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ABSTRACT

As the population and economic growth of every city increases, the demand of transportation also increases. Introducing a new additional mode of transportation system is one of the method in order to fulfill this demand. Based on this the introduction of new light rail transit (LRT) in Addis Ababa city improves the public transportation system, but it is also becoming the barrier for pedestrians and vehicle traffic where it crosses the street at ground level. This study is therefore, focused on the evaluation of the effects of road-rail at grade crossing on traffic performance, by characterizing the existing traffic performance which used to correlate them with the existing flow problems, and by comparing the level of service (LOS) and vehicular delay at different scenarios on Sebategna and Adey Ababa road-rail at grade intersections found in North- South LRT of Addis Ababa city.

In this study, manual traffic counting method aided with video recording during the congested time period and the actual geometry of study junctions have been used for characterizing the existing traffic performance and for the input of vissim software. The existing traffic performance were analyzed by the use of Microsoft excel, while the vehicular delay and LOS have been determined by the use of vissim simulation modeling software version 9.0 in three different scenarios, by considering both light rail vehicle (LRV) and pedestrian crossing, without LRV crossing and in absence of pedestrians.

From the result of the study, most of the movements dominated by the through movements of north bound(41%, 37%) and south bound(31%, 46%) for Adey Ababa and Sebategna intersections respectively, while the west bound left turn and north bound right turn movements of sebategna intersection greater than other left and right turning movements, this was due to both movements were to and from the largest market place merkato. The level of service of the first scenario for both intersections were between LOS_ F and D for all movements except the LRV movements. According 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. From those result of additional delay the traffic performance was more affected by pedestrian crossing than that of LRV crossing. Based on this finding, alternative route was recommended for vehicles whose destination were Merkato market center from southern and western part of the city for Sebategna intersection, and providing pedestrian overpass crossing facility on the near-by intersections along LRT will minimize the existing traffic performance problems.

Key words: Additional traffic delay, light rail transit (LRT), Road-rail at grade intersection, traffic congestion, traffic performance characteristics, Vissim simulation modeling.

TABLE OF CONTENTS

Contents

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

ERA: Ethiopian road authority

EB: east bound

EBL: east bound left turn

EBP: east bound pedestrians

EBR: east bound right turn

EBT: east bound through

E-N: movement from east to north

E-S: movement from east to south

E-W: movement from east to west

ESA: equivalent standard axle

LRT: Light rail transit

LRV: Light rail vehicle

LOS: level of service

NB: north bound

NB-rail: north bound light rail vehicle

NBL: north bound left

NBR: north bound right

NBT: north bound through

NBU: north bound U-turn

N-E: movement from north to east

N-N: movement from north to north (U-turn)

N-S: movement from north to south

N-W: movement from north to west

PED: pedestrian

PTV: Public Transport Victoria, a statutory authority that manages Victoria's train, tram and bus services.

SB: south bound

SBL: south bound left

SBR: south bound right

SBT: south bound through

SBU: south bound U-Turn

SB-rail: south bound light rail vehicle

S-E: movement from south to east

SEC. = Second

S-N: movement from south to north

S-S: movement from south to south (U-turn)

S-W: movement from south to west

WB: west bound

WBL: west bound left Turn

WBP: west bound pedestrian

WBR: west bound right Turn

WBT: west bound through

W-E: movement from west to east

W-N: movement from west to north

W-S: movement from west to south

VEH: vehicle

VISSIM: "Verkehr in Städten – SIMulations modell" (German for "Traffic in cities - simulation model")

CHAPTER ONE

INTRODUCTION

1.1 Background

The transportation system in a developed nation is an aggregation of vehicles, guide-ways, terminal facilities, and control systems that move freight and passengers. These systems are usually operated according to established procedures and schedules in the air, on land, and on water. The set of physical facilities, control systems, and operating procedures referred to as the nation's transportation system is not a system in the sense that each of its components is part of a grand plan or was developed in a conscious manner to meet a set of specified regional or national goals and objectives. Rather, the system has evolved over a period of time and is the result of many independent actions taken by the private and public sectors, which act in their own or in the public's interest [1].

As the population and economic growth of every city increases, the demand of transportation for movement of goods and people from origin to destination should also increases. This demand of transportation can be fulfilled by increasing the existing public transportation facility, by increasing the capacity of existing transportation infrastructure, and or by introducing a new additional mode of transportation system based on which the new light rail transit(LRT) system in Addis Ababa city was introduced.

Addis Ababa which is a capital city of Ethiopia and the seat of many national and international organizations and embassies is becoming the fifth African city in growth of population between 2010 and 2025, next to Dares Salaam Tanzania; Nairobi, Kenya; Kinshasa, Democratic Republic of Congo; Luanda, Angola According to the forecasting reports of African Development Bank (2014). The bank also estimates that between 1960 and 2011, Africa's urban population rose from 19 percent to 39 percent, and projects that 50 percent of Africans will live in urban areas by 2040.This fast growing of population and also traffic in the city result in high demand of transportation system and infrastructure, that's why the introduction of new light rail transit (LRT) system requires.

To solve effectively the problem of urban transportation, especially the downtown area, the government of Ethiopia has decided to build a light rail in the city of Addis Ababa. This project has been planned and constructed in two lines namely east –west (E-W) line and south-north (N-S) line. About 3 km is the shared section, which has the greatest passenger flow. The N-S route goes along Giyorgis Street, Ras Mekonin Avenue and Ras Biru Avenue from the southern to the northern in the city. The first phase of the project which had been completed has the total length of 16.97km. Twenty two LRT stations are placed along N-S route, five of which are shared with E-W route, and average interval between two adjacent stations is 793 meters while the longest and shortest intervals were 1370 meters and 510 meters respectively [18].

When designing a new LRT system, the type of alignment that is eventually selected often is a result of the design goals of the system and the area surrounding the LRT tracks, including costs, service considerations, and operational features. From a planning and operations point of view, similar alignment classes have similar features and concerns with respect to safety and effects on traffic [2].

1.2 Statement of the problem

Road traffic jams continue to be a major problem in most cities around the world, especially in developing regions resulting in increased fuel wastage and monetary losses [3]. The forecast of Global Traffic Volume (GTV) shows that road traffic jams would quadruple between 1990 and 2050 [4]. This type of traffic growth pattern, as envisaged by the end of year 2050, is an indication of what the future congestions portends for people living in urban environment. Effective traffic control mechanisms are therefore pertinent to control the danger. Traffic control mechanisms at intersections include prioritization, traffic personnel control, roundabout, channelization, and by grade separation (interchanges). Each of the aforementioned control mechanisms has its areas of applicability and limitations.

In the field of transportation, highway-rail grade crossings are unique because they are intermodal intersections. Unlike intra-modal intersections, where vehicles/trains from adjacent approaches take turns traversing the crossing, trains have the right of way through highway-rail grade crossings [5]. Trains have been given the right-of-way because of their character and momentum. Vehicular traffic must yield to trains at every grade crossing every time, and may not proceed until all trains have cleared the intersection [5].

In Addis Ababa city the performance of intersections has negative effect on road uses day to day activities. Now a days traffic congestion become threat in the city economy growth by limiting the mobility of the road uses and increase delay and fuel consumption. Hence to reduce the congestion problem at intersections it is important to assess the possible causes that affect the performance of the intersections and measure the traffic congestion and the level of services in order to make the traffic performance smooth and effective.

1.3 Research Questions

The research is aimed to answer the following research questions:

1. How looks like the characteristic of the traffic volume and existing condition at the selected junctions?
2. What is the level of service of the selected road-rail at-grade intersections?
3. How much is the additional vehicle traffic delay both due to frequent LRV crossing, and pedestrian crossing on at grade intersection?
4. What will be the possible solutions for the existing traffic congestion?

1.4 Objectives

1.4.1 General Objective

The main objective of this study was to assess the effect of at grade road-rail intersection on traffic performance.

1.4.2 Specific objectives

This research have included the following specific objectives.

- To characterize the traffic volume of the existing condition at the selected junctions.
- To determine the level of service of the selected road-rail at grade intersections.
- To evaluate an additional delay experienced by vehicles due to some of the factors that affect the traffic performance on road-rail at grade intersection.
- To recommend the possible remedies that will be undertaken to minimize the existing traffic performance problems and for future planning.

1.5 Significance of the study

Now a days traffic congestion have becoming a serious problem by affecting the country development so that the research on Assessment of the Effect of Road-Rail crossing on Traffic performance has a wide range of significance for both the researcher and city administer.

The researcher will have a better understanding on how to manage traffic operation at Road-Rail at-grade crossing, determination of level of service, and in evaluating different factors that affect traffic performance at road-rail at grade intersections.

Determining whether or not the new built Addis Ababa LRT affects the traffic performance will be used for the city administration to identify different factors which affect the road-rail at grade intersection, hence the possible counter measures should be taken to minimize those factors and for planning purposes too.

1.6 Scope of the study

The research will focus on the determination of existence of effects of road-rail at grade crossing on traffic performance by determining level of service (LOS) and an additional delay due to LRT vehicle crossing, and pedestrian effects. The result has been evaluated on two selected street-LRT at grade intersections.

The research examined the changes in average total vehicular delays associated with at-grade road-rail crossings of light rail transit lines. A methodology that allows for direct evaluation of the delay impacts, VISSIM 9.0 simulation modeling software have been used. For this study three scenarios were considered namely by considering both LRT and pedestrian, without LRT and without pedestrian. The pedestrian volume, light rail crossing frequencies and duration, and traffic volumes on the roads in conflict with these crossings were considered as the primary variables affecting the change in delay.

1.7 Structure of the thesis

The following figure shows the design frame work which has been followed for execution of this research.

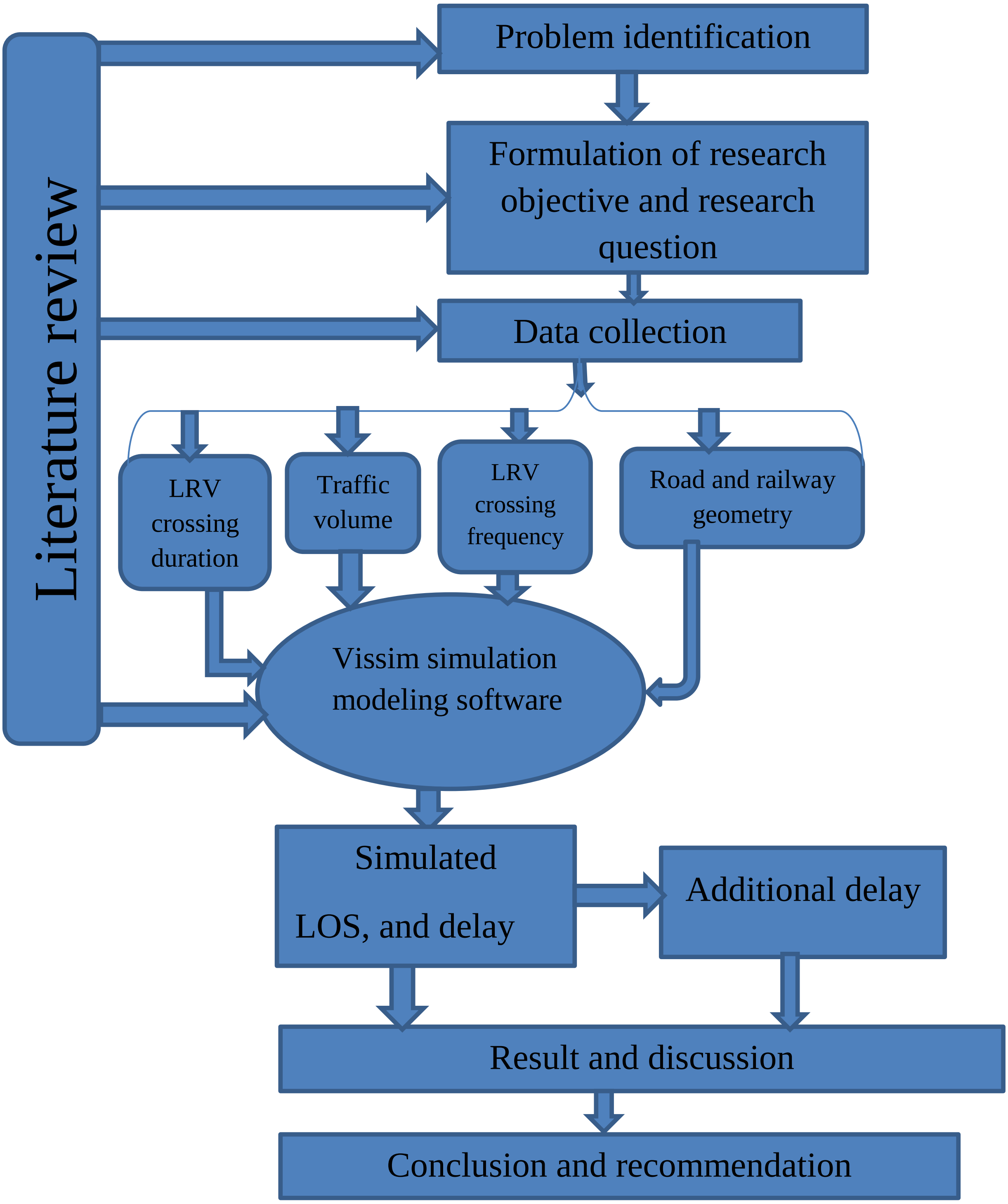


Figure 1. 1 structure work flow of the thesis

1.8 Limitation of the research

The use of manual traffic counting method being difficult to count traffic volume on the study intersections which involve multiple and variety number of traffic, moreover counting the pedestrians being a challenging task since their flow has not constant and they move in a group when the conflicting vehicular traffic give them priority. This makes difficult and time consuming task to identify and count each pedestrians from video. Due to this time and budget constraint the peak hour traffic volume data was collected during the most congested three days of the week, which cannot represent the annual average daily traffic volume. Seasonal variation factors are also not considered which make the traffic volume representing only the time at which it was collected. Those condition may have a negative impact on the output of this research.

CHAPTER TWO

LITERATURES REVIEW

2.1 History of transportation in Ethiopia

Different literature shows that the history of modern and officially managed transport in Ethiopia was emerged in recent year, According to Ethiopian Ministry of Transport and Communications, Modern service delivery of transport in Ethiopia emerged for the first time during the regime of Emperor Menelik-II. After the invading Italian army was driven out of Ethiopia, an office known as "Ministry of Works and Communications" is formed to lead the service of transport and communications. Furthermore the Agency revealed that after staying until 2011 G.C the communication sector was detached from the Ministry with order NO 691/2003 and established bearing the name "Ministry of Transport" changed with the supervision and coordination of the following eleven institutions of transport sectors [6]:

- Chemin de fur Djibouti Ethiopian railway (CDA)
- Ethiopian Airports Enterprise (EAE)
- Ethiopian Airlines (EAL)
- Ethiopian Civil Aviation Authority (ECAA)
- Road Transport Authority (RTA)
- Ethiopian Railway Corporation (ERC)
- Dry Port Administration (DPA)
- Maritime Affairs Authority (MAA)
- Ethiopian Road Authority (ERA)
- Office of Road Fund Agency (ORFA)
- Insurance Fund office(IFO)

2.1.1 Highways

Even though there exist the earliest human road builders recorded history by thousands of years for the foot path, A Study on Problems and Prospects of Transport in Ethiopia, by Chinniah A. & Kalimuthu K. showed that historically planned road building with primitive and local technology, was initiated during emperor Theodros-II (1855 – 1868). With some

European employment, Theodros was able to build roads having a width of 9 to 12 meters from Debre Tabor to Gonder and from Gojam to Mekdella. In 1885, the Italians after invading Massawa started building standard telford based roads towards the south. Emperior Minilik II after defeating the Italian invaders at Adwa in 1896 also used the captured Italian army members to build roads connecting the central region of the country with the northern parts [17].

Moreover the study revealed that in late 1920's with the coming to power of Emperor Haile Selassie-I road building responsibility was bestowed to the Ministry of Public works and considerable efforts were exerted to develop the system. During this period, a number of motor vehicles were imported which promotes a direct impact on the level of the expansion of network. By 1936, before the second Italian invasion, there was about 2,000 Km of roads in the country. During the Italians occupation (1936 – 1941), tremendous road construction was undertaken by the Italians for their militaristic and economic purpose. The Haile Selassie regime allocated an average of 700 million birr of the planned budget for the development of transportation during the three five-year development plans (l957-74). The military government continued to expand and improve the transportation infrastructure by using its own funds and by securing loans from international organizations such as the World Bank. In l991 the transportation system included l3, 000 kilometers of roads [17].

According to the ministry of transport the first part of a 10-year Road Sector Development Program, between 1997 and 2002 the new Ethiopian government began a sustained effort to improve its infrastructure of roads. As a result, as of 2002 Ethiopia has a total (federal and regional) 33,297 km of roads, both paved and gravel. The share of federally managed roads in good quality improved from 14% in 1995 to 31% in 2002 as a result of this program, and to 89% in 2009 the road density increased from 21 km per 1000 km2 (in 1995) to 889 km; per 1000 km2 (in 2009) however, this is much greater than the average of 50 km per 1000 km2 for Africa [7].

The Ethiopian government had begun the second part of the Road Sector Development Program, which was completed in 2007. This had involved the upgrading or construction of over 7,500 km of roads with the goal of improving the average road density for

Ethiopia to 35 km per 1000 km^2. According to the Government of Ethiopia, it has spent over 600 billion birr (USD $50 billion, €30 billion) on infrastructure since 1990 [7].

2.1.2 Expressways

The handbook of highway engineering defined expressways as “those are roads designed for maximum mobility with high speeds and capacities.” Accordingly if there are limited or no controls on the access points to those express way, the capacity, efficiency of travel, and safety levels of the road way may be compromised [29].

The Addis Ababa–Adama Expressway which was the recent development in Ethiopian transportation was completed in 2014 as the first expressway. In December 2015, construction began on a second expressway between Hawasa and Mojo, which will connect to the existing expressway [7].

2.1.3 Railway transport in Ethiopia

The term railway and railroad are sometimes used interchangeably. However, in some literature, railway is generally refer to the track and other closely associated items, i.e., signals, crossings, bridges, etc. while Railroad has been used where the usage connotes the bigger system.

American Railway Engineering and maintenance-of-way association (AREMA) define railway as “A railroad consists of two steel rails which are held a fixed distance apart on a roadbed. Vehicles, guided and supported by flanged steel wheels and connected into trains, are propelled as a means of transportation [30].”

Oxford Dictionary (2000) also defines a railroad as “A system of rail tracks along which trains run, and personnel required for its working”

A study report on “Railway development in Ethiopia” by Yehualaeshet Jemere showed that Ethiopia has over 100 years old diesel railway (781 km) which were owned jointly with the Government of Djibouti and operated by CDE (Chemin de fur Djibouti Ethiopian). The study also revealed about the Present Status of those railways are almost abandoned due to its age deterioration and malfunctioning. But now a day modern and reliable railway system is needed to sustain the economic growth momentum of the country by supporting the demand of freight and passenger mobility [10].

Ethiopia has currently 656 km of railways, which almost entirely consists of the electrified Addis Ababa city`s rail way and Addis Ababa – Djibouti Railway. The Addis Ababa – Djibouti Railway, opened in October 2016, links the capital of Ethiopia to the Port of Djibouti, providing landlocked Ethiopia with an economically much needed link to a Red Sea port. It allows a travel time from Addis Ababa to Djibouti City in less than twelve hours with a designated speed of 120 km/hour. Other railways are under construction [8].

2.2 The choice of mode of transportation

The transportation system that evolves in a developed nation may not be as economically efficient as one that is developed in a more analytical fashion, but it is one in which each of the modes provides unique advantages for transporting the nation's freight and passengers. Each mode has inherent advantages of cost, travel time, convenience, and flexibility that make it "right for the job" under a certain set of circumstances. The auto-mobile is considered to be a reliable, comfortable, flexible, and ubiquitous form of personal transportation for many people. However, when distances are great and time is at a premium, air transportation will be selected supplemented by the auto for local travel. If cost is important and time is not at a premium or if an auto is not available, then intercity bus or rail may be used [1]. Modal decisions relate to what mode of transport the traveler intends to use, would it be car, bus, train or slower modes such as cycling/walking [31]. The transport policy must take account of both social and economic considerations during the choice of mode of transportation. When an area is first supplied with motorized transport, the most relevant question with regard to transport policy is to decide on which mode of transport and which standard should be provided. This will be based primarily on social and financial considerations [32].

Selecting a mode to haul freight follows a similar approach. Trucks have the advantages of flexibility and the ability to provide door-to-door service. They can carry a variety of parcel sizes and usually can pick up and deliver to meet the customer's schedule. Waterways can ship heavy commodities at low cost, but only at slow speeds and between points on a river or canal. Railroads can haul a wide variety of commodities between any two points, but usually require truck transportation to deliver the goods to a freight terminal or to their final destination [1].

2.3 Definition and type of LRT

Different literatures give different related definition for the term Light Rail Transit, among which a Frankfort press by Barry, M (1991), define LRT as “it is a mode of urban transportation that uses predominantly reserved, but not necessarily grade-separated, right-of-way.” Furthermore the press reveals that Light Rail Transit was electrically propelled and it provides a wide range of passenger capabilities with performance characteristics at moderate cost [28].

LRT can also be defined According to American transport research board as it is “A metropolitan electric railway system characterized by its ability to operate single cars or short trains along exclusive rights-of-way at ground level, on aerial structures, in subways, or occasionally, in streets and to board and discharge passengers at track or car floor level” [12].

Manual on uniform traffic control device (MUTCD) discloses that Light rail transit is a mode of metropolitan transportation that employs light rail transit cars (commonly known as light rail vehicles, streetcars, or trolleys) that operate on rails in streets in mixed traffic, in semi-exclusive rights-of-way, or in exclusive rights-of-way. Furthermore the manual describes the groups of Light rail alignments in to the following three types [33]:

A. **Exclusive:** A light rail transit right-of-way that is grade-separated or protected by a fence or traffic barrier. Motor vehicles, pedestrians, and bicycles are prohibited within the right-of-way. Subways and aerial structures are included within this group.

B. **Semi-Exclusive**: A light rail transit alignment that is in a separate right-of-way or along a street or railroad right-of-way where motor vehicles, pedestrians, and bicycles have limited access and cross at designated locations only.

C. **Mixed-Use**: An alignment where light rail transit operates in mixed traffic with all types of road users. This includes streets, transit malls, and pedestrian malls where the right of-way is shared.

The history of Light Rail Transit was initially emerged from northern Europe, which evolved from traditional streetcar systems in many northern European cities during the 1950s and 1960s. Light rail jumped the Atlantic to the North America in the late 1960s and early 1970s [11].

LRT is designed to accommodate a variety of environments, including streets, freeway medians, railroad rights-of-way (operating or abandoned), pedestrian malls, underground or aerial structures, and even in the beds of drained canals. It is this characteristic that most clearly distinguishes it from other rail modes. Because of this design flexibility, LRT generally is less costly to build and operate than other fixed guide way modes [12]

2.4 Traffic Control Devices at Highway-Rail intersections

Intersections near highway-railroad grade crossings involve multiple types of traffic: vehicles, trains, and pedestrians. These intersections require special traffic control devices to properly coordinate the movements of these various types of traffic. There are several levels of traffic control at highway-railroad grade crossings. According to the Research report of Texas Transportation Institute, those traffic control devices at highway-railroad grade crossings divided primarily into passive and active control devices. The most basic of these devices, passive devices, provide static messages of warning, guidance, and perhaps action required by the driver. Among these passive devices are signs and pavement markings. For more advanced traffic control, active control devices are necessary; these devices give warning of the approach or presence of a train and are activated by the passage of a train over a detection circuit in the track. Active control devices are supplemented by the same signs and markings used in passive control [14].

Once a train enters an at-grade crossing area, the right-of-way of the crossing is given to the train, then Vehicle traffic must stop until the train leaves the crossing. Depending on train speed, train length, and traffic control type, this process may take a few minutes or much longer. During this period, both through movements at adjacent intersections are blocked, as are turning movements heading to the crossing. When the traffic volume is high at nearby intersections during peak periods, long queues will form at adjacent intersections, and vehicles do not have sufficient time to get through the crossing and must wait in the queue until the train leaves. In that case, an elongated queue will not only block the traffic at nearby intersections, but also will result in the slowdown or full termination of the mobility of the intersection, or even the entire roadway network in proximity to the railroad [19].

The manual on uniform traffic control device (MUTCD) also reveals that Highway-light rail transit grade crossings in semi-exclusive alignments shall be prepared with a combination of traffic gates and flashing-light signals, or flashing light signals only, or traffic control signals, unless an engineering study indicates that the use of stop, yield, or advance warning signs alone would be adequate. The use of stop or yield signs for road users at highway-light rail transit grade crossings should be limited to those crossings where the need and feasibility is established by an engineering study. Moreover the manual illustrate those crossings into the following characteristics [33]:

- The crossing roadways should be secondary in character (such as a minor street with one lane in each direction, an alley, or a driveway) with low traffic volumes and low speed limits.
- The road user has sufficient sight distance at the stop line to permit the vehicle to cross the tracks before the arrival of the light rail transit vehicle.
- If at an intersection of two roadways, the intersection does not meet the warrants for a traffic control signal.

Accordingly the manual states that if a stop or yield sign is installed beyond the light rail transit crossing such that vehicle queues are likely to extend into the path of the light rail transit, a "do not stop on tracks" sign should be posted on highway-rail grade crossing. The Light Rail Transit Approaching-Activated Blank-Out warning sign supplements the traffic control signal to warn road users turning across the tracks of an approaching parallel light rail transit vehicle. This may be used at signalized intersections near grade crossings or at crossings controlled by stop signs or automatic gates [33].

According to Californian path Research Report(2009), a typical Rail-road signalized intersections should be designed as in such a way that the crossing controller will receive a train approaching signal from detection equipment, and then initiate the warning devices and the necessary traffic signal events including the clearance of tracks, while during the time of train crossing the warning devices will be activated for at least a minimum amount of time prior to the arrival of the train at the crossing. When the automatic crossing gates are lowered and all movements towards the track have stopped, the traffic signal may implement a limited phasing sequence. Finally after the train crossing, the railroad crossing controller will trigger the automatic gates to rise and stop the flashing signals and horns, then the traffic is allowed to move normal [20].

2.5 Traffic characteristics and traffic performance

Traffic performance study is a crucial factor for the traffic management, most literatures verify this, among which Nicholas J. Garber & Lester A. Hoel. Reveals that traffic performance has a fundamental importance in developing and designing strategies for intersection control, rural highways, and freeway segments [1].

The traffic characteristic of developing countries is the large number of pedestrians and cyclists compared to European conditions which influences the capacity of the roads as well as the flow of traffic. Comprehensive and updated traffic counts will only rarely be available, and the traffic engineer will have either to conduct extensive traffic surveys or to make do with some rough estimates, depending on the actual need. Often the only data available are the number of passenger cars and other motor vehicles, hence traffic engineering models or measures cannot be applied without a careful analysis of the local conditions [21].

According to Highway and Traffic Engineering in Developing Countries there are three major factors that affect the flow of traffic and road safety conditions, which are composition of traffic, the behavior of road users and the condition of vehicles [21].

2.6 vehicle classification for traffic volume count

According to ERA flexible pavement design manual revised in 2013, 13 type of vehicle class as shown in table below were recommends for traffic counting.

Those classifications are for the purpose of flexible pavement design in which the average ESA values for the heavy vehicle classes can be very different; this more detailed classification will enable a more accurate estimate of the total ESA values.

Table 2. 1 vehicle classification (source ERA 2013 flexible pavement design manual)

	type	**Axles**	**Description**
1	Car	2	Passenger cars and taxis
2	Pick-up/4-wheel drive	2	Pick-up, minibus, Land Rovers, Land Cruisers
3	Small bus	2	< 27 seats
4	Bus/coach	2	> 27 seats
5	Small truck	2	< 3.5 tones
6	Medium truck	2 or 3	3.5 - 7.5 tones
7	Large 2-axled truck	2	> 7.5 tones
8	3-axled truck	3	>7.5 tones
9	4-axled truck	4	*
10	5-axled truck	5	*
11	6-axled truck	6	*
12	2-axled trailer	2	*
13	3-axled trailer	3	*

So for the purpose of traffic management and for simplicity ERA also recommends the following type of vehicle classes.

Table 2. 2 Basic vehicle classes for traffic volume count (source ERA 2013 flexible pavement design manual)

Vehicles	Classes
Car	1,2,3
Bus and small truck	4,5,6
Large Truck	7-11
Truck with trailers	12&13

2.7 Previous research studies on effect of LRT on traffic performance

A research report on “Effects of Light Rail Transit on Traffic Congestion” by Chad Chandler (2004), examines the effects of light rail crossings on average delays experienced by vehicles using the VISSIM 3.70 computer simulation model. The study examined the following four scenarios:

- Isolated crossings of two-lane,
- Isolated crossings of four-lane roads,
- A case in which light rail transit is located in the median of a street and,
- A larger network that includes four crossings.

On this study the effects of variable traffic volumes and light rail crossing frequencies were studied in the isolated intersection scenarios. The scenario with LRT in the median and the larger network examined the effects of different crossing frequencies as well as full traffic signal preemption. The results of the simulated test scenarios indicate that the average additional delays from light rail transit crossings increase with increasing light rail crossing frequencies and increasing traffic volumes up to the roadway's capacity. As the road enters an over saturated condition, the average total delays continue to increase, but the difference in total delays with and without light rail decreases from the unsaturated condition. The result from this study also revealed that the preemption of traffic signals near light rail crossings increases the total delay experienced by vehicles that are in conflict with the light rail crossing, but it tends to improve travel times for the no conflicting movements due to the increased green time [15].

Based on the results, it was determined that traffic volumes at crossings and the frequency of light rail crossings are important variables that affect the average additional delays experienced by vehicles [15].

Another researcher Yilkal Endeshaw for his partial fulfillment of master of science studied on "Harmonization of Light Rail Transit and Principal Arterial Streets" (A Case Study on the Addis Ababa East-West LRT Line and Principal Arterial Streets), on this study he predicted the future effect of previously under construction Addis Ababa's East West LRT on traffic congestion by projecting the 2013 actual traffic volume on the opening of LRT for traffic which is in 2015 [16].

In order to assess impact on traffic congestion (the possible additional delay to be induced) at Intersections after the introduction of new Light Rail Transit System into existing Principal Arterial Streets, primary data was collected at four study junctions of Addis Ababa E-W corridor where the LRT crosses at grade with the existing principal street intersections. He used the peak hour traffic data and the geometric elements of the study junctions by measuring [16].

In the assessment of impact of traffic congestion due to the new LRT system, his result showed that there is an additional delay to the normal control delay at the three junctions of his study junction (Beshale Hotel Round About, CMC Round About and Ayat Round about) where the LRT crosses at-grade. According to his result with the existing geometric condition and future projected traffic, in 2016 the left turn movements will face about 41.7 sec/vehicle of additional average delay after the introduction of Light Rail transit [16]. On the other hand, the through traffic of North-South direction at these locations will experience more additional delays of about 47.7 sec/vehicle on average [16].

At another his study junction of Bambis Intersection, since the LRT is separated from the city street traffic with median curb stone and North-South Crossing is prohibited, the result showed that additional delays are not observed. Instead, the through traffic of East-West direction at this junction is observed to experience less control delay than before due to the decrease in conflicts of North and South crossing traffic [16].

CHAPTER THREE

METHODOLOGY

3.1 Description of the Study Area

The study area is Addis Ababa city which is the capital city of Ethiopia and the seat of many national and international organizations including the head office of African Union. With an urban population of over 3,400,000, which takes 24% of the total population of Ethiopia. The urban area is 530. 14 km^2, and the density reached 6413.4/km^2 [25].

Based on the world geodetic coordinate reference system (WGS 84) , which is the latest revision of the World Geodetic System, Addis Ababa is geographically located between Latitude: (8°50'11''-9°05′27.89″) N and Longitude: (38°39′37.01″-38°55′00.05″) E with an average elevation of 2405 m above sea level.

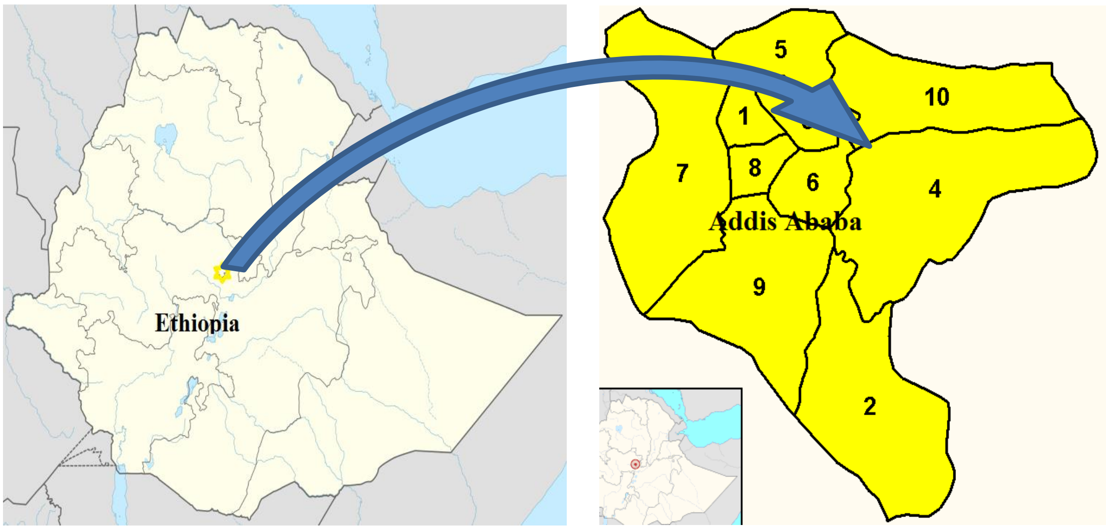


Figure 3. 1 location map of study area (wikipedia may 15/2017)

3.1.1 Description of study corridor

The study corridor is Addis Ababa LRT South-North line, Phase1which has total length of 16.97km. From this corridor the most congested intersections were selected as study junction purposively, which are located at Sebategna and Adey Ababa based on which their respective names has been used in this study.

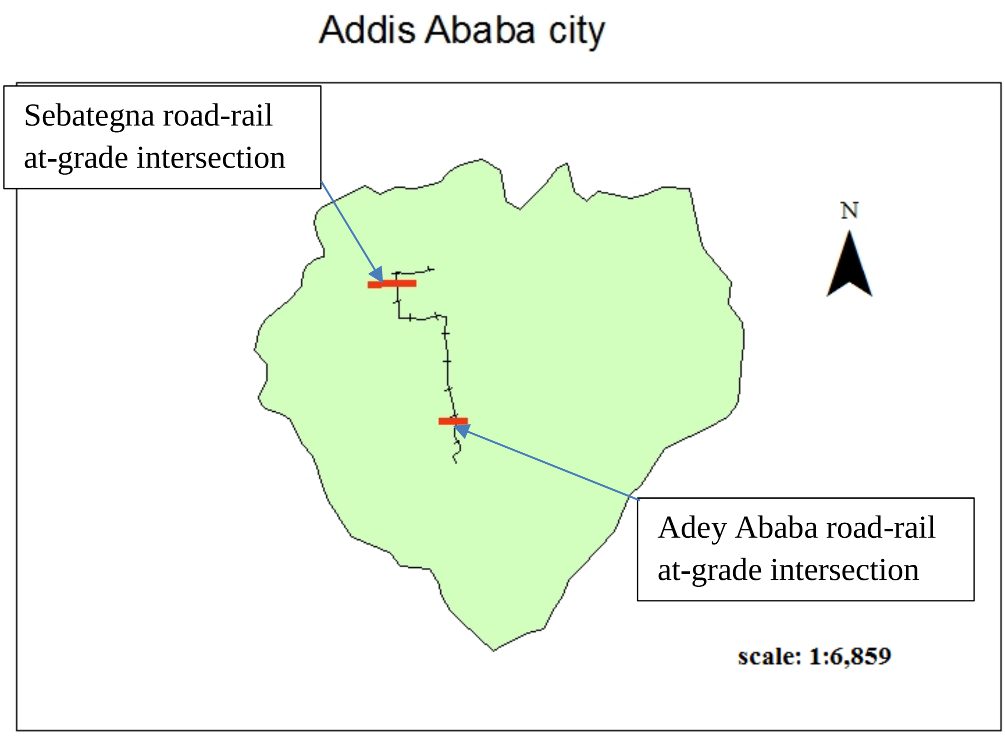


Figure 3. 2 Addis Ababa North-south LRT route (source satellite image digitized by GIS software)

3.1.2 Description of study intersections

This research has been conducted on two different intersections in Addis Ababa city where the route of LRT crosses the street on at ground level. Those at grade street-LRT intersections are located on south-north line, phase-I Addis Ababa's LRT which extends from Menelik-II Square and ends at Kaliti.

The first study junction is Sebategna at-grade street-LRT intersection, which is located in North West part of the city and near to the biggest market place so called Merkato. It was also serving as an entrance from the southern, west, and eastern part of Ethiopia for both public transport buses and commercial vehicles which destinations are Merkato bus station and Merkato market place respectively. Due to those reasons, and according to the interview of traffic police, the selected intersection was among the most congested in traffic, based on which it was selected as study junction purposively.

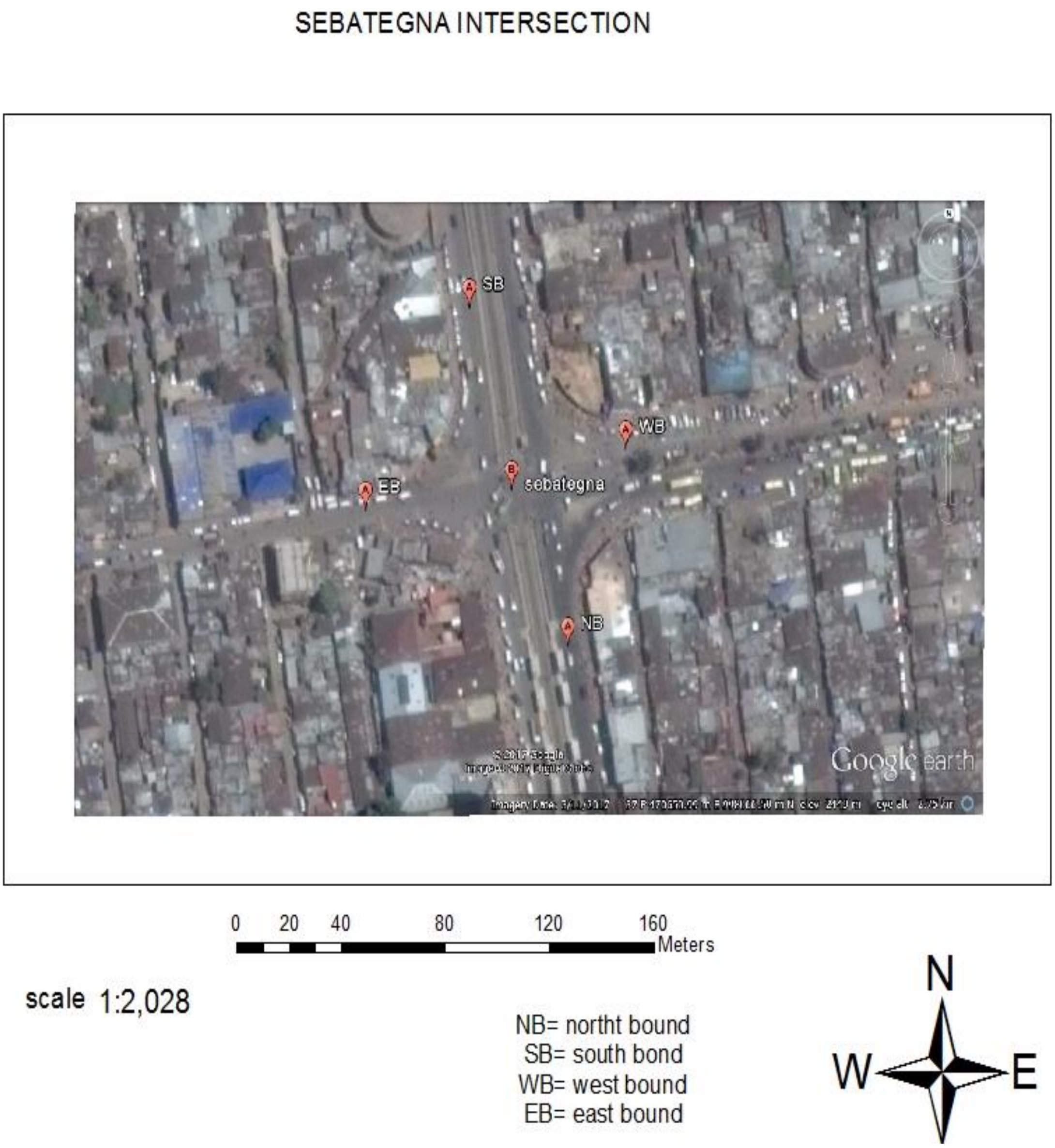


Figure 3. 3 sebategna at grade road-rail intersection (source satellite image scaled with GIS software)

The second study intersection is located in the southern part of the city namely in Adey Ababa, which was the main gate from the southern and eastern part of the country.

In both of the selected intersections the rail way is located at the middle of the main street which used as a median, and the type of intersections are four legged intersections.

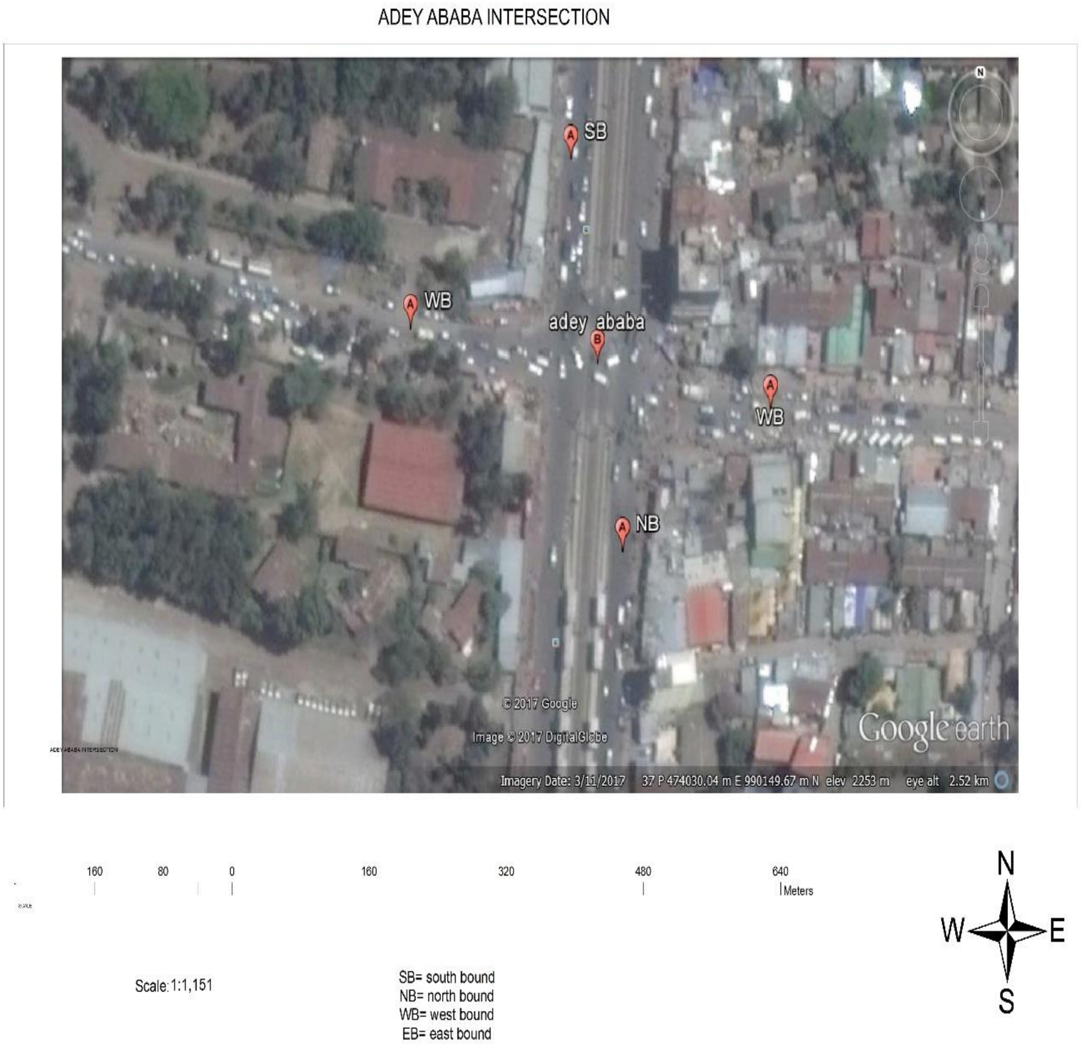


Figure 3. 4 Adey Ababa at grade road-rail intersection (source satellite image scaled with GIS software)

3.2 Study design

In this study both descriptive and explanatory type of survey has been applied, in order to answer this research question. The descriptive one is used to describe the existing condition, while explanatory type is used to determine the effect of at grade road-rail crossing on traffic performance.

The simulation modeling software so called "PTV vissim" version 9.0 developed by PTV group has been used for modeling delay of vehicles in different scenarios and for determination of the level of service analysis. It also realistic and accurate in every detail. Generally Vissim is a microscopic, time step oriented, and behavior-based simulation tool for modeling urban and rural traffic as well as pedestrian flows, which creates the best conditions to test different traffic scenarios before their realization. Accordingly three scenarios have been considered in this study, each of them have almost similar procedures except the difference in the volume entry.

3.2.1 Scenario one (road-rail at grade intersection "with Light Rail Vehicle and pedestrian crossing" model for actual case)

Vissim simulation modeling software has been used for modeling the actual condition of the selected study junctions, which is based on the actual collected peak hour traffic volume and the existing geometry by considering that the light rail vehicle crosses at seven minute time interval and thirty two seconds duration of crossing. Those values were average values obtained from actual and nominal LRV crossing conditions.

This scenario used to indicate the total delay of vehicles due to high volume of vehicles, LRV crossing, pedestrian crossing but excluding the effects of traffic operation problems since every traffic operation condition have been programed and managed by the Vissim software itself. The level of service of existing intersection have been determined by this scenario, since the simulation in Vissim were considered and treated as actual case except that traffic operation problems were not to be shown in Vissim.

3.2.2 Scenario two (road-rail at grade intersection "without Light Rail Vehicle crossing")

This scenario is similar with the first scenario except that in this scenario light rail vehicle crossings were not considered in order to know the vehicle delay due to high volume of vehicles and pedestrian crossing only. Therefore both the effects of LRV crossing and traffic operation problems were not shown in this scenario.

3.2.3 Scenario three (road-rail at grade intersection "without pedestrian")

The last scenario which has been conducted in similar way with that of the first scenario except that pedestrians were not considered in this scenario. This scenario used to determine the effect of pedestrian and total delay of vehicle due to high vehicle volume and LRV crossing only.

Using the above listed three scenarios and with their respective procedure the effects of LRV crossing, and pedestrian crossing were determined as follows.

- The effect of LRV crossing: the effect of LRV crossing could be determined by subtracting vehicle delay of scenario two from scenario one.

$$\textit{Additional delay of vehicle due to LRV crossing} \\ = \textit{vehicle delay of scenario one} - \textit{vehicle delay of scenario two}$$

- The effect of pedestrian crossing: the effect of pedestrian crossing could be determined by subtracting vehicle delay of scenario three from scenario one.

$$\textit{Additional delay due to pedestrian crossing} \\ = \textit{vehicle delay of scenario one} - \textit{vehicle delay of scenario three}$$

3.3 Study variables

3.3.1 Dependent variables

Usually the dependent variable is directly related with the main objective of the research and it was the output of the research hence the dependent variable for this study was; effect of road-rail crossing on traffic performance.

3.3.2 Independent variables

- LRV crossings frequency
- LRV crossings duration
- Traffic volume; both vehicle and pedestrian volumes
- Number and width of lane
- Speed of vehicles and pedestrians

3.4 Data collection

There were two main types of data which has been used for analysis purpose in this research namely primary and secondary data, both of which were obtained from direct field measurement and from secondary sources respectively as their name indicates.

Primary data for this research include:

- Traffic volume counted manually,
- Number and width of lane,
- Width of LRT as median,
- Longitudinal road gradient.
- Actual crossing frequency of light rail vehicle

- Actual crossing time duration of light rail vehicle

Secondary data included

- Nominal crossing frequency of light rail vehicle
- Nominal crossing duration of light rail vehicle

3.4.1 Traffic volume count

There are different traffic counting methods which are manual and automatic counting methods, but due to limitation of available counting materials in this research manual counting method assisted with videos recorded during the congested time period has been used.

For better and accurate traffic volume data different manuals recommend 7 days of traffic counting but due to time and budget constraint, traffic counting for this study was conducted for three days of the week during peak hour of each day.

According to AASHTO geometric design manual, traffic volumes for an interval of time shorter than a day (peak hour) more appropriately reflect the operating conditions that should be used for design. The brief, but frequently repeated, rush-hour periods are significant in this regard. And In nearly all cases, a practical and adequate time period is one hour [24].

Based on the interview of traffic police and the general trend of Addis Ababa city traffic, the predicted peak hour for this study was selected from Monday to Friday during morning, afternoon, and evening time, morning peak hour 8:00am-9:00am, afternoon peak hours 12:00am-1:00pm, and evening peak hour 6:00pm-7:00pm. The researcher used this time period for traffic data collection in this study.

At Sebategna intersection two different places have been used for camera location, dire tower G+10 has been used during morning and afternoon time. But during evening peak hour time recording video from Dire tower couldn’t be allowed by the respective management for security purpose since there were banks and insurances on this building, hence Yologia market center (under construction) has been used for camera location during evening peak hour.

Table 3. 1 Date of video recording and camera location for Sebategna intersection traffic volume

Date of recording	Time of recording	Camera location
July 23/2017	8:00 am-9:00 am	10th floor of Dire Tower
	12:00am-1:00pm	10th floor of Dire Tower
	6:00pm-7:00pm	6th floor of Yologia market center (under construction)
July 24/2017	8:00 am-9:00 am	10th floor of Dire Tower
	12:00am-1:00pm	10th floor of Dire Tower
	6:00pm-7:00pm	6th floor of Yologia market center (under construction)
July 27/2017	8:00 am-9:00 am	10th floor of Dire Tower
	12:00am-1:00pm	10th floor of Dire Tower
	6:00pm-7:00pm	6th floor of Yologia market center (under construction)

For good interpretation of video during traffic counting a better video quality will be required, hence the researcher used a high definition (HD) camera model of "canon 5D" by renting from the respective body. More over counting the pedestrians being difficult and time consuming task since mass number of pedestrians were crossing the intersection at a time. Accordingly the use of high resolution camera quietly solve this problem by identifying each individual from the recorded video.

Accordingly from the result of three day traffic count the researcher has used the maximum volume for the input in vissim simulation modeling software while the average volume of the three day peak hour traffic volumes has been used for characterizing the existing traffic condition. Based on this the maximum volume for Sebategna intersection was observed Tuesday evening, and for Adey Ababa it was on Thursday morning.

Figure 3. 5 camera position for sebategna intersection (July 23/2017)

Table 3. 2 Date of video recording and camera location for Adey Ababa intersection traffic volume

Date of recording	Time of recording	Camera location
July 25/2017	8:00 am-9:00 am	5th floor of Mame building (saris paris café)
	12:00am-1:00pm	5th floor of Mame building (saris paris café)
	6:00pm-7:00pm	5th floor of Mame building (saris paris café)
July 26/2017	8:00 am-9:00 am	5th floor of Mame building (saris paris café)
	12:00am-1:00pm	5th floor of Mame building (saris paris café)
	6:00pm-7:00pm	5th floor of Mame building (saris paris café)
July 30/2017	8:00 am-9:00 am	5th floor of Mame building (saris paris café)
	12:00am-1:00pm	5th floor of Mame building (saris paris café)
	6:00pm-7:00pm	5th floor of Mame building (saris paris café)

Figure 3. 6 camera position for Adey Ababa intersection (July 25/2017)

3.4.2 Road cross sectional geometric data

The actual geometric data were significant for the simulation output in vissim software, hence all actual geometric condition of each study intersection have been considered and based on this the geometry of each intersections drawn in vissim software.

Table 3. 3 Road cross sectional geometric data for sebategna intersection

Direction of movement	Median type	No. of lane	Lane width (m)
North bound	Divided by LRT	2	3.5, 3.3
South bound	Divided by LRT	2	3, 3.3
West bound	Divided	2	3.5
East bound	Undivided	1	3.5

Based on the actual geometric data measured from the study junctions, the width of lane for north and south bound were not common and they were also different from the design geometric data due to the introduction of LRT route as median.

Table 3. 4 Road cross sectional geometric data for Adey Ababa intersection

Direction of movement	Median type	No. of lane	Lane width (m)
North bound	Divided by LRT	2	3.5, 3.3
South bound	Divided by LRT	2	3, 3.3
West bound	Undivided	2	3.5
East bound	Undivided	2	3.5

3.4.3 Railway geometric data

Even though the cross sectional geometric data for railway track has fixed standard for most countries, there were also different railway geometric cross sections for different countries. Due to this difference the researcher has used the actual railway geometry of the study route as shown from the table below.

Table 3. 5 Railway cross sectional geometric data for N-S Addis Ababa's LRT line

Direction of movement	No. of lane	Width of rack gauge (mm)	Sleepers width(m)
North bound	1	1524	2.4
South bound	1	1524	2.4

3.5 Modeling considerations and Base data for simulation

The basic data input for vissim simulation includes the road and railway geometric data, settings for the entire intersection network and all basic objects for modeling vehicle and pedestrian movement, distributions, functions, and behavior parameters.

3.5.1 Traffic flow model

The type of traffic performance model is essential for the quality of the simulation since Vehicles are moving in the network using a traffic performance model in vissim. In contrast to simpler models a largely constant speed and a deterministic car following logic are provided. According to Vissim user manual, the software uses the psycho- physical perception model developed by Wiedemann, R. (1991), which accounts for psychological aspects as well as for physiological restrictions of drivers' perception [22].

Wiedemann's traffic flow model is based on the assumption that there are basically four different driving states for a driver in which Vissim considers, those state includes free flow state, approaching state, following state and Braking state.

Free driving: In this state there is no influence of preceding vehicles observed. The driver seeks to reach and maintain his desired speed, while in reality, the speed in free driving will vary due to imperfect driving control

Approaching: during approaching state the driver decelerates, so that there is no difference in speed after desired safety distance has been attained.

Following: The driver follows the preceding car without consciously decelerating or accelerating by maintaining the desired safety distance.

Braking: based on the movement of the preceding vehicle braking will be applied to keep the desired safety distance.

3.5.2 The use of 2D/3D models

Adjusting all 2D/3D models in vissim to fit with actual case is used to make the model best fit with real case, and hence to have considerably an accurate modeling result.

Since a 2D/3D model can also defines the visualization of static and moving objects like vehicles and pedestrians. Some of the dimensions of those 2D/3D model have defined and made them to fit with the actual objects but due to scope of this study and since the researcher consider the default values for the positions of axles, shaft length and joints, age and sex of pedestrians considerably will not affect the result of the study, those are remain as their default values.

The size and shape of car, bus, truck and truck with trailer were selected from the vissim 2D/3D vehicle category which almost the length and width of them are similar with vehicles from the actual traffic. The model, size, number of attached rail vehicles, and shape of train was also being defined to fit with the actual light rail vehicle which is currently working in case study area.

3.5.3 Approaching and desired speed distributions

According to AASHTO geometric design manual (2001) urban arterial streets should have a design speeds between 30 to 70 km/h. after taking different sample of travel time and by considering their average value the researcher adopted the minimum approaching speed of 30km/hr. until the vehicle reaches to 50m before the intersection, and after which reduced speed zone with 20 km/hr. has been provided at conflict area during the vehicles cross the study junction by considering the condition of study area and high volume of pedestrians.

A driver in vissim whose desired speed is higher than his current speed, will check whether he can overtake other vehicles without endangering anyone. The distribution function of desired speeds is a particularly important parameter, since it has an impact on link capacity and achievable travel times.

3.5.4 Vehicle categories for simulation

The default vehicle category of vissim includes car, truck, bus, tram, pedestrian and bike. Among those all of them were included for this study except bike is not considered by the researcher due to very low volume existence and has considerably less effect on the existing traffic performance at the study junction.

The Vehicle category attribute of a vehicle type specifies its basic behavior in traffic. For example, the vehicle category Train does not allow for lane changes and the speed of vehicles of this category is not based on a desired speed. Vissim's default 2D/3D model distributions are predefined for each vehicle type. For example the distribution for cars contains seven different car models with different percentages of 14%, 20%, 24%, 10% and the remaining three different car models share an equal composition of 16%. These vehicle models have been assigned as a relation 2D/3D model distribution elements of the 2D/3D model distribution Car. Each of models Car represent vehicle models that differ in length, but have a similar driving behavior [22].

3.5.5 Pedestrian walking Speed

The speeds at which pedestrians cross a street has been significant for the result of this study, because they have a broad range of walking speed due to their age difference or physical performance. Average pedestrian walking speeds range from approximately 0.8 to 1.8 m/s. The Manual on Uniform Traffic Control Devices (MUTCD) uses a normal walking speed of 1.2 m/s. older people will generally walk at speeds in the lower end of this range while younger ones may walk above this speed [23].

Walking speeds are faster at midblock locations than at intersections, are faster for men than for women, and are affected by steep grades. Air temperature, time of day, and trip purpose all affect pedestrian walking speeds. Age is the most common cause of slower walking speeds, and in areas where there are many older people AASHTO(2001) recommends a speed of 0.9 m/s[24].

Accordingly the researcher had an assessment by taking sample of travel time for pedestrians then the walking speed of 1.4m/s has been adopted, since most of pedestrians in both study junction were crossing the street at faster speed than they were moving in other location, and most of them were at younger age.

3.6 The general working procedures in vissim software

In order to have scaled correlation of link which is going to be drawn on vissim with the actual geometric intersection, first scaled map of the study area has been added on vissim user interface either from online google map or by using another prepared map. The researcher for this study used scaled map of study area.

The vissim software is simulation modeling software so that all the geometric features were drawn on vissim using the link object and the link behavior need to be set based on the actual grade, link width, roadway surface type and design speed to fit with the actual geometric features. The vehicle static routing were assigned for all driving lanes in all movement directions.

After the geometric feature of study intersection has been drawn, the conflict status and behavior were set according to the purpose and type of traffic lane in which the driving lane supposed to serve. Accordingly ninety seven conflicts for each study junction were developed, and all of them were configured based on priority rule for train, pedestrian and then for vehicles from major road. Vehicle conflicts from similar behavior lane were set to be passive, which means they need to wait each other and the preceded one will get the right of way and then the next vehicle will follow. This could be possible in vissim because vissim simulate every vehicles based on the configured behavior of the driver in similar manner with actual case.

The first priority rule had been given for train, and next for pedestrians, also signal control has been used for pedestrians in order to avoid a complete blockage of vehicle movement by pedestrians.

After setting and configuring all the driving behavior with their respective parameters then the corresponding traffic volume were filled according to the collected traffic volume for each direction and movement type. Accordingly eighteen different movement were developed for each study junction and hence the traffic volume for each of all movements were filled based on the actual peak hour traffic volume for scenario one of this study. For scenario two all procedure and configurations were similar with scenario one but in LRT route the volume filled to be zero. And in similar manner for scenario three the pedestrian volumes of both east and west bound movements filled to zero.

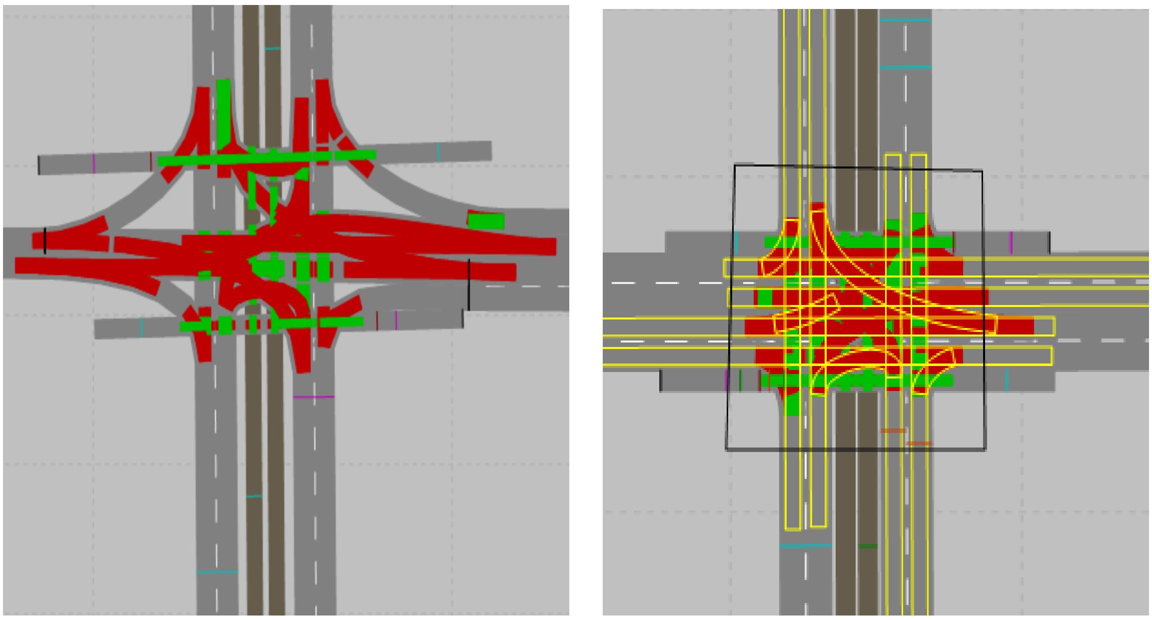


Figure 3. 7 the configuration of conflict areas for Sebategna and Adey Ababa intersections (source: vissim simulation modeling software)

There were different mechanism of output production in vissim software, among which a method of node result output production has been used for this study.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Traffic volume result and character

4.1.1 Traffic volume characteristics of Sebategna intersection

The first study junction located at sebategna was among the congested road-rail at grade intersection in Addis Ababa city. According to the collected traffic data this intersection was characterized by high volume of pedestrians crossing the intersection in the east-west directions, which has a crossing conflict with north-south LRT.

The through movement have been dominated by north and south bound movements while the west bound left turn and north bound right turns reaches to peak volume than other left and right turning movements as shown from fig. 4.1. This was due to the reason that both north bound right turn and west bound left turn movements were to and from the largest market place Merkato.

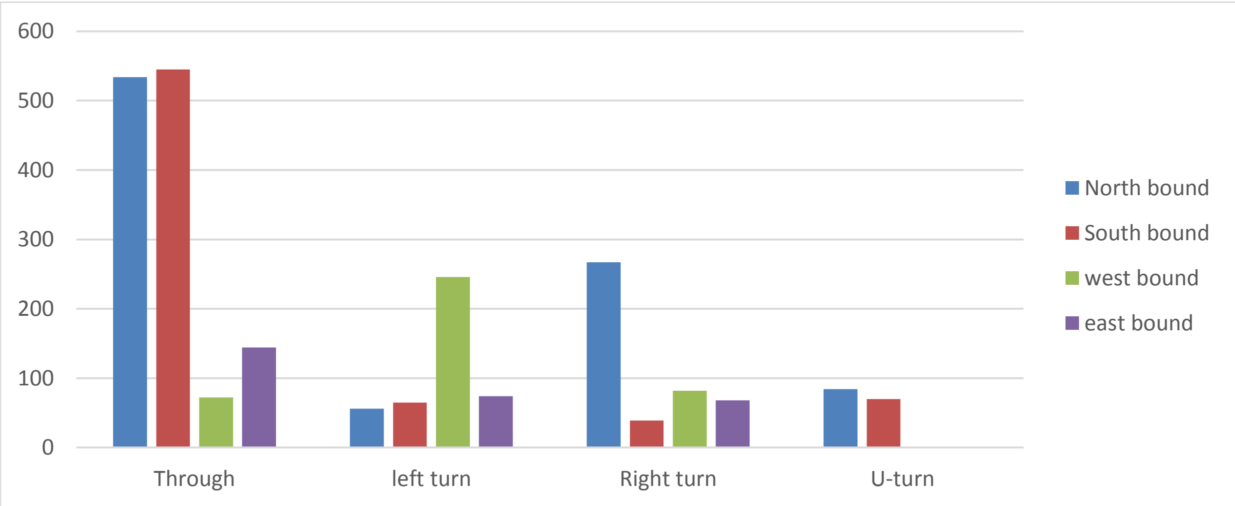


Figure: 4. 1 General Traffic volume characteristics of sebategna intersection

4.1.1.1 Traffic volume characteristics of sebategna intersection by movement

As shown below in the diagram the north bounding traffic is characterized by high traffic volume dominated by the through movement moving from south to north direction. There is also a high traffic volume in right turn movement next to through movements, which indicates the movement of vehicles from southern and western part of the city entering to the largest market place in Addis Ababa and in Ethiopia. The number of U-turning, and left turning vehicles from southern direction were also moderately high, which have direct conflict with LRT.

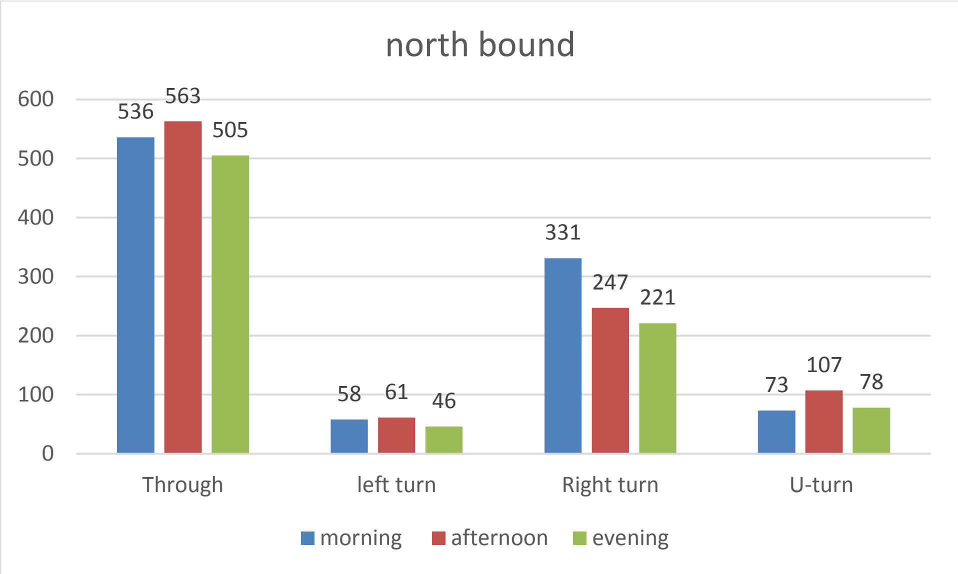


Figure: 4. 2 Traffic volume characteristics of sebategna intersection in north bound movement

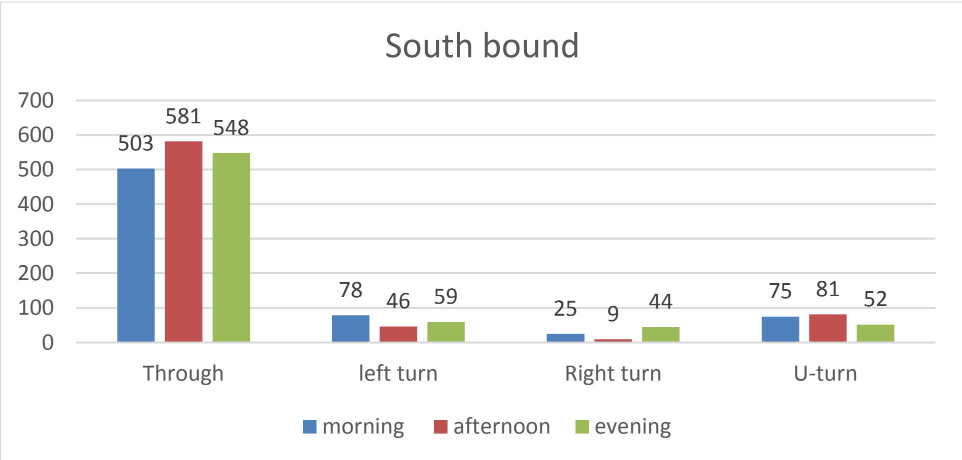


Figure: 4. 3 Traffic volume characteristics of sebategna intersection in south bound movement

The south bound movement was dominated by through movements, while all other movements have moderately less volume of vehicles. This could be due to existence of nearby junctions both to the left and right side in northern part of the study junction.

The west bound movement was dominated by the left turning vehicles unlike north and south bound movements. This left turning movement have a direct conflict with LRT. Those movements were originating from merkato most of which were moving to southern direction, which was indicated by left turn movements in the figure below.

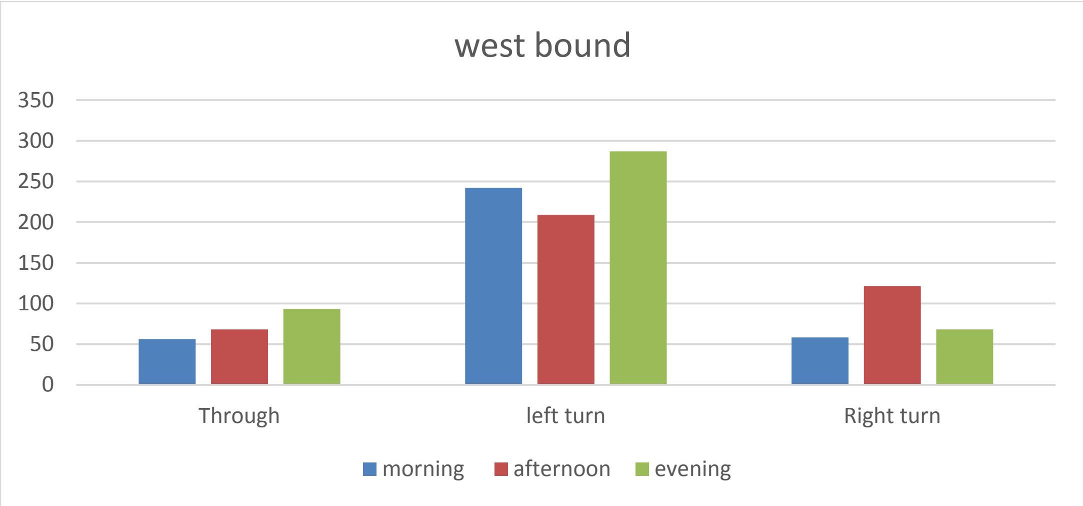


Figure: 4. 4 Traffic volume characteristics of sebategna intersection in west bound movement

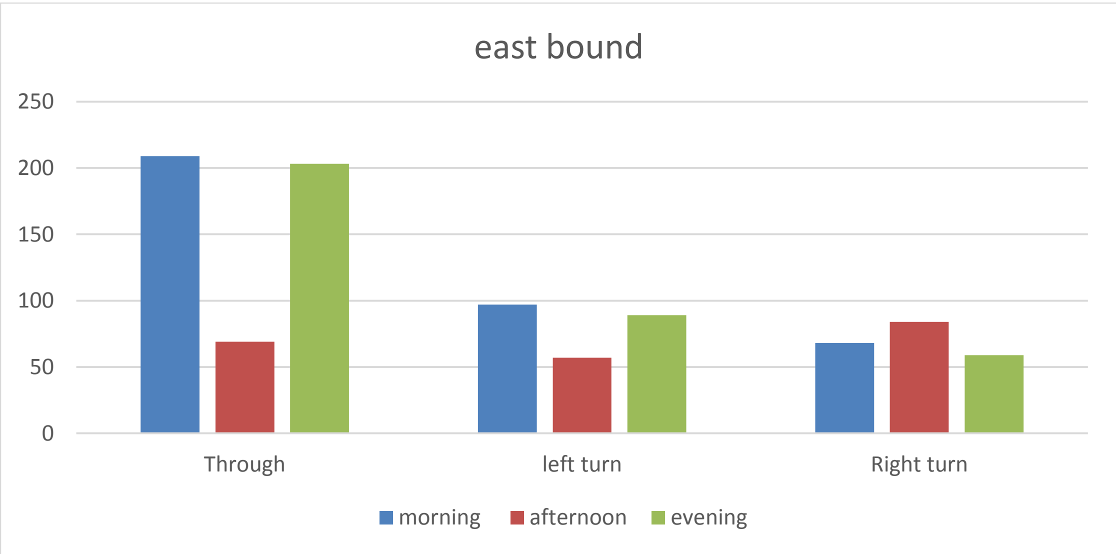


Figure: 4. 5 Traffic volume characteristics of sebategna intersection in east bound movement

Similar to north and south bound movements east bound movement was dominated by through movements, left and right turn movements were nearly an equal volume of traffic. East bound movement was mainly characterized by less volume of afternoon traffic in through and left turn since most of movements were from Merkato market center to residential area in afternoon time.

4.1.1.2 Traffic volume characteristics of sebategna intersection by vehicle type

The traffic performance of either intersection or segments have been affected by the type of vehicle using the intersection or segment. As shown from figure below most of vehicles using sebategna intersection were automobiles, minibus, and small buses < 27 seat which were categorized under car.

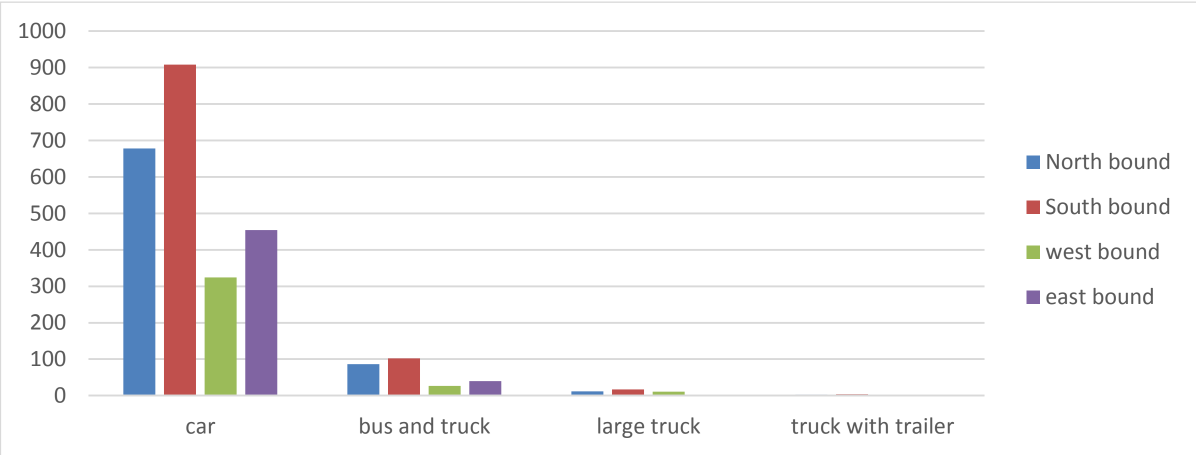


Figure: 4. 6 Traffic volume characteristics of sebategna intersection by vehicle type

4.1.1.3 Traffic compositions having direct conflict with LRT at Sebategna intersection

At Sebategna intersection, 35% of the average peak hour traffic volume have a direct conflict with N-S Addis Ababa's LRT while 65% of traffic were all right turns, north and south bound through traffic, all of which did not cross the LRT.

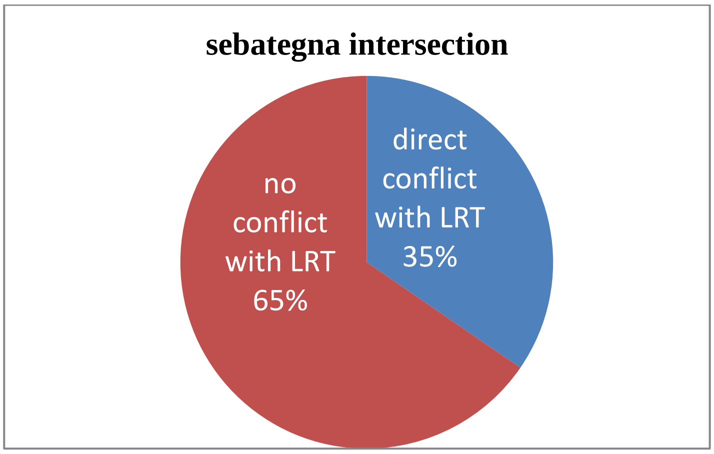


Figure: 4. 7 Traffic compositions having direct conflict with LRT at Sebategna intersection

4.1.1.4 Pedestrian volume characteristics of sebategna intersection

The pedestrian volume at sebategna intersection was dominated by west and east bound crossings, since north and south bound pedestrian crossing were very low pedestrian volume and have no a significant effect on the intersection they were not considered for this study.

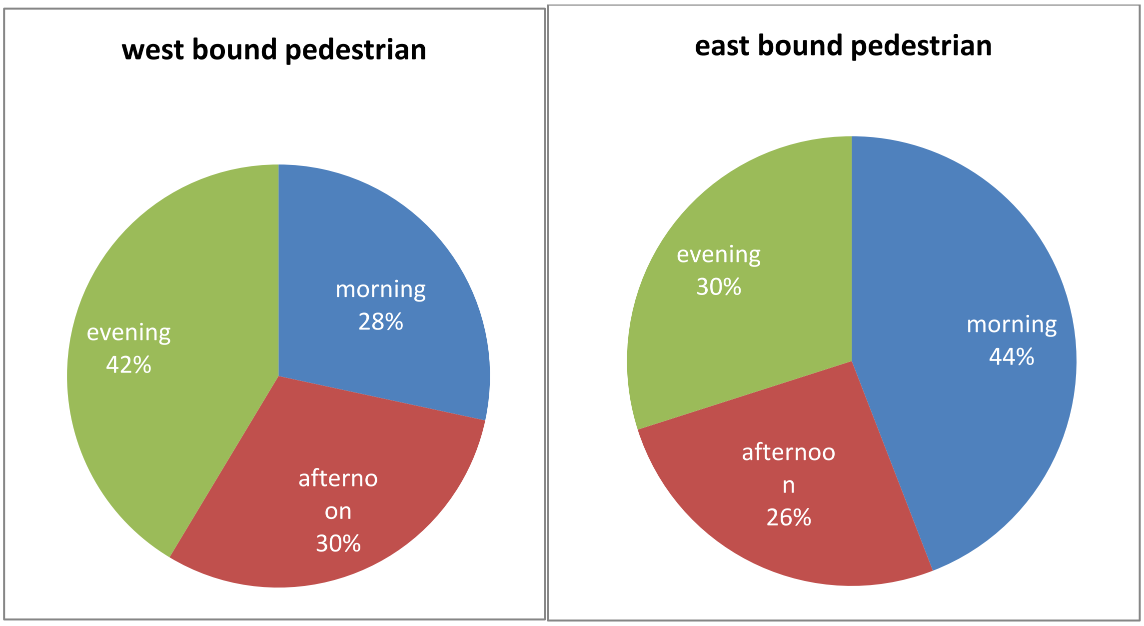


Figure: 4. 8 Pedestrian volume characteristics of sebategna intersection

As shown from figure 3.10 the number of pedestrian were increased in morning and evening time, high number of pedestrians were recorded in west bound during evening time which indicates large number of pedestrians move from Merkato to the residential places. Reversely high number of pedestrians were moving to Merkato during morning time which indicated by east bound movements.

4.1.2 Traffic volume characteristics of Adey Ababa intersection

The collected traffic data from Adey Ababa intersection shows that this intersection was characterized by moderately high volume of pedestrians crossing in the east-west directions. Some large trucks and truck with trailer were observed since the north-south segment of this intersection has been used as the main gate from southern part of country.

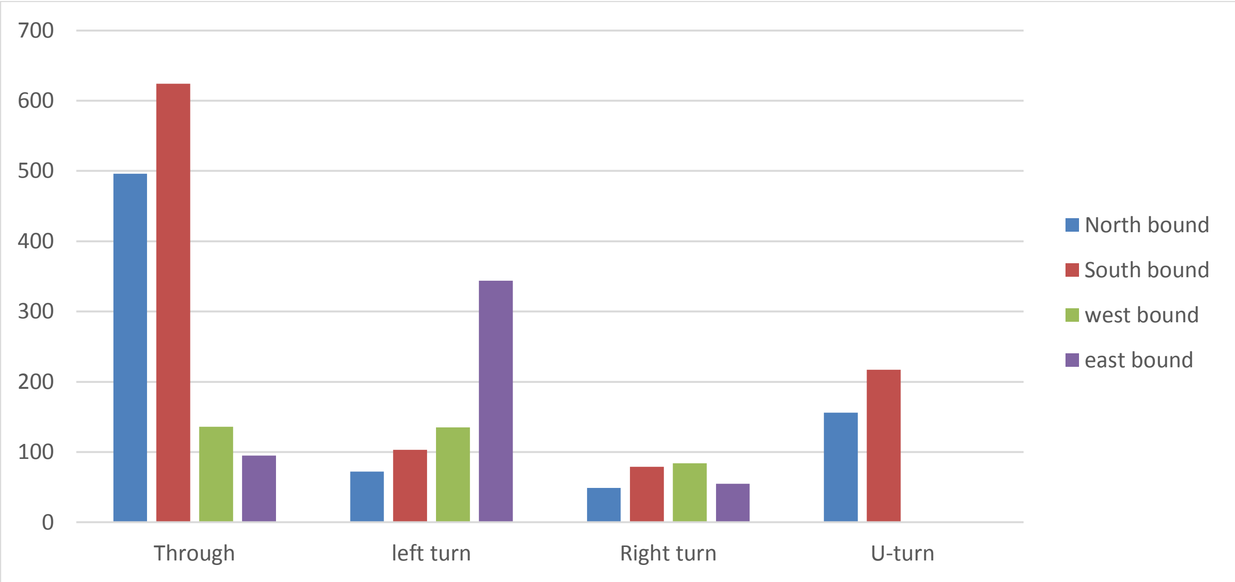


Figure: 4. 9 General Traffic volume characteristics of Adey Ababa intersection

4.1.2.1 Traffic volume characteristics of Adey Ababa intersection by movement

As shown below from the diagrams, both north and south bounding traffic were characterized by high traffic volume dominated with through movements. There were a moderately high number of U-turning vehicles due to absence of nearby crossing facility along the railway alignment in both north and southern part of study junction.

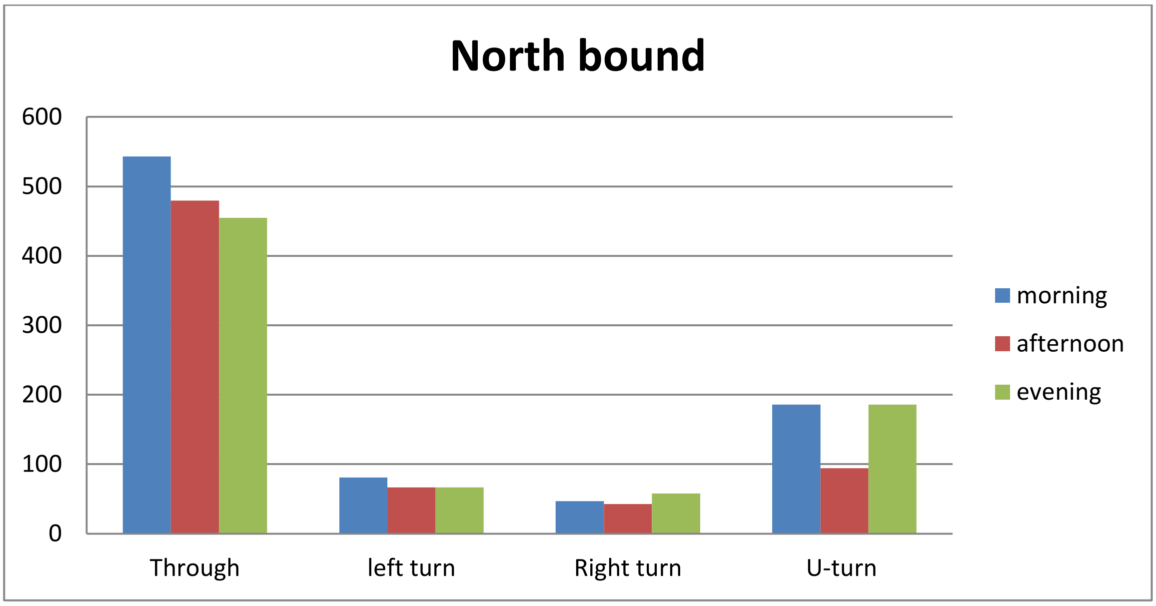


Figure: 4. 10 Traffic volume characteristics of Adey Ababa intersection in north bound movement

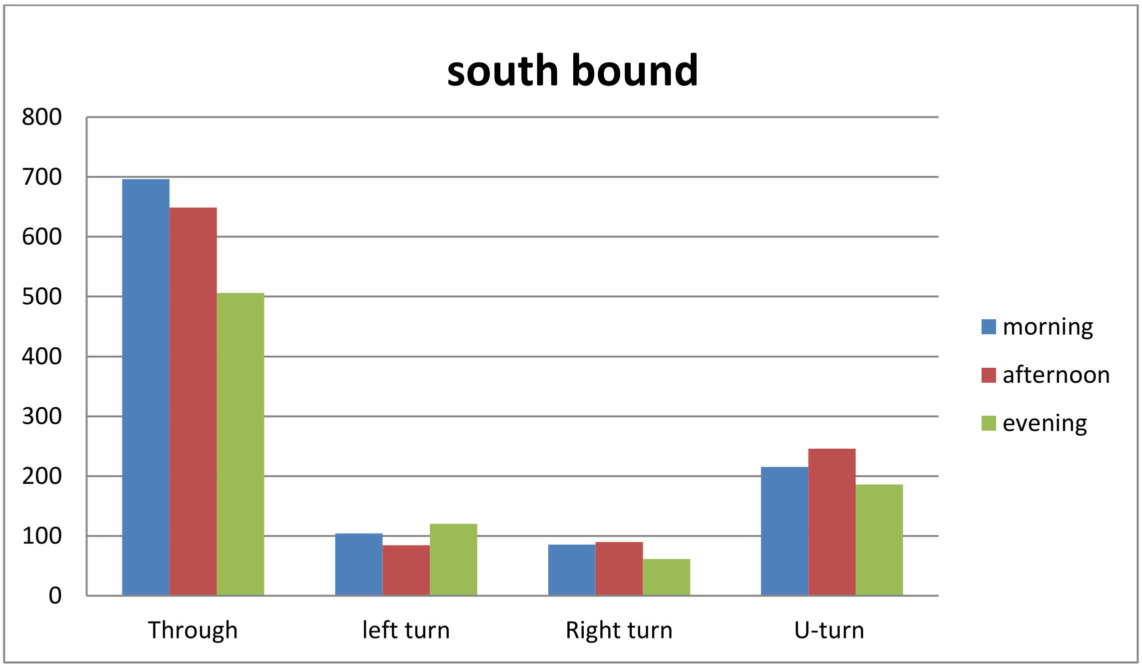


Figure: 4. 11 Traffic volume characteristics of Adey Ababa intersection in south bound movement

The west bound movement have nearly equal volumes, but evening traffic was observed with greater volume than morning and afternoon volumes.

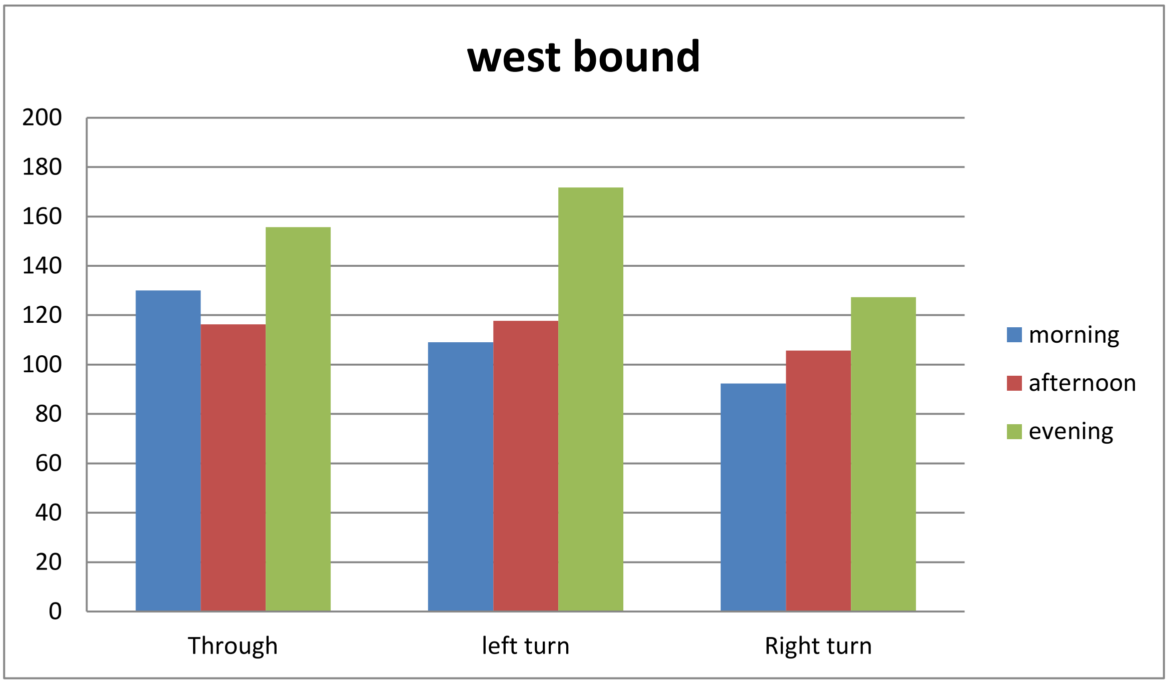


Figure: 4. 12 Traffic volume characteristics of Adey Ababa intersection in west bound movement

Unlike other movements east bound was dominated by high left turn vehicles which shows the traffic performance from residential place to commercial center.

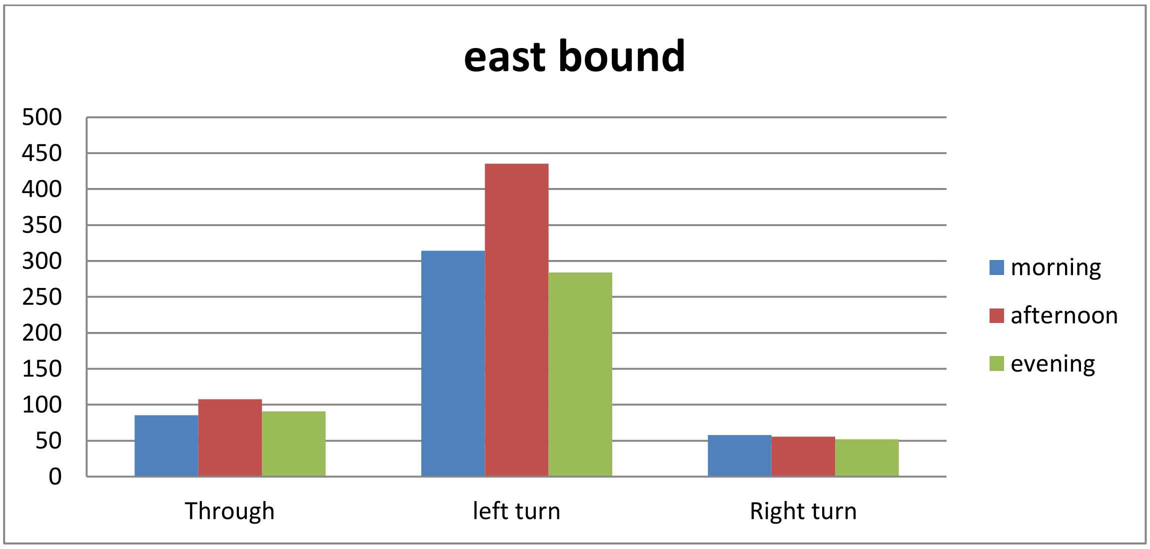


Figure: 4. 13 Traffic volume characteristics of Adey Ababa intersection in east bound movement

4.1.2.2 Traffic volume characteristics of Adey Ababa intersection by vehicle type

Similar to sebategna intersection most of vehicles using Adey Ababa intersection were also automobiles, minibus, and small buses < 27 seat which were categorized under car as shown from the figure below.

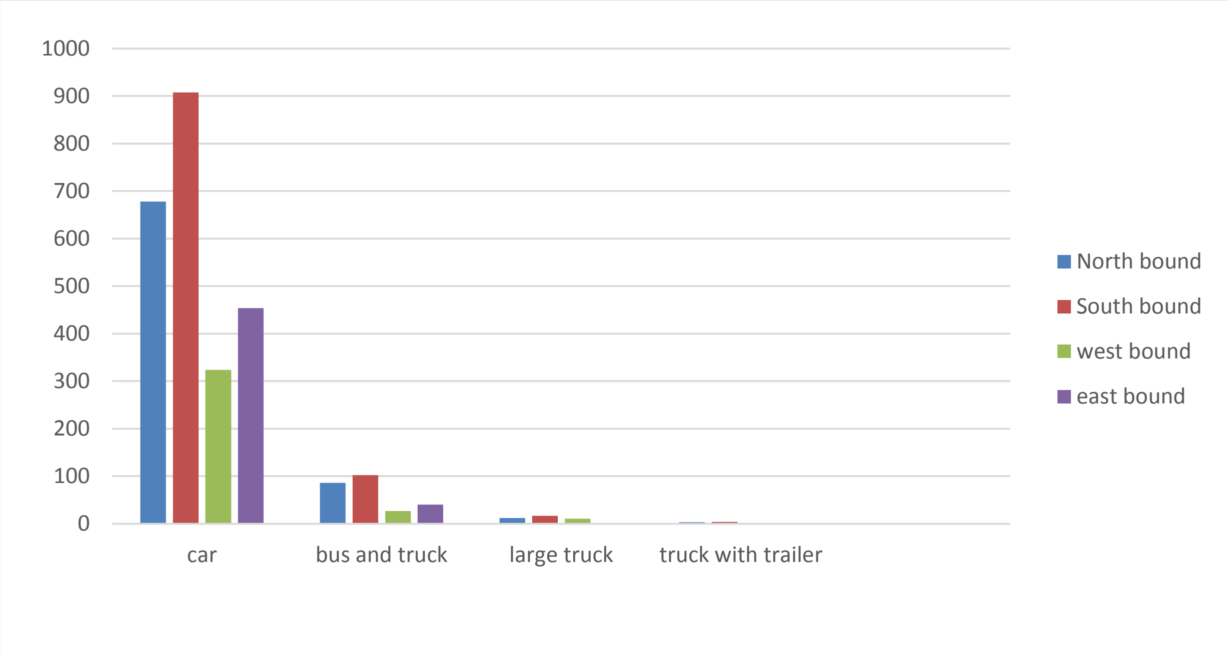


Figure: 4. 14 Traffic volume characteristics of Adey Ababa intersection by vehicle type

4.1.1.3 Traffic compositions having direct conflict with LRT at Adey Ababa intersection

Based on the average peak hour traffic volume data, 48% of all vehicles pass through the intersection have a direct conflict with N-S Addis Ababa's LRT while 52% of traffic were north and south bound through and right turns, east and west bound right turn traffic.

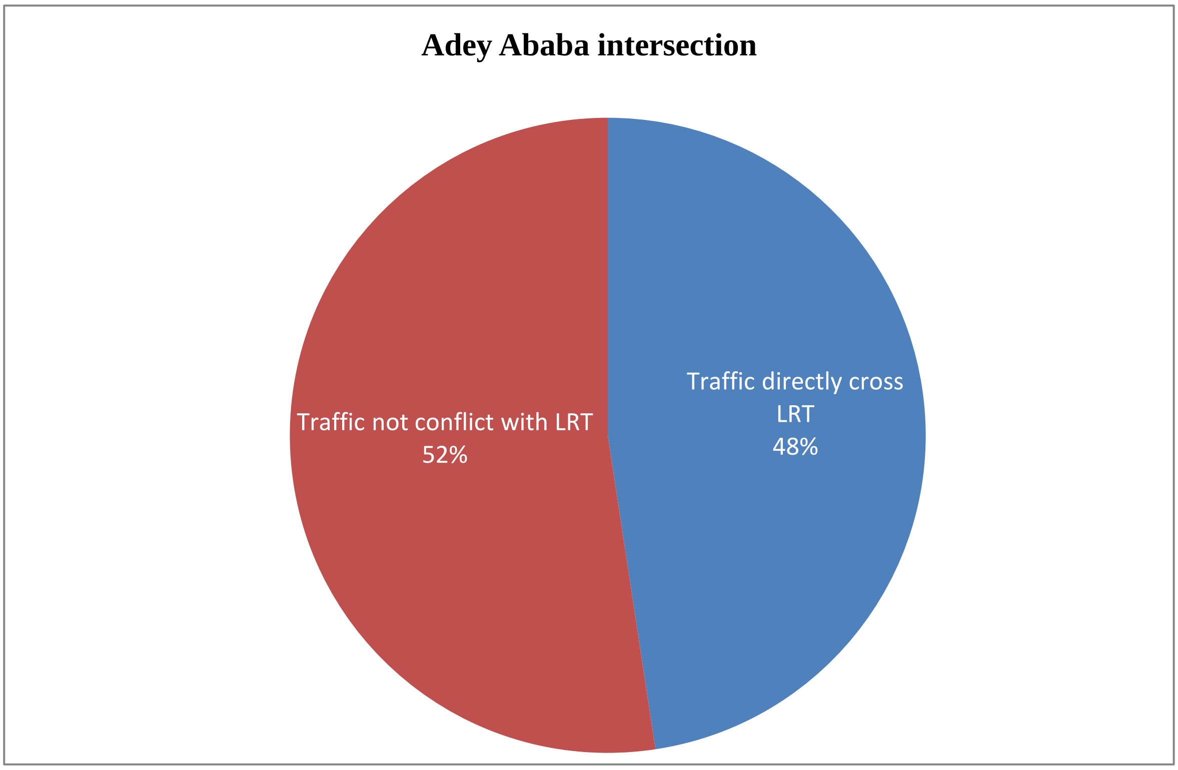
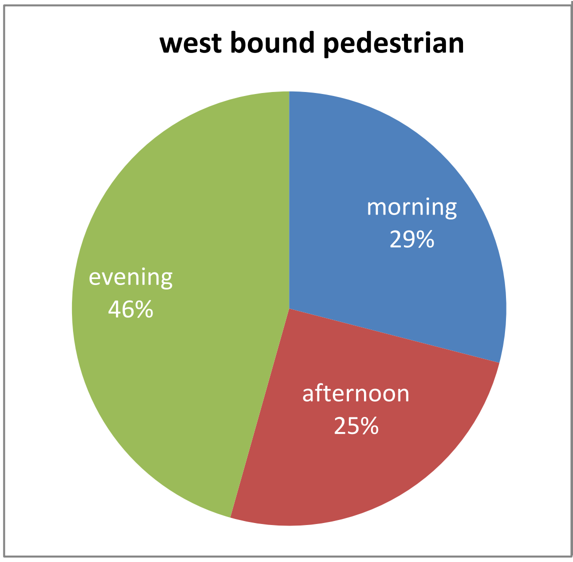


Figure: 4. 15 Traffic compositions having direct conflict with LRT at Adey Ababa intersection

4.1.2.4 Pedestrian volume characteristics of Adey Ababa intersection

The pedestrian volume at this intersection was dominated by west and east bound crossings, since there is no nearby east-west pedestrian crossing facility along the LRT.

As shown from figure 3.14, there were relatively large number of pedestrians at evening peak hour time in both direction due to existence of residential area on both east and west directions.



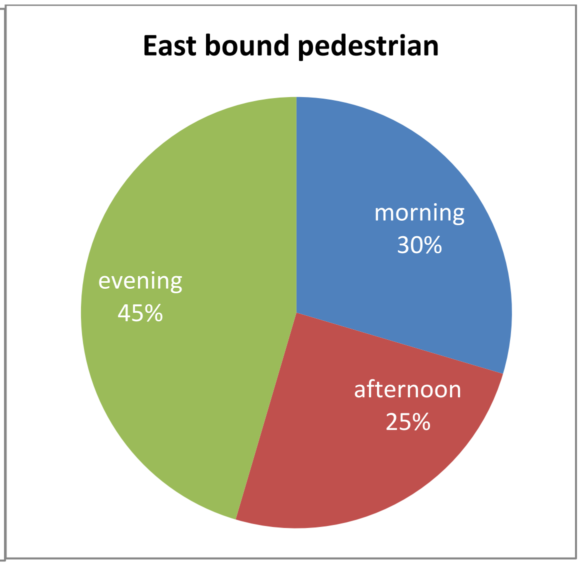


Figure: 4. 16 Pedestrian volume characteristics of Adey Ababa intersection

4.2 Result of level of service

The level of service is a qualitative measure of operational condition of road; hence it indicates the existence and the level of traffic congestion. In this study the level of service have been determined by the use of Vissim simulation modeling software, where the main inputs were the geometric element of road section and intersection parameter, traffic volume in terms of different vehicle type, light rail vehicle, pedestrian, and movement characteristics of vehicles (through movement, right turning, U-turning and left turning).

The normal level of service for both study junction have been analyzed through scenario one of this study; in which both LRV and pedestrians were considered for the analysis in order to fit the model with the actual condition of the study area and to estimate the level of service of the actual operating condition.

4.2.1 Sebategna intersection level of service (LOS)

Based on the vissim simulation modeling output of scenario one, the level of service for Sebategna intersection had been among the lowest level in which most of the movements had LOS_F, LOS_E, and LOS_D except the north and south movements of LRV (SB-rail and NB-rail) which have a LOS_A since priority rule have been given for train due to their character.

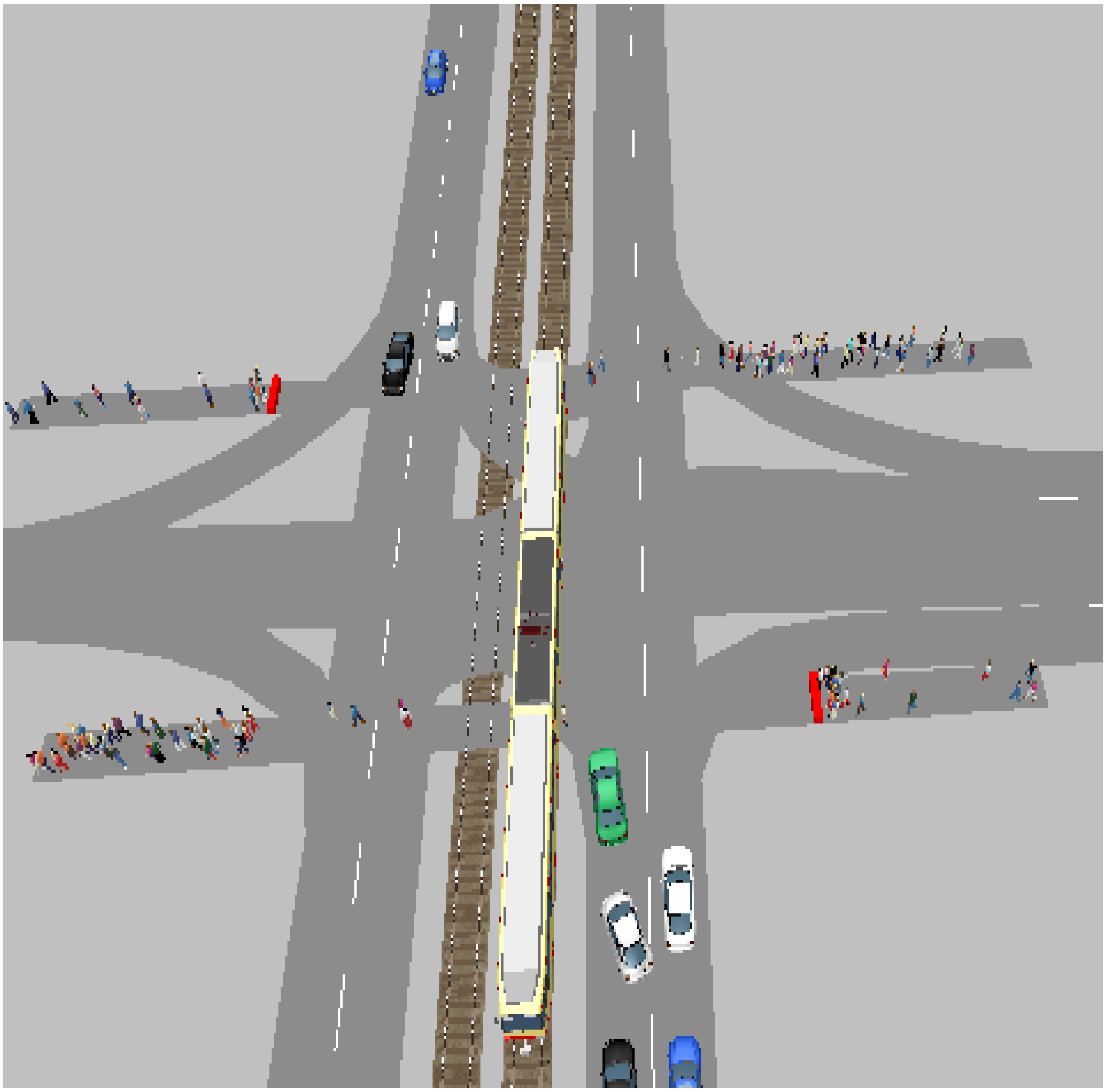


Figure: 4. 17 the condition of priority rule and geometric feature of Sebategna intersection during simulation (source: vissim simulation modeling software)

The level of service for most of east and west bound is LOS_E, which was being comparatively better than that of the north and south bound level of service, this may either due to low volume of vehicle or absence of pedestrian conflicts in east and west bound movements.

Table: 4. 1 Vissim output of Level of service and average delay for Sebategna intersection

No.	Movement type	Movement direction	volumes	LOS	Average Vehicular Delay (Sec.)
1	Through	EBT	142	LOS_E	24.85
2	Right Turn	EBR	157	LOS_E	24.43
3	Left Turn	EBL	143	LOS_E	63.37
4	Through	SBT	178	LOS_F	89.25
5	Right Turn	SBR	204	LOS_F	90.01
6	U-Turn	SBU	151	LOS_F	114.7
7	Left Turn	SBL	186	LOS_F	111.5
8	Through	SB_rail	9	LOS_A	0
9	Left Turn	WBL	47	LOS_F	85.8
10	Through	WBT	53	LOS_E	69.27
11	Right Turn	WBR	69	LOS_E	17.83
12	Right Turn	NBR	49	LOS_F	382.2
13	U-Turn	NBU	56	LOS_F	354.2
14	Left Turn	NBL	53	LOS_F	317.4
15	Through	NBT	61	LOS_F	338.8
16	Through	NB_rail	9	LOS_A	0.337
17	Through	EBPT	2507	LOS_D	53.41
18	Through	WBPT	2691	LOS_D	52.49
19	Total/ average		1567	LOS_E	65.5

4.2.2 Adey Ababa intersection level of service (LOS)

The level of service for Adey Ababa intersection is considerably better than that of Sebategna intersection with almost similar geometry and an equal LRV volume, but with different volumes of pedestrians and vehicles.

Similar to sebategna intersection the north and south bound level of service for Adey Ababa intersection also being LOS_F which shows that the level of service is mainly depends on traffic volume of the road.

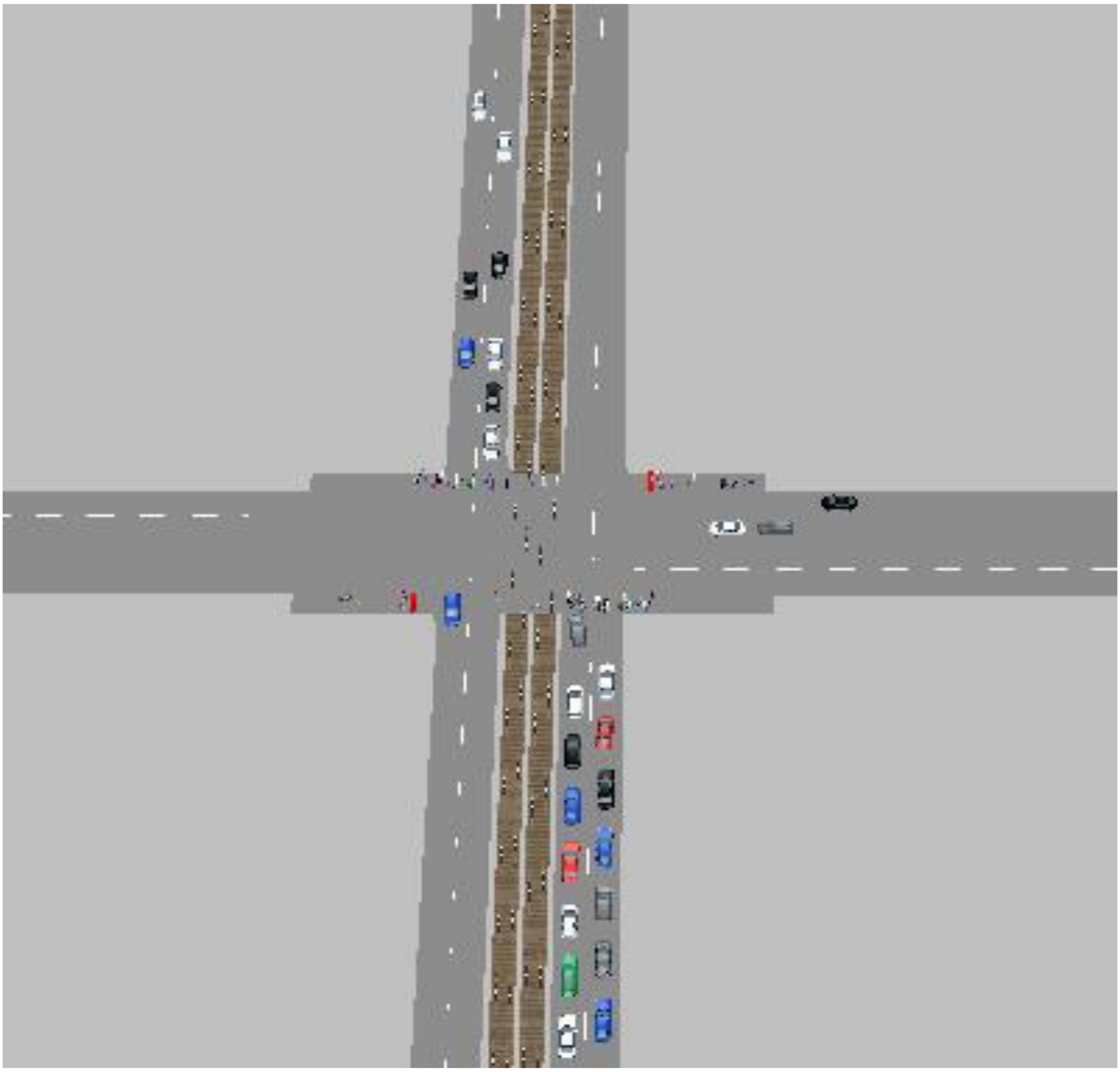


Figure: 4. 18 the geometric feature of Adey Ababa intersection during simulation (source: vissim simulation modeling software)

Table: 4. 2 Vissim output of Level of service and average delay for Adey Ababa intersection

	Movement type	Movement direction	volumes	LOS	Average Vehicular Delay (Sec.)
1	Through	EBT	60	LOS_F	12.38
2	Right Turn	EBR	81	LOS_E	6.307
3	Left Turn	EBL	79	LOS_E	59.51
4	Through	SBT	171	LOS_F	82.93
5	Right Turn	SBR	197	LOS_F	85.19
6	U-Turn	SBU	145	LOS_F	100.9
7	Left Turn	SBL	175	LOS_F	112.2
8	Through	SB_rail	9	LOS_A	0
9	Left Turn	WBL	81	LOS_D	36.08
10	Through	WBT	93	LOS_D	40.12
11	Right Turn	WBR	105	LOS_D	19.99
12	Right Turn	NBR	64	LOS_F	342.1
13	U-Turn	NBU	75	LOS_F	316.8
14	Left Turn	NBL	77	LOS_F	298.2
15	Through	NBT	75	LOS_F	311
16	Through	NB_rail	9	LOS_A	0
17	Through	EBPT	2679	LOS_D	53.89
18	Through	WBPT	2854	LOS_D	52.85
19	Total/ average		1496	LOS_E	66.45794

4.3 Result and analysis of average additional delay

4.3.1 Additional delay of Sebategna intersection

In Scenario one (road-rail at grade intersection "with LRV and pedestrian crossing" model for actual case), which shows the actual operating condition of intersections and the total delay of vehicles due to high volume of vehicles, LRV crossing and pedestrian effect have been indicated. At this scenario most of the north and south bound vehicle movements experience highest delay which corresponds to the level of service LOS_F.

Table: 4. 3 Result summary of additional delay due to both LRV and pedestrian crossings at Sebategna intersection.

movement	No. of simulated vehicles	Scenario_1 veh. Delay (Sec./Veh)	Scenario_2 veh. Delay (Sec./Veh)	Scenario_3 veh. Delay (Sec./Veh))	Additional delay due to LRV crossing (Sec./Veh)	Additional delay due to pedestrian crossing (Sec./Veh)
EBT	142	0.17	0.37	1.33	-0.2	-1.15
EBR	157	0.16	0.33	1.06	-0.17	-0.9
EBL	143	0.44	0.64	1.43	-0.2	-0.99
SBT	178	0.5	0.48	0.91	0.02	-0.41
SBR	204	0.44	0.41	0.85	0.04	-0.4
SBU	151	0.76	0.67	1.28	0.09	-0.52
SBL	186	0.6	0.56	1.1	0.04	-0.5
WBL	47	0.34	0.41	2.07	-0.08	-1.74
WBT	53	0.36	0.46	0.9	-0.09	-0.53
WBR	69	0.26	0.37	0.23	-0.11	0.03
NBR	49	7.8	7.01	1.19	0.79	6.61
NBU	56	6.32	5.6	1.43	0.73	4.9
NBL	53	5.99	5.62	1.6	0.37	4.39
NBT	61	5.55	5.32	1.12	0.23	4.43
Average Total Delay		29.69	28.25	16.5	1.46	13.22

In the second Scenario (road-rail at grade intersection "without LRV crossing" model for actual case) the average vehicular delay result varies slightly with that of the first scenario. On the other hand the result of the third scenario has a considerably large variation from the first scenario which shows that the effect of pedestrian on traffic performance have large severity than the effect of LRV crossing. The existence of those high volume of pedestrian is due to the concentration of pedestrian from the neighborhood surrounding area which were blocked by the route of LRT passes through at ground level, Therefore the effect of pedestrian on traffic performance would be reflected as the effect of road-rail at-grade crossing.

In determining the effect of LRV crossing by subtracting vehicle delay of scenario two from scenario one, some of the result becomes negative value but it doesn't mean that the absence of LRV add an additional delay, the reason for this would be since the traffic simulation have been different with different time and hence the vehicular delay will vary at different time. The main thing to be considered should be the additional total average delay which was 1.46 Sec. /Veh.

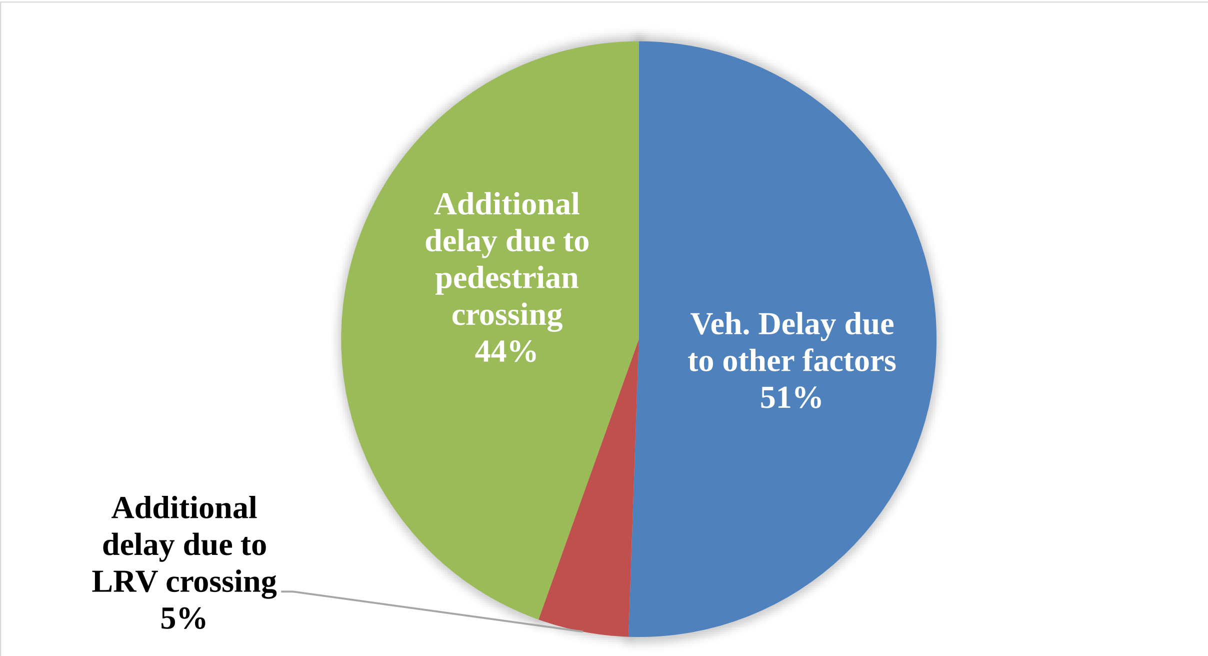


Figure: 4. 19. The composition of additional delay due to pedestrian and due to LRV crossing at Sebategna intersection

In similar manner the effect of pedestrian crossing have been determined by subtracting vehicle delay of scenario three from scenario one. Again the negative value in this result doesn't mean the absence of pedestrians add severity on vehicular delay, instead the total average additional delay of 13.22 Sec./Veh shows existence of pedestrian add greater severity on vehicular delay than that of LRV crossing.

As shown from the figure below the additional delay due to LRV crossing have a considerable less effect on the existing traffic performance problems. Pedestrians contribute greater severity than LRV crossing for the vehicular delay.

Out of the total delay experienced by vehicles, 44% of total delay was due to pedestrian crossing, and only 5% of total delay has been contributed by LRV crossing while other 51% of total delay was due to other factors mainly high volume vehicles.

4.3.2 Additional delay of Adey Ababa intersection

The additional delay due to both LRV and pedestrian crossing have been nearly similar like that of Sebategna intersection except that pedestrian effects reduced for Adey Ababa intersection. The reason for reduction of pedestrian effect for this intersection would be due to the reduction of pedestrian volume, which was recorded a lower volume than that of Sebategna intersection as it has been indicated on appendix-A and B.

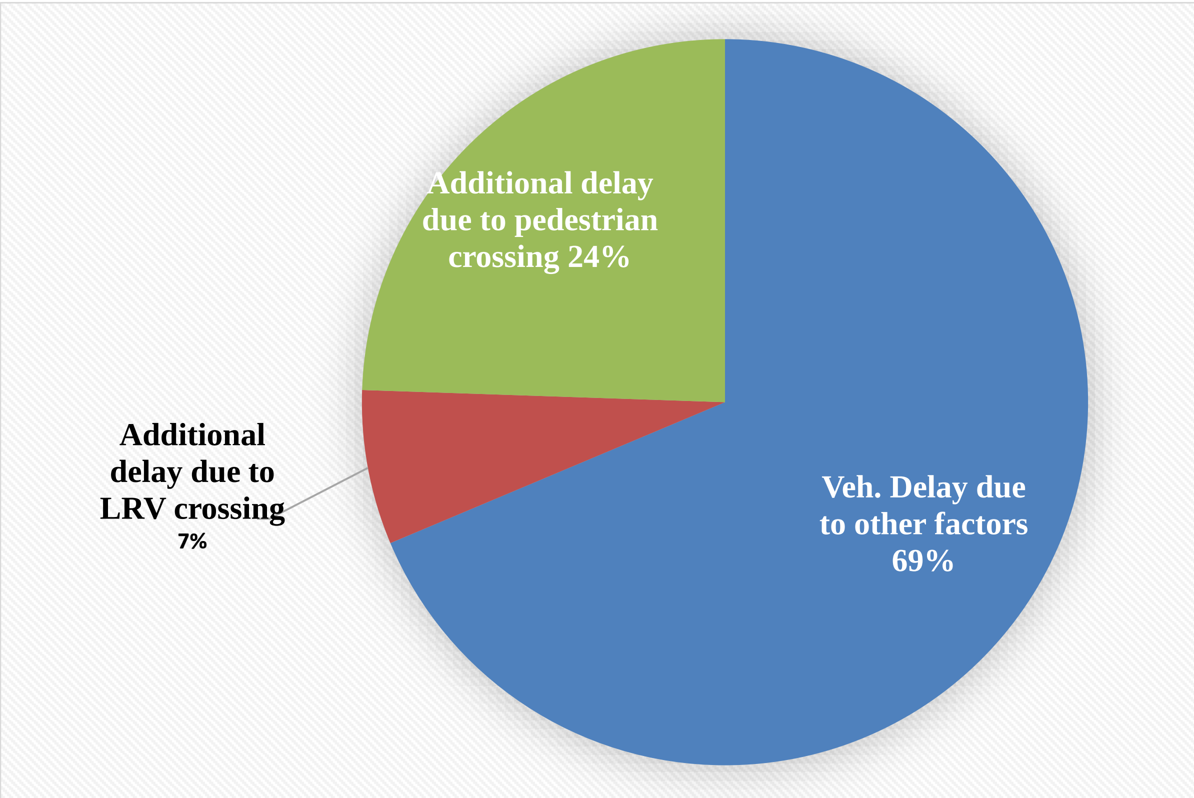


Figure: 4. 20 The composition of additional delay due to pedestrian and due to LRV crossing at Adey Ababa intersection

Table: 4. 4 Result summary of additional delay due to both LRV and pedestrian crossings for Adey Ababa intersection

movement	No. of simulated vehicles	scenario_1 veh Delay (Sec./Veh)	scenario_2 veh Delay (Sec./Veh)	scenario_3 veh Delay (Sec./Veh)	Additional delay due to LRV crossing (Sec./Veh)	Additional delay due to pedestrian crossing (Sec./Veh)
EBT	60	0.21	0.13	1.16	0.07	-0.95
EBR	81	0.08	0.08	0.78	0	-0.7
EBL	79	0.75	0.47	1.74	0.28	-0.99
SBT	171	0.48	0.51	0.92	-0.02	-0.44
SBR	197	0.43	0.49	0.73	-0.05	-0.3
SBU	145	0.7	0.77	1.24	-0.08	-0.54
SBL	175	0.64	0.65	1.11	0	-0.47
SB_railT	9	0	0	0	0	0
WBL	81	0.45	0.32	1.64	0.12	-1.2
WBT	93	0.43	0.24	0.91	0.19	-0.48
WBR	105	0.19	0.1	0.79	0.09	-0.6
NBR	64	5.35	5.47	1.41	-0.12	3.93
NBU	75	4.22	3.76	1.47	0.47	2.75
NBL	77	3.87	3.52	1.43	0.36	2.45
NBT	75	4.15	3.95	1.23	0.2	2.91
NB_railT	8	0	0	0	0	0
Average Total Delay		21.95	20.46	16.56	1.51	5.37

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study the following major conclusions were drawn:

- The average peak hour traffic volume results of both study junction shows that out of total peak hour volume of 2369veh/hr and 2645veh/hr, the car category took 2022veh/hr and 2364veh/hr for Sebategna and Adey Ababa intersections respectively. Most movements were north and south bound through movements for both intersections. The west bound left turn and north bound right turn movements were greater in volume than other left and right turn movements at sebetegna intersection, while the east bound left turn and U-turning movement were greater than other turning movements at Adey Ababa intersection. The reason for both cases would be due to existence of market place around sebategna intersection and absence of the nearby east-west vehicular crossing location around Adey Ababa intersection. Based on the average peak hour traffic volume data, 35% of the average peak hour traffic volume for Sebategna intersection have a direct conflict with N-S Addis Ababa's LRT, while for Adey Ababa intersection about 48% of all vehicles pass through the junction have a direct conflict with N-S Addis Ababa's LRT. Accordingly the total delay due to high vehicular volume and other factor for Adey Ababa intersection became 69% which was greater than 51% of Sebategna intersection.
- The level of service for different movements at Adey Ababa intersection was between LOS_D and LOS_F while that of Sebategna intersection was under the capacity of LOS_E and LOS_F except LRV and pedestrians movements which were under capacity of LOS_A and LOS_D respectively, since first priority was given for LRV and second priority was for pedestrians. This shows that the level of service of Adey Ababa intersection was relatively better than that of Sebategna,

and the reason could be the pedestrian volume of 5772 ped/hr. for Sebategna intersection is more than that of Adey Ababa which is 4472 ped/hr.

- Additional delay due to pedestrian effect on traffic performance for Adey Ababa intersection has been reduced to 24% from 44% of Sebategna intersection. On the other hand additional delay due to LRV crossing effect for Adey Ababa intersection has been increased to 7% from 5% of Sebategna intersection. For both intersection most of delay experienced by vehicles were contributed from high volume of pedestrian crossing. Therefore, more of the effect of road-rail crossing on traffic performance was due to absence of nearby pedestrian overpass crossing facility along the LRT route.

5. 2 Recommendations

5.2.1 Recommendation for existing facility

Based on the result of this study and findings the following recommendations have been given by the researcher.

- Another alternative road way should be used by vehicles whose destination were Merkato market center from southern and western part of the city for Sebategna intersection.
- The Addis Ababa city transport planning management office have to provide separate and clearly marked lane for pedestrian and vehicles at both study junctions.
- As it was indicated from the result of this study most of vehicular delay were encountered due to high volume of pedestrian crossing. Therefore, the Addis Ababa city transport planning management office and the Addis Ababa city road authority should be responsible to construct pedestrian overpass crossing facility along N-S Addis Ababa's LRT, particularly in business and commercial area where large number of pedestrians demanding to cross the LRT route like around Sebatena and Adey Ababa.
- Further research should be carried for further investigation and to improve the existing result by collecting more data. Among those data traffic volume is the one and it is recommended to count for seven days. And also by collecting the actual travel time data, an additional delay due to traffic operation problem could be determined and hence the effectiveness of the existing traffic operation method could be evaluated quantitatively.

5.2.2 Recommendation for future planning and design

- Road-rail crossing having high volume of vehicle and pedestrian should be designed as grade separated.
- Pedestrian crossing facility should be separated from road-rail crossing.
- An adequate pedestrian overpass crossing facility should be provided along LRT line on town section where it`s route pass at ground level with in 100m to 200m distance depending on the purpose of surrounding area and density of population living around.

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APPENDIX-A

Peak hour traffic volume at Sebategna intersection

sebategna traffic volume			date: Monday, july 23/2017 Morning													
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer
8:00-9:00	513	37	14	0	53	9	3	0	266	65	5	0	57	6	4	0
Sub total	564				65				336				67			
Total	1032															
	south bound															
8:00-9:00	444	56	4	1	48	21	5	0	17	10	4	0	67	9	7	0
Sub total	505				74				31				83			
Total	693															
	west bound															
8:00-9:00	51	7	1	0	191	53	2	0	34	20	0	0	2482			
Sub total	59				246				54							
Total	359															
	east bound															
8:00-9:00	194	19	0	0	85	8	0	0	55	10	0	0	3645			
Sub total	213				93				65							
Total	371															

sebategna traffic volume			date: july 23/2017 afternoon													
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer
12:00-1:00	487	54	4	0	45	2	5	0	197	44	1	0	94	7	2	1
sub total	545				52				242				104			
Total	943															
	south bound															
12:00-1:00	546	51	15	0	45	15	4	0	39	8	1	0	71	9	1	0
sub total	612				64				48				81			
Total	805															
	west bound															
12:00-1:00	46	15	0	0	148	52	3	0	84	26	1	1	2769			
sub total	61				203				112							
Total	376															
	east bound															
12:00-1:00	54	14	0	0	40	3	0	0	57	9	0	0	2170			
sub total	68				43				66							
Total	177															

sebategna traffic volume			date: Monday, july 23/2017 evening													
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer
6:00-7:00	472	27	1	0	39	4	0	0	174	39	0	0	72	3	0	0
Sub total	500				43				213				75			
Total	831															
	south bound															
Sub total1	467	56	2	1	48	10	1	0	29	9	0	0	47	7	0	0
Sub total2	526				59				38				54			
Total	677															
	west bound															
Sub total1	76	12	1	0	231	57	2	0	59	10	3	0	3736			
Sub total2	89				290				72							
Total	451															
	east bound															
Sub total1	91	12	1	0	52	11	0	0	79	7	3	0	2568			
Sub total2	104				63				89							
Total	256															

sebategna traffic volume			date: Tuesday, july 24/2017 Morning													
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer
8:00-9:00	493	54	6	1	49	14	0	0	295	68	0	0	62	10	0	0
Sub total	554				63				363				72			
Total	1052															
	south bound															
8:00-9:00	449	59	17	1	51	25	0	0	19	11	1	0	70	10	0	0
Sub total	526				76				31				80			
Total	713															
	west bound															
8:00-9:00	58	8	0	0	186	56	0	0	36	23	0	1	2565			
Sub total	66				242				60							
Total	368															
	east bound															
8:00-9:00	156	15	0	0	49	9	0	0	53	14	0	0	3645			
Sub total	171				58				67							
Total	296															

sebategna traffic volume				date: Tuesday, july 24/2017 afternoon												
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer
12:00-1:00	506	51	5	0	48	3	0	0	194	46	0	0	94	8	0	1
sub total	562				51				240				103			
Total	956															
	south bound															
12:00-1:00	530	49	7	0	48	18	0	0	43	11	0	0	77	10	0	0
sub total	586				66				54				87			
Total	793															
	west bound															
12:00-1:00	49	19	5	1	151	63	0	0	91	32	2	0	2764			
sub total	74				214				125							
Total	413															
	east bound															
12:00-1:00	62	18	0	0	51	5	0	0	49	12	0	0	2244			
sub total	80				56				61							
Total	197															

sebategna traffic volume				date: Tuesday, july 24/2017 evening												
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer
6:00-7:00	480	35	5	1	37	6	3	0	178	44	0	0	75	14	1	0
Sub total	521				46				222				90			
Total	879															
	south bound															
6:00-7:00	516	64	4	0	56	14	0	0	37	15	0	0	35	9	0	0
Sub total	584				70				52				44			
Total	750															
	west bound															
6:00-7:00	79	12	1	0	242	49	3	1	63	12	0	0	3490			
Sub total	92				295				75							
Total	462															
	east bound															
6:00-7:00	177	22	0	0	91	6	0	0	47	12	0	0	2601			
Sub total	199				97				59							
Total	355															

sebategna traffic volume	date: Friday, july 27/2017 Morning															
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer
8:00-9:00	475	33	5	1	44	6	0	0	240	59	1	0	64	10	0	0
Sub total	514				50				300				74			
Total	938															
	south bound															
8:00-9:00	449	51	7	0	63	25	0	0	13	6	0	0	62	6	0	0
Sub total	507				88				19				68			
Total	682															
	west bound															
8:00-9:00	39	6	0	0	179	61	0	0	47	14	0	0	2536			
Sub total	45				240				61							
Total	346															
	east bound															
8:00-9:00	186	16	0	0	93	11	0	0	61	12	1	0	3832			
Sub total	202				104				74							
Total	380															

sebategna traffic volume	date: Friday, july 27/2017 afternoon															
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer
12:00-1:00	518	71	2	1	69	15	3	0	212	48	0	0	106	9	0	0
sub total	592				87				260				115			
Total	1054															
	south bound															
12:00-1:00	526	40	5	2	38	11	0	0	37	10	0	0	62	13	0	0
sub total	573				49				47				75			
Total	744															
	west bound															
12:00-1:00	56	18	0	0	155	58	3	0	92	37	1	0	2556			
sub total	74				216				130							
Total	420															
	east bound															
12:00-1:00	42	17	0	1	59	12	1	0	62	17	0	0	2127			
sub total	60				72				79							
Total	211															

sebategna traffic volume	date: Friday, july 27/2017 evening															
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer	car	bus and medium truck	large truck	truck with trailer
6:00-7:00	478	19	7	2	44	9	3	0	185	43	0	0	63	8	0	0
Sub total	506				56				228				71			
Total	861															
	south bound															
Sub total1	472	67	4	0	41	7	0	0	36	5	0	0	54	5	0	0
Sub total2	543				48				41				59			
Total	691															
	west bound															
Sub total1	85	15	1	0	220	60	3	0	51	8	0	0	3837			
Sub total2	101				283				59							
Total	443															
	east bound															
Sub total1	189	8	0	0	72	6	0	0	47	6	0	0	2376			
Sub total2	197				78				53							
Total	328															

APPENDIX-B

Peak hour traffic volume at Adey Ababa intersection

adey ababa traffic volume	date: wednsday, july 25/2017 Morning															
Time	north bound															
	Through				left turn				Right turn				U-turn			
	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer
8:00-3:00	472	54	6	3	52	13	0	0	31	6	4	0	176	17	2	0
Sub total	535				65				41				195			
Total	836															
	SOUTH BOUND															
8:00-3:00	633	59	2	1	97	7	5	0	80	5	0	0	201	11	1	0
Sub total	695				109				85				213			
Total	1102															
	west bound															
8:00-3:00	120	13	0	0	101	5	3	0	80	6	2	0	1755			
Sub total	133				109				88							
Total	330															
	east bound															
Sub total1	73	7	1	0	310	25	3	0	39	11	2	0	2079			
Sub total2	81				338				52							
Total	471															

adey ababa traffic		date: wednsday, july 25/2017 afternoon														
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer
12:00-1:00	415	66	8	5	64	3	3	0	30	3	0	0	80	4	3	1
sub total	494				70				33				88			
Total	685															
	SOUTH BOUND															
12:00-1:00	585	77	8	7	72	5	1	0	82	12	1	0	240	6	0	0
sub total	677				78				95				246			
Total	1096															
	west bound															
12:00-1:00	116	7	0	0	101	4	0	0	107	3	2	0	1502			
sub total	123				105				112							
Total	340															
	east bound															
12:00-1:00	106	8	0	0	366	32	2	0	53	10	0	0	1723			
sub total	114				400				63							
Total	577															

Adey ababa traffic volume	date: wednsday, july 25/2017 evening															
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer
6:00-1:00	360	55	2	0	50	10	0	0	42	5	1	0	167	10	1	0
Sub total	417				60				48				178			
Total	703															
	South bound															
6:00-1:00	392	93	5	1	106	9	0	0	48	5	1	0	162	9	0	0
Sub total	491				115				54				171			
Total	831															
	west bound															
6:00-1:00	134	10	2	0	170	18	3	0	50	5	0	0	2785			
Sub total	146				191				55							
Total	392															
8:00-8:16	east bound															
Sub total1	72	9	1	0	289	9	0	0	32	4	2	0	3212			
Sub total2	82				298				38							
Total	418															

adey ababa traffic volume	date: Thursday, july 26/2017 Morning															
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer
8:00-9:00	487	57	3	6	55	19	0	0	40	9	1	0	179	23	3	0
Sub total	553				74				50				205			
Total	882															
	SOUTH BOUND															
8:00-9:00	622	51	1	4	91	7	2	0	80	9	1	0	195	9	0	0
Sub total	678				100				90				204			
Total	1072															
	west bound															
8:00-9:00	128	13	1	0	110	13	2	0	79	8	1	0	1848			
Sub total	142				125				88							
Total	355															
	east bound															
8:00-9:00	99	11	2	0	279	33	2	0	45	13	0	0	2149			
Sub total	112				314				58							
Total	484															

adey ababa traffic			date: Thursday, july 26/2017 afternoon													
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer
12:00-1:00	430	68	3	7	67	7	0	0	36	6	1	0	88	7	2	0
sub total	508				74				43				97			
Total	722															
	SOUTH BOUND															
12:00-1:00	572	86	0	4	78	8	0	0	85	8	0	0	252	5	1	0
sub total	662				86				93				258			
Total	1099															
Time	west bound															
12:00-1:00	107	10	0	0	109	2	0	0	102	5	1	0	1547			
sub total	117				111				108							
Total	336															
Time	east bound															
12:00-1:00	96	4	0	0	418	30	2	0	44	7	0	0	1752			
sub total	100				450				51							
Total	601															

Adey ababa traffic volume				date: Thursday, july 26/2017 evening												
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer
6:00-7:00	386	60	0	0	58	7	2	0	49	7	0	0	164	7	2	0
Sub total	446				67				56				173			
Total	742															
	South bound															
6:00-7:00	408	96	5	5	110	12	0	0	51	8	0	0	197	6	1	0
Sub total	514				122				59				204			
Total	899															
	west bound															
6:00-7:00	175	16	1	0	151	13	0	0	44	8	0	0	2886			
Sub total	192				164				52							
Total	408															
	east bound															
6:00-7:00	111	7	0	0	240	11	3	0	59	7	0	0	3258			
Sub total	118				254				66							
Total	438															

adey ababa traffic volume	date: monday, july 30/2017 Morning															
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer
8:00-9:00	497	50	4	4	87	17	1	0	50	4	0	0	156	7	2	0
Sub total	555				105				54				165			
Total	879															
	SOUTH BOUND															
8:00-9:00	650	66	2	3	106	5	2	0	75	7	0	0	216	14	1	0
Sub total	721				113				82				231			
Total	1147															
	west bound															
8:00-9:00	102	14	1	0	90	8	3	0	96	8	1	0	1806			
Sub total	117				101				105							
Total	323															
	east bound															
8:00-9:00	61	5	0	0	278	17	0	1	56	9	1	0	2164			
Sub total	66				296				66							
Total	428															

adey ababa traffic		date: monday, july 30/2017afternoon														
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer
12:00-1:00	389	56	4	3	51	7	1	1	47	6	0	0	94	8	5	0
sub total	452				60				53				107			
Total	672															
Time	SOUTH BOUND															
12:00-1:00	539	66	3	10	86	5	1	0	71	11	1	0	225	9	0	1
sub total	618				92				83				235			
Total	1028															
Time	west bound															
12:00-1:00	107	2	2	0	130	6	1	1	91	9	1	0	1677			
sub total	111				138				101							
Total	350															
Time	east bound															
12:00-1:00	96	13	3	0	416	43	8	1	48	5	4	0	1921			
sub total	112				468				57							
Total	637															

Adey ababa traffic volume				date: monday, july 30/2017 evening												
	north bound															
	Through				left turn				Right turn				U-turn			
Time	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer	car	bus and truck	large truck	truck with trailer
6:00-7:00	434	68	15	1	59	15	2	0	61	9	3	0	204	6	0	0
Sub total	518				76				73				210			
Total	877															
	South bound															
6:00-7:00	415	105	7	3	111	12	3	0	66	7	1	0	178	6	3	0
Sub total	530				126				74				187			
Total	917															
	west bound															
6:00-7:00	117	15	0	0	150	12	1	1	46	9	2	0	2835			
Sub total	132				164				57							
Total	353															
	east bound															
6:00-7:00	65	9	2	0	297	5	6	1	42	12	3	0	3352			
Sub total	76				309				57							
Total	442															

APPENDIX-C

Result and output of vissim simulation modeling software for Sebategna intersection

		SCENARIO-1 WITH LRT AND PEDESTRIANS											
moveme nt/ direction	from link	to	time interval (Sec.)	Qlen	max. Qlen	vehicles	pers	LOS All	LOS val	veh Delay (Sec.)	person Delay (Sec.)	stop Delay (Sec.)	stops
W-E	1: EB	1: EB	0-3600	35.87237	120.3129	142	0	LOS_E	5	24.84579	24.84579	16.5101	2.126761
W-S	1: EB	2: SB	0-3600	34.19562	118.3131	157	0	LOS_E	5	24.43485	24.43485	14.52069	1.33758
W-N	1: EB	5: NB	0-3600	35.66132	120.067	143	0	LOS_E	5	63.36507	63.36507	49.37578	5.412587
N-S	2: SB	2: SB	0-3600	213.3387	256.977	178	0	LOS_F	6	89.2548	89.2548	61.33855	3.404494
N-W	2: SB	4: WB	0-3600	212.9937	256.63	204	0	LOS_F	6	90.0079	90.0079	62.23925	3.27451
N-N	2: SB	5: NB	0-3600	213.3387	256.977	151	0	LOS_F	6	114.6922	114.6922	81.99226	4.781457
N-E	2: SB	EB	0-3600	212.9036	256.5399	186	0	LOS_F	6	111.5143	111.5143	78.58523	5.596774
N-S	3: SB_rail	3: SB_rail	0-3600	0.641766	57.63059	9	0	LOS_A	1	0	0	0	0
E-S	4: WB	2: SB	0-3600	7.688647	62.28783	47	0	LOS_F	6	15.80474	15.80474	10.43504	0.531915
E-W	4: WB	4: WB	0-3600	7.764068	62.4569	53	0	LOS_E	5	19.2667	19.2667	16.02604	1
E-N	4: WB	5: NB	0-3600	7.016324	59.89709	69	0	LOS_E	5	17.8263	17.8263	13.53124	0.434783
S-E	5: NB	1: EB	0-3600	222.9434	254.339	49	0	LOS_F	6	382.2062	382.2062	312.5874	11.65306
S-S	5: NB	2: SB	0-3600	222.9434	254.339	56	0	LOS_F	6	354.1947	354.1947	281.6245	14.23214
S-W	5: NB	4: WB	0-3600	222.9434	254.339	53	0	LOS_F	6	317.4357	317.4357	247.9176	12.83019
S-N	5: NB	5: NB	0-3600	222.9434	254.339	61	0	LOS_F	6	338.7604	338.7604	273.7277	10.31148
S-N	7: NB_rail	7: NB_rail	0-3600	0.496008	57.59956	9	0	LOS_A	1	0.337122	0.337122	0	0
W-E	8: EBP	8: EBP	0-3600	12.36854	14.14399	0	2507	LOS_D	4	53.4135	53.4135	51.51241	1.211009
E-W	9: WBP	9: WBP	0-3600	11.89425	13.68875	0	2691	LOS_D	4	52.4856	52.4856	50.86159	1.069119
Total			0-3600	68.23112	256.977	1567	5198	LOS_E	5	65.5026	65.5026	57.89797	1.925614

	SCENARIO-2 WITHOUT LRT												
movement/ direction	from link	to	time interval	Qlen	max. Qlen	vehicles	pers	LOS All	LOS val	veh Delay	persDelay	stop Delay	stops
W-E	1: EB	1: EB	0-3600	48.18297	148.2247	151	0	LOS_D	4	53.22827	53.22827	38.39645	3.847682
W-S	1: EB	2: SB	0-3600	46.43146	146.225	171	0	LOS_D	4	51.62745	51.62745	34.46513	2.421053
W-N	1: EB	5: NB	0-3600	47.94048	147.9789	146	0	LOS_F	6	92.05667	92.05667	70.34612	9.575342
N-S	2: SB	2: SB	0-3600	209.1347	256.9694	180	0	LOS_F	6	84.85638	84.85638	59.18267	3.183333
N-W	2: SB	4: WB	0-3600	208.7897	256.6225	209	0	LOS_F	6	82.83747	82.83747	57.35846	2.990431
N-N	2: SB	5: NB	0-3600	209.1347	256.9694	154	0	LOS_F	6	101.3314	101.3314	70.2836	5.766234
N-E	2: SB	EB	0-3600	208.6996	256.5324	190	0	LOS_F	6	104.4968	104.4968	73.61787	7.084211
N-S	3: SB_rail	3: SB_rail	0-3600	0	0	0	0	LOS_A	1	0	0	0	0
E-S	4: WB	2: SB	0-3600	9.177214	67.23031	45	0	LOS_D	4	19.43561	19.43561	12.37378	3
E-W	4: WB	4: WB	0-3600	9.264368	67.39939	54	0	LOS_E	4	24.17083	24.17083	19.54133	5.777778
E-N	4: WB	5: NB	0-3600	8.328699	64.83957	69	0	LOS_C	3	25.73991	25.73991	19.74811	0.710145
S-E	5: NB	1: EB	0-3600	223.4941	254.3844	57	0	LOS_F	6	343.2534	343.2534	278.4613	11.07018
S-S	5: NB	2: SB	0-3600	223.4941	254.3844	75	0	LOS_F	6	313.3444	313.3444	247.0945	14.57333
S-W	5: NB	4: WB	0-3600	223.4941	254.3844	80	0	LOS_F	6	297.9792	297.9792	233.2718	13.1625
S-N	5: NB	5: NB	0-3600	223.4941	254.3844	75	0	LOS_F	6	324.7405	324.7405	261.568	11.26667
S-N	7: NB_rail	7: NB_rail	0-3600	0	0	0	0	LOS_A	1	0	0	0	0
W-E	8: EBP	8: EBP	0-3600	12.36854	14.14399	0	2795	LOS_D	4	52.8412	52.8412	51.3159	1.022898
E-W	9: WBP	9: WBP	0-3600	11.89425	13.68875	0	2711	LOS_D	4	49.60091	49.60091	48.23146	0.896348
Total			0-3600	70.19221	256.9694	1656	5506	LOS_E	5	66.42389	66.42389	58.5389	2.12678

			SCENARIO-3 WITHOUT PEDESTRIAN CROSSING										
movement/ direction	from link	to	time interval	Qlen	max. Qlen	vehicles	pers	LOS All	LOS val	veh Delay	persDelay	stop Delay	stops
W-E	1: EB	1: EB	0-3600	143.0557	197.1292	133	0	LOS_D	4	188.2884	188.2884	153.4683	7.112782
W-S	1: EB	2: SB	0-3600	141.0968	195.1294	149	0	LOS_D	4	166.1947	166.1947	132.45	4.604027
W-N	1: EB	5: NB	0-3600	142.8106	196.8833	130	0	LOS_E	5	205.0249	205.0249	166.7313	13.14615
N-S	2: SB	2: SB	0-3600	220.8796	256.9409	117	0	LOS_E	5	161.8965	161.8965	130.9532	5.623932
N-W	2: SB	4: WB	0-3600	220.5421	256.594	116	0	LOS_D	4	172.6161	172.6161	142.2428	3.758621
N-N	2: SB	5: NB	0-3600	220.8796	256.9409	93	0	LOS_F	6	193.3703	193.3703	157.5407	5.172043
N-E	2: SB	EB	0-3600	220.4542	256.5039	111	0	LOS_F	6	204.3245	204.3245	168.4747	11.40541
N-S	3: SB_rail	3: SB_rail	0-3600	0.641766	57.63059	9	0	LOS_A	1	0	0	0	0
E-S	4: WB	2: SB	0-3600	16.081	76.58678	44	0	LOS_F	6	97.43307	97.43307	85.09288	6.136364
E-W	4: WB	4: WB	0-3600	16.2001	76.75586	53	0	LOS_D	4	47.58953	47.58953	39.94331	10.9434
E-N	4: WB	5: NB	0-3600	14.53554	74.19604	70	0	LOS_C	3	15.66573	15.66573	11.32255	2.228571
S-E	5: NB	1: EB	0-3600	96.63756	254.3022	169	0	LOS_E	5	58.13292	58.13292	37.16218	2.550296
S-S	5: NB	2: SB	0-3600	96.63756	254.3022	151	0	LOS_E	5	79.99326	79.99326	53.66846	4.251656
S-W	5: NB	4: WB	0-3600	96.63756	254.3022	175	0	LOS_F	6	84.96733	84.96733	57.46335	7.4
S-N	5: NB	5: NB	0-3600	96.63756	254.3022	167	0	LOS_E	5	68.31669	68.31669	45.68246	3.113772
S-N	7: NB_rail	7: NB_rail	0-3600	0.56527	57.61591	9	0	LOS_A	1	0	0	0	0
W-E	8: EBP	8: EBP	0-3600	0	0	0	0	LOS_A	1	0	0	0	0
E-W	9: WBP	9: WBP	0-3600	0	0	0	0	LOS_A	1	0	0	0	0
Total			0-3600	83.30542	256.9409	1695	1695	LOS_D	4	125.177	125.177	97.7688	5.944543

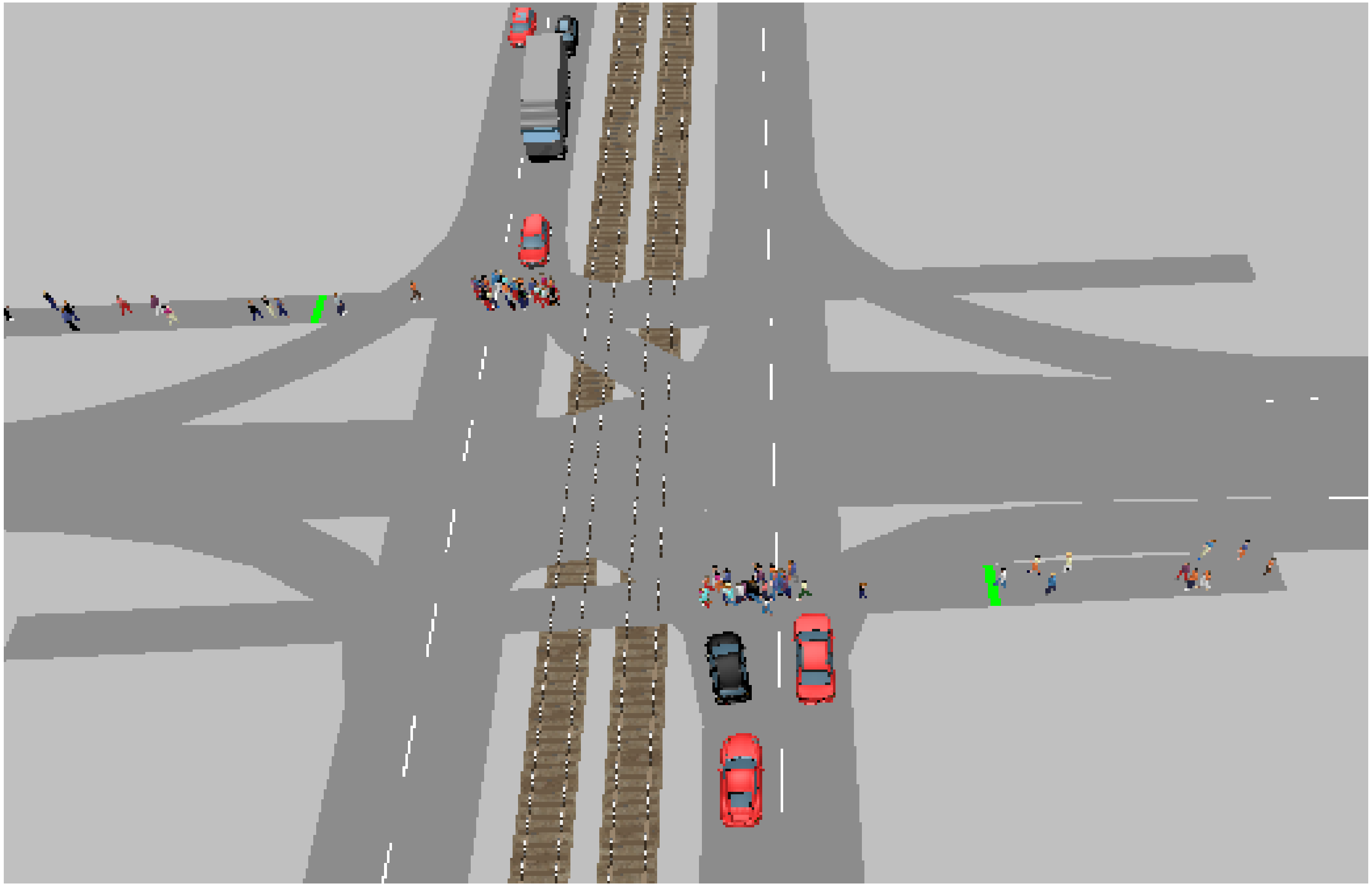

Fig. the geometric feature of Sebategna intersection during simulation

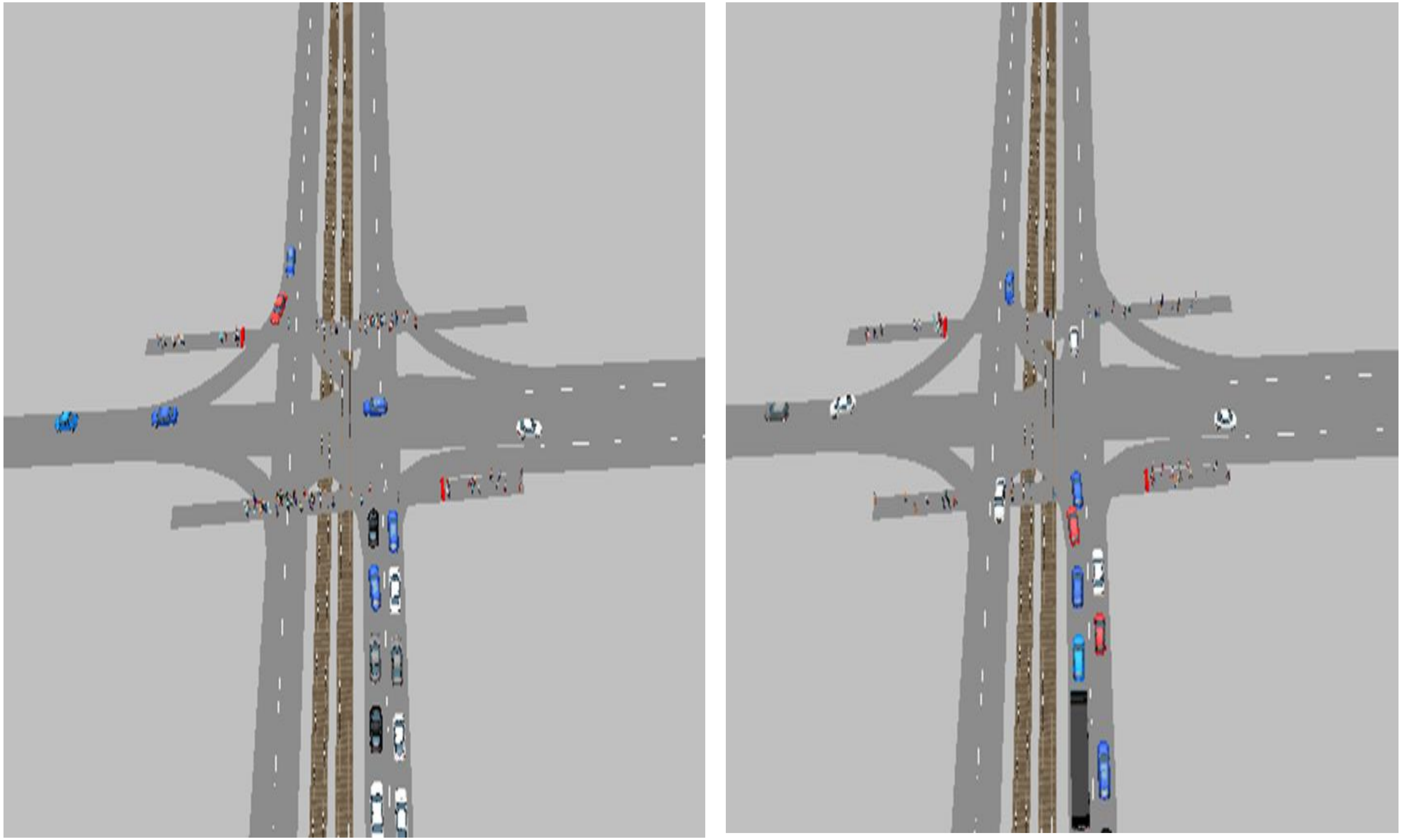

Fig. the geometric feature of Sebategna intersection during simulation

APPENDIX -D

Result and output of vissim simulation modeling software for Adey Ababa intersection

		SCENARIO-1 WITH LRT AND PEDESTRIANS											
moveme nt/ direction	from link	to	time interval	Qlen	max. Qlen	vehicles	pers	LOS All	LOS value	veh Delay	persDela y	stop Delay	stops
W-E	1: EB	1: EB	0-3600	18.59443	112.6643	60	0	LOS_F	6	12.38475	12.38475	8.617091	2.983333
W-S	1: EB	2: SB	0-3600	17.31899	110.6646	81	0	LOS_E	5	6.306586	6.306586	2.330762	0.382716
W-N	1: EB	5: NB	0-3600	18.43501	112.4185	79	0	LOS_E	5	59.50951	59.50951	48.20317	10.40506
N-S	2: SB	2: SB	0-3600	185.4946	256.98	171	0	LOS_F	6	82.92864	82.92864	59.40739	2.766082
N-W	2: SB	4: WB	0-3600	185.1522	256.633	197	0	LOS_F	6	85.19296	85.19296	61.0671	2.84264
N-N	2: SB	5: NB	0-3600	185.4946	256.98	145	0	LOS_F	6	100.883	100.883	71.63613	5.572414
N-E	2: SB	EB	0-3600	185.0283	256.5429	175	0	LOS_F	6	112.2065	112.2065	79.91843	6.708571
N-S	3: SB_rail	3: SB_rail	0-3600	0.641766	57.63059	9	0	LOS_A	1	0	0	0	0
E-S	4: WB	2: SB	0-3600	17.86268	83.63756	81	0	LOS_D	4	36.07862	36.07862	26.00161	3.135802
E-W	4: WB	4: WB	0-3600	17.98549	83.80663	93	0	LOS_D	4	40.11793	40.11793	32.86512	5.419355
E-N	4: WB	5: NB	0-3600	16.52719	81.24681	105	0	LOS_D	4	19.98729	19.98729	13.70295	1.133333
S-E	5: NB	1: EB	0-3600	234.6183	254.3848	64	0	LOS_F	6	342.0994	342.0994	269.6921	12.21875
S-S	5: NB	2: SB	0-3600	234.6183	254.3848	75	0	LOS_F	6	316.8237	316.8237	242.3189	15.42667
S-W	5: NB	4: WB	0-3600	234.6183	254.3848	77	0	LOS_F	6	298.2393	298.2393	224.609	14.98701
S-N	5: NB	5: NB	0-3600	234.6183	254.3848	75	0	LOS_F	6	311.0117	311.0117	242.1122	11.04
S-N	7: NB_rail	7: NB_rail	0-3600	0.56527	57.61591	9	0	LOS_A	1	0	0	0	0
W-E	8: EBP	8: EBP	0-3600	12.2796	14.14438	0	2679	LOS_D	4	53.88613	53.88613	51.94147	1.215752
E-W	9: WBP	9: WBP	0-3600	11.9684	13.68792	0	2854	LOS_D	4	52.84649	52.84649	51.20753	1.117029
Total			0-3600	62.689	256.98	1496	5533	LOS_E	5	66.45794	66.45794	58.88761	2.175583

	SCENARIO-2 WITHOUT LRT												
movement/ direction	from link	to	time interval	Qlen	max. Qlen	vehicles	pers	LOS All	LOS val	veh Delay	persDelay	stop Delay	stops
W-E	1: EB	1: EB	0-3600	12.51026	75.97157	68	0	LOS_E	5	8.085339	8.085339	4.816334	1.382353
W-S	1: EB	2: SB	0-3600	11.51785	73.97185	89	0	LOS_D	4	6.507792	6.507792	2.47497	0.337079
W-N	1: EB	5: NB	0-3600	12.39303	75.72574	86	0	LOS_E	5	37.44684	37.44684	26.71424	15.32558
N-S	2: SB	2: SB	0-3600	196.8161	256.9243	165	0	LOS_F	6	86.79085	86.79085	60.20914	3.587879
N-W	2: SB	4: WB	0-3600	196.4553	256.5773	193	0	LOS_F	6	95.76447	95.76447	70.40617	3.393782
N-N	2: SB	5: NB	0-3600	196.8161	256.9243	146	0	LOS_F	6	111.8028	111.8028	80.08457	6.184932
N-E	2: SB	EB	0-3600	196.3499	256.4872	174	0	LOS_F	6	113.0702	113.0702	79.56488	10.14368
N-S	3: SB_rail	3: SB_rail	0-3600	0	0	0	0	LOS_A	1	0	0	0	0
E-S	4: WB	2: SB	0-3600	12.92327	82.75021	85	0	LOS_D	4	26.07385	26.07385	17.14971	4.235294
E-W	4: WB	4: WB	0-3600	13.00809	82.91929	94	0	LOS_C	3	22.25651	22.25651	15.92173	9.308511
E-N	4: WB	5: NB	0-3600	11.95844	80.35947	107	0	LOS_C	3	10.39844	10.39844	6.110607	0.448598
S-E	5: NB	1: EB	0-3600	234.6188	254.3759	67	0	LOS_F	6	349.9512	349.9512	279.5981	11.77612
S-S	5: NB	2: SB	0-3600	234.6188	254.3759	78	0	LOS_F	6	281.8942	281.8942	214.4053	15.83333
S-W	5: NB	4: WB	0-3600	234.6188	254.3759	82	0	LOS_F	6	270.7574	270.7574	202.9412	14.2561
S-N	5: NB	5: NB	0-3600	234.6188	254.3759	79	0	LOS_F	6	296.2079	296.2079	230.2172	10.32911
S-N	7: NB_rail	7: NB_rail	0-3600	0	0	0	0	LOS_A	1	0	0	0	0
W-E	8: EBP	8: EBP	0-3600	12.2796	14.14438	0	2695	LOS_D	4	51.29519	51.29519	49.85706	0.967347
E-W	9: WBP	9: WBP	0-3600	11.9684	13.68792	0	2875	LOS_D	4	50.10625	50.10625	48.76886	0.899478
Total			0-3600	62.38149	256.9243	1513	5570	LOS_E	5	63.8012	63.8012	56.52594	2.236623

	SCENARIO-3 WITHOUT PEDESTRIAN CROSSING												
movement/ direction	from link	to	time interval	Qlen	max. Qlen	vehicles	pers	LOS All	LOS val	veh Delay	persDelay	stop Delay	stops
W-E	1: EB	1: EB	0-3600	34.16154	138.6455	66	0	LOS_E	5	69.58902	69.58902	59.02488	11.15152
W-S	1: EB	2: SB	0-3600	32.42246	136.6458	85	0	LOS_E	5	63.12023	63.12023	52.59952	2.588235
W-N	1: EB	5: NB	0-3600	33.94069	138.3997	87	0	LOS_E	5	137.6531	137.6531	122.084	12.17241
N-S	2: SB	2: SB	0-3600	229.696	256.9815	103	0	LOS_E	5	157.4707	157.4707	133.1401	2.970874
N-W	2: SB	4: WB	0-3600	229.3548	256.6345	109	0	LOS_E	5	143.8232	143.8232	118.302	2.275229
N-N	2: SB	5: NB	0-3600	229.696	256.9815	87	0	LOS_F	6	179.545	179.545	151.715	4.896552
N-E	2: SB	EB	0-3600	229.2986	256.5444	99	0	LOS_F	6	194.6635	194.6635	165.6282	5.616162
N-S	3: SB_rail	3: SB_rail	0-3600	0.641766	57.63059	9	0	LOS_A	1	0	0	0	0
E-S	4: WB	2: SB	0-3600	44.97265	217.6565	72	0	LOS_D	4	132.9013	132.9013	116.9516	6.944444
E-W	4: WB	4: WB	0-3600	45.13003	217.8256	81	0	LOS_F	6	84.62555	84.62555	70.21303	9.555556
E-N	4: WB	5: NB	0-3600	43.06046	215.2658	99	0	LOS_C	3	83.12243	83.12243	71.84621	1.707071
S-E	5: NB	1: EB	0-3600	211.8741	254.3801	194	0	LOS_E	5	90.53362	90.53362	58.47062	3.778351
S-S	5: NB	2: SB	0-3600	211.8741	254.3801	177	0	LOS_F	6	110.3449	110.3449	73.54879	7.898305
S-W	5: NB	4: WB	0-3600	211.8741	254.3801	194	0	LOS_F	6	109.9478	109.9478	73.55549	6.35567
S-N	5: NB	5: NB	0-3600	211.8741	254.3801	186	0	LOS_E	5	92.51378	92.51378	59.40648	3.989247
S-N	7: NB_rail	7: NB_rail	0-3600	0.56527	57.61591	9	0	LOS_A	1	0	0	0	0
W-E	8: EBP	8: EBP	0-3600	0	0	0	0	LOS_A	1	0	0	0	0
E-W	9: WBP	9: WBP	0-3600	0	0	0	0	LOS_A	1	0	0	0	0
Total			0-3600	78.67273	256.9815	1656	0	LOS_D	4	114.1346	114.1346	88.22101	5.495169

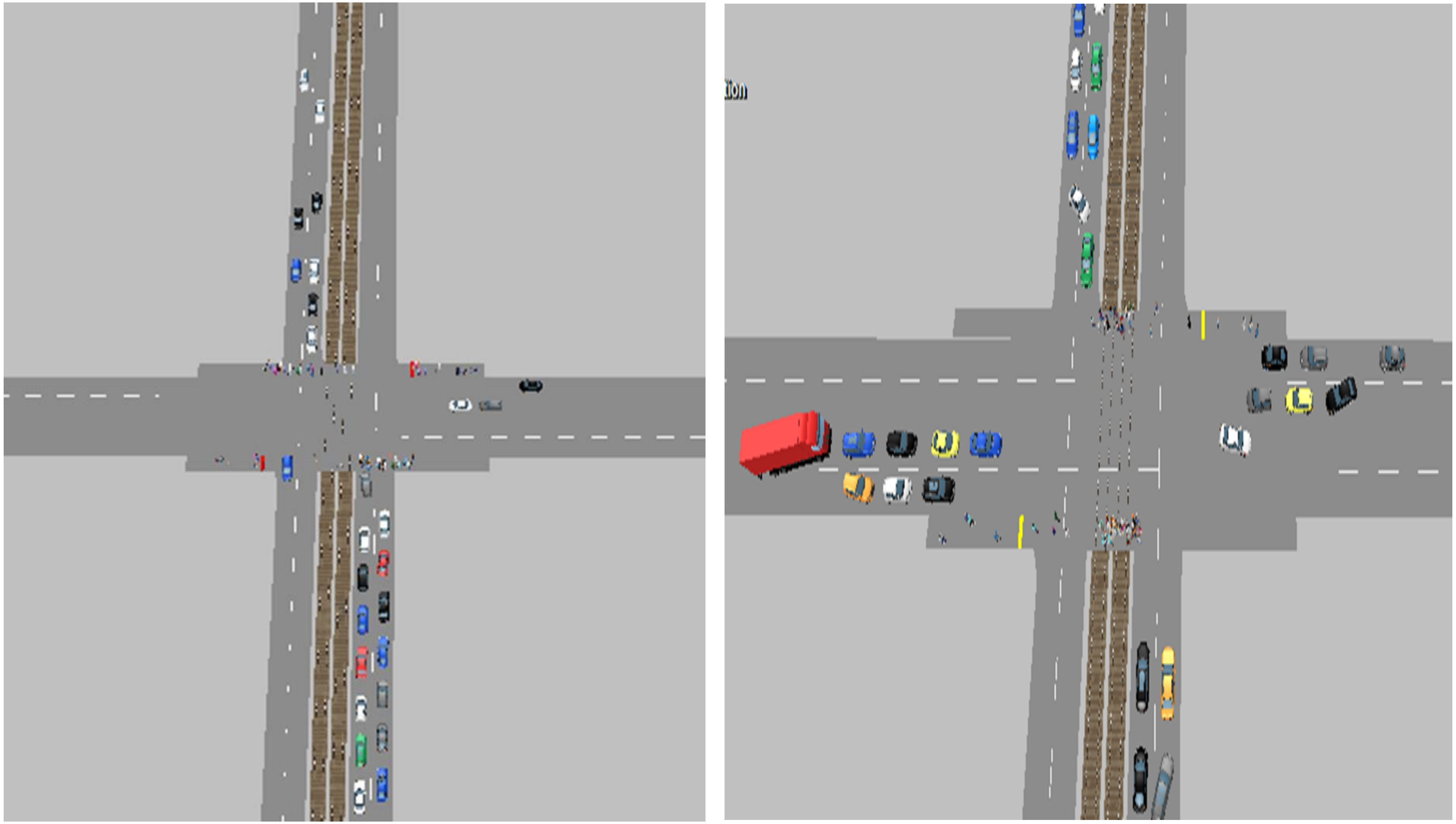

Fig. the geometric feature of Adey Ababa intersection in vissim software during simulation