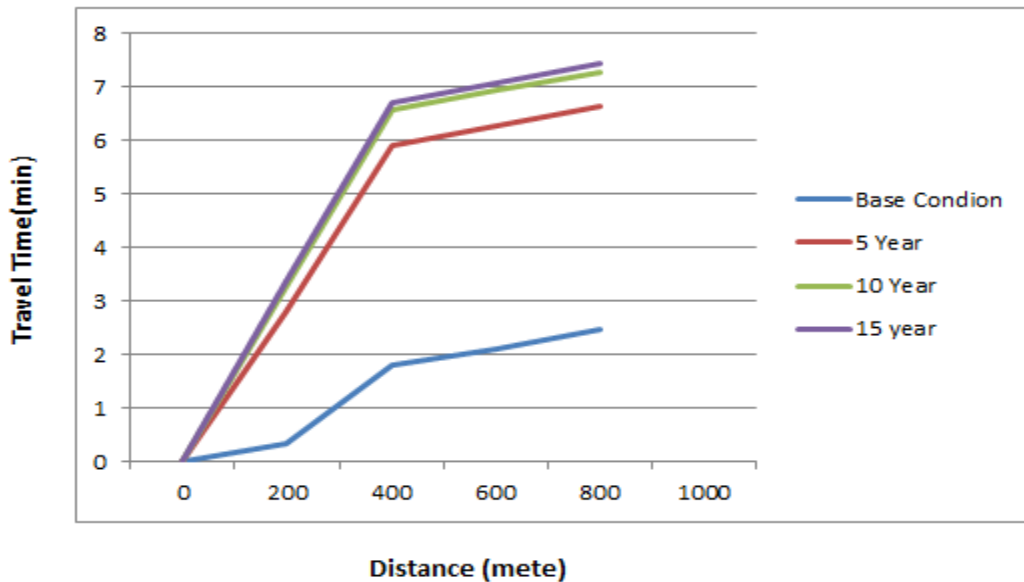
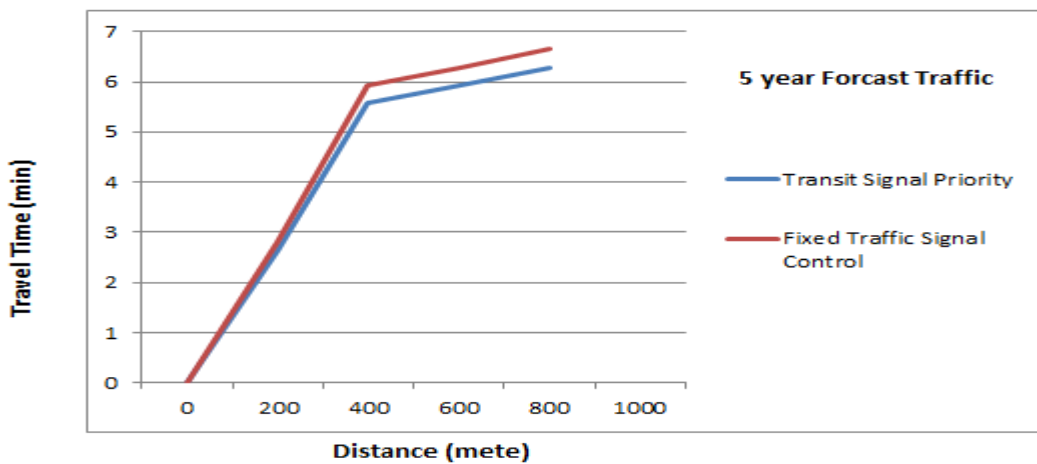
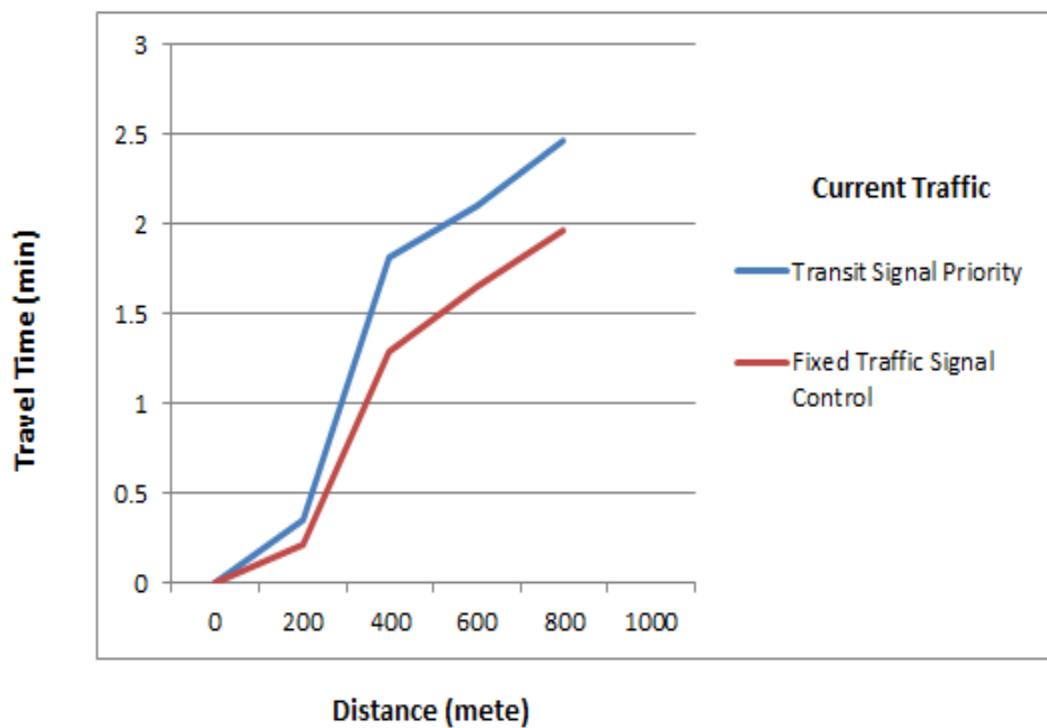
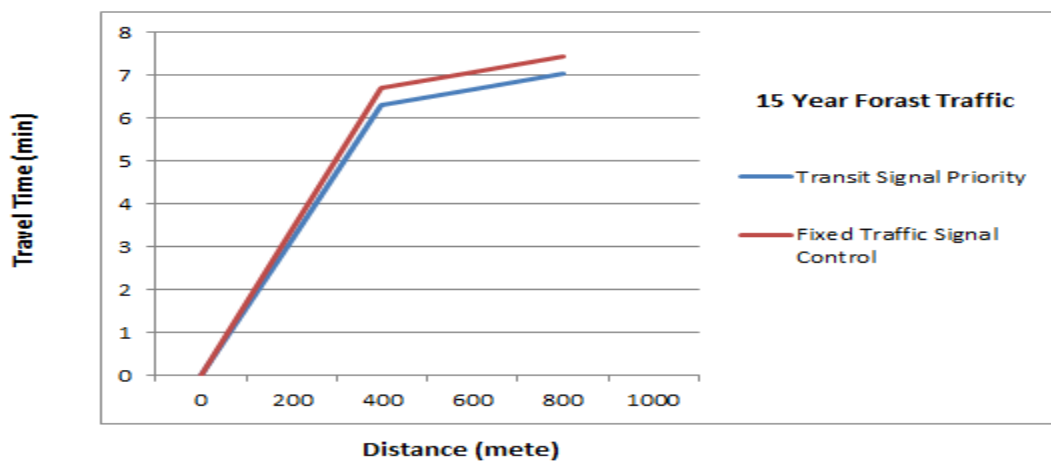
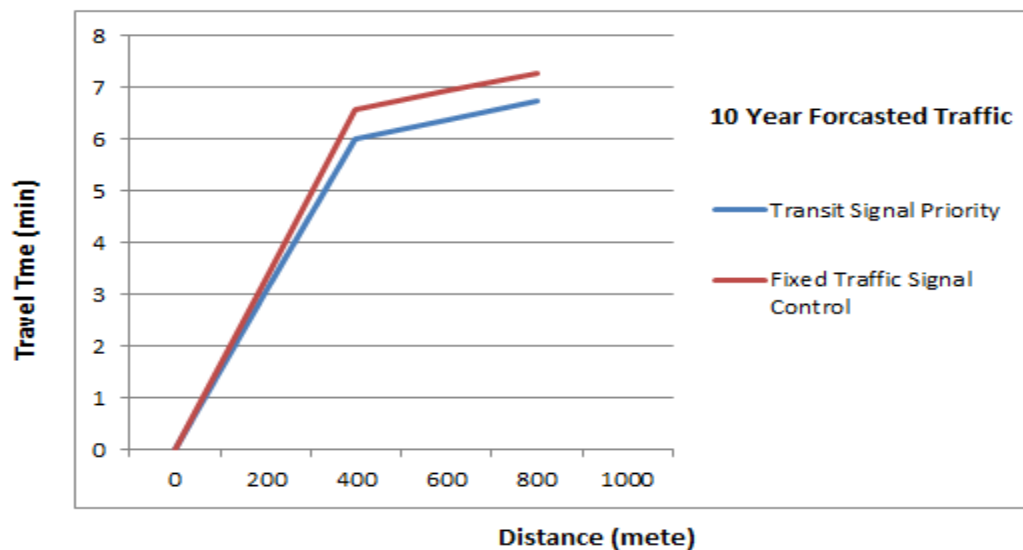


Figure 45. Travel time – Distance for Fixed Traffic Signal under Forecasted Traffic Comparison between Fixed Traffic Signal Control and Transit Signal Priority under Forecasted Traffic Flow





## CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

There are many studies related to the effect of provision of LRT line on the median of existing city road and the studies indicated there is additional delay and reduction of Level of Service on vehicles in roundabout and intersections. (Eskindr, 2014) (Demelash, 2019). In addition to this the previous study also show that signalized roundabout is a solid and effective alternative to improving the additional delay expected without considering actual tram arrival frequency (Rediet., 2018). This study concern on mitigating the effect by considering alternative improvements with the actual tram arrival frequency.

This study was done on Adey Ababa intersection which locates in North to South LRT direction. This intersection is at grade crossing of Light Train line pass through the media, Pedestrian and Vehicles shared Space. Light Train line pass through the media of the road.

Traffic data was collected for 6 hour by using video recording in order to determine traffic volume, travel time for fixed length of 834m at the study area. Based on the collected traffic data travel speed was determined for free and congested time of the study area.

Fixed traffic signal is designed for the study area with calibrated value of base saturation flow (So) from the pick hour traffic volume. Accordingly it was proposed as one alternative solution for the study area.

The aim of this study was to understand the performance of the intersection and identify the critical problem which affects the intersection performance. Accordingly based on the identified problems alternative improvising solutions was proposed and analyzed. The proposed alternative improving solutions are Transit Signal Priority, Fixed Traffic Signal Control, diverting of U turns far away from the intersection and Provision of Pedestrian Signal control. VISSIM simulation Software was used to model and analyses the proposed solutions and based on queue length, Travel time, intersection delay and level of Service the proposed solutions compared under base traffic forecasted traffics.

VISSIM simulation software was used to analyze the base condition, fixed traffic signal and transit signal priority alternative improvement solutions for light train, pedestrian and motorized vehicle shared space intersection.

As per the analysis it is found that fixed traffic signal control has less intersection delay of 72.98sec/veh vehicles and additional delay on tram whereas Transit Signal Priority has intersection delay of 79.9sec/veh on vehicles and deduce tram delay from base condition. Both alternatives have similar level of service of E.

A different major problem that affects the performance of Adey Abeba at grade intersection which located in the North-South LRT corridor was identified and accordingly Transit Signal Priority alternative solution with diverting of U- Turn and pedestrian signal can be a best and effective solution than that of Fixed Traffic Signal Controller.

## Recommendation

The final recommendation of this study is that, provision of Transit Signal Priority with green Extension and Red Truncation should be implemented on Adey Ababa at grade intersection in order to improve the performance of the intersection and to increase the efficiency of LRT service with very low delay.

Further study can be done

- Further improving the performance of the signalized alternatives by considering multiple/successive multi- shared spaced intersections.
- Assessment the impact of Transit Signal Priority on perspective of safety

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## APPENDIX A. ROW DATA

Table 26. Counted Traffic Data

Period	Time interval	Kadisco					Saris					Bihertsige				Addis Sefer			
		Left	through	Right	U-turn	total	Left	through	Right	U-turn	Total	Left	through	Right	Total	Left	through	Right	Total
Morning time 1:00 am - 3:00 am	1:00 - 1:15	26	165	0	30	221	19	96	4	21	140	115	40	10	165	45	25	33	103
	1:15 - 1:30	26	122	9	34	191	14	140	6	12	172	91	33	4	128	71	26	47	144
	1:30 - 1:45	98	202	23	60	383	10	138	4	24	176	149	23	6	178	64	33	53	150
	1:45 - 2:00	65	131	20	47	263	54	105	7	32	198	95	22	4	121	80	34	40	154
	2:00 - 2:15	72	188	22	71	353	62	138	12	40	252	96	27	6	129	55	33	33	121
	2:15 - 2:30	50	175	24	70	319	52	139	14	57	262	35	24	3	62	34	32	28	94
	2:30 - 2:45	40	170	20	53	283	80	143	5	40	268	46	41	4	91	48	46	36	130
2:45 - 3:00	39	159	16	50	264	20	111	3	30	164	67	21	2	90	38	32	26	96	
Mid day time 7:00 pm - 9:00 pm	7:00 - 7:15	38	153	24	61	276	9	86	13	22	130	67	31	7	105	42	40	27	109
	7:15 - 7:30	47	178	14	80	319	14	126	23	35	198	69	61	3	133	45	36	37	118
	7:30 - 7:45	70	180	25	74	349	20	97	17	25	159	55	29	6	90	29	24	24	77
	7:45 - 8:00	28	106	20	25	179	22	73	16	23	134	54	27	11	92	19	27	13	59
	8:00 - 8:15	58	99	23	17	197	19	85	20	29	153	60	23	15	98	30	23	19	72
	8:15 - 8:30	49	120	31	23	223	33	91	25	30	179	62	28	19	109	29	28	22	79
	8:30 - 8:45	32	146	30	45	253	35	133	22	36	226	70	36	10	116	40	20	27	87
8:45 - 9:00	70	180	28	74	352	20	97	17	25	159	55	29	6	90	29	24	24	77	
Night time 11:00 pm - 1:00 pm	11:00 - 11:15	76	130	23	58	287	27	92	17	38	174	11	16	14	41	8	4	4	16
	11:15 - 11:30	80	186	31	76	373	25	123	10	35	193	18	55	7	80	15	35	5	55
	11:30 - 11:45	117	224	23	87	451	27	146	27	52	252	21	46	9	76	19	42	7	68
	11:45 - 12:00	37	178	25	85	325	18	133	18	51	220	20	15	19	54	16	9	9	34
	12:00 - 12:15	75	218	32	67	392	33	156	28	55	272	6	11	11	28	10	2	14	26
	12:15 - 12:30	70	237	24	82	413	43	154	25	45	267	29	21	13	63	22	17	15	54
	12:30 - 12:45	87	186	19	78	370	27	98	24	36	185	11	12	7	30	13	10	11	34
12:45 - 1:00	96	205	23	86	410	23	89	18	44	174	14	9	11	34	18	13	15	46	

Table 27. Pick Hour Travel Time and Speed data Analysis

Vehicle No	Travel Time		Travel Distance	Speed Km/hr	crossing time			crossing distance (m)	crossing Speed (km/hr)	Approach distance (m)	Approach Speed (Km/hr)
	start time	end time (min)			crossing in (min)	crossing out (min)	crossing time (min)				
1	0.00	7.32	0.834	7	4.32	4.49	0.17	34	7	400	6
2	0.00	9.25	0.834	5	5.51	5.71	0.2	34	6	400	4
3	0.00	8.54	0.834	6	4.6	4.95	0.35	34	3	400	5
4	0.00	12.3	0.834	4	7.6	8.01	0.41	34	3	400	3
5	0.00	12.4	0.834	4	8.1	8.28	0.18	34	7	400	3
6	0.00	14.6	0.834	3	12.1	12.36	0.26	34	5	400	3
7	0.00	7.63	0.834	7	4.2	4.51	0.31	34	4	400	6
8	0.00	15.7	0.834	3	12.4	12.66	0.26	34	5	400	2
9	0.00	8.65	0.834	6	6.1	6.44	0.34	34	4	400	4
10	0.00	7.86	0.834	6	8.2	9	0.8	34	2	400	3
11	0.00	9.6	0.834	5	7.8	8.03	0.23	34	5	400	3
12	0.00	9.7	0.834	5	6.2	6.39	0.19	34	6	400	4
13	0.00	7.91	0.834	6	5.6	5.84	0.24	34	5	400	4
14	0.00	10.2	0.834	5	7.5	7.91	0.41	34	3	400	3
15	0.00	13.4	0.834	4	9.31	9.74	0.43	34	3	400	3
16	0.00	15.6	0.834	3	12.6	13.05	0.45	34	3	400	2
17	0.00	8.96	0.834	6	7.31	7.49	0.18	34	7	400	3
18	0.00	11.56	0.834	4	9.34	9.55	0.21	34	6	400	3
19	0.00	9.54	0.834	5	5.4	5.62	0.22	34	6	400	4
20	0.00	8.88	0.834	6	9.2	9.52	0.32	34	4	400	3
21	0.00	9.53	0.834	5	6.51	6.77	0.26	34	5	400	4
22	0.00	10.88	0.834	5	7.4	7.74	0.34	34	4	400	3
23	0.00	11.69	0.834	4	8.41	8.68	0.27	34	5	400	3
24	0.00	16.5	0.834	3	11.6	11.99	0.39	34	3	400	3
25	0.00	12.33	0.834	4	8.45	8.71	0.26	34	5	400	3
26	0.00	15.46	0.834	3	11.4	11.64	0.24	34	5	400	2
27	0.00	8.63	0.834	6	8.89	9.23	0.34	34	4	400	3
28	0.00	9.12	0.834	5	9.64	9.83	0.19	34	6	400	3
29	0.00	10.63	0.834	5	7.61	7.94	0.33	34	4	400	3
30	0.00	8.56	0.834	6	5.8	6.05	0.25	34	5	400	4
31	0.00	9.99	0.834	5	7.66	7.95	0.29	34	4	400	3
32	0.00	14.8	0.834	3	11.64	11.99	0.35	34	3	400	3
33	0.00	12.63	0.834	4	8.41	8.83	0.42	34	3	400	3
34	0.00	10.7	0.834	5	6.4	6.78	0.38	34	3	400	4
35	0.00	7.86	0.834	6	4.61	4.77	0.16	34	8	400	5
36	0.00	8.23	0.834	6	5.6	6.04	0.44	34	3	400	4

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
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37	0.00	11.52	0.834	4	7.44	7.73	0.29	34	4	400	3
38	0.00	13.62	0.834	4	7.54	7.75	0.21	34	6	400	3
39	0.00	12.95	0.834	4	8.41	8.76	0.35	34	3	400	3
40	0.00	11.63	0.834	4	6.41	6.77	0.36	34	3	400	4
41	0.00	8.37	0.834	6	5.91	6.32	0.41	34	3	400	4
42	0.00	9.56	0.834	5	6.47	6.64	0.17	34	7	400	4
43	0.00	15.63	0.834	3	12.4	12.6	0.2	34	6	400	2
44	0.00	16.45	0.834	3	13.6	13.95	0.35	34	3	400	2
45	0.00	12.96	0.834	4	7.61	8.02	0.41	34	3	400	3
46	0.00	8.91	0.834	6	5.68	5.86	0.18	34	7	400	4
47	0.00	7.61	0.834	7	4.6	4.86	0.26	34	5	400	5
48	0.00	10.67	0.834	5	6.4	6.71	0.31	34	4	400	4
49	0.00	11.23	0.834	4	5.14	5.4	0.26	34	5	400	5
50	0.00	14.98	0.834	3	9.51	9.85	0.34	34	4	400	3
51	0.00	15.62	0.834	3	10.54	11.34	0.8	34	2	400	3
52	0.00	7.89	0.834	6	4.9	5.13	0.23	34	5	400	5
53	0.00	9.47	0.834	5	6.4	6.59	0.19	34	6	400	4
54	0.00	8.36	0.834	6	5.4	5.64	0.24	34	5	400	4
55	0.00	10.56	0.834	5	6.1	6.51	0.41	34	3	400	4
56	0.00	11.95	0.834	4	6.4	6.54	0.14	34	9	400	4
57	0.00	13.22	0.834	4	9.14	9.59	0.45	34	3	400	3
58	0.00	14.66	0.834	3	10.4	10.58	0.18	34	7	400	3
59	0.00	15.88	0.834	3	11.6	11.81	0.21	34	6	400	3
60	0.00	11.66	0.834	4	5.61	5.83	0.22	34	6	400	4
61	0.00	12.33	0.834	4	7.62	7.94	0.32	34	4	400	3
62	0.00	17.23	0.834	3	14.3	14.44	0.14	34	9	400	2
63	0.00	11.26	0.834	4	6.11	6.45	0.34	34	4	400	4
64	0.00	10.35	0.834	5	5.4	5.65	0.25	34	5	400	4
65	0.00	9.86	0.834	5	6.4	6.68	0.28	34	4	400	4
66	0.00	7.62	0.834	7	5.2	5.51	0.31	34	4	400	5
67	0.00	6.99	0.834	7	4.1	4.49	0.39	34	3	400	6
68	0.00	14.27	0.834	4	10.4	10.55	0.15	34	8	400	3
69	0.00	7.68	0.834	7	3.5	3.76	0.26	34	5	400	7
70	0.00	8.34	0.834	6	4.4	4.71	0.31	34	4	400	5
71	0.00	9.45	0.834	5	5.4	5.78	0.38	34	3	400	4
72	0.00	14.63	0.834	3	10.32	10.56	0.24	34	5	400	2
73	0.00	15.23	0.834	3	10.54	10.72	0.18	34	7	400	2
74	0.00	16.52	0.834	3	11.64	11.84	0.2	34	6	400	2
75	0.00	9.53	0.834	5	5.6	6.03	0.43	34	3	400	4
76	0.00	8.34	0.834	6	4.6	4.91	0.31	34	4	400	5
77	0.00	10.66	0.834	5	6.54	6.8	0.26	34	5	400	4
78	0.00	11.25	0.834	4	6.6	6.98	0.38	34	3	400	4
79	0.00	10.67	0.834	5	7.1	7.28	0.18	34	7	400	3

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

80	0.00	11.23	0.834	4	5.12	5.37	0.25	34	5	400	5
81	0.00	14.98	0.834	3	10.35	10.49	0.14	34	9	400	2
82	0.00	15.62	0.834	3	11.61	11.99	0.38	34	3	400	2
83	0.00	7.89	0.834	6	4.9	5.14	0.24	34	5	400	5
84	0.00	9.47	0.834	5	5.1	5.49	0.39	34	3	400	5
85	0.00	8.36	0.834	6	4.3	4.54	0.24	34	5	400	6
86	0.00	10.56	0.834	5	5.5	5.69	0.19	34	6	400	4
87	0.00	11.95	0.834	4	6.1	6.51	0.41	34	3	400	4
88	0.00	13.22	0.834	4	7.4	7.66	0.26	34	5	400	3
89	0.00	14.66	0.834	3	8.3	8.75	0.45	34	3	400	3
90	0.00	15.88	0.834	3	9.8	9.97	0.17	34	7	400	2
91	0.00	10.35	0.834	5	6.4	6.81	0.41	34	3	400	4
92	0.00	9.56	0.834	5	5.1	5.24	0.14	34	9	400	5
93	0.00	11	0.834	5	6.4	6.6	0.2	34	6	400	4
94	0.00	15.3	0.834	3	9.14	9.49	0.35	34	3	400	3
95	0.00	7.33	0.834	7	4.1	4.51	0.41	34	3	400	6
96	0.00	8.69	0.834	6	4.9	5.08	0.18	34	7	400	5
97	0.00	14.62	0.834	3	8.4	8.66	0.26	34	5	400	3
98	0.00	17.23	0.834	3	10.5	10.81	0.31	34	4	400	2
99	0.00	11.26	0.834	4	5.6	5.86	0.26	34	5	400	4
100	0.00	10.35	0.834	5	4.5	4.84	0.34	34	4	400	5
101	0.00	9.86	0.834	5	4.6	5.4	0.8	34	2	400	5
102	0.00	7.62	0.834	7	3.9	4.13	0.23	34	5	400	6
103	0.00	6.99	0.834	7	4.1	4.29	0.19	34	6	400	6
104	0.00	14.27	0.834	4	8.31	8.55	0.24	34	5	400	3
105	0.00	7.68	0.834	7	3.5	3.91	0.41	34	3	400	7
106	0.00	8.34	0.834	6	4.1	4.53	0.43	34	3	400	6
107	0.00	9.45	0.834	5	5.4	5.85	0.45	34	3	400	4
108	0.00	14.63	0.834	3	9.21	9.39	0.18	34	7	400	3
109	0.00	15.23	0.834	3	10.5	10.71	0.21	34	6	400	2
110	0.00	15.46	0.834	3	9.5	9.72	0.22	34	6	400	3
111	0.00	8.63	0.834	6	4.1	4.42	0.32	34	4	400	6
112	0.00	9.12	0.834	5	5.5	5.69	0.19	34	6	400	4
113	0.00	10.63	0.834	5	4.9	5.13	0.23	34	5	400	5
114	0.00	8.56	0.834	6	3.9	4.21	0.31	34	4	400	6
115	0.00	9.99	0.834	5	5.4	5.66	0.26	34	5	400	4
116	0.00	11.23	0.834	4	5.12	5.46	0.34	34	4	400	5
117	0.00	14.98	0.834	3	10.35	10.63	0.28	34	4	400	2
118	0.00	15.62	0.834	3	11.61	11.8	0.19	34	6	400	2
119	0.00	7.89	0.834	6	4.9	5.11	0.21	34	6	400	5
120	0.00	9.47	0.834	5	5.1	5.46	0.36	34	3	400	5
121	0.00	8.36	0.834	6	4.3	4.64	0.34	34	4	400	6
122	0.00	10.56	0.834	5	5.5	5.89	0.39	34	3	400	4

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

123	0.00	11.95	0.834	4	6.1	6.35	0.25	34	5	400	4
124	0.00	13.22	0.834	4	7.4	7.69	0.29	34	4	400	3
125	0.00	14.66	0.834	3	8.3	8.48	0.18	34	7	400	3
126	0.00	15.88	0.834	3	9.8	10.11	0.31	34	4	400	2
127	0.00	10.35	0.834	5	6.4	6.75	0.35	34	3	400	4
128	0.00	9.56	0.834	5	5.1	5.49	0.39	34	3	400	5
129	0.00	11	0.834	5	6.4	6.65	0.25	34	5	400	4
130	0.00	15.3	0.834	3	9.14	9.41	0.27	34	5	400	3
131	0.00	7.33	0.834	7	4.1	4.44	0.34	34	4	400	6
132	0.00	8.69	0.834	6	4.9	5.29	0.39	34	3	400	5
133	0.00	14.62	0.834	3	8.4	8.75	0.35	34	3	400	3
134	0.00	17.23	0.834	3	10.5	10.74	0.24	34	5	400	2
135	0.00	11.26	0.834	4	5.6	5.78	0.18	34	7	400	4
136	0.00	12.3	0.834	4	6.2	6.46	0.26	34	5	400	4
137	0.00	12.4	0.834	4	7.1	7.34	0.24	34	5	400	3
138	0.00	14.6	0.834	3	9.61	9.98	0.37	34	3	400	2
139	0.00	7.63	0.834	7	3.4	3.81	0.41	34	3	400	7
140	0.00	15.7	0.834	3	10.5	10.95	0.45	34	3	400	2
141	0.00	8.65	0.834	6	4.1	4.42	0.32	34	4	400	6
142	0.00	7.86	0.834	6	3.9	4.16	0.26	34	5	400	6
143	0.00	9.6	0.834	5	4.5	4.88	0.38	34	3	400	5
144	0.00	9.7	0.834	5	7.1	7.36	0.26	34	5	400	3
145	0.00	7.91	0.834	6	3.5	3.79	0.29	34	4	400	7
146	0.00	10.2	0.834	5	6.1	6.29	0.19	34	6	400	4
147	0.00	9.99	0.834	5	6.1	6.3	0.2	34	6	400	4
148	0.00	15.62	0.834	3	9.15	9.49	0.34	34	4	400	3
149	0.00	13.24	0.834	4	9.14	9.55	0.41	34	3	400	3
150	0.00	12.67	0.834	4	7.4	7.86	0.46	34	3	400	3
151	0.00	11.21	0.834	4	5.6	5.95	0.35	34	3	400	4
152	0.00	8.61	0.834	6	4.8	5.08	0.28	34	4	400	5
153	0.00	9.45	0.834	5	4.5	4.76	0.26	34	5	400	5
154	0.00	7.93	0.834	6	3.4	3.64	0.24	34	5	400	7
155	0.00	8.12	0.834	6	4.6	4.94	0.34	34	4	400	5
156	0.00	16.84	0.834	3	9.15	9.54	0.39	34	3	400	3
157	0.00	15.46	0.834	3	9.45	9.86	0.41	34	3	400	3
158	0.00	11.35	0.834	4	6.1	6.3	0.2	34	6	400	4
159	0.00	12.53	0.834	4	6.4	6.75	0.35	34	3	400	4
160	0.00	8.61	0.834	6	4.1	4.51	0.41	34	3	400	6
161	0.00	7.96	0.834	6	3.6	3.78	0.18	34	7	400	7
162	0.00	9.64	0.834	5	4.5	4.76	0.26	34	5	400	5
163	0.00	10.67	0.834	5	6.1	6.41	0.31	34	4	400	4
164	0.00	8.97	0.834	6	4.6	4.86	0.26	34	5	400	5
165	0.00	7.92	0.834	6	4.9	5.24	0.34	34	4	400	5

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

166	0.00	14.67	0.834	3	9.4	10.2	0.8	34	2	400	3
167	0.00	13.54	0.834	4	9.6	9.83	0.23	34	5	400	3
168	0.00	16.78	0.834	3	11.4	11.59	0.19	34	6	400	2
169	0.00	9.88	0.834	5	4.6	4.84	0.24	34	5	400	5
170	0.00	12.66	0.834	4	6.4	6.81	0.41	34	3	400	4
171	0.00	11.57	0.834	4	5.5	5.93	0.43	34	3	400	4
172	0.00	10.99	0.834	5	5.1	5.55	0.45	34	3	400	5
173	0.00	9.82	0.834	5	4.8	4.98	0.18	34	7	400	5
174	0.00	8.62	0.834	6	4.5	4.71	0.21	34	6	400	5
175	0.00	9.56	0.834	5	4.1	4.32	0.22	34	6	400	6
176	0.00	10.23	0.834	5	5.6	5.92	0.32	34	4	400	4
177	0.00	11.34	0.834	4	6.4	6.66	0.26	34	5	400	4
178	0.00	15.62	0.834	3	8.9	9.24	0.34	34	4	400	3
179	0.00	16.78	0.834	3	9.74	10.01	0.27	34	5	400	2
180	0.00	8.92	0.834	6	4.2	4.59	0.39	34	3	400	6
181	0.00	7.65	0.834	7	3.4	3.66	0.26	34	5	400	7
182	0.00	10.96	0.834	5	5.9	6.14	0.24	34	5	400	4
183	0.00	9.74	0.834	5	5.1	5.44	0.34	34	4	400	5
184	0.00	12.85	0.834	4	8.14	8.33	0.19	34	6	400	3
185	0.00	9.14	0.834	5	4.9	5.23	0.33	34	4	400	5
186	0.00	8.55	0.834	6	4.1	4.35	0.25	34	5	400	6
187	0.00	7.32	0.834	7	3.4	3.69	0.29	34	4	400	7
188	0.00	9.25	0.834	5	4.2	4.55	0.35	34	3	400	6
189	0.00	7.89	0.834	6	3.6	4.02	0.42	34	3	400	7
190	0.00	12.35	0.834	4	8.16	8.54	0.38	34	3	400	3
191	0.00	6.98	0.834	7	3.8	3.96	0.16	34	8	400	6
192	0.00	8.61	0.834	6	4.21	4.65	0.44	34	3	400	6
193	0.00	14.62	0.834	3	9.64	9.93	0.29	34	4	400	2
194	0.00	12.38	0.834	4	7.1	7.31	0.21	34	6	400	3
195	0.00	11.67	0.834	4	5.9	6.04	0.14	34	9	400	4
196	0.00	10.62	0.834	5	5.9	6.26	0.36	34	3	400	4
197	0.00	11.34	0.834	4	5.9	6.31	0.41	34	3	400	4
198	0.00	15.64	0.834	3	10.5	10.64	0.14	34	9	400	3
199	0.00	14.75	0.834	3	8.12	8.32	0.2	34	6	400	3
200	0.00	13.64	0.834	4	7.5	7.85	0.35	34	3	400	3
201	0.00	11.23	0.834	4	5.4	5.81	0.41	34	3	400	4
202	0.00	12.67	0.834	4	6.4	6.59	0.19	34	6	400	4
203	0.00	8.79	0.834	6	4.9	5.16	0.26	34	5	400	5
204	0.00	14.67	0.834	3	8.15	8.46	0.31	34	4	400	3
205	0.00	7.21	0.834	7	3.5	3.67	0.17	34	7	400	7
206	0.00	8.99	0.834	6	4.1	4.44	0.34	34	4	400	6
207	0.00	14.39	0.834	3	9.18	9.98	0.8	34	2	400	3
208	0.00	7.91	0.834	6	3.7	3.93	0.23	34	5	400	6

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

209	0.00	8.39	0.834	6	4.1	4.29	0.19	34	6	400	6
210	0.00	7.86	0.834	6	8.2	8.44	0.24	34	5	400	3
211	0.00	9.6	0.834	5	7.8	7.94	0.14	34	9	400	3
212	0.00	9.7	0.834	5	6.2	6.63	0.43	34	3	400	4
213	0.00	7.91	0.834	6	5.6	6.05	0.45	34	3	400	4
214	0.00	10.2	0.834	5	7.5	7.66	0.16	34	8	400	3
215	0.00	13.4	0.834	4	9.31	9.52	0.21	34	6	400	3
216	0.00	15.6	0.834	3	12.6	12.82	0.22	34	6	400	3
217	0.00	8.96	0.834	6	7.31	7.45	0.14	34	9	400	3
218	0.00	11.56	0.834	4	9.34	9.6	0.26	34	5	400	3
219	0.00	9.54	0.834	5	5.4	5.74	0.34	34	4	400	4
220	0.00	8.88	0.834	6	9.2	9.45	0.25	34	5	400	3
221	0.00	9.53	0.834	5	6.51	6.79	0.28	34	4	400	4
222	0.00	10.88	0.834	5	7.4	7.71	0.31	34	4	400	3
223	0.00	11.69	0.834	4	8.41	8.8	0.39	34	3	400	3
224	0.00	16.5	0.834	3	11.6	11.85	0.25	34	5	400	2
225	0.00	12.33	0.834	4	8.45	8.71	0.26	34	5	400	3
226	0.00	15.46	0.834	3	11.4	11.71	0.31	34	4	400	2
227	0.00	8.63	0.834	6	8.89	9.07	0.18	34	7	400	3
228	0.00	9.12	0.834	5	9.64	9.87	0.23	34	5	400	2
229	0.00	10.63	0.834	5	7.61	7.95	0.34	34	4	400	3
230	0.00	8.56	0.834	6	5.8	6.28	0.48	34	3	400	4
231	0.00	9.99	0.834	5	7.66	8.12	0.46	34	3	400	3
232	0.00	14.8	0.834	3	11.64	11.9	0.26	34	5	400	2
233	0.00	12.63	0.834	4	8.41	8.78	0.37	34	3	400	3
234	0.00	10.7	0.834	5	6.4	6.72	0.32	34	4	400	4
235	0.00	7.86	0.834	6	4.61	4.87	0.26	34	5	400	5
236	0.00	8.23	0.834	6	5.6	5.79	0.19	34	6	400	4
237	0.00	11.52	0.834	4	7.44	7.68	0.24	34	5	400	3
238	0.00	13.62	0.834	4	7.54	7.99	0.45	34	3	400	3
239	0.00	12.95	0.834	4	8.41	8.9	0.49	34	2	400	3
240	0.00	11.63	0.834	4	6.41	6.57	0.16	34	8	400	4
241	0.00	11.37	0.834	4	5.4	5.81	0.41	34	3	400	4
242	0.00	16.88	0.834	3	9.15	9.51	0.36	34	3	400	3
243	0.00	14.69	0.834	3	8.24	8.49	0.25	34	5	400	3
244	0.00	11.37	0.834	4	5.1	5.44	0.34	34	4	400	5
245	0.00	12.67	0.834	4	5.9	6.19	0.29	34	4	400	4
246	0.00	10.56	0.834	5	5.1	5.34	0.24	34	5	400	5
247	0.00	8.69	0.834	6	4.1	4.41	0.31	34	4	400	6
248	0.00	7.34	0.834	7	3.65	3.81	0.16	34	8	400	7
249	0.00	10.62	0.834	5	6.1	6.56	0.46	34	3	400	4
250	0.00	11.67	0.834	4	5.4	5.55	0.15	34	8	400	4
251	0.00	9.64	0.834	5	4.5	4.68	0.18	34	7	400	5

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252	0.00	12.34	0.834	4	5.1	5.24	0.14	34	9	400	5
253	0.00	8.61	0.834	6	4.8	5.16	0.36	34	3	400	5
254	0.00	14.62	0.834	3	8.41	8.8	0.39	34	3	400	3
255	0.00	12.38	0.834	4	6.1	6.24	0.14	34	9	400	4
256	0.00	11.67	0.834	4	5.74	5.98	0.24	34	5	400	4
257	0.00	10.62	0.834	5	5.4	5.65	0.25	34	5	400	4
258	0.00	11.34	0.834	4	6.4	6.54	0.14	34	9	400	4
259	0.00	15.64	0.834	3	9.6	10.01	0.41	34	3	400	3
260	0.00	14.75	0.834	3	8.45	8.63	0.18	34	7	400	3
261	0.00	13.64	0.834	4	7.51	7.72	0.21	34	6	400	3
262	0.00	11.23	0.834	4	5.7	6.01	0.31	34	4	400	4
263	0.00	12.67	0.834	4	5.9	6.25	0.35	34	3	400	4
264	0.00	8.79	0.834	6	4.1	4.26	0.16	34	8	400	6
265	0.00	14.67	0.834	3	9.64	10.13	0.49	34	2	400	2
266	0.00	7.21	0.834	7	3.64	4.06	0.42	34	3	400	7
267	0.00	8.99	0.834	6	4.4	4.54	0.14	34	9	400	5
268	0.00	14.39	0.834	3	8.64	8.89	0.25	34	5	400	3
269	0.00	6.48	0.834	8	3.5	3.84	0.34	34	4	400	7
270	0.00	8.91	0.834	6	4.67	5.13	0.46	34	3	400	5
271	0.00	12.61	0.834	4	6.14	6.29	0.15	34	8	400	4
272	0.00	11.34	0.834	4	5.64	5.91	0.27	34	5	400	4
273	0.00	14.65	0.834	3	9.5	9.89	0.39	34	3	400	3
274	0.00	13.64	0.834	4	8.4	8.54	0.14	34	9	400	3
275	0.00	14.64	0.834	3	6.9	7.25	0.35	34	3	400	3
276	0.00	10.34	0.834	5	5.1	5.36	0.26	34	5	400	5
277	0.00	9.88	0.834	5	4.8	4.95	0.15	34	8	400	5
278	0.00	7.91	0.834	6	3.14	3.36	0.22	34	6	400	8
279	0.00	9.63	0.834	5	4.67	4.86	0.19	34	6	400	5
280	0.00	10.37	0.834	5	9.64	9.78	0.14	34	9	400	2
281	0.00	11.21	0.834	4	4.98	5.44	0.46	34	3	400	5
282	0.00	10.61	0.834	5	4.64	5.13	0.49	34	2	400	5
283	0.00	8.61	0.834	6	3.89	4.05	0.16	34	8	400	6
284	0.00	12.34	0.834	4	5.21	5.47	0.26	34	5	400	5
285	0.00	14.35	0.834	3	8.67	8.88	0.21	34	6	400	3
286	0.00	12.38	0.834	4	6.45	6.82	0.37	34	3	400	4
287	0.00	12.45	0.834	4	5.89	6.04	0.15	34	8	400	4
288	0.00	10.91	0.834	5	4.64	5.12	0.48	34	3	400	5
289	0.00	9.37	0.834	5	4.12	4.58	0.46	34	3	400	6
290	0.00	8.61	0.834	6	4.26	4.52	0.26	34	5	400	6
291	0.00	16.34	0.834	3	9.64	9.78	0.14	34	9	400	2
292	0.00	8.62	0.834	6	4.1	4.42	0.32	34	4	400	6
293	0.00	9.56	0.834	5	4.65	4.91	0.26	34	5	400	5
294	0.00	10.23	0.834	5	5.14	5.29	0.15	34	8	400	5

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

295	0.00	11.34	0.834	4	5.47	5.71	0.24	34	5	400	4
296	0.00	15.62	0.834	3	10.24	10.69	0.45	34	3	400	2
297	0.00	16.78	0.834	3	9.64	10.13	0.49	34	2	400	2
298	0.00	8.92	0.834	6	4.78	4.92	0.14	34	9	400	5
299	0.00	7.65	0.834	7	3.56	3.97	0.41	34	3	400	7
300	0.00	10.96	0.834	5	4.5	4.86	0.36	34	3	400	5
301	0.00	9.74	0.834	5	3.89	4.14	0.25	34	5	400	6
302	0.00	12.85	0.834	4	7.24	7.58	0.34	34	4	400	3
303	0.00	9.14	0.834	5	6.31	6.6	0.29	34	4	400	4
304	0.00	8.55	0.834	6	4.26	4.4	0.14	34	9	400	6
305	0.00	7.32	0.834	7	5.68	5.99	0.31	34	4	400	4
306	0.00	9.25	0.834	5	5.67	5.85	0.18	34	7	400	4
307	0.00	8.54	0.834	6	3.68	4.14	0.46	34	3	400	7
308	0.00	12.3	0.834	4	7.12	7.41	0.29	34	4	400	3
309	0.00	8.96	0.834	6	4.12	4.3	0.18	34	7	400	6
310	0.00	12.34	0.834	4	6.54	6.85	0.31	34	4	400	4
311	0.00	11.35	0.834	4	6.95	7.33	0.38	34	3	400	3
312	0.00	14.36	0.834	3	8.64	9.03	0.39	34	3	400	3
313	0.00	13.64	0.834	4	7.61	7.95	0.34	34	4	400	3
314	0.00	9.56	0.834	5	5.21	5.47	0.26	34	5	400	5
315	0.00	8.67	0.834	6	4.98	5.27	0.29	34	4	400	5
316	0.00	7.61	0.834	7	4.1	6.5	2.4	34	1	400	6
317	0.00	12.37	0.834	4	7.56	7.97	0.41	34	3	400	3
318	0.00	10.64	0.834	5	6.54	7.03	0.49	34	2	400	4
319	0.00	11.35	0.834	4	6.89	7.06	0.17	34	7	400	3
320	0.00	8.61	0.834	6	4.56	4.93	0.37	34	3	400	5
321	0.00	9.64	0.834	5	5.45	5.72	0.27	34	5	400	4
322	0.00	12.64	0.834	4	7.65	7.79	0.14	34	9	400	3
323	0.00	11.34	0.834	4	6.84	7.15	0.31	34	4	400	4
324	0.00	10.94	0.834	5	5.91	6.17	0.26	34	5	400	4
325	0.00	9.64	0.834	5	5.68	5.94	0.26	34	5	400	4
326	0.00	10.56	0.834	5	7.34	7.72	0.38	34	3	400	3
327	0.00	11.37	0.834	4	6.54	6.8	0.26	34	5	400	4
328	0.00	9.39	0.834	5	5.14	5.43	0.29	34	4	400	5
329	0.00	8.34	0.834	6	4.56	4.75	0.19	34	6	400	5
330	0.00	7.61	0.834	7	4.51	4.71	0.2	34	6	400	5
331	0.00	16.54	0.834	3	10.54	10.88	0.34	34	4	400	3
332	0.00	15.64	0.834	3	9.61	10.02	0.41	34	3	400	3
333	0.00	14.35	0.834	3	9.64	10.1	0.46	34	3	400	3
334	0.00	11.39	0.834	4	5.64	5.99	0.35	34	3	400	4
335	0.00	10.29	0.834	5	5.61	5.89	0.28	34	4	400	4
336	0.00	12.36	0.834	4	7.64	7.9	0.26	34	5	400	3
337	0.00	14.3	0.834	3	8.92	9.16	0.24	34	5	400	3

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

338	0.00	15.7	0.834	3	9.65	9.99	0.34	34	4	400	3
339	0.00	16.9	0.834	3	9.51	9.9	0.39	34	3	400	3
340	0.00	10.37	0.834	5	6.1	6.51	0.41	34	3	400	4
341	0.00	9.34	0.834	5	5.6	5.8	0.2	34	6	400	4
342	0.00	8.93	0.834	6	4.52	4.87	0.35	34	3	400	5
343	0.00	9.34	0.834	5	5.98	6.39	0.41	34	3	400	4
344	0.00	10.38	0.834	5	6.54	6.72	0.18	34	7	400	4
345	0.00	11.29	0.834	4	6.54	6.8	0.26	34	5	400	4
346	0.00	9.64	0.834	5	4.65	4.96	0.31	34	4	400	5
347	0.00	9.34	0.834	5	6.51	6.77	0.26	34	5	400	4
348	0.00	8.61	0.834	6	4.52	4.86	0.34	34	4	400	5
349	0.00	7.91	0.834	6	3.54	4.34	0.8	34	2	400	7
350	0.00	11.23	0.834	4	5.5	5.73	0.23	34	5	400	4
351	0.00	12.67	0.834	4	6.1	6.29	0.19	34	6	400	4
352	0.00	14.67	0.834	3	8.61	8.85	0.24	34	5	400	3
353	0.00	15.64	0.834	3	9.61	10.02	0.41	34	3	400	3
354	0.00	16.89	0.834	3	8.34	8.77	0.43	34	3	400	3
355	0.00	12.64	0.834	4	6.54	6.99	0.45	34	3	400	4
356	0.00	13.26	0.834	4	7.64	7.82	0.18	34	7	400	3
357	0.00	11.34	0.834	4	6.4	6.61	0.21	34	6	400	4
358	0.00	15.46	0.834	3	9.61	9.83	0.22	34	6	400	3
359	0.00	14.62	0.834	3	8.5	8.82	0.32	34	4	400	3
360	0.00	12.34	0.834	4	5.89	6.15	0.26	34	5	400	4
361	0.00	11.67	0.834	4	5.4	5.74	0.34	34	4	400	4
362	0.00	9.64	0.834	5	4.5	4.77	0.27	34	5	400	5
363	0.00	12.34	0.834	4	5.1	5.24	0.14	34	9	400	5
364	0.00	8.61	0.834	6	4.8	4.96	0.16	34	8	400	5
365	0.00	14.62	0.834	3	8.41	8.56	0.15	34	8	400	3
366	0.00	12.38	0.834	4	6.1	6.24	0.14	34	9	400	4
367	0.00	11.67	0.834	4	5.74	6.12	0.38	34	3	400	4
368	0.00	10.62	0.834	5	5.4	5.55	0.15	34	8	400	4
369	0.00	11.34	0.834	4	6.4	6.55	0.15	34	8	400	4
370	0.00	15.64	0.834	3	9.6	9.87	0.27	34	5	400	3
371	0.00	14.75	0.834	3	8.45	8.71	0.26	34	5	400	3
372	0.00	13.64	0.834	4	7.51	7.69	0.18	34	7	400	3
373	0.00	11.23	0.834	4	5.7	5.86	0.16	34	8	400	4
374	0.00	12.67	0.834	4	5.9	6.04	0.14	34	9	400	4
375	0.00	8.79	0.834	6	4.1	4.47	0.37	34	3	400	6
376	0.00	14.67	0.834	3	9.64	9.79	0.15	34	8	400	2
377	0.00	7.21	0.834	7	3.64	3.87	0.23	34	5	400	7
378	0.00	8.99	0.834	6	4.4	4.74	0.34	34	4	400	5
379	0.00	14.39	0.834	3	8.64	8.99	0.35	34	3	400	3
380	0.00	6.48	0.834	8	3.5	3.68	0.18	34	7	400	7

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

381	0.00	8.91	0.834	6	4.67	4.83	0.16	34	8	400	5
382	0.00	12.61	0.834	4	6.14	6.43	0.29	34	4	400	4
383	0.00	11.34	0.834	4	5.64	5.98	0.34	34	4	400	4
384	0.00	14.65	0.834	3	9.5	9.64	0.14	34	9	400	3
385	0.00	13.64	0.834	4	8.4	8.61	0.21	34	6	400	3
386	0.00	14.64	0.834	3	6.9	7.05	0.15	34	8	400	3
387	0.00	10.34	0.834	5	5.1	5.44	0.34	34	4	400	5
388	0.00	9.88	0.834	5	4.8	5.17	0.37	34	3	400	5
389	0.00	7.91	0.834	6	3.14	3.39	0.25	34	5	400	8
390	0.00	9.63	0.834	5	4.67	5.08	0.41	34	3	400	5
391	0.00	10.37	0.834	5	9.64	10	0.36	34	3	400	3
392	0.00	11.21	0.834	4	4.98	5.12	0.14	34	9	400	5
393	0.00	10.61	0.834	5	4.64	4.79	0.15	34	8	400	5
394	0.00	8.61	0.834	6	3.89	4.23	0.34	34	4	400	6
395	0.00	12.34	0.834	4	5.21	5.47	0.26	34	5	400	5
396	0.00	14.35	0.834	3	8.67	8.81	0.14	34	9	400	3
397	0.00	12.38	0.834	4	6.45	6.81	0.36	34	3	400	4
398	0.00	12.45	0.834	4	5.89	6.13	0.24	34	5	400	4
399	0.00	10.91	0.834	5	4.64	4.95	0.31	34	4	400	5
400	0.00	9.37	0.834	5	4.12	4.27	0.15	34	8	400	6
401	0.00	8.61	0.834	6	4.26	4.67	0.41	34	3	400	6
402	0.00	6.99	0.834	7	2.94	3.28	0.34	34	4	400	8
403	0.00	8.14	0.834	6	3.67	3.93	0.26	34	5	400	7
404	0.00	14.61	0.834	3	8.64	8.83	0.19	34	6	400	3
405	0.00	13.24	0.834	4	5.84	6.01	0.17	34	7	400	4
406	0.00	14.61	0.834	3	8.94	9.1	0.16	34	8	400	3
407	0.00	12.34	0.834	4	5.5	5.67	0.17	34	7	400	4
408	0.00	9.63	0.834	5	4.61	4.87	0.26	34	5	400	5
409	0.00	10.37	0.834	5	5.41	5.69	0.28	34	4	400	4
410	0.00	11.21	0.834	4	5.6	5.75	0.15	34	8	400	4
411	0.00	10.61	0.834	5	4.98	5.37	0.39	34	3	400	5
412	0.00	8.61	0.834	6	3.98	4.23	0.25	34	5	400	6
413	0.00	12.34	0.834	4	5.61	5.97	0.36	34	3	400	4
414	0.00	14.35	0.834	3	8.41	8.68	0.27	34	5	400	3
415	0.00	12.38	0.834	4	6.51	6.75	0.24	34	5	400	4
416	0.00	12.45	0.834	4	7.25	7.64	0.39	34	3	400	3
417	0.00	10.91	0.834	5	4.68	4.82	0.14	34	9	400	5
418	0.00	9.37	0.834	5	4.65	4.81	0.16	34	8	400	5
419	0.00	8.61	0.834	6	3.89	4.07	0.18	34	7	400	6
420	0.00	14.54	0.834	3	8.64	8.99	0.35	34	3	400	3
421	0.00	13.15	0.834	4	6.89	7.26	0.37	34	3	400	3
422	0.00	16.48	0.834	3	9.61	9.84	0.23	34	5	400	2
423	0.00	9.84	0.834	5	4.65	4.9	0.25	34	5	400	5

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

424	0.00	7.16	0.834	7	3.59	4	0.41	34	3	400	7
425	0.00	8.51	0.834	6	4.1	4.25	0.15	34	8	400	6
426	0.00	16.45	0.834	3	8.61	8.86	0.25	34	5	400	3
427	0.00	7.34	0.834	7	4.89	5.25	0.36	34	3	400	5
428	0.00	14.21	0.834	4	9.54	9.68	0.14	34	9	400	3
429	0.00	8.16	0.834	6	5.1	5.47	0.37	34	3	400	5
430	0.00	14.23	0.834	4	7.61	7.92	0.31	34	4	400	3
431	0.00	16.14	0.834	3	9.61	9.84	0.23	34	5	400	2
432	0.00	15.21	0.834	3	9.61	9.98	0.37	34	3	400	2
433	0.00	14.36	0.834	3	8.61	8.97	0.36	34	3	400	3
434	0.00	12.34	0.834	4	5.64	5.88	0.24	34	5	400	4
435	0.00	8.19	0.834	6	6.84	7.02	0.18	34	7	400	4
436	0.00	14.23	0.834	4	6.94	7.31	0.37	34	3	400	3
437	0.00	8.36	0.834	6	4.6	4.74	0.14	34	9	400	5
438	0.00	14.62	0.834	3	9.61	10.02	0.41	34	3	400	2
439	0.00	12.34	0.834	4	5.41	5.55	0.14	34	9	400	4
440	0.00	10.32	0.834	5	4.65	4.89	0.24	34	5	400	5
441	0.00	9.34	0.834	5	3.89	4.25	0.36	34	3	400	6
442	0.00	15.46	0.834	3	6.89	7.28	0.39	34	3	400	3
443	0.00	14.23	0.834	4	7.64	7.95	0.31	34	4	400	3
444	0.00	10.34	0.834	5	4.65	4.91	0.26	34	5	400	5
445	0.00	11.34	0.834	4	5.65	5.93	0.28	34	4	400	4
446	0.00	12.38	0.834	4	6.41	6.55	0.14	34	9	400	4
447	0.00	9.37	0.834	5	4.56	4.72	0.16	34	8	400	5
448	0.00	8.61	0.834	6	5.1	5.51	0.41	34	3	400	5
449	0.00	7.91	0.834	6	3.56	3.92	0.36	34	3	400	7
450	0.00	8.61	0.834	6	4.95	5.23	0.28	34	4	400	5
451	0.00	10.48	0.834	5	5.6	5.95	0.35	34	3	400	4
452	0.00	11.94	0.834	4	6.1	6.26	0.16	34	8	400	4
453	0.00	10.67	0.834	5	4.6	4.92	0.32	34	4	400	5
454	0.00	9.99	0.834	5	5.1	5.36	0.26	34	5	400	5
455	0.00	8.37	0.834	6	5.41	5.75	0.34	34	4	400	4
456	0.00	10.24	0.834	5	5.55	5.94	0.39	34	3	400	4
457	0.00	9.34	0.834	5	4.3	4.46	0.16	34	8	400	6
458	0.00	16.14	0.834	3	9.64	9.92	0.28	34	4	400	2
459	0.00	13.24	0.834	4	6.84	7.21	0.37	34	3	400	4
460	0.00	11.37	0.834	4	5.94	6.08	0.14	34	9	400	4
461	0.00	14.61	0.834	3	8.94	9.35	0.41	34	3	400	3
462	0.00	10.31	0.834	5	4.65	4.83	0.18	34	7	400	5
463	0.00	11.64	0.834	4	6.1	6.36	0.26	34	5	400	4
464	0.00	9.54	0.834	5	4.84	5.15	0.31	34	4	400	5
465	0.00	8.61	0.834	6	4.62	4.88	0.26	34	5	400	5
466	0.00	7.61	0.834	7	3.89	4.23	0.34	34	4	400	6

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

467	0.00	8.15	0.834	6	5.21	6.01	0.8	34	2	400	5
468	0.00	14.26	0.834	4	8.45	8.68	0.23	34	5	400	3
469	0.00	16.34	0.834	3	8.61	8.8	0.19	34	6	400	3
470	0.00	12.34	0.834	4	5.95	6.19	0.24	34	5	400	4
471	0.00	11.39	0.834	4	5.89	6.3	0.41	34	3	400	4
472	0.00	8.64	0.834	6	4.23	4.66	0.43	34	3	400	6
473	0.00	8.19	0.834	6	5.61	6.06	0.45	34	3	400	4
474	0.00	10.26	0.834	5	4.1	4.28	0.18	34	7	400	6
475	0.00	9.14	0.834	5	4.89	5.1	0.21	34	6	400	5
476	0.00	15.61	0.834	3	6.89	7.11	0.22	34	6	400	3
477	0.00	13.24	0.834	4	5.95	6.27	0.32	34	4	400	4
478	0.00	12.36	0.834	4	6.1	6.36	0.26	34	5	400	4
479	0.00	11.64	0.834	4	4.68	5.02	0.34	34	4	400	5
480	0.00	8.69	0.834	6	3.86	4.13	0.27	34	5	400	6
481	0.00	10.34	0.834	5	6.1	6.24	0.14	34	9	400	4
482	0.00	11.67	0.834	4	6.84	7	0.16	34	8	400	4
483	0.00	12.67	0.834	4	7.65	7.8	0.15	34	8	400	3
484	0.00	8.99	0.834	6	4.8	4.94	0.14	34	9	400	5
485	0.00	8.92	0.834	6	4.1	4.49	0.39	34	3	400	6
486	0.00	7.65	0.834	7	3.89	4.04	0.15	34	8	400	6
487	0.00	10.96	0.834	5	4.65	4.84	0.19	34	6	400	5
488	0.00	9.74	0.834	5	4.36	4.53	0.17	34	7	400	6
489	0.00	12.85	0.834	4	5.47	5.68	0.21	34	6	400	4
490	0.00	9.14	0.834	5	3.89	4.15	0.26	34	5	400	6
491	0.00	8.55	0.834	6	4.11	4.45	0.34	34	4	400	6
492	0.00	7.32	0.834	7	3.56	3.94	0.38	34	3	400	7
493	0.00	9.25	0.834	5	4.65	4.79	0.14	34	9	400	5
494	0.00	8.54	0.834	6	4.91	5.07	0.16	34	8	400	5
495	0.00	6.31	0.834	8	3.11	3.34	0.23	34	5	400	8
496	0.00	10.61	0.834	5	4.61	4.95	0.34	34	4	400	5
497	0.00	11.34	0.834	4	6.4	6.54	0.14	34	9	400	4
498	0.00	12.64	0.834	4	7.1	7.29	0.19	34	6	400	3
499	0.00	10.5	0.834	5	5.2	5.41	0.21	34	6	400	5
500	0.00	8.32	0.834	6	4.3	4.69	0.39	34	3	400	6

Table 29. Off Hour Travel Time and Speed data Analysis

Veh.No	Travel Time		Travel Distance (m)	Approch Sped Km/hr	crossing time		crossing time (sec)	crossing distance (m)	crossing Speed (km/hr)
	start time	end time (Sec)			crossing in (sec)	crossing out (sec)			
1	0.00	25	400	58	25	29.3	4.3	34	28
2	0.00	29	400	50	29	33.5	4.5	34	27

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3	0.00	31	400	46	31	35.6	4.6	34	27
4	0.00	36	400	40	36	41.2	5.2	34	24
5	0.00	37	400	39	37	43.1	6.1	34	20
6	0.00	40	400	36	40	46.2	6.2	34	20
7	0.00	41	400	35	41	47	6	34	20
8	0.00	26	400	55	26	33.2	7.2	34	17
9	0.00	30	400	48	30	37	7	34	17
10	0.00	29	400	50	29	33.3	4.3	34	28
11	0.00	27	400	53	27	31.9	4.9	34	25
12	0.00	26	400	55	26	32.5	6.5	34	19
13	0.00	33	400	44	33	38.1	5.1	34	24
14	0.00	39	400	37	39	44.3	5.3	34	23
15	0.00	34	400	42	34	38.6	4.6	34	27
16	0.00	38	400	38	38	44.1	6.1	34	20
17	0.00	31	400	46	31	38.3	7.3	34	17
18	0.00	26	400	55	26	33.2	7.2	34	17
19	0.00	24	400	60	24	28.6	4.6	34	27
20	0.00	27	400	53	27	31.5	4.5	34	27
21	0.00	26	400	55	26	30.8	4.8	34	26
22	0.00	28	400	51	28	32.9	4.9	34	25
23	0.00	29	400	50	29	34.6	5.6	34	22
24	0.00	34	400	42	34	39.1	5.1	34	24
25	0.00	36	400	40	36	41.8	5.8	34	21
26	0.00	31	400	46	31	35.3	4.3	34	28
27	0.00	38	400	38	38	42.8	4.8	34	26
28	0.00	37	400	39	37	42.6	5.6	34	22
29	0.00	34	400	42	34	39.7	5.7	34	21
30	0.00	33	400	44	33	39.4	6.4	34	19
31	0.00	27	400	53	27	34.1	7.1	34	17
32	0.00	26	400	55	26	30.6	4.6	34	27
33	0.00	29	400	50	29	34.9	5.9	34	21
34	0.00	31	400	46	31	35.1	4.1	34	30
35	0.00	36	400	40	36	40	4	34	31
36	0.00	34	400	42	34	27.5	6.5	34	19
37	0.00	41	400	35	41	35	6	34	20
38	0.00	39	400	37	39	31.9	7.1	34	17
39	0.00	35	400	41	35	30.4	4.6	34	27
40	0.00	36	400	40	36	31.2	4.8	34	26
41	0.00	26	400	55	26	21.1	4.9	34	25
42	0.00	28	400	51	28	22.2	5.8	34	21
43	0.00	29	400	50	29	23.4	5.6	34	22
44	0.00	25	400	58	25	18.5	6.5	34	19
45	0.00	30	400	48	30	23.2	6.8	34	18

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46	0.00	36	400	40	36	31.4	4.6	34	27
47	0.00	38	400	38	38	32.9	5.1	34	24
48	0.00	39	400	37	39	32.5	6.5	34	19
49	0.00	37	400	39	37	31.9	5.1	34	24
50	0.00	31	400	46	31	25.7	5.3	34	23
51	0.00	26	400	55	26	21.4	4.6	34	27
52	0.00	29	400	50	29	22.9	6.1	34	20
53	0.00	41	400	35	41	33.7	7.3	34	17
54	0.00	40	400	36	40	32.8	7.2	34	17
55	0.00	35	400	41	35	30.4	4.6	34	27
56	0.00	36	400	40	36	31.5	4.5	34	27
57	0.00	32	400	45	32	27.2	4.8	34	26
58	0.00	26	400	55	26	21.1	4.9	34	25
59	0.00	29	400	50	29	25.4	3.6	34	34
60	0.00	28	400	51	28	22.9	5.1	34	24
61	0.00	27	400	53	27	22.3	4.7	34	26
62	0.00	26	400	55	26	21.7	4.3	34	28
63	0.00	30	400	48	30	24.4	5.6	34	22
64	0.00	34	400	42	34	30.3	3.7	34	33
65	0.00	36	400	40	36	29.2	6.8	34	18
66	0.00	35	400	41	35	27.9	7.1	34	17
67	0.00	38	400	38	38	33.7	4.3	34	28
68	0.00	34	400	42	34	28.4	5.6	34	22
69	0.00	37	400	39	37	30.6	6.4	34	19
70	0.00	40	400	36	40	36.2	3.8	34	32
71	0.00	41	400	35	41	36.4	4.6	34	27
72	0.00	26	400	55	26	21.2	4.8	34	26
73	0.00	30	400	48	30	25.8	4.2	34	29
74	0.00	29	400	50	29	25.6	3.4	34	36
75	0.00	27	400	53	27	20.9	6.1	34	20
76	0.00	26	400	55	26	20.5	5.5	34	22
77	0.00	33	400	44	33	27.1	5.9	34	21
78	0.00	39	400	37	39	33.9	5.1	34	24
79	0.00	34	400	42	34	30.9	3.1	34	39
80	0.00	38	400	38	38	31.5	6.5	34	19
81	0.00	31	400	46	31	24.2	6.8	34	18
82	0.00	26	400	55	26	21.2	4.8	34	26
83	0.00	24	400	60	24	20.5	3.5	34	35
84	0.00	27	400	53	27	21.4	5.6	34	22
85	0.00	26	400	55	26	21.4	4.6	34	27
86	0.00	28	400	51	28	23.1	4.9	34	25
87	0.00	29	400	50	29	22.2	6.8	34	18
88	0.00	34	400	42	34	28.9	5.1	34	24

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89	0.00	36	400	40	36	31.7	4.3	34	28
90	0.00	25	400	58	25	19.6	5.4	34	23
91	0.00	26	400	55	26	20.5	5.5	34	22
92	0.00	28	400	51	28	21.5	6.5	34	19
93	0.00	29	400	50	29	25.7	3.3	34	37
94	0.00	27	400	53	27	19.7	7.3	34	17
95	0.00	23	400	63	21	13.8	7.2	34	17
96	0.00	31	400	46	31	26.4	4.6	34	27
97	0.00	36	400	40	36	31.5	4.5	34	27
98	0.00	25	400	58	25	20.2	4.8	34	26
99	0.00	37	400	39	37	32.1	4.9	34	25
100	0.00	41	400	35	41	35.4	5.6	34	22
101	0.00	40	400	36	40	34.9	5.1	34	24
102	0.00	26	400	55	26	21.3	4.7	34	26
103	0.00	37	400	39	37	32.7	4.3	34	28
104	0.00	29	400	50	29	23.4	5.6	34	22
105	0.00	36	400	40	36	30.6	5.4	34	23
106	0.00	34	400	42	34	27.2	6.8	34	18
107	0.00	38	400	38	38	30.9	7.1	34	17
108	0.00	26	400	55	26	21.7	4.3	34	28
109	0.00	28	400	51	28	22.4	5.6	34	22
110	0.00	41	400	35	41	34.6	6.4	34	19
111	0.00	40	400	36	40	34.3	5.7	34	21
112	0.00	29	400	50	29	24.4	4.6	34	27
113	0.00	36	400	40	36	28.9	7.1	34	17
114	0.00	31	400	46	31	24.5	6.5	34	19
115	0.00	37	400	39	37	30.9	6.1	34	20
116	0.00	35	400	41	35	29.4	5.6	34	22
117	0.00	41	400	35	41	35.6	5.4	34	23
118	0.00	42	400	34	42	36.1	5.9	34	21
119	0.00	26	400	55	26	20.9	5.1	34	24
120	0.00	35	400	41	35	28.4	6.6	34	19
121	0.00	39	400	37	39	31.8	7.2	34	17
122	0.00	31	400	46	31	24	7	34	17
123	0.00	26	400	55	26	21.2	4.8	34	26
124	0.00	41	400	35	41	36.7	4.3	34	28
125	0.00	35	400	41	35	30.4	4.6	34	27
126	0.00	38	400	38	38	32.1	5.9	34	21
127	0.00	40	400	36	40	34.9	5.1	34	24
128	0.00	36	400	40	36	30.4	5.6	34	22
129	0.00	38	400	38	38	31.6	6.4	34	19
130	0.00	39	400	37	39	32.5	6.5	34	19
131	0.00	31	400	46	31	24.7	6.3	34	19

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132	0.00	25	400	58	25	19.7	5.3	34	23
133	0.00	26	400	55	26	21.1	4.9	34	25
134	0.00	27	400	53	27	22.9	4.1	34	30
135	0.00	29	400	50	29	23.9	5.1	34	24
136	0.00	30	400	48	30	24.3	5.7	34	21
137	0.00	38	400	38	38	32.6	5.4	34	23
138	0.00	41	400	35	41	36.4	4.6	34	27
139	0.00	40	400	36	40	35.2	4.8	34	26
140	0.00	26	400	55	26	21.8	4.2	34	29
141	0.00	27	400	53	27	22.3	4.7	34	26
142	0.00	29	400	50	29	24.9	4.1	34	30
143	0.00	35	400	41	35	31.5	3.5	34	35
144	0.00	38	400	38	38	33.4	4.6	34	27
145	0.00	37	400	39	37	31.4	5.6	34	22
146	0.00	31	400	46	31	25.3	5.7	34	21
147	0.00	30	400	48	30	26.4	3.6	34	34
148	0.00	26	400	55	26	19.6	6.4	34	19
149	0.00	24	400	60	24	16.9	7.1	34	17
150	0.00	28	400	51	28	24.6	3.4	34	36
151	0.00	27	400	53	27	22.4	4.6	34	27
152	0.00	31	400	46	31	27.4	3.6	34	34
153	0.00	36	400	40	36	32.3	3.7	34	33
154	0.00	34	400	42	34	29.5	4.5	34	27
155	0.00	39	400	37	39	33.9	5.1	34	24
156	0.00	31	400	46	31	25.4	5.6	34	22
157	0.00	35	400	41	35	28.5	6.5	34	19
158	0.00	26	400	55	26	19.6	6.4	34	19
159	0.00	24	400	60	24	17.2	6.8	34	18
160	0.00	29	400	50	27	22.7	4.3	34	28
161	0.00	28	400	51	28	24.7	3.3	34	37
162	0.00	28	400	51	28	23.5	4.5	34	27
163	0.00	29	400	50	29	24.9	4.1	34	30
164	0.00	25	400	58	25	19.5	5.5	34	22
165	0.00	30	400	48	30	24.4	5.6	34	22
166	0.00	36	400	40	36	29.9	6.1	34	20
167	0.00	38	400	38	38	31.5	6.5	34	19
168	0.00	39	400	37	39	32.2	6.8	34	18
169	0.00	37	400	39	37	29.9	7.1	34	17
170	0.00	31	400	46	31	27.5	3.5	34	35
171	0.00	26	400	55	26	22.1	3.9	34	31
172	0.00	29	400	50	29	24.8	4.2	34	29
173	0.00	41	400	35	41	36.4	4.6	34	27
174	0.00	40	400	36	40	35.1	4.9	34	25

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175	0.00	35	400	41	35	29.4	5.6	34	22
176	0.00	36	400	40	36	30.3	5.7	34	21
177	0.00	32	400	45	32	25.6	6.4	34	19
178	0.00	26	400	55	26	19.1	6.9	34	18
179	0.00	29	400	50	29	22.9	6.1	34	20
180	0.00	28	400	51	28	24.5	3.5	34	35
181	0.00	27	400	53	27	23.3	3.7	34	33
182	0.00	26	400	55	26	22.9	3.1	34	39
183	0.00	30	400	48	30	26	4	34	31
184	0.00	34	400	42	34	29	5	34	24
185	0.00	31	400	46	31	24.7	6.3	34	19
186	0.00	26	400	55	26	19.6	6.4	34	19
187	0.00	21	400	69	21	18	3	34	41
188	0.00	28	400	51	28	22.9	5.1	34	24
189	0.00	41	400	35	41	34.6	6.4	34	19
190	0.00	40	400	36	40	35.8	4.2	34	29
191	0.00	31	400	46	31	-6	37	34	3
192	0.00	39	400	37	39	35.2	3.8	34	32
193	0.00	34	400	42	34	28.4	5.6	34	22
194	0.00	37	400	39	37	30.6	6.4	34	19
195	0.00	26	400	55	26	19.5	6.5	34	19
196	0.00	28	400	51	28	21.7	6.3	34	19
197	0.00	29	400	50	29	23.7	5.3	34	23
198	0.00	23	400	63	21	16.1	4.9	34	25
199	0.00	26	400	55	26	21.9	4.1	34	30
200	0.00	34	400	42	34	28.9	5.1	34	24
201	0.00	38	400	38	38	32.3	5.7	34	21
202	0.00	31	400	46	31	25.6	5.4	34	23
203	0.00	26	400	55	26	21.4	4.6	34	27
204	0.00	24	400	60	24	19.2	4.8	34	26
205	0.00	26	400	55	26	21.8	4.2	34	29
206	0.00	21	400	69	21	16.3	4.7	34	26
207	0.00	29	400	50	29	24.9	4.1	34	30
208	0.00	34	400	42	34	30.5	3.5	34	35
209	0.00	36	400	40	36	31.4	4.6	34	27
210	0.00	38	400	38	38	32.4	5.6	34	22
211	0.00	41	400	35	41	35.3	5.7	34	21
212	0.00	36	400	40	36	32.4	3.6	34	34
213	0.00	40	400	36	40	33.6	6.4	34	19
214	0.00	39	400	37	39	31.9	7.1	34	17
215	0.00	44	400	33	44	40.5	3.5	34	35
216	0.00	26	400	55	26	22.1	3.9	34	31
217	0.00	35	400	41	35	31.6	3.4	34	36

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218	0.00	35	400	41	35	30.4	4.6	34	27
219	0.00	39	400	37	39	34.9	4.1	34	30
220	0.00	34	400	42	34	28.8	5.2	34	24
221	0.00	26	400	55	26	20.7	5.3	34	23
222	0.00	42	400	34	42	34.9	7.1	34	17
223	0.00	26	400	55	26	22.6	3.4	34	36
224	0.00	25	400	58	25	21.1	3.9	34	31
225	0.00	31	400	46	31	25.6	5.4	34	23
226	0.00	36	400	40	36	30.4	5.6	34	22
227	0.00	37	400	39	37	30.4	6.6	34	19
228	0.00	39	400	37	39	34.4	4.6	34	27
229	0.00	35	400	41	35	29.1	5.9	34	21
230	0.00	31	400	46	31	25.3	5.7	34	21
231	0.00	36	400	40	36	32.1	3.9	34	31
232	0.00	30	400	48	30	26.9	3.1	34	39
233	0.00	38	400	38	38	32.2	5.8	34	21
234	0.00	29	400	50	29	23.1	5.9	34	21
235	0.00	25	400	58	25	18.9	6.1	34	20
236	0.00	26	400	55	26	19.3	6.7	34	18
237	0.00	30	400	48	30	23.1	6.9	34	18
238	0.00	34	400	42	34	27.4	6.6	34	19
239	0.00	36	400	40	36	31.8	4.2	34	29
240	0.00	38	400	38	38	34.7	3.3	34	37
241	0.00	31	400	46	31	25.9	5.1	34	24
242	0.00	26	400	55	26	22.6	3.4	34	36
243	0.00	24	400	60	24	17.9	6.1	34	20
244	0.00	29	400	50	29	21.8	7.2	34	17
245	0.00	34	400	42	34	28.9	5.1	34	24
246	0.00	41	400	35	41	36.4	4.6	34	27
247	0.00	42	400	34	42	36.9	5.1	34	24
248	0.00	44	400	33	44	38.3	5.7	34	21
249	0.00	23	400	63	21	15.6	5.4	34	23
250	0.00	28	400	51	28	23.4	4.6	34	27
251	0.00	41	400	35	41	36.2	4.8	34	26
252	0.00	40	400	36	40	35.8	4.2	34	29
253	0.00	31	400	46	31	26.3	4.7	34	26
254	0.00	39	400	37	39	34.9	4.1	34	30
255	0.00	34	400	42	34	30.5	3.5	34	35
256	0.00	37	400	39	37	32.4	4.6	34	27
257	0.00	26	400	55	26	20.4	5.6	34	22
258	0.00	28	400	51	28	22.3	5.7	34	21
259	0.00	29	400	50	29	25.4	3.6	34	34
260	0.00	23	400	63	21	14.6	6.4	34	19

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261	0.00	26	400	55	26	18.9	7.1	34	17
262	0.00	34	400	42	34	30.6	3.4	34	36
263	0.00	38	400	38	38	33.4	4.6	34	27
264	0.00	27	400	53	27	23.4	3.6	34	34
265	0.00	29	400	50	29	25.3	3.7	34	33
266	0.00	34	400	42	34	29.5	4.5	34	27
267	0.00	36	400	40	36	30.9	5.1	34	24
268	0.00	41	400	35	41	35.4	5.6	34	22
269	0.00	35	400	41	35	31.7	3.3	34	37
270	0.00	42	400	34	42	38.5	3.5	34	35
271	0.00	38	400	38	38	33.8	4.2	34	29
272	0.00	29	400	50	29	24.4	4.6	34	27
273	0.00	26	400	55	26	19.5	6.5	34	19
274	0.00	35	400	41	35	29.5	5.5	34	22
275	0.00	41	400	35	41	35.9	5.1	34	24
276	0.00	39	400	37	39	35.6	3.4	34	36
277	0.00	42	400	34	42	38.2	3.8	34	32
278	0.00	43	400	33	43	35.9	7.1	34	17

**APPENDIX B: VISSIM SIMULATION OUT PUT**

Queue Results (2)						
Select layout...						
Count: 8	SimRun	TimeInt	QueueCounter	QLen	QLenMax	QStops
1	1	0-3600	1: nb	355.11	398.07	721
2	1	0-3600	2: nb2	347.85	396.66	1726
3	1	0-3600	3: sb	334.84	402.01	1563
4	1	0-3600	4: sb2	281.50	401.58	2661
5	1	0-3600	5: eb	287.39	344.37	1285
6	1	0-3600	6: eb2	283.80	348.56	419
7	1	0-3600	7: wb	184.23	337.92	299
8	1	0-3600	8: wb	341.11	403.06	685

Figure 46. Queue Result for Base Condition

Data Collection Results (2)												
Select layout...												
Count: 1	SimRun	TimeInt	DataCollectionMeasurement	Acceleration(All)	Dist(All)	Length(All)	Vehs(All)	Pers(All)	QueueDelay(All)	SpeedAvgArith(All)	SpeedAvgHarm(All)	OccupRate(All)
1	1	0-3600	1: NB T	0.22	407.25	5.13	615	615	61.36	32.39	32.17	8.43 %
2	1	0-3600	2: NBR	0.43	406.51	5.31	78	78	67.84	32.90	32.57	1.26 %
3	1	0-3600	3: NBL	0.32	408.39	5.09	279	279	108.14	32.24	31.96	4.42 %
4	1	0-3600	4: NU				0	0				0.00 %
5	1	0-3600	5: ST	0.42	400.70	5.23	509	509	49.72	31.53	31.09	7.50 %
6	1	0-3600	6: SR	0.80	399.11	4.98	28	28	60.66	31.80	31.07	0.44 %
7	1	0-3600	7: SL	0.81	389.93	5.49	240	240	180.97	26.32	17.71	5.92 %
8	1	0-3600	8: SU				0	0				0.00 %
9	1	0-3600	9: ET	1.02	219.34	5.23	49	49	57.17	30.15	29.14	0.85 %
10	1	0-3600	10: EL	0.85	211.13	5.12	225	225	36.17	28.38	23.77	4.24 %
11	1	0-3600	11: ER	0.90	220.47	4.90	73	73	48.34	31.50	30.87	1.13 %
12	1	0-3600	12: WT	1.03	163.76	5.13	98	98	52.56	29.48	28.30	1.70 %
13	1	0-3600	13: WR	0.71	170.27	4.92	22	22	58.11	31.90	31.68	0.34 %
14	1	0-3600	14: WL	0.47	157.97	5.02	450	450	53.98	30.68	27.82	7.59 %
15	1	0-3600	15: TRA N	0.05	395.23	37.65	7	1210	20.09	24.35	24.35	1.08 %
16	1	0-3600	16: TRA S	0.28	387.97	37.65	6	1160	44.98	23.65	23.65	0.92 %

Figure 47. Table Delay Result for Base Condition

Table 28. Travel Time in VISSIM out Put for Base Condition

TIMEINT	VEHICLE TRAVEL TIME MEASUREMNT	VEHS(ALL)	TRAVTM(ALL) (Sec)	TRAVTM(ALL) (Min)	Commulative	DISTTRAV(ALL) (M)
0-3600	1	803	29.310	0.489	0.489	20
0-3600	2	796	30.036	0.501	0.989	20
0-3600	3	788	34.560	0.576	1.565	20
0-3600	4	780	32.573	0.543	2.108	20
0-3600	5	773	32.746	0.546	2.654	20
0-3600	6	766	34.800	0.580	3.234	20
0-3600	7	756	33.445	0.557	3.791	20
0-3600	8	748	35.314	0.589	4.380	20
0-3600	9	741	34.734	0.579	4.959	20
0-3600	10	734	36.018	0.600	5.559	20
0-3600	11	726	37.800	0.630	6.189	20
0-3600	12	718	34.560	0.576	6.765	20
0-3600	13	710	34.860	0.581	7.346	20
0-3600	14	703	33.162	0.553	7.899	20
0-3600	15	696	35.057	0.584	8.483	20
0-3600	16	687	34.779	0.580	9.063	20
0-3600	17	681	34.803	0.580	9.643	20
0-3600	18	674	35.888	0.598	10.241	20
0-3600	19	664	35.848	0.597	10.838	20
0-3600	20	336	29.350	0.489	11.327	20
0-3600	21	335	28.600	0.477	11.804	20
0-3600	22	335	15.980	0.266	12.070	20
0-3600	23	542	1.750	0.029	12.100	20
0-3600	24	542	2.590	0.043	12.143	20
0-3600	25	542	1.720	0.029	12.171	20
0-3600	26	542	1.680	0.028	12.199	20
0-3600	27	542	1.530	0.026	12.225	20
0-3600	28	542	1.680	0.028	12.253	20
0-3600	29	542	1.680	0.028	12.281	20
0-3600	30	542	1.506	0.025	12.306	20
0-3600	31	542	1.507	0.025	12.331	20
0-3600	32	542	1.580	0.026	12.357	20
0-3600	33	542	1.599	0.027	12.384	20
0-3600	34	542	1.505	0.025	12.409	20
0-3600	35	541	1.501	0.025	12.434	20
0-3600	36	541	1.411	0.024	12.458	20
0-3600	37	541	1.590	0.027	12.484	20
0-3600	38	541	1.497	0.025	12.509	20
0-3600	39	540	1.560	0.026	12.535	20
0-3600	40	540	1.510	0.025	12.560	20
0-3600	41	540	1.501	0.025	12.585	20
0-3600	42	540	1.100	0.018	12.604	14
			<b>Delay (min)</b>	<b>12.660</b>	12.066	834

Table 29. Travel time Analysis result in Fixed Traffic Signal Control

VEHICLE TRAVEL TIME MEASUREMENT	VEHS (ALL)	TRAVTM(ALL) Sec.	TRAVTM(ALL) min.	Comu. TRAVTM(ALL) min.	TRAVDIS(ALL) Meter.
15: N1	727	2.09	0.035	0.035	20
16: N1	726	2.06	0.034	0.069	20
17: N1	725	2.07	0.035	0.104	20
18: N1	724	2.10	0.035	0.139	20
19: N1	724	2.10	0.035	0.174	20
20: N1	724	2.09	0.035	0.209	20
21: N1	724	2.09	0.035	0.243	20
22: N1	724	2.09	0.035	0.278	20
23: N1	723	2.10	0.035	0.313	20
24: N1	723	2.11	0.035	0.348	20
25: N1	722	2.27	0.038	0.386	20
26: N1	721	2.74	0.046	0.432	20
27: N1	720	4.02	0.067	0.499	20
28: N1	720	5.32	0.089	0.588	20
29: N1	720	8.75	0.146	0.733	20
30: N1	716	11.59	0.193	0.927	20
31: N1	711	16.66	0.278	1.204	20
32: N1	705	18.91	0.315	1.519	20
33: N1	699	19.40	0.323	1.843	20
34: N1	699	2.19	0.037	1.879	20
35: N1	840	2.18	0.036	1.915	20
33: N2	862	2.18	0.036	1.952	20
34: N2	862	2.18	0.036	1.988	20
35: N2	862	2.19	0.036	2.025	20
33: N3	862	2.20	0.037	2.061	20
34: N3	862	2.23	0.037	2.099	20
35: N3	862	2.26	0.038	2.136	20
33: N2	862	2.24	0.037	2.174	20
34: N2	862	2.19	0.036	2.210	20
35: N2	862	2.16	0.036	2.246	20
33: N3	862	2.16	0.036	2.282	20
34: N3	862	2.17	0.036	2.318	20
35: N3	862	2.17	0.036	2.354	20
33: N4	862	2.17	0.036	2.390	20
34: N4	862	2.23	0.037	2.428	20
35: N4	862	2.17	0.036	2.464	20
33: N3	861	2.17	0.036	2.500	20
34: N3	861	2.17	0.036	2.536	20
35: N3	861	2.21	0.037	2.573	20
33: N4	861	2.16	0.036	2.609	20
34: N4	861	2.14	0.036	2.645	20
35: N4	861	1.47	0.025	2.669	14
		<b>travel time (min)</b>		<b>2.669</b>	<b>834</b>

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Table 30. Travel time Analysis result for Transit Signal Priority

TIMEIN	VEHICLE TRAVEL TIME MEASUREMENT	VEHS (ALL)	TRAVTM(ALL) Sec.	TRAVTM(ALL) min.	Comu. TRAVTM(ALL) min.	TRAVDIS(ALL) Meter.
0-3600	15: N1	727	2.17	0.036	0.04	20
0-3600	15: N1	726	2.17	0.036	0.07	20
0-3600	17: N1	725	2.19	0.036	0.11	20
0-3600	18: N1	724	2.22	0.037	0.15	20
0-3600	19: N1	724	2.24	0.037	0.18	20
0-3600	20: N1	724	2.23	0.037	0.22	20
0-3600	21: N1	724	2.19	0.037	0.26	20
0-3600	22: N1	724	2.16	0.036	0.29	20
0-3600	23: N1	723	2.16	0.036	0.33	20
0-3600	24: N1	723	2.16	0.036	0.36	20
0-3600	25: N1	722	2.16	0.036	0.40	20
0-3600	26: N1	721	2.17	0.036	0.44	20
0-3600	27: N1	720	2.23	0.037	0.47	20
0-3600	28: N1	720	2.16	0.036	0.51	20
0-3600	29: N1	720	2.16	0.036	0.55	20
0-3600	30: N1	720	2.17	0.036	0.58	20
0-3600	31: N1	714	15.40	0.257	0.84	20
0-3600	32: N1	709	14.30	0.238	1.08	20
0-3600	33: N1	703	14.30	0.238	1.32	20
0-3600	34: N2	845	14.23	0.237	1.55	20
0-3600	29: N2	866	1.89	0.032	1.58	20
0-3600	30: N2	866	2.19	0.037	1.62	20
0-3600	31: N2	866	2.21	0.037	1.66	20
0-3600	32: N2	866	2.23	0.037	1.69	20
0-3600	33: N2	866	2.22	0.037	1.73	20
0-3600	28: N3	863	2.18	0.036	1.77	20
0-3600	33: N5	860	2.16	0.036	1.80	20
0-3600	35: N5	858	2.05	0.034	1.84	20
0-3600	33: N6	856	2.15	0.036	1.87	20
0-3600	35: N6	856	2.05	0.034	1.91	20
0-3600	33: N7	856	1.90	0.032	1.94	20
0-3600	35: N7	856	1.90	0.032	1.97	20
0-3600	33: N8	855	1.90	0.032	2.00	20
0-3600	35: N8	855	2.24	0.037	2.04	20
0-3600	33: N9	855	2.23	0.037	2.08	20
0-3600	35: N9	854	2.19	0.037	2.11	20
0-3600	33: N10	854	2.16	0.036	2.15	20
0-3601	35: N10	854	2.16	0.036	2.19	20
0-3602	33: N11	854	2.16	0.036	2.22	20
0-3603	35: N11	854	2.16	0.036	2.26	20
0-3604	33: N12	854	2.17	0.036	2.29	20
0-3605	35: N12	854	2.23	0.037	2.33	14
		<b>Total Travel Time (min)</b>			<b>2.33</b>	<b>834.00</b>

**APPENDIX C: TABLES FORM REFERENCE BOOKS**

Table 31. Adjustment factors

Highway Capacity Manual 2000

EXHIBIT 16-7. ADJUSTMENT FACTORS FOR SATURATION FLOW RATE<sup>a</sup>

Factor	Formula	Definition of Variables	Notes
Lane width	$f_w = 1 + \frac{(W - 3.6)}{9}$	W = lane width (m)	W ≥ 2.4 If W > 4.8, a two-lane analysis may be considered
Heavy vehicles	$f_{HV} = \frac{100}{100 + \% HV(E_T - 1)}$	% HV = % heavy vehicles for lane group volume	E <sub>T</sub> = 2.0 pc/HV
Grade	$f_g = 1 - \frac{\% G}{200}$	% G = % grade on a lane group approach	-6 ≤ % G ≤ +10 Negative is downhill
Parking	$f_p = \frac{N - 0.1 - \frac{18N_m}{3600}}{N}$	N = number of lanes in lane group N <sub>m</sub> = number of parking maneuvers/h	0 ≤ N <sub>m</sub> ≤ 180 f <sub>p</sub> ≥ 0.050 f <sub>p</sub> = 1.000 for no parking
Bus blockage	$f_{bb} = \frac{N - \frac{14.4N_B}{3600}}{N}$	N = number of lanes in lane group N <sub>B</sub> = number of buses stopping/h	0 ≤ N <sub>B</sub> ≤ 250 f <sub>bb</sub> ≥ 0.050
Type of area	f <sub>a</sub> = 0.900 in CBD f <sub>a</sub> = 1.000 in all other areas		
Lane utilization	$f_{LU} = v_g / (v_{g1}N)$	v <sub>g</sub> = unadjusted demand flow rate for the lane group, veh/h v <sub>g1</sub> = unadjusted demand flow rate on the single lane in the lane group with the highest volume N = number of lanes in the lane group	
Left turns	Protected phasing: Exclusive lane: f <sub>LT</sub> = 0.95 Shared lane: $f_{LT} = \frac{1}{1.0 + 0.05P_{LT}}$	P <sub>LT</sub> = proportion of LTs in lane group	See Exhibit C16-1, Appendix C, for nonprotected phasing alternatives
Right turns	Exclusive lane: f <sub>RT</sub> = 0.85 Shared lane: f <sub>RT</sub> = 1.0 - (0.15)P <sub>RT</sub> Single lane: f <sub>RT</sub> = 1.0 - (0.135)P <sub>RT</sub>	P <sub>RT</sub> = proportion of RTs in lane group	f <sub>RT</sub> ≥ 0.050
Pedestrian-bicycle blockage	LT adjustment: f <sub>LPb</sub> = 1.0 - P <sub>LT</sub> (1 - A <sub>pbt</sub> ) (T - P <sub>LTA</sub> ) RT adjustment: f <sub>RPb</sub> = 1.0 - P <sub>RT</sub> (1 - A <sub>pbt</sub> ) (T - P <sub>RTA</sub> )	P <sub>LT</sub> = proportion of LTs in lane group A <sub>pbt</sub> = permitted phase adjustment P <sub>LTA</sub> = proportion of LT protected green over total LT green P <sub>RT</sub> = proportion of RTs in lane group P <sub>RTA</sub> = proportion of RT protected green over total RT green	Refer to Appendix D for step-by-step procedure

Note:  
See Chapter 10, Exhibit 10-12, for default values of base saturation flow rates and variables used to derive adjustment factors.  
a. The table contains formulas for all adjustment factors. However, for situations in which permitted phasing is involved, either



Table 32. Through - Car equivalents for permitted left turns

EXHIBIT C16-3. THROUGH-CAR EQUIVALENTS,  $E_{L1}$ , FOR PERMITTED LEFT TURNS

Type of Left-Turn Lane	Effective Opposing Flow, $v_{oe} = v_o / f_{LUo}$						
	1	200	400	600	800	1000	1200 <sup>a</sup>
Shared	1.4	1.7	2.1	2.5	3.1	3.7	4.5
Exclusive	1.3	1.6	1.9	2.3	2.8	3.3	4.0

Table Typical values for minimum green to satisfy driver expectancy

Table 33. Typical values for minimum green to satisfy driver expectancy

Phase Type	Facility Type	Minimum Green (Seconds)
Through	Major Arterial (> 40 mph)	10 to 15
	Major Arterial ( $\leq$ 40 mph)	7 to 15
	Minor Arterial	4 to 10
	Collector, Local, or Driveway	2 to 10
Left Turn	Any	2 to 5

## APPENDIX C: HEADWAY COUNTED DATA

### A. NORTH APPROCH (KADISCKO)

North Through mov.				
Car .No.	Count. Period			Headway (sec)
	hr	min	sec	
1	7	30	27	27
2	7	30	33	6
3	7	30	38	5
4	7	30	43	5
5	7	30	49	6
6	7	30	53	4
7	7	30	56	3
8	7	30	59	3
9	7	31	1	2
10	7	31	3	2
11	7	31	5	2
12	7	31	9	4
13	7	31	12	3
14	7	31	19	7
15	7	32	10	51
16	7	32	15	5
17	7	32	19	4
18	7	32	22	3
19	7	32	25	3
20	7	32	27	2
21	7	32	30	3
22	7	32	33	3
23	7	32	38	5
24	7	32	40	2
25	7	32	44	4
26	7	33	7	23
27	7	33	16	9
28	7	33	20	4
29	7	33	26	6
30	7	33	30	4
31	7	33	50	20
32	7	33	55	5
33	7	33	59	4
34	7	34	3	4

North Left turn				
Car No.	Count. Period			Headway (Sec)
	hr	min	sec	
1	7	30	35	35
2	7	30	43	8
3	7	30	54	11
4	7	30	59	5
5	7	31	7	8
6	7	31	14	7
7	7	31	28	14
8	7	32	5	37
9	7	32	11	6
10	7	32	16	5
11	7	32	18	2
12	7	32	22	4
13	7	32	24	2
14	7	32	30	6
15	7	32	35	5
16	7	32	39	4
17	7	32	43	4
18	7	32	48	5
19	7	33	19	31
20	7	33	25	6
21	7	33	34	9
22	7	34	5	31
23	7	34	14	9
24	7	34	25	11
25	7	35	16	51
26	7	35	20	4
27	7	35	25	5
28	7	35	38	13
29	7	35	54	16
30	7	35	59	5
31	7	36	26	27
32	7	37	58	92
33	7	38	4	6
34	7	38	9	5

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35	7	34	9	6
36	7	34	12	6
37	7	35	13	61
38	7	35	17	4
39	7	35	28	11
40	7	35	33	5
41	7	35	37	4
42	7	35	39	2
43	7	35	43	4
44	7	35	46	3
45	7	35	53	7
46	7	36	20	27
47	7	36	34	14
48	7	36	41	7
49	7	37	39	58
50	7	37	41	2
51	7	37	44	3
52	7	37	47	3
53	7	37	51	4
54	7	37	54	3
55	7	37	56	2
56	7	38	0	4
57	7	38	3	3
58	7	38	6	3
59	7	38	9	3
60	7	38	17	8
61	7	39	13	56
62	7	39	28	15
63	7	39	31	3
64	7	39	36	5
65	7	39	38	2
66	7	39	40	2
67	7	39	43	3
68	7	39	45	2
69	7	39	48	3
70	7	39	50	2
71	7	39	53	3
72	7	39	58	5
73	7	40	2	4
74	7	41	4	62
75	7	41	8	4
76	7	41	11	3
77	7	41	14	3

35	7	38	15	6
36	7	38	23	8
37	7	38	27	4
38	7	38	31	4
39	7	38	41	10
40	7	38	46	5
41	7	38	53	7
42	7	39	2	9
43	7	39	27	25
44	7	39	29	2
45	7	39	38	9
46	7	39	43	5
47	7	39	48	5
48	7	39	55	7
49	7	40	1	6
50	7	40	7	6
51	7	40	28	21
52	7	41	7	39
53	7	41	12	5
54	7	41	18	6
55	7	41	24	6
56	7	41	43	19
57	7	41	48	5
58	7	41	54	6
59	7	42	2	8
60	7	42	14	12
61	7	42	50	36
62	7	42	55	5
63	7	42	59	4
64	7	43	43	44
65	7	44	2	19
66	7	44	15	13
67	7	44	26	11
68	7	44	30	4
69	7	44	43	13
70	7	45	15	32
71	7	45	20	5
72	7	45	25	5
73	7	45	29	4
74	7	45	43	14
75	7	45	49	6
76	7	46	8	31
77	7	46	21	31

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

78	7	41	18	4
79	7	41	22	4
80	7	41	24	2
81	7	41	26	2
82	7	41	30	4
83	7	41	35	5
84	7	41	41	6
85	7	41	44	3
86	7	41	49	5
87	7	42	37	48
88	7	42	44	7
89	7	42	48	4
90	7	42	52	4
91	7	42	54	2
92	7	42	59	5
93	7	43	12	13
94	7	43	20	8
95	7	43	22	2
96	7	43	26	4
97	7	43	29	3
98	7	43	32	3
99	7	43	35	3
100	7	43	37	2
101	7	43	49	12
102	7	43	56	7
103	7	43	59	3
104	7	44	3	4
105	7	44	6	3
106	7	44	12	6
107	7	44	56	44
108	7	44	59	3
109	7	45	2	3
110	7	45	5	3
111	7	45	8	3
112	7	45	11	3
113	7	45	14	3
114	7	45	17	3
115	7	45	20	3
116	7	46	3	43
117	7	46	8	5
118	7	46	12	4
119	7	46	18	6
120	7	46	23	5

78	7	47	8	47
79	7	47	20	12
80	7	48	11	51
81	7	48	52	41
82	7	49	18	26
83	7	49	45	27
84	7	50	20	0
85	7	51	10	-10
86	7	52	45	35
87	7	53	38	233
88	7	53	43	5
89	7	53	47	4
90	7	53	51	4
91	7	53	56	5
92	7	54	6	10
93	7	54	12	6
94	7	54	15	3
95	7	54	23	8
96	7	54	44	21
97	7	55	20	45
98	7	56	45	55
99	7	57	30	45
100	7	58	6	202
101	7	58	9	3
102	7	58	13	4
103	7	59	14	1
104	7	59	19	5
105	7	59	25	6
106	8	0	0	35
107	8	1	10	45
108	8	2	7	162
109	8	2	15	8
110	8	2	23	8
111	8	2	31	8
112	8	3	20	59
113	8	4	16	56
114	8	4	22	6
115	8	4	27	5
116	8	5	1	34
117	8	5	45	44
118	8	6	1	16
119	8	6	46	45
120	8	6	50	4

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

121	7	46	28	5
122	7	46	33	5
123	7	46	38	5
124	7	46	42	4
125	7	46	49	7
126	7	46	53	4
127	7	46	58	5
128	7	47	2	4
129	7	47	7	5
130	7	47	11	4
131	7	47	18	7
132	7	47	26	8
133	7	47	33	7
134	7	47	44	11
135	7	47	51	7
136	7	47	59	8
137	7	48	6	7
138	7	48	14	8
139	7	48	17	3
140	7	48	28	11
141	7	48	33	5
142	7	48	46	13
143	7	49	6	20
144	7	49	9	3
145	7	49	14	5
146	7	49	20	6
147	7	49	27	7
148	7	49	33	6
149	7	49	41	8
150	7	49	46	5
151	7	49	55	9
152	7	50	2	7
153	7	50	12	10
154	7	50	14	2
155	7	50	18	4
156	7	50	28	10
157	7	50	37	9
158	7	50	45	8
159	7	50	52	7
160	7	50	59	7
161	7	51	8	9
162	7	51	16	8
163	7	51	23	7

121	8	6	56	6
122	8	7	46	48
123	8	7	49	3
124	8	7	58	9
125	8	8	49	51
126	8	8	57	8
127	8	9	3	6
128	8	9	8	5
129	8	9	18	10
130	8	9	38	20
131	8	10	46	8
132	8	10	58	12
133	8	11	20	0
134	8	12	2	64
135	8	12	11	9
136	8	13	0	70
137	8	13	8	8
138	8	13	11	3
139	8	13	14	3
140	8	13	22	8
141	8	14	44	22
142	8	14	47	3
143	8	15	3	16
144	8	15	16	13
145	8	15	24	8
146	8	15	27	3
147	8	16	20	53
148	8	17	6	53
149	8	17	14	8
150	8	17	18	4
151	8	17	23	5
152	8	17	32	9
153	8	17	35	3
154	8	17	43	8
155	8	17	51	8
156	8	17	59	8
157	8	18	41	42
158	8	18	49	8
159	8	19	18	29
160	8	19	22	4
161	8	19	31	9
162	8	19	39	8
163	8	19	45	6

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

164	7	51	31	8
165	7	51	39	8
166	7	51	43	4
167	7	51	49	6
168	7	51	56	7
169	7	52	3	7
170	7	52	9	6
171	7	52	15	6
172	7	52	33	18
173	7	52	40	7
174	7	52	46	6
175	7	52	51	5
176	7	53	19	28
177	7	53	25	6
178	7	53	28	3
179	7	53	31	3
180	7	53	34	3
181	7	53	39	5
182	7	53	46	7
183	7	53	49	3
184	7	53	51	2
185	7	53	58	7
186	7	54	2	4
187	7	54	7	5
188	7	54	12	5
189	7	54	15	3
190	7	54	20	5
191	7	54	28	8
192	7	54	31	3
193	7	55	10	39
194	7	55	18	8
195	7	55	27	9
196	7	55	35	8
197	7	55	42	7
198	7	55	54	12
199	7	56	6	12
200	7	56	14	8
201	7	56	23	9
202	7	56	30	7
203	7	56	36	6
204	7	56	42	6
205	7	56	51	9
206	7	57	50	59

164	8	19	49	4
165	8	19	51	2
166	8	19	56	5
167	8	20	3	7
168	8	20	5	2
169	8	20	12	7
170	8	20	19	7
171	8	20	25	6
172	8	20	31	6
173	8	20	38	7
174	8	20	46	8
175	8	20	52	6
176	8	20	59	7
177	8	21	4	5
178	8	21	12	8
179	8	21	19	7
180	8	21	27	8
181	8	21	32	5
182	8	21	40	8
183	8	21	55	15
184	8	22	3	8
185	8	22	15	12
186	8	22	23	8
187	8	22	28	5
188	8	22	35	7
189	8	22	41	6
190	8	22	49	8
191	8	22	52	3
192	8	23	5	13
193	8	23	13	8
194	8	23	21	8
195	8	23	33	12
196	8	23	43	10
197	8	23	48	5
198	8	23	56	8
199	8	24	5	9
200	8	24	14	9
201	8	24	24	10
202	8	24	29	5
203	8	24	37	8
204	8	24	42	5
205	8	24	48	6
206	8	24	59	11

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

207	7	57	58	8
208	7	58	5	7
209	7	58	11	6
210	7	58	14	3
211	7	58	37	23
212	7	58	40	3
213	7	58	43	3
214	7	58	46	3
215	7	58	50	4
216	7	58	55	5
217	7	58	59	4
218	7	59	3	4
219	7	59	8	5
220	7	59	13	5
221	7	59	16	3
222	7	59	22	6
223	7	59	25	3
224	7	0	15	50
225	7	0	27	12
226	7	0	35	8
227	7	0	42	7
228	8	1	1	39
229	8	1	1	0
230	8	1	6	5
231	8	1	13	7
232	8	1	18	5
233	8	1	23	5
234	8	1	33	10
235	8	1	41	8
236	8	1	50	9
237	8	2	1	11
238	8	2	9	8
239	8	2	13	4
240	8	2	19	6
241	8	2	23	4
242	8	2	33	10
243	8	2	38	5
244	8	2	48	10
245	8	2	51	3
246	8	2	56	5
247	8	3	1	5
248	8	3	7	6
249	8	4	17	10

207	8	25	5	6
208	8	25	13	8
209	8	25	17	4
210	8	25	24	7
211	8	25	29	5
212	8	25	35	6
213	8	25	40	5
214	8	25	46	6
215	8	25	52	6
216	8	26	1	9
217	8	26	6	5
218	8	26	11	5
219	8	26	20	9
220	8	26	28	8
221	8	26	36	8
222	8	26	42	6
223	8	26	49	7
224	8	26	54	5
225	8	27	7	13
226	8	27	16	9
227	8	27	20	4
228	8	27	28	8
229	8	27	34	6
230	8	27	45	11
231	8	27	55	10
232	8	28	5	10
233	8	28	12	7
234	8	28	19	7
235	8	28	22	3
236	8	28	32	10
237	8	28	40	8
238	8	28	45	5
239	8	28	51	6
240	8	28	56	5
241	8	29	4	8
242	8	29	11	7
243	8	29	19	8
244	8	29	25	6
245	8	29	31	6
246	8	29	38	7
247	8	29	42	4
248	8	29	49	7
249	8	29	54	5

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

250	8	4	24	7
251	8	4	32	8
252	8	4	34	2
253	8	4	38	4
254	8	4	42	4
255	8	4	47	5
256	8	5	13	26
257	8	5	16	3
258	8	5	19	3
259	8	5	23	4
260	8	5	26	3
261	8	5	33	7
262	8	5	40	7
263	8	5	52	12
264	8	6	2	10
265	8	6	5	3
266	8	6	8	3
267	8	6	12	4
268	8	6	18	6
269	8	6	25	7
270	8	7	3	38
271	8	7	9	6
272	8	7	15	6
273	8	7	19	4
274	8	7	22	3
275	8	7	27	5
276	8	7	36	9
277	8	7	42	6
278	8	7	44	2
279	8	7	46	2
280	8	7	50	4
281	8	7	52	2
282	8	7	57	5
283	8	8	1	4
284	8	8	3	2
285	8	8	5	2
286	8	8	47	42
287	8	8	51	4
288	8	8	55	4
289	8	8	1	6
290	8	8	12	11
291	8	8	23	11
292	8	8	27	4

250	8	29	57	3
251	8	30	3	6
252	8	30	10	7
253	8	30	18	8
254	8	30	26	8
255	8	30	33	7
256	8	30	39	6
257	8	30	45	6
258	8	30	49	4
259	8	30	55	6
260	8	30	59	4

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

293	8	8	40	13
294	8	8	46	6
295	8	9	9	23
296	8	9	12	3
297	8	9	16	4
298	8	9	20	4
299	8	9	26	6
300	8	9	44	18
301	8	10	4	20
302	8	10	7	3
303	8	10	10	3
304	8	10	13	3
305	8	10	17	4
306	8	10	33	16
307	8	10	39	6
308	8	10	48	9
309	8	10	52	4
310	8	10	55	3
311	8	11	3	8
312	8	11	9	6
313	8	11	17	8
314	8	11	22	5
315	8	11	27	5
316	8	12	1	34
317	8	12	4	3
318	8	12	9	5
319	8	12	13	4
320	8	12	16	3
321	8	12	32	16
322	8	12	26	54
323	8	12	42	16
324	8	12	48	6
325	8	12	55	7
326	8	13	1	6
327	8	13	9	8
328	8	13	12	3
329	8	13	15	3
330	8	13	31	16
331	8	13	35	4
332	8	13	43	8
333	8	13	47	4
334	8	13	59	12
335	8	14	5	6

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

336	8	14	15	10
337	8	14	42	27
338	8	14	46	4
339	8	14	49	3
340	8	14	54	5
341	8	15	8	14
342	8	15	39	31
343	8	15	45	6
344	8	15	49	4
345	8	15	57	8
346	8	16	2	5
347	8	16	8	6
348	8	16	10	2
349	8	16	58	48
350	8	17	3	5
351	8	17	7	4
352	8	17	11	4
353	8	17	14	3
354	8	17	17	3
355	8	17	27	10
356	8	17	35	8
357	8	17	39	4
358	8	17	42	3
359	8	17	46	4
360	8	17	48	2
361	8	18	7	19
362	8	18	11	4
363	8	18	14	3
364	8	18	19	5
365	8	18	22	3
366	8	18	31	9
367	8	18	36	5
368	8	18	39	3
369	8	17	1	21
370	8	17	12	11
371	8	17	28	16
372	8	17	37	9
373	8	17	39	2
374	8	18	2	22
375	8	18	6	4
376	8	18	22	16
377	8	18	28	6
378	8	18	30	2

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

379	8	18	42	12
380	8	19	7	27
381	8	19	19	12
382	8	19	30	11
383	8	19	38	8
384	8	20	1	23
385	8	20	12	11
386	8	20	15	3
387	8	20	19	4
388	8	20	41	22
389	8	20	44	3
390	8	20	47	3
391	8	20	52	5
392	8	21	1	9
393	8	21	6	5
394	8	21	30	24
395	8	21	34	4
396	8	21	44	10
397	8	22	11	25
398	8	22	15	4
399	8	22	19	4
400	8	22	26	7
401	8	22	34	8
402	8	22	36	2
403	8	22	38	2
404	8	22	41	3
405	8	22	43	2
406	8	22	45	2
407	8	22	50	5
408	8	22	58	8
409	8	23	2	4
410	8	23	6	4
411	8	23	16	10
412	8	23	39	23
413	8	23	44	5
414	8	24	3	19
415	8	24	5	2
416	8	24	13	8
417	8	24	16	3
418	8	24	19	3
419	8	24	23	4
420	8	24	26	3
421	8	25	13	48

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

422	8	25	19	6
423	8	25	23	4
424	8	25	26	3
425	8	25	32	6
426	8	25	43	11
427	8	25	47	4
428	8	26	10	27
429	8	26	14	4
430	8	26	18	4
431	8	26	21	3
432	8	26	23	2
433	8	26	27	4
434	8	26	32	5
435	8	26	40	8
436	8	27	13	33
437	8	27	23	10
438	8	27	29	6
439	8	27	33	4
440	8	27	40	7
441	8	27	44	4
442	8	27	49	5
443	8	27	54	5
444	8	27	57	3
445	8	28	6	9
446	8	28	22	16
447	8	28	46	24
448	8	28	52	6
449	8	28	55	3
450	8	28	58	3
451	8	29	4	6
452	8	29	12	8
453	8	29	15	3
454	8	29	20	5
455	8	29	36	16
456	8	29	45	9
457	8	29	47	2
458	8	29	49	2
459	8	29	59	10
460	8	27	23	-36
461	8	27	29	6
462	8	27	33	4
463	8	27	40	7
464	8	27	44	4

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

465	8	27	49	5
466	8	27	54	5
467	8	27	57	3
468	8	28	6	9
469	8	28	14	8
470	8	28	22	8
471	8	28	34	12
472	8	28	40	6
473	8	28	47	13
474	8	28	52	5
475	8	28	55	3
476	8	28	58	3
477	8	29	4	6
478	8	29	12	8
479	8	29	15	3
480	8	29	20	5
481	8	29	25	5
482	8	29	36	11
483	8	29	45	9
484	8	29	47	2
485	8	29	49	2
486	8	29	59	10
487	8	30	4	5
488	8	30	16	12
489	8	30	19	3

B. SOUTH APPROCH (SARIS )

Car .No.	Count. Period			Headway (Sec)
	hr	min	sec	
1	7	30	9	9
2	7	30	34	25
3	7	30	42	8
4	7	31	15	33
5	7	31	21	6
6	7	31	33	12
7	7	31	40	7
8	7	31	58	18
9	7	32	3	5
10	7	32	12	9
11	7	32	23	11
12	7	32	24	1
13	7	32	33	9

Car No.	Count. Period			Headway (Sec)
	hr	min	sec	
1	7	30	4	4
2	7	31	50	46
3	7	31	59	9
4	7	32	32	33
5	7	32	40	8
6	7	33	0	20
7	7	33	13	83
8	7	33	36	23
9	7	36	39	3
10	7	36	50	11
11	7	36	58	8
12	7	37	3	5
13	7	37	37	34

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

14	7	32	40	7
15	7	32	50	51
16	7	32	56	6
17	7	33	0	4
18	7	33	9	9
19	7	33	21	12
20	7	33	31	10
21	7	33	41	10
22	7	33	50	9
23	7	33	57	7
24	7	34	4	7
25	7	34	11	7
26	7	34	19	23
27	7	34	33	14
28	7	34	45	12
29	7	35	3	18
30	7	35	7	4
31	7	35	26	19
32	7	35	44	18
33	7	35	51	7
34	7	35	59	4
35	7	36	4	6
36	7	36	21	17
37	7	36	33	6
38	7	36	40	61
39	7	36	51	11
40	7	36	59	8
41	7	37	4	5
42	7	37	18	14
43	7	37	25	7
44	7	37	35	10
45	7	37	40	5
46	7	37	48	8
47	7	37	52	27
48	7	38	2	10
49	7	38	7	5
50	7	38	27	20
51	7	38	44	17
52	7	38	50	6
53	7	38	59	9
54	7	39	10	70
55	7	39	15	5
56	7	39	20	5

14	7	38	50	13
15	7	38	57	7
16	7	39	30	33
17	7	40	11	41
18	7	41	40	29
19	7	42	45	5
20	7	42	55	10
21	7	43	10	15
22	7	44	25	15
23	7	44	45	20
24	7	45	20	35
25	7	45	37	17
26	7	46	0	23
27	7	47	13	96
28	7	47	30	17
29	7	48	2	32
30	7	48	19	17
31	7	48	30	11
32	7	48	55	25
33	7	49	1	6
34	7	49	17	16
35	7	49	23	6
36	7	49	27	4
37	7	49	41	14
38	7	50	12	41
39	7	50	22	10
40	7	50	31	9
41	7	50	39	8
42	7	50	50	11
43	7	51	3	13
44	7	51	12	9
45	7	51	19	7
46	7	51	22	3
47	7	51	24	2
48	7	51	38	14
49	7	51	44	6
50	7	51	48	4
51	7	51	56	8
52	7	52	5	11
53	7	52	20	15
54	7	52	31	11
55	7	53	11	70
56	7	53	21	10

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

57	7	39	35	15
58	7	39	41	6
59	7	39	56	15
60	7	40	4	7
61	7	40	8	4
62	7	40	19	11
63	7	40	24	5
64	7	40	39	15
65	7	40	45	6
66	7	40	53	8
67	7	41	2	9
68	7	41	14	12
69	7	41	25	11
70	7	41	31	6
71	7	41	39	8
72	7	41	43	4
73	7	41	55	12
74	7	42	7	12
75	7	42	18	11
76	7	42	27	9
77	7	42	34	7
78	7	42	40	6
79	7	42	54	14
80	7	43	17	23
81	7	43	24	7
82	7	43	28	4
83	7	43	39	11
84	7	43	49	10
85	7	44	33	44
86	7	44	45	12
87	7	45	8	23
88	7	45	23	15
89	7	45	33	10
90	7	46	32	59
91	7	46	42	10
92	7	47	11	29
93	7	47	31	20
94	7	47	38	7
95	7	47	43	5
96	7	47	47	4
97	7	47	51	4
98	7	48	7	8
99	7	48	11	4

57	7	53	33	12
58	7	53	40	7
59	7	53	46	6
60	7	53	53	7
61	7	53	59	6
62	7	54	5	6
63	7	54	14	9
64	7	54	20	6
65	7	54	37	17
66	7	54	40	3
67	7	54	46	6
68	7	55	0	
69	7	55	5	79
70	7	55	8	3
71	7	55	14	6
72	7	55	19	5
73	7	55	29	10
74	7	55	35	6
75	7	55	39	4
76	7	55	49	10
77	7	55	54	5
78	7	55	59	5
79	7	56	5	6
80	7	56	13	8
81	7	56	19	6
82	7	56	23	4
83	7	56	31	8
84	7	56	38	7
85	7	56	49	11
86	7	56	56	7
87	7	57	2	6
88	7	57	23	21
89	7	57	30	7
90	7	57	37	7
91	7	57	50	13
92	7	58	1	11
93	7	58	7	6
94	7	58	12	5
95	7	58	23	11
96	7	58	34	11
97	7	58	42	8
98	7	58	58	16
99	7	59	12	14

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

100	7	48	23	12
101	7	48	35	12
102	7	48	46	11
103	7	48	56	10
104	7	49	0	4
105	7	49	10	10
106	7	49	29	19
107	7	49	49	20
108	7	49	55	6
109	7	50	10	15
110	7	50	16	6
111	7	50	20	4
112	7	50	26	6
113	7	50	35	9
114	7	50	40	5
115	7	51	3	23
116	7	51	12	9
117	7	51	17	5
118	7	51	22	5
119	7	51	45	23
120	7	51	56	11
121	7	52	6	10
122	7	53	4	58
123	7	53	16	12
124	7	53	23	7
125	7	53	29	6
126	7	53	40	11
127	7	53	45	5
128	7	53	50	5
129	7	53	56	6
130	7	53	60	4
131	7	54	7	7
132	7	54	11	4
133	7	54	25	14
134	7	54	33	8
135	7	54	39	6
136	7	54	50	11
137	7	55	4	14
138	7	55	12	8
139	7	55	18	6
140	7	55	26	8
141	7	55	29	3
142	7	55	31	2

100	7	59	19	7
101	7	59	29	10
102	7	59	45	16
103	7	59	50	5
104	8	0	2	12
105	8	0	8	6
106	8	0	20	12
107	8	0	30	10
108	8	0	35	5
109	8	0	39	4
110	8	0	53	14
111	8	1	5	12
112	8	1	19	14
113	8	1	37	18
114	8	1	45	8
115	8	2	7	22
116	8	2	20	13
117	8	2	27	7
118	8	2	34	7
119	8	3	8	32
120	8	3	18	10
121	8	3	52	34
122	8	4	13	-39
123	8	4	25	12
124	8	5	8	43
125	8	5	13	5
126	8	5	19	6
127	8	5	30	11
128	8	5	45	15
129	8	5	49	4
130	8	5	55	6
131	8	6	0	5
132	8	6	5	5
133	8	6	13	8
134	8	6	24	11
135	8	6	39	15
136	8	6	45	6
137	8	6	52	7
138	8	7	4	12
139	8	7	20	16
140	8	7	27	7
141	8	7	32	5
142	8	7	58	26

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

143	7	55	34	3
144	7	55	37	3
145	7	55	49	12
146	7	55	56	7
147	7	56	13	17
148	7	56	18	5
149	7	56	29	11
150	7	56	42	13
151	7	56	45	3
152	7	56	48	3
153	7	56	56	8
154	7	56	59	3
155	7	57	1	2
156	7	57	9	8
157	7	57	20	11
158	7	57	45	25
159	7	58	12	28
160	7	58	19	7
161	7	58	21	2
162	7	58	33	12
163	7	58	43	10
164	7	58	49	6
165	7	59	7	23
166	7	59	9	2
167	7	59	12	3
168	7	59	17	5
169	7	59	21	4
170	7	59	33	12
171	7	59	46	13
172	7	59	49	3
173	7	59	52	3
174	7	59	58	6
175	8	0	8	10
176	8	0	21	13
177	8	0	32	11
178	8	0	50	18
179	8	0	53	3
180	8	0	57	4
181	8	1	0	0
182	8	1	6	69
183	8	1	15	9
184	8	1	19	4
185	8	1	25	6

143	8	8	3	5
144	8	8	13	10
145	8	8	18	5
146	8	8	52	34
147	8	9	21	29
148	8	9	26	5
149	8	9	36	10
150	8	10	11	35
151	8	10	33	22
152	8	10	37	4
153	8	11	20	43
154	8	12	42	22
155	8	12	45	3
156	8	12	49	4
157	8	12	53	4
158	8	13	3	10
159	8	13	10	7
160	8	13	19	9
161	8	14	10	51
162	8	14	16	6
163	8	14	21	5
164	8	14	27	6
165	8	14	31	4
166	8	14	38	7
167	8	14	43	5
168	8	14	53	10
169	8	15	3	10
170	8	15	12	9
171	8	15	19	7
172	8	15	24	5
173	8	15	31	7
174	8	15	35	4
175	8	15	40	5
176	8	15	49	9
177	8	15	55	6
178	8	16	7	12
179	8	16	12	5
180	8	16	24	12
181	8	16	36	12
182	8	17	5	39
183	8	17	13	8
184	8	17	18	5
185	8	17	25	7

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

186	8	1	32	7
187	8	1	38	6
188	8	1	57	19
189	8	2	34	37
190	8	3	10	36
191	8	3	44	34
192	8	3	50	6
193	8	3	55	5
194	8	4	2	7
195	8	4	6	4
196	8	4	19	13
197	8	4	34	15
198	8	4	40	6
199	8	5	2	12
200	8	5	26	24
201	8	5	29	3
202	8	5	33	4
203	8	5	43	10
204	8	5	56	13
205	8	5	60	4
206	8	6	5	5
207	8	6	9	4
208	8	6	25	16
209	8	6	32	7
210	8	6	39	7
211	8	6	50	11
212	8	6	20	30
213	8	6	49	29
214	8	6	55	6
215	8	7	1	6
216	8	7	4	3
217	8	7	8	4
218	8	7	15	7
219	8	8	5	40
220	8	8	13	8
221	8	8	18	5
222	8	8	34	16
223	8	8	40	6
224	8	8	47	7
225	8	8	48	1
226	8	9	14	26
227	8	9	23	9
228	8	9	40	17

186	8	17	43	18
187	8	17	45	2
188	8	17	54	9
189	8	18	0	66
190	8	18	11	11
191	8	18	13	2
192	8	18	27	14
193	8	18	44	17
194	8	19	14	30
195	8	19	27	13
196	8	19	32	5
197	8	19	58	26
198	8	20	7	9
199	8	20	11	4
200	8	20	14	3
201	8	20	35	21
202	8	20	51	16
203	8	20	57	6
204	8	21	12	15
205	8	21	19	7
206	8	21	31	12
207	8	21	39	8
208	8	21	43	4
209	8	21	49	6
210	8	22	1	12
211	8	22	4	3
212	8	22	10	6
213	8	22	11	1
214	8	22	26	15
215	8	22	33	7
216	8	22	41	8
217	8	22	47	6
218	8	23	0	63
219	8	24	5	5
220	8	24	12	7
221	8	24	34	22
222	8	24	40	6
223	8	24	47	7
224	8	25	7	20
225	8	25	17	10
226	8	25	33	16
227	8	25	39	6
228	8	26	15	36

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

229	8	9	50	10
230	8	9	59	9
231	8	10	8	9
232	8	10	18	10
233	8	10	29	11
234	8	10	55	26
235	8	10	59	4
236	8	11	1	2
237	8	11	18	17
238	8	11	36	18
239	8	11	45	9
240	8	11	51	6
241	8	12	55	4
242	8	13	8	13
243	8	13	14	6
244	8	13	18	4
245	8	13	28	10
246	8	13	41	13
247	8	13	55	14
248	8	14	2	7
249	8	14	5	3
250	8	14	11	6
251	8	14	23	12
252	8	15	1	34
253	8	15	5	4
254	8	15	14	9
255	8	15	20	6
256	8	16	9	49
257	8	16	14	5
258	8	16	15	1
259	8	16	34	19
260	8	16	43	9
261	8	16	56	13
262	8	16	58	2
263	8	17	4	6
264	8	17	12	8
265	8	17	14	2
266	8	17	18	4
267	8	17	27	9
268	8	17	40	13
269	8	17	42	2
270	8	17	44	2
271	8	17	46	2

229	8	26	36	21
230	8	26	45	9
231	8	26	50	5
232	8	26	58	8
233	8	27	26	28
234	8	27	39	13
235	8	27	47	8
236	8	27	52	5
237	8	27	59	7
238	8	28	9	10
239	8	28	19	10
240	8	28	22	3
241	8	28	27	5
242	8	28	40	13
243	8	29	3	23
244	8	29	19	16
245	8	29	52	33
246	8	30	3	11
247	8	30	7	4

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

272	8	17	49	3
273	8	17	53	4
274	8	17	57	4
275	8	18	22	25
276	8	18	25	3
277	8	18	42	17
278	8	18	44	2
279	8	18	48	4
280	8	18	52	4
281	8	19	14	22
282	8	19	18	4
283	8	19	20	2
284	8	19	22	2
285	8	19	25	3
286	8	19	28	3
287	8	19	30	2
288	8	19	37	7
289	8	19	42	5
290	8	20	12	30
291	8	20	20	8
292	8	20	29	9
293	8	20	31	2
294	8	20	36	5
295	8	20	37	1
296	8	20	40	3
297	8	20	57	17
298	8	20	59	2
299	8	21	2	3
300	8	21	5	3
301	8	21	9	4
302	8	21	33	24
303	8	21	39	6
304	8	21	42	3
305	8	21	45	3
306	8	22	2	17
307	8	22	11	9
308	8	22	13	2
309	8	22	17	4
310	8	22	23	6
311	8	22	34	11
312	8	22	38	4
313	8	22	47	9
314	8	22	52	5

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

315	8	23	5	13
316	8	23	7	2
317	8	23	9	2
318	8	23	11	2
319	8	23	21	10
320	8	23	26	5
321	8	23	33	7
322	8	23	40	7
323	8	24	12	32
324	8	24	18	6
325	8	24	22	4
326	8	24	24	2
327	8	24	28	4
328	8	24	40	12
329	8	24	41	1
330	8	24	53	12
331	8	24	56	3
332	8	24	57	1
333	8	24	59	2
334	8	25	3	4
335	8	25	18	15
336	8	25	45	27
337	8	26	6	21
338	8	26	7	1
339	8	26	15	8
340	8	26	18	3
341	8	26	19	1
342	8	26	21	2
343	8	26	24	3
344	8	26	28	4
345	8	26	41	13
346	8	26	46	5
347	8	26	56	10
348	8	27	0	4
349	8	27	13	13
350	8	27	45	32
351	8	27	51	6
352	8	27	54	3
353	8	27	57	3
354	8	28	7	10
355	8	28	27	20
356	8	28	32	5
357	8	28	46	14

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

358	8	29	7	21
359	8	29	35	28
360	8	29	45	10
361	8	29	56	11
362	8	30	1	5
363	8	30	3	2
364	8	30	8	5
365	8	30	23	15
366	8	30	36	13
367	8	30	39	3

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C. WEST APPROCH (BIHERETSIGE)

Through  
mov.

Car .No.	Count. Period			Headway (Sec)
	hr	min	sec	
1	7	30	6	6
2	7	30	12	6
3	7	30	25	13
4	7	31	1	36
5	7	31	7	6
6	7	31	12	5
7	7	31	25	13
8	7	32	11	46
9	7	32	19	8
10	7	32	55	36
11	7	33	9	14
12	7	33	15	6
13	7	33	26	11
14	7	33	36	10
15	7	33	41	5
16	7	33	55	14
17	7	34	14	19
18	7	34	36	22
19	7	34	45	9
20	7	35	20	35
21	7	35	48	88
22	7	35	54	7
23	7	36	7	13
24	7	36	15	8
25	7	36	22	7
26	7	36	29	7

Left turn

Car No.	Count. Period			Headway (Sec)
	hr	min	sec	
1	7	30	31	31
2	7	30	41	10
3	7	30	56	15
4	7	31	20	24
5	7	31	30	10
6	7	32	19	49
7	7	32	39	20
8	7	33	27	57
9	7	33	35	8
10	7	34	32	57
11	7	35	15	43
12	7	35	22	7
13	7	35	30	8
14	7	35	41	11
15	7	35	52	11
16	7	36	6	14
17	7	37	7	61
18	7	37	19	12
19	7	38	28	67
20	7	38	40	12
21	7	38	49	9
22	7	38	56	7
23	7	39	23	27
24	7	39	31	8
25	7	39	48	17
26	7	40	6	18

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

27	7	36	37	8
28	7	36	52	15
29	7	37	1	9
30	7	37	11	10
31	7	38	16	41
32	7	38	24	8
33	7	39	4	40
34	7	39	30	26
35	7	40	16	46
36	7	40	21	5
37	7	41	40	80
38	7	41	44	4
39	7	41	55	11
40	7	42	16	21
41	7	42	30	14
42	7	42	45	29
43	7	43	10	25
44	7	43	53	40
45	7	44	4	7
46	7	44	16	12
47	7	45	26	60
48	7	45	58	32
49	7	48	3	5
50	7	48	6	3
51	7	48	31	25
52	7	48	45	14
53	7	50	32	47
54	7	50	41	9
55	7	50	47	6
56	7	51	12	25
57	7	51	19	7
58	7	51	22	3
59	7	52	12	50
60	7	52	38	26
61	7	53	47	60
62	7	54	34	47
63	7	54	55	21
64	7	55	22	27
65	7	55	52	30
66	7	56	4	12
67	7	56	21	17
68	7	56	35	14
69	7	57	35	60

27	7	40	27	21
28	7	41	6	39
29	7	41	26	20
30	7	41	47	21
31	7	42	9	21
32	7	42	12	3
33	7	42	25	13
34	7	42	45	20
35	7	43	5	20
36	7	43	25	20
37	7	43	48	23
38	7	44	6	18
39	7	44	19	13
40	7	44	30	11
41	7	44	52	22
42	7	45	12	16
43	7	45	20	8
44	7	45	29	17
45	7	45	45	16
46	7	45	55	10
47	7	46	25	30
48	7	46	31	6
49	7	47	1	30
50	7	47	13	12
51	7	47	32	19
52	7	47	46	14
53	7	47	59	13
54	7	48	2	3
55	7	48	4	2
56	7	48	28	24
57	7	48	59	31
58	7	49	5	6
59	7	49	14	9
60	7	49	19	5
61	7	49	24	5
62	7	49	26	2
63	7	49	32	6
64	7	50	1	29
65	7	50	9	8
66	7	50	54	45
67	7	51	30	36
68	7	51	32	2
69	7	51	58	26

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

70	7	57	50	15	70	7	52	2	4
71	7	58	19	29	71	7	52	8	6
72	7	58	56	37	72	7	52	34	26
73	7	59	20	24	73	7	53	8	34
74	7	59	28	8	74	7	53	10	2
75	7	59	37	9	75	7	53	12	2
76	8	0	36	59	76	7	53	16	4
77	8	0	43	7	77	7	53	19	3
78	8	1	9	26	78	7	53	49	30
79	8	1	25	16	79	7	53	54	5
80	8	2	30	5	80	7	54	10	14
81	8	2	45	15	81	7	54	26	16
82	8	3	6	21	82	7	54	29	3
83	8	3	20	14	83	7	55	25	56
84	8	3	42	22	84	7	55	51	26
85	8	4	26	44	85	7	56	25	34
86	8	4	53	27	86	7	56	45	20
87	8	5	26	33	87	7	56	48	3
88	8	5	40	14	88	7	56	52	4
89	8	5	55	15	89	7	56	57	5
90	8	6	22	27	90	7	57	1	4
91	8	6	31	9	91	7	57	5	4
92	8	7	12	41	92	7	57	12	7
93	8	7	35	23	93	7	57	21	9
94	8	7	45	10	94	7	58	4	43
95	8	8	15	30	95	7	58	14	10
96	8	8	55	40	96	7	58	18	4
97	8	9	20	25	97	7	58	22	4
98	8	9	40	20	98	7	58	29	7
99	8	10	2	22	99	7	58	35	6
100	8	10	41	39	100	7	58	42	7
101	8	11	25	44	101	7	58	45	3
102	8	11	52	27	102	7	58	47	2
103	8	12	21	29	103	7	58	51	4
104	8	12	51	30	104	7	59	7	16
105	8	13	5	14	105	7	59	17	10
106	8	13	14	9	106	7	59	39	22
107	8	13	35	21	107	7	59	43	4
108	8	14	38	61	108	7	59	49	6
109	8	14	55	17	109	7	59	53	4
110	8	15	5	10	110	7	59	58	5
111	8	15	12	7	111	8	0	3	5
112	8	15	19	7	112	8	0	27	24

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

113	8	16	32	51
114	8	17	38	6
115	8	18	42	10
116	8	19	56	14
117	8	20	45	40
118	8	21	26	41
119	8	23	27	60
120	8	24	20	50
121	8	24	40	20
122	8	25	15	35
123	8	25	30	15
124	8	26	10	40
125	8	26	33	23
126	8	26	44	11
127	8	26	54	10
128	8	27	8	14
129	8	27	34	26
130	8	27	49	15
131	8	28	25	36
132	8	28	45	20
133	8	29	30	45
134	8	29	48	18
135	8	30	5	17
136	8	30	30	25
137	8	30	45	15

113	8	0	30	3
114	8	0	40	10
115	8	0	50	20
116	8	1	14	24
117	8	1	27	13
118	8	1	41	14
119	8	1	43	2
120	8	1	46	3
121	8	1	50	4
122	8	1	55	5
123	8	2	51	56
124	8	2	56	5
125	8	2	59	3
126	8	3	15	16
127	8	3	24	9
128	8	3	38	14
129	8	3	45	7
130	8	3	51	6
131	8	4	12	13
132	8	4	37	25
133	8	4	44	7
134	8	4	48	4
135	8	4	54	6
136	8	5	10	14
137	8	5	21	11
138	8	5	31	10
139	8	5	42	11
140	8	5	51	9
141	8	5	55	4
142	8	5	59	8
143	8	6	12	13
144	8	6	24	12
145	8	6	31	7
146	8	6	41	10
147	8	6	49	8
148	8	6	51	2
149	8	6	56	5
150	8	7	2	6
151	8	7	10	8
152	8	7	19	9
153	8	7	26	7
154	8	7	29	3
155	8	7	32	3

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

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156	8	7	35	3
157	8	7	41	6
158	8	7	50	9
159	8	7	57	7
160	8	8	2	5
161	8	8	5	3
162	8	8	12	7
163	8	8	20	8
164	8	8	30	10
165	8	8	41	11
166	8	8	46	5
167	8	8	50	4
168	8	8	55	5
169	8	8	59	4
170	8	9	8	9
171	8	9	14	6
172	8	9	18	4
173	8	9	22	4
174	8	9	30	8
175	8	9	33	3
176	8	9	36	3
177	8	9	39	3
178	8	9	45	6
179	8	9	55	10
180	8	10	3	8
181	8	10	12	9
182	8	10	22	10
183	8	10	32	10
184	8	10	36	4
185	8	10	39	3
186	8	10	43	4
187	8	10	54	11
188	8	11	9	15
189	8	11	15	6
190	8	11	22	7
191	8	11	30	8
192	8	11	36	27
193	8	11	42	6
194	8	11	49	7
195	8	11	55	6
196	8	11	57	2
197	8	12	12	15
198	8	12	25	13

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

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199	8	12	37	12
200	8	12	55	18
201	8	12	59	4
202	8	13	12	13
203	8	13	17	5
204	8	13	22	5
205	8	13	24	2
206	8	13	30	6
207	8	13	35	5
208	8	13	42	7
209	8	13	51	16
210	8	13	56	5
211	8	13	59	3
212	8	14	4	5
213	8	14	14	10
214	8	14	21	7
215	8	14	29	8
216	8	14	35	6
217	8	14	45	10
218	8	14	50	5
219	8	14	55	5
220	8	14	58	3
221	8	15	0	2
222	8	15	4	4
223	8	15	6	2
224	8	15	15	9
225	8	15	20	5
226	8	15	24	4
227	8	15	29	5
228	8	15	33	4
229	8	15	57	24
230	8	16	14	17
231	8	16	18	4
232	8	16	26	8
233	8	16	30	4
234	8	16	33	3
235	8	17	23	43
236	8	17	28	5
237	8	17	34	6
238	8	17	54	20
239	8	18	10	14
240	8	18	20	10
241	8	19	25	5

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

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242	8	19	34	9
243	8	20	0	24
244	8	20	17	17
245	8	20	19	2
246	8	20	23	4
247	8	20	40	17
248	8	20	47	7
249	8	21	7	20
250	8	21	55	48
251	8	21	59	4
252	8	22	32	33
253	8	22	37	5
254	8	22	40	3
255	8	23	18	38
256	8	24	22	4
257	8	24	26	4
258	8	24	31	5
259	8	24	42	11
260	8	24	46	4
261	8	25	7	21
262	8	25	28	21
263	8	25	35	7
264	8	25	40	5
265	8	25	59	19
266	8	26	12	13
267	8	26	25	13
268	8	26	45	20
269	8	26	51	6
270	8	27	13	21
271	8	27	16	3
272	8	27	42	26
273	8	28	1	19
274	8	28	3	2
275	8	28	7	4
276	8	28	53	46
277	8	28	56	3
278	8	29	0	4
279	8	29	6	6
280	8	29	14	8
281	8	29	29	15
282	8	29	36	7
283	8	29	39	3
284	8	29	44	5

285	8	29	11	25
286	8	30	36	25
287	8	30	46	10

D. EAST APPROCH (ADDIS SEFER)

Through mov.

Car .No.	Count. Period			Headway (Sec)
	hr	min	sec	
1	7	30	9	9
2	7	30	15	6
3	7	30	24	9
4	7	30	41	17
5	7	31	25	64
6	7	31	37	12
7	7	31	49	12
8	7	31	57	8
9	7	32	13	16
10	7	32	41	28
11	7	32	55	14
12	7	33	3	8
13	7	33	8	5
14	7	33	16	8
15	7	34	13	19
16	7	34	20	7
17	7	34	38	18
18	7	34	56	18
19	7	36	44	48
20	7	36	50	6
21	7	38	9	79
22	7	40	8	59
23	7	40	16	8
24	7	40	29	13
25	7	40	57	28
26	7	43	18	21
27	7	43	42	24
28	7	43	50	8
29	7	43	57	7
30	7	44	31	34
31	7	44	42	11

Left turn

Car No.	Count. Period			Headway (Sec)
	hr	min	sec	
1	7	30	1	1
2	7	30	6	5
3	7	30	12	6
4	7	30	38	26
5	7	31	24	46
6	7	31	38	14
7	7	31	44	6
8	7	31	56	12
9	7	34	12	76
10	7	34	19	7
11	7	34	26	7
12	7	34	34	8
13	7	34	42	8
14	7	34	52	10
15	7	34	59	7
16	7	35	6	7
17	7	35	13	7
18	7	35	31	18
19	7	35	44	13
20	7	36	6	22
21	7	36	10	4
22	7	36	16	6
23	7	36	22	6
24	7	36	31	9
25	7	37	8	36
26	7	37	26	18
27	7	37	33	7
28	7	37	42	9
29	7	37	51	9
30	7	37	58	7
31	7	38	5	7

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

32	7	44	52	10
33	7	45	35	43
34	7	45	52	17
35	7	45	59	7
36	7	46	12	13
37	7	46	18	6
38	7	47	2	20
39	7	47	30	28
40	7	47	54	24
41	7	48	3	9
42	7	48	54	51
43	7	49	1	7
44	7	49	56	55
45	7	50	8	12
46	7	50	17	9
47	7	51	1	6
48	7	52	14	23
49	7	52	20	6
50	7	53	48	60
51	7	53	55	7
52	7	54	25	30
53	7	54	50	25
54	7	55	8	18
55	7	55	16	8
56	7	56	21	65
57	7	56	35	14
58	7	56	55	20
59	7	57	48	53
60	7	57	50	2
61	7	58	10	12
62	7	58	26	16
63	7	58	54	28
64	7	59	14	20
65	7	59	21	7
66	8	0	22	60
67	8	1	24	2
68	8	2	54	75
69	8	3	22	28
70	8	4	45	23
71	8	5	43	58
72	8	5	49	6
73	8	5	55	6
74	8	6	40	55

32	7	38	12	7
33	7	38	20	8
34	7	39	14	54
35	7	39	20	6
36	7	39	25	5
37	7	39	31	6
38	7	39	37	6
39	7	39	41	4
40	7	39	48	7
41	7	39	53	5
42	7	39	58	5
43	7	40	56	58
44	7	41	1	5
45	7	41	11	10
46	7	41	23	12
47	7	41	31	8
48	7	41	39	8
49	7	41	41	2
50	7	41	50	9
51	7	41	57	7
52	7	42	27	30
53	7	42	31	4
54	7	43	7	36
55	7	43	19	12
56	7	43	23	4
57	7	43	30	7
58	7	43	37	7
59	7	43	43	6
60	7	43	50	7
61	7	43	56	6
62	7	44	11	15
63	7	44	20	9
64	7	44	27	7
65	7	44	31	4
66	7	44	38	7
67	7	44	45	7
68	7	44	51	6
69	7	45	6	15
70	7	45	11	5
71	7	45	19	8
72	7	45	24	5
73	7	45	29	5
74	7	45	34	5

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

75	8	6	48	8
76	8	6	55	7
77	8	7	45	50
78	8	7	51	6
79	8	8	21	30
80	8	8	30	9
81	8	9	19	49
82	8	9	23	4
83	8	9	34	11
84	8	9	45	11
85	8	9	56	11
86	8	10	15	19
87	8	11	20	5
88	8	11	32	12
89	8	12	35	56
90	8	12	41	6
91	8	12	50	9
92	8	13	20	40
93	8	14	6	46
94	8	14	11	5
95	8	14	14	3
96	8	15	27	65
97	8	15	33	6
98	8	15	36	3
99	8	15	43	7
100	8	16	21	36
101	8	16	28	7
102	8	17	21	53
103	8	18	5	68
104	8	18	15	10
105	8	18	21	6
106	8	18	30	9
107	8	18	41	11
108	8	18	56	15
109	8	19	5	9
110	8	19	12	7
111	8	19	19	7
112	8	19	23	4
113	8	19	45	22
114	8	19	55	10
115	8	20	6	11
116	8	20	14	8
117	8	20	24	10

75	7	45	42	8
76	7	45	52	10
77	7	46	24	32
78	7	46	52	28
79	7	47	31	39
80	7	47	45	14
81	7	48	11	36
82	7	48	24	13
83	7	48	31	7
84	7	48	52	21
85	7	49	4	12
86	7	49	9	5
87	7	49	13	4
88	7	49	34	21
89	7	50	15	39
90	7	50	17	2
91	7	50	27	10
92	7	50	35	8
93	7	51	26	51
94	7	51	54	28
95	7	52	5	11
96	7	52	25	20
97	7	52	33	8
98	7	52	36	3
99	7	53	13	37
100	7	53	45	32
101	7	53	57	12
102	7	54	15	18
103	7	54	24	9
104	7	55	25	1
105	7	55	55	33
106	7	56	28	33
107	7	56	40	12
108	7	56	55	15
109	7	57	17	22
110	7	57	21	4
111	7	57	25	4
112	7	58	35	10
113	7	58	42	7
114	7	58	46	4
115	7	58	49	3
116	7	58	53	4
117	7	59	15	22

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

118	8	20	30	6
119	8	20	41	11
120	8	20	50	9
121	8	20	56	6
122	8	21	5	9
123	8	21	10	5
124	8	21	20	10
125	8	22	8	48
126	8	22	51	43
127	8	22	25	31
128	8	22	32	7
129	8	22	50	18
130	8	22	59	9
131	8	23	15	16
132	8	24	4	46
133	8	24	6	2
134	8	24	48	42
135	8	25	19	39
136	8	25	23	4
137	8	25	25	2
138	8	26	12	47
139	8	26	20	8
140	8	26	25	5
141	8	26	35	10
142	8	26	45	10
143	8	26	50	5
144	8	26	55	5
145	8	27	4	9
146	8	27	11	7
147	8	27	21	10
148	8	27	34	13
149	8	27	49	15
150	8	27	54	5
151	8	28	3	9
152	8	28	21	18
153	8	28	30	9
154	8	28	46	16
155	8	28	51	5
156	8	29	4	12
157	8	29	15	11
158	8	29	19	4
159	8	29	23	4
160	8	30	13	20

118	7	59	25	10
119	7	59	35	10
120	7	59	47	12
121	8	0	10	27
122	8	0	14	4
123	8	0	16	2
124	8	0	22	6
125	8	0	35	13
126	8	0	44	9
127	8	0	49	5
128	8	0	55	6
129	8	1	27	32
130	8	1	37	10
131	8	1	48	11
132	8	1	54	6
133	8	2	38	44
134	8	3	12	34
135	8	3	17	5
136	8	3	25	8
137	8	3	34	9
138	8	3	52	18
139	8	4	4	12
140	8	4	33	29
141	8	4	37	4
142	8	4	45	8
143	8	4	57	12
144	8	5	5	8
145	8	5	15	78
146	8	5	24	9
147	8	5	34	10
148	8	5	41	7
149	8	5	55	14
150	8	6	18	23
151	8	6	57	39
152	8	7	10	13
153	8	7	21	11
154	8	7	34	13
155	8	7	42	8
156	8	7	49	7
157	8	7	55	6
158	8	8	11	16
159	8	8	14	3
160	8	8	35	21

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

161	8	30	20	7
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161	8	8	38	3
162	8	8	42	4
163	8	9	17	35
164	8	9	27	10
165	8	9	35	8
166	8	9	41	6
167	8	9	51	10
168	8	9	58	7
169	8	10	14	16
170	8	10	41	27
171	8	11	14	33
172	8	11	20	6
173	8	11	37	17
174	8	11	51	14
175	8	12	16	25
176	8	12	20	4
177	8	12	30	10
178	8	12	37	7
179	8	12	42	5
180	8	13	5	13
181	8	13	14	9
182	8	13	25	11
183	8	13	37	12
184	8	13	42	5
185	8	13	51	9
186	8	13	58	7
187	8	14	7	9
188	8	14	15	8
189	8	14	20	5
190	8	14	26	6
191	8	14	32	6
192	8	14	42	10
193	8	15	12	24
194	8	15	21	9
195	8	15	34	13
196	8	15	41	7
197	8	15	51	10
198	8	15	55	4
199	8	16	23	29
200	8	16	29	6
201	8	16	46	17
202	8	16	51	5
203	8	16	59	8

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space Intersection

204	8	17	4	5
205	8	17	10	6
206	8	17	35	25
207	8	18	12	37
208	8	18	25	13
209	8	18	34	9
210	8	18	54	20
211	8	19	12	18
212	8	19	21	9
213	8	19	30	9
214	8	19	38	8
215	8	19	49	11
216	8	19	55	6
217	8	20	8	13
218	8	20	20	12
219	8	20	35	15
220	8	21	10	35
221	8	21	20	10
222	8	21	35	15
223	8	21	45	10
224	8	21	56	11
225	8	22	9	13
226	8	22	19	10
227	8	22	28	9
228	8	22	36	8
229	8	22	46	10
230	8	22	51	5
231	8	22	59	8
232	8	23	15	16
233	8	23	24	9
234	8	23	35	11
235	8	23	46	11
236	8	23	55	9
237	8	24	20	25
238	8	24	35	15
239	8	24	45	10
240	8	24	55	10
241	8	25	3	8
242	8	25	13	10
243	8	25	25	12
244	8	25	35	10
245	8	25	45	10
246	8	25	56	11

Improving Level of Service of Light Train, Pedestrian and Motorized Vehicle Shared – Space  
Intersection

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247	8	26	14	18
248	8	26	25	11
249	8	26	36	11
250	8	26	46	10
251	8	26	56	10
252	8	27	15	19
253	8	27	45	30
254	8	28	50	5
255	8	28	53	3
256	8	29	18	25
257	8	29	50	32
258	8	30	18	28
259	8	30	28	10
260	8	30	35	7
261	8	30	43	8
262	8	30	50	7
263	8	30	59	9