ASSESSMENT OF TRAFFIC CONGESTION AND ITS IMPACT OVER SELECTED ROAD CORRIDOR IN ADDIS ABABA CITY

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ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled"_**Assessment of Traffic Congestion And Its Impact over Selected Road Corridor In Addis Ababa City**" submitted in partial fulfillment of the requirements for the degree of **Master's** with specialization in **Road and Transport Engineering**, the Graduate Program of the Department/School of Civil engineering, and has been carried out by **Dawit Getachew (ID.No: PGRo/007/10),** under our supervision. Therefore, we recommend that the student has fulfilled the requirements, and hence hereby can submit the thesis to the Department.

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DECLARATION

This MSc. thesis is my original work conducted under the supervision of Dr.Alemayehu Ambo (PhD) and Mr. Daniel Chufamo (MSc.) and submitted to Hawassa University Department of Civil Engineering for the partial fulfilment of Master of Science (MSc.) degree in Road and Transport Engineering stream. I further declare that this Thesis is my original work and has not been presented for a degree award in any other university, and all sources of material used for this thesis have been duly acknowledged.

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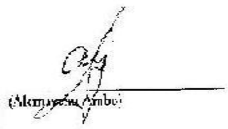

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LIST OF ABBREVIATIONS

AARTB:	Addis Ababa Road and Transport Bureau
SPSS:	Statistical Package for the Social Sciences
LRT:	Light rail transit
DOS:	Degree of saturation
LOS:	Level of service
PSL:	Posted speed limit
ETB:	Ethiopian Birr
LRT:	Light rail transport
NA:	Not available
SIDRA:	Signalized (un-Signalized) Intersection Design and Research Aid
HCM:	High way capacity manual
MOE:	Ministry of education
NCHRP:	National Cooperative Highway Research Program
TTI:	Texas Transportation Institute
UMR:	Urban mobility report
VOT:	Value of travel time
VOC:	Vehicle operating cost
CNG:	Compressed Natural gas
LCV:	Light Commercial Vehicle
HCV:	Heavy commercial Vehicle

ABSTARCT

Traffic congestion problem is becoming a common problem in most developing countries of world. This study was conducted with an objective making assessment of traffic congestion and its impact over the selected road corridor in Addis Ababa City. Through reconnaissance survey the corridor from 'Awutobis Tera' Bus station to 'Lamberet Menahereya' in Addis Ababa city was identified and for analysis purpose the corridor was divided into three sections. The study was conducted starting from June up to October, 2019. Both quantitative and qualitative approach were used. 384 samples were used to conduct questionnaire survey for traffic congestion cause analysis. Out of this 32.5% of the required sample were drawn from section A, 27% from section B and the rest 40.5% was from section C. For making analysis on the performance level of road corridors and economic cost of traffic congestion, traffic volume, travel time delay, average travel speed and vehicle occupancy data were collected manually for a period of 12 hours a day at 15 minutes intervals on respective road corridors and for intersections the data were collected for two hours interval during rush periods. In addition to traffic condition data, the geometric data were also measured as part of the study. The analysis on causal factors for traffic congestion was conducted by SPSS software and analysis on level and economic cost of traffic congestion of the selected road corridor was conducted by utilizing both SIDRA and Microsoft excel. Based on the result of analysis multi variable linear regression model, the imbalance between vehicle volume and road capacity, number of pedestrians that cross and move along the side of the road, inflexible work schedule, inadequate mass transit service along the corridor and illegal on-street vehicle parking were identified as the main causes of traffic congestion over the road corridor. As the result from SIDRA and Microsoft excel showed that the intersections along the corridor and the road corridor in section C were operating beyond the standard set by HCM 2010 which recommends LOS 'C' or 'D'. As per the economic analysis result of the study showed about 2667.8 person-hours/year and ETB104048.75 /year per individual traveler are being wasted due to traffic congestion over the study road corridor. Building vehicle parking apartment, elevated pedestrian crossway and improving performance of intersections were some of the engineering measures recommended to overcome the traffic congestion problem of the corridor.

Keywords: Traffic Congestion Causes, Multi Variable Linear Regression Model, Road Corridor, Level of Service, Travel Time Delay Cost

1. INTRODUCTION

1.1 Background of the Study

Traffic congestion is a major urban transportation problem and it is more related with urbanization. The demand for mobility has risen significantly all over the world as a result of the fast pace of urbanization. Since the end of the Second World War, there have been rapid urbanization and growth in economic activities in the third world cities, resulting in high demand for mobility to those countries (Popoola, et al., 2013).

Urban transport in the third world countries is characterized by huge traffic growth along with shortage of adequately maintained transport facilities, traffic system inefficiency and poor settlement structure causing traffic congestion. Traffic congestion leads to increase in operating costs of vehicles, delay, pollution and stress. As Key Statistics report from emerging countries shows that the transport sector consumes 5 to 10 per cent of the GDP of third world countries. In Ethiopia, different reports estimate the transportation expenditure to be about 10% of the country's GDP; although the actual cost is not yet known (Taddesse, 2011).

In Ethiopia, the urban share of the population has more than doubled in 35 years, from 8.5 percent of the national population in 1967 to 17.4 percent in 2012. The UN estimated that the rate of urban growth between 2010 and 2015 in Ethiopia averaged 3.6 percent per year, placing Ethiopia among the fastest urbanizing countries in sub-Saharan Africa. As with many fast-growing economies, much economic growth is driven from urban areas; thus, 17 percent of the population produce over 58 percent of Ethiopia's Gross Domestic Product (GDP), mostly in Addis Ababa.

Addis Ababa is the principal commercial center of Ethiopia and is experiencing rapid urban growth. The population of Addis Ababa more than doubled every decade since the 1980s. According to the 2007 National Census, the city of Addis Ababa had a population of 2.7 million, though the Central Statistical Agency estimates the current population as 3.3 million, and extrapolation of similar growth rates push the population to about 3.7 million by 2020. However, the current unofficial number of population of Addis Ababa is observed to be more than five million.

Even though Addis Ababa currently manifests low motorization rates by global standard which is reflected by130 vehicles per 1000 people, with a total registered vehicle fleet of about 42600 (World Bank Report, 2015), the rapid economic growth in recent years is expected to lead to a strong increase in vehicle ownership. And the Urban Transport study report of Addis Ababa estimates that the travel demand of Addis Ababa will be doubled in 2020 and the daily trip will become 7.7 million from 3.6 million in 2004 (Taddesse, 2011).

Currently, the Addis Ababa City Transport Authority has realized the problem of traffic congestion and has planned to launch an advanced traffic management system and is working on the establishment of a Traffic Operation Center (TOC). According to the unpublished draft project profile prepared by the Ministry of Transport and Communication, the planned TOC will improve safety and mobility relief congestion and provide traveler information service.

Even if there are different actions and transportation system improvement plan that are undertaken by the Addis Ababa City Roads Authority (AACRA) and the City Traffic Management Office (CTMO), the problem is still affecting the road users' day-to-day activities. Daily time spent on traveling in the city has increased and the city is facing high levels of road traffic accidents, frequent congestion, and high levels of air pollution.

Despite the well-known problem of traffic congestion and the city's administration effort to tackle the problem, limited quantitative researches have been conducted on the City's traffic congestion level and its impact. Therefore, proper quantification, measuring the extent or level of congestion and knowing its impact is an important step for proposing congestion mitigation measures. Hence, this thesis focuses on this information gap and assess and quantify the level of the traffic congestion and its economic cost on selected study corridors in the city of Addis Ababa based on travel time delay approach.

1.2 Statement of the Problem

Traffic jam problem is becoming common in most developing countries of world. Traffic jams in urban areas are annoying and harmful to the residents and travelers. Even if the development of transportation systems shaped the socio-economic benefit for any country, it is also responsible for wasting productive hours and polluting the environment (Banerjee, 2009). According to the Global Greenhouse Gas Emission

Report (2017), the rate of emission from the transport sector has increased from 14% in 2010 to 29% in 2017.

In Addis Ababa, despite the intensive road network expansion and improvement action by the City Transport Authority and Traffic Management Office, traffic congestion is still the major threat to the city's economic growth by restraining the road users' mobility, especially at peak hours even if the city has less number of vehicle ownership compared to the other sub Saharan countries (Taddesse, 2011). A study conducted by Netsanet, (2017) on selected intersection in Addis Ababa City revealed that about Birr 210,805.87 per year during off peak period and Birr 343,597.99 per year during peak period per passenger was lost due to traffic congestion for selected approach within 500m length.

The extent of the problem may increase in the near future due to high growth rate of urbanization and increase in vehicle-km coverage. According to the Urban Transport Study Report (2009), the rate of trips per day will grow to 7.7 in 2020 from 3.6 in 2004. The rate of urbanization and vehicle ownership is very high compared to city road network expansion rate. A study conducted by Asres, (2018), found that the population of the Addis Ababa city has been growing by 3.8% yearly while the physical built up area has been correspondingly increasing by 3.2%. On the other hand, due to high economic growth and people's interest in owning private cars, the number of vehicles has been increasing by 13.5% yearly causing the yearly average urban mobility increment by 10 %. However, the road network coverage has grown only by an average of 4.1% per year which cannot accommodate the increasing transportation demand and vehicle fleets. This resulted in imbalance between the growing demand of transport and transport service, creates social problems of the city like congestion, traffic accidents and environmental impacts. Beside to the above, the 2018 published official report of Addis Ababa traffic management office states that in average about one and half hour per a day per traveler is being lost due to traffic congestion.

There are a lot of researches conducted on traffic congestion in developed as well as in developing countries by using different methodologies in respect of its negative effect. In the case of Ethiopia, specifically in Addis Ababa and regional capitals, the attempts made by different scholar to address the traffic congestion problem was found insignificant as compared to its adverse effect on the nation economy. Those attempt made by scholars to tackle traffic congestion problem were done by concentrating on selected intersection and links rather than the whole road corridor. For example, Tadele, (2017) tried to analyze the economic cost of traffic congestion for selected intersection based on travel time and fuel consumption rate approaches.

In the Highway Capcity Manual (2010), different approaches have been used to evalaute system performance such as: area wide, corridor, link and point analysis. To observe the overall effect that road user' s impose on one other, area or corridor analysis is a prefered approach. Despite to this, all previous research work on traffic congestion cause for Addis Ababa City were done based on descriptive statistic approach. No one had strategically tried to develop multi variable linear regresion model for identifying the major causal facotrs for traffic congestion of Addis Ababa city based inferential statistic approach before now. Under this, it is felt that the gap has been filled by developing a model through analysis of the available data pertaining to cause traffic congestion for selected road corridor between 'Awutobis Tera' ('Merkato' area) and 'Lamberet Menahereya', within a distance of 10.3km.

Further more, the selected road is serve to connect the newly built residential area of 'Hayat', 'Xafo', 'Summit' and 'kuye fache' with the down town and central business district zone of the city. As observed, there is serious traffic flow problem during peak morning and afternoon periods.

In view of the above, it was found important to conduct this study to estimate the negative impacts of traffic congestion in Addis Ababa City in general and on the selected road corridor in particular and come up with possible actions to be undertaken to counter that. Therefore, the study mainly focused on identifying the major causal factors of traffic congestion by developing multi variable linear regression model, measuring the level of traffic congestion and estimating its economic impact per individual traveler over the selected road corridor using travel time approach.

1.3 Significance of the Study

The findings from this study are envisaged to provide basic information to relevant authorities by identifying the most significant causal factors for traffic congestion along the 'Awutobis Tera' Bus station to 'Lamberet Menahereya' road corridor.

Furthermore, the results from this study are likely to give additional information to the Addis Ababa City administrative body regarding the performance level of road corridor, signalized junctions and roundabouts along the selected road corridor to improve the corridor.

In addition to the above, policy makers in the city transport sector can be addressed regarding the adverse impact of traffic congestion on the national economy and also possible solutions can be forwarded through engineering measures. Finally, the study is expected to help researchers in this area by providing insight.

1.4 Objective

1.4.1 General objective

The overall objective of this research is to analysis traffic congestion and its impact over Lamberet Menahereya to Awutobis Tera Bus station road corridor in Addis Ababa City.

1.4.2 Specific objectives

The specific objectives of this research are:

- To develop multi variable linear regression model in order to identify the major causal factors for the traffic congestion over the selected road corridor.
- To investigate the level of traffic congestion in order to quantify the performance level of selected road corridor.
- To estimate economic loss per individual traveler due to traffic congestion over selected road corridor.

1.5. Research Questions

The following are research questions regarding this research:

- What are the major causes of traffic congestion on the selected road corridor through multi variable linear regression model?
- How we quantify the level of traffic congestion on the selected road corridor? and

- How much is the economic loss per individual traveler due to traffic congestion on selected road corridor?

1.6. Scope and Limitation of the Study

Even if traffic congestion is a common problem on roads Addis Ababa city, the scope of this study was limited on the road corridor from 'Awutobis' Tera' Bus Sstation (Merkato Area) to ''Lamberet Menahereya''. Furthermore, the analysis dealt with corridor study rather than city wide. Hence, the study mainly focuses on the road corridor and the relative effects of consecutive intersections were also discussed.

Traffic congestion cost is made up of numerous costs such as: economic costs (travel time delay, VOCs), environmental costs, healthy costs, social costs and others.

However in the case of this study, travel time delay costs due to traffic congestion were estimated using pertinent (relevant or appropriate) parameters.

There were challenges faced during this study and these were: reluctance of some road users to fill the questionnaires and those that expressed willingness did not respond to all questions. ; Furthermore, problems were encountered to get assistances from pertinent government agencies to get permission to conduct field survey and to acquire secondary data.

There are numerous software that are being used to develop models for traffic congestion assessment in most developed countries. In the case of developing countries like Ethiopia, there are technology, capacity and economic constraints.

2. LITERATURE REVIEW

2.0 Introduction

Transport is the basic components of a cities service category which mainly used to overcome the distance to where a person needs to be travel. People need transport service for doing their daily tasks. Population growth and the need for transport has a direct relation. As the population increase the need for transportation demand also increases. This increase in demand for transportation increases traffic volume and traffic congestion which incurring different costs to both the road users and non- road users. Proper traffic management and additional transport facilities are needed to control traffic congestion (Tadele, 2017).

Many researchers and professionals in the field of transportation agree that road traffic congestion is an ever growing problem and global phenomenon of major cities throughout the world. It is a negative output of a transportation system which has many detrimental effects on the performance of the road network, the traffic flow, the society, the national economy and the environment. (Taddesse W., 2011). (Lomax, 1997) showed that traffic congestion is expanding toward the suburbs as commercial activities are being pulled out of the central Business. In fact, it is almost certain that traffic congestion will also get worse during at least the coming decades mainly due to the increasing population number and the growing economy of nations.

2.1 Definition of Traffic Congestion

The Joint Transport Research Centre of the Organization for Economic Cooperation and Development (OECD) and the European Conference of Ministers of Transport (ECMT, 2007) provide conceptual definitions of traffic congestion as impediment imposed by vehicles on each other, where the volume equals or more than capacity (ECMT, 2007). It equally expressed as the difference between the roadway system design capacity and the actually operating capacity, and simply put a situation where demand for road space exceeds supply (ECMT, 2007). These definitions actually point to inability of the current system to accommodate the contemporary traffic situation.

Traffic congestion may also be defined as state of traffic flow on a transportation facility characterized by high densities and low speeds, relative to some chosen reference state (with low densities and high speeds) (Bovy and Salomon, 2002).

Even if there is a definition for traffic congestion given by different professionals, there is no single broadly accepted definition of traffic congestion (Lomax, 1997). One of the principal reasons for this lack of consensus is that traffic congestion is both a physical phenomenon relating to the manner in which vehicles impede each other's progression as demand for limited road space approaches full capacity and a relative phenomenon relating to user expectations with road system performance (European Conference of Ministers of Transport, 2007). However, in order to quantify or measure the effect of traffic congestion, defining traffic congestion based on its impacts are more appropriate due to the fact that the impact of traffic congestion can be felt by many road users and is easy to understand (Taddesse W., 2011) shown in Figure: -2.1 shows the conceptual frame work of traffic congestion Cause and impact.

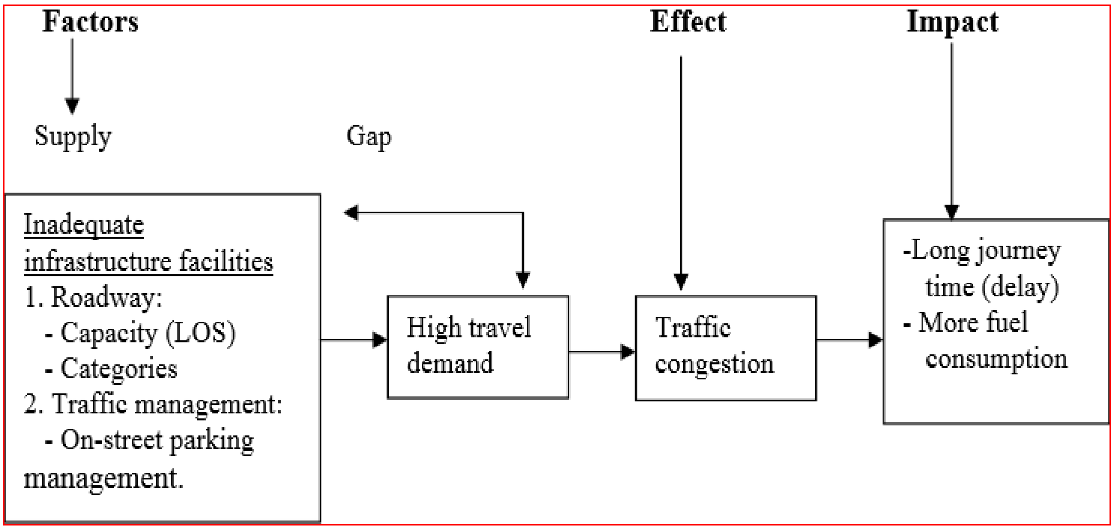


Figure 2-1: Conceptual Fame-work of the traffic congestion cause & impact

Source: (Adopted from Haregewoin, 2010)

2.2 Definition of Conceptual Terms

A queue: is a line of waiting vehicles, such as at street and an intersection (Victoria Transport Policy Institute, 2008).

Delay (vehicle-minutes and person-minutes): Delay expressed or measured in time per vehicle and per person. For instance, Texas Transportation Institute (2005) stated, as it is a phenomena of a slow speed unlike other normal daytime. Equivalently Corpus Christi Metropolitan Planning Organization (2009) argued that delay is a manner in which journeys are taking long time than what would have been in a normally occurrences (Haregewoin, 2010).

Impact: Is a result of forceful or a strong effect on something (word netweb.princeton website).

Level- of- Service: Is one and the most commonly measure that used to assess the level of congestion. LOS measures a traffic volume of a given area qualitatively (Mathew and Krishna, 2007). Six different levels are defined (LOS A, B, C, D, E, and F) with LOS-A representing the best condition and LOS-F representing the worst condition). Many agencies defining congestion in relation with LOS value, either LOS-E or F (Corpus Christi Metropolitan Planning Organization, 2009).

Types of Congestion

The two types of congestion are outlined as recurrent congestion and non-recurrent congestion. These types are based upon the frequency and predictability of the congestion the factors which are capable to impact on driver behavior. The costs associated with each type of congestion are likely to be different.

Re**current congestion: -** occurs mainly when there are too many vehicles wanting to use the road at the same time. Recurrent congestion typically occurs during weekday morning and afternoon peak periods, when most people go to work and return home at around the same time. In large urban areas, the peak periods can range from 7:00 to 9:30 a.m. and from 3:30 to 7:00 p.m. In smaller urban areas, the peaks may have a shorter duration (one or two hours). Of interest is the growing recurrent congestion that occurs during off-peak periods (i.e. during other weekday hours, and even on weekends). This reflects, in large part, a rapid growth in off-peak travel (off-peak travel is growing faster than peak-period travel in some areas) (Admasu, 2017).

Non –recurrent congestion: - is the other main source of traffic congestion. Non-recurrent congestion is associated with random conditions or special and unique events, such as traffic incidents, truck spills, accidents, work zones, unusual or disruptive maneuvers by individual drivers, irregular facility maintenance operations (e.g., seasonal street cleaners), and adverse weather and special events. Because of the random nature of this type of congestion, non-recurrent congestion is more difficult to predict and address. Non-recurrent congestion costs may be more difficult to quantify due to the inherent sparseness of adequate amounts of data needed. It may be argued that the costs could be higher as drivers have not been able to take the possibility of congestion into account in planning their journey or alternatively the costs not have come into play. Some routes are increasingly subject to non-recurrent congestion, for example with accident black spots. In these cases drivers may "learn‟ an expected cost in terms of likely delay and successful contingency routes. (Laird et al, 2006)

2.3 Causes of Traffic Congestion

Traffic congestion is one of the consequences of urbanization, it is a reflection of the urban development, housing, employment and cultural policies which influence where people live and work. OECD and ECMT put the relationship between urban cities and traffic congestion in perspective, "Cities and traffic have developed hand-in-hand since the earliest large human settlements. The same forces that draw inhabitants to congregate in large urban areas also lead to sometimes intolerable levels of traffic congestion on urban streets and thoroughfares." (ECMT 2007:5).

Causal factors of traffic congestion can be categorized into two principal groups' i.e. micro level and macro level. Micro level factors consist of movements of people at a single moment e.g. social and political gatherings. While on the other hand, macro level factors consist of land use patterns, infrastructure establishments, employment patterns, and regional economic dynamics (Nilanchal & Alok, 2015).

2.4 Measuring the Performance of Transportation system

According to the Highway Capacity Manual, (2010), performance of transportation system can be measured in more than one dimension. When a single intersection is analyzed, it may suffice to compute only the peak-period delay; however, when a system is analyzed, the geographic extent, the duration of delay, and any shifts in demand among facilities and modes must also be considered. Performance of transportation system can be measured according to the following dimensions (HCM 2010, Volume I):

Quantity of Service: Quantity of service measures the utilization of the transportation system in terms of the number of people using the system, the distance they travel (person miles of travel, PMT) and the time they require to travel (person-minutes of travel).

Intensity of Congestion: The intensity of congestion can be measured by using total person-hours of delay and mean trip speed. Other metrics, such as mean delay per person-trip, can also be used. In planning and preliminary engineering applications, intensity of congestion is sometimes measured in terms of volume-to-capacity ratio or demand-to-capacity ratio.

Duration of Congestion: The duration of congestion is measured in terms of the maximum amount of time that congestion occurs anywhere in the system. A segment is congested if the demand exceeds the segment's discharge capacity. Transit subsystem congestion can occur either when the passenger demand exceeds the capacity of the transit vehicles or when the need to move transit vehicles exceeds the vehicular capacity of the transit facility.

Extent of Congestion: The extent of congestion may be expressed in terms of the directional miles of facilities congested or—more meaningfully for the public—in terms of the maximum percentage of system miles congested at any one time.

Variability: Is the day-to-day variation in congestion intensity, duration and extent along a system.

Delay: The analysis of a transportation system starts with estimates of delay at the point and segment level. Point delays arise from the effects of traffic control devices such as traffic signals and STOP signs. Segment delays combine the point delay incurred at the end of the segment with other delays incurred within the segment. The other cause for segmental delays are; midblock turning activity into driveways, parking activity and midblock pedestrian crossings.

Level of Service:- The HCM 2010 defines LOS for most combinations of travel mode (i.e., automobile, pedestrian, bicycle, and transit) and roadway system element (e.g., freeway, multilane highway, urban street, intersection) addressed by HCM methodologies .Six levels are defined, ranging from A to F. LOSA represents the best operating conditions from the traveler's perspective and LOSF the worst. LOS is used to translate complex numerical performance results into a simple A-F system representative of the travelers' perceptions of the quality of service provided by a facility or service.

LOSA describes primarily free-flow operation. Vehicles are completely unimpeded in their ability to maneuver within the traffic stream. Control delay at the boundary intersections is minimal. The travel speed exceeds 85% of the base free-flow speed.

LOSB describes reasonably unimpeded operation. The ability to maneuver within the traffic stream is only slightly restricted and control delay at the boundary intersections is not significant. The travel speed is between 67% and 85% of the base free-flow speed.

LOS C describes stable operation. The ability to maneuver and change lanes at mid segment locations may be more restricted than at LOS B. Longer queues at the boundary intersections may contribute to lower travel speeds. The travel speed is between 50% and 67% of the base free-flow speed.

LOSD indicates a less stable condition in which small increases inflow may cause substantial increases in delay and decreases in travel speed. This operation maybe due to adverse signal progression, high volume, or inappropriate signal timing at the boundary intersections. The travel speed isbetween40% and 50% of the base free-flow speed.

LOS E is characterized by unstable operation and significant delay. Such operations may be due to some combination of adverse progression, high volume, and inappropriate signal timing at the boundary intersections. The travel speed isbetween30% and 40% of the base free-flow speed.

LOS F is characterized by flow at extremely low speed. Congestion is likely occurring at the boundary intersections, as indicated by high delay and extensive queuing. The travel speed is 30% or less of the base free-flow speed. Also, LOS F is assigned to the subject direction of travel if the through movement at one or more boundary intersections has a volume-to-capacity ratio greater than 1.0

Table 2-1: LOS thresholds established for the automobile mode on urban streets

Travel Speed as a Percentage of Base free	LOS by Critical Volume-to-Capacity Ratio		
	≤ 1.0	LOS Definition	≥ 1.0
>85	A	0.0 to 0.6	F

>67-85	B	0.61 to 0.70	F
>50-67	C	0.71 to 0.8	F
>40-50	D	0.81 to 0.9	F
>30-40	E	0.91 to 1.0	F
≤ 30	F	Greater than	F

Source: (HCM 2010, Volume-III)

In this particular case, it should be noted that the critical volume-to-capacity ratio is based on consideration of the through movement volume-to capacity ratio at each boundary intersection in the subject direction of travel. The critical volume-to capacity ratio is the largest ratio of those considered. The base free flow speed of segment is determined based on posted speed limit along segment by adding 5km/h. Table 2.2 shows LOS criteria for road junctions.

Table 2-2: Level of Service criteria for road junctions /intersections

Level of Service	Delay at signalized	Delay at un signalized
A	≤ 10 sec	≤ 10 sec
B	10-20 sec	10-15 sec
C	20-35 sec	15-25 sec
D	35-55 sec	25-35 sec
E	55-80 sec	35-50 sec
F	≥80 sec	≥50 sec

Source: (HCM 2010)

2.5 SIDRA Intersection Software

SIDRA (Signalized Intersection Design and Research Aid) is a software package developed by the Australian road research board as an aid for capacity, timing and performance analysis of signalized intersection. It is a software for use as an aid for design and evaluation of signalized intersections (fixed-time / pre timed and actuated), signalized pedestrian crossings, single point interchanges (signalized), roundabouts, roundabout metering, two-way stop sign control, all-way stop sign control, and give-way/yield sign-control (Nilanchal & Alok, 2015).

The SIDRA intersection software was first released in 1984. With input and output facilities at individual turn, lane, lane group, approach road, movement grouping and intersection levels, SIDRA provides a flexible structure which allows multilevel analysis from simple to very complex intersection. The ability of the user's to calibrate SIDRA models for local condition is an important feature of SIDRA. The software not only estimates capacity and other measures directly related to the performance of the traffic system, but also gives estimates on fuel consumptions and operating cost for the specified facility (Anna, 2013).

A highway capacity manual option has been implemented fully in SIDRA intersection software in order to facilitate the comparison of the SIDRA HCM methodologies, to incorporate some useful features of the HCM into SIDRA for the benefit of its users (Rahmi, 1990).

2.5.1 Calibration of SIDRA Intersection Software

Since the Sidra Intersection was developed for Australian conditions as default, it requires calibration for use in other countries. Calibration of the Sidra Intersection is performed by changing values of the parameters affecting capacity. This can be done in a few different ways, either by changing the value of the critical gap and the follow-up headway directly or by using the calibration parameters; environment factor and entry/circulating flow ratio adjustment (Chufamo, 2018 and Anna, 2013)).

The environment factor can be seen as a collection factor that includes everything at the junction environment e.g. design type, visibility, grade, speed, driver response time and aggressiveness, amount of heavy vehicles and pedestrians and parking near the Junction (Alemayehu, 2015). On the one hand, factors in the environment with positive effects on traffic are for example; good visibility, small volumes of pedestrians, short driver response times, and low levels of heavy vehicles and parking on the approaches. In cases like that, environment factor should be lower which leads to higher capacity (Anna, 2013). On the other hand situations such as bad visibility, large volumes, long driver response times and large volumes of heavy vehicles have negative effects on capacity. Environment factor should therefore be higher which will lead to lower capacity. Default the environment factor is set to 1, which is also what is used in Australia. According to Myre, (2010) studies in Norway have shown that 1.1 is a good value of environment factor for Norwegian conditions. The HCM version of the SIDRA Intersection model uses 1.2 as environment factor.

Table 2.3 shows input data required for the performance analysis of intersection using SIDRA.

Table 2-3: Some of the input data required for the performance analysis of intersection using SIDRA

Input data	Input data	Input data
Intersection ID	Gap acceptance	Movement data
Road Geometry data	Pedestrian volume	Priorities
Traffic volume data	Phasing and timing	Demand and sensitivity
Path data	Modell setting	

Source: (Rahmi, 1990)

2.6 SPSS Statistical software

SPSS (Statistical Package for the Social Science), also known as IBM SPSS Statistical, is a software package used for the analysis of statistical data ((Matthew, 2018).

Assumption of multivariable linear regression

Regression is a parametric approach. ‘Parametric’ means it takes assumptions about data for the purpose of analysis. Due to its parametric side, regression is restrictive in nature. It fails to deliver good result with data sets which doesn’t fulfill its assumptions.

Important assumption need to be considered in analysis of statistical data through linear regression.

1. There should be a linear and additive relation between dependent and independent variables. A linear relationship suggests that a change in dependent variable (Y) due to unit change in independent variable (X). An additive relationship suggests that the effect of ‘x’ on ‘Y’ is independent of other variables.
2. There should be no correlation between the residual (error) terms. Absence of this phenomena is known as Autocorrelation.
3. The independent variables should could not correlated. Absence of this phenomena is known as multicollinearity.
4. The error term must have constant variance. This phenomena is known as homoscedasticity. The presence of non-constant variance is heteroscedasticity.
5. The error term must be normally distributed.

2.7 Different Approaches for Estimating Traffic Congestion Costs.

The Texas Transportation Institute (TTI) publishes an annual urban mobility report (UMR) covering some 100 cities and municipalities in the USA. The procedures used in the report have been developed over a number of years and as a result of several research projects. The congestion estimates for all study years were recalculated in 2010 to provide a consistent data trend as the methodology had been amended (Lomax, et al 2010). The TTI (2007) study measures congestion relative to a free-flow base case, represented by the travel times involved in making the trip in question in the early hours of the morning. The UMR provides estimates of mobility at the area-wide level. The approach used describes congestion in consistent ways allowing for comparisons across urban areas or groups of urban areas. The calculation uses a dataset of traffic speeds from a private company (INRIX) that provides travel time information to a variety of customers; and volume and roadway inventory data from the Federal Highway Administration Highway Performance Monitoring System (HPMS). Most of the basic performance measures presented in the UMR were developed as part of the process of calculating travel delay. The amount of extra time spent travelling due to congestion. The INRIX speed data reflects the effects of both recurring (or usual) delay and incident delay (crashes, vehicle breakdowns, etc.). The delay calculations are performed at the individual roadway section level for each hour of the week.

But, all this methodology is done based on "free flow speed" which means with the state of zero congestion. However, it is important to note that there is no implication that zero congestion is a possible or desirable goal for policy.

Another approach is methodology adopted by Lindsey, (2007). Lindsey, (2007) provides an example of a cost of congestion calculation using 'acceptable' levels of congestion as the comparison. He quotes statistics that had recently been compiled by Transport Canada quantifying the costs of travel delay, additional fuel consumption, and greenhouse gas emissions for the nine largest urban areas of Canada. Rather than taking free-flow conditions as the baseline, the study adopted a percentage of the speed limit as a threshold below which congestion could be considered 'unacceptable'. Since this threshold varies across municipalities and road networks, the study undertook calculations with thresholds of 50%, 60% and 70% of the speed limit.

Since it is difficult to get free flow (zero congestion) condition on some mega cities with great hourly traffic volume, (Prud'homme, 1998) calls another arbitrary approach by taking reference speed, defined as acceptable speed, such as 50km/h on a non-urban road. When the speed of traffic falls below this threshold, the situation is called congested. Congestion costs are then defined as the difference between the time actually spent and the time that it would take if traffic were flowing at the acceptable speed, multiplied by the volume.

2.8 Previous Study Regarding Traffic Congestion Cause, Level and Impact analysis

2.8.1 The Experiences of Developing Countries

1. A study conducted by (Asres, 2018), tried to analyzes the land use and transportation demand interaction in Addis Ababa considering the Akaki Kality Sub City as a Case Study. Transportation demand analysis in conjunction with studying the extents of urban expansion along with land use pattern changes and analysis on interactions of the two were the major undertakings that were dealt with in the study. It assessed and analyzed the continual day-to-day increment of public transportation demands and transportation problems due to high variability of land use change and high rate of urban expansion that are taking place around the peripheral of the Addis Ababa City.

The four step transportation demand model was utilized in the study to analyze the present and future land use patterns of the city, Satellite image classification along with analyzing the change of land use for the past twenty-nine (29) years were performed. To carry out the study successfully; primary, secondary, and tertiary data were collected. In analyzing the spatial data, the Arc GIS 10.1 software was utilized. Similarly, statistical, mathematical, and graphical analysis was dealt with. To make the research specific and effective, six major destinations of the Akaki Kality sub-city passengers were selected and dealt with.

By analyzing the data, adopting different equations, models, and calibrate parameters; it was found that the population of the Addis Ababa city has been growing by 3.8% yearly while the physical built up area has been correspondingly increasing by 3.2%. On the other hand, due to high economic growth and people's interest in owning private cars, the number of vehicles has been increasing by 13.5% yearly causing the yearly average urban mobility increment by 10 %. However, the road network coverage has grown only by an average of 4.1% per year which cannot accommodate the increasing transportation demand and vehicle fleets. This results in continual day-to-day transportation and social problems of the city like congestion, traffic accidents and environmental impacts.

2. A study had been conducted by Desmond, (2018), for identifying the significant causes of traffic congestion in Port Harcourt metropolis, Nigeria. In examining the most significant causes of congestion in Port Harcourt metropolis, the city was zoned into 13 study area by using land-use activity centers. 2601 questionnaires were administered which represents 0-24% of the population. 78 commuters were interviewed whilst vehicular traffic counts were conducted at 13 locations for the period of 6am-6pm from Monday – Sunday. The causes of vehicular traffic congestion in Port Harcourt metropolis identified through the questionnaires reflect the vehicular traffic congestion matrix in an urban center. There are variables that separately or collectively act to cause vehicular traffic congestion. The causes of vehicular traffic congestion are many and varied from one urban area to another. In Port-Harcourt metropolis, the critical causes of vehicular traffic congestion as identified from the questionnaires are inadequate means of public transportation, wrong parking, bad road, poor traffic signalizations, road-side trading/markets and road capacity. Other causes of vehicular traffic congestion identified include Alcoholic effects, burial ceremonies, poor road geometries, queuing for fuel at filling station, abandonment of broken down vehicles, over population, dumping of waste, non-integration of land-use planning, use of heavy-duty vehicles, poor drainage etc. Because the respondents scored some of the factors very low and their inclusions in the analysis will not contribute to explaining the causes of vehicular traffic congestion in Port-Harcourt metropolis, they were therefore expunged.

In examining the most significant cause of vehicular traffic congestion, the causes of vehicular traffic congestion in the study area were used as the independent variable X. This was measured by summing up the identified causes of vehicular traffic congestion. The total number of vehicular traffic in each zone made up the dependent variable y. In running the regression analysis, the independent X variables are plotted with the dependent y variables in the ANOVA SPSS. The variables used are:

Y = Aggregated vehicular traffic

X_1 = Inadequate means of public transportation X_2 = Wrong parking

X_3 = Poor state of road X_4 = Poor traffic signalization

X_5 = Roadside market X_6 = Road size capacity.

The linear regression equation of the most significant causes of vehicular traffic equation used by Desmond, is shown thus: (See equation 2.2)

Y = -2.26723.9 – 85371.440X_1 + 107792.89X_2 – 61721.102X_3 – 33815.874X_4 – 258777.5X_5 + 4534.689X_6……………………………………………………..2.1

Base on regression analysis, wrong parking has been identified as the most significant causes of traffic congestion in Port Harcourt metropolis.

3. A research had been done by Madhu, et al., (2015) to estimate fuel loss and travel time delay cost at steady and congested state flow on Multi-Lane Highways in India as follows:

By considering variables operating speed, road roughness, rise and fall, fuel consumption equation for steady state has been developed by Madhu, *et al.*, as shown by the equation 2.3 and 2.4:

$$FC_{SC}{}^{ST} = 30 + \frac{844.085}{V_{SC}} + 0.003 * V_{SC}{}^{2} + 0.001 * R + 0.4552 * RS - 0.89 * FL \ldots\ldots 2.2$$

$$FC_{BC}{}^{ST} = 35 + \frac{983.503}{V_{BC}} + 0.003 * V_{BC}{}^{2} + 0.002 * R + 0.452 * RS - 1.914 * FL \ldots\ldots 2.3$$

$$FC_{HCV}{}^{ST} = 50 + \frac{8049.95}{V_{HCV}} + 0.012 * V_{HCV}{}^{2} + 0.005 * R + 4.565 * RS - 4.904 * FL - 7.285 * P/W \ldots\ldots 2.4$$

Where

FC = Fuel consumption in ml/km; V = Speed in Kmph;

R = Roughness in mm/km RS = Rise in m/km;

FL = Fall in m/km; P/W = Power – weight ratio;

Superscript ‘ST’ represents steady state condition.

Subscript ‘SC’, ‘BC’, and ‘HCV’ represents small car, big car and Heavy commercial vehicle respectively.

Since the data collection for HCV was carried out under varying load conditions namely empty, half and fully loaded, the variable P/W has been introduced in the fuel consumption equation for HCV.

The fuel consumption under congested state is estimated by multiplying the steady state fuel consumption by multiplying with conversion factor as follows.

$$FC_i^{CON} = f(V_i) * FC_i^{ST} \quad \ldots\ldots 2.5$$

Where f(v) is a factor defined as the ratio of congested and steady state of FC.

Superscript ‘CON’ and ‘ST’ represents congested and steady state respectively.

Subscript ‘i ‘represents vehicle type.

Using the collected fuel consumption data under both steady and congested state condition and associated speed, equations for f(Vi) for different vehicle types have been developed considering speed as influencing variable is given below:

$$f(V_{SC}) = 0.0003 * {V_{SC}}^2 - 0.0344 * V_{SC} + 1.9555 \qquad [R^2 = 0.51] \ldots\ldots 2.6$$

$$f(V_{BC}) = 0.0005 * {V_{BC}}^2 - 0.0609 * V_{BC} + 2.8175 \qquad [R^2 = 0.44] \ldots\ldots 2.7$$

$$f(V_{HCV}) = 0.0017 * {V_{HCV}}^2 - 0.2014 * V_{HCV} + 7.0539 \qquad [R^2 = 0.55] \ldots\ldots 2.8$$

$$f(V_{TW}) = 0.0005 * {V_{TW}}^2 - 0.0465 * V_{TW} + 2.0556 \qquad [R^2 = 0.60] \ldots\ldots 2.9$$

The comparison of steady state and congested state fuel consumptions under varying speeds are illustrated: (See: Figure 2.2)

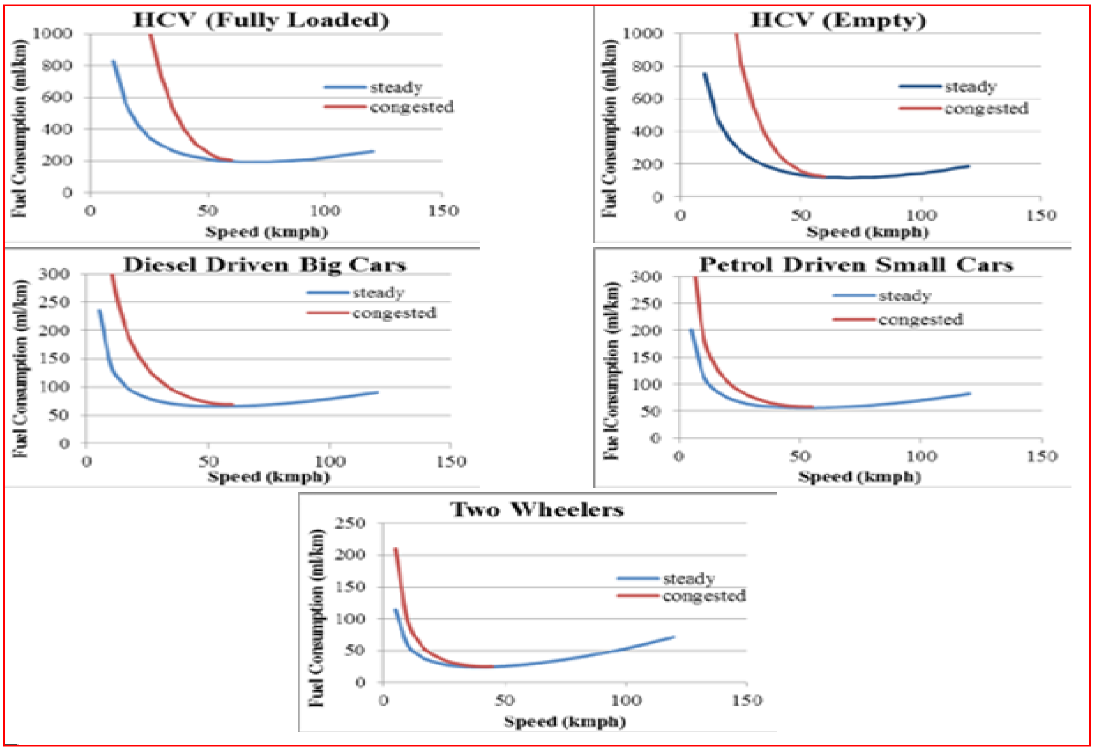


Figure 2-2: Comparison of steady state and congested state fuel consumptions under varying speed

Source: (Madhu, et al., 2015)

As per the study result fuel consumption of the vehicles are highly dependent on the vehicles operating speed and also the road geometry characteristics and pavement condition namely roughness.

For estimating travel time cost due to traffic congestion, Madhu, *et al.*, collected VOT (value of travel time) through survey from the commuters of Buses, private vehicles (i.e. cars and two wheelers) and goods vehicles separately through specially designed questionnaire on the selected multi-lane road corridors. The travel time cost for passenger vehicles is obtained by multiplying the travel time per km with the VOT of passengers and average occupancy of the vehicle.

Mathematically it can be represented as:

$PTTC_{ih} = T_{ih}*O_i*VOT_i$……………………………………………………………….3.0

Where, PTTC = Passenger Travel Time Cost in Rs/veh-km

T = Average travel time in min/km;

O = Average vehicle occupancy;

VOT = Value of travel time of the Passengers in Rs/min

Subscripts ‘i ‘and ‘h’ represents the vehicle type and traffic flow condition (Steady or congested)

According to Madhu, et al.(2015), the travel time cost for goods vehicles is obtained by multiplying the travel time per km with the commodity holding cost (CHC) of the vehicle which is basically determined from the value of goods in transit which is obtained from value of commodity surveys. Mathematically it can be written as:

$GTTC_{ih} = T_{ih}*CHC_i$……………………………………………………………..……3.1

Where, GTTC = Goods Travel time cost in Rs/ Veh-km

CHC = Commodity Holding cost in Rs/Min

Considered vehicles are MCV = Medium commercial vehicle

HCV = Heavy commercial vehicle

TW = Two Wheelers LCV = Light Commercial vehicles

The travel time cost due to traffic congestion on national highway-2 for 1km stretch is presented. (See Table: 2.4)

Table 2.4 shows the estimated total travel time cost of selected vehicles under steady and congested traffic flow conditions.

Vehicle type	Total travel time cost under Steady state (in $)	Total travel time cost under Congested state (in	Percent Change	Time Loss (in $)
Car	8352.04	12917.04	54.66	4565.00
TW	457.36	836.62	82.92	758.52
HCV	4.32	6.16	42.65	1.84
Buses	3160.20	3750.08	18.67	589.88
LCV	10.06	15.12	50.37	5.06
MCV	3.06	4.70	52.70	1.62
Total	11987.06	17529.72	47.59	5921.92

Source: (Madhu, et al., 2015)

4. A study had also been conducted by Tadele, (2017) to analyze the traffic congestion effect for Addis Ababa City. In his analysis of traffic congestion causes, cumulative percentage obtained from respondents through questionnaire was used to rank the major causal factors of traffic congestion over the corridor and he made a conclusion based on descriptive statistic approach. For conducting questionnaire Tadele draws one hundred representative samples from the total target population.

5. A study had been conducted by Stephen , et al., (2015) to analyze capacity and performance of 3 major roundabouts (Jubilee Park, Cocoa House and Post Office) in Sunyani, Ghana. Sunyani municipality is the regional capital of the BrongAhafo Region of Ghana and is among the fastest growing cities in Ghana. The region shares borders with Wenchi municipal to the north, Berekum municipal and Dormaa East district to the west, Asutifi district to the south and Tano South district to the east. According to the 2012 housing and population census, Sunyani municipal has population of about 248, 496.

To check the performance of the roundabouts traffic data were collected manually at the roundabouts during peak hours in the interval of 15 minutes. Also, as-built geometric data of the roundabouts were measured in the field. Geometry measurements for each roundabout were obtained from as-built construction plans. Synchro plus SimTraffic 7 software's were used to run computer simulations to estimate the capacities and performances of the roundabouts. Results showed that the Jubilee Park and Post Office roundabouts were performing above capacities based on the overall volume to capacity ratios of 0.78 and 1.13 respectively, with intersection capacity utilization (ICU) level of service H. As per Stephen , et al The roundabouts were at least 9% above capacity and were being subjected to congestion periods in excess of 120 minutes per day. Similarly, the Cocoa House roundabout with volume to capacity ratio of 0.51 and ICU level of service G was 9% above the traffic-carrying ability and undergoing successive congestion periods of 60 to 120 minutes. To improve on vehicular movement he 3 roundabouts, increasing the island diameter and changing the roundabouts to signalized intersection are some of the recommendation given by the researchers.

6. Another study conducted by Tadesse, (2011) assessing & quantifing the level of traffic congestion at major intersections in addis ababa, Ethiopia. The city's one of the most congested East-West corridor was considered by this study and travel time, traffic volume, and vehicle occupancy data were collected at four midblock and four intersections. Accordingly, the travel rate, the delay rate, total travel delay (Veh-Min and Per-min), buffer index and planning time index were calculated. And also, the average hourly travel rate is correlated with the average hourly traffic accident data and congestion spots and accident black spots were plotted on the GIS map to see the relationship between the traffic accident and traffic congestion. The research approach in this thesis involves both quantitative and qualitative approaches. Quantitative data analysis were used to determine the level of service of intersections and to measure the congestion levels quantitatively. Observation, direct field measurements and secondary data were the main sources of quantitative data. Furthermore, qualitative data from questionnaire were also used to determine whether the congestion in Addis Ababa is considerable or not and to assess other related parameters.

Accordingly, the result showed that on average about 18,000 Veh-min or 38 Veh-day and about 169,000 Per-min or 352-person-day are wasted at each major intersection entry and the city incurs annually about 5-8 Million Birr per intersection only for vehicle and fuel cost.

As per the study result of Tadese, the common causes of traffic congestion were: shortage of mass transport, poor traffic management, imbalance of vehicle volume and road capacity, especially at intersections, parking of passenger cars for loading and unloading of passengers near intersection entry and exit, on street parking on walkways and road ways which forces passengers to use roadways and conflict with vehicles, inflexible work zone and to some extent, traffic accidents are the major causes of traffic congestion.

Based on travel time delay cost analysis, it was found that total congestion cost including delay, wasted fuel and operating cost of passenger vehicles and truck vehicles at each road segments on average was about Birr 53.2 million per year.

2.8.2 The Experiences of Developed Countries

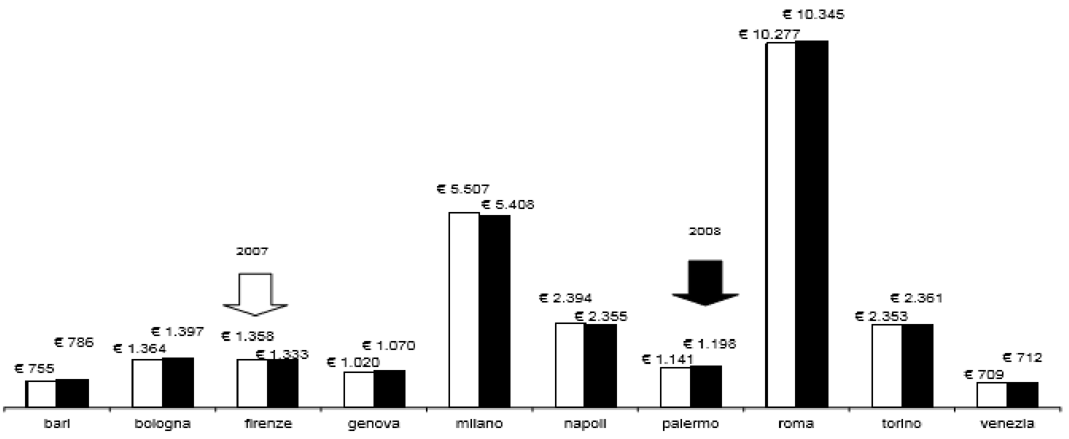
1. In case of developed countries, there is a study conducted by Francesco & Jeanne , (2013) and it presented a methodology to measure the cost of congestion in cities and to identify levers of action to manage traffic. The study focused on the ten largest Italian cities and considers the evolution between 2007 and 2008.

   The study had conducted by taking into account the extra costs (the extra consumption of fuel, the extra time spent in traffic, and the extra CO2 emission) induced by the reduction in speed below 30 km/h due to the increasing demand for the use of road (assumed that the cost of fuel, time and CO2 emission induced by traffic when running at a higher speed are the "normal" costs of traffic, and are not taken into account in our analysis). By taking into account the cost of fuel, the cost of CO2 emission and cost of time spent in traffic due to congestion, the methodology allows to assess the socio-economic cost of congestion as a proxy of the net reduction of GDP induced by traffic. The study used a model that may not only provide a systematic measurement of the costs of congestion in cities, but also the identification of the precise levers to be used in order to reduce these costs.

   The data were collected through GPS devices embedded in cars for insurance purpose (and that were collected by an Italian firm called Octo Telematics). The sample encompasses 257 400 cars equipped with this GPS technology. For the purposes of this study, congestion is defined as the time spent in a car that runs below 30 km/h. Therefore, we assume that the costs of traffic when travelling above 30km/h are the normal cost of traffic associated to a normal speed. Then, we focus on the cost of congestion, not to be confused with the total social cost of traffic referred to as the cost of road use.

   Given the total population, the total car fleet for each city and assuming the sample was representative, the survey then allows to assess: a) the average distance (km) travelled per trip, b) the average speed (km/hour), c) the average duration of trips, d) the fuel consumption, d) the CO_2 emissions, e) the percentage of time/ Km spent in congestion. This measurement allows to quantify, per citizen and per city: The cost of time spent in the car which is a function of average speed, km traveled and opportunity cost of time (which is a function of average income per capita and therefore varies by city), the cost of fuel which is the number of travelled miles which multiplies the average consumption of fuel in liters per km at the recorded average speed multiplied again by the average price of a liter of fuel and the cost of CO_2 emission which is a function of the average number of miles covered per car, the amount of CO_2 (in tons) produced per km, and the average price per ton (calculated considering the price of certificates of CO_2 in future markets).

The study result revealed that the congestion cost amounted to 27 billion euros per year for around 8.5 million people living in the ten most populated cities of Italy.



Graph 1. Total cost of congestion, million Euros, 2007 and 2008

Source: (Francesco & Jeanne , 2013)

Figure 2-3: Total traffic congestion in Ten Italian Cities

The figure above represents about 2% of the GDP, and is rather impressive, considering that the model did not take into account several parameters such as the cost of pollution other than CO_2, the public services, or the depreciation of car.

As a logical consequence of this measurement, the study puts forward a proposal to address congestion in city through the implementation of a policy relying on the "pay as you pollute" principle: the flexible congestion rights. This incentive scheme would reflect the real externalities of car usage by considering the characteristic of the vehicles, of the journeys, and the effective use of public goods – roads and road related infrastructures. It would also provide rewards to environment friendly behaviors, while any surplus would be reinvested in the public transportation system. Thus, the mechanism would have the advantage of higher flexibility, making it more effective, equitable, and capable to win political resistance than more traditional road pricing schemes.

2.9 Summary of Literature Review

2.9.1 Approach for Traffic Congestion causes Assessment

A study conducted by Desmond, (2018), for identifying the significant causal factors of traffic congestion in Port Harcourt metropolis, Nigeria had used multi variable linear regression model to analyze the traffic congestion causes and to identify the major factors. In examining the most significant cause of vehicular traffic congestion, the causes of vehicular traffic congestion in the study area were used as the independent variable X and the total number of vehicular traffic (volume of traffic) in each zone made up the dependent variable y.

The multi variable linear regression model developed by Desmond was shown below:

$$Y = -2.26723.9 - 85371.440X_1 + 107792.89X_2 - 61721.102X_3 - 33815.874X_4 - 258777.5X_5 + 4534.689X_6 \ldots\ldots 3.2$$

Another study conducted by Tadele, (2017) to analyze the traffic congestion effect for Addis Ababa City. In his analysis of traffic congestion causes, cumulative percentage obtained from respondents through questionnaire was used to rank the major causal factors of traffic congestion over the corridor and he made a conclusion based on descriptive statistic approach. As the review result of researcher indicated, most study conducted by previous scholars on traffic congestion causes analysis for Addis Ababa City was based on descriptive statistical approach.

With presented study the traffic congestion causal factors were analyzed and the major causal factors were identified based on inferential statistic approach through multi variable linear regression model development. The approach followed on the presented study was related to the approach followed by Desmond, (2018).

2.9.2 Approach for Level of Traffic Congestion Analysis

As per Highway Capacity manual the performance level of transportation is measured in terms of area wide (over the region), corridor, link and point analysis. To observe the overall effect that road user' s impose on one other, area or corridor analysis is a prefered approach. With this approach the effect of road segment, sub-arterial acesses road, side friction such as on-street parking, pedestrian interuption and other effect over the corridor can be felt. In addition to the above, the effect of consecuative intersection along the corridor can be evaluated. Most paper reveiwed by researcher were conducted by taking a control point and road links or mid-blocks between control points as a study subject to analyze the level of traffic congestion.

The present study was conducted following corridor analysis approach in order to see the effect of side frictions and consecuative intersections on the normal traffic flow for the road corridor 'Lamberet Menahereya' to 'Awutobis Tera' Bus station.

For considering the effect of sub-arterial accesses road which intersects the road corridor, the traffic and geometric condition survey within five hundred meters both at upward and downward side of sub-arterial accesses roads were made at selected sites.

With the present study, the performance level of the road corridor sections were evaluated through average travel speed as compared to speed limit provided. And the performance level of intersections were analyzed using SIDRA intersection software by taking control delay and queue as performance indicator.

2.9.3 Approach for Traffic Congestion Cost Analysis

The Texas Transportation Institute (TTI) publishes an annual urban mobility report (UMR) covering some 100 cities and municipalities in the USA. The TTI study measures congestion cost relative to a free-flow base case. However, it is important to note that there is no implication that free flow or zero congestion in Mega city. Another approach is adopted by Lindsey, (2007). Lindsey, (2007) provides an example of a cost of congestion cost calculation using 'acceptable' levels of congestion as the comparison. Rather than taking free-flow conditions as the baseline, the study adopted a percentage of the speed limit as a threshold below which congestion could be considered unacceptable. Since this threshold varies across municipalities and road networks, the study undertook calculations with thresholds of 50%, 60% and 70% of the speed limit.

The study conducted by Madhu, et al., (2015) used the parameters such as vehicle operating cost, passenger travel time delay and goods travel time delay cost for analyzing the traffic congestion effect.

There are a number of costs relating to traffic congestion such as goods travel time delay cost, vehicle operating cost, environmental and other socio-economic costs. Due to time and financial constrain, the present study considers only the passenger travel time delay cost to analyze the economic cost of traffic congestion.

The passenger travel time delay cost for the present study was measured by taking the travel time of a vehicle which operating at posted speed as reference. Then travel time delay was obtained by taking the time difference of travel time at posted speed and normal operating speed.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

Addis Ababa, the capital city of the Federal Democratic Republic of Ethiopia, is located at the center of the country. Established in 1886, the city has experienced several planning changes that have influenced its physical and social growth. As a chartered city ('Rasgez Astedader'), Addis Ababa has the status of both a city and a state. It is where the African Union is based. Addis Ababa is therefore often referred to as the political capital of Africa, due to its historical, diplomatic and political significance for the continent (Alemayehu, 2015). The city is dwelled by people from different regions of Ethiopia – the country has as many as 80 nationalities speaking 80 languages and belonging to a wide variety of religious communities. It is home to different embassy. The Federation of African Societies of Chemistry (FASC) and Horn of Africa Press Institute (HAPI) are also headquartered in Addis Ababa.

The area of Addis Ababa is 530.14 square kilometers. Its current population is about 3,384,569 (2008 estimate). It also represents about 26 percent of the urban population of Ethiopia. Addis Ababa has an aggregate population density of 4,847.8 persons per square kilometer (Minalu , 2014).

Figure 3.1 Shows the Study Area Map and subsequent Figure 3.2 shows the Addis Ababa City urban population demography.

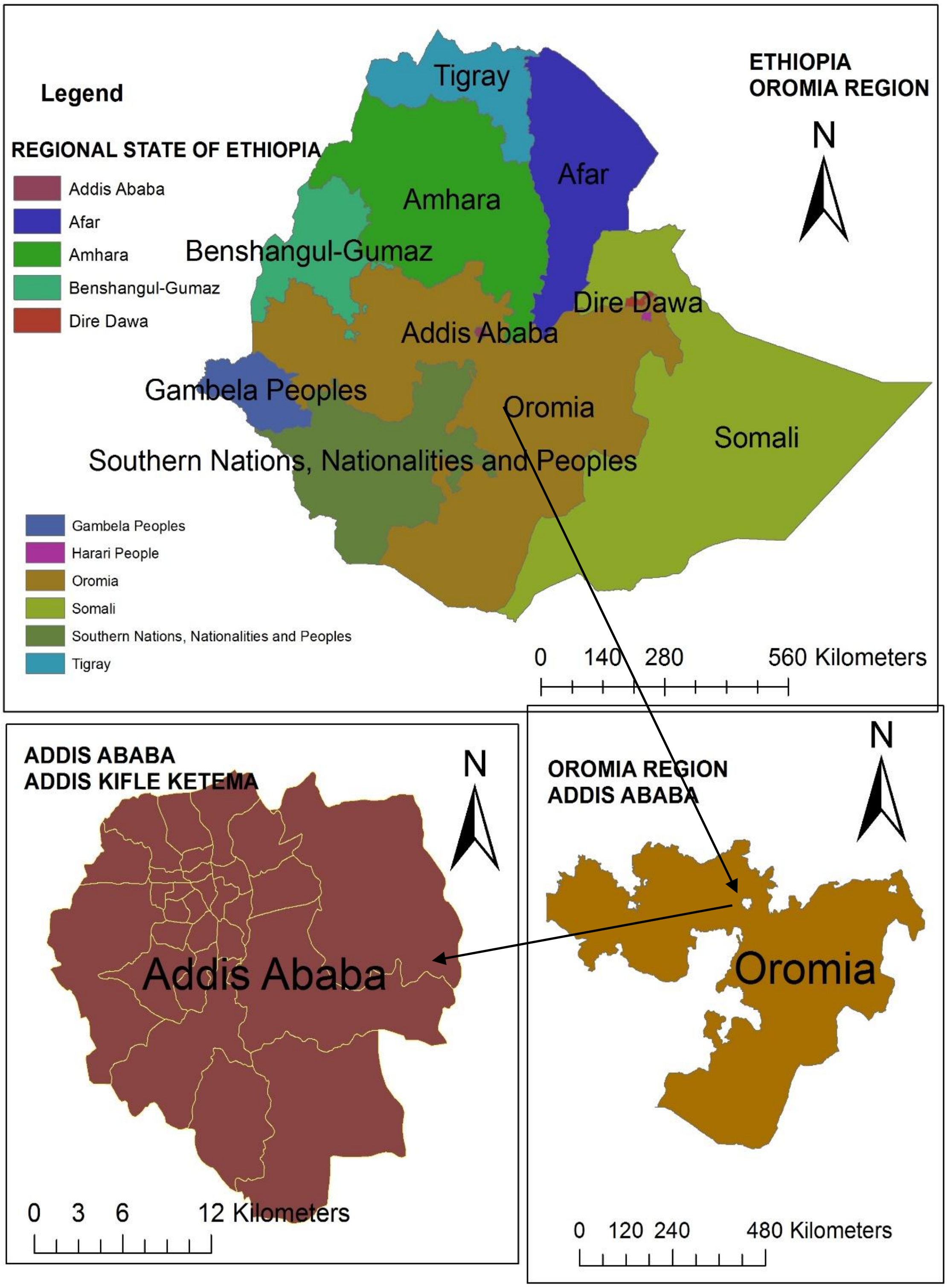


Figure 3-1: Study area map

Source: (Google earth, GIS and researcher, 2019)

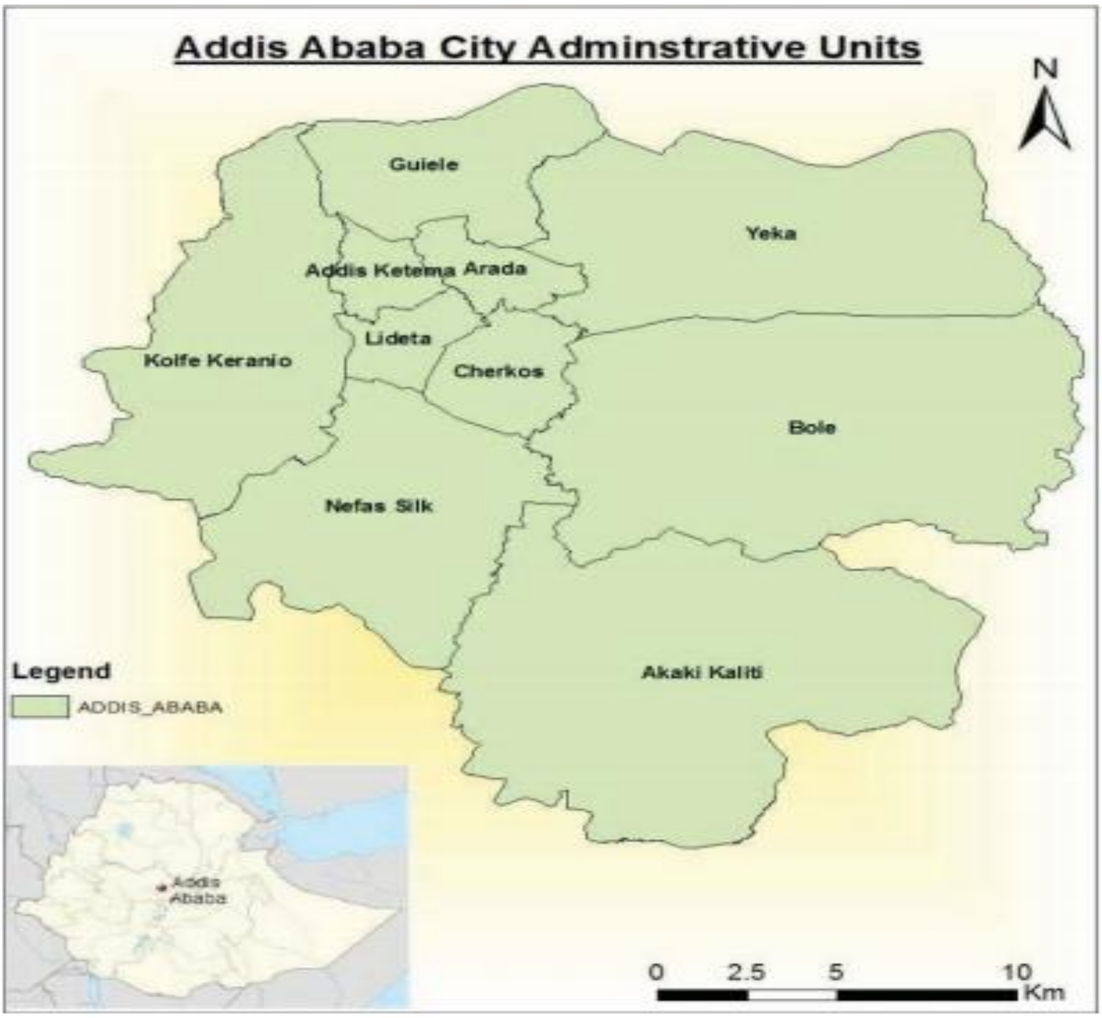


Figure 3-2: Addis Ababa City Administrative units

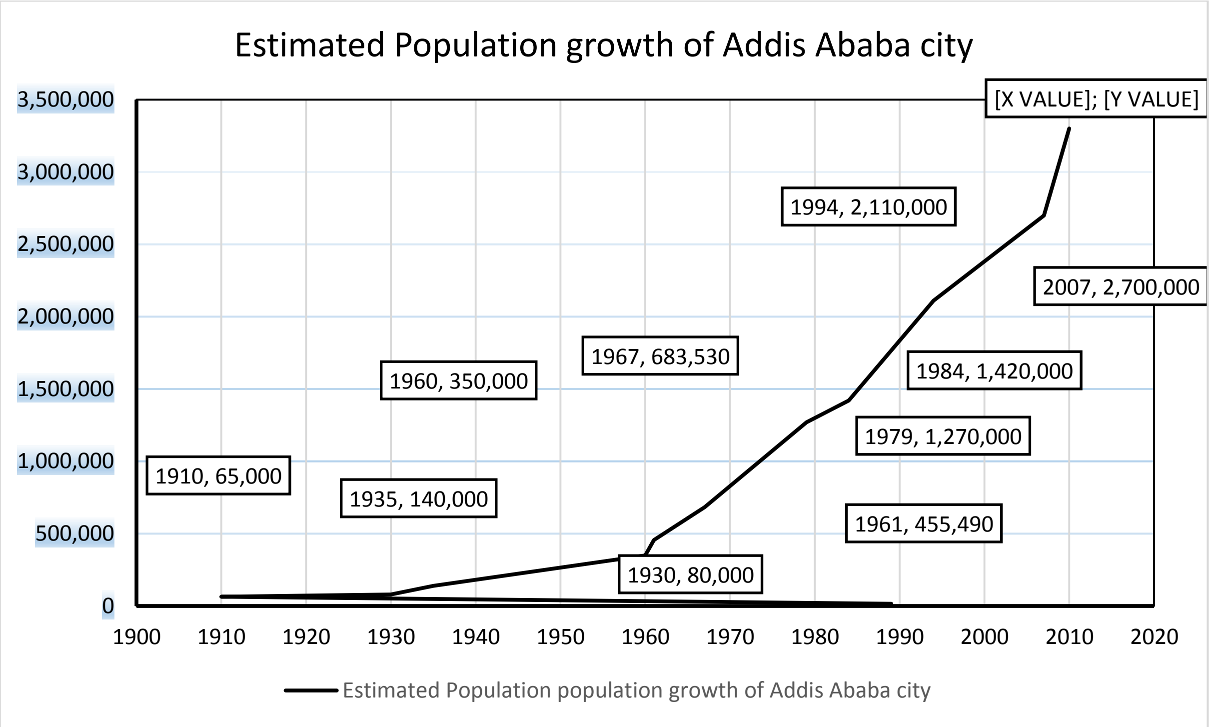
Source: (Addis Ababa city municipality, 2017)

3.1.1. Addis Ababa City Urban Population Demography

According to the (central statistical agency) CSA July 2015 estimate, Ethiopia's total population is about 90 million people. Of the total population 19.5% (17.5 million people) live in urban areas. This number is rising fast due to an annual urban population growth of 4.89%. Ethiopia's urban population is expected to triple by 2037 (World Bank, 2015). Addis Ababa hosts an estimated 3.238 million people, which is a 17% share of Ethiopia's total urban population. Currently, Addis Ababa is experiencing an annual growth rate of 3.8% and is estimated to reach 4.7 million inhabitants by 2030.

There is no reliable comprehensive statistical data to show Addis Ababa's population trends since its establishment. The first census data was obtained only in 1961.

However, several researchers have provided estimated population numbers for the City since 1889 (See Figure: 3.3).



Source: (Addis Ababa City Government, CSA (2012))

Figure 3-3: Population growth of Addis Ababa city

Table 3-0-1: Addis Ababa City population density at Sub-city level

No	Sub-city	Area (km^2)	Population	Density
1	Addis Ketema	7.41	271,644	36,659.1
2	Akaky Kaliti	118.08	195,273	1,653.7
3	Arada	9.91	225,999	23,000
4	Bole	122.08	328,900	2,694.1
5	Gullele	30.18	284,865	9,438.9
6	Kirkos	14.62	235,441	16,104
7	Kolfe Keranio	61.25	546,219	7,448.5
8	Lideta	9.18	214,769	23,000
9	Nifas Silk-Lafto	68.30	335,740	4,915.7
10	Yeka	85.46	337,575	3,950.1

Source: (Addis Ababa City Municipality, 2019),

3.1.2. Traffic and Transport Operations in Addis Ababa City

Road transport is the dominant mode of transports in Addis Ababa city. The most common urban road transport modes in the city are; public Buses, taxis that either scheduled or non-scheduled or based on demand, individuals motorized passengers (automobiles) and freight transport (trucks), and non-motorized “slow modes” of transport, principally walking and cycling, sometimes animals: donkey and horse riding also. Non-motorized travel, such as walking and cycling movements has a positive impact for reducing automobile trips in most urban areas. However due to poor infrastructures development for non-motorized mode of transport in the city, passengers forced to use cars even for short trip.

In the city, there are different vehicle types that gives public transport service, primarily they can be categorized in to government owned (‘Anbessa’ and ‘Sheger’ Buses) and private owned enterprise (Alliance Bus) including other union giving daily transport service. According to the information obtained from the Transport Bureau currently there are 1,500 city Buses (‘Higer’, ‘Qexqex’ and other) and around 10,000 miniBus.

Furthermore the city administration has also recently introduced 50 double-decker Buses, and 100 school Buses to ease the transport problem. Beside to road transport service, the Federal Government of Ethiopia had signed contractual agreement with China, regarding the Addis Ababa Light Rail Transport (AALRT) which was completed and started service in 2017. However, all these provisions cannot cope with the public’s demand for transportation, which costs residents in both time and money.

Studies indicate that companies engaged in mass transport in the capital are not operating at capacity due to high traffic congestion in the City. The finding of a study ‘Performance Analysis on Public Bus Transport of the City of Addis Ababa’ which was published by the Addis Ababa University in 2015, revealed that the operational and financial performance of the ‘Anbessa’ Bus is low and its service is below international standards, despite the fact that the company is subsidized by the government. According to the study, the efficiency of Bus services is mainly dependent on the existence of infrastructure such as roads, and capable transport systems, as well as labor, fuel, and spare part costs. Without resolving these issues, interventions like increasing the number of Buses will not address the transport problem. Rather, these schemes create higher congestion in the existing mixed traffic system. As per the city transport report, privately owned Alliance Bus service was terminated due to its ineffectiveness to give service with the existing city traffic condition and cannot give the required number of daily trip.

As per the Addis Ababa City Road Authority (AACRA) report (2015) states that, the city road network has increased by 320 Percent in the last 20 years from 1,500 kilometer to 6,300 kilometers. Currently, roads are mainly built to link the expanding peripheries of the city with the center to accommodate the needs of both mass transport and automobiles. In addition to road network expansion the agency take a lot of intensive action, decade ago the Addis Ababa City Administration imported and introduced 'Higer' Buses from China to tackle the city's transport problem. Locally assembled 'Bishoftu, and 'Sheger Buses; hundreds of imported Buses by Alliance Transport Services, and various metered taxies, all started operation in different periods. However none have been able to cope with the demand for transportation of the City.

The study conducted by (Dr. Dipti, 2015) revealed that aged fleet, and the chaotic movement of mini –Buses and taxis is making life and property in the city unsafe and hazardous. This is also making the emission level high thus making Addis Ababa a polluted City. As per Dr. Dipti, the cumulative figure of vehicles in 1998 in Addis Ababa was 79, 464 and was expected to increase to 2, 72, 741 by the year 2021 of which will be 1, 02, 263 car, 32,870 Bus and 7,961 two-wheelers approximately.

Table 3-0-2: Number of cars in Addis Ababa city

Vehicle Type	Number
Bus	1500
Taxi / MiniBus;	≤10,000
Private cars / plate number 2	≥200,000
Company cars / plate number 3	≥200,000
Gov't cars / plate number 4	≥30,000

Source: (AARTB, 2017)

In the City land use and transport developments are poorly coordinated. Housing and land-use decisions are taken on the basis of the location of available land, with almost no assessment of transport impacts while road transport investment decisions are made on the basis of criteria often unrelated to land-use patterns. For example, new condominium housing has been developed on the (current) outskirts of the metropolitan area, with no coordination with transport services, rendering them largely inaccessible not only to employment locations, but also to social services and interaction. As a result, the emerging transport and land-use disconnect is particularly burdensome to women, who need to devote more time each day using transport to meet their household obligations (World Bank report, 2016).

Experts argue that most of the initiatives could not improve the transport crisis because the government failed to see the big picture. The city is expanding with different land use patterns, the workforce is concentrated in some areas while residential and recreational areas are located far away.

Table 3-0-3: Summary of Trends in Addis Ababa

Parameter	Trend
Population growth rate	Increase annually by 3.8%
GDP	Average yearly GDP of 8.5%
Vehicle number	Increase by 33% over the last
Travel demand	Will increase by 106% in 2020
Number of daily trip	7.7 Million and more

Source: (AARTB, 2017)

3.2. Study Subject

According to Tadesse, (2011) study, the Addis Ababa city road network has four road corridors: the East-West Axis or corridor, the North-South Axis or corridor, the ring road and the CBD orbit. The road corridor for this study is situated on the East-West road corridor. The selected road corridor 'Awutobis Tera' Bus station to 'Lamberet Menahereya' is the corridor which connects the different part of the city with central Business district zone / down town such as piazza, 'Arat Kilo' and other with largest market center 'Merkato' which is not only center for Addis Ababa City but also for the regions. The selected road corridor starts from 'Awutobis Tera' Bus station and passes through piazza, 'Arat Kilo' and finally ends at 'Lamberet Menahereya' with total distance of 10.3 km. It is also a road corridor which passes through three sub-cities ('Addis Ketema', 'Arada' and Yeka'). Some of the intersections and streets that lies along the corridor are:‘Awutobis Tera’ uncontrolled intersection, ‘Ft. Habte Gyorgis’ Street, ‘Abune’ Petrus roundabout, ‘Kebena’ roundabout, ‘Shola’ signalized intesection, diaspora roundabout, ‘Fickre Mariam Techan’ street.

Along the selected corridor there are different government and non-governmental organization which attracts and generate daily trips. Recently highly populated ‘Hayat’, ‘Summit’, ‘Xafo’ and ‘Bole Arabsa’ residential zones connected with the down town through the study road corridor.

Figure 3-4:The study road corriodor from ‘Awtobis Tera’ Bus station to ‘Abune’ Petrus roundabout

Source: (Google earth, 2019)

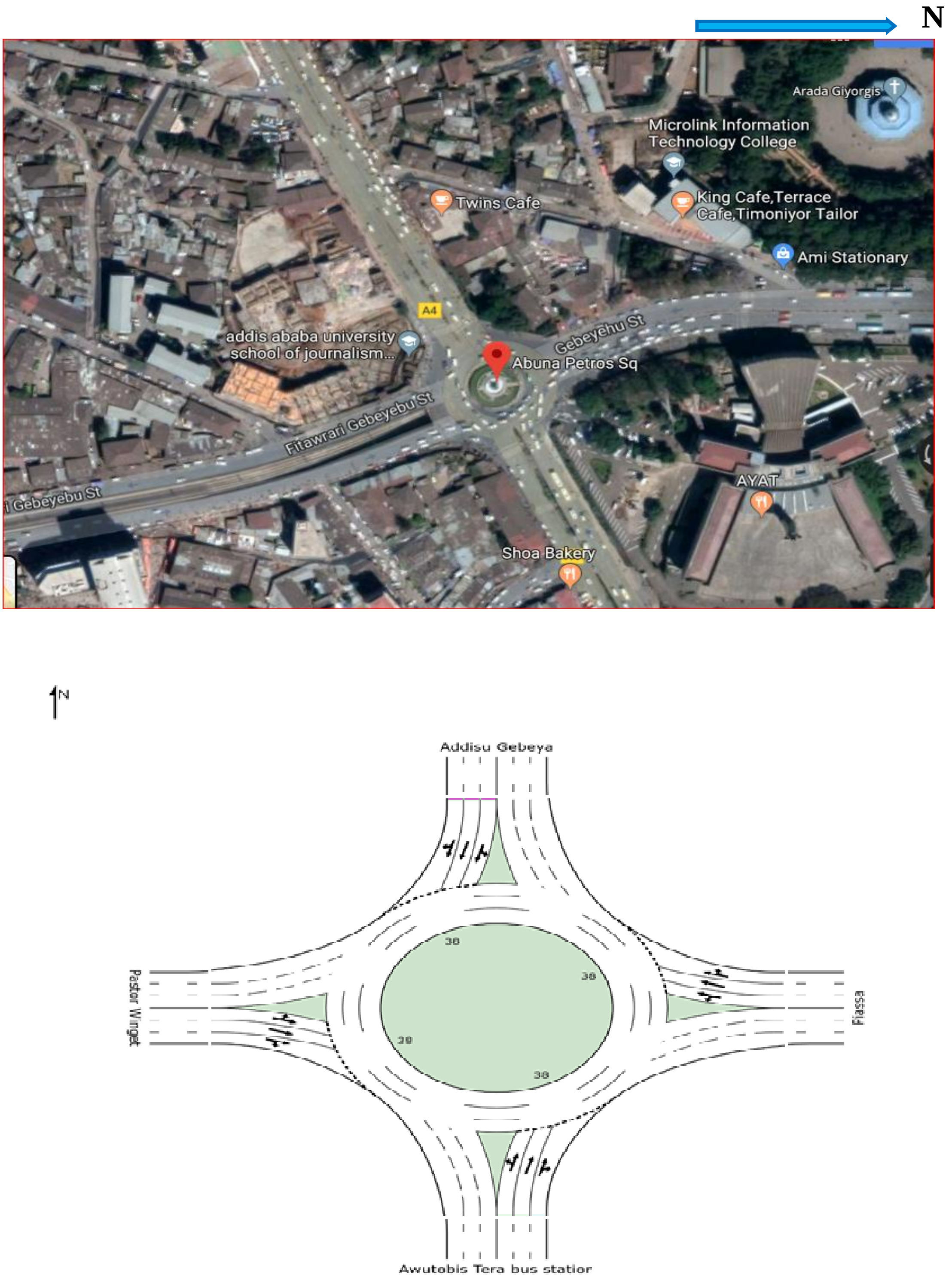


Figure 3-5: Piazza ‘Abune petrus’ round about along the road corridor section A.

Source: (Google earth and researcher, 2019)

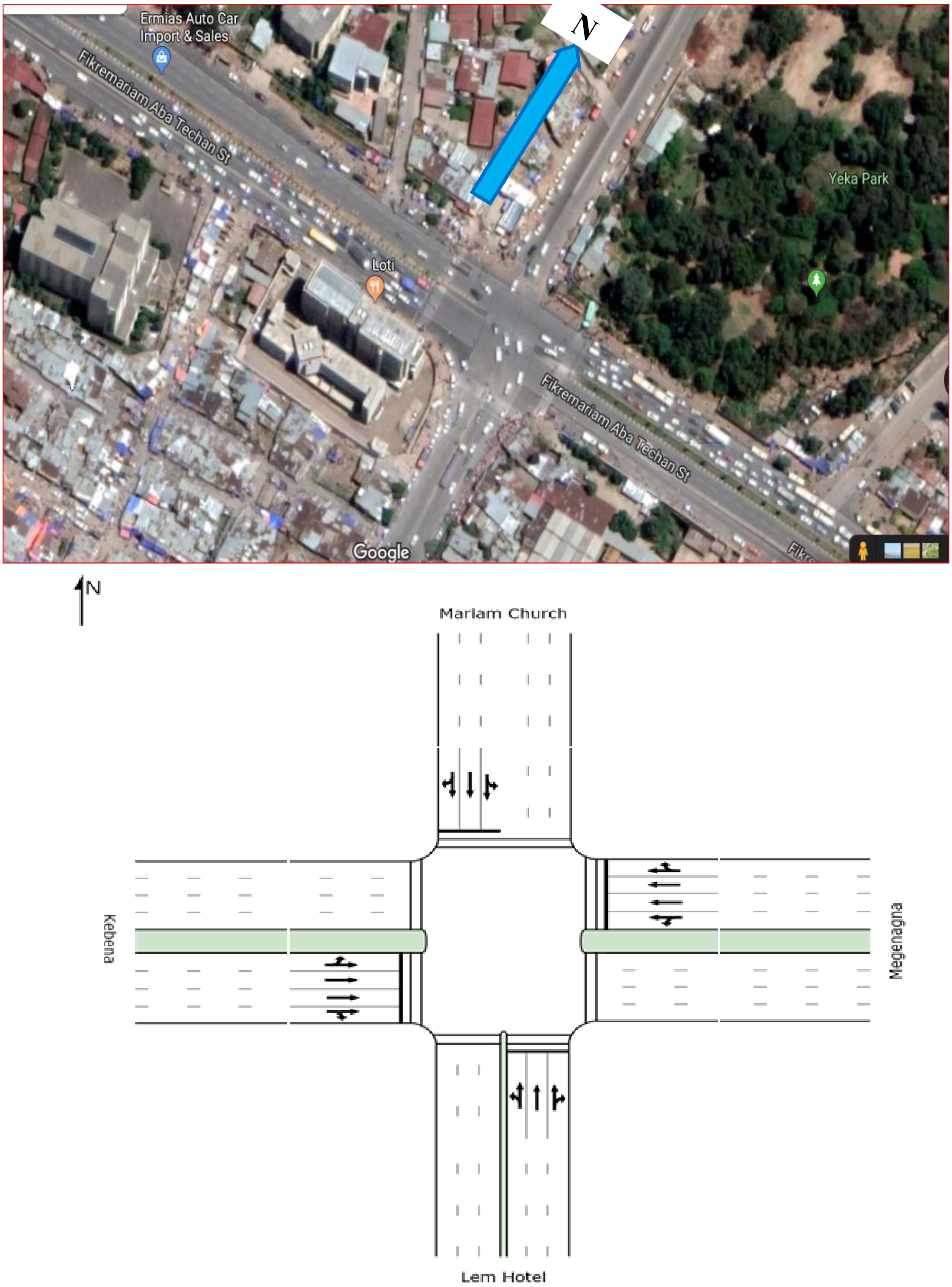


Figure 3-6:‘Shola’ signalized junction between embassy of Britain and ‘megenagna’

(Source: Google earth and researcher, 2019)

3.3. Study Methodology

As known traffic congestion problem in Addis Ababa is common problem on every part of the City specifically during peak and off-peak hours even if the intensity vary from place to place. So to address the problem, the preliminary stage involved on this study was to reconnaissance the study area in order to identify the most congested road corridor, to know the traffic composition and daily road users along the selected road corridor.

Reconnaissance of network traffic congestion in the study area requires information regarding the status of traffic on different routes in the city, and the condition of road surfaces along the routes of the study area. Further the behavior of pedestrians on different routes needs to be assessed to determine the compound effect of these parameters on traffic congestion. Therefore the investigation began with a collection of traffic data, assessment of road surface conditions and pedestrian behavior in different parts of the study area.

Rigorous field survey was done to assess the status of congestion, road surface conditions and the behavior of pedestrian movements on different routes in the City (‘Awutobis Tera’ Bus station to ‘Megenagna, ‘Legehar’ to ‘Kality’, ‘Torhayloch’ to ‘Ayer Tena’ and ‘Megenagna’ to ‘Lamberet Menahereya’). The moving observer technique (Taylor et al., 1999) was used to collect free flow time, total travel time etc., on the selected road corridors. In the moving observer technique, it was driven in real time to collect physical congestion parameters using stopwatches. The data was collected for different time intervals comprising off-peak period (10:00 am to 12:00 pm and 12:00 pm to 3:00 pm) and a peak period (0:07 am to 09:00 am and 4:00 pm to 6:00 pm).

Collection of data at different time periods enabled to understand the spatial-temporal complexities of congestion. Then the status of traffic congestion, i.e. the congestion index was computed using the formula (C-C0) / C0 (Taylor et al., 1992 and Nilanchal & Alok, 2015). However, it was not found feasible to quantify the condition of road surfaces and pedestrian behavior on different sections of the study area. Instead the assessment of these factors was made on the basis of empirical observations. On the basis of empirical observations, knowledge-based weightings i.e. pedestrian weight and road surface weight were assigned to each and every route on a scale of 0 to 1 representing road surface conditions and pedestrian movements. (See Table: 3.4) A weight close 1 represents a worse situation whereas weight approaching 0 represents the best. This is explained as follows:

CIV: Congestion Index Value of current route = (C-C0) / C0………………………...3.1

Where Co is free flow time and C is total travel time.

Congestion weight = (CIV)/ CIV_{max} ………………………………………….…...3.2

Traffic management parameter (TMP) is average of pedestrian and road surface weight

Table 3-0-4: Representation of congestion weights and values for Traffic Management Parameters (TMP) for different road corridor in the study area

Corridor Name	CIV	Congestion weight	Pedestrian weight	Road surface weight	TMP
'Legehar – Kality'	0.72	0.77	0.57	0.93	0.75
'Torhaloch – Ayertena	0.63	0.67	0.84	0.7	0.77
'Awutobis Tera' Bus station – Megenagna'	0.80	0.86	0.90	0.65	0.77
'Kera – Mexico'	0.84	0.90	0.6	1	0.8
Megenagna – Lamberet'	0.93	1	0.75	0.70	0.72

Based on congestion weight and traffic management parameter (TMP), usefulness of the road, the road corridor from 'Awutobis Tera' Bus station to 'Lamberet Menahereya' was selected as study road corridor for this study. (See Table 3-4) For traffic congestion causes analysis purpose, the road corridor was sectioned in to three homogeneous road corridor sections, they are road corridor section A, road corridor section B and road corridor section C.

The following road corridor representation were used throughout the thesis while conducting corridor analysis:

Road corridor section A = Road corridor from ‘Lamberet Menahereya’ to ‘Megenagna’ Road corridor section B = Road corridor from ‘Arat Kilo’ Ministry of Education building to Piazza ‘Ras Mekonene’ Bridge and

Road corridor section C = Road corridor from ‘Abune’ Petrus roundabout to ‘Awutobis Tera’ Bus station.

The road corridor sectioning work was made based on the Addis Ababa city administrative system, the geometric and traffic condition over the corridor. The names of the road corridor were adopted from local people who lives around the study area.

After the study road corridor was selected and sectioned, to achieve the objectives of this study, the researcher choose techniques and steps that have to be followed to address the traffic congestion problem along ‘Awutobis Tera’ Bus station to ‘Lamberet Menahereya’ road corridor.

Both primary and secondary data source were used to collect the required data.

Some of the secondary sources that were used as data source for this study include: different journal articles, demographic condition of the population of sub-cities through which the study corridor passes from Addis Ababa City Municipality, data on general transportation trend of the city from Addis Ababa City Road Authority, trusted website, books and different manuals.

In collecting primary data both quantitative and qualitative research design approach were applied. Some of the primary data that were collected through quantitative research approach includes: geometric condition of the road corridor (median and lane width, number of lane, island diameter, length of the road, radius of curve for roundabout; cycle and phase time for signalized intersection), manual traffic volume count, average travel time for both peak and free flow period, average travel time delay, average travel speed and vehicle occupancy.

Quantitative data and analysis were used to determine the level of service of road corridor sections and intersections and to measure the congestion levels quantitatively.

Beside to the above, through qualitative approach primary data were also collected. Qualitative approach was used in this study to rank the severity of traffic congestion causal factors by using phrases like: the listed causal factor is at very serious level, at high level, at medium level, at lower lever and none, on questionnaire survey to know the level of traffic congestion causal factors over the whole corridor and sub-section of the corridor and make interview of stakeholders. There are five types of road users that frequently utilize the prescribed road corridor as per the reconnaissance, these are: passenger who use public transport, private car and taxi (mini Bus) drivers, daily commuters, pedestrians and traffic polices.

3.3.1. Approach for analysis of Traffic Congestion Cause

The purpose of questionnaire was to understand the perception of road users regarding the current condition traffic congestion. In this respect pertinent data had to be acquired regarding the root causes of traffic congestion the selected road corridor. According to the definition by (Taddesse, 2011 and Lomax, 1997), congestion is a function of people's perception toward their time and their trip purpose, so involving users in traffic congestion causes and effect is very important to gather information and data on how the road users perceive the current traffic congestion and the extent of delay that is acceptable for them. In this study, linkert scale method was used in developing questionaire to rank the causal factor of traffic congestion by road users . The full questinaire is aattached on appendix I.

3.3.1.1.Sample Size determination methodology

The sample size of a statistical sample is the number of observations that constitute the population. The population is very large, making a census of all the values in the population impractical or impossible. Samples are collected and statistics are calculated from the samples so that one can make inferences or extrapolations from the sample to the population. To ensure that a sample is representative it is necessary that the persons included in it, are distributed geographically throughout the survey area in the same proportion as the distribution of the total population. The size of sample to be interviewed depends upon the total population of the area under study, the degree of accuracy required and the density of population.

In this study the required sample size was determined based on the formula developed by (Hamed, 2017):

$$n = Z^2 P(100 - P)/ME^2$$

For proportions, the sample size requirements vary based on the value of the proportion. It is recommended by most scholars to set P equal to 50% if the right value of population proportion is unsure. This will produce a conservative sample size estimate; that is, the sample size will produce at least the precision called for and may produce better precision.

The following values was used as an input for determining the sample size

- Margin of error (ME) = ± 5%.
- The confidence level = 95%.
- Alpha is equal to one minus the confidence level. ∝ = 1 - 0.95 = 0.05.
- Determine the critical standard score (z). The critical standard score is the value for which the cumulative probability or degree of freedom (df) 1 - ∝/2 = 1 - 0.05/2 = 0.975.

Using the normal calculator or Z score tables with: df (1 - ∝/2) = 0.975; Mean = 0; and Standard deviation = 1 (assume normal distribution). Z (standard score) = 1.96.

$$n = \frac{Z^2 P(100 - P)}{ME^2} = n = \frac{1.96^2 x 50(100 - 50)}{5^2} = 384$$

The total population size under the study area is the sum of the total population of the Addis ketema, Arada and Yeka Sub-city which is equal to 835218. As key findings of the federal democratic republic of Ethiopia on the 2018 urban employment unemployment survey indicates, from the total urban population of Addis Ababa city only 49.48 percent of the total population is economically active. So our target population size (N) was:

N = 0.4948 X 835218 = 413277

Table 3-0-5: Provides the minimum sample size for known size of target population

Population Size	Confidence level = 95%, Margin Error		
25000	378	1023	6939
50,000	381	1045	8057
100,000	383	1056	8762
250,000	384	1063	9249
500,000	384	1065	9423
1,000,000	384	1066	9513

Source: (Hamed, 2017)

Based on the Table 3.5: In comparison to the target population, the estimated sample size is enough and would provide the desired level of precision.

3.3.1.2.Sampling Techniques and Procedures

For drawing out the required sample size for the analyses of traffic congestion causes for the road corridor from ‘Awutobis Tera’ Bus station to ‘Lamberet Menahereya’ , the corridor was sectioned in to three zones or homogeneous road sections and questionnaire were distributed over the three zones as mentioned in section 3.3. The target population to conduct questionnaire survey for traffic congestion cause analysis were the active part of population from ‘Addis Ketema’, ‘Arada’ and ‘Yeka’ sub-cities.

The total sample size as determined in section 3.3.1.1 was about 384 road users. Out of this 32.5% of the required sample were drawn from road corridor section A, 27% from road corridor section B and the rest 40.5% were drawn from road corridor section C. The sampling procedures were certainly aimed at satisfying the main demographic variables and the targeted same frame consists of all relevant types and the right mix of individuals to ensure that it reflects and represents the whole road users along the corridor. In order to achieve this, the researcher applied quota non-probability sampling technique. Based on quota sampling 36.5 % was given for passengers who use Mini and Mid – Bus, 31% was given for passengers who use standard Bus (‘Anbesa’, Bishoftu’’ and other large Bus), 15.5% was given for passengers who use private vehicle, 10% was given for passengers who use lada taxi and the remaining 6% was given for traffic polices who control the traffic condition of the study road corridor.

The questionnaire was distributed for road users along study corridor which live at 500m radius around study area. The content of questionnaire was attached at the end of the page on Appendix I.

3.3.2. Approach for Level of Traffic Congestion Analysis

There are a number of approaches used by different researchers to determine the level of traffic congestion of road network, in this study the basic measure considered were travel time delay, average travel speed, queue length and Level of service (control delay).

Performance analysis urban road corridor is function traffic flow on the road segment and control points. At control point sub-arterial accesses roads intersects the major road corridor. For considering the effect of sub-arterial accesses road which intersects the road corridor, the traffic and geometric condition survey within five hundred meters both at upward and downward side of sub-arterial accesses roads were made at selected sites.

For this study the selected sites where the effect of sub-arterial accesses road was high were ‘Abune’ Petrus and ‘Shola’ signalized junction.

3.3.2.1.Approach for Level of Traffic Congestion Analysis over the road corridor Sections

3.3.2.1.1. Sample Size for Travel Time Data

The sample size was determined using the formula as acquired from Travel Time Data Collection Handbook. Accordingly the equation is:

$$n = \left(\frac{z * c.v}{e}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..3.4$$

Where n= sample size

Z = value correspond with confidence level, for the present the confidence level

C.V = Coefficient of variation

e = margin error

Using the Handbook the following value were taken, for congested traffic, 15 – 30 minutes time period, for 90% confidence of interval with 10% allowable error, the minimum required sample size was 18 plate.

In order to collect travel time data at the selected locations, the procedures described in Travel Time Data Collection Handbook (1998) were followed. Accordingly, Manual Methods of License plate matching technique was used. License plates were collected in the field using simple pen and paper or an audio tape recorder. In this study, both simple pen and paper as well as audio tape recorder technique were used. This method was chosen because; it used to collect travel time data for long distance or over the corridor at different locations. It was cheap and required less number of people, giving opportunity for observing different flow pattern.

Travel Time Delay

Travel time delay has been defined as the additional time experienced by a road user in comparison to the free flow travel or the acceptable travel time between mid-blocks or along road segment (Tadesse, 2011). In this regard, the following equation were utilized:

$D_s = [TT_{ac} - TT_{FFS}] *V$…………………………………………………….……….. 3.5

$D's = [TT_{ac} - TT_{FFS}] *V*V_{oc}$………………………………………………………. 3.6

Where, D_s = segment delay (vehicle-minutes) D's = segment delay (person-minutes)

TT_{ac} = actual travel time (minutes) TT_{FFS} = FFS travel time (minutes)

V_{oc} = Vehicle occupancy (Persons/vehicle) V= Vehicle Volume (vehicles)

In this study the annual travel delay was estimated based on the equation 3.7:

$$(Delay\ per\ traveler\ (annual\ hours) =$$

$$\left(\frac{\left(\frac{actual\ travel}{(min.)} - \frac{FFS\ trave\ time}{(min.)}\right) x \frac{vehicle\ volume}{(vehicles)}\ x \frac{Vehicle\ occupancy}{(\frac{persons}{vehicle})}\ x\ K}{Vehicle\ volume\ (vehicles) x Vehicle\ occupancy\ (\frac{persons}{vehicles})}\right) \dots\dots\dots\dots\dots 3.7$$

Where k = (250 weekdays per year x 1hour/60 minutes)

Source: (Okland, C.A & San, 2008)

30km/hr was taken as the free flow speed for estimating travel time delay estimation. Travel time delay was estimated by taking the difference of travel time at free flow speed and speed at congested condition.

3.3.2.1.2. Average Travel Speed for Urban Corridor Performance Analysis

In this study the level of traffic congestion of urban road corridor was estimated based on average travel speed of over selected road corridor. Since the primary aim of urban street is to give mobility for all vehicle type that use the facility, Highway Capacity Manual also recommends to use average travel speed to measure its performance. To measure the average travel speed of urban street spot speed data was collected at 15-minute interval for twelve hours of representative day starting from 6:00 am to 6:00 pm.

The minimum sample size required for conducting travel speed has determined as per the formula of travel time data collection handbook and Roes traffic engineering book third edition:

$$N = \left(\frac{Z\sigma}{d}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.8$$

Where

N = minimum sample size for travel speed study for each 15 minute consecutive interval.

Z = Number of standard deviation corresponding to the required confidence level, for the purpose of this study was Z= 1.96 which corresponds to 95% confidence level

σ = standard deviation drawn from raw speed data

d= acceptable error ($\pm$1.5 km/h)

After the minimum sample size was determined additional five observation was added to increase the precision of value average of travel speed.

3.3.2.1.3 Traffic volume analysis of homogeneous road corridor sections

Traffic volume count for the selected homogeneous road corridor section was conducted based on the time frame arranged as per the information obtained from study area traffic control division office and local road users. (See Table 3.10). The traffic volume count was made for 11 formal working hours starting from morning 7:00 am to night 6:00 pm at 15 minutes interval of time. The passenger car equivalence value used over the whole homogeneous road corridor sections to convert different vehicle category into a single passenger car was similar.

3.3.2.2.Approach for Level of Traffic Congestion Analysis over the selected intersections

Control Delay: Control delay is considered as the most important measure of effectiveness at signalized intersections because it is used in the estimation of level-of-service (LOS) and intersection design (Ibrahim, et al., 2016). For the junctions along the study corridor, the level of traffic congestion was determined by using control delay as congestion indicator. Since easy to calibrate to local traffic and geometric condition, the SIDRA intersection software was used for the analysis of LOS of intersection along the road corridor. In this regard LOS D or below indicates there is no traffic congestion since the HCM mostly recommends the design capacity of intersections along urban road corridor to be either LOS C or D. Further LOS E and above indicates the existence of traffic congestion. Table 3.6 Shows the LOS criteria for interrupted flows.

Table 3-0-6: Level of Service criteria for interrupted flow

Level of Service	Delay at signalized	Delay at un signalized
A	≤ 10 sec	≤ 10 sec
B	10-20 sec	10-15 sec
C	20-35 sec	15-25 sec
D	35-55 sec	25-35 sec
E	55-80 sec	35-50 sec
F	≥80 sec	≥50 sec

Source: (HCM 2010)

In order to use SIDRA for performance analysis of intersection, it is necessary to calibrate or adjust to local traffic and geometric condition in addition to consideration for environmental factors. Environmental factor can be used to make general conclusions about the model for an area (state, country etc.). There can be problems with using one specific value for a whole country; for example, regional difference in driver behavior and weather conditions. Hence, the calibration process would be interesting to do but requires more extensive research in to the subject for the specific case of Addis Ababa. In the case of this Study an environment factor of 1.1 and entry/circulating flow adjustment Medium were applied considering practices in different drivers' behavior in Addis Ababa. This is because, most of the drivers in Addis Ababa are aggressive and do not obey traffic rules and regulation, some of their behaviors are manifested through parking on turnings, neglect traffic light at red indication, etc.

Some of the input used for calibrating the software for local condition in this study are shown in table (See Table: 3.7)

Table 3-0-7: SIDRA Calibration Values used in this research

Parameters	Calibrating values
Critical gap	4.0
Follow up headway	2.0

Basic Saturation flow rate	1950 veh/hr
Lane utilization	100%

Source:(Rahmi, 1990)

Queue length is one the measure for the level of traffic congestion at an intersection and it is usually expressed by the total number of vehicles that form queue around an intersections or by measuring the distance covered by the vehicles that form the queue.

3.3.3. Approach to Estimate Traffic Congestion Cost

In general, the total congestion cost is made up of different costs, primarily travel time delay and vehicle operating (fuel) costs. Another very important part is the externality costs (that is costs imposed on others). Externality includes the effects on the individual groups, society or the environment resulting from the activities of some other groups of people. As mentioned above, in case of components of congestion cost, the present study estimated only direct travel time delay cost.

Specifically traffic congestion cost is composed of numerous costs such as: economic cost (delay, VOC), environmental costs, healthy costs, social costs and others. This study was aimed at estimating the economic cost of travel time while they were moving in congested environment and during idling at red traffic intersections. In travel time cost calculation, to convert delay into cost, the actual travel time was subtracted from free flow travel time and then multiplied by value of time (VOT).

As discussed under the methodology section of above, VOT is the monetary value that a person will be ready to pay for a unit travel time reduction or it is the estimates of hours lost due to congestion in monetary terms, usually determined from willingness-to-pay (WTP) surveys or reviewing literature. It certainly depends on many factors, i.e. socio-economic condition of the traveler, trip purpose, condition of travel or the mode types, time of travel and there are lots of estimates available in literature regarding VOT depending on the various factors that affect VOT.

According to Dipti (2015), the Value of Time (VOT) has been estimated for the population of Addis Ababa City for those above 5 years of age, based on the average earnings per person in Addis Ababa. The unit VOT for work is taken as the average earning per hour.

The unit VOT of a person in Addis Ababa for this study has been estimated based on the average monthly earnings per person in Addis Ababa. It was estimated at ETB 6, 8581/hour (USD 340/hour) considering 8 hours per day and 22working days per month which became ETB 39 (USD 2.06) as wage rate or VOT for business trip.

In this study the methodology followed for analyzing the economic cost of traffic congestion based on travel time delay was estimated by taking the travel time delay result obtained from the analysis result of traffic congestion level. Due to financial and time constraints the present study used the wage rate value estimated by (Dipti, 2015) which was about ETB 39 for converting travel time delay in to travel time delay cost.

Equation 3.10: was used for estimating the economic cost of traffic congestion along the selected road corridor.

Y = TTD * VOT……………………………………………………………… 3.10

Where Y = Annual Traffic congestion cost per traveler (ETB/per traveler)

TTD = Delay per traveler (Annual hours/per traveler)

VOT = Value of time (ETB/hr)

To estimate the economic impact of traffic congestion per traveler over the selected road corridor, collecting vehicle occupancy and travel time delay data is important. Vehicle occupancy is the number of persons per vehicles, is an extremely important parameter in traffic engineering and transportation planning. Usually it is used to convert person trip to vehicle under the four step travel demand forecasting process and to determine parking space requirement for public facility and spaces. Its use is becoming increasingly important in the congestion management process to compute person-delay; person-mile etc. Hence, vehicle occupancy is very important parameter for calculating congestion intensity parameters.

Travel time delay cost is the economic concept that the time spent on travelling has an opportunity cost as it could be used on alternate activity that could produce some significant utility.

The most widely used approach used to estimate the traffic congestion cost per traveler is to impose the Value of Time (VOT) on the calculated travel time delay (annual hours) due to congestion. By definition, VOT is the monetary value that a person will be ready to pay for a unit travel time reduction or it is the estimates of hours lost due to congestion in monetary terms, usually determined based on willingness-to-pay (WTP) surveys or reviewing literature. It certainly depends on many factors, i.e. socio-economic condition of the traveler, trip purpose, condition of travel or the mode types, time of travel and there are lots of estimates available in literature regarding VOT depending on the various factors that affect VOT.

The analysis work for achieving the third specific objective which was to make an analysis on the cost of traffic congestion in order to know the economic loss per individual traveler over selected road corridor was highly dependent on the analysis result of specific objective two the study. So using the travel time delay analysis result of the second specific objective, the third specific objective was analyzed by multiplying all annual travel time delays on each road corridor sections with value of time.

Equation 3.8 was used in this study for estimating the travel time delay cost per traveler.

$$(\text{Annualtravel time delay cost per traveler (ETB)} =$$

$$\left(\frac{\left(\frac{\text{actual travel}}{(\text{min.})} - \frac{\text{FFS trave time}}{(\text{min.})}\right) \text{x} \frac{\text{vehicle volume}}{(\text{vehicles})} \text{x} \frac{\text{Vehicle occupancy}}{(\frac{\text{persons}}{\text{vehicle}})} \text{x K}}{\text{Vehicle volume (vehicles)xVehicle occupancy } (\frac{\text{persons}}{\text{vehicles}})}\right) \text{x(VOT)} \ldots .3.9$$

K = $250 \text{ week} \frac{\text{days}}{\text{year}} \text{x} \frac{\text{hour}}{60\text{minutes}}$

Source: (Okland, C.A & San, 2008)

3.4. Data Management and Analysis

3.4.1. Traffic Congestion Cause Data Collection and Analysis

In this study, the Statistical Package Software for Social Science (SPSS) software was used in order to analyze the questionnaire data which was used to assess the causes and effects of road traffic congestion problem. The questionnaires were designed in such a way that the appropriate parameters are incorporated and were addressed to acquire the opinions from drivers, transporters and road user’s on cause and effect of traffic congestion.

In analyzing the raw qualitative data or road user's perception regarding the root cause of traffic congestion which were obtained from field questionnaire survey Linkert scale system (0 up to 5) were used. Each qualitative external variable or severity level of each causal factors were defined with code (0 up to 5) and then feed into SPSS software package for developing multi variable linear regression model. Linkert scale (0 up to 5) were used to code the severity level each causal factors that were obtained from road users. The code used to input the raw data to software were summarized. (See Table: 4.6)

Table 3-0-8: Code for qualitative data

Causal factors	Code
The cause is at extreme level	5
The cause is at highest level	4
The cause is at medium level	3
The cause is at lower level	2
The cause does not occur on the	1
The cause have never occurred	0

After all responses from the participants were feed into the SPSS software and the percentage of each response were calculated, ranked and also a multi variable linear ravel time delay model was developed which estimate the cause - effect relation of traffic congestion for the road corridor 'Awutobis Tera' Bus station to 'Lamberet Menahereya'. In developing the linear travel time model for cause analysis of traffic congestion travel time delay was taken as dependent external variable and other causal factors for traffic congestion for the road corridor 'Awutobis Tera' Bus station to 'Lamberet Menahereya' were considered as an independent external variables. After the developing the model, different statistical test such as T-test, F-test and P-tests was carried out using standard value.

Table 3-0-9:-Standard values for testing statistical results

Statistical test pa rameters	Standard Statistical tes ting value	Purpose
P- test	P ($P \leq 5\%$)	Significance of independent variables for the model

R^2	(> 0.75 strong, > 0.5 good and < 0.25 poor)	For Testing Goodness of Fit
F-test	F ($F \geq 0$)	The overall significance of the model
VIF	VIF ≤ 0.8	To check the correlation between independent variables

Source: (Zulfiqar Ali, 2016)

3.4.2. Collecting and Analyzing Traffic Flow Condition data

3.4.2.1.Collecting and Analyzing Traffic Flow data of the road corridor sections

The traffic flow parameters like travel time, speed and density vary from place to place and as well as with different time interval. So conducting traffic survey by taking the date which will be representative of the flow condition of the road network facility is important step in traffic flow analysis. In case of this study, the schedule set in (Table 3.10) was used for conducting traffic flow survey for the road corridor section A, B and C.

The time frame in (Table: 3.10) was chosen and used to conduct traffic flow condition survey based on the information obtained from local traffic police office, road users and field observation.

Date and Time		Target section
Thursday Sep18, 2019	6:00 am – 6:00 pm	Road corridor section A
Tuesday Sep 20, 2019	6:00 am – 6:00 pm	Road corridor section B
Tuesday Sep 24, 2019	6:00 am – 6:00 pm	Road corridor section C

Table 3-0-10:-Time frame for average travel time, speed and vehicle occupancy survey

To collect average travel time and speed data, first two group of observer's were stationed at two different locations along the corridor where the spot speed and travel time study was being conducted. To draw the required sample size from the total travel speed at 15 minutes interval, systematic random probability sampling was used, i.e. taking the travel speed and the time of every k^{th} vehicle systematically for estimating both average travel speed and time. Then, the first observing group that was stationed at the location where the vehicle enter the control section record the departure time and the other group stationed at the place where the vehicle leave the control section record the arrival time. After acquiring the required sample size for each consecutive 15 minutes interval, the travel speed and travel time pattern of the traffic condition for the whole selected corridor for formal working period was determined.

The average travel speed was used to estimate the LOS of urban road corridor by comparing the speed of vehicles that traveled along the selected road corridor with speed at free flow (FFS) period using (Table 3.11).

Table 3-0-11: LOS thresholds established for the automobile mode on urban corridor

Average Travel Speed as a Percentage of Base	LOS by Critical Volume-to-Capacity Ratio		
	≤ 1.0	LOS Definition	≥ 1.0
>85	A	0.0 to 0.6	F
>67-85	B	0.61 to 0.70	F
>50-67	C	0.71 to 0.8	F
>40-50	D	0.81 to 0.9	F
>30-40	E	0.91 to 1.0	F
≤ 30	F	Greater than 1.0	F

Source: (HCM 2010, Volume-III)

The vehicle occupancy data for this study was obtained through field observation or counting the number of individuals in the vehicle. The raw data gave the occupancy for each vehicle type over the period of the study. However, as a single average value is needed for the analysis, the weighted average vehicle occupancy was calculated using Equation 3.9 :(Taddesse , 2011)

Weighted Average Vehicle Occupancy:

$$AVO_W = \frac{V_t x VO_t}{\sum_{i=0}^{n} V_t} \quad \ldots \ldots \quad 3.9$$

Where AVO_W is Weighted Average Vehicle occupancy

V_t is traffic volume at time interval t

VO_t =the Vehicle occupancy at time interval t

Figure 3-7: Photo taken while conducting travel time and vehicle occupancy survey.

Source: (Researcher, 2019)

3.4.2.2. Collecting and Analyzing Traffic Volume Data of the Selected Intersections

The traffic count was conducted for four hours during morning time, between 7:00 am and 9:00 am and during afternoon time, between 4:00 pm and 6:00 pm. At 'Abune' Petrus roundabout, the survey was conducted during morning between (7:00 am – 9:00 am) and during afternoon between (4:00 pm – 6:00 pm) hours at 15 minutes interval. At 'Shola' the traffic count was conducted at signalized intersection, during morning hours between 7:30 am and 9:30 am and during afternoon time between 4:00 pm and 6:00 pm at 15 minutes interval.

Table 3.12 shows the time frame for traffic survey, Table 3.13 shows conversion factors for PCEs and Table 3.14 shows geometric data by roundabouts along study road corridor

Table 3-0-12: Time frame for traffic volume survey

Date and Time		Target section	Station for video camera
Thursday Sep 19, 2019	7:30 am – 9:30 am	'Shola' signa lized intersec tion	On the second floor Yeka s ub city traffic control divisi on Office building.
	4:00 pm – 6:00 pm		
Tuesday Sep	7:00 am – 9:00 am	'Abune'	On the second floor of

17, 2019	4:00 pm – 6:00 pm	Petrus roundabout	Addis Ababa University school of Journalism and Mass Communication building (Which is under construction).

The time frame in (Table: 3.12) was chosen and used to conduct traffic volume survey based on the information obtained from local traffic police office, road users and field observation.

There were different categories of vehicles like Bus, mini / midi Buses, pickups, Automobile, taxis, motor bicycles and so on that were using the road segment and junctions. To measure the performance of road network facility (intersections), the counted vehicle on the selected intersection must be converted into a single counting unit called Passenger Car Equivalents.

Regarding PCE values, there was no earlier study conducted for determining the PCE values for different road network infrastructures such as PCE for signalized/signalized intersection and PCE for road segment. For the present study the PCE combination used for the analyzing the counted traffic volume was similar for the whole homogeneous road corridor sections. The PCE values used was adopted from HCM 2010.

With this study the passenger car equivalence unit listed in (Table 3.13) were used.

Table 3-0-13: Conversion factors for passenger car equivalents (PCE).

Vehicle Type	Passenger Vehicles				Goods Vehicles			
	Car & Taxi	4-WD	M/Bus	Std. Bus	Small		Medium	Heavy
					Pickup	LCV	2/3-Axle	MAV > 3-Axle
PCU factors	1	1	1.5	3	1	1.5	3	3

Table 3-0-14:-Hourly traffic volume data of 'Abune' Petrus roundabout				
'Awutobis Tera' Bus station approach leg				
Duration	Left turn	Right turn	Through	Total
7:00 am-8:00 am	112	259	234	605
7:15 am-8:15 am	102	303	294	699
7:30 am-8:30 am	252	239	312	803
7:45 am-8:45 am	173	263	317	753
8:00 am-9:00 am	95	238	368	701
4:00 pm-5:00 pm	144	231	298	673
4:15 pm-5:15 pm	115	219	294	628
4:30 pm-5:30 pm	203	451	516	1170
4:45 pm-5:45 pm	214	256	330	800
5:00 pm-6:00 pm	136	305	370	811
PHV				5.7%
PHF				0.64
'Pastor Winget' approach leg				
Duration	Left turn	Right turn	Through	Total
7:00 am-8:00 am	89	144	345	578
7:15 am-8:15 am	114	283	355	752
7:30 am-8:30 am	103	301	241	645
7:45 am-8:45 am	164	293	318	775
8:00 am-9:00 am	144	311	250	705
4:00 pm-5:00 pm	128	253	204	585
4:15 pm-5:15 pm	122	291	241	654
4:30 pm-5:30 pm	174	225	145	544
4:45 pm-5:45 pm	119	233	164	516
5:00 pm-6:00 pm	216	122	114	452
PHV				3.2%
PHF				0.86

(Source: HCM 2010)

Table 3-0-15:-Geometric data of 'Abune' Petrus roundabouts

Junction name	Number of leg at	Name of leg on each approach	Number of lane	Median width (m)	Number of circulatory
'Abune' P etrus roun d about	4 – Leg	'Awutobis Tera'	3	11.5 (LRT)	3
		'Piazza leg'	3	0.7	
		'Adisu Gebeya'	3	0.5	
		'Paster Winget'	3	0.7	

Junction name	Island diameter (m)	Average lane width (m)	Circulatory road width (m)
'Abune' Petrus roundabout	38	3.8	3.5

'Adisu Gebeya' approach leg				
Duration	Left turn	Right turn	Through	Total
7:00 am-8:00 am	88	144	322	554
7:15 am-8:15 am	121	235	311	667
7:30 am-8:30 am	114	147	244	505
7:45 am-8:45 am	215	231	320	766
8:00 am-9:00 am	155	262	290	707
4:00 pm-5:00 pm	104	164	280	548
4:15 pm-5:15 pm	91	182	245	518
4:30 pm-5:30 pm	150	199	118	467
4:45 pm-5:45 pm	114	204	135	453
5:00 pm-6:00 pm	142	219	211	572
PHV				0.68
PHF				3%
'Piazza' approach leg				
Duration	Left turn	Right turn	Through	Total
7:00 am-8:00 am	138	76	155	369
7:15 am-8:15 am	204	248	181	633
7:30 am-8:30 am	321	215	156	692
7:45 am-8:45 am	245	113	220	578
8:00 am-9:00 am	224	215	125	564
4:00 pm-5:00 pm	262	201	277	740
4:15 pm-5:15 pm	221	247	340	808
4:30 pm-5:30 pm	172	105	226	503
4:45 pm-5:45 pm	131	233	178	542
5:00 pm-6:00 pm	188	227	243	658
PHV				1.8%
PHF				0.75

Source: (field survey, 2019)

Table 3-0-16: Geometric data of 'Shola' Signalized junction

Junction name	Approach	No. of entry	No. of exit lane	Average lane width	Median width
Shola signalized intersection	Kebena	4	4	3.5 m	4.5m
	Lem Hotel	3	3	3 m	0.9
	Megenagna	4	4	3.5 m	4.5
	Kidane	3	3	3 m	NA

Source: (Field survey, 2019)

Table 3-0-17:-Hourly traffic volume data of 'Shola' signalized intersection

'Megenagna' leg approach				
Duration	Left turn	Right turn	Through	Total
7:30 am - 8:30 am	234	60	1128	1422
7:45 am – 8:45 am	402	169	1529	2100
8:00 am – 9:00 am	384	120	1645	2149
8:15 am – 9:15 am	516	110	1656	2282
8:30 am - 9:30 am	335	77	929	1341
4:00 pm - 5:00 pm	590	207	1216	2013
4:15 pm – 5:15 pm	295	83	1024	1402
4:30 pm – 5:30 pm	296	108	1020	1424
4:45 pm – 5:45 pm	342	92	956	1390
5:00 pm - 6:00 pm	522	85	1561	2168
PHV				6.6%
PHF				0.63
'Lem Hotel' leg approach				
Duration	Left turn	Right turn	Through	Total
7:30 am - 8:30 am	427	110	50	587
7:45 am – 8:45 am	429	109	47	585
8:00 am – 9:00 am	403	122	42	567
8:15 am – 9:15 am	375	110	43	528
8:30 am - 9:30 am	364	110	32	506
4:00 pm - 5:00 pm	240	220	50	510
4:15 pm – 5:15 pm	198	343	65	606
4:30 pm – 5:30 pm	167	419	81	667
4:45 pm – 5:45 pm	196	467	82	745
5:00 pm - 6:00 pm	205	567	74	846
PHV				4.3%
PHF				0.70

'Kebena' leg approach				
Duration	Left turn	Right turn	Through	Total
7:30 am - 8:30 am	88	424	1075	1587
7:45 am – 8:45 am	116	412	1245	1773
8:00 am – 9:00 am	118	431	1183	1732
8:15 am – 9:15 am	75	440	1133	1648
8:30 am - 9:30 am	63	475	1492	2030
4:00 pm - 5:00 pm	91	401	1278	1770
4:15 pm – 5:15 pm	76	435	1261	1772
4:30 pm – 5:30 pm	27	466	1313	1806
4:45 pm – 5:45 pm	35	417	1450	1902
5:00 pm - 6:00 pm	61	345	1137	1543
PHV				7.2%
PHF				0.83
'Mariam Church' leg approach				
Duration	Left turn	Right turn	Through	Total
7:30 am - 8:30 am	168	75	274	517
7:45 am – 8:45 am	491	74	113	678
8:00 am – 9:00 am	504	103	106	713
8:15 am – 9:15 am	457	97	84	638
8:30 am - 9:30 am	143	113	264	520
4:00 pm - 5:00 pm	465	54	142	661
4:15 pm – 5:15 pm	197	93	260	550
4:30 pm – 5:30 pm	172	110	240	522
4:45 pm – 5:45 pm	170	128	231	529
5:00 pm - 6:00 pm	348	89	78	515
PHV				0.00
PHF				0.60

Source: (Field survey, 2019)

Figure 3-8:- Traffic volume survey at ‘shola’ signalized junction and diaspora roundabout

Source: (Researcher, 2019)

The overall research process is illustrated in Figure 3.9

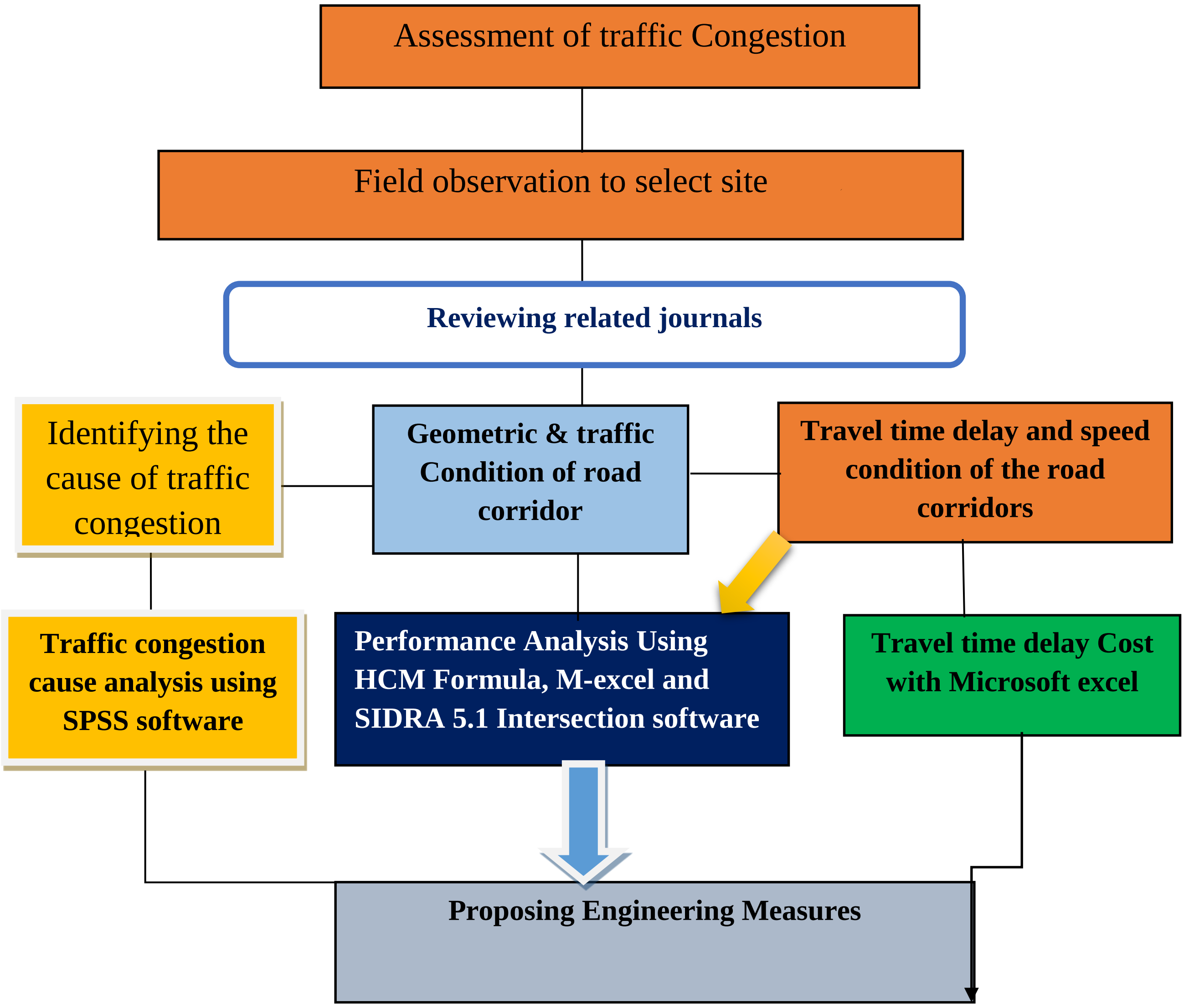


Figure 3-9: Schematic diagram showing the overall research approach

4. RESULTS AND DISCUSSIONS

4.1. Introduction

This section describes and presents key findings from the analysis of data which were gathered during the study, discussions were made on the different aspects of the findings. All results presented and discussed below were based on one directional corridor analysis from ‘Lamberet Menahereya’ to ‘Awutobis Tera’ Bus station.

For analyzing the traffic congestion causes, the data obtained from questionnaire survey were feed into SPSS statistical package software. Multi variable linear regression analysis model was developed to analyze the major causal factors of traffic congestion. Even if there are a number factors that affect the normal traffic flow of Addis Ababa City, the study identified only the significant factors through the developed linear regression model. The major significant causal factors identified were: imbalance between vehicle volume and road capacity, high number of pedestrian that cross the road and move along the side of the road, inflexible work schedule, inadequate mass transit service along the corridor and illegal on-street vehicle parking.

The analysis result for the level of traffic congestion presented in Section 4.3 and 4.4 were based on the following road corridor representation which were used throughout the study while conducting level of traffic congestion analysis on the road corridor sections:

Road corridor section A = Road corridor from ‘Lamberet Menahereya’ to ‘Megenagna’
Road corridor section B = Road corridor from ‘Arat Kilo’ Ministry of Education building to Piazza ‘Ras Mekonene’ Bridge and

Road corridor section C = Road corridor from ‘Abune’ Petrus roundabout to ‘Awutobis Tera’ Bus station.

The overall performance of urban road corridor sections were good as per the highway capacity manual. But this mean not that no improvement action are needed in the future. From the whole corridor, the corridor in section C which is the road corridor from ‘Abune’ Petrus roundabout to ‘Awutobis Tera’ Bus station was experiencing operational difficulty with level of service E. The traffic demand growth rate related with the economic growth of the City. So to accommodate the current as well as the future traffic demand it is mandatory to apply improvement action over the whole road corridor.

To consider the effect of sub-arterial accesses roads on the major study road corridor, the traffic and the geometric condition of the sub-arterial accesses road within five hundred meters stretch length was taken on both upward and downward side at ‘Abune’ petrous and ‘Shola’ signalized intersection approaches of the selected sub-arterial accesses road while conducting performance analysis of the whole corridor.

As it was observed during the survey time, the ‘Shola’ signal intersection does not have Traffic lights countdown timer (Countdown timers that let motorists know when a traffic light will go from green to yellow lead to safer responses from drivers) and the leads increase in vehicle operating cost through making engine-on for the whole red time.

Beside to the above, ‘Shola’ signal intersection is not safe for the blind peoples because of the signals do not have any sound alerts for the blind people to let them to cross the junction when the signal gives green for pedestrian crossing and the current traffic demand of ‘Shola’ signalized junction beyond the intersection capacity and this problem leads the drivers to respond in wrong way. There are many mechanisms to improve the operational efficiency of the intersections. Some of these methods are listed as follows.

1. Optimizing the signal timings for existing phase sequence (only for the signalized intersections)
2. Changing current phase sequences and optimizing the signal timings (only for the signalized intersections)

In comparison to ‘Shola’ signalized intersection, ‘Abune’ Petrus had better operational performance. But as per highway capacity manual, the current operational condition of ‘Abune’ Petrus roundabout was below the standard with level of service E. The introduction of LRT on the ‘Awutobis Tera’ approach leg had brought an effect the overall operational performance of the roundabout. As it was observed during the survey time and information obtained from local traffic polices who control the traffic, there was frequent collision between vehicles to take priority specifically during peak periods at 'Abune' Petrus roundabout. The paint marking zebra along all approach legs for pedestrian crossing was not visible for drivers and this leads to collision between pedestrian and vehicles on this roundabout.

At the end by using the annual travel time delay which was obtained from the analysis result of the second specific objective which is level of traffic congestion was used to estimate the economic cost of traffic congestion cost over the selected road corridor sections by applying time value of money.

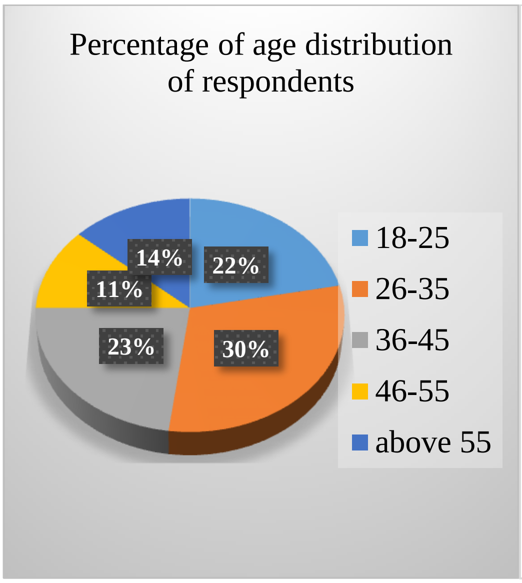
4.2.Traffic Congestion Cause Analysis Result

Making an analysis on the causes of traffic congestion by developing multi variable multi variable linear regression model in order to identify the major causal factors for the traffic congestion over selected road corridor was the first specific objective of the study. So based on this specific objective the results and discussions on the various result were presented. (See Section 4.2.1 up to section 4.2.4)

4.2.1. Descriptive Statistics Analysis Result

4.2.1.1.Road Users Socio-Economic Cultural Characteristics

Basic characteristics such as road user's status, age, gender, and level of education were considered. And the demographic condition of road users participated in the study was summarized. (See Figure: 4.1a) The age distribution of the road users revealed that 22% are between 18 – 25 years, 30% are between ages 26 – 35, 23% are between 36-45 years, 11% are between 46-55 years while above 55 years accounted for 14%. This structure revealed a uniform distribution across the age structure. Further revealed the gender of the road users, 33.3% are male while 66.7% are female. (See Figure 4.1b)



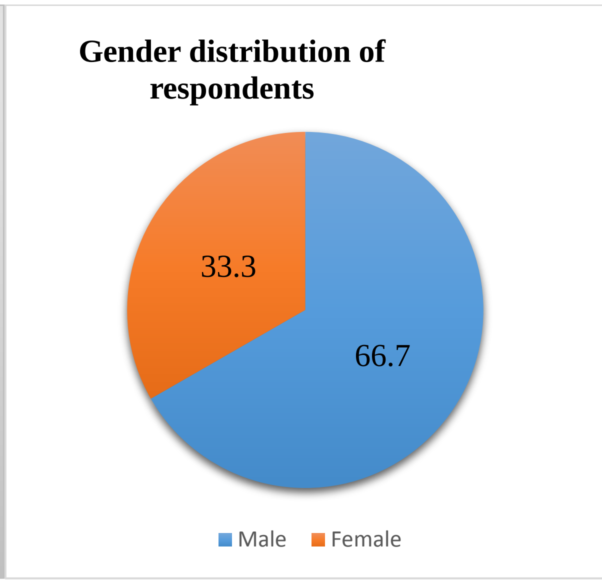


Figure 4-1a Figure 4-1b

Figure 4-1:-Demographic condition of research participants

Road user's level of education were also presented. (See Table: 4.1)

From thus, 13.5% had primary level of education, those with secondary education accounted for 24.0% and 28.1% had diploma while 20.8 % had first degree and the rest 13.5% had second degree and above. In the aggregate, over 85% road users had educational background from secondary and up to second degree education level, hence, the road users are literate.

Table: 4.1 Educational status of road users

Education Level	Percentage of
Primary School (1-8)	13.50%
Secondary School(9-12)	24.00%
Diploma	28.10%
First Degree	20.50%
Second degree and above	13.50%

Figure 4.2 showed the percentage of road users from different employment group who were participated in conducting questionnaire survey. In drawing the required sample size for questionnaire survey for traffic congestion cause analysis, non-probability sampling technique was followed and based on this, the quota value which was showed in (Figure 4.2) was given for each different employment group.

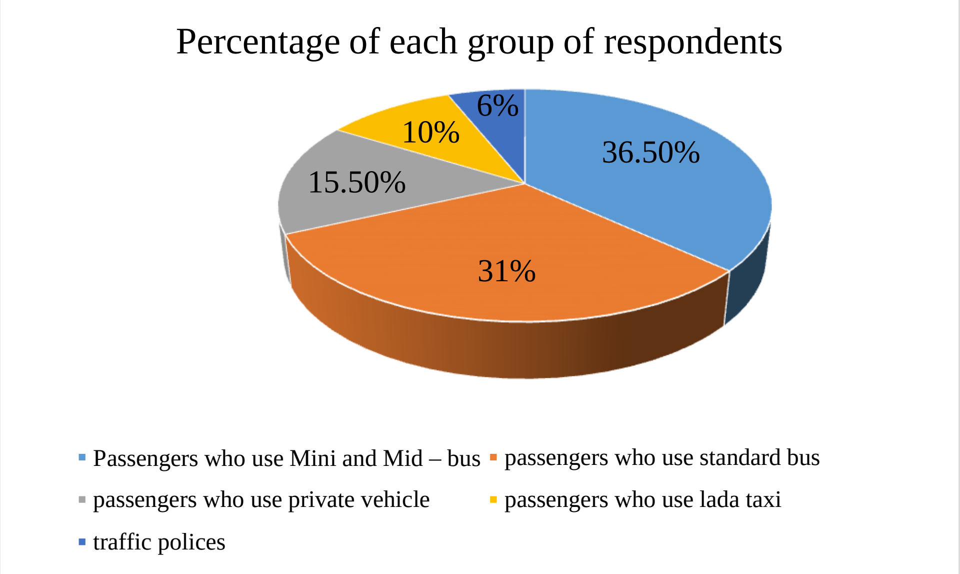


Figure 4-2:-Percentage share of each group of respondents

4.2.2. Multi variable linear regression model for Traffic Congestion Cause Analysis

In traffic congestion causal factors analysis both recurrent and non-recurrent congestion types was taken into consideration.

There are three approaches for making linear regression of statistical data through SPSS software (enter, stepwise, remove, forward and backward approaches). In developing the multi variable linear regression model in this study all three approaches were attempted and finally the forward approach was applied since it incorporates all the external variable that were most significant for the fitting the model with actual condition. Based on this the model was developed by considering imbalance between vehicle volume and road capacity (X_1), high number of pedestrian that cross the road and move along the side of the road (X_3), inflexible work schedule (X_4), inadequate mass transit service along the corridor (X_7) and illegal on-street vehicle parking (X_{10}) as independent variables and travel time delay as a dependent external variable(Y). The p-value for all selected external independent variable X_1, X_3, X_4, X_7 and X_{10} were found to be less than 5% (See Table 4-4) and this shows the selected external independent variables were statistically significant to describe the model.

The results of the statistical analysis using SPSS are summarized and presented below.

. (See Table 4-1 up to 4-4)

Table 4-1:-Variables entered and removed

Variables entered	Variables removed	Method
X_1, X_3, X_4, X_7 and X_{10}	Remaining variables	Linear regression method

Table 4-2:-Analysis Result Summary

R	R^2	Adjusted R^2	Std. Error
0.935	0.875	0.873	8.25545

Table 4-3:-ANOVA Table

Source	Sum of squares	d.f	Mean square	F	Sign
Regression	180486.225	5	36097.245		
Residual	25761.608	378	68.152	529.655	0.000
Total	206247.833	383			

Table 4-4:-Coefficients of Multi Variable Linear Regression Model

Intercept and Variables	Coefficients	Standard error	T-value	Significance
Intercept	-10.02	1.15	-8.70	0.00
X_1	1.284	0.354	12.34	0.00
X_3	4.02	0.186	21.55	0.00
X_4	0.325	0.032	10.13	0.00
X_7	1.285	0.268	4.78	0.00
X_{10}	4.371	0.269	4.77	0.00
F-value		529.655		
Sample size		384		

Based on the multi variable linear regression analysis result (p-value), the identified significant independent variable which were expected to be the major causal factors for traffic congestion were: imbalance between vehicle volume and road capacity, high number of pedestrian that cross the road and move along the side of the road, inflexible work schedule, inadequate mass transit service along the corridor and illegal on-street vehicle parking. Beside to the above causal factors result of multi variable linear regression model result, on-street trading along the study road corridor section C that is from ‘Awutobis Tera’ Bus station to ‘Abune’ Petrus roundabout were observe by researcher during field survey . (See Figure: 4-3)

Figure 4-3: On – street trading along the study road corridor section C from ‘Awutobis Tera’ Bus station to ‘Abune’ Petrus round about.

(Source: Field survey, 2019)

The value of R^2 was used for measuring the fitness of the model with actual condition. The value of R^2 in this study was found to be 87.5%, this shows the model was a good model to estimate the cause-effect relation of traffic congestion on the road corridor.

The model developed for traffic congestion causes analysis based on road user’s (respondents) perception was presented below. (See Equation 4.1)

$$Y = -10.02 + 1.284X_1 + 4.02X_3 + 0.325X_4 + 1.285X_7 + 4.37X_{10} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 4.1$$

Where Y = travel time delay in minute.

X_1 = imbalance between vehicle volume and road capacity

X_3 = High number of pedestrian that cross the road and move along the side of the road

X_4 = Inflexible work schedule of people

X_7 = inadequate mass transit service along the corridor

X_{10} = Illegal on-street vehicle parking

The minimum value of F (F-test) was found to be zero. To check the overall significance of the model, based on the analysis of the results, the value of F- for this study was calculated at 529.665. Therefore, the overall significance of the model is good.

4.2.2.1 Model Validation result

In order to test the fitness of the developed travel time delay model with actual condition, model validation is very important. Based on this after the linear model is developed, the model validation was made by taking sample trial from the total drawn samples as shown in Table:-4-5 The overall summation of variation (error) is 0.65 which is less than 1, so the model is successfully verified.

Table 4-5: Model validation result

Sample	Actual value	Predicted value	Variation
1	28	27.45	0.55
2	37	36.69	0.31
3	10	6.44	3.56
4	45	45.64	-0.64
5	18.00	15.90	2.1
6	14	14.98	-0.98
7	81.00	82.75	-1.75
8	3	3.5	-0.5
9	37	37.46	-0.46
10	37.00	38.54	-1.54
$\sum_{i}^{n}(Variation)_i$	Variation = Actual – Predicted		0.65

From questionnaire survey, the perception of road users on the root causal factors for the traffic congestion over the study road corridor was obtained.

The descriptive analysis result summarization presented below were made for significant independent external variables of traffic congestion which were obtained from multi variable linear regression analysis result for the purpose of describing the traffic congestion causal factors through statistical approach. (See Section: 4.2.2 above)

The raw data which were obtained from road users regarding the traffic congestion causes for significant independent variable analyzed through descriptive statistic approach and the result is summarized below. (See Figure: 4.4 up to 4.8).

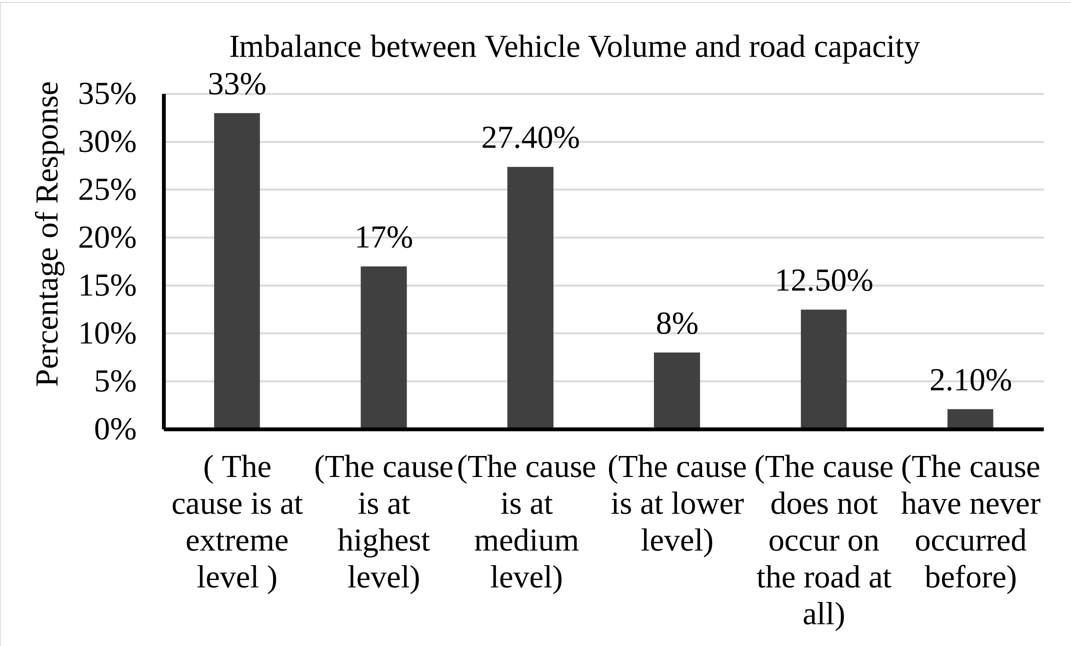


Figure 4-4: Percentage of road user's response for the imbalance between vehicle volume and road capacity

As percentage of response from respondents indicated the 'The cause is at extreme level' or code (5) has got 33% for the imbalance between vehicle volume and road capacity which mean is that 'The cause is extreme level' through descriptive statistical approach. (See Figure: 4-4)

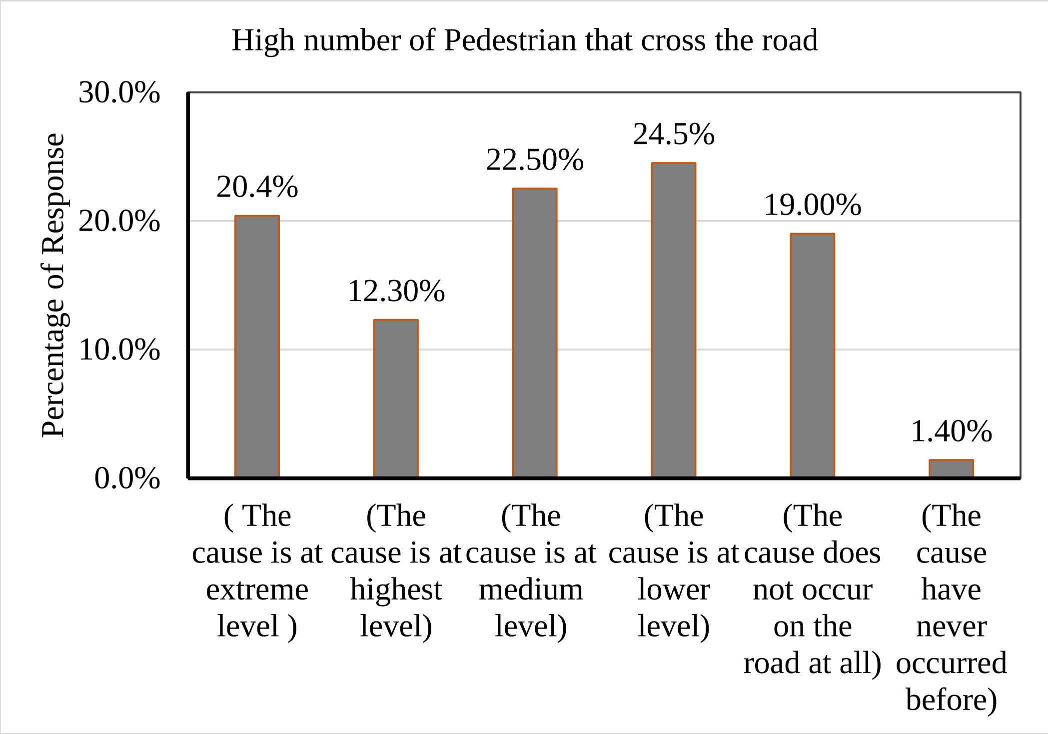


Figure 4-5: Percentage of road user's response for high number of pedestrian that cross the road

For the case of high number of pedestrian that cross the road, the maximum percentage given from road users was for code 2 or ' The cause is at lower level'. (See Figure: 4-5)

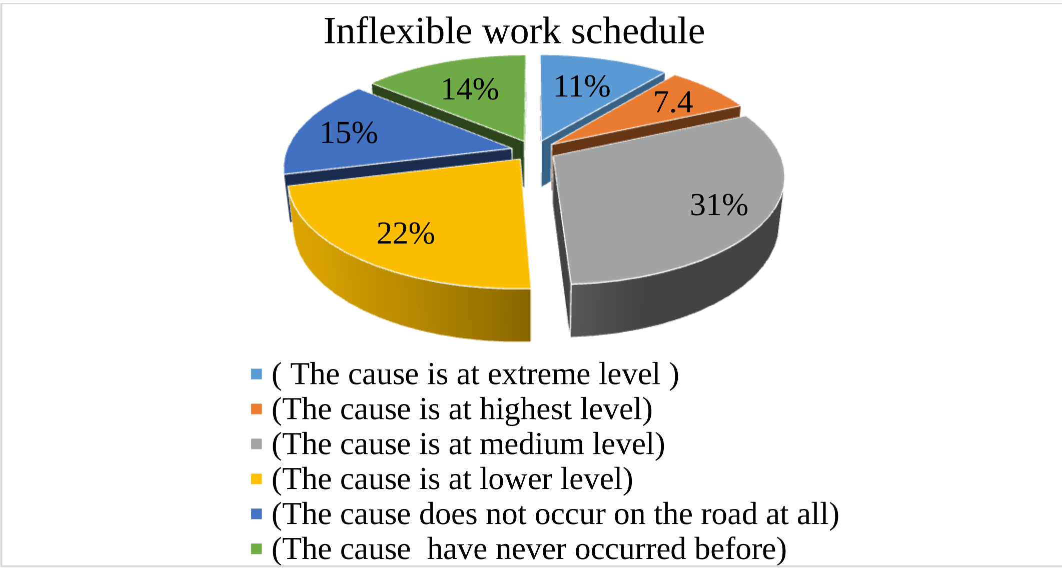


Figure 4-6: Percentage of road user's response for inflexible work schedule

For the case of inflexible work schedule, the maximum percentage response given from road users was for code 3 or ‘The cause is at medium level’.

(See Figure: 4-6)

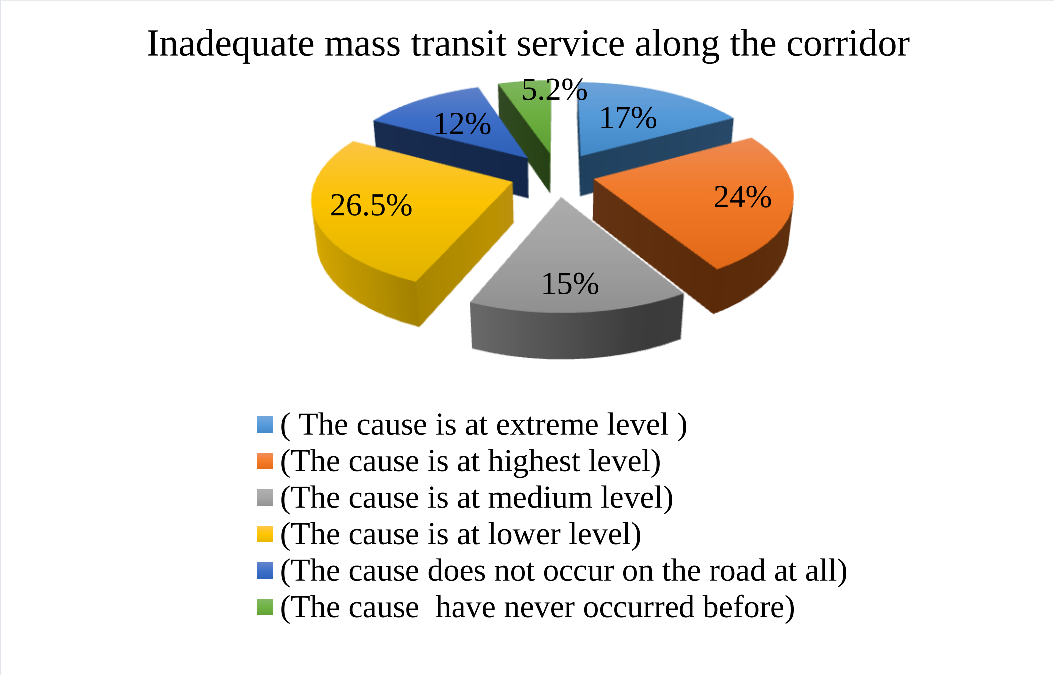


Figure 4-7: Percentage of road user’s response for inadequate mass transit service along the corridor

For the case of inadequate mass transit service along the corridor, the maximum percentage response given from road users was for code 4 or ‘The cause is at the highest level’. (See Figure: 4-7)

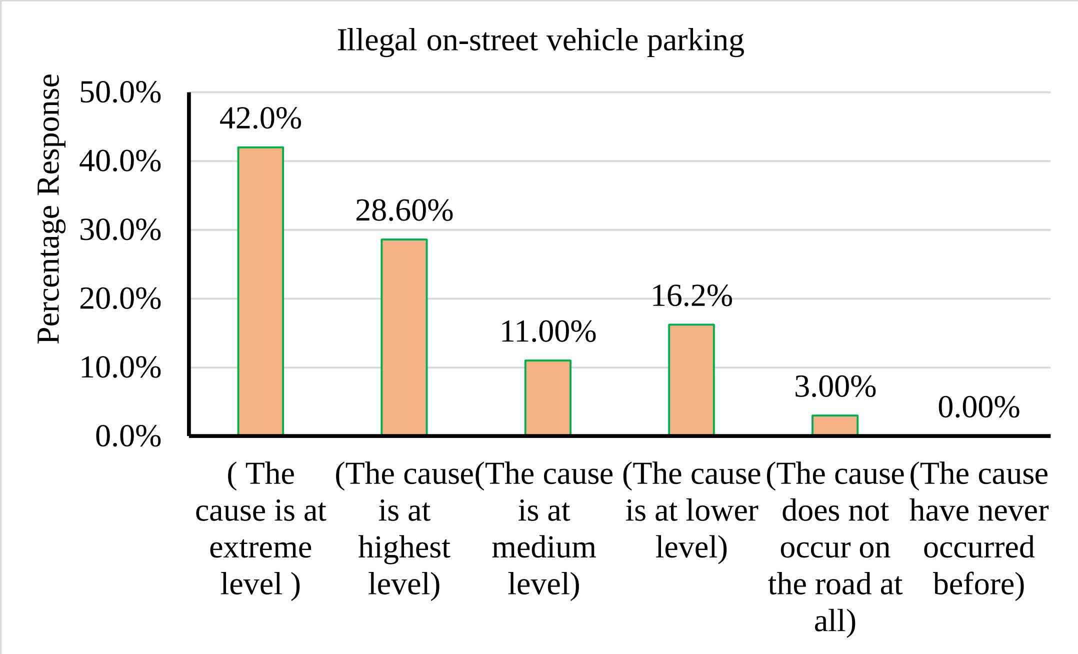


Figure 4-8: Percentage of road user's response for illegal on-street vehicle parking

For the case of illegal on-street vehicle parking along the corridor, the maximum percentage response given from road users was for code 5 or 'the cause is at the extreme level'. (See Figure: 4-8)

4.2.3 Discussion on Traffic Congestion Cause Analysis Result

The present study, tried to identify the main causal factors for traffic congestion cause along east _ west line of Addis Ababa City from 'Awutobis Tera' Bus station ('Merkato' area) to 'Lamberet Menareheya'. Based on this imbalance between vehicle volume and road capacity, high number of pedestrians, inflexible work schedule, inadequate mass transit service and illegal on-street vehicle parking were identified as the main reasons for the traffic congestion cause over the study road corridor. The result obtained with this study was related with previous study result of (Tadele, 2017).

The thesis conducted by Tadele, (2017) at Addis Ababa University tried to analyze traffic congestion causes along north to south west road corridor from Meskel Square to Kality interchange with about 12 km stretch in Addis Ababa City. To analyze the traffic congestion cause, Tadele used the descriptive statistical approach. On his work, the major traffic congestion causal factors of traffic congestion over the corridor were identified based on descriptive statistic approach or using percentile frequency response he got from road users. Based on this he tried to identify; shortage of mass transport, poor traffic management, imbalance of vehicle volume and road capacity, especially at intersections, parking of passenger cars for loading and unloading of passengers near intersection entry and exit, on street parking on walkways and road ways which forces passengers to use roadways and conflict with vehicles, inflexible work zone and to some extent, traffic accidents as main reasons for the traffic congestion cause along the selected road corridor.

Even if the approach followed with the present and previous study is different the result obtained were almost similar. The present study was conducted following inferential statistics approach to make conclusion on the major causal factors of traffic congestion over the study road corridor by considering collinearity effect between independent external variables.

The descriptive approach followed by previous scholar may not adequately describe the causal factors for traffic congestion since their might be some correlation between independent variables and also one independent variable may mask the effect other independent variable on traffic congestion effect. On the other hand, the drawn sample size to be representative of the target population was one hundred sample with previous study.

With this study, the sample drawn to be representative of the target population was three hundreds eighty four samples which describe the true mean of the population than Tadele. Since as sample size increases, the study finding more close to the actual population mean. Even if the study result obtained from previous scholar and present study were similar, the present study result had more descriptive power than previous scholar result.

Beside to this, as per the study conducted by Aworemi, et.al, (2009), the common feature in the causes of traffic congestion in most developing countries emanate from the lack of proper planning, management and proper use of limited road network. Also the study conducted by (Haregewoin, 2010) for the road section 'Total – Ayer tena' has found imbalance between the traffic volume and road capacity, inflexible work schedules, inadequate public transport, and poor urban land-use plan as the main reasons for traffic congestion causes. Beside to the above the causal factors for the traffic congestion of Addis Ababa city, the causal factors usually raised by a number of road users include:-interruption of traffic flow by pedestrians crossing a road, higher fleet population than available infrastructure, illegal on street parking, insufficient parking area and so on. The result obtained from statistical analysis also related with what actually observed and with previous scholar result, so this make sense (good model to predict the actual condition).

4.3 Analysis Result for Level Traffic Congestion over the Road Corridor

Investigating the level of traffic congestion in order to quantify the performance level of selected road corridor was the second specific objective of the study. Based on this specific objective results were summarized in sections 4.31. Up to 4.3.4

Directional traffic volume analysis was done for eleven hours of a day starting at 7:00 am and ending 6:00 pm for the traffic flow analysis and for four hours for selected intersection between 7:00 am and 9:00 am in the morning and between4:00 pm and 6:00 pm in the afternoon. The directional traffic volume was analyzed on the following three road corridors sections and two intersections. The three study road corridors are: road corridor section A, road corridor section B and road corridor section C. And the two intersections are: ‘Abune’ Petrus roundabout and ‘Shola’ signalized intersection.

4.3.1 Travel Time Delay Analysis Result of the Road Corridor Sections

Travel time delay is the difference between travel time on free flow condition (acceptable travel time) and actual travel time. Based on travel time delay analysis result, the annual hours of delay per a single traveler for the Road corridor section A, Road corridor section B and Road corridor section C was estimated to be 761.67, 788.8 and 1117.5 person-hours/year for each respective corridor section. And the total annual travel time delay per passenger for the three road corridor sections including the annual control delay effect of the two intersection (‘Abune’ Petrus roundabout and ‘Shola’ signalized intersection) was estimated to be 2667.8 person-hours/year per single traveler. According to travel time delay analysis result, there was a maximum delay on the road corridor section C and minimum delay on the road corridor section A. Some of the reasons for this result were presence a number of pedestrian that move along the road and cross the road by interrupting the traffic, construction of LRT (light rail transit) which has significantly reduced the design capacity of the road corridor, presence of on street traders on the corridor section C. The annual hours of travel time delay per traveler for the three road corridor section is shown below. (See Figure 4-9 up to 4-11). The detail analysis result of traffic congestion level was attached in Appendix: IV

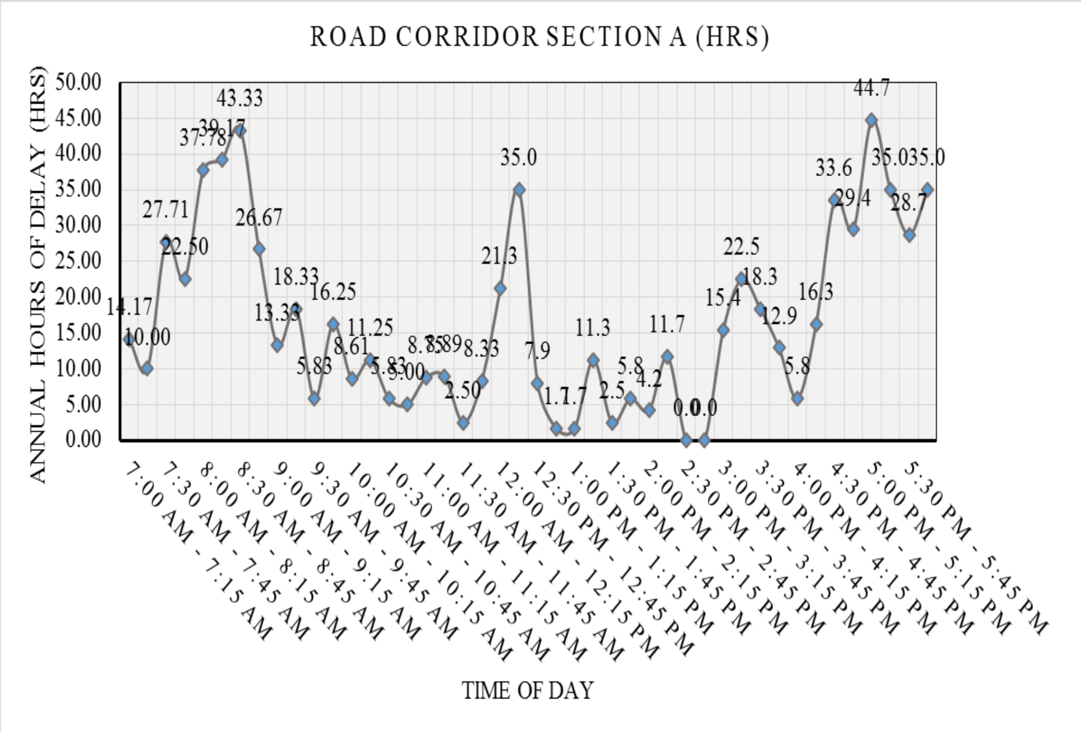


Figure 4-9: Travel time delay for the corridor section A

Where Road corridor section A is the road corridor from ‘Lamberet Menahereya’ to ‘Megenagna’

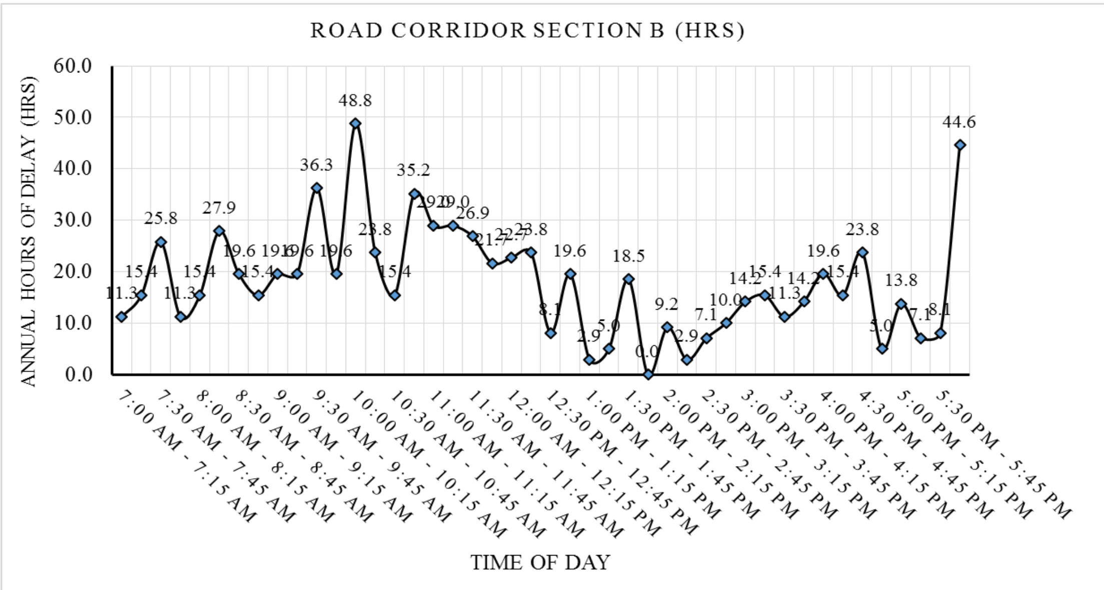


Figure 4-10: Travel time delay for the corridor section B

Road corridor section B is road corridor from ‘Arat Kilo’ Ministry of Education building to Piazza ‘Ras Mekonene’ Bridge

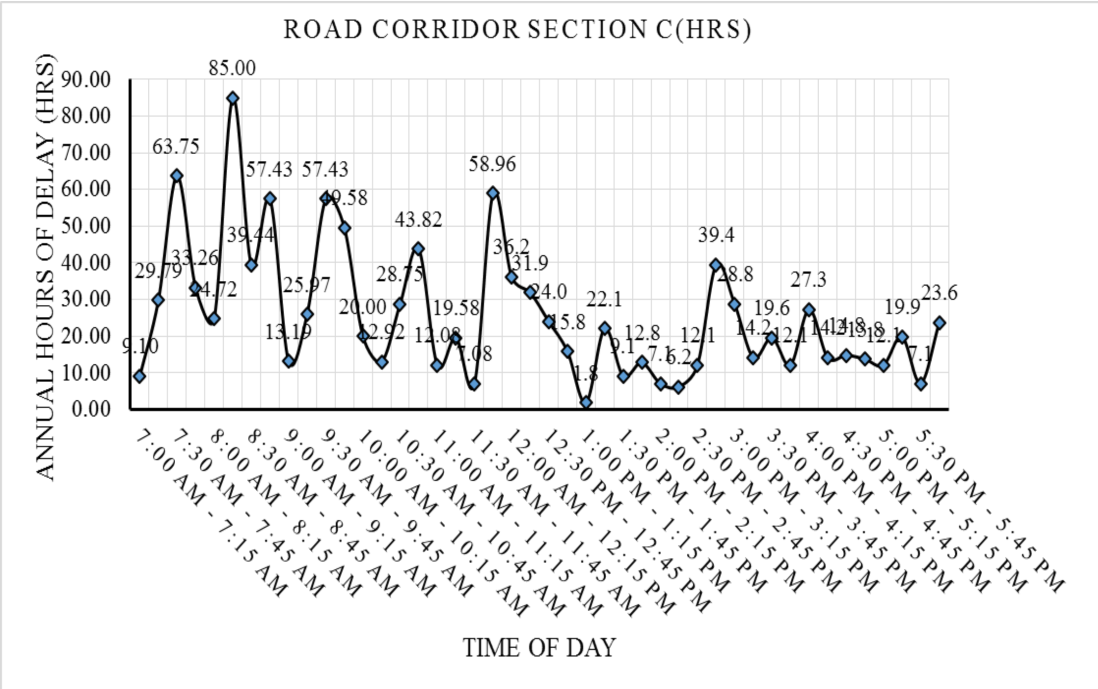


Figure 4-11: Travel time delay for the corridor section C

Road corridor section C is the road corridor from ‘Abune’ Petrus roundabout to ‘Awutobis Tera’ Bus station.

4.3.2 Average Travel Speed analysis result of the Road Corridor Sections

The average travel speed or the performance level of the selected road corridor is determined by comparing the hourly or daily average travel speed with posted speed limit. Based on the analysis result of average travel speed, the road corridor section A, road corridor section B and road corridor section C had performance level of ‘C’, ‘D’ and ‘E’ respectively. The corridor performance level of the road corridor section A and B was at acceptable range of performance level as per HCM urban corridor performance guide line. And the road corridor section C was operating nearly close to its capacity and it was considered as congested corridor. (See Figure: 4-12 up to 4-14).

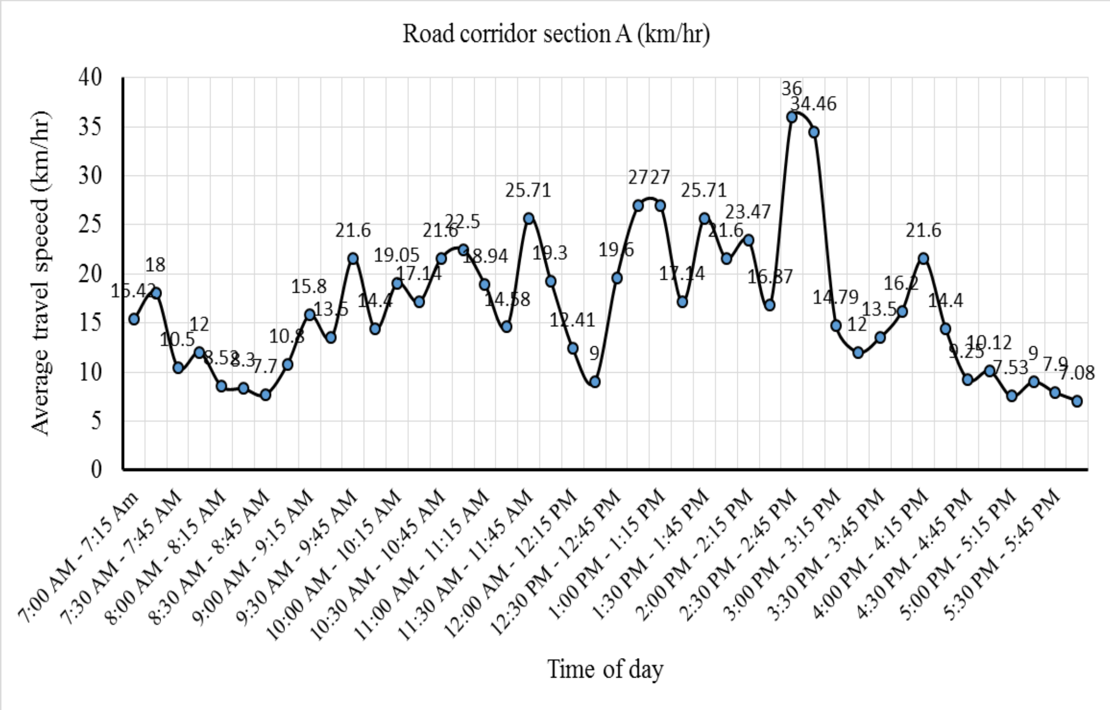


Figure 4-12:-Average travel speed for the road corridor section A

Where Road corridor section A = Road corridor from ‘Lamberet Menahereya’ to ‘Megenagna’

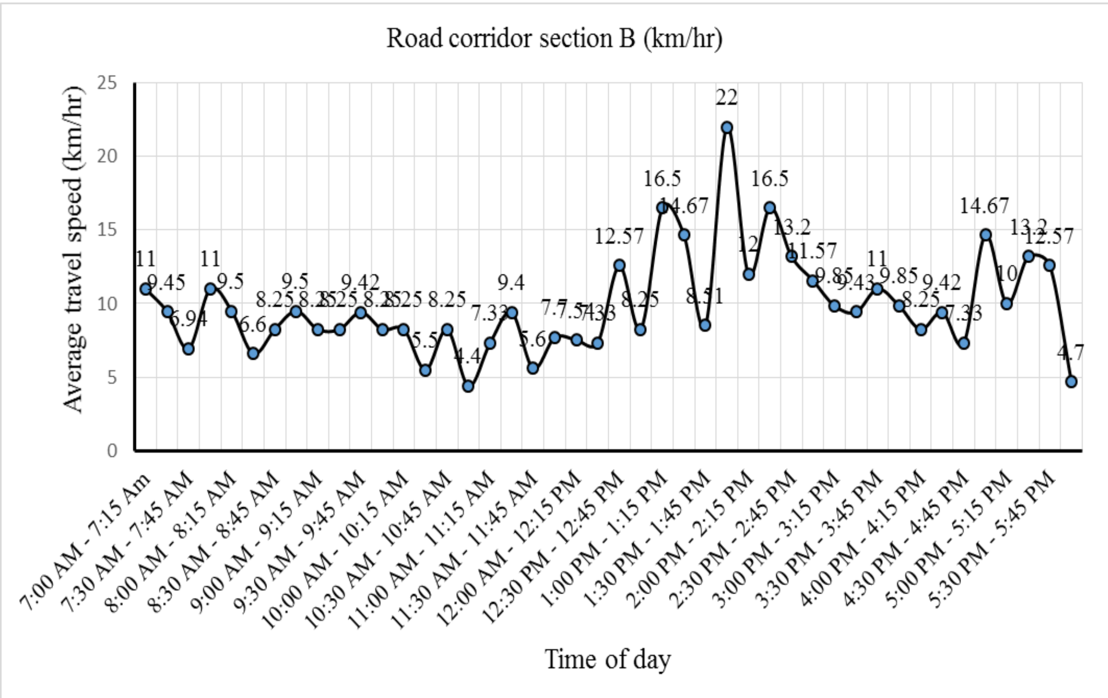


Figure 4-13: Average travel speed for the road corridor section B

Road corridor section B = Road corridor from ‘Arat Kilo’ Ministry of Education building to Piazza ‘Ras Mekonene’ Bridge

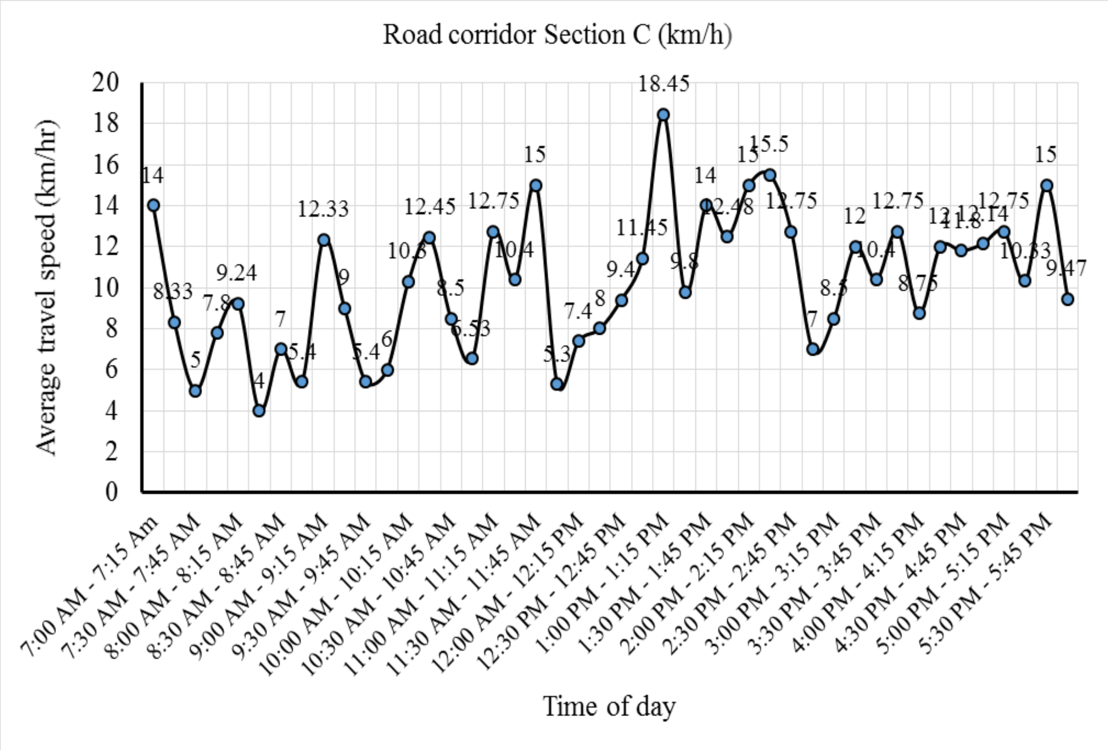


Figure 4-14: Average travel speed for the road corridor section C

Road corridor section C is the road corridor from ‘Abune’ Petrus roundabout to ‘Awutobis Tera’ Bus station.

The average travel speed recorded during formal working period from 7:00 am to 6:00 pm of selected homogeneous road corridor sections were estimated with equation 3.9:

$$U = \frac{\sum_i^n V_{15}}{N}$$

Where V_{15} is the average travel speed vehicles recorded during each fifteen minutes interval.

N is the total number of average travel speed recorded during the formal working period, in this study the value of N was 44.

The LOS of urban road corridor were determined by comparing the average travel speed of vehicles that traveled along the selected road corridor with speed at free flow (FFS) period using (Table 4.6).

Table 4-6: LOS thresholds established for the automobile mode on urban corridor

Average Travel Speed as a Percentage of Base free Flow Speed (%)	LOS by Critical Volume-to-Capacity Ratio		
	≤ 1.0	LOS Definition	≥ 1.0
>85	A	0.0 to 0.6	F
>67-85	B	0.61 to 0.70	F
>50-67	C	0.71 to 0.8	F
>40-50	D	0.81 to 0.9	F
>30-40	E	0.91 to 1.0	F
≤ 30	F	Greater than 1.0	F

Source: (HCM 2010, Volume-III)

Table 4-7:-The overall average travel speed of selected road corridor for the study period

Corridor name	Average travel speed (km/hr)	As percentage of FFS	LOS
Road corridor section A	16.75	55.83%	C
Road corridor section B	9.58	47.90%	D
Road corridor section C	10.27	34.23%	E

4.3.3 Traffic Volume Analysis result of Selected Intersections

The performance of ‘Shola’ signalized intersection and ‘Abune’ Petrus roundabout were measured in terms of Capacity and volume-to capacity ratio (degree of saturation), Delay, back of queue and queue storage ratio, and level of service (LOS) as it was mentioned in the methodology part of the research. The selected intersections has four approach legs and the signal is fixed type with total cycle time = 126 seconds (User given phase times) and with four phases as indicated in the following (See Table 4-7).

Table 4-8:-Phase time sequence of 'shola' signalized intersection under existing condition

Phase	A	B	C	D
Green Time (sec)	33	15	20	38
Yellow Time (sec)	3	3	3	3
All-Red Time (sec)	2	2	2	2
Phase Time (sec)	38	20	25	43
Phase Split	30%	16%	20%	34%

Phases assigned at Shola signalized intersection are diagrammatically illustrated in Appendix III.

According to the analysis outputs of the SIDRA 5.1 version, average control delay for 'Shola' signalized junction was 314.6 sec/hr per vehicle with LOS value of 'F' with maximum queue length of 770.0m which was around 107 queued vehicles and for that of 'Abune' Petrus roundabout the average control delay was found to be 44.8 sec /hr per vehicle with LOS value of 'E' with maximum queue length of 295.9m which was around 41 queued vehicles. The movement summary that resulted using SIDRA 5.1 at 'Shola' signalized intersection result is shown below. (See Table 4.9)

Table 4-9: - Movement summary of 'shola' signalized intersection

Movement summary							Shola Signalized Intersection	
Signal Fixed time		Cycle time = 126 Seconds (User-Given time)						
MOVE ID	Turn	Demand flow veh/h	HV(%)	Deg.Satn (v/c)	Average Delay (Sec)	LOS	95% Back of Queue	
							Veh	Distance (m)
South: Lem Hotel								
1	L	263	4.3	0.592	45.2	LOS D	14.3	103.7
2	T	95	4.3	0.197	39.6	LOS D	4.6	33.1
3	R	727	4.3	1.589	335.7	LOS F	106.1	770
Approach		1085	4.3	1.589	239.4	LOS F	106.1	770
East: Megenanga								
4	L	550	6.6	1.62	351.6	LOS F	81.5	603
5	T	1645	6.6	1.62	351.3	LOS F	85.8	634.6
6	R	90	6.6	1.62	351.4	LOS F	84.2	623.1
Approach		2285	6.6	1.62	351.4	LOS F	85.8	634.6
North: Mariam Church								
7	L	554	0.0	1.614	349.5	LOS F	81.4	569.6

8	T	169	0.0	0.318	47.7	LOS D	6.3	44.2
9	R	64	0.0	0.318	48.6	LOS D	6.1	43
Approach		787	0	1.614	260.1	LOS F	81.4	569.6
West: Kebena								
10	L	71	7.2	1.563	332.6	LOS F	82.9	615.9
11	T	1682	7.2	1.563	332.6	LOS F	83.4	619.9
12	R	536	7.2	1.563	331.5	LOS F	78.5	583.6
Approach		2289	7.2	1.563	332.3	LOS F	83.4	619.9
All Vehicles		6445	5.6	1.62	314.6	LOS F	106.1	770

The layout of the layout of 'Shola' signalized intersection and the individual lane LOS values for each approach is shown with Figure: 4.15. As showed on the (Figure:4.15), the leg from 'Megenagna' and 'Kebena' approach of this junction is an approach with four lane and all lanes along this approach were operating with LOS 'F' and all the approaches of the intersection have equal average lane width of 3.5 m.

And the overall performance of intersection was found to be LOS 'F'. This indicates that 'Shola' signalized junction was operating beyond its operational capacity or the standard set by highway capacity manual 2010 which recommends the level of service for urban road corridor to be either LOS C or D.

Level Of Service Summary   Site: Shola intersection

Shola Signalized Intersection

Signals - Fixed Time   Cycle Time = 126 seconds (User-Given Cycle Time)

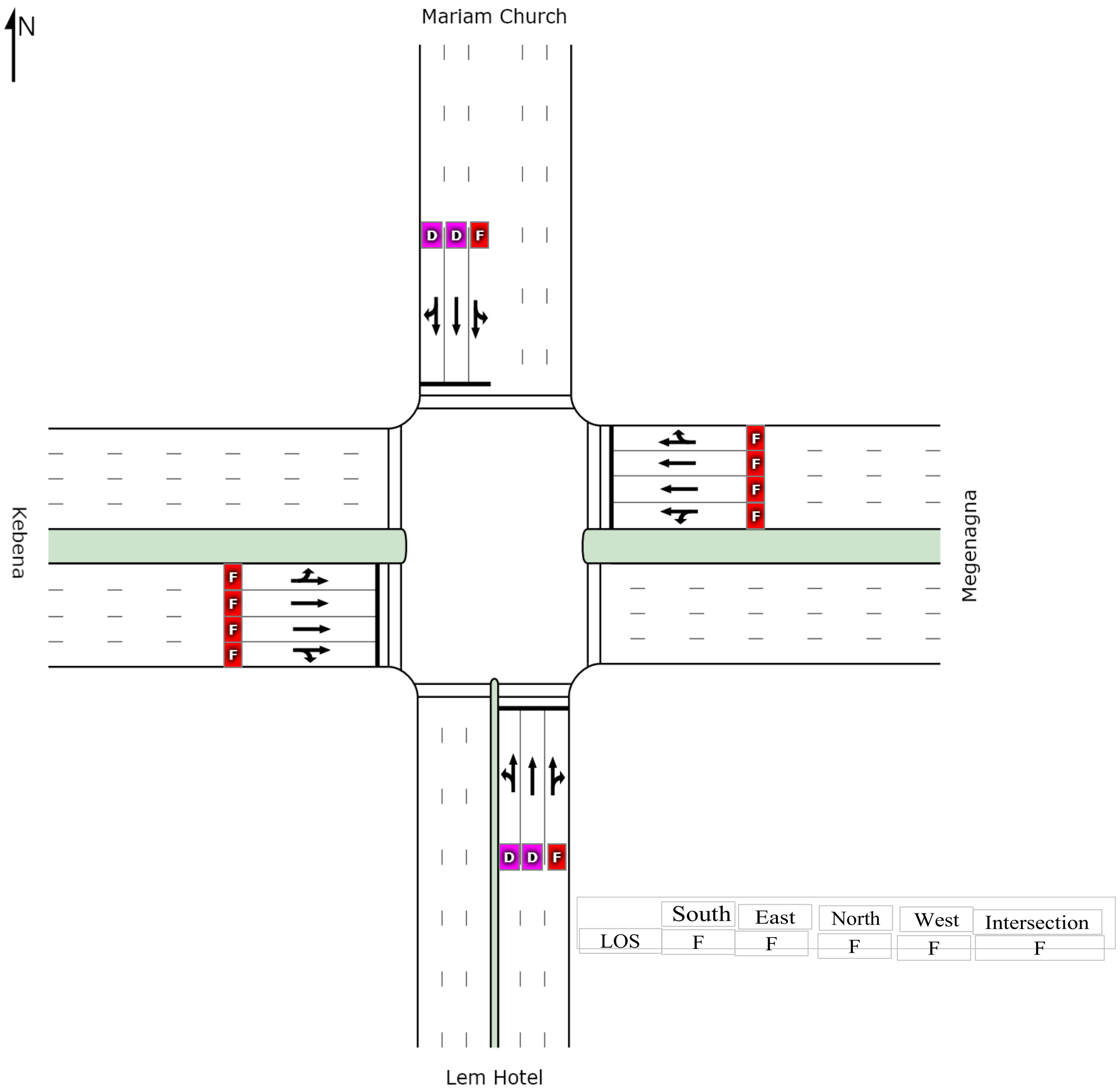


Figure 4-15: Layout of 'Shola' signalized intersection with LOS summary

As shown in Table: 4.8 all approach lane of ‘megenagna’ and ‘Kebena’ of shola signalized intersection were operating above their capacities because the volume to capacity ratio (degree of saturation) of the approaches were greater than one. Currently, the intersection was operating under congested condition with LOS ‘F’ during the peak hour with degree of saturation (DOS) of 1.62. The two approach leg ‘Megenagna’ and ‘Kebena’ are experiencing an average control delay of 351.4 seconds per vehicle and 332.3 seconds per vehicle. ‘Megenagna’ approach leg was experiencing major operational difficulties.

Table 4-10:-SIDRA 5.1 Lane summary output of SIDRA for ‘Shola’ signalized intersection

Lane summary										Shola signalized intersection		
Signal Fixed time time)								Cycle time = 126 Seconds (User-Given				
	Demand flow (veh/h)											
	L	T	R	Total (Veh/h)	HV(%)	Cap. (Veh/h)	Deg.Satn (v/c)	Lane Utili. %	Average Delay (Sec)	LOS	Veh	Distance (m)
South: Lem Hotel												
Lane 1	263	0	0	263	4.3	444	0.592	37	45.2	LOS D	14.3	103.7
Lane 2	0	95	0	95	4.3	452	0.197	12	39.6	LOS D	4.6	33.1
Lane 3	0	0	727	727	4.3	458	1.589	100	335.7	LOS F	106.1	770
Approach	263	95	727	1085	4.3		1.589		239.4	LOS F	106.1	770
East: Megenanga												
Lane 1	550	3	0	553	6.6	341	1.62	100	351.6	LOS F	81.5	603
Lane 2	0	583	0	583	6.6	360	1.62	100	351.2	LOS F	85.8	634.6
Lane 3	0	577	0	577	6.6	356	1.62	100	351.3	LOS F	84.9	628.2
Lane 4	0	482	90	572	6.6	353	1.62	100	351.4	LOS F	84.2	623.1
Approach	550	1645	90	2285	6.6		1.62		351.4	LOS F	85.8	634.6

North: Mariam Church												
Lane 1	554	0	0	554	0.0	343	1.614	100	349.5	LOS F	81.4	569.6
Lane 2	0	118	0	118	0.0	371	0.318	20	47.6	LOS D	6.3	44.2
Lane 3	0	51	64	115	0.0	361	0.318	20	48.2	LOS D	6.1	43
Approach	554	169	64	787	0		1.614		260.1	LOS F	81.4	569.6
West: Kebena												
Lane 1	71	509	0	580	7.2	371	1.563	100	332.6	LOS F	82.9	615.8
Lane 2	0	583	0	583	7.2	373	1.563	100	332.5	LOS F	83.4	619.9
Lane 3	0	577	0	577	7.2	370	1.563	100	332.6	LOS F	82.6	613.7
Lane 4	0	13	536	548	7.2	351	1.563	100	331.5	LOS F	78.5	583.6
Approach	71	1682	536	2289	7.2		1.563		332.3	LOS F	83.4	619.9
Intersection				6445	5.6		1.62		314.6	LOS F	106.1	770

The performance measures shown in Table 4.10 indicates that the ‘Abune’ Petrus roundabout was performing nearly close its design capacity operating condition with LOS ‘‘E’’ and with degree of saturation of 1.162. Because of enough number of approaches, exit lane, and lane width, which conveys the existing traffic without having severe congestion at a junction. The approach legs at ‘Adisugebeya’ and ‘Pastor Winget’ are operating at acceptable levels of service set by the Highway Capacity Manual. This may not mean that the two approaches do not need any modification in the future but will accommodate the current as well as the future traffic demand which will be generated with economic growth of the city taking improvement action over the whole intersection is necessary.

Table 4-11: - Movement summary of ‘Abune’ Petrus roundabout

Movement summary							‘Abune’ Petrus Roundabout	
MOVE ID	Turn	flow veh/h	HV (%)	Deg.Satn (v/c)	Average Delay (Sec)	LOS	95% Back of Queue	
							Veh	Distance (m)
South: ‘Awutobis Tera’ Bus station								
1	L	242	5.7	0.835	30.6	LOS D	7.2	52.9
2	T	806	5.7	0.835	32.6	LOS D	7.2	52.9
3	R	705	5.7	1.162	114	LOS F	40.3	295.9
Approach			1753	5.7	1.162	65.1	LOS F	40.3
East: Piazza								
4	L	340	1.8	0.878	48	LOS E	6	42.4
5	T	523	1.8	0.878	46.4	LOS E	6	42.4
6	R	329	1.8	0.878	48	LOS E	6	42.4
Approach			1192	1.8	0.878	47.3	LOS E	6
North: Addisu Gebeya								
7	L	316	3.0	0.748	29.7	LOS D	4	28.4
8	T	471	3.0	0.748	28.7	LOS D	4	28.4
9	R	340	3.0	0.748	29.7	LOS D	4	28.4
Approach			1125	3.0	0.748	29.3	LOS	4
West: Pastor Winget								
10	L	191	3.2	0.578	20	LOS C	2.4	17
11	T	370	3.2	0.578	20	LOS C	2.4	17
12	R	341	3.2	0.664	23.1	LOS C	3	21.3
Approach		901	3.2	0.664	21.2	LOS C	3	21.3
All Vehicles		4973	3.7	1.162	44.6	LOS E	40.3	295.9

The ‘Abune’ Petrus roundabout has four approaches legs and at this roundabout, there is structure erected to commemorate the notable person called ‘Abune’ Petrus. According to (Federal Work Highway Administration) FWHA, this roundabout cannot be categorized as urban roundabouts because it has no splitter island raised with crosswalk. The overall performance the roundabout was expressed as LOS ’’E”. The (Figure 4.16) shows the diagram of ‘Abune’ Petrus roundabout.

Level of Service Summary

Piazza Abune Petrus roundabout
Roundabout

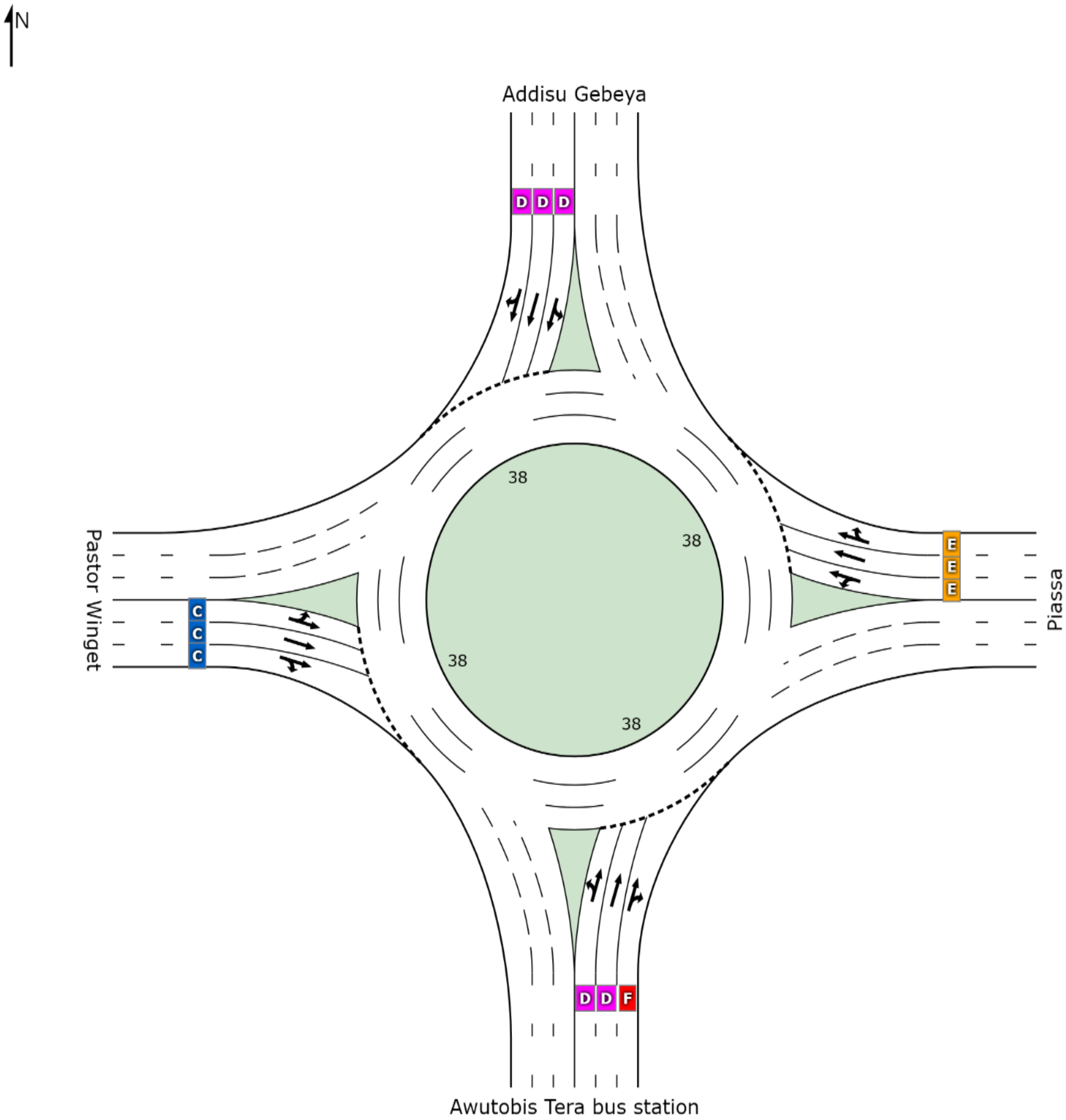


Figure 4-16:-LOS of ‘Abune’ Petrus roundabout (LOS is Level of service)

Table 4-12:-Lane summary of ‘Abune’ Petrus roundabout

LANE SUMMARY									Shola signalized intersection			
Signal Fixed time			(User-Given time)			Cycle time = 126 Seconds						
	Demand flow (veh/h)											
	L	T	R	Total (Veh/h)	HV(%)	Cap. (Veh/h)	n (v/c)	Lane Utili. %	Delay (Sec)	LOS	Veh	Distance (m)
South: ‘Awutobis Tera’station												
Lane1	242	322	0	563	5.7	67	0.83	72	30.6	LOS D	7.2	52.9
Lane 2	0	485	0	485	5.7	58	0.83	72	34.2	LOS D	5.9	43.5
Lane 3	0	0	705	705	5.7	60	1.16	100	114	LOS F	40.	295.9
Approac	242	806	705	175	5.7		1.16		65.1	LOS F	40.	295.9
East: Piazza												
Lane1	340	49	0	389	1.8	44	0.87	100	48	LOS E	6	42.4
Lane 2	0	414	0	414	1.8	47	0.87	100	46	LOS E	5.9	41.7
Lane 3	0	60	329	389	1.8	44	0.87	100	48	LOS E	6	42.4
Approac	340	532	329	119	1.8		0.87		47.3	LOS E	6	42.4
North: Addisu Gebeya												
Lane1	316	52	0	368	3.0	49	0.74	100	29.7	LOS D	4	28.4
Lane 2	0	389	0	389	3.0	52	0.74	100	28.4	LOS D	3.9	27.7
Lane 3	0	29	340	368	3.0	49	0.74	100	29.7	LOS D	4	28.4
Approac	316	471	340	112	3.0		0.74		29.3	LOS D	4	28.4
West: Pastor Winget												
Lane1	191	90	0	280	3.2	48	0.57	87	20	LOS C	2.4	17
Lane 2	0	280	0	280	3.2	48	0.57	87	20	LOS C	2.4	17
Lane 3	0	0	341	341	3.2	51	0.66	100	23.1	LOS C	3	21.3
Approac	191	370	341	901	3.2		0.66		21.2	LOS C	3	21.3
Intersection				4973	3.7		1.162		44.8	LOS E	40.3	295.9

The peak period for the two intersections found along the study road corridor was summarized with (Figure 4-17 and 4-18). The result in (Figure 4-17) showed the peak hourly volume for ‘Abune’ Petrus roundabout was occurred at morning from 7:45 am to 8:45 am. This is due to the fact on the morning peak period, most road users go to market for shopping and also to cross to the western part of the country through the ‘Awutobis Tera’ Bus station. And for ‘shola’ signalized junction the peak period was occurred at morning from 8:00 am to 9:00 am as showed in (Figure 4-18), this due to the fact that most road users from the newly built residential house (‘Hayat’, ‘Xafo’, ‘Summit’ and ‘Kuye fache’ condominium) make a trip to the down town area of the city for work, education, shopping and other purpose at the morning period.

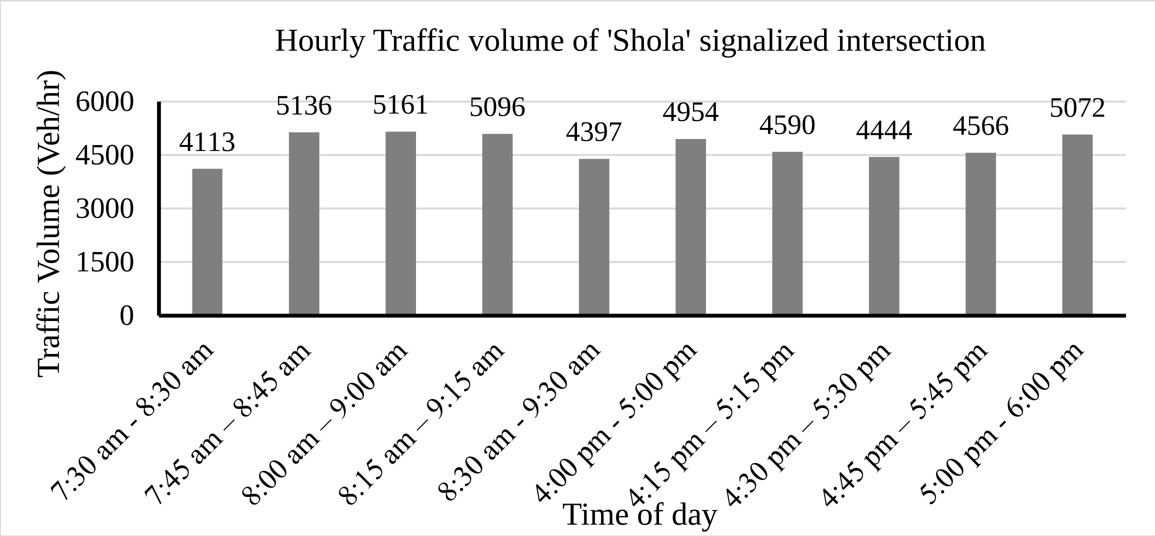


Figure 4-17:Hourly traffic volume of ‘Shola’ signalized intersection

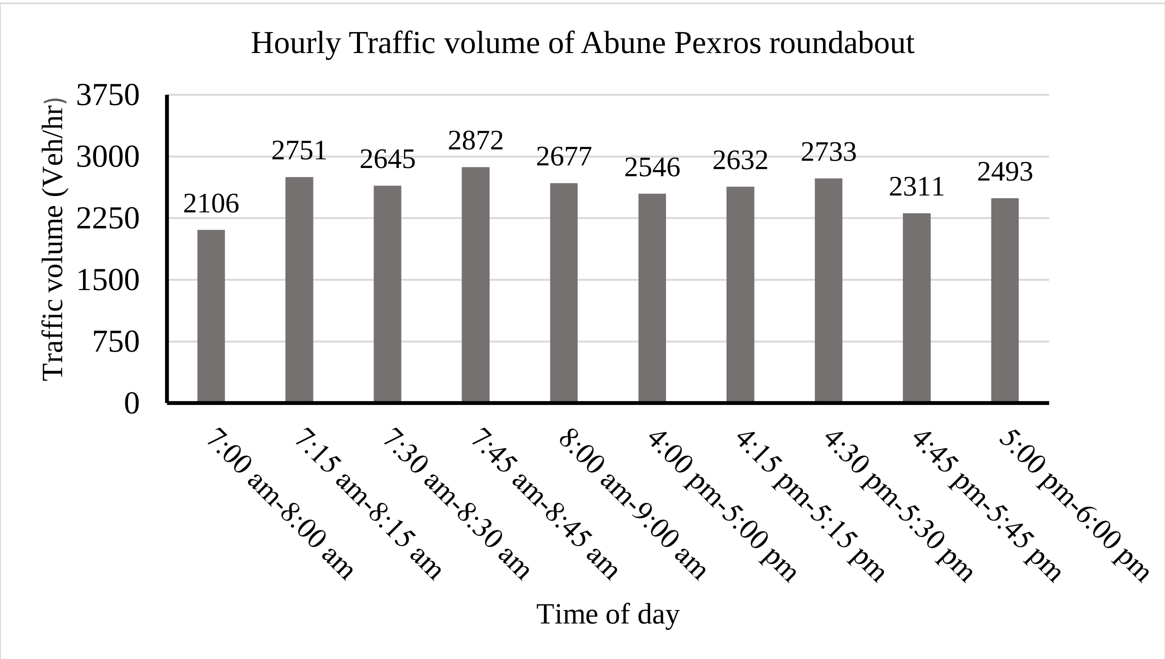


Figure 4-18:Hourly traffic volume of ‘Abune’ Petrus roundabout

4.3.4 Discussion on the Level of Traffic Congestion Analysis Results

The result obtained from presented study indicated that, the overall performance of the selected road corridor sections along east-west line was good as the standard set by highway capacity manual 2010. The road corridor section A and B were in a good operational condition with level of service ‘C’ and ‘D’ respectively, even though the road corridor section C was with level of service ‘E’. The ‘Shola’ signalized intersection and ‘Abune’ roundabout has overall level of service ‘F and ‘E’.

The performance of each approach of selected intersection with the present study were summarized below. (See Table 4-12)

Table 4-13: The performance result summary intersections from present study

Intersection	Approach Leg	Degree of saturation	LOS
‘Abune’ Petrus roundabout	‘Awutobis Tera’ leg	1.162	F
	Piazza leg	0.87	E
	‘Addisu gebeya’ leg	0.74	D
	‘Pastor winget’ leg	0.66	C
‘Shola’ signalized intersection	‘Kebena’ leg	1.62	F
	‘Lem’ Hotel leg	1.589	F
	‘Megenagna’ leg	1.62	F
	Mariam church leg	1.64	F

The study conducted by Tadesse, (2011) tried to analyze and quantify the level of traffic congestion along east-west line in the direction of Addis Ababa Light Rail line. He selected three intersections namely Urael intersection, Legehar intersection and Haihulet intersections. The performance summary result of the three selected intersections as per Tadesse were presented below. (See Table 4-13)

Table 4-14: The performance result summary intersections from previous study

Intersection	Approach Leg	Degree of saturation	LOS
Urael intersection	Meskel Approach	2.308	F
	Wuhalimat Approach	3.544	F
	Atlas Hotel Approach	6.30	F
	Kasanchis Approach	1.96	F
Legehar intersection	Mexico Approach	1.79	F
	Meskel Square Approach	1.79	F
	Railway Station approach	1.33	F
	Piazza Approach	1.29	F
Haihulet intersections	Wuhalimat Approach	2.46	F
	Megenagna Approach	3.702	F
	Bole Brass Approach	1.732	F
	British Embassy Approach	`2.33	F

The two study, the present and the previous one conducted by Tadese, were on the direction of east-west line even though the previous study was done along in the direction of LRT. When we compare the two study result, the present study result has good operational performance than the one conducted previously and the degree of saturation for each approach were also greatly vary, this might be due to the improvement action plan taken by the Addis Ababa City Transport office and also study subject variation could result in different study output that means as the study area or study subject is varied, the geometric and traffic condition also vary. Beside to this, most uncontrolled intersection in Addis Ababa City that is either roundabout or stop-way intersection were converted into signal in recent period. This all could result variation in study result.

4.4 Traffic Congestion Cost Analysis Result

Making an analysis on the cost of traffic congestion in order to know the economic loss per individual traveler over selected road corridor was the third specific objective of the study. Based on this about 2667.8 person-hours/year and ETB 104048.75 /year per individual traveler being wasted due to traffic congestion over the study road corridor. (See Section 4.4.1 up to 4.4.3). (See Figure 4-19 up to 4-21)

4.4.1 Travel Time Delay Cost over the Road Corridor Sections

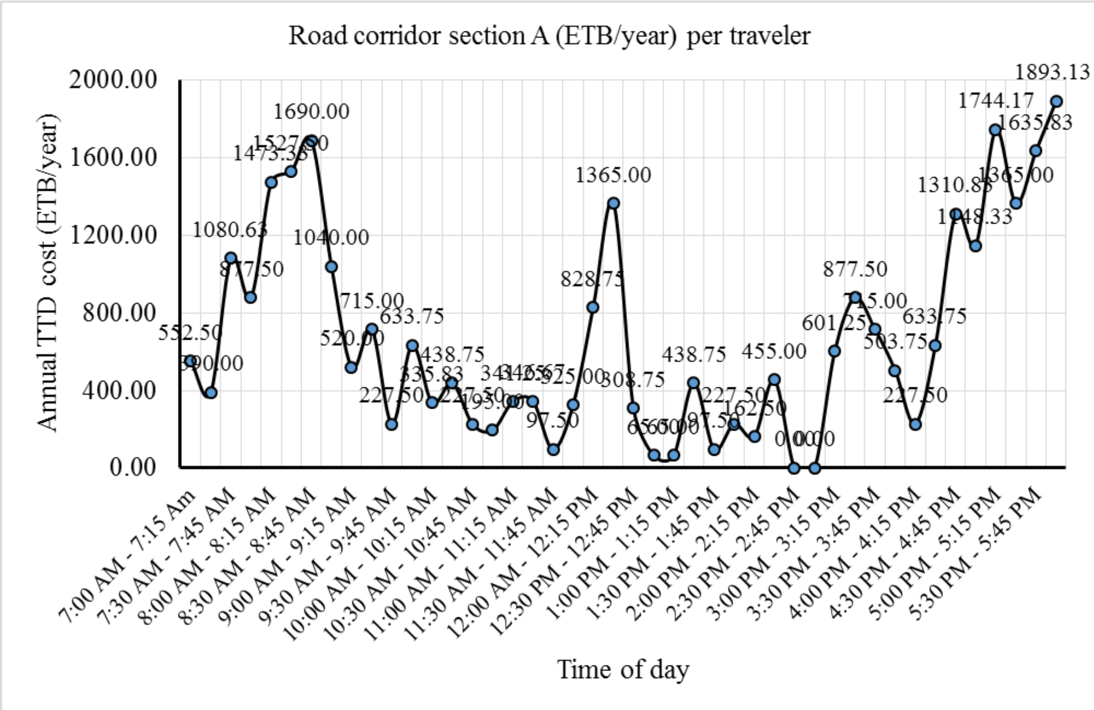


Figure 4-19:-Annual traffic congestion cost per traveler for the corridor section A

Where TTD represents travel time delay.

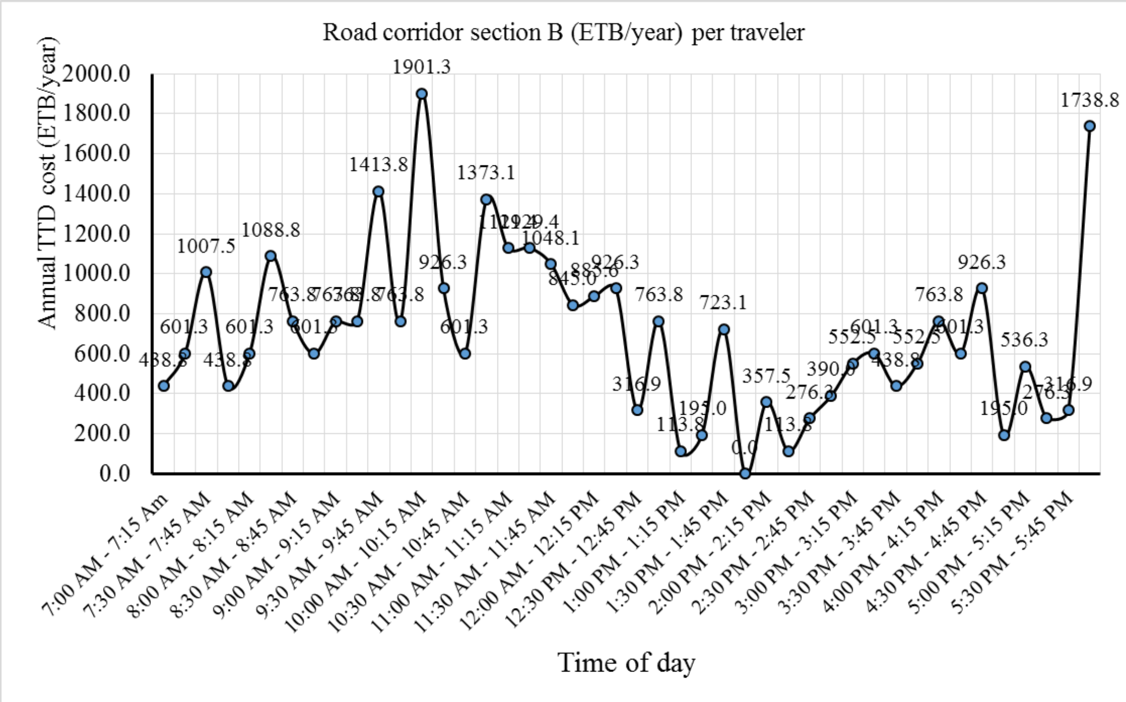


Figure 4-20:-Annual traffic congestion cost per traveler for the corridor section B

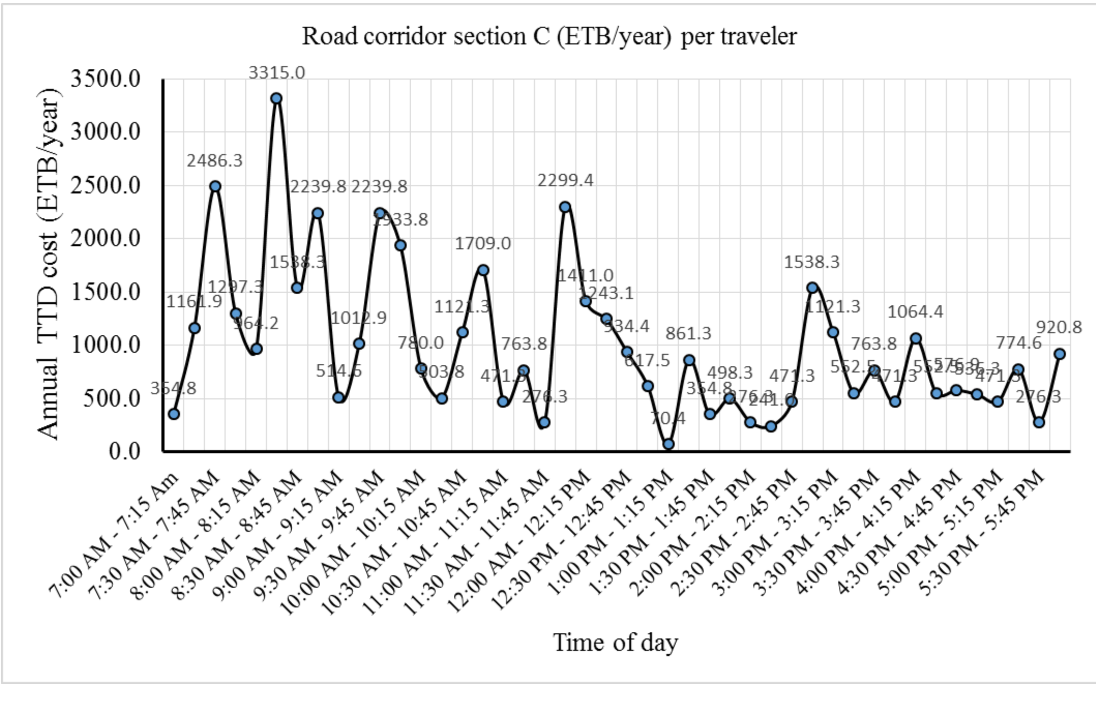


Figure 4-21:-Annual traffic congestion cost per traveler for the corridor section C

In estimating the annual travel time delay cost, the annual travel time delay per each 15 minutes time interval of that specific day obtained from the analysis result of level of traffic congestion obtained from specific objective two was multiplied with value of time. Based on this economic analysis result, annual travel time delay cost for the road corridor section A, B and C was totally ETB 29705 , ETB 30761.3 and 43582 .5 ETB/year per traveler for each respective corridor was wasted due to traffic congestion. And the total annual travel time delay cost over the corridor 'Lamberet Menahereya' to 'Awutobis Tera' Bus station was estimated to be ETB 104048.75 /year per traveler. The maximum travel time delay cost was recorded on the road corridor section C and this shows there was serious traffic congestion on this corridor. The detail analysis of traffic congestion cost was presented in Appendix: IV

4.4.2 Control Delay Cost over Selected Intersections

In estimating the control delay cost of traffic congestion cost of 'shola' signalized intersection and also 'Abune' Petrus roundabout, the control delay (sec) obtained from SIDRA 5.1 software was used. The value of time (VOT) which was used in this study to convert annual travel time delay in to congestion cost was 39(ETB/hr). Based on this, the total congestion cost due control point (intersection) was estimated to be 11,680.5 ETB/year per vehicle. (Figure 4.22) showed the control delay cost over the two intersections.

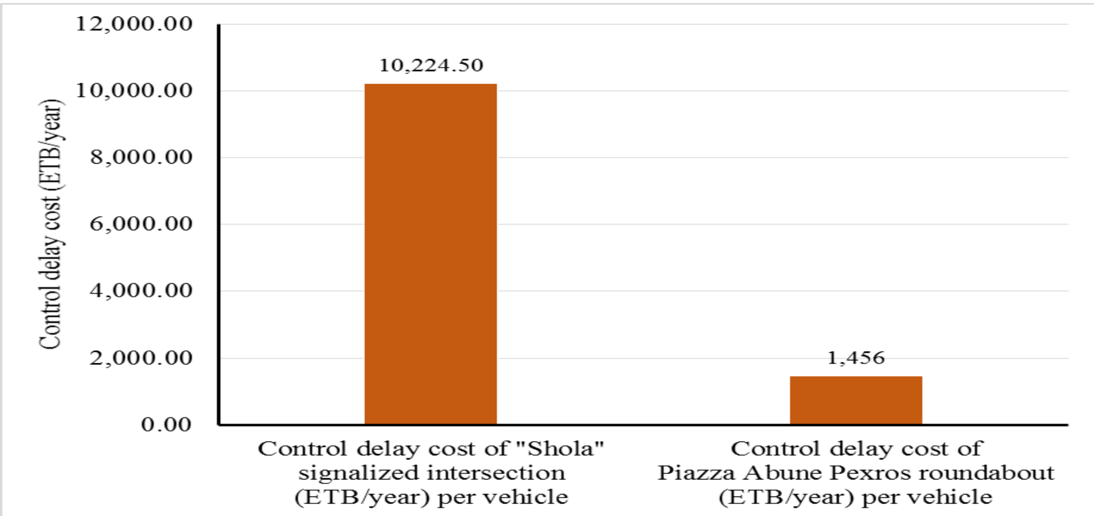


Figure 4-22:-Annual congestion cost for 'shola' signalized intersection and 'Abune' Petrus roundabout

4.4.3 Discussion on Traffic Congestion Cost Analysis Results

According to the present study, passenger annual travel time delay cost for the road corridor section A, B and C was totally of ETB 29705 , ETB 30761.3 and ETB 43582 .5 per year per traveler for each respective corridor. And the total annual travel time delay cost over the corridor 'Awutobis Tera' Bus station to 'Lamberet Menahereya' was estimated to be ETB 104048.75 per year per traveler. The travel time delay cost due to traffic congestion was analyzed by considering only passenger travel time delay cost. But by including additional parameters such as; travel time delay cost of goods, vehicle operating cost, environmental cost, socio-economic and health cost, the total economic cost of traffic congestion for the selected study road corridor could more. Beside to this, the present study conducted on formal working period from morning 6:00 am to evening 6:00 pm due to unsafe working environment. The passenger travel time delay cost could be more than the present study result if the study were conducted by extending the study to night 8:00 pm since there was serious traffic congestion starting from evening 6:00 pm to night 8:00 pm as observed during road traffic condition survey specifically on the road corridor section 'Megenagna' to 'Lamberet Menaherey'.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- The result of multi variable linear regression model identified the major external independent variables for the cause's traffic congestion over the corridor based on their level of significance (p-value) and correlation coefficient (R^2).
- The R^2 in this study was 87.5%, based on this it is possible to say that their strong correlation between the actual value and model.
- Imbalance between vehicle volume and road capacity, presence high number of pedestrian that cross the road and move along the side of the road, inflexible work schedule, inadequate of mass transit along the corridor and illegal on-street vehicle parking are the significant external independent variables identified by linear regression analysis as the major causal factors for the traffic congestion problem for the road corridor 'Awutobis Tera' Bus station to 'lamberet Menahereya'.
- In the performance analysis of selected road corridors the hourly average travel speed was determined by comparing average travel speed along the selected road corridors with posted speed limit. Based on this, the performance level of the road corridor section A, B and C were operating with level of service 'C', 'D' and 'E' respectively.
- The annual passenger hours of delay per a single traveler for the road corridor Section A, B and C was estimated to be 761.67, 788.8 and 1117.5 person-hours/year respectively.

  And the total annual travel time delay per passenger for the whole corridor was estimated to be 2667.8 person-hours/year per individual traveler.
- The traffic volume analysis result for 'Abune' Petrus roundabout and 'Shola' signalized intersection shows that the traffic volume reaches its peak volume during morning peak hours from 7:45 am to 8:45 am and 8:00 am to 9:00 am respectively.

  As per performance analysis SIDRA 5.1 version result, average control delay for 'shola' signalized junction is 314.6 sec/hr per vehicle with LOS value of 'F' with maximum queue length of 770.0m which is around 107 queued vehicles and for that of 'Abune' Petrus roundabout the average control delay is 44.8 sec /hr per vehicle with LOS value of 'E' with maximum queue length of 295.9m which is around 41 queued vehicles.

- Based on congestion cost analysis result, passenger annual travel time delay cost for the road corridor section A, B and C was totally of ETB 29705 , ETB 30761.3 and ETB 43582 .5 per year per traveler for each respective corridor. The total congestion cost due 'shola' signalized intersection and 'Abune' Petrus roundabout found along the study road was estimated to be ETB 11,680.5 /year per individual vehicle. The total passenger travel time delay cost for the whole corridor 'Awutobis Tera' Bus station to 'Lamberet Menahereya' was obtained to be ETB 104048.75 /year per individual traveler.

5.2 Recommendations

- The regression results showed that there is strong correlation among high number of vehicles and poor road capacity, high number of pedestrian cross the road and move along the side of the road, inflexible work schedule, inadequate mass transit service along the corridor, illegal on-street vehicle parking and traffic congestion or travel time delay.
- The main reason behind increasing in traffic congestion was mainly due to the significant increase in the number of vehicles without a corresponding increase in the road capacity. Thus, more roads need to be constructed, especially from the suburbs to the city downtown area. This would result in commuters taking different routes, thereby reducing traffic congestion. And also constructing wide enough pedestrian walk way and vehicle parking apartments would result in overcoming the traffic congestion effect along the corridor.
- The road corridor in section A that is 'Abune' Petrus to 'Awutobis Tera' Bus station was experiencing higher delay than other two corridors. This was mainly due to the interruption of corridor traffic flow by the east-west line of Addis Ababa city light rail transit (LRT) and significant number of pedestrian who crosses the road. So in order reduce the effect of both LRT and pedestrian interruption, alternative road and elevated pedestrian crossing structure has to be constructed.
- As the study results indicated the overall intersections performance level was below the standard set by Highway Capacity Manual2010. The traffic demand of Addis Ababa City is growing from time to time with the city economic growth. Therefore to accommodate the current as well as the future traffic demand, the city transport

authority has to improve the performance road network capacity for both road corridor and intersections.

The two approach legs ‘Kebena’ and ‘Megenagna’ of shola signalized intersection were experiencing higher delay than other two approach, so the phase time should have to be re-allocated.

Some of the possible improvement methods for ‘Shola’ signalized intersection are listed as follows.

1. Optimizing the signal timings for existing phase sequence
2. Changing current phase sequences and optimizing the signal timings

Beside to improving the signalized intersection, ‘Abune’ Petrus roundabout also need improvement to accommodate the current as well as the future traffic demand by applying the methods listed below:

1. Increasing the island diameter if their space adequacy
2. Changing the roundabout to signalized junction if there is no adequate space to increase the island diameter of roundabout

- In order to reduce the traffic congestion adverse effect on the national economy the following additional engineering solution has to be applied:
    1. Providing adequate space while constructing high rise building for accommodating the current as well as for future pedestrian walk way and carriage way requirement to reduce the interruption of traffic flow by Pedestrian who move along the side roadway specifically for the road corridor section C that is the road corridor from ‘Abune’ Petrus roundabout to ‘Awutobis Tera’ Bus station.
    2. Encouraging public and private sector to build parking apartment and putting legal restriction and enforcement for illegal on street parking are some the engineering measures that should be recommended nationally and along the study road corridor in particular.
    3. Adopting congestion pricing and constructing public bus dedicated lane over the study road corridor which is a common trend used by most developed countries to reduce the adverse effect of traffic congestion on their nation economy.

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APPENDICES

Appendix I:-Questionaire used for traffic congestion causes analysis

HAWASSA UNIVERSITY

INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND BUILT ENVIRONMENT

Dear Respondent;

Thank you for taking part in this study. I am Dawit Getachew from Hawassa University, institute of technology department of Civil and Built Environmental Engineering. May I wish to notify you that this questionnaire has the aim of gathering information about the study titled “**Assessment of traffic congestion and its impact over selected road corridor in Addis Ababa City (a case study of ‘Awutobis Tera’ Bus station to ‘Lamberet Menahereya’)**” This is purely an academic study, which is being conducted as a partial fulfillment for the award of degree on Masters of Science in Road and Transport Engineering.

Through this information, the researcher will be able to assess and document the economic impact of road traffic congestion in Addis Ababa city. It should be noted that all information obtained will be treated very confidentially and used for intended purpose only. Please feel free to answer the questions according to your experience and your personal understanding

.

Your sincerely!!!

Researcher Contact Address:

Phone: +251917306208

E-mail: dawitgetachew034@gmail.com

QUESTIONNAIRE

Part I: General Information

: Answer by choosing from listed options

1. Gender A. Male B. Female
2. Age A. 18-25 Year B. 26-35 Year
   C. 36-45 Year D. 45-55 Year E. Above 55 years
3. Educational background, answer by choosing the right answer.
   A. Primary level B. Secondary level C. Diploma graduate
   D. First degree graduate E. Masters and above F. other_________
4. Employment condition
   A. government employed B. private-employed
   D. self-Busines D. Student E. other ______
5. Income level per month (in ETB)

   A. Less than 5,000 B. 5,000 to 10,000 C. 10,000 to 15,000

   D. 15,000 to 20,000 E. Above 20,000

Part II: Specific Information
Choose from the listed options

6. Which mode of transportation do you use daily or mostly?
   A. Private B. Public C. Non-motorized

7. What is your feeling regarding the traffic congestion along the road corridor from 'Awutobis Tera' Bus station to 'Lamberet Menahereya'?
   A) No problem traffic congestion problem B) The problem is at lower level C) The problem is at medium level D) The problem is at extreme level
8. How long you would exercise the average distance from your home to work?
   A) Less than 3 km B) 3– 7 km C) 7 – 10 km
   D) 10 – 14 km E) Above 14 km

9. How long do you estimate the travel time on this route to reach your destination from your home?

   During congested condition ___________________

   During free flow condition____________________

10. What is the purpose of your journey on this route?

    A) Educational B) Recreational C) Business

    D) Shopping E) to ask family F) Other

11. How much is the frequency of occurrence of traffic congestion over the study road corridor?

    A) Every day at morning and night
    B) In a week at some days during morning and night
    C) Every day at any time of the day
    D) In a week at some days at any time of the day

    Question No. 13 & 14 is filled by drivers only

12. Your vehicle fuel consumption while you travel on the road corridor from 'Awutobis Tera' Bus station to 'Lamberet Menahereya':

    A) Fuel consumption per kilometer on congested condition________
    B) Fuel consumption per kilometer on free flow condition________
    C) Fuel consumption per hour on congested condition________
    D) Fuel consumption per hour on free flow condition________

13. How many trips in a day do you make along the study road corridor? ____

14. Rank the cause of traffic congestion for the road corridor 'Awutobis Tera' Bus station to 'Lamberet Menahereya' by giving the value 0 up to 5 based on your daily observation and perception.

Table A.1: List of causal factors for traffic congestion

Causes of road traffic congestion	0	1	2	3	4	5
Imbalance between the vehicles volume and road capacity						
Bottle neck						
High number of pedestrian that cross the road and move along the side of the road						
Inflexible work schedule of people						
Poor road surface condition						
Un-integrated land use						
Inadequate mass transit service along the corridor						
Traffic accident						
Poor traffic management system						
Illegal on-street vehicle parking						
Inadequate parking area						
Poor performance of intersections						
Informal on-street trade						

Hint: On the table above the number 0 up to 5 represents the following values: 0 = the cause never have occurred 1= the cause does not occur on the road at all,
2 = the cause occur at lower level, 3 = cause occur at medium level and 4 = cause occur at highest level 5 = the cause is at extreme level and creating dangerous situation on road users

15. If there are any other factors that you think to be the cause of traffic congestion for the road corridor from 'Awutobis Tera' Bus station to 'Lamberet Menahereya' in addition to the those listed factors in the table A.1 above, you can write those factors on the black spaces provided below:------------------------
----

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16. What do you recommend as a remedial solution for the existing traffic congestion problem for the road corridor ‘Awutobis Tera’ Bus station to Lamberet Menahereya?--
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17. Anything you want to say?--

በሀዋሳ ዩኒቨርስቲ

ኢንስቲትዩት ኦፍ ቴክኖሎጂ

የሲቪል ምህንድስና ትምህርት ቤት

<u>የድህረ ምረቃ ትምህርት ፕሮግራም ጥናት ማሟያ (ግብአት) የቀረቡ የናሙና መጠይቆች</u>

<u>ውል መጠይቅ</u>

በመጀመሪያ ለዚህ ጥናት ስራ ተባባሪ ለመሆን ፍቃደኛ ስለሆኑ አመሰግናለሁ። ዳዊት ጌታቸዉ እባላላሁ፣ ከሀዋሳ ዩኒቨርስቲ ኢንስቲትዩት ኦፍ ቴክኖሎጂ ፣ ሲቪል ምህንድስና ትምህርት ቤት፣ መንገድና ትራንስፖርት ምህንድስና ፕሮግራም። እንዲረዱት ምፍልገዉ ነገር፣ ከዚህ መጠይቅ የሚሰበሰበዉ መረጃ ሙሉ በሙሉ “Assessment of traffic congestion and its impact over selected road corridor in Addis Ababa City (a case study of ‘Awutobis Tera’ Bus station to ‘Lamberet Menahereya’)” በሚል ርዕስ እየሰራሁ ላለሁት የድህረ ምረቃ ትምህርት ፕሮግራም ጥናት ጽሁፍ ግብአትንት ብቻ የሚዉል ስለሆነ ፥ የሚስጡት መረጃ ሚስጥራዊነቱ በደንብ የተጠበቀ ነዉ። ስለዚህ ስለሚጠቀሙት መንገድ የትራፊክ ፍሰት እና አጠቃላይ በመንገዱ ላይ ስለ ታዘቡት ነገር በነፃነት እና በታማኝነት በመጠይቅ ላይ ያስፍሩ።

‘‘ ውድ የሆነ ሰዓትዎን ለእኛ ሰዉተዉ ይህን መጠይቅ ለመሙላት ስለተባበሩን እናመሰግናለን ’’

ከሠላምታ ጋር !

<u>የጥናት ጽሁፍ አዘጋጅ አድራሻ:</u>

ስልክ: - +251917306208

ኢ - ሜይል: - dawitgetachew034@gmail.com

<u>መጠይቅ</u>

ክፍል አንድ፡- አጠቃላይ መረጃ

<u>ለሚከተሉት ጥያቄዎች ትክክለኛውን መልስ በመምረጥ አክብቡ፡፡</u>

1. ፆታ ሀ. ወንድ ለ. ሴት

2. እድሜ ሀ. 18-25 ዓመት ለ. 26-35 ዓመት ሐ. 36-45 ዓመት

መ. 45-55 ዓመት ሠ. ከ55 ዓመት በላይ

3, የትምህርት ደረጃ፡ ሀ.የመጀመሪያ ደረጃ(1-8) መ.የመጀመሪያ ዲግሪ

ለ. የሁለተኛ ደረጃ (9-12) ሠ.የሁለተኛ ዲግሪ እና በላይ

ሐ.ዲፕሎማ ረ. ሌላ ከሆነ ይጥቀሱ -

____

4. የስራ ሁኔታ፡ ሀ. የመንግስት ድርጅት ተቀጣሪ ለ. የግል ድርጅት ተቀጣሪ

ሐ. የንግድ ድርጅት ባለቤት መ. ተማሪ

ሠ. ሌላ ከሆነ ይጥቀሱ

____

5. የወር ገቢ በትክክል (በተጠጋጋ ግምት) በብር፡

ሀ. ከ 5,000 በታች ለ. 5,000 እስከ 10,000 ሐ. 10,000 እስከ 15,000

መ. 15,000 እስከ 20,000 ሠ. ከ 20,000 በላይ

ክፍል ሁለት፡ ዝርዝር የጉዞ መረጃ

ለሚከተሉት ጥያቄዎች ትክክለኛ መልስ በመምረጥ አክብቡ፡፡

1.በየቀኑ በሚያደረጉት ጉዞ የትኛዉን የትራንስፖርት አማራጭ ይጠቀማሉ ?

ሀ. በግል ተሸከርካሪ ለ. በህዝብ ትራንስፖርት ሐ. እግር ጉዞ

2.ከአዉቶቢስ ተራ እስከ ላምበረት መነሐሪያ መንገድ ላይ ስላለዉ የትራፊክ መጨናነቅ ሁኔታ መጠን ይግለጹ ?

ሀ. ምንም የትራፊክ መጨናነቅ የለም ለ. በዝቅተኛ ደረጃ አለ

ሐ. በመካከለኛ ደረጃ አለ መ. በከፍተኛ ደረጃ አለ

3.ከቤት ወደ ስራ ቦታ ለመድርስ ምን ያክል ርቅት ይጎዛሉ ?

ሀ. ከ 3 ኪ.ሜ በታች ለ. ከ 3 – 7 ኪ.ሜ ሐ. ከ 7 – 10 ኪ.ሜ

መ. ከ 10 – 14 ኪ.ሜ ሠ. ከ 14 ኪ.ሜ በላይ

4.ከቤት ወደ ስራ ቦታ ለመድርስ ምን ያክል ደቂቃ ይወስድቦታል?

- የትራፊክ መጨናነቅ ሁኔታ ባለበት ሰዓት____________________________________

- የትራፊክ መጨናነቅ ሁኔታ በማይኖረበት ሰዓት____________________________

5. አብዛኛዉን ጊዜ በዚህ የመንገድ መስመር ሲንቀሳቀሱ የጉዞዉ ምክንያት

ሀ. ለትምህርት ለ. ለመገበያየት ሐ. ለመዝናናት መ. ለስራ

መ. ሰው ለመጠያየቅ መ. ለሌላ ዓላማ

6.ከአዉቶቢስ ተራ እስከ ላምበረት መነሐሪያ ባለው መንገድ ላይ የትራፊክ መጨናነቅ ሁኔታ ሚከሰተበትን ጊዜ ይግለጹ

ሀ.በየቀኑ ከስራ መዉጫና መግቢያ ሰዓት ለ. በየቀኑ በማንኛዉም ሰዓት

ሐ.በሳምንት በተወሰኑ ቀናት ከስራ መዉጫና መግቢያ ሰዓት

መ.በሳምንት በተወሰኑ ቀናት በቀኑ በማንኛዉም ሰዓት

ጥያቄ ቁጥር 7 እና 8 በአሽከረካሪዎች ብቻ የሚመለሱ ናቸዉ።

7. ከአዉቶቢስ ተራ እስከ ላምበረት መነሐሪያ ባለው የመንገድ መስመር ላይ ሲጓዙ የተሽከረካሪዎን የነዳጅ ፈጆታ

ሀ. የትራፊክ መጨናነቅ ሁኔታ ሲኖር በኪሎ ሜትር ምን ያክል ሊትር ይፈጃል_________________________

ለ. የትራፊክ መጨናነቅ ሁኔታ ሳይኖር በኪሎ ሜትር ምን ያክል ሊትር ይፈጃል_________________________

ሐ. የትራፊክ መጨናነቅ ሁኔታ ሳይኖር በሰዓት ምን ያክል ሊትር ይፈጃል_________________________

መ. የትራፊክ መጨናነቅ ሁኔታ ሲኖር በሰዓት ምን ያክል ሊትር ይፈጃል_________________________

8. ከአዉቶቢስ ተራ እስከ ላምበረት መነሐሪያ ባለው የመንገድ መስመር ላይ በቀን ምን ያክል ምልልስ ያደርጋሉ ? ______

9.ከአዉቶቢስ ተራ እስከ ላምበረት መናረያ መንገድ ላይ ላለዉ የትራፊክ መጨናነቅ ሁኔታ መነሻ ምክንያት ይሆናሉ ብለዉ ሚያስቡትን መንሴዎች ከስር ባለዉ ሰንጠርዥ ዉስጥ ከ 0 እስከ 5 ደረጃ በመምርጥ ያስቀመጡ

ተ.ቁ	የትራፊክ መጨናነቅ ሁኔታ መንሻ ምክንያቶች	0	1	2	3	4	5
1	ያለዉ የተሽከርካሪዉ ቁጥር ከመንገዱ የማስተናገድ አቅም በላይ መሆን						
2	የመንገዶች ስፋት ወጥ አለመሆን (አንዱ ጋር ሰፊ ሌላ ቦታ ጠባብ)						
3	መንገዱን የሚያቋርጡና የመንገዱ የተወሰነ ክፍል ይዘዉ የሚንቀሳቀሱ የእግረኞች ቁጥር መብዛት						
4	የአብዛኛዉ ሰዉ ለተለያዩ ዓላማዎች የሚሄድበት እና የሚመለስበት ሰዓት አንድ መሆን						
5	የመንግዱ ምቾት መጓደል (የአስፋልት መቦርቦር እና መሻከረ)						
6	ያለተቀናጀ የመሬት አጠቃቀም (የመኖረያ እና የስራ እንዲሁም ሌሎች የአገልግሎት ሰጪ ተቋማት መራራቅ						
7	በተቀሰዉ የመንገድ መስመር ላይ በቂ የህዝብ ትራንስፖርት አለመኖር						
8	የትራፊክ አድጋ ክስተት						
9	የአደባባይ ችግር						
10	የትራፊክ ማኔጅመንት ችግር (የትራፊክ ችግረ በሚከሰትበት ወክት የትራፊክ ፖሊስ በስፈራዉ በፈጥንት ያለመድረስ ችግረ)						
11	በሕገ ወጥ መንገድ ተሽከርካሪ መንገድ ዳር ማቆም						
12	በቂ የተሽከርካሪ ማቆሚያ ቦታ አለመኖር						
13	ህገ_ወጥ የመንገድ ላይ ንግድ						

ማሳሰቢያ፡- ከላይ በሰንጠረዥ ዉስጥ ከ 1 እስከ 5 የተቀመጡት ቁጥሮች የሚከተለዉን ሃሳብ ይወክላሉ፡-

0 = መነሻ ምክንያት ሆኖ ተከስቶ አያዉቅም 1 = እምብዛም እንደ መነሻ ምክንያት አይዎሰድም 2 = በዝቅተኛ ደረጃ መነሻ ምክንያት ነዉ 3 = በመካከለኛ ደረጃ መነሻ ምክንያት ነዉ 4 = በከፈተኛ ደረጃ መነሻ ምክንያት ነዉ 5 = ችግሩ በከፍተኛ እና በአስጊ ደረጃ ላይ ነዉ

10.ሌላ በሰንጠረዥ ዉስጥ ከተዘርዘሩት ከአዉቶቢስ ተራ እስከ ላምበረት መነሐሪያ መንገድ ላይ ላለዉ የትራፊክ መጨናነቅ ሁኔታ መንሻ ምክንያት ይሆናሉ ተብለዉ በጥናት ጽሁፍ አቅራቢዉ ከቀረቡት ዉጪ እረሶ በግሎ መነሻ ምክንያትይሆናሉ ብለዉ ሚያስቡት ካለ በባዶ ቦታ ላይ ይዘርዝሩ :---
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11。 ከአዉቶቢስ ተራ እስከ ላምበረት መነሐሪያ መንገድ ላይ ላለዉ የትራፊክ መጨናነቅ ችግር ይቀርፋል ብለዉ የሚያስቡትን መፍትሔዎች በሚከተለዉ ባዶ ቦታ ላይ ይዘርዝሩ፡--
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12。 እንደ አስተያየት የሚሉት ነገር ካለ?---

‘‘ ውድ የሆነ ሰዓትዎን ሰዉተዉ ይህን መጠይቅ ስለ ሞሉ እናመሰግናለን ’’

APPENDIX II: Summary of coefficient of correlation matrix

Model	X_3	X_{12}	X_8	X_6	X_5	X_9	X_{11}	X_2	X_{10}	X_4	X_7	X_1
X_3	1.00	0.13	0.14	0.19	-0.2	0.0	0.1	0.1	0.2	0.1	.207	0.1
X_{12}	0.13	1.00	-0.10	-0.10	0.1	0.2	-0.1	.212*	0.2	0.1	0.0	0.0
X_8	0.14	-0.10	1.00	0.06	-0.1	0.0	0.0	0.1	0.1	.262	.341	-0.1
X_6	0.19	-0.10	0.06	1.00	0.0	-0.2	0.1	-0.1	0.2	0.2	.217	0.0
X_5	-	0.07	-0.08	-0.02	1.0	0.4	-0.1	-0.1	0.0	-0.1	-0.1	-0.2
X_9	0.03	0.23	0.01	-0.19	0.4	1.0	0.1	0.0	0.0	0.0	-0.1	-0.1
X_{11}	0.14	-0.13	-0.02	0.13	-0.1	0.1	1.0	-0.2	0.0	0.0	-0.1	0.1
X_2	0.08	0.21	0.06	-0.07	-0.1	0.0	-0.2	1.0	0.0	0.0	0.0	0.1
X_{10}	0.17	0.16	0.15	0.18	0.0	0.0	0.0	0.0	1.0	.203	.292	-0.2
X_4	0.07	0.13	0.26	0.15	-0.1	0.0	0.0	0.0	.203*	1.0	.259	-0.1
X7	0.21	-0.01	0.34	0.22	-0.1	-0.1	-0.1	0.0	.292*	.259	1.0	-0.1
X1	0.08	0.04	-0.08	0.04	-0.2	-0.1	0.1	0.1	-0.2	-0.1	-0.1	1.0

NB:- Where High number of pedestrian that crosses the road(X3), Informal on-street trade (X12), Poor road surface condition (X5), Inadequate parking area (X11), Inflexible work schedule of people (X4), Imbalance between the vehicles volume and road capacity (X1), Bottle neck (X2), Illegal on-street vehicle parking, boarding & alighting (X10), inadequate mass transit service along the corridor (X7), Un-integrated land use (X6). Traffic accident (X8) and Poor traffic management system (X9).

Appendix III: - Phasing Summary for Existing phase Condition

Phasing summary

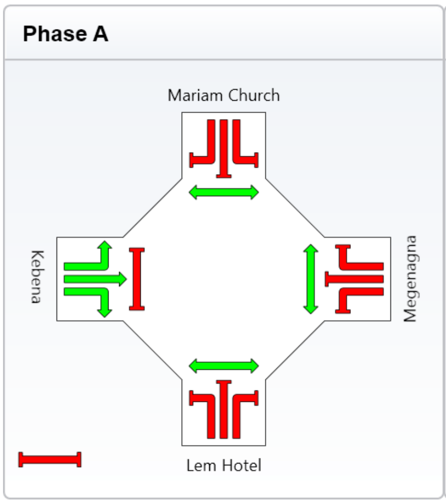
Shola intersection

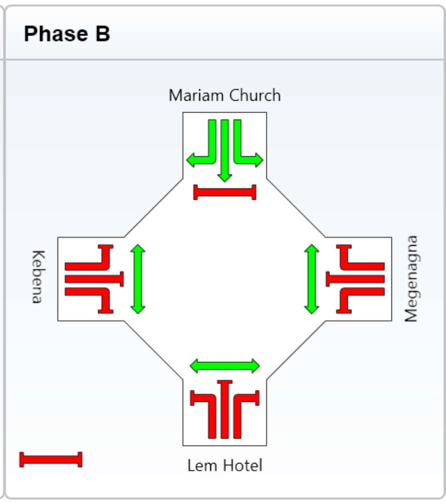
Shola Signalized Intersection
Signals - Fixed Time   Cycle Time = 126 seconds (User-Given Cycle Time)

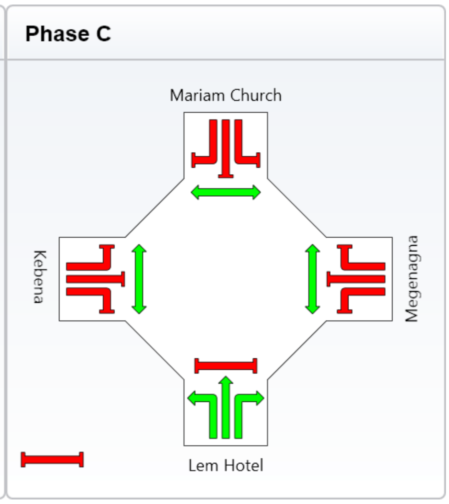
Phase times determined by the program
Sequence: Four-Phase
Input Sequence: A, B, C, D
Output Sequence: A, B, C, D

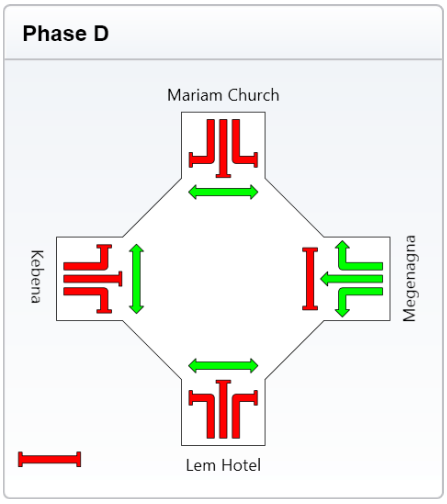
Phase Timing Results

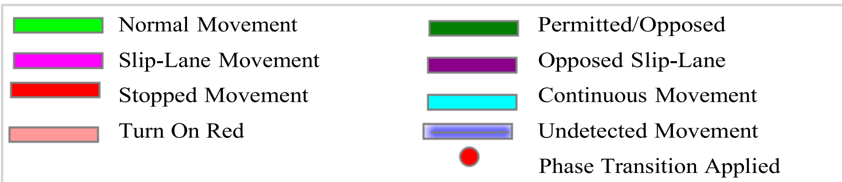
Phase	A	B	C	D
Green Time (sec)	33	15	20	38
Yellow Time (sec)	3	3	4	3
All-Red Time (sec)	2	2	2	2
Phase Time (sec)	38	20	25	43
Phase Split	30%	16 %	30 %	23 %











Appendix IV: - Travel time delay and cost analysis result summary

Date: September 18, 2019			Length of road corridor = 1800 m	Total carriage way width = 18.4m					
Time: 12:00 am – 6:00 pm	PSL = 30 km/h			Corridor name: Road corridor section A					
Duration	Average travel Time (Sec)	Delay (sec)	Average Travel Speed (km/h)	Traffic Volume (Veh)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle - Min)	Total Segment Delay (Person - Min)	Delay Per Traveler (Annual Hours)
12:00 pm - 12:15 pm	522	306	12.41	321	27.6	77078.52	1637.1	45183.96	21.3
12:15 pm - 12:30 pm	720	504	9	253	17.4	52826.4	2125.2	36978.48	35.0
12:30 pm - 12:45 pm	330	114	19.6	184	29.4	29752.8	349.6	10278.24	7.9
12:45 pm - 1:00 pm	240	24	27	154	15	9240	61.6	924	1.7
1:00 pm - 1:15 pm	240	24	27	114	11.6	5289.6	45.6	528.96	1.7
1:15 pm - 1:30 pm	378	162	17.14	244	33	50727.6	658.8	21740.4	11.3
1:30 pm - 1:45 pm	252	36	25.71	277	18	20941.2	166.2	2991.6	2.5
1:45 pm - 2:00 pm	300	84	21.6	211	22.4	23632	295.4	6616.96	5.8
2:00 pm - 2:15 pm	276	60	23.47	166	8.7	6643.32	166	1444.2	4.2
2:15 pm - 2:30 pm	384	168	16.87	215	14.8	20364.8	602	8909.6	11.7
2:30 pm - 2:45 pm	180	0	36	202	17.6	10665.6	0	0	0.0
2:45 pm - 3:00 pm	188	0	34.46	312	25	24440	0	0	0.0
3:00 pm - 3:15 pm	438	222	14.79	266	9.4	18252.92	984.2	9251.48	15.4
3:15 pm - 3:30 pm	540	324	12	216	16.7	32464.8	1166.4	19478.88	22.5
3:30 pm - 3:45 pm	480	264	13.5	216	14.28	24675.84	950.4	13571.712	18.3
3:45 pm - 4:00 pm	402	186	16.2	300	18	36180	930	16740	12.9
4:00 pm - 4:15 pm	300	84	21.6	320	10.45	16720	448	4681.6	5.8
4:15 pm - 4:30 pm	450	234	14.4	293	26.7	58673.25	1142.7	30510.09	16.3
4:30 pm - 4:45 pm	700	484	9.25	256	17	50773.33	2065.067	35106.1333	33.6
4:45 pm - 5:00 pm	640	424	10.12	150	32.5	52000	1060	34450	29.4
5:00 pm - 5:15 pm	860	644	7.53	203	22.5	65467.5	2178.867	49024.5	44.7
5:15 pm – 5:30 pm	720	504	9	123	17.3	25534.8	1033.2	17874.36	35.0
5:30 pm – 5:45 pm	820	604	7.9	215	23	67581.66	2164.333	49779.6667	41.9
5:45 pm - 6:00 pm	915	699	7.08	244	15.6	58047.6	2842.6	44344.56	48.5

Enumerators: Dawit G., Temam A., Jemal B., Naol S., Biruk S., Kaleab A., Alemseged E., Daniel X., Abdi T. and Yonas N.

Date: September 18, 2019 Time: 7:00 am – 12:00 pm Length of road corridor = 1800 m Total carriage way width = 18.4 m

PSL = 30 km/hr Corridor name:- Road corridor Section A

Duration	Average travel Time (Sec)	Delay (sec)	Average Travel Speed (km/h)	Traffic Volume (Veh)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle - Min)	Total Segment Delay (Person - Min)	Delay Per Traveler (Annual Hours)
7:00 am - 7:15 am	420	204	15.42	155	24	26040.	527	12648	14.17
7:15 am - 7:30 am	360	144	18	178	14.7	15699.	427.2	6279.84	10.00
7:30 am - 7:45 am	615	399	10.5	206	35	73902.	1369.9	47946.5	27.71
7:45 am - 8:00 am	540	324	12	240	11.5	24840.	1296	14904	22.50
8:00 am - 8:15 am	760	544	8.52	300	15	57000.	2720	40800	37.78
8:15 am - 8:30 am	780	564	8.3	254	8.3	27406.	2387.6	19817.08	39.17
8:30 am - 8:45 am	840	624	7.7	213	14	41748.	2215.2	31012.8	43.33
8:45 am - 9:00 am	600	384	10.8	165	11.7	19305.	1056	12355.2	26.67
9:00 am - 9:15 am	408	192	15.8	189	3	3855.6	604.8	1814.4	13.33
9:15 am - 9:30 am	480	264	13.5	218	10.5	18312.	959.2	10071.6	18.33
9:30 am - 9:45 am	300	84	21.6	142	22.4	15904.	198.8	4453.12	5.83
9:45 am - 10:00 am	450	234	14.4	211	16	25320.	822.9	13166.4	16.25
10:00 am - 10:15 am	340	124	19.05	274	22.5	34935.	566.2667	12741	8.61
10:15 am - 10:30 am	378	162	17.14	125	33	25987.	337.5	11137.5	11.25
10:30 am - 10:45 am	300	84	21.6	202	15.6	15756.	282.8	4411.68	5.83
10:45 am - 11:00 am	288	72	22.5	254	34.2	41696.	304.8	10424.16	5.00
11:00 am - 11:15 am	342	126	18.94	100	17	9690.0	210	3570	8.75
11:15 am - 11:30 am	444	128	14.58	153	31.5	35664.	326.4	10281.6	8.89
11:30 am - 11:45 am	252	36	25.71	254	21	22402.	152.4	3200.4	2.50
11:45 am - 12:00 pm	336	120	19.3	148	16	13260.80	296	4736	8.33

Enumerators: Dawit G., Temam A., Jemal B., Naol S., Biruk S., Kaleab A., Alemseged E., Daniel X., Abdi T. and Yonas N.

Date: September 20, 2019 Time: 7:00 am - 12:00 pm Length of road corridor = 1100 m Total carriage way width = 14m									
Enumerators: Dawit G., Temam A., Jemal B., Naol S., Biruk S., Kaleab A., Alemseged E., Daniel X., Abdi T. and Yonas N.									
Duration	Average travel Time (Sec)	Delay (sec)	Average Travel Speed (km/h)	Traffic Volume (Veh)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle - Min)	Total Segment Delay (Person - Min)	Delay Per Traveler (Annual Hours)
7:00 am - 7:15 am	360	162	11	251	6.8	10240.8	677.7	4608.36	11.3
7:15 am - 7:30 am	420	222	9.45	272	12	22848	1006.4	12076.8	15.4
7:30 am - 7:45 am	570	372	6.94	301	7	20016.5	1866.2	13063.4	25.8
7:45 am - 8:00 am	360	162	11	423	15.2	38577.6	1142.1	17359.92	11.3
8:00 am - 8:15 am	420	222	9.5	256	26.4	47308.8	947.2	25006.08	15.4
8:15 am - 8:30 am	600	402	6.6	315	11	34650	2110.5	23215.5	27.9
8:30 am - 8:45 am	480	282	8.25	334	31.5	84168	1569.8	49448.7	19.6
8:45 am - 9:00 am	420	222	9.5	314	22	48356	1161.8	25559.6	15.4
9:00 am - 9:15 am	480	282	8.25	281	16.3	36642.4	1320.7	21527.41	19.6
9:15 am - 9:30 am	480	282	8.25	412	12.8	42188.8	1936.4	24785.92	19.6
9:30 am - 9:45 am	720	522	9.42	360	7.3	31536	3132	22863.6	36.3
9:45 am - 10:00 am	480	282	8.25	254	14	28448	1193.8	16713.2	19.6
10:00 am - 10:15 am	900	702	8.25	336	30.2	152208	3931.2	118722.2	48.8
10:15 am - 10:30 am	540	342	5.5	425	15	57375	2422.5	36337.5	23.8
10:30 am - 10:45 am	420	222	8.25	522	27.5	100485	1931.4	53113.5	15.4
10:45 am - 11:00 am	705	507	4.4	326	24	91932	2754.7	66112.8	35.2
11:00 am - 11:15 am	615	417	7.33	200	10.1	20705	1390	14039	29.0
11:15 am - 11:30 am	615	417	9.4	241	8	19762	1674.95	13399.6	29.0
11:30 am - 11:45 am	585	387	5.6	278	11.5	31170.7	1793.1	20620.65	26.9
11:45 am - 12:00 pm	510	312	7.7	255	17	36847.5	1326	22542	21.7

Date: September 20, 2019 Time: 7:00 am - 12:00 pm Length of road corridor = 1100 m Total carriage way width = 14m									
PSL = 30 km/hr Corridor name:- Road Corridor Section B									
Duration	Average travel Time (Sec)	Delay (sec)	Average Travel Speed (km/h)	Traffic Volume (Veh)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle - Min)	Total Segment Delay (Person - Min)	Delay Per Traveler (Annual Hours)
12:00 pm - 12:15 pm	325	327	7.54	186	17.5	17631.25	1013.7	17739.75	22.7
12:15 pm - 12:30 pm	540	342	7.33	265	12.4	29574	1510.5	18730.2	23.8
12:30 pm - 12:45 pm	315	117	12.57	300	11	17325	585	6435	8.1
12:45 pm - 1:00 pm	480	282	8.25	175	17	23800	822.5	13982.5	19.6
1:00 pm - 1:15 pm	240	42	16.5	203	10	8120	142.1	1421	2.9
1:15 pm - 1:30 pm	270	72	14.67	145	14.3	9330.75	174	2488.2	5.0
1:30 pm - 1:45 pm	465	267	8.51	256	7	13888	1139.2	7974.4	18.5
1:45 pm - 2:00 pm	180	0	22	322	5	4830	0	0	0.0
2:00 pm - 2:15 pm	330	132	12	317	13.4	23362.9	697.4	9345.16	9.2
2:15 pm - 2:30 pm	240	42	16.5	277	22	24376	193.9	4265.8	2.9
2:30 pm - 2:45 pm	300	102	13.2	324	25.7	41634	550.8	14155.56	7.1
2:45 pm - 3:00 pm	342	144	11.57	311	18.5	32794.95	746.4	13808.4	10.0
3:00 pm - 3:15 pm	402	204	9.85	344	7.6	17516.48	1169.6	8888.96	14.2
3:15 pm - 3:30 pm	420	222	9.43	246	10.4	17908.8	910.2	9466.08	15.4
3:30 pm - 3:45 pm	360	162	11	322	24	46368	869.4	20865.6	11.3
3:45 pm - 4:00 pm	402	204	9.85	288	15	28944	979.2	14688	14.2
4:00 pm - 4:15 pm	480	282	8.25	205	24.6	40344	963.5	23702.1	19.6
4:15 pm - 4:30 pm	420	222	9.42	311	9.7	21116.9	1150.7	11161.79	15.4
4:30 pm - 4:45 pm	540	342	7.33	244	15.3	33598.8	1390.8	21279.24	23.8
4:45 pm - 5:00 pm	270	72	14.67	300	17.45	23557.5	360	6282	5.0

Enumerators: Dawit G., Temam A., Jemal B., Naol S., Biruk S., Kaleab A., Alemseged E., Daniel X., Abdi T. and Yonas N.
Date: September 24, 2019 Time: 7:00 am - 12:00 pm Length of road corridor = 1700 m Total carriage way width = 21m

Date: September 24, 2019 Length of road corridor = 1700 m Total carriage way width = 21m

Economical speed = 30km/hr				Corridor name:- Road Corridor Section C					
Duration	Average travel Time (Sec)	Delay (sec)	Average Travel Speed (km/h)	Traffic Volume (Veh)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle	Total Segment Delay (Person - Min)	Delay Per Traveler (Annual Hours)
7:00 am - 7:15 am	437	131	14	172	23.7	29689.7	375.533	8900.14	9.10
7:15 am - 7:30 am	735	429	8.33	204	29.4	73470.6	1458.6	42882.84	29.79
7:30 am - 7:45 am	1224	918	5	279	17.3	98464.6	4268.7	73848.51	63.75
7:45 am - 8:00 am	785	479	7.8	345	16	72220	2754.25	44068	33.26
8:00 am - 8:15 am	662	356	9.24	408	7.2	32411.5	2420.8	17429.76	24.72
8:15 am - 8:30 am	1530	1224	4	325	13	107737.	6630	86190	85.00
8:30 am - 8:45 am	874	568	7	384	15	83904	3635.2	54528	39.44
8:45 am - 9:00 am	1133	827	5.4	256	11.6	56075.9	3528.53	40930.99	57.43
9:00 am - 9:15 am	496	190	12.33	328	33	89478.4	1038.66	34276	13.19
9:15 am - 9:30 am	680	374	9	313	18	63852	1951.03	35118.6	25.97
9:30 am - 9:45 am	1133	827	5.4	511	22.4	216146.	7043.28	157769.5	57.43
9:45 am - 10:00 am	1020	714	6	423	8.7	62561.7	5033.7	43793.19	49.58
10:00 am - 10:15 am	594	288	10.3	351	14.8	51428.5	1684.8	24935.04	20.00
10:15 am - 10:30 am	492	186	12.45	300	17.6	43296	930	16368	12.92
10:30 am - 10:45 am	720	414	8.5	341	25	102300	2352.9	58822.5	28.75
10:45 am - 11:00 am	937	631	6.53	285	9.4	41837.0	2997.25	28174.15	43.82
11:00 am - 11:15 am	480	174	12.75	420	16.7	56112	1218	20340.6	12.08
11:15 am - 11:30 am	588	282	10.4	412	14.28	57656.9	1936.4	27651.79	19.58
11:30 am - 11:45 am	408	102	15	315	18	38556	535.5	9639	7.08
11:45 am - 12:00 pm	1155	849	5.3	302	10.45	60751.0	4273.3	44655.99	58.96

Time: 12:00 pm – 6:00 pm Economical speed = 30 km/h Corridor name: Road Corridor Section C									
Duration	Average travel Time (Sec)	Delay (sec)	Average Travel Speed (km/h)	Traffic Volume (Veh)	Average Vehicle Occupancy (persons/veh)	Travel Time (Person - Min)	Total Segment Delay (Vehicle - Min)	Total Segment Delay (Person - Min)	Delay Per Traveler (Annual Hours)
12:00 pm - 12:15	827	521	7.4	256	26.7	94211.84	2222.933	59352.32	36.2
12:15 pm - 12:30	765	459	8	314	17	68059.50	2402.1	40835.7	31.9
12:30 pm - 12:45	651	345	9.4	526	11.5	65631.65	3024.5	34781.75	24.0
12:45 pm - 1:00 pm	534	228	11.45	312	22	61089.60	1185.6	26083.2	15.8
1:00 pm - 1:15 pm	332	26	18.45	294	18.55	30177.14	127.4	2363.27	1.8
1:15 pm - 1:30 pm	624	318	9.8	435	15	67860.00	2305.5	34582.5	22.1
1:30 pm - 1:45 pm	437	131	14	321	8.5	19872.58	700.85	5957.225	9.1
1:45 pm - 2:00 pm	490	184	12.48	324	23	60858.00	993.6	22852.8	12.8
2:00 pm - 2:15 pm	408	102	15	451	12.8	39255.04	766.7	9813.76	7.1
2:15 pm - 2:30 pm	395	89	15.5	421	7.3	20232.56	624.4833	4558.728	6.2
2:30 pm - 2:45 pm	480	174	12.75	611	14	68432.00	1771.9	24806.6	12.1
2:45 pm - 3:00 pm	874	568	7	652	30.2	286823.4	6172.267	186402.5	39.4
3:00 pm - 3:15 pm	720	414	8.5	415	21.75	108315.0	2863.5	62281.13	28.8
3:15 pm - 3:30 pm	510	204	12	522	14	62118.00	1774.8	24847.2	14.2
3:30 pm - 3:45 pm	588	282	10.4	330	13.4	43335.60	1551	20783.4	19.6
3:45 pm - 4:00 pm	480	174	12.75	456	22	80256.00	1322.4	29092.8	12.1
4:00 pm - 4:15 pm	699	393	8.75	500	10.5	61162.50	3275	34387.5	27.3
4:15 pm - 4:30 pm	510	204	12	305	22.4	58072.00	1037	23228.8	14.2
4:30 pm - 4:45 pm	519	213	11.8	545	16	75428.00	1934.75	30956	14.8
4:45 pm - 5:00 pm	504	198	12.14	478	22.5	90342.00	1577.4	35491.5	13.8
5:00 pm - 5:15 pm	480	174	12.75	311	33	82104.00	901.9	29762.7	12.1
5:15 pm – 5:30 pm	592	286	10.33	322	14	44478.93	1534.867	21488.13	19.9
5:30 pm – 5:45 pm	408	102	15	477	33.4	108336.2	810.9	27084.06	7.1
5:45 pm - 6:00 pm	646	340	9.47	321	15	51841.50	1819	27285	23.6