Evaluation of Traffic Congestion and Level of Service at Major Intersections in Adama City

By

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Addis Ababa University

August, 2015

Addis Ababa University

School of Graduate Studies

Addis Ababa Institute of Technology

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A thesis submitted to the School of Graduate Studies of Addis Ababa University in Partial fulfillment of the Degree of Masters of Science in Civil Engineering under Road and Transport Engineering.

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Acknowledgment

First and for most my gratitude goes to Adama Science and Technology University financing my study at Addis Ababa University for last two years.

I cannot fully express my gratitude to my advisor Dr. Bikila Teklu, his generosity and superb guidance starting from proposal writing to the completion of this thesis was vital for the success of the thesis work. Without his guidance and valuable comments and suggestions, it would not been simple to shape this study at this current format.

I would like to extend my heartfelt acknowledgment to the staff members of ASTU civil department staff members for their cooperation and assistance during my study. Lastly, I would like to thank my mother Almi friends and family for their love and moral support through their prayer. I am pent-up to the highest degree indebted to Almighty God who gave me health and era to reach here with happiness and glory.

Abstract

The growth of traffic congestion on many streets and highways is a major concern to travelers, administrators, merchants, developers and the community at large. Its detrimental impacts in terms of longer journey times, higher fuel consumption, increased emissions of air pollutants, greater transport and other affected costs and changing investment decisions are increasingly recognized and felt across the country. Congestion reduces the effective accessibility of residents, activities and jobs resulting in lost opportunities for both the public and business. This issue is now days a great concern for Ethiopia and major cities in the country. Due to this evaluation of traffic congestion and determination of level of service with the cause of traffic congestion is the first step.

From these major cities in Ethiopia, Adama city is now affected by traffic congestion. In this study the level of service and congestion measure using SIDRA intersection software and travel time approach respectively and cost of congestion analysis were done for only four most congested intersections. Accordingly traffic volume, travel rate, travel speed, delay rate and ratio and total segment delay were calculated. Finally correlation between traffic accident and congestion measures has been done.

After the analysis there exist 29,189 vehicles per day on Posta-bet intersection only which is found on the main highway. The total segment delay analysis shows 1067veh-min was lost on the selected four approaches. And also on average about 39.6 million birr lost on one approach per year.

KEY WORDS: Level of Service, Congestion Measures, SIDRA Intersection, HCM Manual

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List of Acronyms

FHWA: Federal Highway Administration

GRP: Gross regional product

HCM: Highway Capacity Manual

L: Left Turning

LOS: level of service

R: Right Turning

TH: Through Traffic

TRR: Transportation Research Record

CHAPTER ONE

1. Introduction

1.1. Background of the Study

Traffic congestion is one of many serious global problems of both developed and developing countries. It always exerts a negative externality up on the society. It poses severe threat to economy as well as the environment (Najneen et.al, 2010). Congestion become a common characteristic in urban road transportation system of the cities of developing countries which results in high operation cost, loss of time, high delay, high travel time and increase in fuel consumption (Haregewoin, 2010).

Adama city is one of the fastest growing cities in Ethiopia. The city is working to become the second most significant conference destination in Ethiopia after Addis Ababa which losses 5-8milion birr per intersection only for vehicle and fuel cost annually (Taddesse, 2011). Accordingly traffic congestion is growing extremely in the city. This is due to the increase in traffic volume with high percentage of heavy vehicle together with high pedestrian volume, even though the city administration tries to mitigate the effect.

Therefore, in order to develop strategies to reduce congestion, extensive research has to be conducted. From which this research proposal aims to assess the performance of major intersection and quantifies their level of traffic congestion in the city. The study result can be used to evaluate the proposed congestion mitigation measure and prioritization purpose.

1.2. Statement of Problem

In Adama city traffic congestion has negative effect on road uses day to day activities. This negative effect has never been evaluated before and the causes are not known yet. Now a days traffic congestion become threat in the city economy growth by limiting the mobility of the road uses and increase delay and fuel consumption.

Hence to reduce the congestion problem it is important to assess the possible causes of congestion, the performance of intersection and measure the traffic congestion and the level of services in order to make the traffic flow smooth and effective.

1.3. Research questions

The major research questions are follows:

- What are the main causes of traffic congestion in the city?
- What are the levels of the traffic congestion quantitatively for the selected Intersections?
- What is the level of service for the selected intersections?
- What is the cost of congestion in the city?
- What is the relationship between traffic congestion and traffic accident in the city?
- What are the possible solutions to mitigate traffic congestion in the city?

1.4. Objective of the Study

General objective:

The overall goal of this research is to assess the causes and impact of traffic congestion, quantify the performance and the level of service of the selected intersection in Adama city.

Specific objectives:

- To assess the causes of traffic congestion
- To evaluate the level of service(LOS) and performance of the intersections
- To estimate the cost of traffic congestion at the intersection
- To assess the relationship of traffic congestion and traffic accident
- To suggest some possible solution to the congestion

1.5. Limitation of the Research

Due to different reasons it was challenging to collect traffic data for solid seven days to get accurate traffic volume but the researcher take only one day traffic volume after collecting three days count. Also for the analysis of congestion measures and cost of congestion only one approach are selected for each intersection.

1.6. Significance of the Research

Now a days traffic congestion has a serious effect on once country development so, without a doubt the research on traffic congestion evaluation has a wide range of significance for both the researcher and city administer.

The researcher will have a better understanding regarding the determination of level of service and congestion measures. For the city admiration the research will help them to identify the cause of congestion and prepare a master plane how to remove this effect. The level of service and congestion measures analysis shows the existing situations and using these result we can predict what will happen in the future.

1.7. Research Outline

The thesis work is organized in five chapters and associated Annex.

The first chapter is an introduction that includes back ground, statement of the problem, research questions and objectives and significance of the study as well as the overall thesis outline.

Chapter two covers the review of the main related facts from references used in the study and review of earlier studies. The various studies conducted in specific parts of the entire study area are well described and used in the study.

Chapter three gives a general description of the study area. This includes location, climate, land use/land and cover. Also describes data input for analysis used in the study with clear methods of collection. This chapter also briefs the methodology to be followed to address objectives of the study.

Chapter four is about result and discussion. And the last chapter, chapter five, is concerned with conclusion and recommendation.

Finally, annex in the form of tables and figures and serving as a supporting document to this thesis are attached to make the work a complete one.

CHAPTER TWO

2. Literature Review

Traffic congestion is an extremely annoying feature of road transport. It consumes substantial amounts of valuable time, creates difficulties for scheduling and on-time deliveries, and thus reduces the potential advantages of road transport. Congestion typically occurs at times of high travel demand or as a consequence of accidents or other non-recurring incidents that temporarily reduce a road's capacity. It is associated with external costs in the sense that an additional driver on a road forces everyone else using this same road at the same time to adapt to the higher traffic volume by lowering driving speeds, so other drivers need more time to cover a given distance. (Schrage, 2006).

It is clear that increasing traffic congestion does impose costs upon travelers and affect broader business operations; it has been difficult to develop and apply empirical measures of the extent of the traffic congestion and its economic costs. Even though, proper measuring the extent or level of congestion is an important step for understanding the performance of the existing road network, for evaluation of proposed congestion mitigation measures and for evaluation of cost of congestion (Weisbrod et.al, 2003; Taddesse, 2011).

2.1. Definition of Traffic Congestion

The definition of congestion is imprecise and is made more difficult since people have different perceptions and expectations of how the system should perform based on whether they are in rural or urban areas, in peak or off peak, and as a result of the history of an area (Bertini, 2005). There is no consistent definition of congestion in terms of a single measure or set of measures that considers severity, duration and spatial extent. Measures related to travel time and speed are the most flexible and useful for a wide range of analyses (R. Narayanan et. al.2003). For instant The Federal Highway Administration (FHWA) defines traffic congestion as: “the level at which transportation system performance is no longer acceptable due to traffic interference.”

According to Lomax et.al, 1997, traffic congestion definition depends on the understanding of the road users. Based on this the definition is divided as congestion and unacceptable congestion and it is defined as:

- Congestion is travel time or delay in excess of that normally incurred under light or free flow travel condition.
- Unacceptable congestion is travel time or delay in excess of an agreed upon norm.

Traffic congestion refers to incremental delays and vehicle operating costs caused by interactions among vehicles, particularly as traffic volumes approach roadway capacity (Todd Litman). Generally definitions of traffic congestion generally fall in to two major categories. These are definitions which based on the cause and the impact of traffic congestion.

Traffic congestion may be recurrent and nonrecurring. Recurrent congestion occurs at the same place at the same time every weekday or weekend. It is a capacity problem and is logically combated with raising roadway capacity. Nonrecurring congestion results from incidents such as accidents, inclement weather or road way maintenance (Lomax et.al, 1997).

2.2. Source and Impact of Traffic Congestion

In 2010, McGroarty explained the source of traffic congestion varies with the congestion type. Hence, recurring congestion occur when the volume of traffic exceeds the roadway capacity while nonrecurring congestion occur mostly by crashes and incident, vehicle breakdown, road construction activities, special events etc. Similarly, Lomax et.al, 1997, supports traffic congestion usually result when the road system is unable to accommodate traffic, conflict among the different type of traffic and traffic control improper uses.

European Conference of Ministers of Transport suggested the sources of traffic congestion as a reduction in road capacity caused by an unplanned event, for example, an accident with wrecks blocking a lane; a planned reduction in capacity due to construction or maintenance of the lane and finally a traffic demand higher than the maximum flow capacity as per European conference of ministers of transport.

According to a research done by Cambridge Systematics, Inc., 2004 with Texas Transportation Institute Traffic Congestion has several root causes that can be broken down into two main categories and summarized the finding in Figure 2.1:

1. Too much traffic for the available physical capacity to handle:

- Bottlenecks

2. Traffic-influencing events:

- Traffic Incidents Such As Crashes And Vehicle Breakdowns;
- Work Zones;
- Bad Weather;
- Special Events; And
- Poorly Timed Traffic Signals.

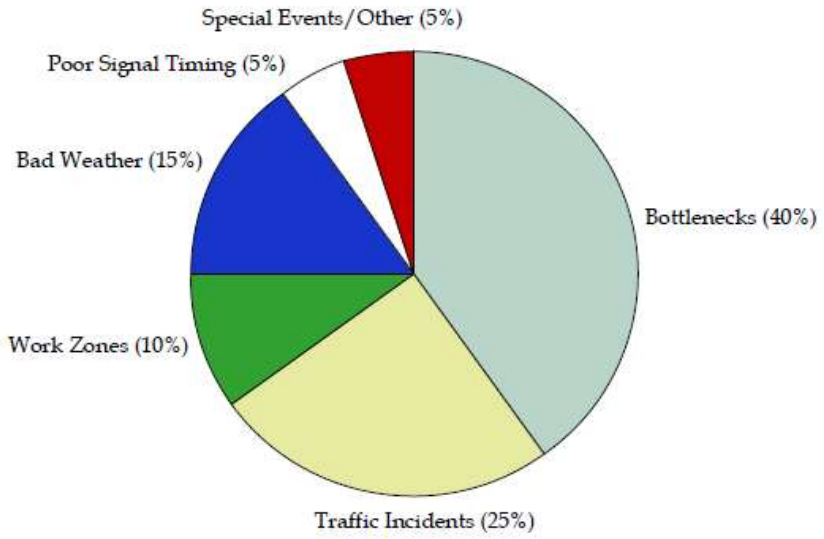

Figure 2.1: Source of Traffic Congestion

The growth of traffic congestion on many streets and highways is a major concern to travelers, administrators, merchants, developers, and the community at large. Its detrimental impacts in terms of longer journey times, higher fuel consumption, increased emissions of air pollutants, greater transport and other affected costs, and changing investment decisions are increasingly recognized and felt across the country. Congestion reduces the effective accessibility of residents, activities, and jobs, resulting in lost opportunities for both the public and business (Herbert & Lomax, TRR 1564).

General traffic congestion has impacts on the economy, environment, and commuters (McGroarty, 2010). European conference of ministers of transport states that congestion involves queuing, slower speeds and increased travel times, which impose costs on the economy and generate multiple impacts on urban regions and their inhabitants. Also it has a range of indirect impacts including the marginal environmental and resource impacts of congestion, impacts on

quality of life, stress, and safety as well as impacts on non-vehicular road space users such as the users of sidewalks and road frontage properties. Although, traffic congestion increase fuel consumption and emit high level of CO_2 correspondingly high greenhouse gas emission on the environment (Spalding, 2008).

2.3. Congestion Measures

Traffic congestion is an unavoidable part of modern-day life. To understand the nature of congestion and to control its growth, a system for measuring the severity of traffic congestion is needed. Such a measure provides the foundation for traffic engineers and policy makers to identify problems and determines the effectiveness of mitigation strategies. In addition, a consistent and uniform measure will allow comparison of traffic conditions at different locations and also over time at the same location so that priorities for improvements can be developed, which helps the public to understand the traffic conditions objectively (S. Hamad & S. Kikuchi, TRR 1802).

Congestion continues to grow in America's urban areas. In 2003, congestion caused increase of 79 million hours and 69 million gallons of wasted fuel from 2002 to a total cost of more than $63 billion (Schrank & Lomax, 2005). This result shows that how traffic congestion has a great effect on once national economy and need to be measured or quantified before it cause irreversible problem. Traffic congestions measures vary depending on the need, from the traditional volume capacity ration to more complicated empirical equations (Lomax et.al, 1997).

Traffic congestion can be measured based on roadway volume to capacity ratios (V/C). A V/C less than 0.85 is considered under-capacity, 0.85 to 0.95 is considered near capacity, 0.95 to 1.0 is considered at capacity, and over 1.0 is considered over-capacity or simply use Level-of-Service (LOS) ratings, a grade from A the best to F worst. Also Congestion is a non-linear function, so as a road approaches its maximum capacity, small changes in traffic volumes can cause proportionately larger changes in congestion delays. (Victoria Transport Policy Institute, 2013). On the other hand Lomax, 1997 suggested measure related to travel time, delay and speed are more flexible and useful for wide range of analysis and also it is easily understandable by the professionals and the public. Further congestion measures can be explained by indexes like travel

time index, delay rate index, delay ratio. Some of the congestion measures are summarized in Table 2.1 below.

Table 2.1: Summary of Congestion Measures

Travel Rate	$\underset{(minutes\ per\ mile)}{Travel\ Rate} = \frac{Travel\ Time\ (minutes)}{Segment\ Length\ (miles)} = \frac{60}{Average\ Speed\ (mph)}$
Delay Rate	$\underset{(minutes\ per\ mile)}{Delay\ Rate} = \underset{(minutes\ per\ mile)}{Actual\ Travel\ Rate} - \underset{(minutes\ per\ mile)}{Acceptable\ Travel\ Rate}$
Total Segment Delay	$\underset{(vehicle-minutes)}{Total\ Segment\ Delay} = \left[\underset{(minutes)}{Actual\ Travel\ Time} - \underset{(minutes)}{Acceptable\ Travel\ Time}\right] x \underset{(vehicles)}{Vehicle\ Volume}$
Relative Dalay Rate	$Relative\ Delay\ Rate = \frac{Delay\ Rate}{Acceptable\ Travel\ Rate}$
Delay Ratio	$Delay\ Ratio = \frac{Delay\ Rate}{Actual\ Travel\ Rate}$
Congested Travel	$\underset{(vehicle-miles)}{Congested\ Travel} = Sum\ of\ all \left(\underset{(miles)}{Congested\ Segment\ Length} x \underset{(vehicle)}{Traffic\ Volume}\right)$

Source: NCHRP Report 398 "Quantifying Congestion" by Lomax et.al, 1997.

Jenks et.al, 2008 suggested that it is important to know the four components of congestion namely; duration, extent, intensity and reliability to measure congestion easily. Duration is the amount of time congestion affect the travel system. Extent described by estimating the number of people or vehicle affected by congestion. Intensity shows the severity of congestion that affect travel and Reliability described as the variation in the other three components.

2.4. Concept of Level of Service (LOS)

The level of service at any intersection on a highway has a significant effect on the overall operating performance of that highway. Thus, improvement of the level of service at each intersection usually results in an improvement of the overall operating performance of the highway. An analysis procedure that provides for the determination of capacity or level of service at intersections is therefore an important tool for designers, operation personnel, and

policy makers. Factors that affect the level of service at intersections include the flow and distribution of traffic, the geometric characteristics, and the signalization system. A major difference between considerations of level of service on highway segments and level of service at intersections is that only through flows are used in computing the levels of service at highway segments, whereas turning flows are significant when computing the levels of service at signalized intersections. (Nicholy J. & Laster A. 2009)

The concept of quality of service uses quantitative measures that characterize operational conditions within a traffic stream. Level of service is defined as a term which denotes a range of operating conditions which occur on a transportation facility when it is accommodating a range of traffic volumes. Highway capacity manual (HCM) developed by the transportation research board of USA provides some procedure to determine level of service. It divides the quality of traffic into six levels ranging from level A to level F. Level A represents the best quality of traffic where the driver has the freedom to drive with free flow speed and level F represents the worst quality of traffic.

HCM has defined six levels of service, level A to level F based on the mentioned measure of effectiveness. Level of service A represents the zone of free flow. Here the traffic volume will be less; traffic will be experiencing free flow. Level of service B represents zone of reasonably free flow; free flow speeds are still maintained at this level of service. The drivers freedom to choose their desired speed is only slightly restricted. At level of service C, the presence of other vehicles begins to restrict the maneuverability within the traffic stream. At level of service D, the average speeds begin to decline with increasing flows. Freedom to maneuver within the traffic stream is noticeably restricted. Level of service E defines operation at capacity. At this level, the stream reaches its maximum density limit. Finally, Level of service F describes conditions in a queue that has formed behind a point of breakdown or disruption.

Level of service is defined based on the measure of effectiveness (MOE). Typically three parameters are used under this and they are speed and travel time, density, and delay. One of the important measures of service quality is the amount of time spent in travel. Therefore, speed and travel time are considered to be more effective in defining LOS of a facility. Density gives the proximity of other vehicles in the stream. Since it affects the ability of the driver to maneuver in

the traffic stream, it is also used to describe LOS. Delay is a term that describes excess or unexpected time spent in travel. Many specific delay measures are defined and used as MOE's in the highway capacity manual. Generally, the LOS criteria on the HCM are given in the form of average travel speed in Kilometer per hour for road way sections and as a maximum delay in second per vehicle for signalized and un-signalized intersection and summarized in the Table 2.2 and Table 2.3 below considering Highway Capacity Manual 2000.

Table 2.2: Urban Street Levels of Service by Class

	I	II	III	IV
Range of free-flow	90 to 70 km/h	70 to 55 km/h	55 to 50 km/h	50 to 40 km/h
Typical free-flow	80 km/h	65 km/h	55 km/h	45 km/h
Level of Service	Average Travel Speed (km/h)			
A	>72	> 59	> 50	> 41
B	> 56 - 72	> 46 - 59	> 39 - 50	> 32 - 41
C	> 40 - 46	> 33 - 46	> 28 - 39	> 23 - 32
D	> 32 - 40	> 26 - 33	> 22 - 28	> 18 - 23
E	> 26 - 32	> 21 - 26	> 17 - 22	> 14 - 18
F	≤ 26	≤ 21	≤ 17	≤ 14

Source: HCM 2000

Table 2.3: Levels of Service Criteria for Intersections

	SIGNALIZED INTERSECTIONS	UN-SIGNALIZED INTERSECTIONS
Level of Service	Average Control Delay (s/veh)	
A	≤ 10	0 - 10
B	> 10 - 20	> 10 - 15
C	>20 - 35	> 15 - 25
D	>35 - 55	> 25 - 35
E	>55 - 80	> 35 - 50
F	> 80	> 50

Source: HCM 2000

Sidra Intersection previously called Sidra and aaSidra is a software package used for intersection or junction and network capacity, level of service and performance analysis by traffic design, operations and planning professionals. First released in 1984, it has been under continuous

development in response to user feedback. A new major version with network modeling capability and new vehicle movement classes was released in April 2013.

Sidra Intersection is a micro-analytical traffic evaluation tool that employs lane-by-lane and vehicle drive cycle models. It can be used to compare alternative treatments of individual intersections and networks of intersections involving signalized intersections (fixed-time/pretimed and actuated), roundabouts (unsignalized), roundabouts with metering signals, fully signalized roundabouts, two-way stop and give-way (yield) sign control, all-way (4-way and 3-way) stop sign control, merging, single-point urban interchanges, traditional diamond and diverging diamond interchanges, basic freeway segments, signalized and unsignalized midblock crossings for pedestrians, and merging analysis.

Sidra Intersection allows modeling of separate Movement Classes (Light Vehicles, Heavy Vehicles, Buses, Bicycles, Large Trucks, Light Rail/Trams and two User Classes) with different vehicle characteristics. These movements can be allocated to different lanes, lane segments and signal phases; for example for modeling bus priority lanes and signals. (From Wikipedia, the free encyclopedia)

2.5. Traffic Congestion and Accident

There is an ongoing debate among transport planners and safety policy makers as to whether there is any association between the level of traffic congestion and road safety. One can expect that the increased level of traffic congestion aids road safety and this is because average traffic speed is relatively low in a congested condition relative to an uncongested condition, which may result in less severe crashes. The relationship between congestion and safety may not be so straightforward, however, as there are a number of other factors such as traffic flow, driver characteristics, road geometry, and vehicle design affecting crash severity. Previous studies have employed count data models while developing a relationship between the frequency of traffic crashes and traffic flow or density. (Quddus et.al, 2010)

Traffic congestion and road accidents are two external costs of transport and the reduction of their impacts is often one of the primary objectives for transport policy makers. The relationship between traffic congestion and road accidents however is not apparent and less studied. It is

speculated that there may be an inverse relationship between traffic congestion and road accidents, and as such this poses a potential dilemma for transport policy makers. Based on the research done on M25 London orbital motorway, divided into 70 segments, after collecting relevant data on road accidents, traffic and road characteristics. Analysis was done to explore the impact of traffic congestion on the frequency of road accidents using a spatial analysis approach, while controlling for other relevant factors that may affect road accidents. Then, the results suggest that traffic congestion has little or no impact on the frequency of road accidents on the M25 motorway. All other relevant factors have provided results consistent with existing studies. (Chaw w. et.al, 2009)

Similarly research done by Charitha D. et al, explains accidents and congestion are two frustrating events, which can be observed very frequently on roads. Accidents, especially on expressways, can trigger heavy traffic congestions imposing huge external costs and reducing the level of service. Therefore it is obvious that accidents clearly have an impact on congestion. But the opposite, i.e. the effect of congestion on occurrence of accidents, is less studied and still questionable. One can argue that congestion can reduce the high speeds on expressways and as a result of that the accident rate is reduced. But in a congested road section vehicles are closely packed and as a result of that rear-end collisions, back-up collisions as well as side collisions can occur. Therefore it is important to analyze the impact on the accidents by congestion so that the policy makers can implement relevant measures to reduce the external costs of both accidents and congestion.

Different researches and reports identified that traffic accidents are an empirically important trigger of congestion, and they exacerbate pre-existing congestion levels (Schrage, 2006; Hanmer & Wu M., 1999). Although in Addis Ababa a link between the traffic accident and the traffic congestion is significant and efforts made to mitigate the traffic congestion minimize the traffic accident (Taddesse, 2011).

2.6. Cost of Traffic Congestion

Congestion has real costs for all travelers, including truckers both long-haul and local pickup and delivery, household and business service providers such as plumbers, computer technicians, police, and ambulance services, and personal travel such as commuters, vacationers, and

shoppers. Congestion causes more fuel to be used and more emissions to be produced. The extra time spent in congestion causes service providers to make fewer calls per day, leading to higher prices for consumers; this is particularly important for emergency medical, fire, and police services which may be unnecessarily delayed from attending to medical, crime, and disaster situations. Companies with production schedules timed to take advantage of trucks delivering components to an assembly line as they are needed must instead plan for items to arrive early. This consumes space and inventory, expending resources that could otherwise be spent on productive activity. For personal travelers, congestion "steals" time that could be put to better use in the workplace or for social or recreational purposes. (Cambridge Systematics, Inc, 2004)

For everyday travelers, the frustration of traffic is obvious. Understanding the impact on cities and the economy, however, is not as straightforward as many would like. From an economic perspective, congestion's main impact is the lost productivity from more time spent traveling to work rather than working, delaying (or missing) meetings, foregoing interactions among individuals or personal activities due to long travel time and spending more time to accomplish tasks than would otherwise be necessary if we could reliably plan for accomplishing the same things at free-flow speeds.

Increasing traffic congestion does impose costs upon travel cost, affect broader business operations costs, vehicle operating costs, environmental costs and productivity, it has been difficult to develop and apply empirical measures of the extent of those economic costs (Weisbrod et.al, 2003). Even though it is difficult to determine the cost of congestion, some researchers determined it by putting their assumption with their results.

In 2009, Hartgen and Fields determine the effect of congestion on gross regional product (GRP); they picked eight cities as representative examples performing detailed modeling and analysis on each. The gross regional product per worker (job) range from $81,700 for Salt Lake City to $125,400 for San Francisco from the eight cities amazingly improving traffic congestion and creating free-flow traffic conditions throughout a region could improvement productivity for workers by as much as 30 percent in highly congested areas.

Similarly, in Addis Ababa on average about 38 Veh-day and 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 on the east-west (Taddesse, 2011).

2.7. Traffic Congestion Mitigation Strategies

Many researchers identified different traffic congestion mitigation measures depends on the causes and the type of congestion. From those researches Managing Urban Traffic Congestion, 2007 conclude there is no prescribe specific congestion management strategies since the appropriateness and applicability of these depends largely on the local context. The report suggests three strategic congestion management principles that should serve to guide policies in this field.

- Ensure that land use planning, and the community objectives it embodies, is coordinated with congestion management policies;
- Deliver predictable travel times; and
- Manage highly trafficked roadways to preserve adequate system performance.

Transportation engineers and planners of Cambridge Systematics, Inc. & Texas Transportation Institute, have developed a variety of strategies to deal with congestion. The strategies can be grouped in to three as follows and each group has key strategies to address congestion:

1. Adding more capacity for highway, transit and railroads

   Key Strategies to Address Congestion:

   - Adding travel lanes on major freeways and streets (including truck climbing lanes on grades)
   - Adding capacity to the transit system (buses, urban rail or commuter rail systems)
   - Closing gaps in the street network
   - Removing bottlenecks
   - Overpasses or underpasses at congested intersections
   - High-occupancy vehicle (HOV) lanes
   - Increasing intercity freight rail capacity to reduce truck use of highways

2. Operating existing capacity more efficiently

   Key Strategies to Address Congestion:

   - Optimizing the timing of traffic signals
   - Faster and anticipatory responses to traffic incidents
   - Providing travelers with information on travel conditions as well as alternative routes and modes
   - Improved management of work zones
   - Geometric improvements to roads and intersections
   - Converting streets to one-way operations
   - Access management.

3. Encouraging travelers to use the system in less congestion-producing ways

   Key Strategies to Address Congestion:

   - Programs that encourage transit use and ridesharing
   - Curbside and parking management
   - Flexible work hours
   - Telecommuting programs

In 2010, Haregewoin summarized the traffic congestion relief strategies on the Total-Ayer Tena road segment which is found in Kolfe Sub city, Addis Ababa. Based on the research congestion relief strategies depends or varies with the existing conditions of the area. Some of the strategies are following;

- Apply flextime working schedules
- Improve capacity of roads
- Improving public transport
- Experiencing adequate parking arrangements
- Implement transit-oriented development and improved access management

CHAPTER THREE

3. Materials and Methods

The methodology in this study includes office and field level investigation of the study area and different methods and techniques applied for data collection and analysis. The methodology of the study also required different materials and methods to arrive at the stated objectives. Therefore, this part of the thesis discusses the methodology followed and the reason for the selection of the methods in order to address the research problem.

3.1. Research Approach

In this thesis the methods followed were designed in such a way that the key questions of the research be answered properly. The research involves both quantitative and qualitative approaches. Quantitative data and analysis were used to determine the level of service of the selected intersections and to measure the congestion levels. As a data source both primary data or direct field measurements and secondary data were the main sources of quantitative data. Although, qualitative data from questionnaire were also used to determine whether the congestion in Adama city is significant or not, select intersections and to assess other related parameters.

3.2. Description of Study Area

Adama is located 100km east of the capital city Addis Ababa. Its climate condition is hot dry with average daily temperature of 30^0c. There is no written history as to when Adama is established, but it is estimated around 1910 GC. Its original name Adama was given after a plant which abundantly found in the area at that time which is called Hadami in local language. Around 1948 GC Emperor Haile Selassie renamed the town Nazareth after Biblical Nazareth. But in the year 2000, the city officially reverted to its original Oromo language name, Adama.

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia, Adama city has a total population of 220,212, an increase of 72.25% over the population recorded in the 1994 census. With an area of 29.86 square kilometers, Adama has a population density of 7,374.82 per square kilometer: all are urban inhabitants. This makes the city among the densely populated urban areas in the country. Therefore provision of good public services

would mean the satisfaction of great number of people. One of the services that are provided by the government is transportation.

Adama city is working to become the second most significant conference destination in Ethiopia after Addis Ababa according to the Culture and Tourism Office. The town has several international standard hotels to provide adequate service for any type of conference. The hotels provide services such as swimming pools, internet access, parking lots and meeting halls that make them desirable to tourists and event organizers. If city wants to achieve this goal of being a conference destination focus must be given to assess the cause and evaluate the level of traffic congestion and proved the proper mitigation measures.

3.2.1. Description of Selected Study Intersection

In the city there exist a number of intersections with different type. From these intersections 15 of them has been selected as major intersection on the basis of the importance they give. The intersections are listed in Table 3.1 below.

Table.3. 1: Name and Type of Major Intersection in the City

No.	Intersection Name	Type of Intersection
1	Awragodana intersection	2-leged roundabout
2	Franco intersection	3-leged intersection
3	Bekele Mola Hotel intersection	3-leged intersection
4	Maya Hotel intersection	4-leged intersection
5	Post bet intersection	4-leged roundabout
6	Amede intersection	4-leged intersection
7	Mebrat Haile intersection	4-leged intersection
8	Mariam intersection	4-leged intersection
9	Hospital intersection	3-leged intersection
10	"04" intersection	4-leged intersection
11	Gendegara intersection	4-leged intersection
12	Campus intersection	3-leged intersection
13	Geda Menafesha intersection	3-leged intersection
14	Sartera intersection	4-leged intersection
15	Genb intersection	4-leged intersection

Due to time and budget constraint, the researcher decided to take only four intersections for further analysis. To do so questionnaire was distributed to the population to participate on the selection of most four congested intersection.

The main reason why the populations were invited, is, Traffic congestion definition depends on the understanding of the road users." (Lomax et.al, 1997). According to Lomax et.al, 1997 report the level of traffic congestion is highly depends on the perception of different road users. Considering this the researcher tried to check the perception of different road users by the help of questioner.

The questioner contains two parts; Part-I: General Information and Part-II: Respondent's Perceptions toward traffic congestion in Adama City. Part-I helps to check whether the questioner is distributed to all road users. Part-II is the main part of the questioner which tells us to know Perceptions of road users toward Traffic congestion in Adama City. The distributed questioner is attached in Annex D.

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia, Adama city has a total population of 220,212. The calculated sample size for a population of 220,212, with a confidence level of 90%, and a margin of error (degree of accuracy) of 10% was 68. Then 68 questioners were distributed and the result is presented in Table 3.2.

Table.3. 2: Name of Selected Intersection for the Analysis

No.	Selected Intersection Name	Type of Intersection	Rank
1	Mebrat Haile intersection	4-leged intersection	1st
2	Posta-bet intersection	4-leged roundabout	2nd
3	Franco intersection	3-leged intersection	3rd
4	Genb intersection	4-leged intersection	4th

3.2.1.1. Description of Mebrat Haile Intersection

According to the result of questioner Mebrate haile intersection is the most congested one in the city. It has 4 approaches namely, Post bet Approach, Sartera Approach, Mariam Approach and Tele Approach. Plain view of the intersections is shown in the Figure 3.1.

Figure 3.1: Mebrat Haile Intersection

3.2.1.2. Description of Posta-bet Intersection

This intersection is the second most congested intersection found on the major highway Addis Ababa-Djibouti. It is roundabout with four legs namely, Franco approach, Mebrat haile approach, Amede approach and Sodere approach. Plain view of the intersections is shown in the Figure 3.2.

Figure 3.2: Posta-bet Intersection

3.2.1.3. Description of Franco Intersection

Franco Intersection is a three legged intersection which is located near to the bus station. Maya hotel Approach, Posta bet Approach and Genb Approach the three approaches. The intersection is the third congested one according to the questioner result. Plain view of the intersections is shown in the Figure 3.3.

Figure 3.3: Franco Intersection

3.2.1.4. Description of Genb Intersection

It is the fourth congested intersection and located around "Genb gebeya". It is four legged approaches namely, Franco Approach, Sartera Approach, Kera Approach and Genb gebeya Approach. Plain view of the intersections is shown in the Figure 3.4.

Figure 3.4: Genb Intersection

3.3. Methods of Data Collection and Equipment

In order to test the specific objective of investigation, data's has been collected from the primary and secondary sources. For both data sources recommended techniques and steps has been followed to minimize errors.

The primary data's are collected using the following techniques:

- Questionnaires
- Manual traffic volume counts
- Passenger car unit
- Manual travel time measure
- Field measures.

Questionnaires were distributed randomly for road users (taxi drivers, private car owners, public transport users) to gather information on the perception of the road users about the traffic congestion at major intersection in the city, possible causes of congestion and to identify the most congested four intersections. (Refer section 3.2.1.)

Manually traffic volume counts and travel time data were collected using pan and paper method on the selected intersection and approaches for the traffic volume count and travel time data respectively.

A field measures has been done to gather data on the geometrical features of intersection for the determination of the level of services of the intersections. These include number of lanes, lane width, configurations of lanes, grade, width of median, and movement policy.

The secondary data are:

- Traffic accident data
- Labor cost
- Fuel Consumption and rental cost of Vehicles

Traffic accident data in the city has been collected from the responsible office namely Adama special zone police administration. For the analysis of cost of congestion labor cost, fuel consumption of vehicles and rental cost of vehicles has been collected by performing

interviews with the vehicle owners and vehicle rental offices and the weighted average values has been taken for the analysis.

3.3.1. Traffic Volume Count

Traffic volume studies are conducted to determine the number, movements and classifications of roadway vehicles at a given location. These data can help identify critical flow time periods, determine the influence of large vehicles or pedestrians on vehicular traffic flow or document traffic volume trends. The length of the sampling period depends on the type of count being taken and the intended use of the data recorded. For example, an intersection count may be conducted during the peak flow period. If so, manual count with 15-minute intervals could be used to obtain the traffic volume data.

For the analysis of LOS traffic volume has been counted on each intersection. This is done by considering different type of vehicles and movement mechanism (TH, L and R). To get accurate result it is important to count at least for 7 days but due to economic and time constraint the count was done only for three days. These days have been selected on the basis of information collected from the traffic police office. According to the traffic police office mostly Thursdays and Fridays have the highest volume due to Thursday is market day and Friday is a day most peoples come from different regions for recreational purpose. The researcher chose Tuesday randomly to consider the days with low traffic volume. From this day's Tuesday's traffic count has been rejected due to multiple errors on the first Tuesday count. Finally, Thursday's traffic volume is found to be higher than Fridays except two approaches. Therefore, I took Thursday's traffic volume count for the analysis purpose.

The traffic volume count was made for 12 hours starting the morning 7:30 AM to the evening 7:30 PM at 15 minutes interval. The vehicles were counted in category as cycle, two wheel, three wheel or Bajaj, cars and taxi, 4WD, minibus taxi, Mid-Bus and standard Bus, Light, Medium and Heavy commercial or truck vehicles. The total traffic volume for each approach is summarized in the Table 3.3 below for both Thursday and Friday count. The raw data of traffic volume for each intersection for Thursday count is summarized in Annex-A.

Table.3. 3: Total Traffic Volume for all Approaches

Post bet Intersection					
		Franco Approach	Mebrat Haile Approach	Amede Approach	Sodere Approach
	5/12/2013	7049	6489	5291	10390
Total	6/12/2013	6839	5675	4464	10671
Franco Intersection					
		Posta-bet Approach	Maya hotel Approach	Genb Approach	
	12/12/2013	7462	17688	4913	
Total	13/12/2013	6598	11520	5640	
Genb Intersection					
		Franco Approach	Sartera Approach	Kera Approach	Genb gebeya Approach
	19/12/2013	13904	6868	8401	7382
Total	20/12/2013	10250	5610	5340	6401
Mebrat Intersection					
		Posta-bet Approach	Sartera Approach	Mariam Approach	Tele Approach
	26/12/2013	14190	26229	26252	12268
Total	27/12/2013	9879	18608	22489	10895

3.3.2. Travel Time Data

Travel time or the time required to traverse a route between any two points of interest, is a fundamental measure in transportation. There exists different method for the determination of travel time. Accordingly, the pen and paper technique requires a driver and a recorder, one or two stopwatches, data collection forms and a test vehicle. The test vehicle is driven along the study route throughout the time period of interest. The recorder starts the first stopwatch as the driver passes the first checkpoint, recording the cumulative elapsed time at subsequent checkpoints on the field sheet. A second stopwatch may be used to record the amount of delay time incurred by the test vehicle when slowed or stopped (0 to 8 km/h, or 0 to 5 mph), also noting the cause of the delay. This procedure is followed through the entire course until the time at the final checkpoint is recorded. Several runs are usually made on the same route,

requiring the test vehicle to return to the starting point. Data is typically collected on the study route in the reverse direction with little or no additional cost. The stop watches are reset, a new field data collection sheet is prepared and the above procedure is repeated until the end of the study time period.

For this research, travel time has been measured manually using stop watch by fixing the length in which the vehicle is travelling to determine congestion measures. To perform this first the researcher had selected only one approach with the highest traffic volume for each intersection except for post-bet intersection. For this intersection the researcher took Franco approach which is on the major highway with highest number of large truck then using the above pen and paper technique the data has been collected considering the following sample size.

The sample size has been determined using the following formula from travel time hand book (M.Turner et.al 1998).

Sample size for travel time (n) = $[(t*c.v)/e]^2$

Where: t=Statistical from student t-distribution for specific confidence level

c.v= Coefficient of variance

e=Relative error

Using the above formula the sample size has been found to be 6 for 30-min. Using the input 95% confidence level and 5% error with coefficient of variance 9% for traffic volume less than 15,000 according to travel time hand book Table 3.3 and Table 3.4 which is about Illustrative test vehicle sample size on arterial street and freeways. Finally 8 samples have been conducted for 30-min and the raw data for the travel time of each approach is summarized in Table 3.4.

Table.3. 4: Travel Time Data in Second

Thursday January 2/2014	Travel Time (sec.)															
	Franco Intersection				Posta-bet Intersection				Mebrat haile Intersection				Genb Intersection			
	Maya hotel Approach				Franco Intersection				Posta-bet Intersection				Franco Intersection			
Time	Length=250m				Length=200m				Length=200m				Length= 150m			
7:30-7:45AM	58.9	44.3	55.1	60.8	62.4	72	76.8	56.2	51.2	46.4	51.2	56	35	16	28	20
7:45-8:00AM	96.1	88.2	72.2	63.2	91.2	64.8	97.2	71.2	47.5	52.8	43.1	52.8	31	34	39	34
8:00-8:15AM	121.6	89.3	106.4	121.6	115.2	105.6	94.8	110.4	110.4	86.4	73.6	107.2	48.5	44.5	32	44.5
8:15-8:30AM	91.2	119.7	127.3	131.1	105.6	91.2	105.6	104.4	116.8	76.8	57.6	113.6	51.5	47	18	37.5
8:30-8:45AM	98.8	121.6	153.9	110.2	104.4	108	109.2	93.6	72	113.6	102.4	112	44.5	53.5	43	32
8:45-9:00AM	131.1	102.6	87.4	127.3	121.2	98.4	98.4	100.8	104	59.2	92.8	94.4	43	44.5	28.5	42
9:00-9:15AM	138.7	91.2	68.4	134.9	116.4	94.8	94.8	106.8	54.4	78.4	110.4	86.4	47	38	46.5	36.5
9:15-9:30AM	85.5	134.9	121.6	133	103.2	110.4	103.2	110.4	107.2	89.6	75.2	76.8	36.5	48.5	33.5	38
9:30-9:45AM	123.5	70.3	110.2	112.1	97.2	98.4	105.6	94.8	67.2	68.8	56	97.6	32	56	37	34
9:45-10:00AM	64.6	93.1	131.1	102.6	90	84	126	104.4	60.8	83.2	73.6	84.8	28	48.5	36.5	28
10:00-10:15AM	127.3	106.4	89.3	91.2	86.4	79.2	102	97.2	51.2	60.8	57.6	78.4	35.6	32.8	31.6	33.6
10:15-10:30AM	79.8	81.7	66.5	115.9	103.2	70.8	105.6	90	52.8	62.4	78.4	73.6	31.6	29.6	29.2	27.6
10:30-10:45AM	72.2	98.8	87.4	100.7	99.6	82.8	86.4	84	51.2	67.2	67.2	97.6	20.6	28.6	32.2	19.8
10:45-11:00AM	60.8	72.2	68.4	93.1	93.6	81.6	81.6	104.4	73.6	68.8	89.6	73.6	21.4	26.6	31.8	32.6
11:00-11:15AM	62.7	74.1	93.1	87.4	102	92.4	112.8	108	78.4	89.6	97.6	76.8	30.2	25	35	29.4
11:15-11:30AM	60.8	79.8	79.8	115.9	82.8	91.2	97.2	99.6	84.8	68.8	83.2	52.8	30.2	29	26.6	25.4
11:30-11:45AM	58.9	51.3	108.3	81.7	99.6	87.6	98.4	75.6	62.4	51.2	70.4	65.6	27	25.4	41.4	32.6
11:45-12:00AM	81.7	60.8	77.9	66.5	82.8	74.4	88.8	85.2	89.6	52.8	91.2	73.6	29.8	29.8	28.2	28.2
12:00-12:15AM	64.6	79.8	70.3	81.7	103.2	75.6	104.4	91.2	62.4	44.8	73.6	57.6	28.6	33.8	20.6	27.4
12:15-12:30AM	102.6	74.1	98.8	102.6	82.8	69.6	91.2	79.2	97.6	62.4	91.2	70.4	24.2	34.2	26.2	26.2
12:30-12:45AM	81.7	64.6	87.4	72.2	109.2	82.8	104.4	88.8	73.6	48	60.8	54.4	28.2	23	29.4	29.4
12:45-1:00AM	60.8	98.8	70.3	81.7	91.2	72	81.6	76.8	57.6	48	59.2	54.4	30.2	25.2	25.8	27.8
1:00-1:15PM	66.5	64.6	66.5	98.8	79.2	72	80.4	76.8	56	41.6	57.6	57.6	30.6	34.2	30.2	26.6
1:15-1:30PM	55.1	87.4	79.8	66.5	78	67.2	79.2	79.2	60.8	49.6	72	54.4	24.6	28.6	34.2	31.4
1:30-1:45PM	77.9	100.7	95	74.1	81.6	73.2	90	76.8	67.2	46.4	60.8	52.8	28.6	37.4	31.4	30.2
1:45-2:00PM	76	79.8	81.7	81.7	86.4	70.8	81.6	75.6	70.4	51.2	67.2	72	29.8	31.4	30.6	36.2
2:00-2:15PM	64.6	68.4	74.1	77.9	88.8	74.4	86.4	90	76.8	44.8	70.4	57.6	33	28.2	38.2	32.6
2:15-2:30PM	85.5	64.6	68.4	106.4	93.6	69.6	88.8	79.2	70.4	40	68.8	65.6	28.6	37.4	34.2	30.6
2:30-2:45PM	115.9	74.1	106.4	95	91.2	66	87.6	85.2	62.4	51.2	62.4	64	30.2	40.6	43.4	36.2
2:45-3:00PM	85.5	81.7	93.1	89.3	82.8	74.4	82.8	84	100.8	73.6	91.2	99.2	35.4	45.4	37.4	30.6
3:00-3:15PM	64.6	117.8	70.3	72.2	86.4	72	103.2	79.2	91.2	99.2	78.4	83.2	36.6	36.2	42.6	37.4
3:15-3:30PM	79.8	70.3	100.7	81.7	93.6	78	110.4	98.4	115.2	94.4	108.8	100.8	32.2	40.6	44.6	39.8
3:30-3:45PM	110.2	91.2	127.3	108.3	98.4	91.2	103.2	79.2	118.4	99.2	115.2	120	46	48.5	51.5	37.5
3:45-4:00PM	129.2	112.1	159.6	153.9	103.2	86.4	123.6	100.8	124.8	92.8	118.4	105.6	43	44.5	48.5	42
4:00-4:15PM	138.7	131.1	123.5	138.7	94.8	79.2	112.8	97.2	118.4	88	116.8	113.6	47	49	56	46
4:15-4:30PM	112.1	159.6	112.1	129.2	110.4	98.4	117.6	91.2	110.4	99.2	110.4	112	54	43	49	43
4:30-4:45PM	129.2	184.3	148.2	136.8	105.6	91.2	124.8	90	115.2	96	137.6	105.6	49	49	39.5	43.5
4:45-5:00PM	87.4	110.2	129.2	121.6	104.4	100.8	109.2	85.2	124.8	104	147.2	131.2	55	50.5	31.5	42.5
5:00-5:15PM	148.2	131.1	172.9	155.8	103.2	109.2	118.8	81.6	131.2	121.6	137.6	105.6	49	42	40	36.5
5:15-5:30PM	121.6	165.3	123.5	144.4	106.8	100.8	122.4	91.2	137.6	115.2	164.8	134.4	39.5	28	49	47
5:30-5:45PM	112.1	129.2	138.7	121.6	111.6	99.6	118.8	99.6	126.4	105.6	150.4	129.6	51	48.5	52.5	47.5
5:45-6:00PM	129.2	150.1	81.7	110.2	108	94.8	116.4	111.6	147.2	131.2	156.8	121.6	49	51.5	49.5	38
6:00-6:15PM	184.3	169.1	110.2	157.7	103.2	110.4	111.6	73.2	140.8	121.6	166.4	120	39	43.5	47.5	53
6:15-6:30PM	169.1	148.2	115.9	150.1	102	91.2	124.8	74.4	139.2	134.4	145.6	113.6	53	49	43.5	43.5
6:30-6:45PM	110.2	127.3	108.3	153.9	117.6	97.2	123.6	90	137.6	145.6	158.4	108.8	49	46.5	54	38
6:45-7:00PM	121.6	169.1	93.1	131.1	93.6	104.4	116.4	112.8	89.6	99.2	116.8	99.2	47.5	52	57.5	47
7:00-7:15PM	148.2	144.4	102.6	121.6	103.2	91.2	115.2	91.2	68.8	100.8	107.2	86.4	43.5	44.5	53	53
7:15-7:30PM	112.1	108.3	127.3	96.9	99.6	90	99.6	93.6	86.4	78.4	92.8	78.4	49	38	43	44.5

During travel time data collection, the data collector location is very significant especially when the method of data collection is using stop watch by fixing the length of the road. This

is due to the length that we fix should be visible for the data collector. The selected locations for all intersections are on buildings located at the mid points of the length fixed. These locations are described in the Figure 3.5 up to 3.8.

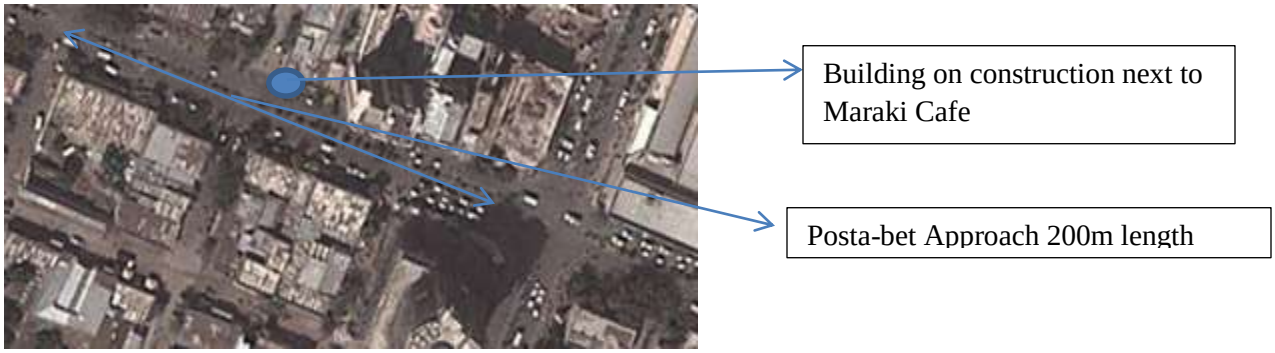

Figure 3.5: Travel Time data Collection Location for Mebrat haile Intersection

Figure 3.6: Travel Time data Collection Location for Posta-bet Intersection

Figure 3.7: Travel Time data Collection Location for Franco Intersection

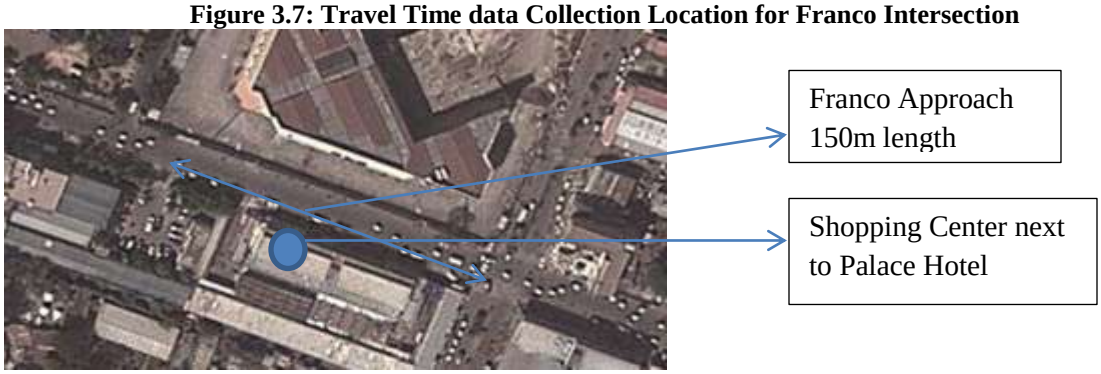

Figure 3.8: Travel Time data Collection Location for Genb Intersection

3.3.3. Passenger Car Unit

Different types of vehicles in a traffic stream have different characteristics like width, length and height and sometimes they produce inconvenience for other vehicles, so for expressing highway capacity a unit is used called passenger car unit. A passenger car unit is essentially the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single car.

According to Ahmed, 2009, several approaches to estimate PCU values have been used. The most commonly applied approaches are the constant volume-to-capacity ratio approach and the headway approach. The constant volume-to-capacity ratio approach was developed based on the output of a multilane freeway simulation model developed at the Midwest Research Institute. PCU values were based on mixed traffic volumes that consumed the same proportion of roadway capacity (produced the same volume-to- capacity ratio) as PC-only volumes. The constant volume-to-capacity ratio approach was appropriate for calculating PCUs when LOS was a consideration for PCU calculation. But it is not applicable to the current procedure, which estimates PCU only under a steady-state condition, that is why headway approaches is used for the determination of PCU for this research.

PCU=hi/hc

Where: PCU=passenger car unit

hi= headway of i-th vehicle

hc= headway of passenger car

Then headways has been collected for each type of vehicles considering three cases; morning, midday and evening peak period and the sample size taken was the same with travel time sample size shown in travel time section. The headways are presented as follow in Table 3.5.

Table.3. 5: Headway in Second

HEADWAY (Second)										
Time	Morning Peak Period									
	Car & Taxi	Cycle	Two wheel	Bajaje	4-WD	Mini Bus	Mediun bus	Std. Bus	Medium Trucks	Large Trucks
1	4.20	9.00	4.30	4.10	4.60	4.70	5.40	7.80	7.20	7.30
2	4.60	8.90	5.10	3.90	4.20	5.20	6.20	8.00	8.30	8.90
3	3.80	9.70	4.10	3.80	4.60	4.80	5.80		7.10	8.50
4	4.30	7.90	3.90	4.10	4.30	4.60	6.30		8.40	8.20
5	4.10	6.80	4.60	3.40	4.60	5.00	4.90		8.30	9.00
6	4.90	8.20		3..9	4.20	4.80	6.20		7.40	10.20
7	2.50			4.20	3.80	4.80	6.50		7.20	8.90
8	3.40			4.60	4.30	5.30	4.80		8.10	8.30
9	4.10			3.80	4.60	4.90	5.70		7.60	7.90
10	3.60			4.30	4.30	5.30	4.80		7.90	10.30
Time	Mid-day Peak Period									
1	3.20	5.30	4.20	3.20	3.80	3.60	4.90	7.20	6.20	6.90
2	3.30	4.90	3.70	3.30	3.90	4.90	4.60	8.20	5.90	7.80
3	3.60	5.10	3.50	3.20	4.20	4.20	6.10		7.10	6.90
4	3.10	4.90	4.30	3.10	2.70	5.70	4.30		6.40	8.40
5	2.90	6.10	3.00	3.00	3.20	5.40	5.40		6.30	6.80
6	3.50		4.20	4.00	2.80	3.90	5.10		5.40	5.70
7	3.60			3.20	3.80	4.60	5.30		7.30	7.40
8	3.70			3.30	3.60	3.90	4.70		6.90	6.90
9	2.80			3.40	3.70	4.20	4.90		8.20	7.80
10	3.30			3.10	3.90	3.90	5.20		7.30	8.60
Time	Evening Peak Period									
1	4.50	7.20	4.30	4.60	4.80	5.30	5.90	7.80	7.30	9.80
2	4.20	5.80	5.10	4.50	4.50	5.20	4.80	7.30	7.80	10.30
3	4.90	6.20	4.30	3.90	3.80	4.80	5.70	9.20	6.90	8.90
4	5.10	4.70	6.20	4.80	4.30	4.90	6.10		7.50	7.90
5	4.30	5.40	3.90	5.30	4.10	4.30	5.80		6.20	10.40
6	3.60	6.20	4.20	4.60	4.70	5.10	6.30		8.00	9.90
7	4.50	4.70	4.30	4.80	3.80	4.20	4.90		7.30	8.70
8	4.40	6.70		4.30	4.70	5.30	5.80		8.30	10.90
9	3.80	5.60		4.10	4.60	4.80	6.90		8.40	9.80
10	4.20			4.10	4.40	4.90	6.70		7.70	10.80

3.3.4. Field Measurements

The field measurements have been conducted on the geometric feature of the intersections selected. Intersection layout is primarily composed of the alignment of the legs, width of traffic lanes, bicycle lanes, crosswalks, sidewalks on each approach, number of lanes, median, street side elements and the method of treating and channelization of turning movements. Like the design of the thoroughfare's cross-section, the design of an intersection's layout requires a balance between the needs of pedestrians, bicyclists, vehicles, freight and transit in the available right of way. Beyond intersection layout, the practitioner needs to work with a multidisciplinary team to address accessibility, traffic control and placement of equipment, traffic operations, lighting (safety and pedestrian scaled), landscaping and urban design.

During field measurement, alignment of the legs, width of traffic lanes, crosswalks, number of lanes, median and the method of treating and channelization of turning movements has been measured on each approach for the selected intersection.

The width of traffic lane and median measurement is done manually using tape meter; the same method is used for the roundabout. The rest of the data were collected by visual observation. The collected data are summarized in the following tables and figures for the four selected intersection.

Table.3. 6: Geometric Data for Mebrat haile Intersection

Mebrat haile Intersection				
Approach	No of lane	Lane width	Median width	Cross walk
Sartera	2	3.5m	2.5m	Yes
Posta-bet	2	3.5m	2.5m	Yes
Mariam	2	3.5m	2.5m	Yes
Tele	2	3.5m	2.5m	Yes

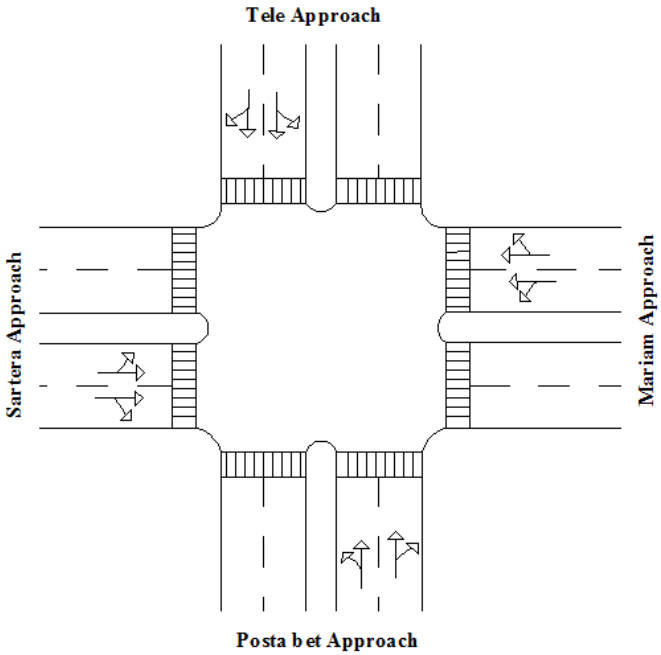

Figure 3.9: Layout of Mebrat haile Intersection

Table.3. 7: Geometric Data for Posta-bet Intersection

Posta-bet Intersection					
Approach	No of lane	Lane width	Median width	Lane type	Cross walk
Franco	2	3.5m	2m	Normal & Giveway	Yes
Amede	2	3.5m	2m	Normal & Giveway	Yes
Mebrat haile	2	3.5m	2m	Normal & Giveway	Yes
Sodere	2	3.5m	2m	Normal & Giveway	Yes
Circulating lane		2			
Circulating width		8.5m			
Island diameter		15m			

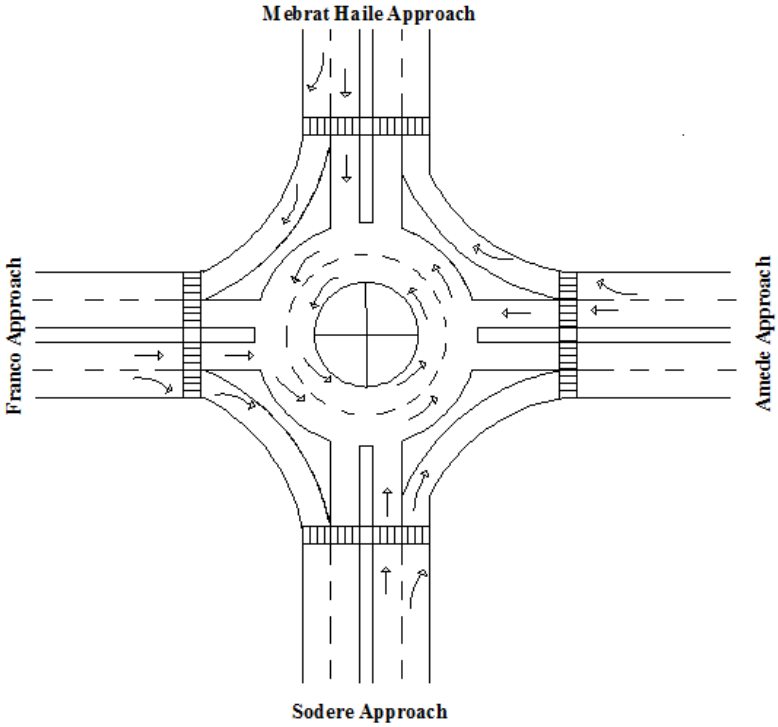

Figure 3.10: Layout of Posta-bet Intersection

Table.3. 8: Geometric Data for Franco Intersection

Franco Intersection				
Approach	No of lane	Lane width	Median width	Cross walk
Maya hotel	2	3.5m	2m	Yes
Posta-bet	2	3.5m	2m	Yes
Genb	1	4m	0	No

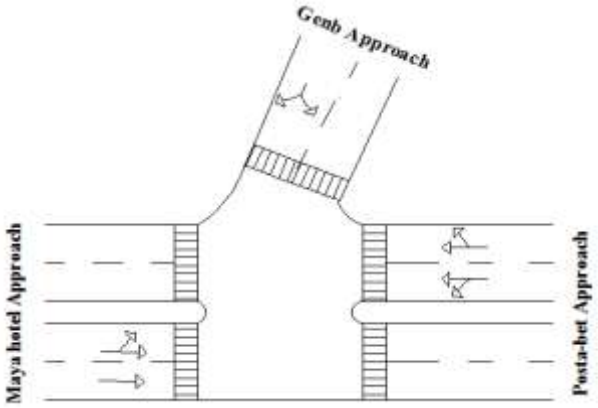

Figure 3.11: Layout of Franco Intersection

Table.3. 9: Geometric Data for Genb Intersection

Genb Intersection				
Approach	No of lane	Lane width	Median width	Cross walk
Franco	1	4m	0	Yes
Sartera	1	4m	0	Yes
Genb-gebeya	2	3m	2m	Yes
Kera	2	3m	2m	Yes

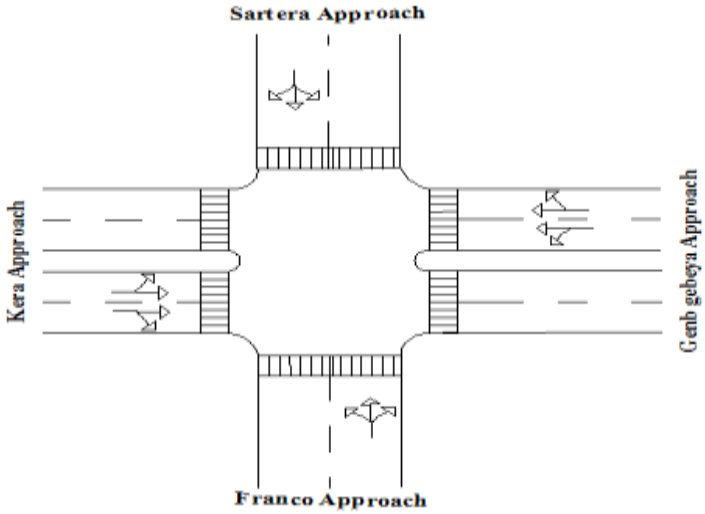

Figure 3.12: Layout of Genb Intersection

3.3.5. Secondary Data

Traffic accident data has been collected from Adama special zone police administration. The office provides the researcher with nine years accident data by time of the day, cause of accident, profiles of drives and etc. But for this particular research the researcher collect only nine years accident data and presented as follow.

Table.3.10: Traffic Accident vs. Accident Severity

Traffic Accident vs. Accident Severity									
Accident Severity	Year								
	1998	1999	2000	2001	2002	2003	2004	2005	2006
Fatal	16	13	25	35	39	24	36	31	22
High	8	13	23	34	36	41	57	29	37
Low	13	7	19	65	27	52	59	52	50
Property Damage	60	42	50	99	116	125	161	175	177

Table.3. 11: Traffic Accident Data by Time of the Day

Total Traffic Accident									
	Year								
Time	1998	1999	2000	2001	2002	2003	2004	2005	2006
7:00AM-8:00AM	10	8	15	21	16	18	24	17	20
8:00AM-9:00AM	15	16	15	17	10	20	26	26	20
9:00AM-10:00AM	6	5	10	13	7	29	25	20	32
10:00AM-11:00AM	6	6	10	10	8	12	22	24	17
11:00AM-12:00AM	5	5	8	8	23	11	19	13	19
12:00Am-1:00PM	4	3	5	14	25	15	21	15	26
1:00PM-2:00PM	5	0	1	9	20	28	15	14	16
2:00PM-3:00PM	4	2	3	12	9	19	16	13	18
3:00PM-4:00PM	4	0	3	11	18	10	27	20	17
4:00PM-5:00PM	5	0	1	14	17	14	25	22	16
5:00PM-6:00PM	4	4	11	7	14	21	21	16	17
6:00PM-7:00PM	7	16	4	6	6	3	14	10	10
7:00PM-8:00PM	4	8	2	3	7	10	15	9	9

CHAPTER FOUR

4. Result and Discussion

Analysis was done on the selected intersection using the collected data's following the proper and best method and the results are presented in the following sections with brief explanation.

4.1. Questionnaire Responses

As discussed in section 3.2.1 questioner was distributed randomly to evaluate the perception of different road users to wards traffic congestion in the city. Out of the distributed 68 questioner 100% of it was returned. Table 4.1 shows questioner respondent profile and Figure 4.1 shows the respondent perception related to the existence and level of traffic congestion at intersections.

Table 4.1: Questionnaire respondents' profile

		Number	Percentage
Questioner	Distributed	68	100.00%
	Returned	68	100.00%
Sex	Male	53	77.94%
	Female	15	22.06%
	Total	68	100.00%
Age Distribution	15-20	7	10.29%
	20-30	30	44.11%
	30-40	13	19.12%
	40-50	10	14.70%
	Above 50	8	11.78%
	Total	68	100.00%

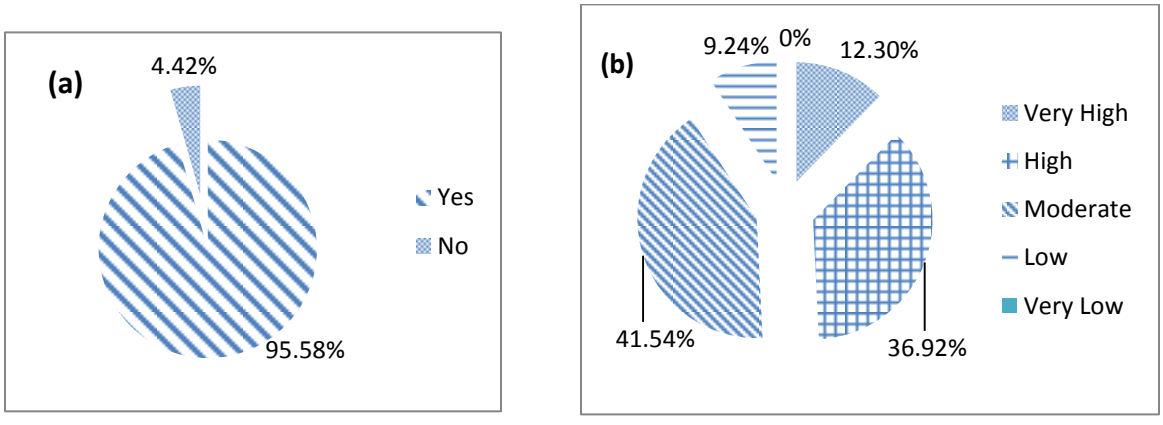

Figure 4.1: Respondent's Perceptions about: (a) Existence of Traffic Congestion and (b) Level of Traffic Congestion at the Intersection

Each respondent was given a chance to rank four intersections they think it is congested for LOS and cost of congestion analysis. Accordingly, the intersection listed in Table 4.2 has been selected for further evaluation. The questioner result shown below was similar with the researcher initial selection except Genb intersection.

Table 4.2: List of Selected Intersection

No.	Selected Intersection Name	Type of Intersection	Totally Selected	Rank
1	Mebrat Haile intersection	4-leged intersection	59	1st
2	Posta-bet intersection	4-leged roundabout	57	2nd
3	Franco intersection	3-leged intersection	53	3rd
4	Genb intersection	4-leged intersection	29	4th

4.2. Traffic Volume and Flow Pattern Analysis

4.2.1. Passenger Car Unit Analysis

Passenger car unit analysis is important because it considers different characteristics like width, length and height that cause serious variations in the traffic stream. Due to this difference each type of vehicle has distinct effect on the traffic steam. Therefor the PCU is important because it compare the effect of different vehicle with respect to single car. Using headway method analysis was made to compute PCU.

Unfortunately this method gave almost same with the average values except cycle and two wheel vehicle, while comparing the result with literature like final report done by Innovative Transport Solutions (iTrans) Pvt.Ltd. on Two and Three wheeler in India (2009) and South African geometric design manual. After this comparison for cycle and two wheel vehicles the calculated values are far from the average values therefore, the PCU values has been taken form these literature's. The result is summarized in the Table 4.3 below and the calculated value has been attached in Annex A Table 5. Finally the result was used for the computation of traffic volume in terms of passenger car unit for the selected intersections.

Table 4.3: PCU Factor Result

Vehicle Type	Cycle	Two wheel	Bajaj	4-WD	Mini Bus	Medium bus	Std. Bus	Medium Trucks	Large Trucks
PCU	0.25	0.5	1	1	1.25	1.5	2	2	2.25

4.2.2. Traffic Volume at Mebrat Haile Intersection

This intersection is located at the center of the city and considered as the most congested by the road users' perception. The traffic count was done for 12hr starting from 7:30AM up to 7:30PM on each approach's. Accordingly Posta-bet, Sartera and Mariam approaches have high number of traffic volume at the morning and evening period but the morning period volume is relatively less than the evening period. When we see Tele approach it has almost uniform traffic volume distribution and low volume of traffic throughout the day. The result is summarized in the Figure 4.2.

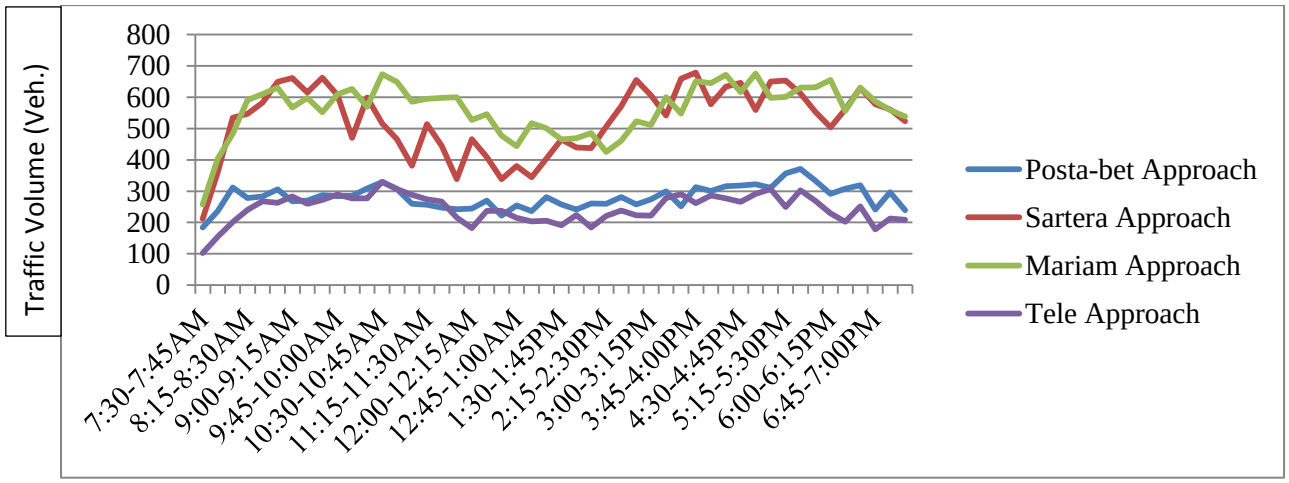

Figure 4.2: Traffic Volume at Mebrat haile Intersection

Figure 4.3 below shows traffic composition by vehicle class. Accordingly, there exist 32,982 vehicles on the four approaches out of this 21,680 vehicles or 65% of the total traffic is composed of Bajaj or three wheel vehicles, passenger cars and mini buses have moderately high but commercial vehicle like std. bus, medium and large trucks have very low volume.

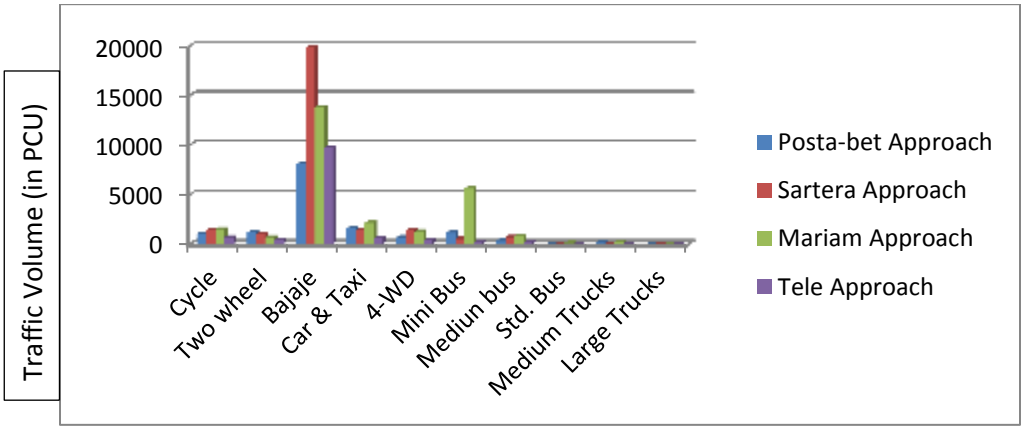

Figure 4.3: Traffic Volume Distribution by Vehicle Type at Mebrat haile Interesction

4.2.3. Traffic Volume at Posta-bet Intersection

Posta-bet intersection is a roundabout intersection found on the main road which connects Addis Ababa with Dire Dawa. The traffic count was performed on the four approaches for 12hr considering all the turning movement independently.

As shown in the Figure 4.4 below Sodere approach has the highest traffic volume and very much variable throughout the day. Next to this approach Franco approach which is found on the main road has the second highest traffic volume and has morning and evening peak period. The rest namely Amede and Mebrat haile approach have moderately high traffic and similarly they have morning and evening peak period.

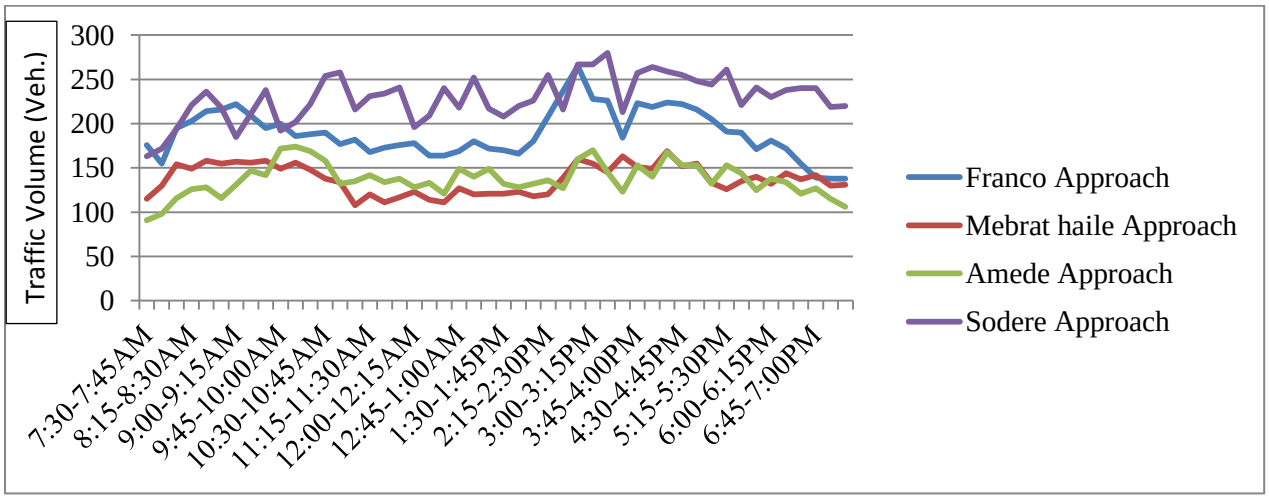

Figure 4.4: Traffic Volume at Posta-bet Intersection

When we see the traffic composition from the total traffic of 29,219 vehicles about 9,165 or 31% are only Bajaj or three wheel vehicles which are found on Sodere and Mebrat haile approach cause Bajaj's are not allowed to travel on the main road. Franco approach has relatively high number of passenger car and commercial vehicles when it is compared with the others according to Figure 4.5.

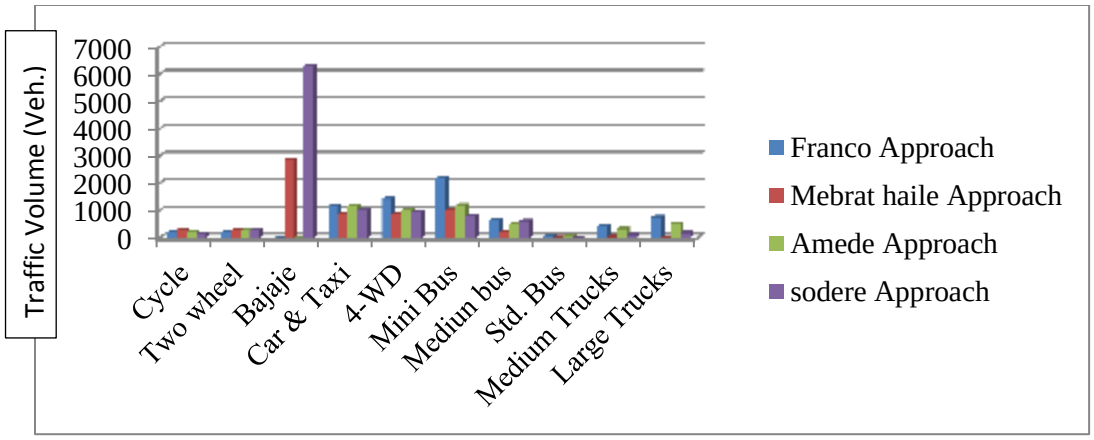

Figure 4.5: Traffic Volume Distribution by Vehicle Type at Posta-bet Intersection

4.2.4. Traffic Volume at Franco Intersection

This intersection is found near the city's bus station and has three approaches. As shown in the Figure 4.6 below Posta-bet approach has the highest traffic volume with both morning and evening peak period. In addition the evening peak period traffic volume is found to be higher than the morning peak period. Similarly Maya hotel approach has relatively higher traffic volume and it has similar characteristics with Posta-bet approach. Finally Genb approach has low traffic volume with uniform distribution of traffic throughout the day.

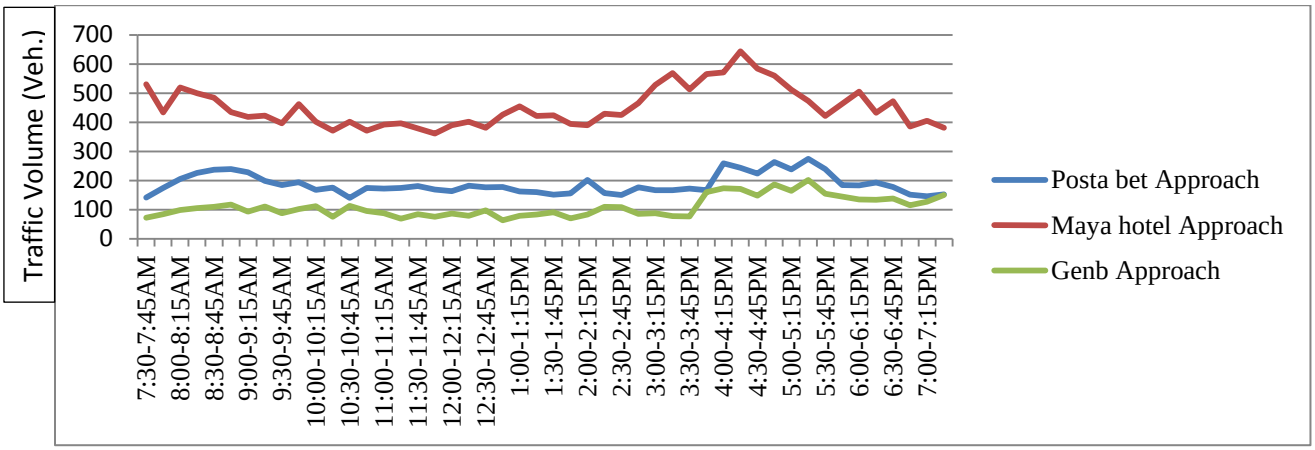

Figure 4.6: Traffic Volume at Franco Intersection

As it is mentioned before the intersection is found near the bus station due to this Figure 4.7 shows there exist 5,322 vehicles or 32% of mini bus from the total of 16,422 vehicles. Again large number of passenger car and commercial vehicles are found on the approach Posta-bet and Maya hotel because this approach found on the main road.

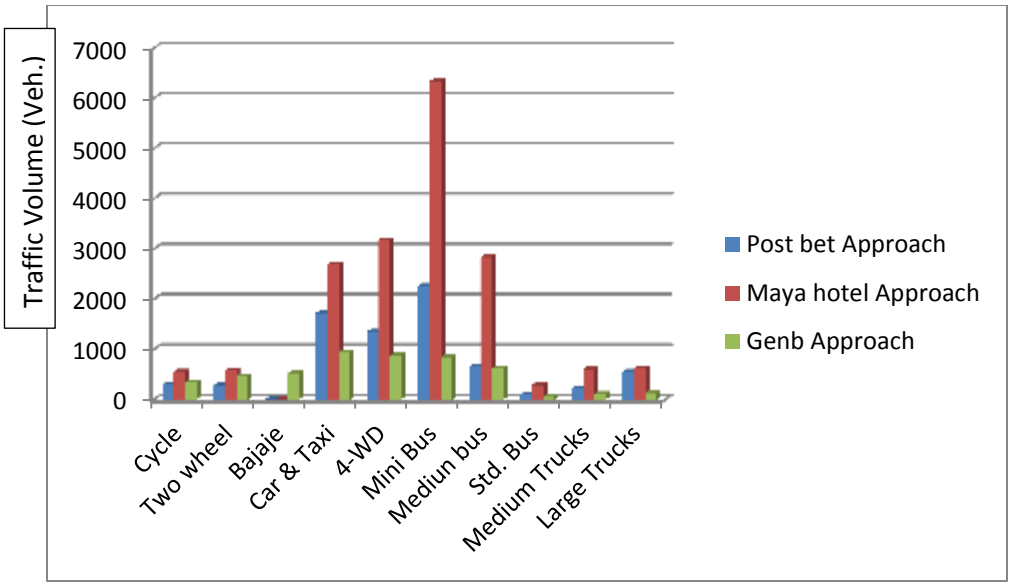

Figure 4.7: Traffic Volume Distribution by Vehicle Type at Franco Intersection

4.2.5. Traffic Volume at Genb Intersection

The intersection has four leg and traffic count was done for 12hr for each intersection. As per the Figure 4.8 Franco intersection which connects the intersection with Franco intersection and the bus station has the highest traffic volume with relatively high evening peak period volume. The others three approaches have relatively moderate traffic volume with similar characteristics with each other.

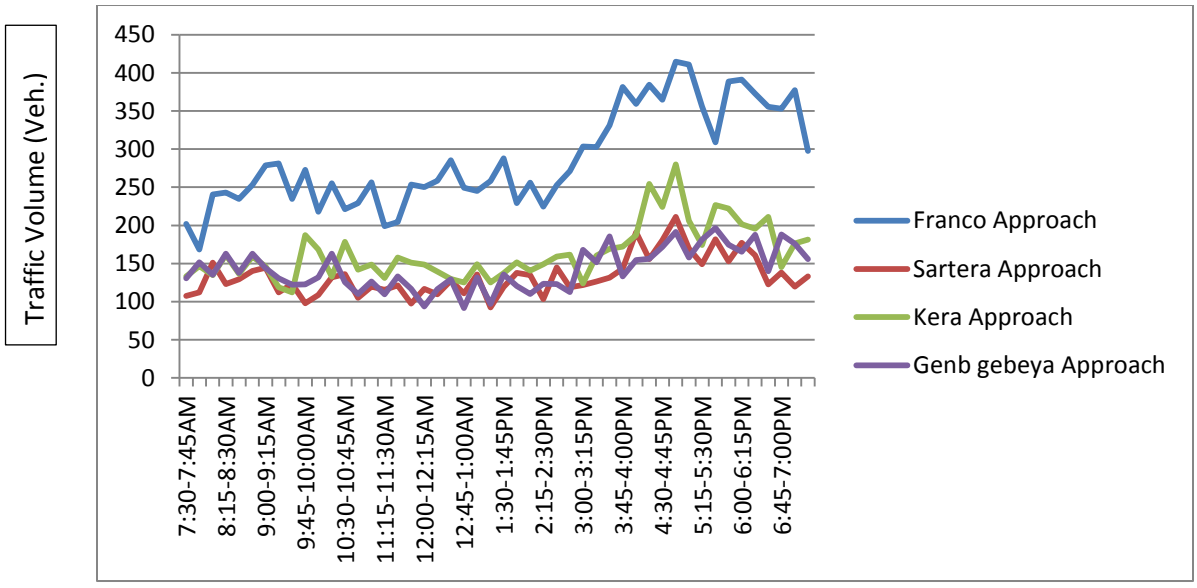

Figure 4.8: Traffic Volume at Genb Intersection

When we see the traffic composition from the total traffic of 23,158 vehicles about 17,463 or 75.4% are only Bajaj or three wheel vehicles which are found on the four approaches. The number of Bajaj is higher because the intersection is located at Genb market center according to Figure 4.9.

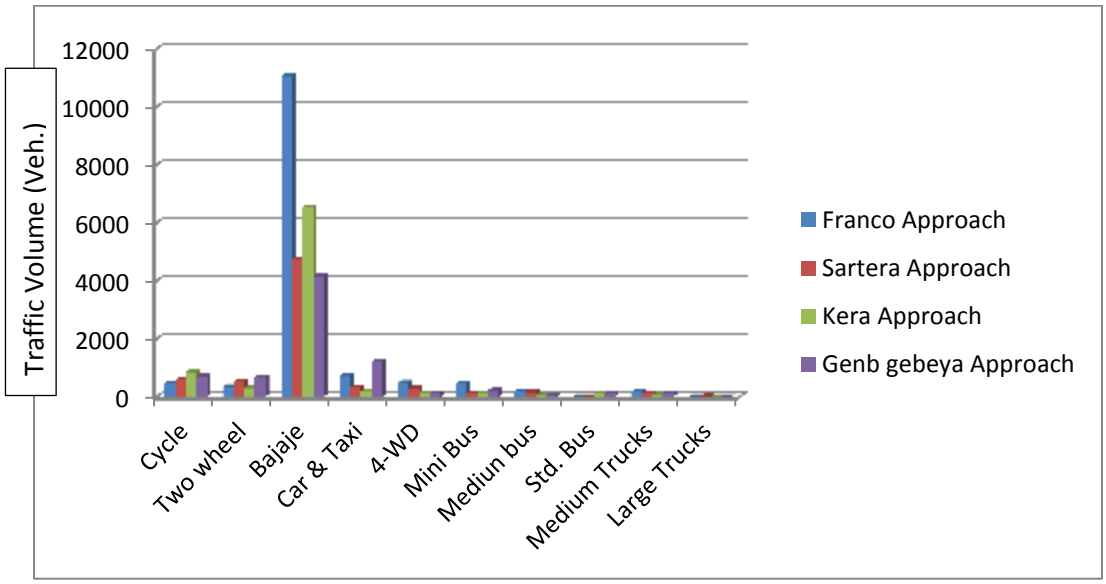

Figure 4.9: Traffic Volume Distribution by Vehicle Type at Genb Intersection

Based on the results presented in section 4.2 traffic volume and flow pattern analysis the following points can be pointed out.

The traffic count was done for solid 12hrs starting from 7:30AM up to 7:30PM on each approach for all intersection considering the turning movement principle. Intersection found on the main highway from Addis Ababa to Dire dawa namely Posta-bet and Franco intersection, the traffic volume distribution as per Figure 4.4 and Figure 4.6 all the approaches have morning and evening peak period except Genb approach on Franco intersection which shows uniform distribution and Sodere approach on Posta-bet intersection which shows variable traffic volume distribution. From Figure 4.5 and Figure 4.7 the traffic distribution considering vehicle type is dominated by car & taxi, 4WD mini & medium bus and medium & large truck for both intersections. But Posta-bet intersection has exceptionally high number of Bajaj's.

The traffic volume distribution at Mebrat haile and Genb intersection which are found around major market centers in the city shows morning and evening peak period for all approaches on Mebrat haile intersection and Franco approach on Genb intersection for the rest the distribution

is uniform with little variation though out the day as per Figure 3.8 and Figure 4.2. Also, Figure 3.3 and Figure 3.9 show the distribution of vehicle by type and Bajaj is the dominant one for both intersections.

4.3. Intersection Level of Service (LOS) Analysis

Using the data collected in the previous section level of service (LOS) analysis was made using aaSIDRA intersection software version 5.0. In order to get the right result proper selection was made to make it compatible with Ethiopian driving rule and HCM 2000 metric version was used.

The level of service (LOS) analysis was made only on the selected four intersections namely:

- Mebrat Haile intersection
- Posta-bet intersection
- Franco intersection
- Genb intersection

Directional traffic hourly flow data, number of pedestrian, peak hour factor, heavy vehicle percentage, number of lane, lane width, median width used from field measure for the analysis of level of service. However default values like saturated flow with the value 1900 Veh/hr have been used as input data for the analysis. Also left turning factor 5 has been used as conversion factor from HCM 2000 manual. This factor is taken because the left lane is shared lane. The default value is adapted from similar analysis done in Addis Ababa by Taddesse W. (2011) unpublished MSc thesis. The input data's for the program are summarized in the Table 4.4. Accordingly the analysis run and the results of the analysis are summarized below in Table 4.5 based on average control delay (sec/veh) levels of service criteria for intersections shown in the Table 2.3 and the outputs of the analysis for each intersection are attached in the Annex B.

Table 4.4: Input Data's for the Analysis of LOS using SIDRA Intersection

						Total Traffic Volume (Veh/hr)			Peak Hour Factor (%)			Heavy Vehicle Factor (%)		
Intersection	Approach leg	Number of Entry Lane	Number of Exit Lane	Lane Width(m)	Median Width (m)	TH	LT	RT	TH	LT	RT	TH	LT	RT
Mebrat Haile	Posta bet	2	2	3.5	2.5	500	564	291	97.81	91.88	96.08	0.82	2.01	0.43
	Sartera	2	2	3.5	2.5	250	2180	161	93.48	94.41	95.04	1.88	0.41	0.87
	Mariam	2	2	3.5	2.5	377	1133	282	95.44	95.8	93.81	2.11	1.46	0
	Tele	2	2	3.5	2.5	93	1097	156	96.88	94.52	96.31	1.88	0.41	0.87
Posta-bet	Franco	2	2	3.5	2	717	0	243	97.21	0	95.66	17.15	0	17.81
	Amede	2	2	3.5	2	513	0	143	96.86	0	90.77	20.87	0	2.5
	Mebrat Hai	2	2	3.5	2	480	0	266	95.96	0	94.84	1.16	0	1.12
	Sodere	2	2	3.5	2	917	0	122	96.86	0	94.44	2.29	0	7.05
Franco	Posta bet	2	2	3.5	2	684	69	183	94.61	81.82	97.32	16.93	7.7	4.06
	Maya hote	2	2	3.5	2	794	1159	0	94.84	93.72	0	15.19	3.58	0
	Genb	2	1	4	0	0	551	76	0	97.94	91.04	0	5.9	7.28
Genb	Franco	1	1	4	0	870	165	240	97.12	91.79	96.53	0.34	4.09	0
	Sartera	1	1	4	0	298	114	122	97.21	85	97	1.27	3.42	0
	Kera	2	2	3	2	133	189	84	93.5	94.01	93.06	2.79	2.12	3.53
	Genb gebey	2	2	3	2	103	173	219	92.25	91.87	94.03	2.6	4.67	0.91

Table 4.5: LOS Output for the Analysis using SIDRA Intersection

		Delay(Sec.)			LOS		
Intersection	Approach leg	TH	LT	RT	TH	LT	RT
Mebrat Haile	Posta bet	512.9	512.6	513.9	F	F	F
	Sartera	189.5	187.9	189.5	F	F	F
	Mariam	370.3	369.7	370.8	F	F	F
	Tele	50.6	48.8	52.2	F	F	F
Posta-bet	Franco	622.7	-	19.5	F	-	B
	Amede	289.5	-	4.5	F	-	A
	Mebrat Haile	29.8	-	4.6	C	-	A
	Sodere	313.5	-	2.8	F	-	A
Franco	Posta bet	15.2	16.6	13.8	F	F	E
	Maya hotel	15.3	20.5		D	E	
	Genb		80.7	80.7	-	F	F
Genb	Franco	44	44	44	E	E	E
	Sartera	69	69	69	F	F	F
	Kera	15.5	42.6	15.5	B	F	B
	Genb gebeya	12.7	28.2	12.2	B	F	B

As mentioned above level of service analysis was performed for Mebrat haile, Posta-bet, Franco and Genb intersection after collecting all the necessary data listed in the Table 4.4 and the result

is presented in Table 4.5 based on LOS criteria for intersection of HCM manual shown in Table 2.3 of chapter two.

According to Table 4.5, on all approaches and turning movement, Mebrat haile intersection has a LOS of F with a very high delay.

The through movement on Franco and Amede on Posta-bet intersection which is found on the main highway and Sodere approach with high number of Bajaj has LOS of F due to the turning difficulty of large truck at the roundabout. But the right turning movement serving well enough.

For Franco intersection Posta-bet and Maya hotel approaches on the main highway although Genb approach which has turning movement crossing the main highway it has LOS F due to the existence of high traffic volume of through movement on the main highway.

Finally Genb Intersection which is dominated by Bajaj traffic on a single lane for the approach Franco and Sartera, the LOS is E and F respectively. However, Kera and Genb gebeya approaches with very low traffic volume characterized by better LOS.

4.4. Congestion Analysis

Congestion analysis was made based on the travel time approach for the determination of congestion measures. These congestion measures are average travel time, delay, average travel speed, travel rate, delay rate, travel time, total segment delay and delay ratio. While performing the analysis only one approach with highest traffic volume and found on the main street was selected for each intersection as follows.

- From Mebrat haile intersection Posta-bet approach length 200m.
- From Posta-bet intersection Franco approach length 200m
- From Franco intersection Maya hotel approach length 250m.
- From Genb intersection Franco approaches length 150m.

Accordingly, the analysis of each congestion measure are presented in the following sections and summarized in the attached Annex C.

4.4.1. Travel Time

Average travel time at15min interval was determined for the selected approaches. According to the result shown in the Figure 4.10 below, it shows the morning and evening peak periods recorded the highest travel time and the lowest travel time recorded during mid-day for all approaches from Mebrat haile, Franco and Posta-bet intersections. Similarly, these approaches have higher peak travel time during the evening time than the morning period. But for the Franco approach of Genb intersection, it has relatively uniform travel time even though it has slightly higher in the morning and evening peak.

When they are compared to each other, the four approaches on the different intersection Maya hotel approach on the Franco intersection has the highest travel time from the other.

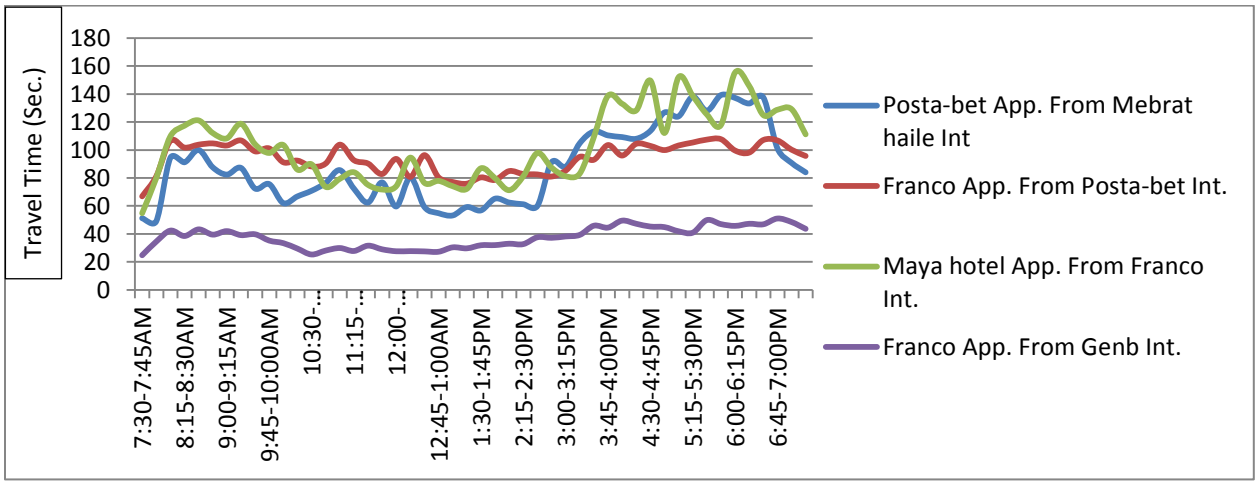

Figure 4.10: Travel Time for the selected approach on all Intersection

Figure 4.10 Maya hotel approach on Franco intersection has the highest morning and evening peak period and on the intersection 80 second is the average travel time assuming all the approaches have equal length.

4.4.2. Travel Speed and Travel Rate

Approaching speed on the selected intersection leg has been performed. This is done for the approach previously selected based on traffic volume and location. Figure 4.11 below shows average speed distribution throughout the day for the approach. As per the result during morning

and evening period the travel speed is lower up to 5km/hr but maximum speed occurs at the mid-day period.

Although for approaches on Mebrat haile, Genb and Franco intersection the evening period average travel speed is lower relative to the morning period. However, for Franco approach on the Posta bet intersection which have relatively uniform travel speed throughout the day.

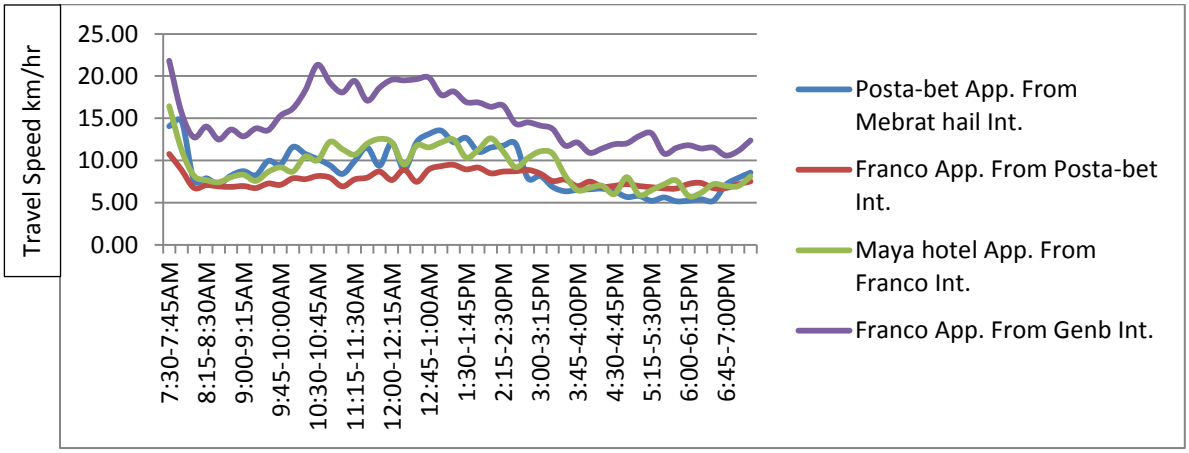

Figure 4.11: Travel Speed for the selected approach on all Intersection

The other important congestion measure is travel rate which is the invers of travel speed has been calculated and presented on the Figure 4.12 below. This congestion measure is significant because it allow the comparison of the four approaches each other even though their length varies. Based on this it shows all approach on the selected intersections have similar characteristics. In short, the travel rate has morning and evening peak period with relatively higher evening peak period and Franco approach on Posta-bet intersection has the highest travel rate until 3:00PM then Posta-bet intersection on Mebrat haile intersection takes over.

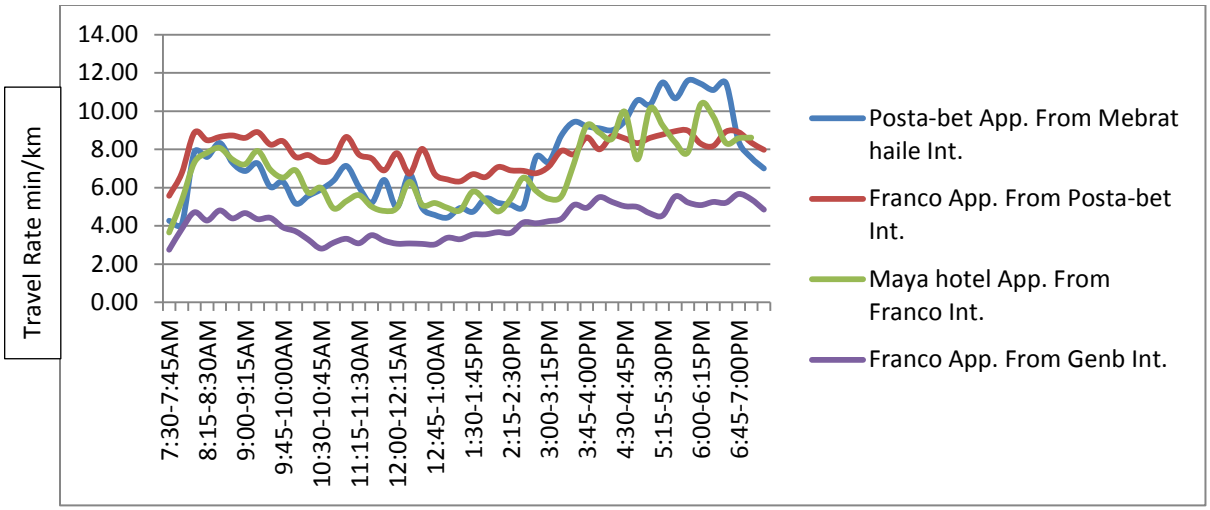

Figure 4.12: Travel Rate for the selected approach on all Intersection

Figure 4.11 and Figure 4.12 shows the travel speed on Posta-bet approach on Mebrat haile intersection has a minimum of 5km/hr. With the highest travel rate of 11min/km this is due to the on street parking near the intersection.

4.4.3. Delay, Delay Rate and Delay Ratio

Delay is one of the important parameter in congestion measure analysis. For the analysis of delay, delay ratio and delay rate the posted speed at the intersection is used as reference.

Delay is the amount of extra time spent in congestion compared to the time it would take under ideal or free-flow conditions.

Delay rate is the rate of time loss for vehicle operating in congested conditions, expressed in minute per kilometer for a specified roadway segment. It is calculated as the difference between the actual travel rate and the acceptable travel rate. The quantity can be used to estimate the difference between system performance and the expectation for those system elements, which can be used to prioritize alternative improvement.

Delay ratio is a dimensionless measure that can be used to compare or combine the relative congestion level of facilities with different operating characteristics like freeways, arterial streets and transit routes. It is calculated as the delay rate divided by the actual travel rate. The delay ratio identifies the magnitude of mobility problem in relation to actual condition.

Accordingly, the result of delay, delay rate and delay ratio are shown in the Figure 4.13 through Figure 4.15 below.

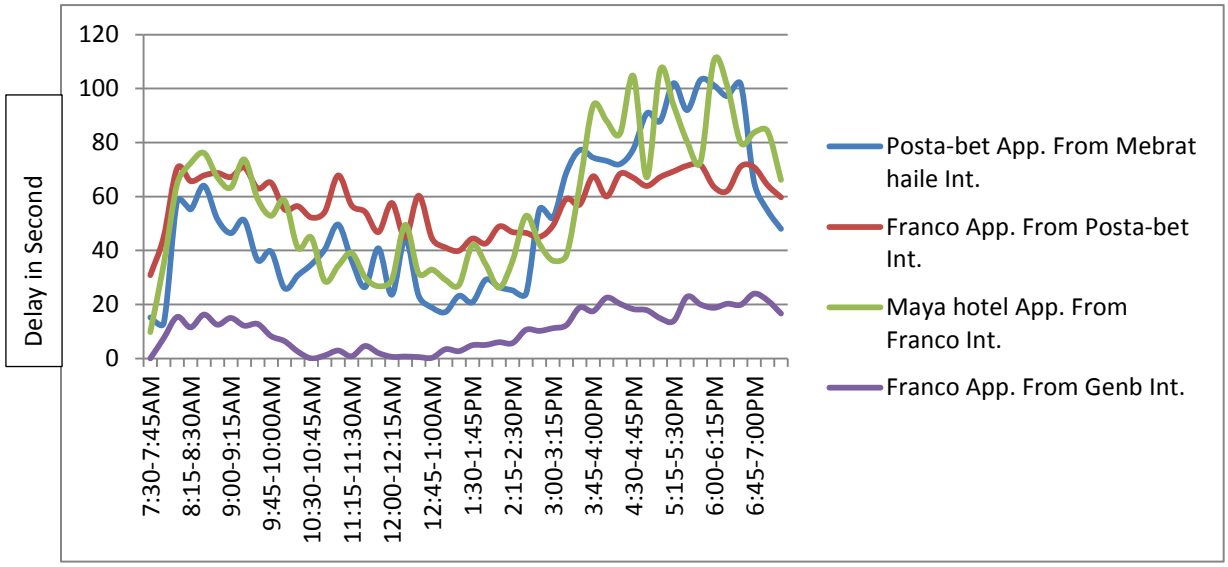

Figure 4.13: Delay for the selected approach on all Intersection

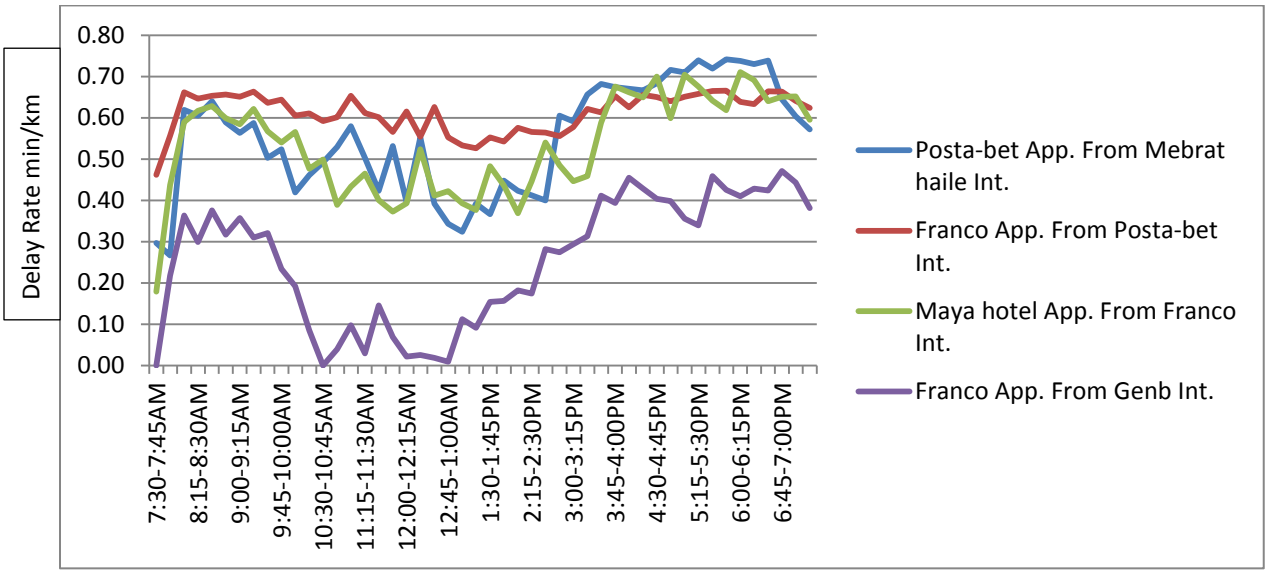

Figure 4.14: Delay Rate for the selected approach on all Intersection

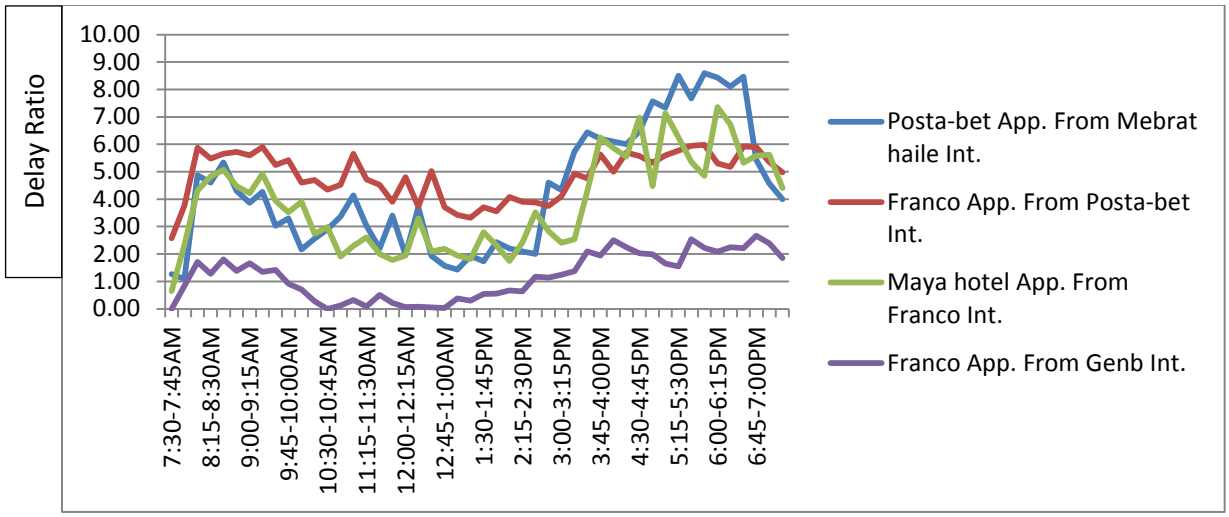

Figure 4.15: Delay Ratio for the selected approach on all Intersection

On the delay analysis, Figure 4.13 and Figure 4.15 shows Maya hotel approach on Franco intersection has the highest delay both at the morning and evening peak period with 73second and 110 second respectively. Again, the four intersections have an average of delay rate of 0.6 to 0.7 was observed except for Genb intersection with 0.4 delay rate. The delay rate 0.6 to 0.7 shows only 30-40% of the time wasted at the intersection was enough to pass the intersection at uncongested condition.

4.4.4. Total Segment Delay

Total segment delay measured in Vehicle-min is the measure of congestion intensity. It shows how the congestion is serious and indicates the extent of the congestion that how much Vehicle is being affected with the congestion. Figure 4.16 shows the total segment delay in Vehicle-Min for the selected approach length considered. The result in the Figure 4.16 should not be compared each other because these approaches are not equal in length, therefore it should be read for a single approach only at once.

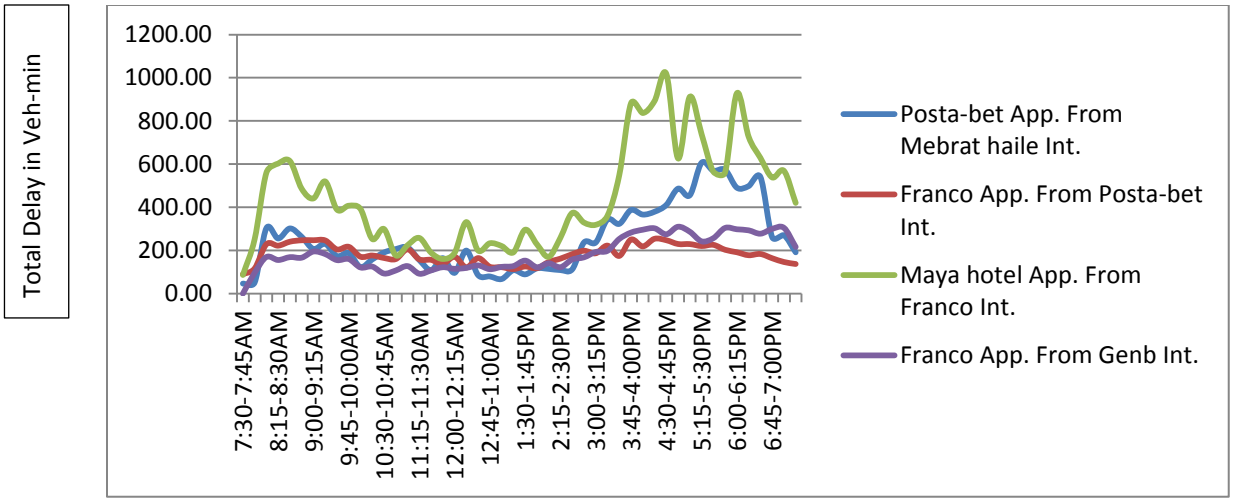

Figure 4.16: Total Segment Delay for the selected approach on all Intersection

However, in order to compare the selected four approaches each other the total delay was divided by the length of the segment and the delay was converted to a unit length delay and shown in the Figure 4.17.

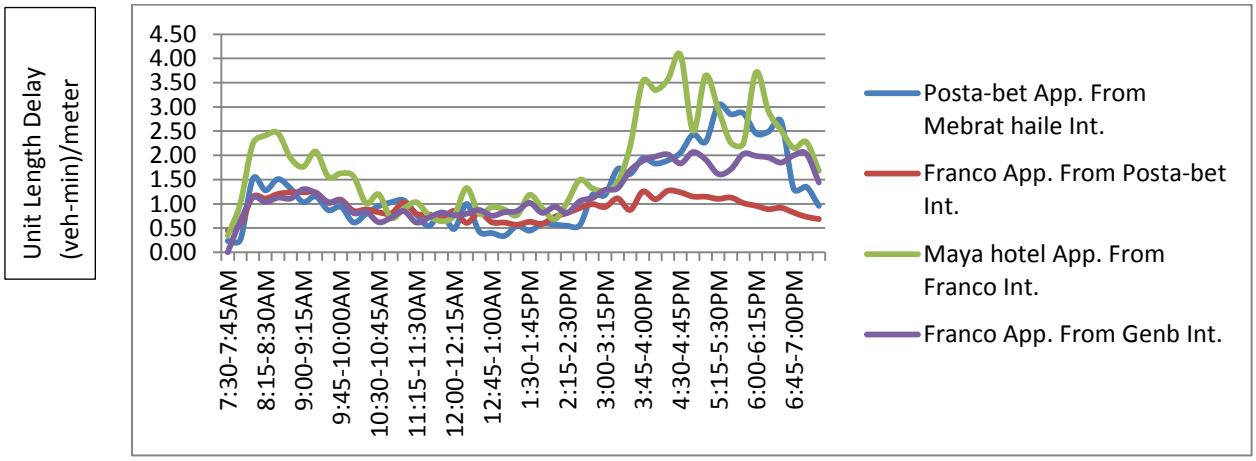

Figure 4.17: Total Unit length Delay for the selected approach on all Intersection

Total segment delays which explain the severity of congestion on Figure 4.16 shows that an average of total delay of approximately 1067 Veh-min was lost on the four approaches selected on each intersections, this means 72 vehicles are idle for full day. On average the maximum delay occurs during the evening peak period, it is about 1623 Veh-min and during the morning 891 Veh-min was lost. Similarly Figure 4.17 shows the comparison of each approach each other, the highest morning peak delay exist on Franco and Maya hotel approach on Posta-bet and

Franco intersection respectively. Although, the highest evening peak delay exist on Posta-bet and Maya hotel approach on Mebrat haile and Franco intersection respectively.

4.5. Causes of Traffic Congestion around the Intersections

Traffic congestion is now a days an unavoidable phenomena due to the rapid growth of traffic volume and reduction of road capacity due to different reasons. Due to this traffic congestion measures should be prepared before it is out of control. After performing some observation for full day time starting 7:30AM up to 7:30PM the cause of traffic congestion for the selected four intersections namely Mebrat haile intersection, Posta-bet intersection, Franco intersection and Genb intersection are more or less the same and explained below.

There exist the presences of on street parking near the intersection on all intersections, this results excessive delay near the intersection. Although most of the pedestrians travers on the outer edge of the travel lane causing discomfort on the driver. Around Mebrat haile intersection, working zone causes reduction on the capacity of Sartera approach causing delay and there exists broken traffic signal.

At Posta bet and Franco intersection on the major highway vehicle breakdown, existence of large traffic in large number and traffic incident like crash is the major causes.

The level of service analysis on the intersections on Table 4.5 shows, almost all of the intersections are under capacity with LOS F. this id due to the increase traffic volume in the city resulting reduction in the road capacity. In short traffic congestion causes are listed below:

- Traffic Incidents (Crash)
- Work Zones
- Damaged Traffic Signals
- Reduction in road capacity
- Vehicle breakdown
- On Street Parking

4.6. Traffic Congestion Mitigation Measures

Most of congestion causes could be avoided with simple traffic management. On all intersections, on street parking near the intersection should be prohibited this will minimize

excessive delay near the intersection; similarly, the pedestrian should be forced to use walk ways rather than the outer lanes.

For nonrecurring causes like work zone, traffic incident and vehicle break down the city administration should use one of the following methods listed literature review part like faster and anticipatory response to traffic incidents, access management and improvement of work zones.

The most serious cause of congestion is reduction in highway capacity, due to increase in traffic volume. To improve the capacity of the highway, there are two possible solutions: increase the capacity of the highway or decrees the traffic volume by any means.

One way to increase the capacity of the highway is adding one or more additional lane. To evaluate the effect of adding lane on the capacity, one lane has been added on the intersections approach and the result is shown in the Table 4.6 below.

Table 4.6: LOS Output after adding one lane using SIDRA Intersection

		Existing LOS			LOS after Adding one lane		
Intersection	Approach leg	TH	LT	RT	TH	LT	RT
Mebrat Haile	Posta bet	F	F	F	F	F	F
	Sartera	F	F	F	F	F	F
	Mariam	F	F	F	F	F	F
	Tele	F	F	F	C	E	F
Posta-bet	Franco	F	-	B	A	-	A
	Amede	F	-	A	A	-	A
	Mebrat Haile	C	-	A	A	-	A
	Sodere	F	-	A	A	-	A
Franco	Posta bet	F	F	F	B	A	B
	Maya hotel	D	E	-	A	A	-
	Genb	-	F	F	-	A	F
Genb	Franco	E	E	E	F	F	F
	Sartera	F	F	F	C	C	F
	Kera	B	E	B	B	B	E
	Genb gebeya	B	F	B	B	B	D

Based on the Table 4.6 adding one lane has significantly change the capacity of Posta-bet, Franco, Genb intersections but not Mebrat haile intersection.

The other method to increase capacity is reducing traffic volume so, for Posta bet and Franco intersection this method was tried by removing large truck vehicles from the highway. This is due to, most of the truck pass through Adama so they can use the newly built express road. Then by removing this vehicles LOS has been evaluated and the following result has been found.

Table 4.7: LOS Output after removing large trucks using SIDRA Intersection

		Existing LOS			LOS after Removing Large Trucks		
Intersection	Approach leg	TH	LT	RT	TH	LT	RT
Posta-bet	Franco	F	-	B	F	-	A
	Amede	F	-	A	F	-	A
	Mebrat Haile	C	-	A	A	-	A
	Sodere	F	-	A	E	-	A
Franco	Posta bet	F	F	F	B	A	B
	Maya hotel	D	E	-	B	A	-
	Genb	-	F	F	-	F	F

According to Table 4.6 the best method to increase the capacity of the intersections is by adding one additional lane. But for Mebrate haile interaction the possible solution is traffic signal to provide orderly movement for conflicting traffics.

4.7. Cost of Traffic Congestion

In order to calculate cost of traffic congestion, there exist a number of parameters to be conceded to in the analysis. But it was difficult to obtain all the parameters to determine the total cost of traffic congestion at the intersections. Therefore, the researchers decided to consider three major parameters which are seriously affected by the congestion namely, ideal time or labour cost, fuel cost and rental cost of vehicles. The rental cost of vehicles was included to consider parameters like vehicle maintenance cost, vehicle emissions, quality of life (due to personal time delays), and business activity (due to the additional costs and reduced service areas for workforce, supplier and customer markets).

The fuel consumption of vehicles varies for different vehicles and whether they are new or old. To consider this variation the weighted average of vehicle fuel consumption is considered and the same thing was done for the rental cost of vehicle. The daily labour cost was taken from a paper prepared by Bemnet Aschenak in march18, 2004 by a title Transport Costs in Ethiopia: As impediment to export.

The total cost of congestion is the summation of labour cost, total fuel cost and total rental cost per day then finally converted to per year by multiply by 365. The total labour income lost has been calculated by multiplying cost of labor per day and total segment delay per day in vehicle-hour unit finally, the total labour income lost is presented in birr per day. The total fuel cost lost per day equals to unit cost of fuel in birr times total fuel consumed per liter by considering weight average of fuel consumption for different type of vehicle. Then for the last parameter total vehicle rental cost in birr per day is calculated by multiplying average daily rental cost of vehicle in birr per day and total segment delay per day in vehicle-hour unit.

Finally, based on the above mentioned parameters the total cost of congestion has been determined and summarized tin the Table 4.6 for the approach selected on the major intersections.

Table 4.8: Traffic Congestion Cost Analysis

Cost of Congestion				
Intersection	Mebrat hail	Posta-bet	Franco	Genb
Approach	Posta-bet	Franco	Maya hotel	Franco
Total Traffic (Vehicle- Day)	9,058.00	9,089.00	10,636.00	10,854.00
Total Segment Delay per day (Vehicle-min)	8,129.58	8,812.39	10,642.12	6,940.16
Total Segment Delay per day (Vehicle-Hr)	135.49	146.87	177.37	115.67
Labour Cost (birr/Hr)	8.40	8.40	8.40	8.40
Labour Cost (birr/Day) for 8Hr	67.20	67.20	67.20	67.20
Average Vehicle Occupancy (Persons/Veh)	9.95	9.95	9.95	9.95
Labour Income Lost (birr/Day)	90,596.00	98,205.25	118,595.84	77,341.18
Weighted Average Fuel Consumption (Lit/hr)	0.24	0.83	0.60	0.12
Total Fuel Consumed (lit)	32.43	122.58	106.54	13.74
Unit Cost of fuel (birr)	20.70	20.70	20.70	20.70
Total Fuel Cost per day	671.35	2,537.39	2,205.46	284.40
Average daily Rental cost of Vehicles (birr/day)	243.79	962.79	887.11	141.00
Total Daily Vehicle Rental cost (birr/day)	4,128.97	17,676.09	19,668.27	2,038.70
Total Daily Labour, Fuel & Vehicle cost (birr/day)	95,396.32	118,418.72	140,469.56	79,664.28
Total Labour, Fuel & Vehicle cost (birr/year)	34,819,655.39	43,222,833.69	51,271,390.34	29,077,463.50

4.8. Traffic Congestion and Traffic Accident

As per the data collected from Adama special zone police administration, the following Figure 4.18 shows the distribution of traffic accident in the city from year 1998 up to 2006EC. It shows that the number of accident increases from year 1998 to 2006EC, it seems fatal accident is in decreasing order but property damage in increasing order.

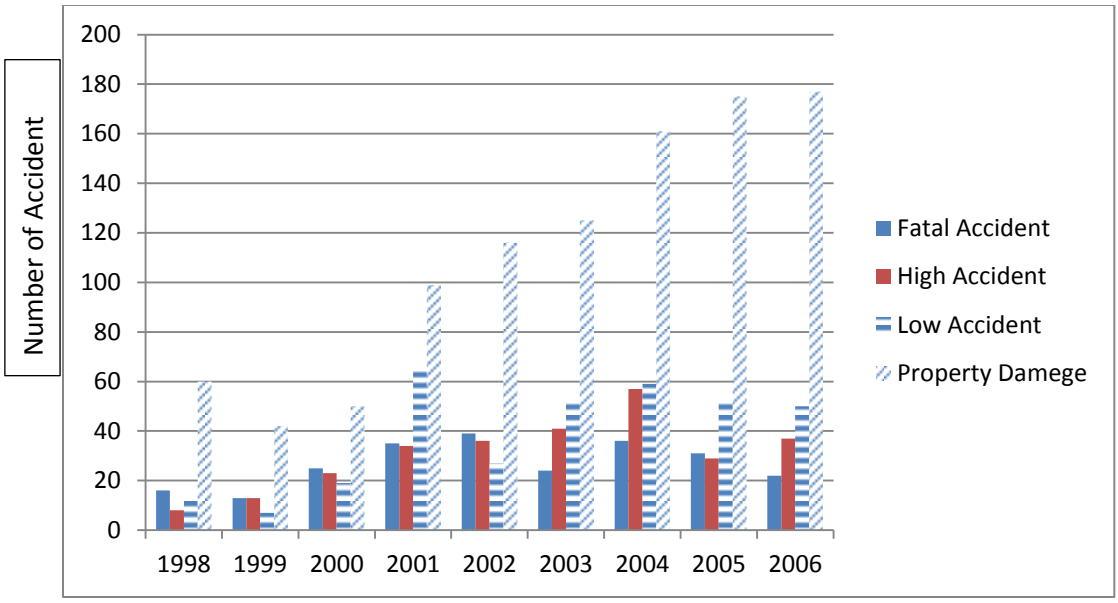

Figure 4.18: Accident Distribution in recent Nine year

According to Figure 4.19 and Figure 4.20 the average number of accident is higher during the morning peak period and decreases around midday and evening period. But the average traffic volume shows higher during evening time and relatively low at morning period.

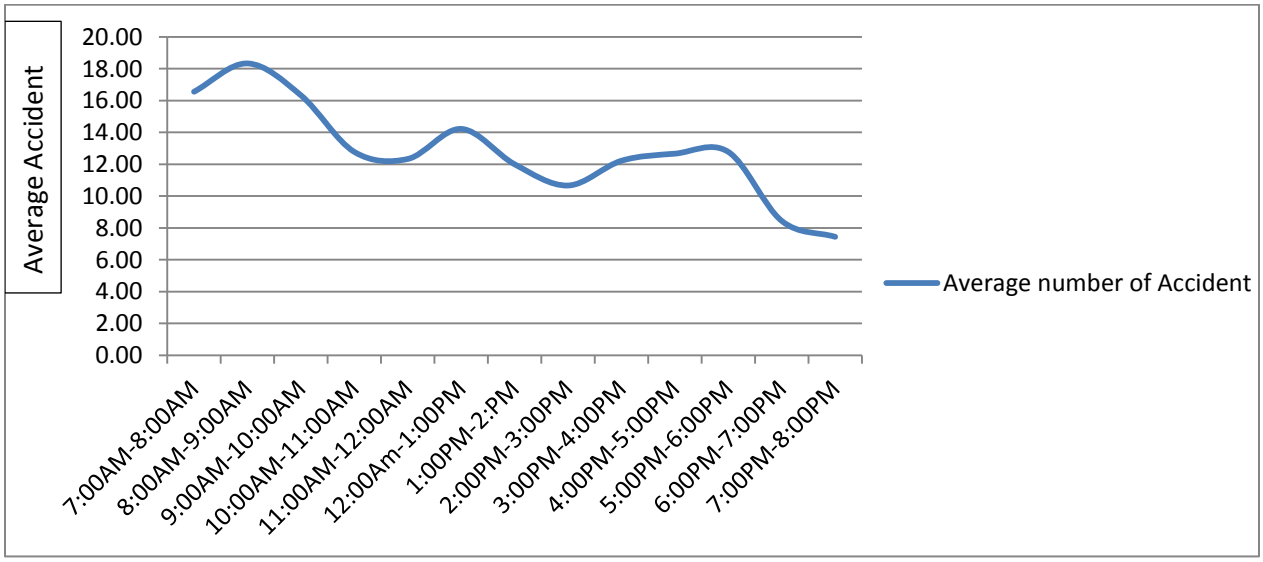

Figure 4.19: Average Traffic Accident for the Past Nine Years

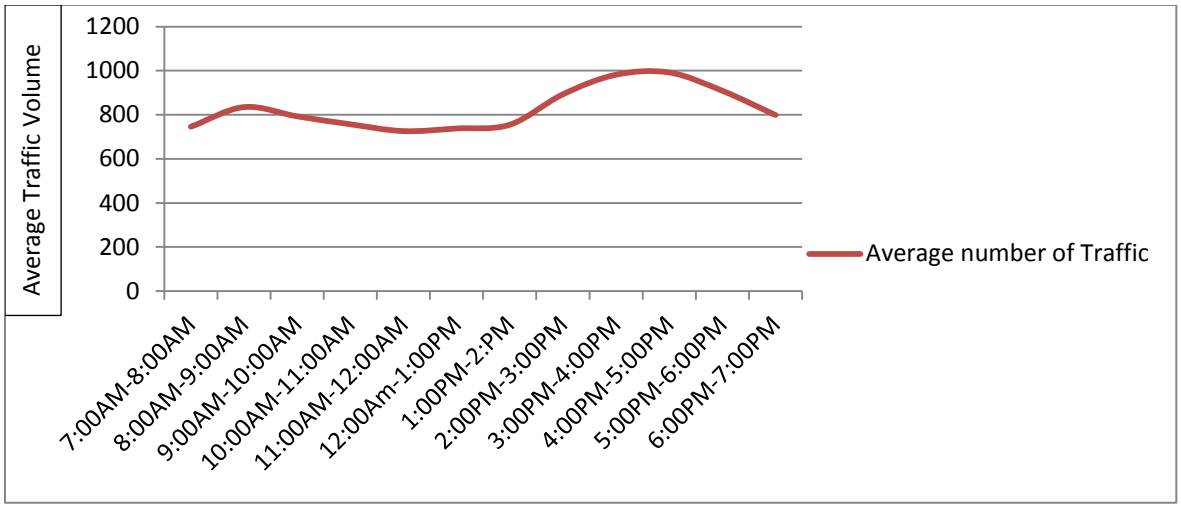

Figure 4.20: Average Traffic Volume on the Selected Approaches

According to Figure 4.21 below both number of accidents and travel speed has almost exactly opposite characteristics. Average travel speed decreases at the morning and evening period but the number of accident is higher during these periods.

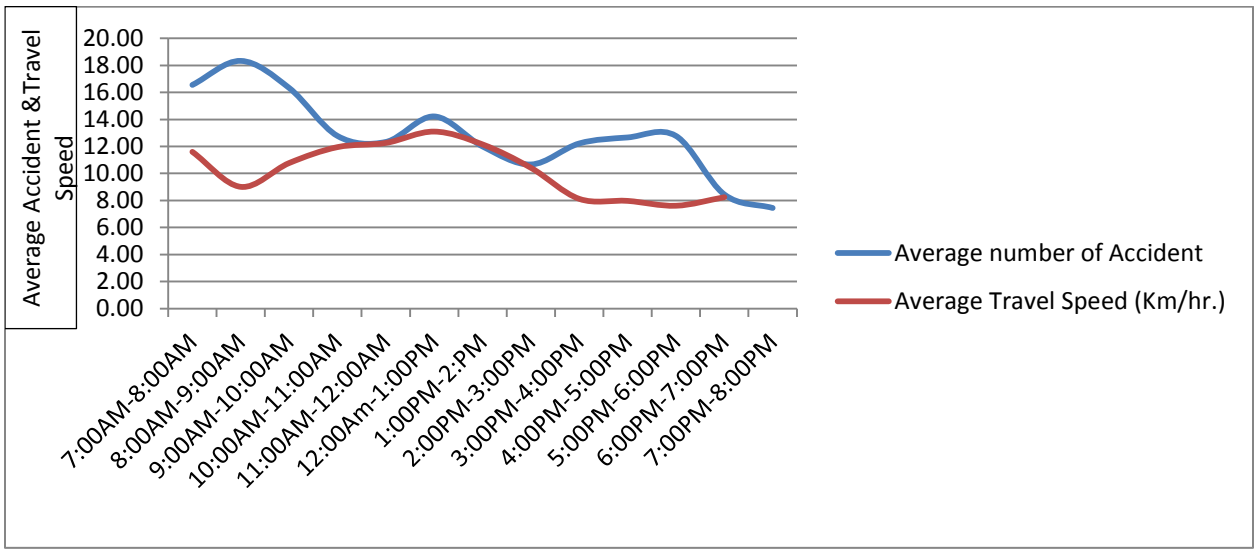

Figure4.21: Average Accident and Average Travel Speed

In order to see the correlation between traffic volume and travel time with traffic accident, linear equations and regression coefficients were determined as shown in Figure 4.22 and Figure 4.23 respectively. Accordingly, the regression coefficient of travel speed with traffic accident is greater than the regression coefficient of traffic volume. But, the R^2 is almost zero this means both travel speed and traffic volume has almost no relation with traffic accident in the city.

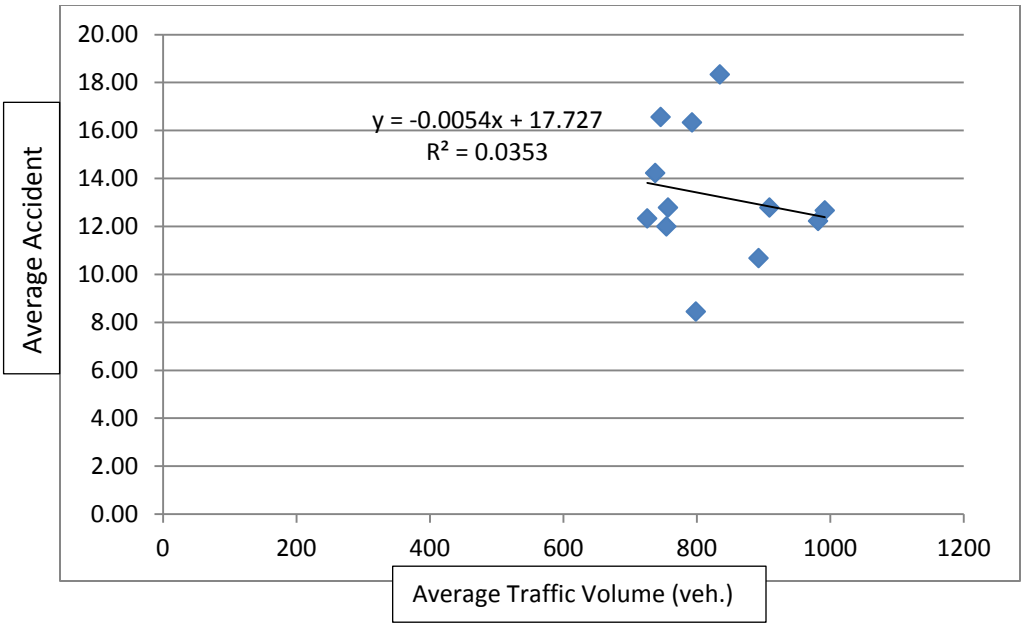

Figure 4.22: Correlation between Average Accident and Average Traffic Volume

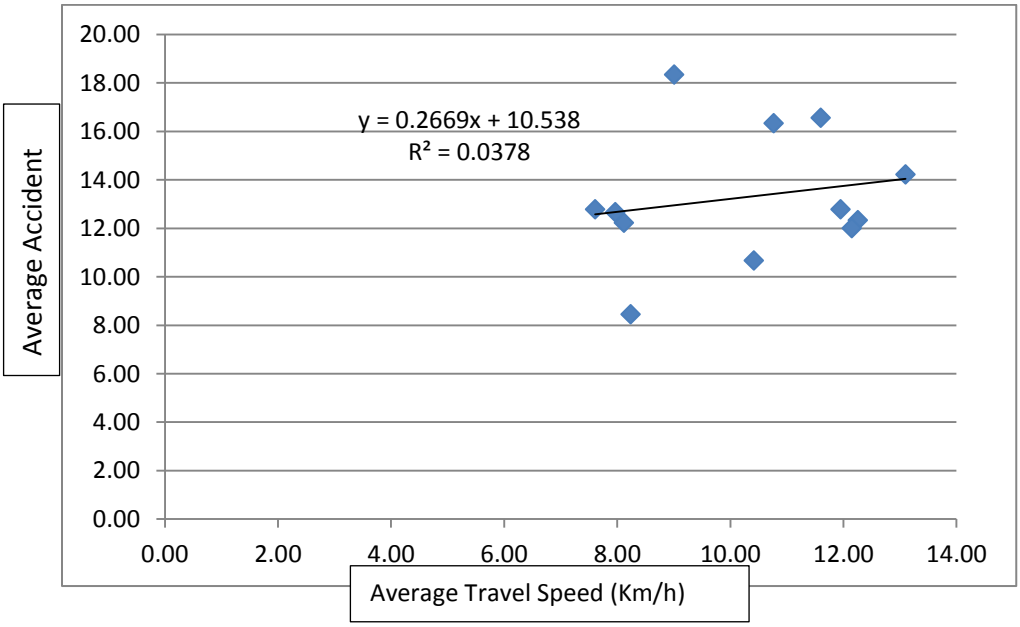

Figure 4.23: Correlation between Average Accident and Average Travel Speed

This is because the correlation is done with the average accident, the result may change if the correlation was done with fatal accident vs travel speed and property damage vs traffic volume based on the theory. The correlations mentioned above were not done because traffic accident data for fatal accident and property damage were not given by time of the day.

However, correlation was done by dividing full day accident data in to morning period from 7AM-11AM, mid-day period 11AM-3PM and evening period 3PM-7PM. Then similar analysis has been done and the results are presented in the figure below.

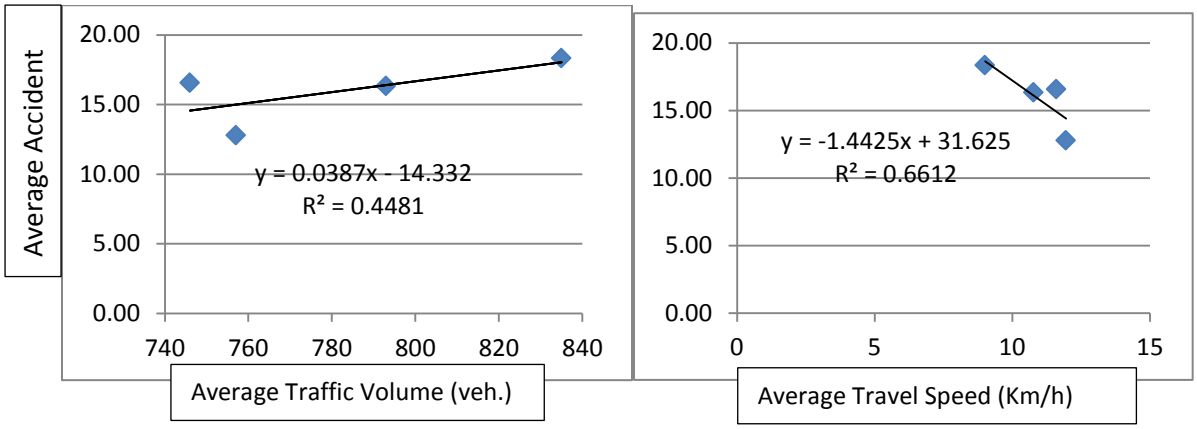

Figure 4.24: Correlation between: Accident vs. Traffic volume and Accident vs. Travel Speed (Morning)

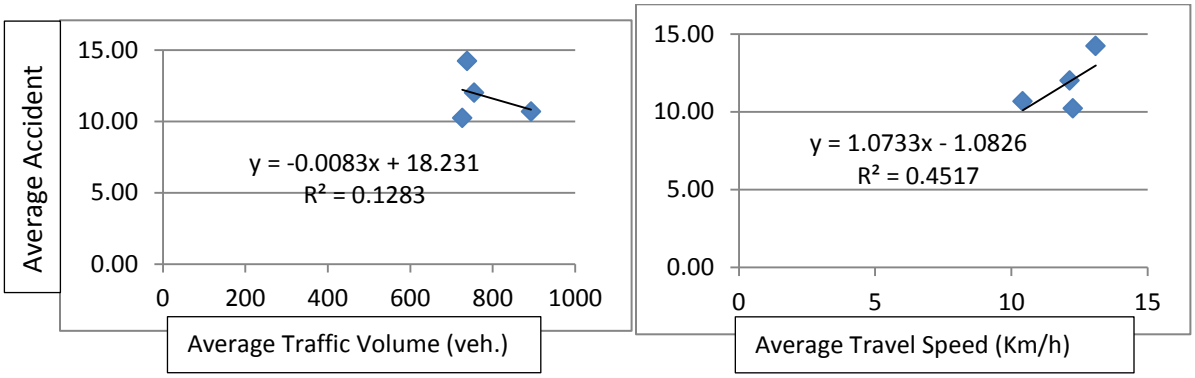

Figure 4.25: Correlation between: Accident vs. Traffic volume and Accident vs. Travel Speed (Mid-day)

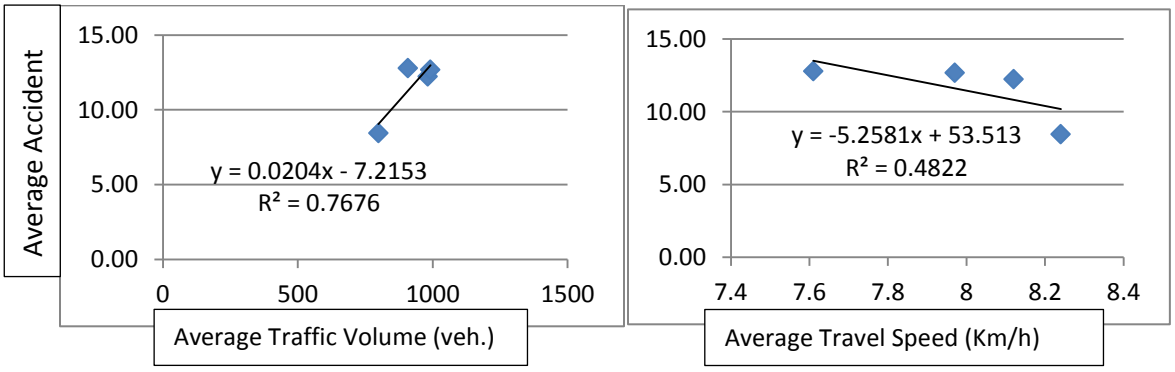

Figure 4.26: Correlation between: Accident vs. Traffic volume and Accident vs. Travel Speed (Evening)

According to the figure above average travel speed has better relation with accident for morning and mid-day period. For the evening period traffic volume has better relation. Therefore, considering time as a variable, accident has relation with speed and traffic volume.

CHAPTER FIVE

5. Conclusions and Recommendations

5.1. Conclusions

The following conclusions can be drawn from the study:

- Traffic volume distribution and congestion are similar with the theoretical principle. Traffic volume has the morning and evening peak period for almost all approaches on the selected four intersections. Similarly, traffic congestion during morning and evening peak period are congested and during midday it is relatively uncongested.
- The level of service on the intersections are performing above their capacity specially Mebrat haile, Posta-bet and Genb intersection with the LOS of F for most approach.
- For all selected approach the average delay and total segment delay have the morning and evening peak period. Accordingly, based on the delay analysis delay rate 0.6 to 0.7 shows on average only 30-40% of the time wasted at the intersection was enough to pass the intersection at uncongested condition.
- Based on total segment delay, on average approximately 48 vehicles are idle for full day on one intersection per day in Adama city and on average the maximum delay of 1623 Veh-min and 891 Veh-min was lost during the evening and the morning peak period respectively.
- Based on observation, most of causes of congestion are due to improper traffic. However LOS analysis shows almost all approach on the intersections are serving above their capacity resulting increase in travel time and transportation cost.
- As a mitigation measure, increase the capacity of the highway has a better result than decrees the traffic volume.
- Assuming ideal time or labour cost, fuel cost and rental cost of vehicles only, on average the cost of congestion at the selected approach varies from 29 to 51 million birr per year with the average of 39.6 million birr on one approach per year.
- Even though it is difficult to explain their correlation, it shows when the travel speed is lower the accident rate increases. However, correlation analysis has been done between average accident & average travel speed and average accident & average traffic volume and based on the R^2 values it seems it is almost insignificant for full day analysis.

5.2. Recommendations

To further enhance the results of this study the following recommendations are formulated:

- Further research should be conducted to extend all aspects of this research, such as by collecting more data in order to improve results. From this data traffic volume is the one and it is recommended to count at least for seven days. Similarly during collecting travel speed and travel time automatic data collection method are better to minimize error.
- To fully estimate the cost of congestion it is recommended to use different factors like vehicle operation cost specifically maintenance.
- The result shows traffic accident has no or insignificant relation with traffic volume and speed. Therefore, further research should be conducted to evaluate the possible cause of accident in the city.
- From the analysis result, it shows the intersections are serving above their capacity. Therefore, the city administration should consider this issue and formulate capacity improvement methods.

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Annexes

Annex-A: Traffic Volume and PCU Analysis

Table 1: Traffic volume at Mebrat haile Intersection

Mebrat haile Intersection	Traffic Volume															26/12/2013
	Post bet Approach				Sartera Approach				Mariam Approach				Tele Approach			
	TH	R	L	Ped.	TH	R	L	Ped.	TH	R	L	Ped.	TH	R	L	Ped.
7:30-7:45AM	80	41	80	65	24	20	180	24	38	27	195	23	15	21	85	45
7:45-8:00AM	88	58	105	103	41	31	315	185	67	46	295	98	15	33	125	65
8:00-8:15AM	119	64	140	298	54	32	460	298	81	58	345	256	21	33	165	250
8:15-8:30AM	126	61	120	300	56	32	475	286	91	53	435	289	25	40	195	125
8:30-8:45AM	121	53	135	235	56	33	505	300	101	49	455	213	20	37	230	345
8:45-9:00AM	112	62	155	214	62	32	577	215	97	52	455	245	30	42	215	268
9:00-9:15AM	101	61	130	106	58	39	585	196	87	62	405	256	18	42	235	276
9:15-9:30AM	94	64	135	118	70	39	526	250	85	54	420	300	19	39	205	310
9:30-9:45AM	121	66	120	248	52	39	595	196	67	55	420	298	24	41	215	248
9:45-10:00AM	113	68	125	216	52	39	515	310	66	68	460	165	25	39	240	213
10:00-10:15AM	111	65	130	200	50	28	410	287	85	63	475	180	24	38	225	201
10:15-10:30AM	101	60	150	240	57	31	525	296	93	59	405	196	26	31	235	289
10:30-10:45AM	125	75	155	270	61	38	430	315	98	72	485	265	20	45	270	256
10:45-11:00AM	111	46	170	261	50	34	400	320	92	53	475	213	24	37	255	189
11:00-11:15AM	107	48	120	178	49	36	310	215	78	58	445	101	12	37	255	198
11:15-11:30AM	113	50	105	179	51	36	450	236	93	56	425	113	20	41	220	214
11:30-11:45AM	104	56	100	132	34	35	390	198	73	57	450	189	18	35	240	231
11:45-12:00AM	82	48	125	98	37	37	285	124	88	69	435	214	13	34	180	225
12:00-12:15AM	91	48	110	103	46	36	410	135	79	51	385	97	13	37	140	187
12:15-12:30AM	96	48	135	98	38	32	351	147	64	50	415	110	14	38	195	165
12:30-12:45AM	89	42	115	115	38	29	290	168	64	65	350	123	15	30	200	132
12:45-1:00AM	100	42	130	87	34	31	330	200	56	49	345	148	18	25	180	114
1:00-1:15PM	93	58	110	96	42	33	291	189	83	53	350	214	13	33	170	214
1:15-1:30PM	108	53	135	100	42	36	340	98	74	58	355	101	12	28	175	89
1:30-1:45PM	106	59	115	87	46	36	396	103	66	57	335	97	11	38	155	97
1:45-2:00PM	108	53	85	215	36	36	395	142	86	48	320	98	14	27	195	65
2:00-2:15PM	111	48	115	235	42	31	385	136	87	50	335	197	15	26	150	111
2:15-2:30PM	109	55	110	210	42	35	456	215	68	54	310	246	19	36	170	168
2:30-2:45PM	100	45	145	189	48	32	515	178	62	57	340	223	8	37	200	214
2:45-3:00PM	120	41	105	231	54	30	591	264	88	53	370	241	15	44	175	253
3:00-3:15PM	106	53	120	248	58	36	530	232	89	47	370	123	9	40	175	278
3:15-3:30PM	109	45	145	263	56	29	485	225	84	51	450	289	14	39	230	254

3:30-3:45PM	121	39	110	104	52	34	593	345	72	58	400	243	15	35	245	263
3:45-4:00PM	128	52	140	361	60	29	615	310	90	74	465	231	20	39	205	214
4:00-4:15PM	124	60	130	341	55	44	501	302	89	80	450	315	15	45	250	187
4:15-4:30PM	112	69	145	298	67	41	535	289	97	81	475	326	20	31	235	214
4:30-4:45PM	106	70	135	310	68	47	550	186	101	79	420	286	23	41	210	234
4:45-5:00PM	121	79	140	256	54	44	485	186	94	74	485	213	22	37	255	198
5:00-5:15PM	126	74	120	234	55	30	586	245	89	71	415	245	27	37	255	124
5:15-5:30PM	129	77	165	264	59	48	565	234	73	62	445	261	22	39	200	138
5:30-5:45PM	115	81	175	231	66	42	526	251	84	67	440	203	18	40	250	116
5:45-6:00PM	121	82	155	310	58	37	490	168	81	81	450	189	26	40	215	121
6:00-6:15PM	102	69	140	201	56	47	420	245	63	80	465	234	17	33	185	187
6:15-6:30PM	104	73	150	256	60	46	482	214	93	68	375	253	24	33	165	215
6:30-6:45PM	95	71	160	198	52	38	560	189	77	67	460	231	27	39	200	234
6:45-7:00PM	78	70	115	231	48	40	507	245	73	49	455	201	22	26	145	256
7:00-7:15PM	101	59	150	314	49	41	490	168	61	82	410	231	18	33	175	245
7:15-7:30PM	84	62	120	261	49	36	465	187	66	62	410	114	20	42	150	214

Table 2: Traffic volume at Posta-bet Intersection

Posta-bet Intersection				**Traffic Volume**						**05/12/2013**		
	Franco Approach			Mebrat haile Approach			Kela Approach			Sodere Approach		
	TH	R	Ped.	TH	R	Ped.	TH	R	Ped.	TH	R	Ped.
7:30-7:45AM	94	40	70	60	56	37	59	17	26	132	26	42
7:45-8:00AM	92	33	135	64	65	45	66	22	89	129	32	86
8:00-8:15AM	106	47	115	74	77	98	69	30	116	165	24	142
8:15-8:30AM	117	40	135	74	76	124	76	26	189	189	21	156
8:30-8:45AM	122	46	142	82	74	136	84	26	112	185	32	113
8:45-9:00AM	132	44	104	78	74	87	73	23	96	181	25	103
9:00-9:15AM	131	42	170	83	75	96	86	23	85	151	25	97
9:15-9:30AM	114	51	192	79	76	84	87	27	93	164	34	96
9:30-9:45AM	114	43	254	83	71	101	85	27	105	192	32	124
9:45-10:00AM	102	48	161	83	69	86	93	34	86	148	33	101
10:00-10:15AM	99	42	215	82	74	98	101	35	75	167	21	76
10:15-10:30AM	101	40	241	66	76	87	95	36	34	184	26	65
10:30-10:45AM	103	41	164	76	63	46	100	27	26	210	28	97
10:45-11:00AM	97	39	150	73	59	68	80	25	56	212	28	112
11:00-11:15AM	95	44	96	51	58	95	89	18	38	174	27	86
11:15-11:30AM	95	35	48	61	57	76	85	27	49	195	28	34
11:30-11:45AM	88	42	50	53	57	68	78	32	65	192	28	76
11:45-12:00AM	87	45	74	61	56	103	82	30	76	202	27	56

12:00-12:15AM	106	36	68	60	58	86	81	24	85	155	27	35
12:15-12:30AM	92	39	84	53	58	89	80	26	24	174	21	86
12:30-12:45AM	88	42	96	53	56	57	79	23	89	200	28	94
12:45-1:00AM	93	40	87	58	61	68	94	20	76	176	24	93
1:00-1:15PM	104	36	93	59	58	96	91	18	85	213	24	103
1:15-1:30PM	101	31	103	62	54	103	91	22	34	183	24	123
1:30-1:45PM	101	33	142	65	53	86	80	26	64	178	17	96
1:45-2:00PM	95	33	91	67	51	68	79	22	65	188	17	76
2:00-2:15PM	110	35	103	59	59	64	88	23	45	198	21	98
2:15-2:30PM	123	37	146	64	53	101	92	21	87	209	29	84
2:30-2:45PM	143	40	96	70	66	104	90	14	96	175	30	114
2:45-3:00PM	158	40	76	86	67	90	101	28	125	225	32	139
3:00-3:15PM	137	52	130	78	72	76	99	36	111	217	25	124
3:15-3:30PM	130	43	198	75	70	87	97	24	132	246	20	96
3:30-3:45PM	101	35	214	96	62	104	81	20	142	180	18	135
3:45-4:00PM	125	47	236	84	64	96	100	25	132	214	31	189
4:00-4:15PM	120	45	346	84	62	103	94	23	136	219	33	154
4:15-4:30PM	127	45	265	101	61	123	112	20	176	210	30	163
4:30-4:45PM	136	39	189	86	63	98	92	29	103	215	29	143
4:45-5:00PM	132	36	245	81	64	103	104	21	98	214	22	103
5:00-5:15PM	120	38	213	73	58	134	94	19	86	201	27	87
5:15-5:30PM	108	36	236	68	61	124	97	22	124	219	29	98
5:30-5:45PM	106	40	178	67	69	189	100	13	105	174	32	126
5:45-6:00PM	103	28	126	76	63	214	84	19	86	198	33	246
6:00-6:15PM	108	28	243	72	57	176	94	14	76	203	20	156
6:15-6:30PM	107	23	214	76	65	132	84	20	84	204	24	134
6:30-6:45PM	93	26	198	70	62	102	73	23	63	201	27	104
6:45-7:00PM	87	23	176	80	62	132	85	13	57	193	29	123
7:00-7:15PM	88	20	200	73	58	142	80	9	52	183	24	98
7:15-7:30PM	93	17	158	74	56	136	69	16	43	190	19	103

Table 3: Traffic volume at Franco Intersection

Franco Intersection	**Traffic Volume**									**12/12/2013`**
	Maya hotel Approach			Posta bet Approach				Genb Approach		
	TH	L	Pedestrian	TH	R	L	Pedestrian	R	L	Pedestrian
7:30-7:45AM	102	305	115	65	26	30	104	15	60	265
7:45-8:00AM	114	235	389	90	33	25	246	16	75	321
8:00-8:15AM	130	305	574	101	33	45	378	17	90	450
8:15-8:30AM	132	290	486	107	44	50	460	17	75	436
8:30-8:45AM	149	245	368	123	33	50	524	18	100	426
8:45-9:00AM	140	215	345	115	36	50	345	19	95	368
9:00-9:15AM	152	180	425	119	34	30	365	16	75	256

9:15-9:30AM	136	190	462	103	35	45	420	18	85	364
9:30-9:45AM	134	195	268	106	31	10	487	19	70	246
9:45-10:00AM	144	230	297	102	36	25	286	19	70	420
10:00-10:15AM	132	200	278	89	35	10	201	18	90	316
10:15-10:30AM	104	220	365	83	29	30	214	17	70	253
10:30-10:45AM	117	220	210	79	26	10	145	23	85	243
10:45-11:00AM	112	190	195	82	28	40	89	12	90	364
11:00-11:15AM	117	215	211	81	29	25	264	13	65	346
11:15-11:30AM	124	200	264	85	31	20	126	14	55	460
11:30-11:45AM	123	190	195	98	32	15	98	16	70	367
11:45-12:00AM	106	205	111	97	21	20	87	12	60	450
12:00-12:15AM	100	225	89	96	26	20	101	14	60	362
12:15-12:30AM	101	240	65	93	31	25	96	11	70	249
12:30-12:45AM	100	225	89	95	24	30	136	16	70	126
12:45-1:00AM	107	245	109	106	22	15	86	10	50	105
1:00-1:15PM	117	260	104	82	23	25	94	12	55	148
1:15-1:30PM	121	220	99	80	24	20	65	11	60	198
1:30-1:45PM	98	255	87	83	23	15	110	13	70	249
1:45-2:00PM	103	225	76	77	23	30	98	9	55	281
2:00-2:15PM	108	215	92	92	20	50	108	8	75	348
2:15-2:30PM	138	225	198	81	22	25	125	14	85	497
2:30-2:45PM	136	205	245	88	24	10	94	10	90	560
2:45-3:00PM	137	235	265	82	27	35	87	12	55	346
3:00-3:15PM	139	300	195	94	21	15	126	9	70	305
3:15-3:30PM	162	310	245	88	28	30	368	9	60	489
3:30-3:45PM	149	285	368	91	25	25	426	13	65	517
3:45-4:00PM	169	305	379	105	27	5	394	22	125	435
4:00-4:15PM	165	295	420	137	39	40	486	8	150	525
4:15-4:30PM	158	350	398	133	33	30	510	7	155	489
4:30-4:45PM	162	295	285	130	44	20	543	11	135	456
4:45-5:00PM	151	305	460	142	33	45	480	17	155	501
5:00-5:15PM	143	265	580	132	32	35	456	11	135	467
5:15-5:30PM	156	235	461	158	41	35	497	14	165	518
5:30-5:45PM	139	185	510	127	46	30	510	16	115	489
5:45-6:00PM	130	235	285	92	45	20	420	17	110	387
6:00-6:15PM	150	260	312	96	32	25	365	11	110	498
6:15-6:30PM	120	220	482	85	30	40	496	12	100	386
6:30-6:45PM	127	245	346	99	19	25	471	13	120	398
6:45-7:00PM	126	180	412	83	25	20	501	12	95	478
7:00-7:15PM	126	205	319	79	24	10	389	14	95	465
7:15-7:30PM	112	190	294	81	25	20	394	18	105	348

Table 4: Traffic volume at Genb Intersection

Genb Intersection	Traffic Volume												19/12/2013			
	Franko Approach				Sartera Approach				Kera Approach				Geng gebeya Approach			
	TH	R	L	Ped.	TH	R	L	Ped.	TH	R	L	Ped.	TH	R	L	Ped.
7:30-7:45AM	112	41	60	65	53	27	40	98	25	18	110	7	29	28	85	24
7:45-8:00AM	106	35	30	75	60	30	9	87	27	12	130	16	25	34	90	89
8:00-8:15AM	128	35	80	64	61	30	14	65	29	16	115	12	25	29	105	65
8:15-8:30AM	148	29	70	56	52	33	8	142	33	17	110	45	29	39	105	78
8:30-8:45AM	131	38	75	87	55	28	12	189	23	13	120	68	33	36	90	111
8:45-9:00AM	144	36	70	104	60	36	13	256	25	20	115	124	26	46	100	106
9:00-9:15AM	157	37	85	165	66	28	12	316	25	17	120	87	23	43	80	123
9:15-9:30AM	162	44	85	187	61	27	7	378	16	14	100	76	31	42	75	98
9:30-9:45AM	144	34	60	249	57	27	11	265	24	6	100	92	26	41	65	103
9:45-10:00AM	139	31	100	156	64	28	5	198	22	13	165	105	27	36	80	104
10:00-10:15AM	143	29	50	210	65	24	4	165	25	10	140	110	24	45	75	114
10:15-10:30AM	179	31	55	236	65	30	11	246	22	11	105	96	29	44	90	89
10:30-10:45AM	165	24	30	214	60	24	12	236	22	12	150	87	31	34	70	79
10:45-11:00AM	152	23	65	200	60	24	5	351	29	10	120	65	28	31	65	98
11:00-11:15AM	144	31	85	146	62	30	7	303	23	13	125	43	27	46	70	110
11:15-11:30AM	163	21	20	98	57	29	10	268	17	9	110	89	29	37	60	68
11:30-11:45AM	150	26	35	65	49	28	12	271	29	11	115	82	19	40	85	95
11:45-12:00AM	173	25	40	86	53	27	7	186	27	16	120	94	19	49	55	112
12:00-12:15AM	185	28	50	50	51	29	10	103	20	13	110	56	30	34	50	89
12:15-12:30AM	168	27	80	98	49	23	11	96	21	18	115	46	26	36	55	86
12:30-12:45AM	170	27	85	76	44	25	12	111	14	13	110	84	23	39	75	94
12:45-1:00AM	158	29	70	101	48	29	8	86	25	16	95	62	17	35	50	56
1:00-1:15PM	167	26	50	126	49	30	14	62	21	13	120	34	23	32	95	89
1:15-1:30PM	164	21	85	187	54	23	3	74	21	12	105	76	24	37	50	76
1:30-1:45PM	161	24	85	234	47	19	13	93	25	12	115	65	23	43	65	75
1:45-2:00PM	154	33	50	226	48	27	13	56	24	11	115	43	30	37	70	89
2:00-2:15PM	164	31	65	164	41	22	15	146	26	17	120	89	20	42	50	88
2:15-2:30PM	151	23	45	180	41	29	8	135	27	12	120	79	30	43	65	96
2:30-2:45PM	173	36	50	97	53	22	15	312	29	17	120	68	22	46	70	103
2:45-3:00PM	158	30	75	103	48	33	10	186	29	17	135	94	27	37	60	1113
3:00-3:15PM	179	32	90	111	44	29	12	256	28	16	95	100	31	36	115	83
3:15-3:30PM	212	38	55	213	51	27	13	247	22	12	140	86	35	40	90	96
3:30-3:45PM	202	49	80	98	46	35	12	234	32	14	125	104	30	46	90	120
3:45-4:00PM	242	49	85	213	82	31	9	315	38	18	130	96	21	50	75	118

4:00-4:15PM	215	54	95	123	62	29	18	289	35	23	140	79	23	53	95	99
4:15-4:30PM	200	65	115	134	81	28	12	176	39	23	195	94	28	57	85	126
4:30-4:45PM	221	64	100	120	77	35	17	200	31	21	190	96	30	55	105	105
4:45-5:00PM	216	70	120	132	81	34	18	315	37	20	220	130	30	67	95	135
5:00-5:15PM	226	56	125	240	73	33	15	214	29	19	170	98	29	64	75	110
5:15-5:30PM	217	55	100	180	70	32	12	302	38	22	115	111	29	61	105	127
5:30-5:45PM	197	49	70	198	66	31	18	345	33	18	195	86	23	60	130	98
5:45-6:00PM	230	52	110	256	74	36	11	214	31	20	175	135	19	58	115	78
6:00-6:15PM	218	53	120	235	81	28	14	158	34	16	165	98	19	48	115	89
6:15-6:30PM	195	58	130	215	74	40	9	251	28	19	175	76	25	38	135	86
6:30-6:45PM	174	72	115	170	65	27	9	180	26	20	180	56	19	49	90	111
6:45-7:00PM	178	59	110	231	61	31	10	251	24	13	130	100	25	53	110	89
7:00-7:15PM	209	66	110	261	62	34	8	190	30	17	140	45	17	48	120	102
7:15-7:30PM	197	47	55	193	55	34	11	187	30	16	145	32	22	43	120	97

Table 5: PCU Factor Analysis

PCU Factor										
	Car & Taxi	Cycle	Two wheel	Bajaj	4-WD	Mini Bus	Medium bus	Std. Bus	Medium Trucks	Large Trucks
1.00	4.20	9.00	4.30	4.10	4.60	4.70	5.40	7.80	7.20	7.30
2.00	4.60	8.90	5.10	3.90	4.20	5.20	6.20	8.00	8.30	8.90
3.00	3.80	9.70	4.10	3.80	4.60	4.80	5.80	-	7.10	8.50
4.00	4.30	7.90	3.90	4.10	4.30	4.60	6.30	-	8.40	8.20
5.00	4.10	6.80	4.60	3.40	4.60	5.00	4.90	-	8.30	9.00
6.00	4.90	8.20	-	3..9	4.20	4.80	6.20	-	7.40	10.20
7.00	2.50	-	-	4.20	3.80	4.80	6.50	-	7.20	8.90
8.00	3.40	-	-	4.60	4.30	5.30	4.80	-	8.10	8.30
9.00	4.10	-	-	3.80	4.60	4.90	5.70	-	7.60	7.90
10.00	3.60	-	-	4.30	4.30	5.30	4.80	-	7.90	10.30
Avetage h,	3.95	8.42	4.40	3.62	4.35	4.94	5.66	7.90	7.75	8.75
PCU=hi/hcar	1.00	2.13	1.11	0.92	1.10	1.25	1.43	2.00	1.96	2.22
1.00	3.20	5.30	4.20	3.20	3.80	3.60	4.90	7.20	6.20	6.90
2.00	3.30	4.90	3.70	3.30	3.90	4.90	4.60	8.20	5.90	7.80
3.00	3.60	5.10	3.50	3.20	4.20	4.20	6.10	-	7.10	6.90
4.00	3.10	4.90	4.30	3.10	2.70	5.70	4.30	-	6.40	8.40
5.00	2.90	6.10	3.00	3.00	3.20	5.40	5.40	-	6.30	6.80
6.00	3.50	-	4.20	4.00	2.80	3.90	5.10	-	5.40	5.70
7.00	3.60	-	-	3.20	3.80	4.60	5.30	-	7.30	7.40
8.00	3.70	-	-	3.30	3.60	3.90	4.70	-	6.90	6.90

9.00	2.80	-	-	3.40	3.70	4.20	4.90	-	8.20	7.80
10.00	3.30	-	-	3.10	3.90	3.90	5.20	-	7.30	8.60
Avetage h,	3.30	5.26	3.82	3.28	3.56	4.43	5.05	7.70	6.70	7.32
PCU=hi/hcar	1.00	1.59	1.16	0.99	1.08	1.34	1.53	2.33	2.03	2.22
1.00	4.50	7.20	4.30	4.60	4.80	5.30	5.90	7.80	7.30	9.80
2.00	4.20	5.80	5.10	4.50	4.50	5.20	4.80	7.30	7.80	10.30
3.00	4.90	6.20	4.30	3.90	3.80	4.80	5.70	9.20	6.90	8.90
4.00	5.10	4.70	6.20	4.80	4.30	4.90	6.10	-	7.50	7.90
5.00	4.30	5.40	3.90	5.30	4.10	4.30	5.80	-	6.20	10.40
6.00	3.60	6.20	4.20	4.60	4.70	5.10	6.30	-	8.00	9.90
7.00	4.50	4.70	4.30	4.80	3.80	4.20	4.90	-	7.30	8.70
8.00	4.40	6.70	-	4.30	4.70	5.30	5.80	-	8.30	10.90
9.00	3.80	5.60	-	4.10	4.60	4.80	6.90	-	8.40	9.80
10.00	4.20	-	-	4.10	4.40	4.90	6.70	-	7.70	10.80
Avetage h,	4.35	5.83	4.61	4.50	4.37	4.88	5.89	8.10	7.54	9.74
PCU=hi/hcar	1.00	1.34	1.06	1.03	1.00	1.12	1.35	1.86	1.73	2.24
Average PCU	1.00	1.69	1.11	0.98	1.06	1.24	1.44	2.07	1.91	2.22
	1.00	0.25	0.50	1.00	1.00	1.25	1.50	2.00	2.00	2.25

Annex-B: Level of Service Analysis Input and Output of SIDRA Intersection

Table 6: Input data for LOS Analysis at Mebrat haile Intersection

Intersection Parameters	
Title	Mebrat-haile Intersection
Intersection ID	Mebrat
Unit Time (for volumes)	60 minutes
Peak Flow Period (for performance)	15 minutes

Geometry - Approach Data

Location	Name	Type	No. of App. Lanes	No. of Exit Lanes	Median Width m	Extra Bunching %
South	Posta-bet Approach	Two-way	2	2	3.50	0.0
East	Mariam Approach	Two-way	2	2	3.50	0.0
North	Tele Approach	Two-way	2	2	3.50	0.0
West	Sartera Approach	Two-way	2	2	3.50	0.0

Geometry - Approach Lane Data

Lane Number	Lane Type	Lane Discip.	Basic Sat'n Flow veh/h	Utilisation Ratio %	Saturation Speed km/h	Capacity Adjustment %
South Posta-bet Approach						
App. Lane 1	Normal	LT	1900	–	–	0.0
App. Lane 2	Normal	TR	1900	–	–	0.0
East Mariam Approach						
App. Lane 1	Normal	LT	1900	–	–	0.0
App. Lane 2	Normal	TR	1900	–	–	0.0
North Tele Approach						
App. Lane 1	Normal	LT	1900	–	–	0.0
App. Lane 2	Normal	TR	1900	–	–	0.0
West Sartera Approach						
App. Lane 1	Normal	LT	1900	–	–	0.0
App. Lane 2	Normal	TR	1900	–	–	0.0

Geometry - Approach & Exit Lane Data

Lane Number	Lane Width m	Lane Length m	Grade %	SL Type
South Posta-bet Approach				
App. Lane 1	3.50	500.0	0.50	–
App. Lane 2	3.50	500.0	0.50	–
Exit Lane 1	3.50	500.0	0.00	–
Exit Lane 2	3.50	500.0	0.00	–
East Mariam Approach				
App. Lane 1	3.50	500.0	0.50	–
App. Lane 2	3.50	500.0	0.50	–
Exit Lane 1	3.50	500.0	0.00	–
Exit Lane 2	3.50	500.0	0.00	–
North Tele Approach				
App. Lane 1	3.50	500.0	0.50	–
App. Lane 2	3.50	500.0	0.50	–
Exit Lane 1	3.50	500.0	0.00	–
Exit Lane 2	3.50	500.0	0.00	–
West Sartera Approach				
App. Lane 1	3.50	500.0	0.50	–
App. Lane 2	3.50	500.0	0.50	–
Exit Lane 1	3.50	500.0	0.00	–
Exit Lane 2	3.50	500.0	0.00	–

Lanes are numbered from left to right in the direction of travel.

Volumes

To Approach	Total veh	HV %	Peak Flow Factor %	Vehicle Occupancy pers/veh	Flow Scale %	Growth Rate %/year
From: South Posta-bet Approach						
West	564.0	2.01	91.9	1.20	100.00	2.00
North	500.0	0.82	97.8	1.20	100.00	2.00
East	291.0	0.43	96.1	1.20	100.00	2.00
From: East Mariam Approach						
South	1133.0	1.46	95.8	1.20	100.00	2.00
West	377.0	2.11	95.4	1.20	100.00	2.00
North	282.0	0.00	93.8	1.20	100.00	2.00
From: North Tele Approach						
East	1097.0	0.41	96.3	1.20	100.00	2.00
South	93.0	1.88	96.9	1.20	100.00	2.00
West	156.0	0.87	94.5	1.20	100.00	2.00
From: West Sartera Approach						
North	443.0	0.41	94.4	1.20	100.00	2.00
East	250.0	1.88	93.5	1.20	100.00	2.00
South	2180.0	0.87	95.0	1.20	100.00	2.00

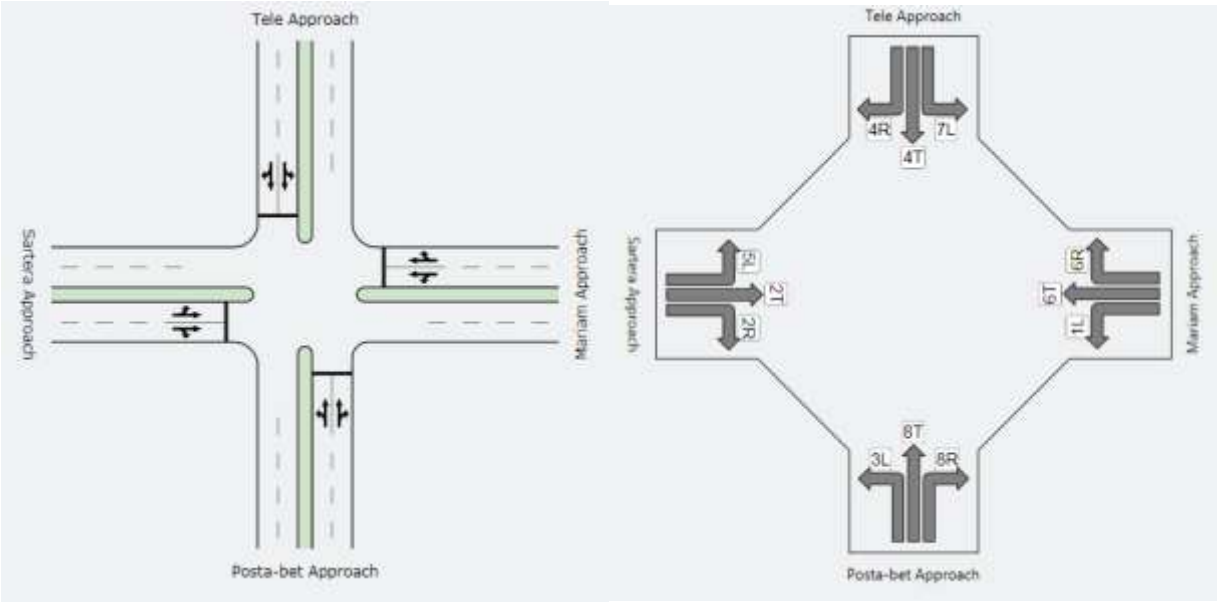

Figure 1: Lay out and Intersection Movement ID of Mebrat haile Intersection

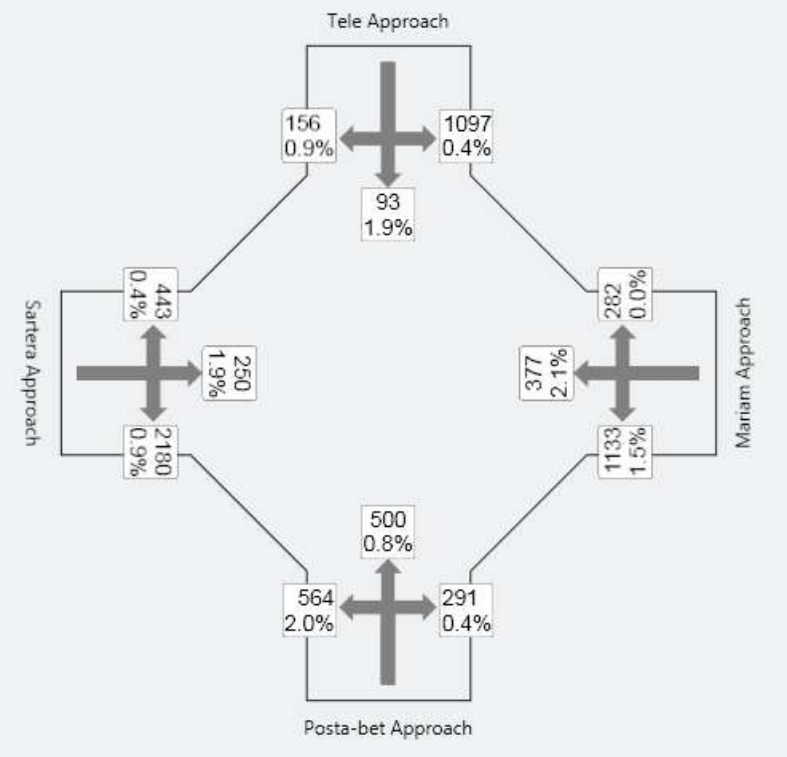

Figure 2: Traffic Volume Distribution and Truck Percentage on the Mebrat haile Intersection

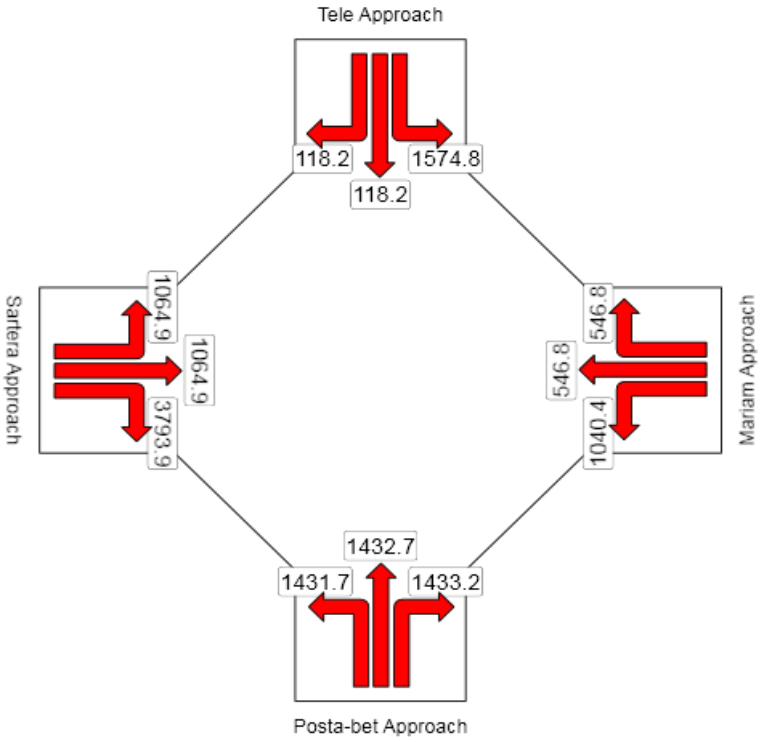

Figure 3: Delay in second for all movement ID

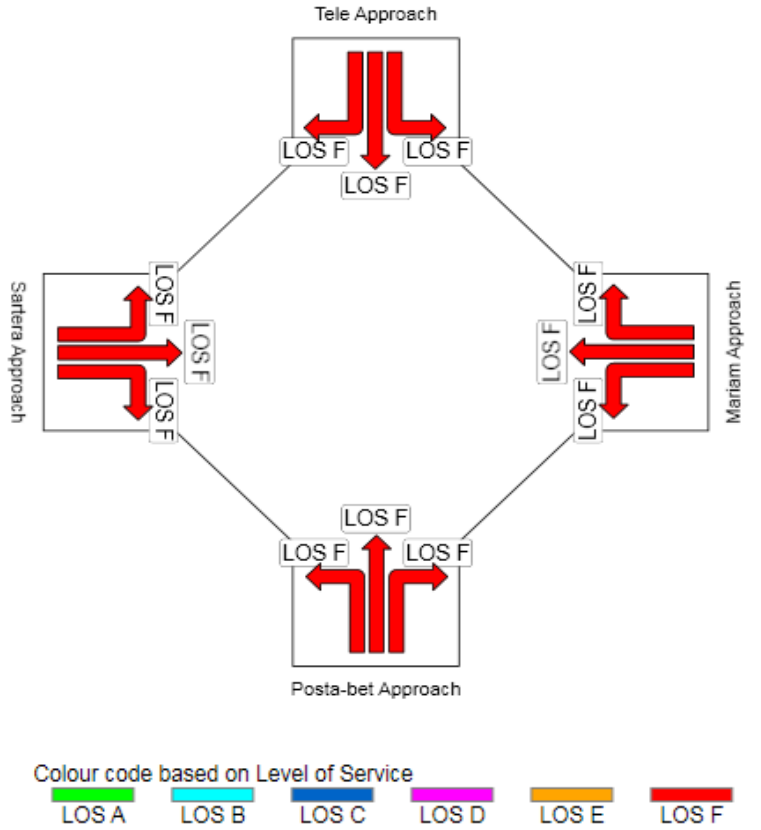

Figure 4: LOS values for Mebrat haile Intersection

Table 6: Input data for LOS Analysis Posta-bet Intersection

Intersection Parameters	
Title	Post-bet Intersection
Intersection ID	Posta
Unit Time (for volumes)	60 minutes
Peak Flow Period (for performance)	15 minutes

Geometry - Approach Data

Location	Name	Type	No. of App. Lanes	No. of Exit Lanes	Median Width m	Extra Bunching %
South	Sodere Approach	Two-way	2	2	2.00	0.0
East	Kela Intersection	Two-way	2	2	2.00	0.0
North	Mebrat-haile Intersection	Two-way	2	2	2.00	0.0
West	Franco Intersection	Two-way	2	2	2.00	0.0

Geometry - Roundabout Data

Location	Name	Island Diameter m	Circ. Width m	Circ. Lanes	Env. Factor	Entry/Circ. Flow Adjust.
South	Sodere Approach	7.50	8.50	2	1.2000	Medium
East	Kela Intersection	7.50	8.50	2	1.2000	Medium
North	Mebrat-haile Intersection	7.50	8.50	2	1.2000	Medium
West	Franco Intersection	7.50	8.50	2	1.2000	Medium

Geometry - Approach Lane Data

Lane Number	Lane Type	Lane Discip.	Basic Satn Flow tcu/h	Utilisation Ratio %	Saturation Speed km/h	Capacity Adjustment %
South	Sodere Approach					
App. Lane 1	Normal	T	1900	–	–	0.0
App. Lane 2	Slip (Giveway/Yield)	R	1900	–	–	0.0
East	Kela Intersection					
App. Lane 1	Normal	T	1900	–	–	0.0
App. Lane 2	Slip (Giveway/Yield)	R	1900	–	–	0.0
North	Mebrat-haile Intersection					
App. Lane 1	Normal	T	1900	–	–	0.0
App. Lane 2	Slip (Giveway/Yield)	R	1900	–	–	0.0
West	Franco Intersection					
App. Lane 1	Normal	T	1900	–	–	0.0
App. Lane 2	Slip (Giveway/Yield)	R	1900	–	–	0.0

Geometry - Approach & Exit Lane Data

Lane Number	Lane Width m	Lane Length m	Grade %	SL Type
South	Sodere Approach			
App. Lane 1	3.50	500.0	0.50	–
App. Lane 2	3.50	500.0	0.50	–
Exit Lane 1	3.50	500.0	0.00	–
Exit Lane 2	3.50	500.0	0.00	–
East	Kela Intersection			
App. Lane 1	3.50	500.0	0.50	–
App. Lane 2	3.50	500.0	0.50	–
Exit Lane 1	3.50	500.0	0.00	–
Exit Lane 2	3.50	500.0	0.00	–
North	Mebrat-haile Intersection			
App. Lane 1	3.50	500.0	0.50	–
App. Lane 2	3.50	500.0	0.50	–
Exit Lane 1	3.50	500.0	0.00	–
Exit Lane 2	3.50	500.0	0.00	–
West	Franco Intersection			
App. Lane 1	3.50	500.0	0.50	–
App. Lane 2	3.50	500.0	0.50	–
Exit Lane 1	3.50	500.0	0.00	–
Exit Lane 2	3.50	500.0	0.00	–

Lanes are numbered from left to right in the direction of travel.

Volumes						
To Approach	Total veh	HV %	Peak Flow Factor %	Vehicle Occupancy pers/veh	Flow Scale %	Growth Rate %/year
From: South	Sodere Approach					
North	917.0	2.29	96.9	1.20	100.00	2.00
East	122.0	7.05	94.4	1.20	100.00	2.00
From: East	Kela Intersection					
West	513.0	20.87	96.3	1.20	100.00	2.00
North	143.0	2.50	90.8	1.20	100.00	2.00
From: North	Mebrat-haile Intersection					
South	480.0	1.16	96.0	1.20	100.00	2.00
West	266.0	1.12	94.8	1.20	100.00	2.00
From: West	Franco Intersection					
East	717.0	17.15	97.2	1.20	100.00	2.00
South	243.0	17.81	95.7	1.20	100.00	2.00

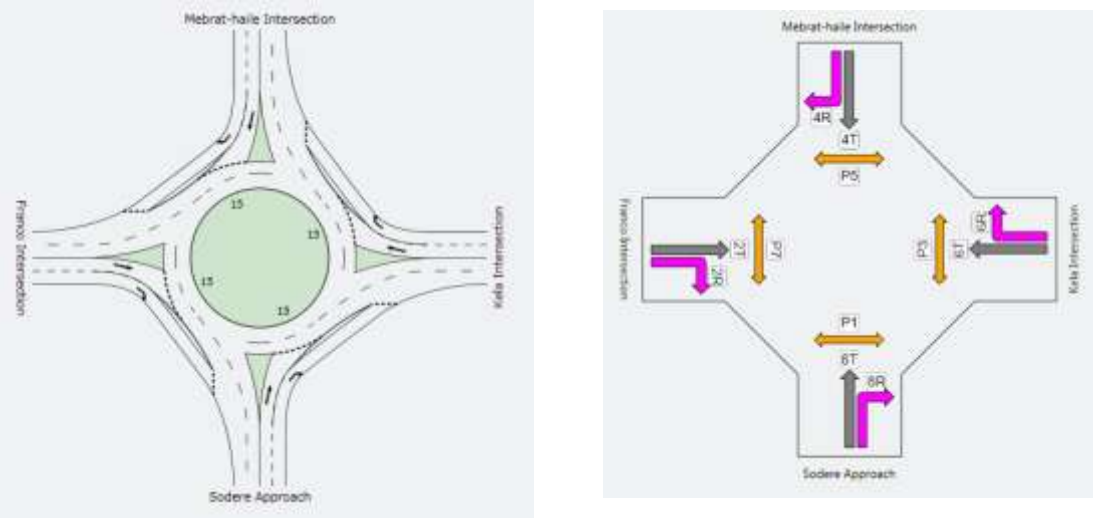

Figure 5: Lay out and Intersection Movement ID of Posta-bet Intersection

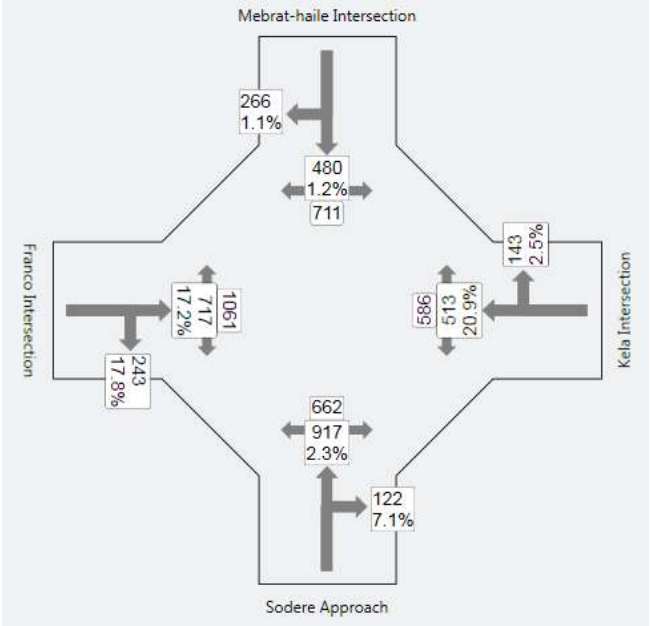

Figure 6: Traffic Volume Distribution and Truck Percentage on the Posta-bet Intersection

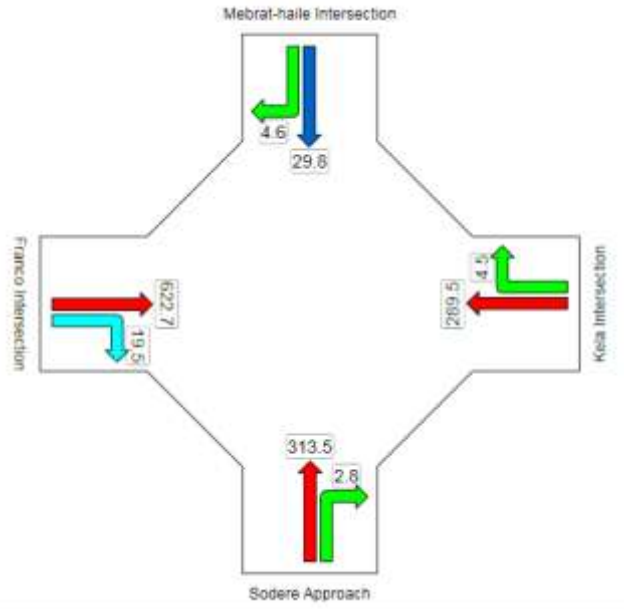

Figure 7: Delay in second for all movement ID

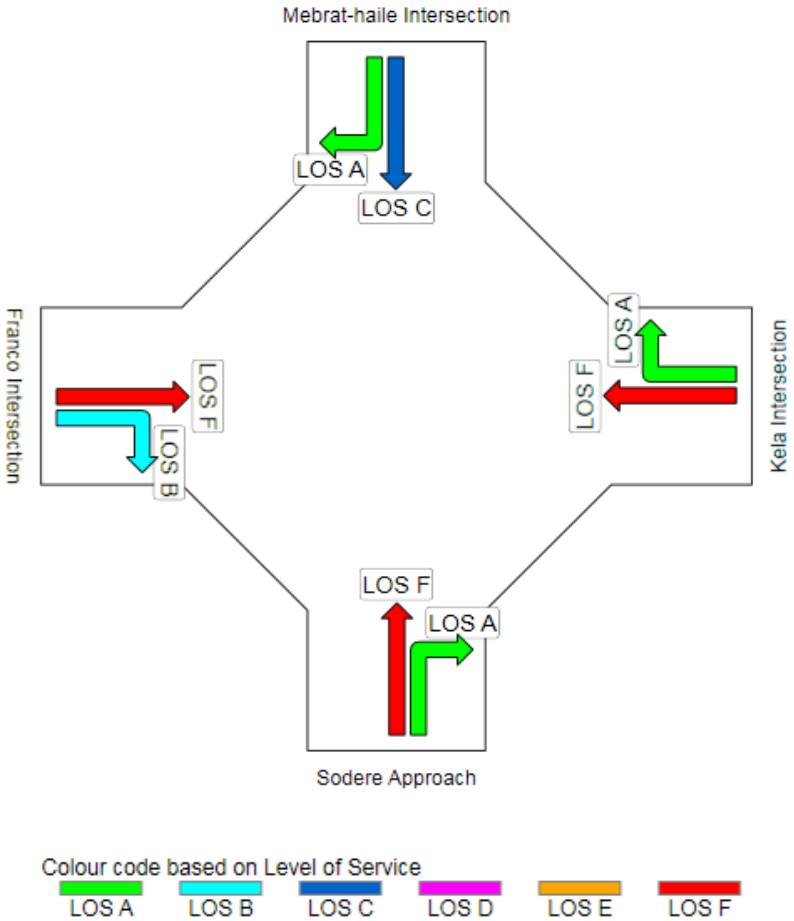

Figure 8: LOS values for Posta-bet Intersection

Table 7: Input data for LOS Analysis Franco Intersection

Intersection Parameters	
Title	Franco Intersection
Intersection ID	Franco
Unit Time (for volumes)	60 minutes
Peak Flow Period (for performance)	15 minutes

Geometry - Approach Data

Location	Name	Type	No. of App. Lanes	No. of Exit Lanes	Median Width m	Extra Bunching %
East	Posta-bet Approach	Two-way	2	2	2.00	0.0
North East	Genb Approach	Two-way	1	1	–	0.0
West	Maya-hotel Approach	Two-way	2	2	2.00	0.0

Geometry - Approach Lane Data

Lane Number	Lane Type	Lane Discip.	Basic Satn Flow tcu/h	Utilisation Ratio %	Saturation Speed km/h	Capacity Adjustment %
East Posta-bet Approach						
App. Lane 1	Normal	LT	1900	–	–	0.0
App. Lane 2	Normal	TR	1900	–	–	0.0
North East Genb Approach						
App. Lane 1	Normal	LR	1900	–	–	0.0
West Maya-hotel Approach						
App. Lane 1	Normal	LT	1900	–	–	0.0
App. Lane 2	Normal	T	1900	–	–	0.0

Geometry - Approach & Exit Lane Data

Lane Number	Lane Width m	Lane Length m	Grade %	SL Type
East Posta-bet Approach				
App. Lane 1	3.50	500.0	0.50	–
App. Lane 2	3.50	500.0	0.50	–
Exit Lane 1	3.50	500.0	0.00	–
Exit Lane 2	3.50	500.0	0.00	–
North East Genb Approach				
App. Lane 1	4.00	500.0	0.50	–
Exit Lane 1	4.00	500.0	0.00	–
West Maya-hotel Approach				
App. Lane 1	3.50	500.0	0.50	–
App. Lane 2	3.50	500.0	0.50	–
Exit Lane 1	3.50	500.0	0.00	–
Exit Lane 2	3.50	500.0	0.00	–

Lanes are numbered from left to right in the direction of travel.

Volumes

To Approach	Total veh	HV %	Peak Flow Factor %	Vehicle Occupancy pers/veh	Flow Scale %	Growth Rate %/year
From: East Posta-bet Approach						
East	69.0	7.70	81.8	1.20	100.00	2.00
West	684.0	16.93	94.6	1.20	100.00	2.00
North East	183.0	4.06	97.3	1.20	100.00	2.00
From: North East Genb Approach						
East	551.0	5.90	97.9	1.20	100.00	2.00
West	76.0	7.28	91.0	1.20	100.00	2.00
From: West Maya-hotel Approach						
North East	253.0	3.58	93.7	1.20	100.00	2.00
East	794.0	15.19	94.8	1.20	100.00	2.00

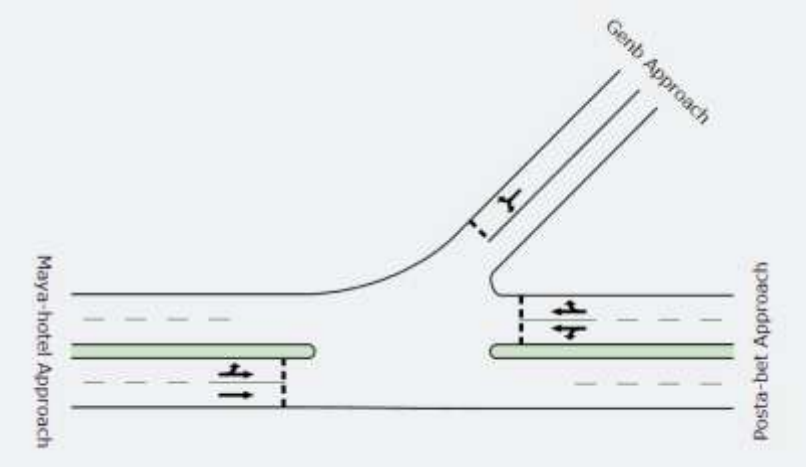

Figure 9: Lay out of Franco Intersection

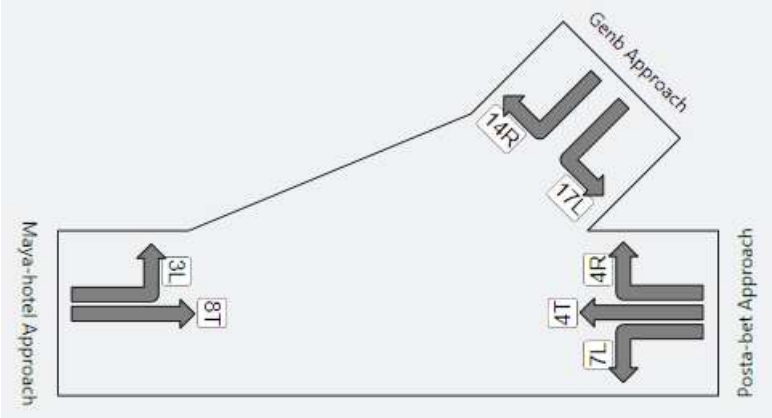

Figure 10: Movement ID of Franco Intersection

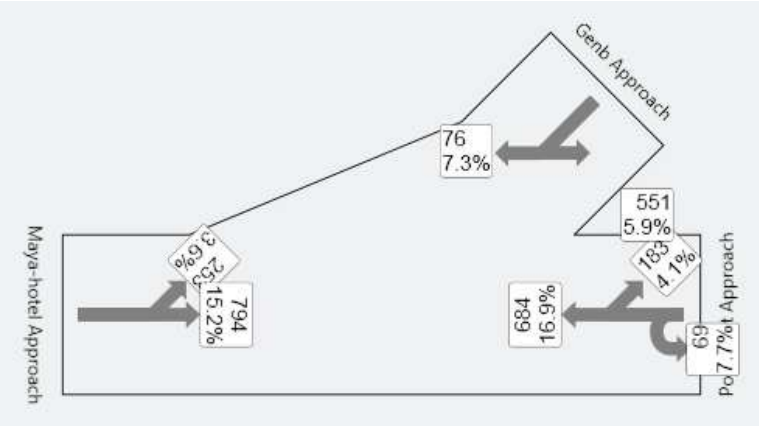

Figure 11: Traffic Volume Distribution and Truck Percentage on the Franco Intersection

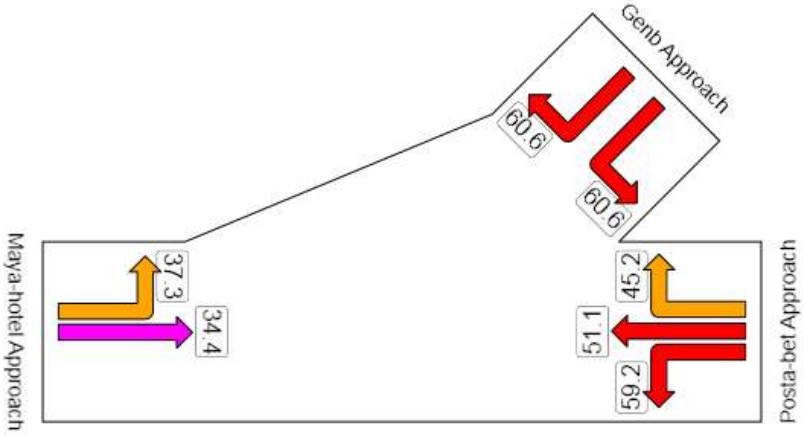

Figure 12: Delay in second for all movement ID

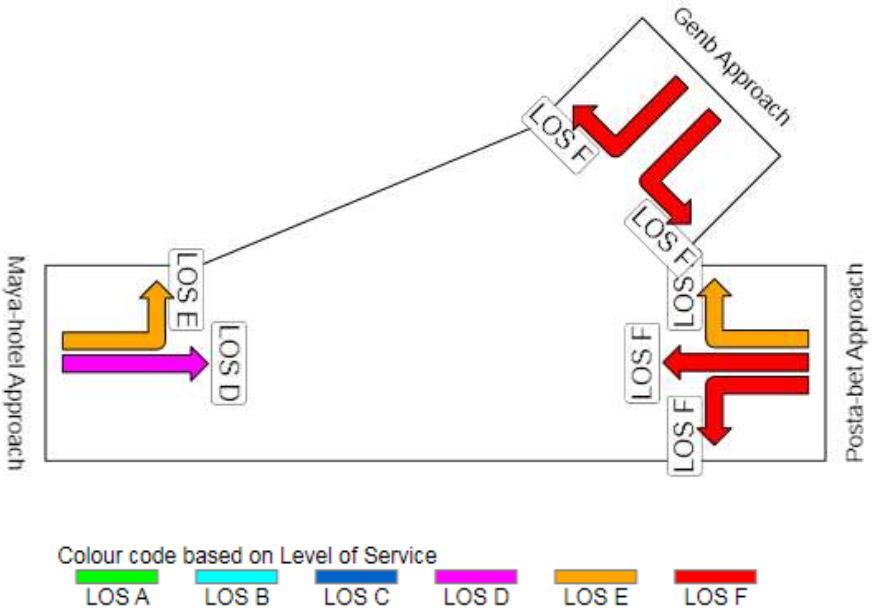

Figure 13: LOS values for Franco Intersection

Table 8: Input data for LOS Analysis Genb Intersection

Intersection Parameters	
Title	Genb Intersection
Intersection ID	Genb
Unit Time (for volumes)	60 minutes
Peak Flow Period (for performance)	15 minutes

Geometry - Approach Data

Location	Name	Type	No. of App. Lanes	No. of Exit Lanes	Median Width m	Extra Bunching %
South	Franco Approach	Two-way	1	1	–	0.0
East	Genb-gebeya Approach	Two-way	2	2	2.00	0.0
North	Sartera Approach	Two-way	1	1	–	0.0
West	Kera Approach	Two-way	2	2	2.00	0.0

Geometry - Approach Lane Data

Lane Number	Lane Type	Lane Discip.	Basic Satn Flow tcu/h	Utilisation Ratio %	Saturation Speed km/h	Capacity Adjustment %
South Franco Approach						
App. Lane 1	Normal	LTR	1900	–	–	0.0
East Genb-gebeya Approach						
App. Lane 1	Normal	LT	1900	–	–	0.0
App. Lane 2	Normal	TR	1900	–	–	0.0
North Sartera Approach						
App. Lane 1	Normal	LTR	1900	–	–	0.0
West Kera Approach						
App. Lane 1	Normal	LT	1900	–	–	0.0
App. Lane 2	Normal	TR	1900	–	–	0.0

Geometry - Approach & Exit Lane Data

Lane Number	Lane Width m	Lane Length m	Grade %	SL Type
South Franco Approach				
App. Lane 1	4.00	500.0	0.50	–
Exit Lane 1	4.00	500.0	0.00	–
East Genb-gebeya Approach				
App. Lane 1	3.00	500.0	0.50	–
App. Lane 2	3.00	500.0	0.50	–
Exit Lane 1	3.00	500.0	0.00	–
Exit Lane 2	3.00	500.0	0.00	–
North Sartera Approach				
App. Lane 1	4.00	500.0	0.50	–
Exit Lane 1	4.00	500.0	0.00	–
West Kera Approach				
App. Lane 1	3.00	500.0	0.50	–
App. Lane 2	3.00	500.0	0.50	–
Exit Lane 1	3.00	500.0	0.00	–
Exit Lane 2	3.00	500.0	0.00	–

Lanes are numbered from left to right in the direction of travel.

Volumes

To Approach		Total veh	HV %	Peak Flow Factor %	Vehicle Occupancy pers/veh	Flow Scale %	Growth Rate %/year
From: South	Franco Approach						
West		165.0	4.09	91.8	1.20	100.00	2.00
North		870.0	0.34	97.1	1.20	100.00	2.00
East		240.0	0.00	96.5	1.20	100.00	2.00
From: East	Genb-gebeya Approach						
South		173.0	4.67	91.9	1.20	100.00	2.00
West		103.0	2.60	92.3	1.20	100.00	2.00
North		219.0	0.91	94.0	1.20	100.00	2.00
From: North	Sartera Approach						
East		114.0	3.42	85.3	1.20	100.00	2.00
South		298.0	1.27	97.2	1.20	100.00	2.00
West		122.0	0.00	97.0	1.20	100.00	2.00
From: West	Kera Approach						
North		136.0	2.12	94.0	1.20	100.00	2.00
East		133.0	2.79	93.5	1.20	100.00	2.00
South		189.0	3.53	93.1	1.20	100.00	2.00

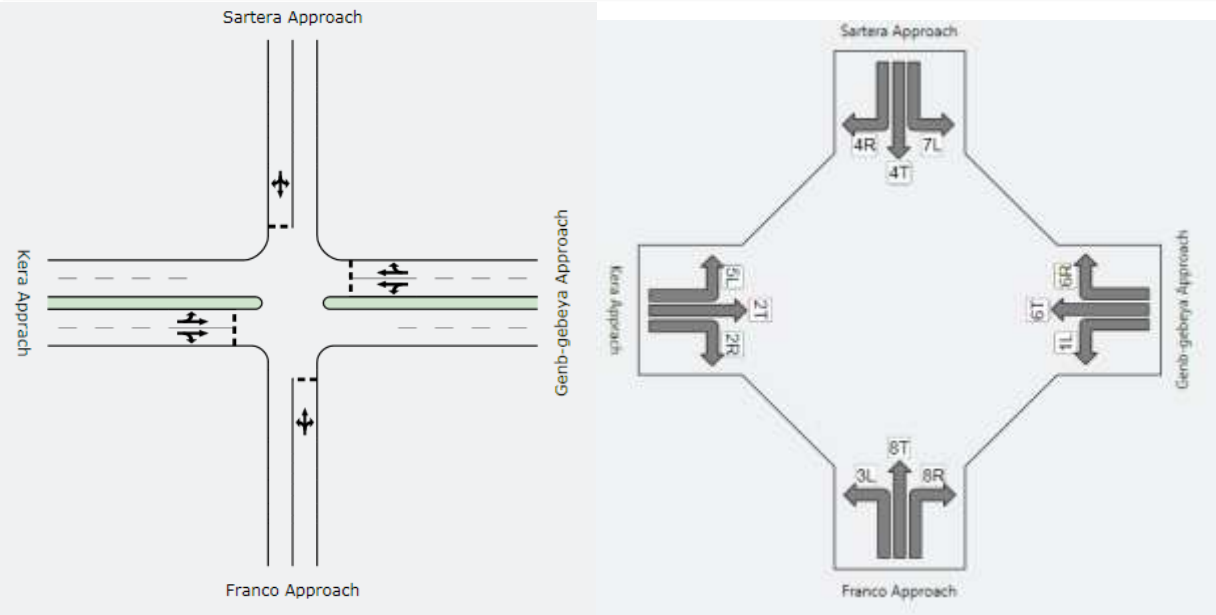

Figure 14: Lay out and Intersection Movement ID of Genb Intersection

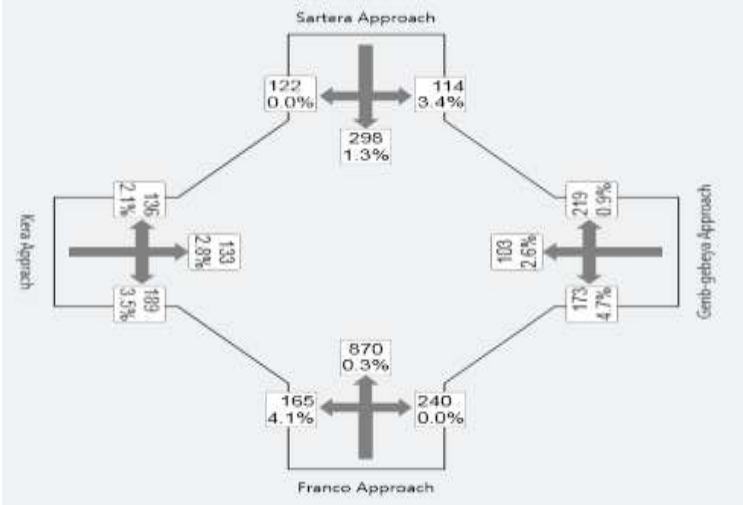

Figure 15: Traffic Volume Distribution and Truck Percentage on the Genb Intersection

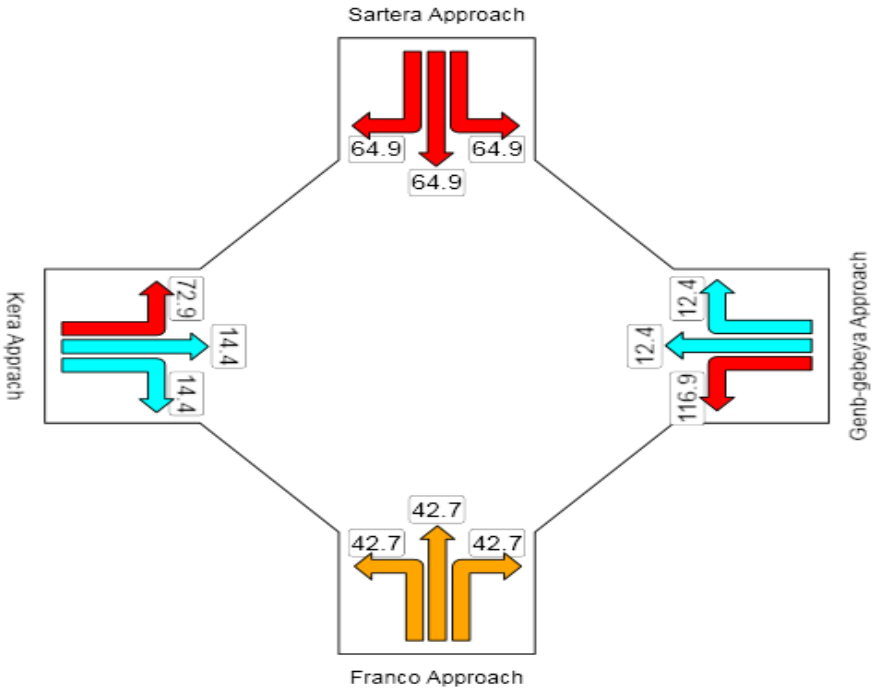

Figure 16: Delay in second for all movement ID

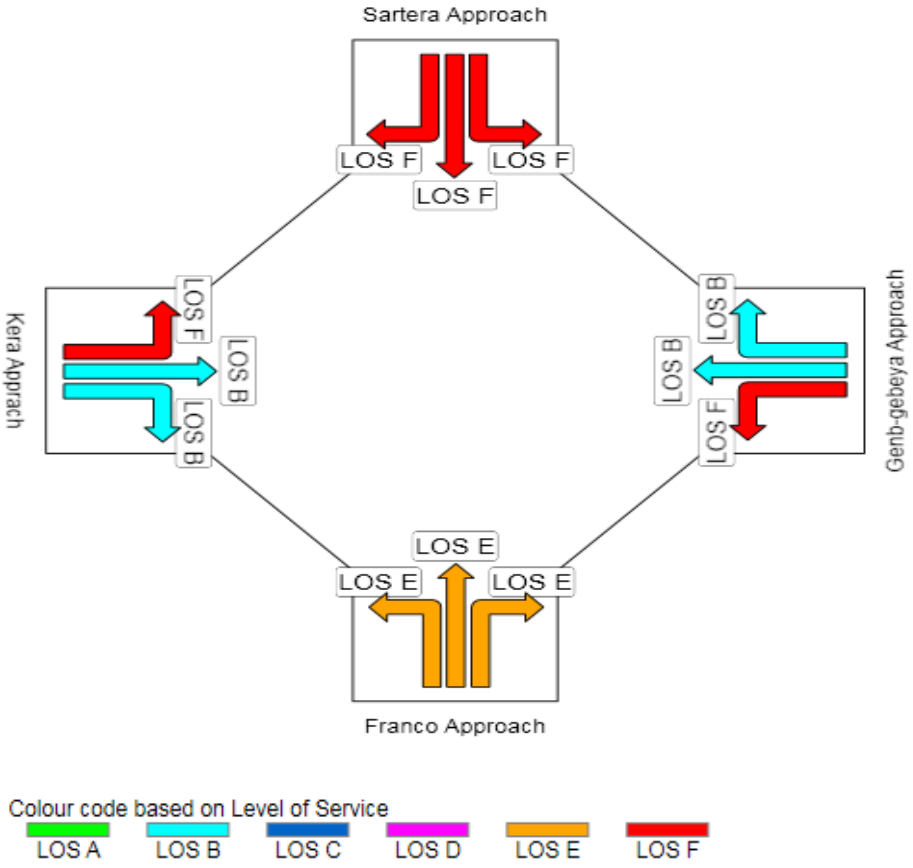

Figure 17: LOS values for Franco Intersection

Annex-C: Congestion Measures Analysis

Table 9: Congestion Measures Analysis for Mebrat haile Intersection

Intersection:	Mebrat haile									
Approach:	Posta-bet									
Length:	200m									
Duration	Average Travel Time(Sec)	Delay (Sec)	Average Travel Speed (Km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Veh)	Total Segment Delay (Veh-Min)	Total Segment Delay (Veh-Min)/meter	Delay Ratio
7:30-7:45AM	51.2	15.2	14.06	4.27	1.27	1.42	184	46.61	0.17	0.30
7:45-8:00AM	49.05	13.05	14.68	4.09	1.09	1.36	237	51.44	0.18	0.27
8:00-8:15AM	94.4	58.4	7.63	7.87	4.87	2.62	312	303.68	1.02	0.62
8:15-8:30AM	91.2	55.2	7.89	7.60	4.60	2.53	278	255.53	0.93	0.61
8:30-8:45AM	100	64	7.20	8.33	5.33	2.78	283	302.13	1.05	0.64
8:45-9:00AM	87.6	51.6	8.22	7.30	4.30	2.43	306	263.16	0.85	0.59
9:00-9:15AM	82.4	46.4	8.74	6.87	3.87	2.29	268	207.06	0.70	0.56
9:15-9:30AM	87.2	51.2	8.26	7.27	4.27	2.42	270	230.61	0.76	0.59
9:30-9:45AM	72.4	36.4	9.94	6.03	3.03	2.01	287	173.96	0.63	0.50
9:45-10:00AM	75.6	39.6	9.52	6.30	3.30	2.10	284	187.61	0.65	0.52
10:00-10:15AM	62	26	11.61	5.17	2.17	1.72	285	123.39	0.42	0.42
10:15-10:30AM	66.8	30.8	10.78	5.57	2.57	1.86	309	158.62	0.49	0.46
10:30-10:45AM	70.8	34.8	10.17	5.90	2.90	1.97	329	190.68	0.66	0.49
10:45-11:00AM	76.4	40.4	9.42	6.37	3.37	2.12	307	206.38	0.64	0.53
11:00-11:15AM	85.6	49.6	8.41	7.13	4.13	2.38	259	214.31	0.73	0.58
11:15-11:30AM	72.4	36.4	9.94	6.03	3.03	2.01	257	155.76	0.57	0.50
11:30-11:45AM	62.4	26.4	11.54	5.20	2.20	1.73	247	108.68	0.39	0.42
11:45-12:00AM	76.8	40.8	9.38	6.40	3.40	2.13	242	164.56	0.52	0.53
12:00-12:15AM	59.6	23.6	12.08	4.97	1.97	1.66	245	96.17	0.32	0.40
12:15-12:30AM	80.4	44.4	8.96	6.70	3.70	2.23	270	199.62	0.63	0.55
12:30-12:45AM	59.2	23.2	12.16	4.93	1.93	1.64	222	85.74	0.29	0.39
12:45-1:00AM	54.8	18.8	13.14	4.57	1.57	1.52	254	79.67	0.25	0.34
1:00-1:15PM	53.2	17.2	13.53	4.43	1.43	1.48	236	67.73	0.24	0.32
1:15-1:30PM	59.2	23.2	12.16	4.93	1.93	1.64	281	108.56	0.36	0.39
1:30-1:45PM	56.8	20.8	12.68	4.73	1.73	1.58	258	89.44	0.32	0.37
1:45-2:00PM	65.2	29.2	11.04	5.43	2.43	1.81	241	117.29	0.44	0.45
2:00-2:15PM	62.4	26.4	11.54	5.20	2.20	1.73	261	114.62	0.40	0.42
2:15-2:30PM	61.2	25.2	11.76	5.10	2.10	1.70	260	109.20	0.39	0.41
2:30-2:45PM	60	24	12.00	5.00	2.00	1.67	282	112.60	0.34	0.40
2:45-3:00PM	91.2	55.2	7.89	7.60	4.60	2.53	258	237.13	0.83	0.61
3:00-3:15PM	88	52	8.18	7.33	4.33	2.44	274	237.03	0.79	0.59
3:15-3:30PM	104.8	68.8	6.87	8.73	5.73	2.91	300	343.71	1.04	0.66
3:30-3:45PM	113.2	77.2	6.36	9.43	6.43	3.14	251	323.28	1.14	0.68
3:45-4:00PM	110.4	74.4	6.52	9.20	6.20	3.07	313	387.50	1.31	0.67
4:00-4:15PM	109.2	73.2	6.59	9.10	6.10	3.03	300	366.31	1.27	0.67
4:15-4:30PM	108	72	6.67	9.00	6.00	3.00	316	379.50	1.25	0.67
4:30-4:45PM	113.6	77.6	6.34	9.47	6.47	3.16	318	410.96	1.31	0.68
4:45-5:00PM	126.8	90.8	5.68	10.57	7.57	3.52	322	486.54	1.69	0.72
5:00-5:15PM	124	88	5.81	10.33	7.33	3.44	311	455.77	1.66	0.71
5:15-5:30PM	138	102	5.22	11.50	8.50	3.83	357	606.48	1.98	0.74
5:30-5:45PM	128	92	5.63	10.67	7.67	3.56	372	569.63	1.77	0.72
5:45-6:00PM	139.2	103.2	5.17	11.60	8.60	3.87	334	573.62	1.98	0.74
6:00-6:15PM	137.2	101.2	5.25	11.43	8.43	3.81	291	490.82	1.63	0.74
6:15-6:30PM	133.2	97.2	5.41	11.10	8.10	3.70	308	498.15	1.62	0.73
6:30-6:45PM	137.6	101.6	5.23	11.47	8.47	3.82	319	540.60	1.64	0.74
6:45-7:00PM	101.2	65.2	7.11	8.43	5.43	2.81	241	261.62	0.90	0.64
7:00-7:15PM	90.8	54.8	7.93	7.57	4.57	2.52	296	270.58	0.86	0.60
7:15-7:30PM	84	48	8.57	7.00	4.00	2.33	239	191.40	0.64	0.57

Table 10: Congestion Measures Analysis for Posta-bet Intersection

Intersection:	**Posta-bet**									
Approach:	**Franko**									
Length:	**200m**									
Duration	Average Travel Time(Sec)	Delay (Sec)	Average Travel Speed (Km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Veh)	Total Segment Delay (Veh-Min)	Total Segment Delay (Veh-Min)/meter	Delay Ratio
7:30-7:45AM	66.85	30.85	10.77	5.57	2.57	1.86	175	89.98	0.45	0.46
7:45-8:00AM	81.10	45.10	8.88	6.76	3.76	2.25	155	116.51	0.58	0.56
8:00-8:15AM	106.50	70.50	6.76	8.88	5.88	2.96	195	229.13	1.15	0.66
8:15-8:30AM	101.70	65.70	7.08	8.48	5.48	2.83	203	222.29	1.11	0.65
8:30-8:45AM	103.80	67.80	6.94	8.65	5.65	2.88	213	240.69	1.20	0.65
8:45-9:00AM	104.70	68.70	6.88	8.73	5.73	2.91	216	247.32	1.24	0.66
9:00-9:15AM	103.20	67.20	6.98	8.60	5.60	2.87	221	247.52	1.24	0.65
9:15-9:30AM	106.80	70.80	6.74	8.90	5.90	2.97	209	246.62	1.23	0.66
9:30-9:45AM	99.00	63.00	7.27	8.25	5.25	2.75	195	204.75	1.02	0.64
9:45-10:00AM	101.10	65.10	7.12	8.43	5.43	2.81	200	217.00	1.09	0.64
10:00-10:15AM	91.20	55.20	7.89	7.60	4.60	2.53	186	171.12	0.86	0.61
10:15-10:30AM	92.40	56.40	7.79	7.70	4.70	2.57	188	176.72	0.88	0.61
10:30-10:45AM	88.20	52.20	8.16	7.35	4.35	2.45	190	165.30	0.83	0.59
10:45-11:00AM	90.30	54.30	7.97	7.53	4.53	2.51	177	160.19	0.80	0.60
11:00-11:15AM	103.80	67.80	6.94	8.65	5.65	2.88	182	205.66	1.03	0.65
11:15-11:30AM	92.70	56.70	7.77	7.73	4.73	2.58	168	158.76	0.79	0.61
11:30-11:45AM	90.30	54.30	7.97	7.53	4.53	2.51	173	156.57	0.78	0.60
11:45-12:00AM	82.80	46.80	8.70	6.90	3.90	2.30	176	137.28	0.69	0.57
12:00-12:15AM	93.60	57.60	7.69	7.80	4.80	2.60	178	170.88	0.85	0.62
12:15-12:30AM	80.70	44.70	8.92	6.73	3.73	2.24	163	121.44	0.61	0.55
12:30-12:45AM	96.30	60.30	7.48	8.03	5.03	2.68	164	164.82	0.82	0.63
12:45-1:00AM	80.40	44.40	8.96	6.70	3.70	2.23	168	124.32	0.62	0.55
1:00-1:15PM	77.10	41.10	9.34	6.43	3.43	2.14	179	122.62	0.61	0.53
1:15-1:30PM	75.90	39.90	9.49	6.33	3.33	2.11	171	113.72	0.57	0.53
1:30-1:45PM	80.40	44.40	8.96	6.70	3.70	2.23	170	125.80	0.63	0.55
1:45-2:00PM	78.60	42.60	9.16	6.55	3.55	2.18	166	117.86	0.59	0.54
2:00-2:15PM	84.90	48.90	8.48	7.08	4.08	2.36	180	146.70	0.73	0.58
2:15-2:30PM	82.80	46.80	8.70	6.90	3.90	2.30	208	162.24	0.81	0.57
2:30-2:45PM	82.50	46.50	8.73	6.88	3.88	2.29	236	182.90	0.91	0.56
2:45-3:00PM	81.00	45.00	8.89	6.75	3.75	2.25	265	198.75	0.99	0.56
3:00-3:15PM	85.20	49.20	8.45	7.10	4.10	2.37	228	186.96	0.93	0.58
3:15-3:30PM	95.10	59.10	7.57	7.93	4.93	2.64	226	222.61	1.11	0.62
3:30-3:45PM	93.00	57.00	7.74	7.75	4.75	2.58	184	174.80	0.87	0.61
3:45-4:00PM	103.50	67.50	6.96	8.63	5.63	2.88	223	250.88	1.25	0.65
4:00-4:15PM	96.00	60.00	7.50	8.00	5.00	2.67	219	219.00	1.10	0.63
4:15-4:30PM	104.40	68.40	6.90	8.70	5.70	2.90	223	254.22	1.27	0.66
4:30-4:45PM	102.90	66.90	7.00	8.58	5.58	2.86	222	247.53	1.24	0.65
4:45-5:00PM	99.90	63.90	7.21	8.33	5.33	2.78	216	230.04	1.15	0.64
5:00-5:15PM	103.20	67.20	6.98	8.60	5.60	2.87	205	229.60	1.15	0.65
5:15-5:30PM	105.30	69.30	6.84	8.78	5.78	2.93	191	220.61	1.10	0.66
5:30-5:45PM	107.40	71.40	6.70	8.95	5.95	2.98	190	226.10	1.13	0.66
5:45-6:00PM	107.70	71.70	6.69	8.98	5.98	2.99	170	203.15	1.02	0.67
6:00-6:15PM	99.60	63.60	7.23	8.30	5.30	2.77	181	191.86	0.96	0.64
6:15-6:30PM	98.10	62.10	7.34	8.18	5.18	2.73	172	178.02	0.89	0.63
6:30-6:45PM	107.10	71.10	6.72	8.93	5.93	2.98	155	183.68	0.92	0.66
6:45-7:00PM	106.80	70.80	6.74	8.90	5.90	2.97	139	164.02	0.82	0.66
7:00-7:15PM	100.20	64.20	7.19	8.35	5.35	2.78	137	146.59	0.73	0.64
7:15-7:30PM	95.70	59.70	7.52	7.98	4.98	2.66	138	137.31	0.69	0.62

Table 11: Congestion Measures Analysis for Franco Intersection

Intersection:	Franco									
Approach:	Maya hotel									
Length:	250m									
Duration	Average Travel Time(Sec)	Delay (Sec)	Average Travel Speed (Km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Veh)	Total Segment Delay (Veh-Min)	Total Segment Delay (Veh-Min)/meter	Delay Ratio
7:30-7:45AM	54.78	9.78	16.43	3.65	0.65	1.22	531	86.47	0.13	0.18
7:45-8:00AM	79.93	34.93	11.26	5.33	2.33	1.78	434	252.33	0.47	0.44
8:00-8:15AM	109.73	64.73	8.20	7.32	4.32	2.44	520	560.41	1.03	0.59
8:15-8:30AM	117.33	72.33	7.67	7.82	4.82	2.61	500	602.71	1.13	0.62
8:30-8:45AM	121.13	76.13	7.43	8.08	5.08	2.69	484	614.08	1.24	0.63
8:45-9:00AM	112.10	67.10	8.03	7.47	4.47	2.49	435	485.92	1.01	0.60
9:00-9:15AM	108.30	63.30	8.31	7.22	4.22	2.41	418	441.25	1.00	0.58
9:15-9:30AM	118.75	73.75	7.58	7.92	4.92	2.64	423	519.94	1.07	0.62
9:30-9:45AM	104.03	59.03	8.65	6.94	3.94	2.31	396	389.32	0.82	0.57
9:45-10:00AM	97.85	52.85	9.20	6.52	3.52	2.17	463	407.39	0.84	0.54
10:00-10:15AM	103.55	58.55	8.69	6.90	3.90	2.30	402	392.29	0.80	0.57
10:15-10:30AM	85.98	40.98	10.47	5.73	2.73	1.91	371	253.19	0.49	0.48
10:30-10:45AM	89.78	44.78	10.03	5.99	2.99	2.00	401	299.43	0.61	0.50
10:45-11:00AM	73.63	28.63	12.22	4.91	1.91	1.64	372	177.24	0.35	0.39
11:00-11:15AM	79.33	34.33	11.35	5.29	2.29	1.76	392	224.26	0.44	0.43
11:15-11:30AM	84.08	39.08	10.70	5.61	2.61	1.87	396	258.06	0.52	0.46
11:30-11:45AM	75.05	30.05	11.99	5.00	2.00	1.67	379	189.82	0.40	0.40
11:45-12:00AM	71.73	26.73	12.55	4.78	1.78	1.59	361	160.68	0.31	0.37
12:00-12:15AM	74.10	29.10	12.15	4.94	1.94	1.65	390	188.91	0.36	0.39
12:15-12:30AM	94.53	49.53	9.52	6.30	3.30	2.10	402	331.61	0.62	0.52
12:30-12:45AM	76.48	31.48	11.77	5.10	2.10	1.70	381	199.74	0.39	0.41
12:45-1:00AM	77.90	32.90	11.55	5.19	2.19	1.73	426	233.59	0.43	0.42
1:00-1:15PM	74.10	29.10	12.15	4.94	1.94	1.65	455	220.68	0.40	0.39
1:15-1:30PM	72.20	27.20	12.47	4.81	1.81	1.60	422	191.31	0.37	0.38
1:30-1:45PM	86.93	41.93	10.35	5.80	2.80	1.93	424	296.27	0.53	0.48
1:45-2:00PM	79.80	34.80	11.28	5.32	2.32	1.77	394	228.67	0.42	0.44
2:00-2:15PM	71.25	26.25	12.63	4.75	1.75	1.58	390	170.63	0.33	0.37
2:15-2:30PM	81.23	36.23	11.08	5.42	2.42	1.81	430	259.31	0.52	0.45
2:30-2:45PM	97.85	52.85	9.20	6.52	3.52	2.17	425	373.91	0.79	0.54
2:45-3:00PM	87.40	42.40	10.30	5.83	2.83	1.94	466	329.31	0.65	0.49
3:00-3:15PM	81.23	36.23	11.08	5.42	2.42	1.81	528	318.93	0.59	0.45
3:15-3:30PM	83.13	38.13	10.83	5.54	2.54	1.85	569	361.23	0.71	0.46
3:30-3:45PM	109.25	64.25	8.24	7.28	4.28	2.43	513	548.80	1.08	0.59
3:45-4:00PM	138.70	93.70	6.49	9.25	6.25	3.08	565	882.34	1.81	0.68
4:00-4:15PM	133.00	88.00	6.77	8.87	5.87	2.96	571	836.73	1.70	0.66
4:15-4:30PM	128.25	83.25	7.02	8.55	5.55	2.85	643	892.51	1.61	0.65
4:30-4:45PM	149.63	104.63	6.02	9.98	6.98	3.33	584	1018.35	1.97	0.70
4:45-5:00PM	112.10	67.10	8.03	7.47	4.47	2.49	560	626.27	1.16	0.60
5:00-5:15PM	152.00	107.00	5.92	10.13	7.13	3.38	512	912.18	1.79	0.70
5:15-5:30PM	138.70	93.70	6.49	9.25	6.25	3.08	473	739.06	1.58	0.68
5:30-5:45PM	125.40	80.40	7.18	8.36	5.36	2.79	422	565.15	1.25	0.64
5:45-6:00PM	117.80	72.80	7.64	7.85	4.85	2.62	463	561.77	1.12	0.62
6:00-6:15PM	155.33	110.33	5.79	10.36	7.36	3.45	505	928.11	1.90	0.71
6:15-6:30PM	145.83	100.83	6.17	9.72	6.72	3.24	433	726.78	1.41	0.69
6:30-6:45PM	124.93	79.93	7.20	8.33	5.33	2.78	472	629.08	1.23	0.64
6:45-7:00PM	128.73	83.73	6.99	8.58	5.58	2.86	386	538.28	1.13	0.65
7:00-7:15PM	129.20	84.20	6.97	8.61	5.61	2.87	406	569.05	1.19	0.65
7:15-7:30PM	111.15	66.15	8.10	7.41	4.41	2.47	381	420.33	0.87	0.60

Table 12: Congestion Measures Analysis for Genb Intersection

Intersection:	**Genb**									
Approach:	**Franco**									
Length:	**150m**									
Duration	Average Travel Time(Sec)	Delay (Sec)	Average Travel Speed (Km/h)	Travel Rate (min/Km)	Delay Rate (min/Km)	Travel Time Index	Traffic Volume (Veh)	Total Segment Delay (Veh-Min)	Total Segment Delay (Veh-Min)/meter	Delay Ratio
7:30-7:45AM	24.75	0.00	21.82	2.75	0.00	0.92	202	0.00	0.00	0.00
7:45-8:00AM	34.50	7.50	15.65	3.83	0.83	1.28	169	96.89	0.57	0.22
8:00-8:15AM	42.38	15.38	12.74	4.71	1.71	1.57	241	169.85	0.82	0.36
8:15-8:30AM	38.50	11.50	14.03	4.28	1.28	1.43	243	155.93	0.81	0.30
8:30-8:45AM	43.25	16.25	12.49	4.81	1.81	1.60	235	169.22	0.86	0.38
8:45-9:00AM	39.50	12.50	13.67	4.39	1.39	1.46	253	166.72	0.85	0.32
9:00-9:15AM	42.00	15.00	12.86	4.67	1.67	1.56	279	195.13	0.98	0.36
9:15-9:30AM	39.13	12.13	13.80	4.35	1.35	1.45	281	183.40	0.95	0.31
9:30-9:45AM	39.75	12.75	13.58	4.42	1.42	1.47	235	155.36	0.83	0.32
9:45-10:00AM	35.25	8.25	15.32	3.92	0.92	1.31	273	160.39	0.75	0.23
10:00-10:15AM	33.40	6.40	16.17	3.71	0.71	1.24	218	121.35	0.66	0.19
10:15-10:30AM	29.50	2.50	18.31	3.28	0.28	1.09	255	125.50	0.71	0.08
10:30-10:45AM	25.30	0.00	21.34	2.81	0.00	0.94	221	93.19	0.54	0.00
10:45-11:00AM	28.10	1.10	19.22	3.12	0.12	1.04	229	107.37	0.57	0.04
11:00-11:15AM	29.90	2.90	18.06	3.32	0.32	1.11	256	127.70	0.63	0.10
11:15-11:30AM	27.80	0.80	19.42	3.09	0.09	1.03	199	92.20	0.57	0.03
11:30-11:45AM	31.60	4.60	17.09	3.51	0.51	1.17	205	107.70	0.62	0.15
11:45-12:00AM	29.00	2.00	18.62	3.22	0.22	1.07	254	122.53	0.68	0.07
12:00-12:15AM	27.60	0.60	19.57	3.07	0.07	1.02	250	115.00	0.65	0.02
12:15-12:30AM	27.70	0.70	19.49	3.08	0.08	1.03	259	119.34	0.62	0.03
12:30-12:45AM	27.50	0.50	19.64	3.06	0.06	1.02	286	130.85	0.65	0.02
12:45-1:00AM	27.25	0.25	19.82	3.03	0.03	1.01	250	113.31	0.59	0.01
1:00-1:15PM	30.40	3.40	17.76	3.38	0.38	1.13	245	124.13	0.69	0.11
1:15-1:30PM	29.70	2.70	18.18	3.30	0.30	1.10	258	127.71	0.66	0.09
1:30-1:45PM	31.90	4.90	16.93	3.54	0.54	1.18	288	152.99	0.73	0.15
1:45-2:00PM	32.00	5.00	16.88	3.56	0.56	1.19	229	122.27	0.69	0.16
2:00-2:15PM	33.00	6.00	16.36	3.67	0.67	1.22	256	140.80	0.75	0.18
2:15-2:30PM	32.70	5.70	16.51	3.63	0.63	1.21	225	122.35	0.66	0.17
2:30-2:45PM	37.60	10.60	14.36	4.18	1.18	1.39	253	158.39	0.91	0.28
2:45-3:00PM	37.20	10.20	14.52	4.13	1.13	1.38	271	168.18	0.84	0.27
3:00-3:15PM	38.20	11.20	14.14	4.24	1.24	1.41	303	193.07	0.98	0.29
3:15-3:30PM	39.30	12.30	13.74	4.37	1.37	1.46	303	198.30	1.14	0.31
3:30-3:45PM	45.88	18.88	11.77	5.10	2.10	1.70	331	253.27	1.36	0.41
3:45-4:00PM	44.50	17.50	12.13	4.94	1.94	1.65	382	282.95	1.52	0.39
4:00-4:15PM	49.50	22.50	10.91	5.50	2.50	1.83	359	296.18	1.57	0.45
4:15-4:30PM	47.25	20.25	11.43	5.25	2.25	1.75	385	302.79	1.51	0.43
4:30-4:45PM	45.25	18.25	11.93	5.03	2.03	1.68	365	275.08	1.49	0.40
4:45-5:00PM	44.88	17.88	12.03	4.99	1.99	1.66	415	310.01	1.55	0.40
5:00-5:15PM	41.88	14.88	12.90	4.65	1.65	1.55	411	286.84	1.41	0.36
5:15-5:30PM	40.88	13.88	13.21	4.54	1.54	1.51	356	242.35	1.29	0.34
5:30-5:45PM	49.88	22.88	10.83	5.54	2.54	1.85	309	256.86	1.42	0.46
5:45-6:00PM	47.00	20.00	11.49	5.22	2.22	1.74	389	304.52	1.59	0.43
6:00-6:15PM	45.75	18.75	11.80	5.08	2.08	1.69	391	298.14	1.49	0.41
6:15-6:30PM	47.25	20.25	11.43	5.25	2.25	1.75	373	293.34	1.44	0.43
6:30-6:45PM	46.88	19.88	11.52	5.21	2.21	1.74	356	277.73	1.38	0.42
6:45-7:00PM	51.00	24.00	10.59	5.67	2.67	1.89	353	300.05	1.45	0.47
7:00-7:15PM	48.50	21.50	11.13	5.39	2.39	1.80	377	304.94	1.59	0.44
7:15-7:30PM	43.63	16.63	12.38	4.85	1.85	1.62	298	216.31	1.24	0.38

Annex-D: Questionnaire

Addis Ababa University

Addis Ababa Institute of Technology

School of Civil & Environmental Engineering

Dear Sir/Madam

I, the researcher, am student in Addis Ababa Institute of Technology, currently doing my M.Sc. in Civil Engineering under Road and Transport Engineering at Addis Ababa Institute of technology. I am doing my M.Sc. research/thesis entitled: **Evaluation of traffic congestion and level of service at major intersection in Adama City** with the aim of assessing the causes and impact of traffic congestion, quantify the performance and the level of service of the selected intersection in Adama city.

Your genuine, honest and prompt response to the questionnaire will have contribution to the success of the research. Your **response will be kept confidential**, and anonymity will be maintained. Moreover, the information you provide will be **used strictly for academic purpose**.

Filling the questionnaire will not take more than **10 minutes**. I thank you in advance for the time you devote, effort you make, and consideration you give in filling this questionnaire.

If you have any question concerning the items of the questionnaire, please call on mobile: 0911 16 25 78, or e-mail Fasomeku@gmail.com

With Great Respect

Fasika Mekonnen

Questionnaire

Title: Evaluation of traffic congestion and level of service at major intersections in Adama City

Objective of the Research:

- To assess the causes of traffic congestion
- To evaluate the level of service(LOS) and performance of the intersections
- To estimate the cost of traffic congestion at the intersection
- To assess the relationship of traffic congestion and traffic accident
- To suggest some possible solution to the congestion

Part-I: General Information

1. Respondent's Name (Optional):_____
2. Respondent's: (Use X)
   Sex_____
   Age: 15- 20___ 20-30___ 30-40___ 40-50___ above 50___
3. Respondent's occupation:_____

Part-II: Respondent's Perceptions toward Traffic congestion in Adama City

1. Do you think there is traffic congestion at intersections in Adama city at some level?

   Yes_____ No_____

2. If your answer for question number 1 is yes. What do you think the level of traffic congestion at the intersections?

   Very High___ High___ Moderate___ Low___ Very Low___

3. What do you think the cause of traffic congestion at the intersection in the city?

   ___Bottlenecks ___Traffic Incidents (Crash) ___Work Zones

   ___Road construction activities ___Poorly Timed Traffic Signals ___Special Events

   ___Reduction in road capacity ___Bad Weather ___vehicle breakdown

   ___On Parking Street

   Other_____

   _____

4. Rank the four most congested intersections from the listed below.

___Roundabout at Awragodana ___4 Leg intersection at Maya Hotel

___3 Leg intersection at Franco ___Roundabout at Post bet

___3 Leg intersection at Bekele Mola Hotel ___4 Leg intersection at Amede

___4 Leg intersection at Mebrat Hiyle ___4 Leg intersection at Mariam

___3 Leg intersection at Hospital ___4 Leg intersection at 04

___4 Leg intersection at Gendegara ___3 Leg intersection at Campus

___3 Leg intersection at Geda Menafesha ___4 Leg intersection at Sartera

___4 Leg intersection around National Building

Other_____

_____

5. What do you suggest to minimize the congestion at the intersections in the city?

___Improve capacity of roads ___Adding travel lanes on major freeways and streets

___ Improve parking arrangements ___ converting streets to one-way operations

___Geometric improvements to roads and intersections; ___ improving public transport;

Other_____

_____

Thank you for your Time.