Mekelle University

Ethiopian institute of technology-Mekelle (EIT-M)

School of Civil Engineering

Road and transport engineering

Identifying and evaluating various regulatory countermeasures to traffic congestion in selected intersections of Mekelle city

A thesis submitted in partial fulfillment of the Degree of Masters of Science in Civil Engineering

(under Road and Transport Engineering)

By:

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Declaration

I, Rahwa Berhe Baryagabr, declare that this thesis is my own original work and that it has not been presented and will not be presented by me to any other University for similar or any other degree award and not submitted partially or in full by any other person for a degree in any other university, and that all sources of materials used for the purpose of this thesis have been duly acknowledged.

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Abstract

Traffic congestion reduces the effective accessibility of residents, activities and jobs resulting in lost opportunities for both the public and business. Longer journey times, higher fuel consumption and increased emissions of air pollutants are some of the impacts of congestion.

Traffic congestion is a major phenomenon in most intersection of Mekelle city, especially in kedamay weyane sub city. Therefore, this thesis attempts to first evaluate the state of traffic congestion, then offers some suggested countermeasures to lessen the congestion, illustrates the results of applying the countermeasures at the chosen intersections, and finally outlines the factors that contribute to the congestion. The congestion is measured by determining the level of service (LOS) . And the LOS was analyzed by VISSIM software using peak hour turning traffic volume, vehicle composition and geometry of the intersections as input data. For determining peak hour turning traffic volume the calculation is made through the manual counting of vehicles and multiplying by passenger car unit factor (PCU factor) to determine passenger car equivalent (PCE).

The LOS output among the 9 selected intersections around kedamay weyane sub city the 6 of them are below D. By applying some regulatory countermeasures for the only 6 congested intersections and reanalyze the LOS of all intersections, most LOS of the selected intersections is become to above LOS C.

Even though the LOS of intersection 1 and some turning movements in intersection 8 are decrease after apply the counter measures; because some minibus taxi routes are changes to them, most LOS of the selected intersections are become A, B and C.

At final this thesis concluded that high number of bajaj using the intersection, the route of minibus taxi concentrated to one direction, stop vehicles near intersections and illegal trading on walk way and traffic lane are the cause of the traffic congestion.

Key words: Traffic congestion, Level of service (LOS), VISSIM

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List of Abbreviations

CBE	Commercial Bank of Ethiopia
HOV	High occupancy Vehicles
LT	Left Turn
LOS	Level of Service
LOV	Low occupancy vehicles
PCU	passenger car unit
RT	Right Turn
TH	Through movement
UTM	Universal Transverse Mercator
V/C	volume to capacity ratio

CHAPTER ONE

1. INTRODUCTION

Cities are complex spatial entities backed by transportation networks, with a significant concentration and accumulation of economic activity. The network of transportation modes and facilities that facilitate passenger and freight mobility inside metropolitan areas is known as an urban transportation system. The complexity and possibility for disruptions in a city increase with its size, especially if this complexity is not adequately handled. The effectiveness of an urban area's transportation system in moving people, goods, and labor between various origins and destinations has a significant impact on its productivity.

Urban transport leads to a number of problems like congestion and delays, parking difficulties; longer travel time, public transport inadequacy, difficulties for non-motorized transport, environmental impact and energy consumption. In this thesis more is deal on congestion.

The concentration of the economic potential and population in the metropolitan areas results in the occurrence of very large transport needs in a spatially limited area, and when these needs are met at the same time, the congestion occurs. This applies to congestion in respect of both the road network and the vehicles. Significant disproportions between the transport needs and the possibilities of their meeting at the desired level of quality can be seen also in Mekelle cities especially around kedamay weyane sub city.

There could be two approaches to solve this problem of congestion. First and the most obvious solution are to come up with infrastructure involving wider roads, flyovers, bypass and expressways. But for developing countries like Ethiopia, money and space are serious concerns. Second approach is to manage existing traffic, with the use of technology and by involving commuters in process which is traffic management.

Traffic management requires finding a solution for the traffic problems including traffic congestion. Success in traffic management directly influences the efficiency of the transportation network, the economic competitiveness of a city, and the quality of life for the communities. Hence, the goal of this thesis is to provide an adequate and safe transport in Mekelle city

especially around kedamay weyane sub city by present some measures to reduce traffic congestion. And this goal is achieved by identify the congested intersections, suggest measures and examine the causes using VISSIM software on the selected sub city and at the last to provide conclusion and recommendation.

And, this study will help for the city administration, to develop and direct strategies; to make policy to curb the demand and service mismatch on road transportation around the city especially around kedamay weyane sub city.

1.1. Problem statement

Traffic congestion is growing problem in Ethiopia. It is becoming alarming issue for largest cities in the country including Mekelle city. Mekelle, the capital city of Tigrai region, is characterized by the largest share of road traffic flow comparative to other cities in the region. As a result, the majority of road accidents, congestion and related traffic problems are highly concentrated in the city. The total number of registered passenger cars in Mekelle city increased by 23% between 2017 and 2019, according to data released by the Mekelle City Administration (2019) similarly, the rate of traffic accidents, Voice pollution and other related traffic problems in Mekelle goes up together with the increase of motor vehicles and population size. On the other hand, the daily movement of people and freights within the city especially around kedamay weyane sub city is becoming more difficult and complex.

Now days it seems that traffic congestions are becoming forcefully acceptable excuses for workers being late to work in the city. The poor road infrastructure of the city, coupled with inadequate and inefficient transport activities, the erratic behavior of drivers and careless or shortage of knowledge of traffic law of pedestrians have combined to complicate Mekelle traffic problems. Thus, traffic cannot flow efficiently and the overall result is the congestion complexity of the city roads networks. The inadequate traffic management is one of the many causes of the city's serious traffic issues, though.

Despite being the most prevalent complaint from the people using that area, traffic congestion is still an issue even though it is obvious to both specialists and non-experts on roads and transportation. Therefore, the goal of this study is to provide some remedies to lessen traffic congestion in the kedamay weyane sub city.

1.2. Objectives of the Study

1.2.1. General objective

The purpose of this study is to evaluate the level of traffic congestion, or LOS, at the currently chosen intersections, identify the congested ones with LOS D and below, recommend solutions, and reanalyze the LOS to determine the factors contributing to the traffic congestion in Mekelle City, particularly in the Kedamamay Weyane Sub City.

1.2.2. Specific objective

- Use VISSIM software to evaluate the LOS of the all currently chosen intersections and identify the congested intersections.
- Suggest remedial measures for reducing the traffic congestion.
- Apply the suggested measures to the congested intersections with LOS below D, and then show the change in congestion (change in LOS) at that location.
- If there is an improvement in the LOS, determine the reasons behind the traffic congestion among the recommended mitigation measures. And
- Verify whether there hasn't been any negative shift at the other intersections.

1.3. Significance of the study

Mekelle the most populated city in Tigrai region is faced with series of traffic congestions especially around kedamay weyane sub city. This indisputable issue of traffic hold is occasioned by the growing population concentration, rapid urbanization, and increasing commercial and economic activities. High population generates heavy vehicular traffic, leading to vehicular conflict and congestion as well as other mobility related challenges, which adversely affect the ultimate goal of people’s mobility.

Growing traffic congestion and number of registered vehicles in urban areas are linked with a traffic congestion, growing number of accidents and fatalities. Significant disproportions between the transport needs and the possibilities of their meeting at the desired level of quality can be seen also in Mekelle cities. As traffic increases, people feel less safe to use the roads. It is observed that traffic congestion in the center of Mekelle city especially around kedamay weyane could be viewed in mandatory daily trips. Due to increase the vehicular traffic on the limited and

almost stagnant road capacity. The volume capacity ratio is over one at many locations based on different scholar studies before in the area.

Therefore traffic management requires finding a solution for the traffic problems related to congestion. Success in traffic management directly influences the efficiency of the transportation network, the economic competitiveness of a city, and the quality of life for the communities. Hence, the goal of this thesis is to provide an adequate and safe transport in Mekelle city especially around kedamay weyane sub city by present some measures to reduce traffic congestion. Even though the study is carried out for academic purposes and it is confined to a single city, it could be helpful to have a deeper knowledge about the complexity of traffic practiced in the city.

Furthermore, the findings obtained from the study will be helpful to gain information and knowledge about the patterns of road traffic in the city, which in turn, could help to develop countermeasures that could reduce the related traffic problem in the city.

In addition, the result of the study is expected to generate important findings that can help as useful input for further research to refine the conceptual and methodology of the present study.

1.4. Scope and Limitation of the Study

This study analyzes different measures to reduce traffic problems related to congestion. The study is limited to Mekelle city in kedamay weyane sub city to suggest a solution for the traffic congestion only.

CHAPTER TWO

2. LITERATURE REVIEW

Transport is the most important requirements for overall development of a region for trade, commerce and industry. Transport has a major impact on the spatial and economic development of cities and regions. The transportation system and the transport has been playing strong role to increase the economic development of a country. Efficient and affordable transport system is a pre requisite for economic growth.

Improving the social and economic well being of the citizenry is the aim of every nation. One basic economic and social necessity that comes into focus when discussing economic and social development is transportation. Transportation is an activity of life processes and seeks to provide access to various activities that satisfy mobility needs of human kind (Arasan, 2012).

An effective transportation system is significantly important in sustaining economic growth in contemporary economies since it provides linkages between different parts of the country and the global world (Eddington, 2009). It links to work, deliver products to market, underpins logistics and supply chain, and support local and international trade. A good established transportation system is not the only key to national growth but also serves as catalyst for economic development of a country (Lu,et al., 2009).

But in other hand economic development of a country has its own problem on transportation system that must be handled. (Broadstock,et al.,2011) state that increasing wealth and high population, and availability of vehicle loan facility result in more car ownership than current transportation network can handle. It could be inferred from the above statement that there is a relationship between income level and car ownership and that the dominance of private car usage, particularly within cities, is likely to increase even further as a result of rise in household income with its attendant traffic congestion and high consumption of fuel.

2.1. Urban Transportation and its problems

Urban transport is an important sector in the sustainable development of urban areas. Urban Transportation refers to the system of transportation that provides access and mobility for people and goods within cities. Elements of urban transportation include public transit (collective

transport); non-motorized transport (pedestrians, cyclists) and freight. Urban transportation opens up opportunities to access essential services as well as social activities. (Rodrigue,et al.,2013) states that Business activities depend on urban transportation systems to ensure the mobility of its customers, employees and suppliers. The urban transport services cover a range of important social and economic services such as leisure trips business journeys; commuting; shopping; trips to places of education and freight distribution. Effective urban transport fulfills the demand for accessibility within cities.(Rodrique,et al.,2013), further report that transportation infrastructure is one of the key factors that directly affect urban transportation effectiveness and capacity within the metropolis. Transportation infrastructure mainly includes roads, parking lots, vehicles and transportation terminals. Urban traffic management system is also an important component which can properly control and guide the distribution of traffic flows on roads.

In (Arasan,2012) has discussed Transport demand in most of the cities has increased substantially due to an increase in population as a result of both natural birth rates and migration from rural areas and smaller towns. Availability of motorized transport increases in household income, and increases in commercial and industrial activities have further added to it. In many cases, demand has outstripped road capacity. Congestion and delays in both passenger and commercial traffic are widespread in cities and indicate the seriousness of their transport problems. As a result, costs particularly fuel costs increase substantially, affecting commerce and industry. A high level of pollution is another undesirable feature of overloaded streets. The result has been a serious decline in productivity and city efficiency, a drain on city and national budget, and a strain on urban institutions. The transport crisis also takes a human toll. Statistics indicate that traffic accidents are a primary cause of accidental deaths in the cities .

(Eddington,2009) studied inadequate urban transport leads to a number of problems. First is congestion and delays. Due to increase the vehicular traffic on the limited and almost stagnant road capacity. The volume capacity ratio is over one at many locations. The speeds are continuously decreasing to level as low as 5-10 kmph in central area. This leads to increased time of travel resulting in loss of productive man-hour .

As reviewed above, Urban transport leads to a number of problems like congestion and delays, parking difficulties; longer travel time, public transport inadequacy, difficulties for non-

motorized transport, environmental impact and energy consumption. The aim of this thesis is to examine the traffic congestion situation in the Mekelle and how to solve it.

2.2. Factors of Effective and Efficient Transportation System

(Eddington,2009) come up with the study that tells us, adequate transport network, traffic management and control system and effective, efficient and reliable mass transit as key factors that affect urban transportation system. Postulates that investment in adequate transport infrastructure improves transport efficiency in terms of increased productivity and continue that transportation infrastructure involves good road network, adequate bus stops, parking areas with traffic signals. In addition to that he states that mass transit is prerequisite for ensuring efficient and effective transportation system in urban areas in terms of energy conservation reduced traffic congestion and environmental preservation. and argue that effective mass transit system is underpinned by availability, accessibility, and reliability of buses. On other study (Arasan, 2012) states that, Effective traffic management and control system is the key to ensuring effective transportation system in the urban areas. This involves management and control of road signals, road space, and parking space and road users .

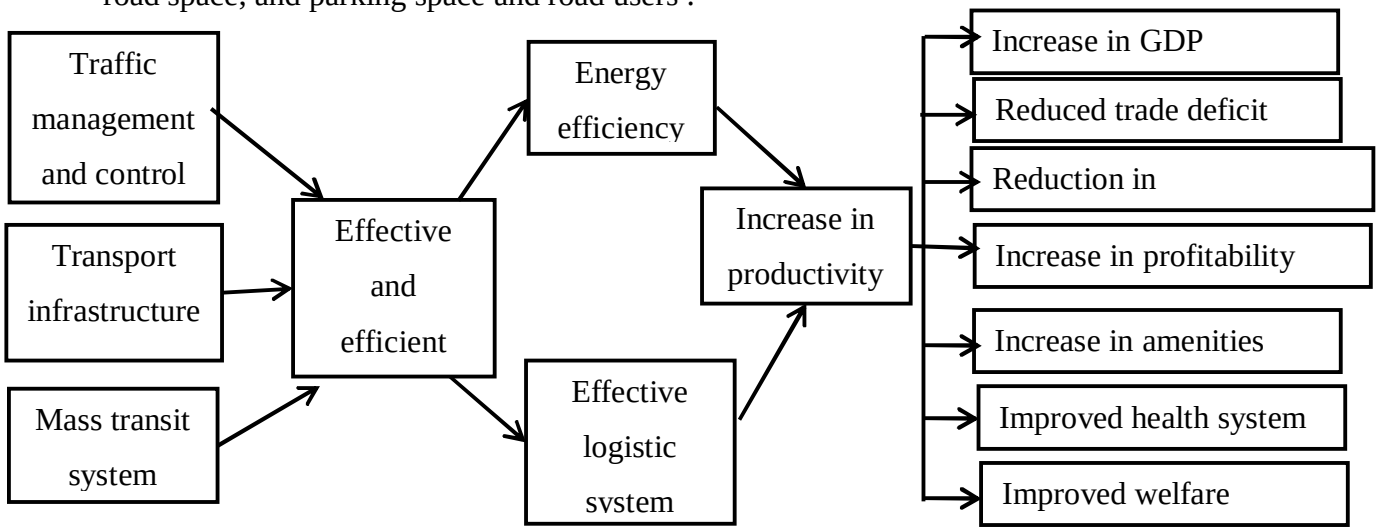


Chart 1: Effective and efficient transportation system and its output

Source: Adopted and modified from (Arasan, 2012)

Adequate infrastructure, effective traffic management and effective public transportation as key factors in place, will lead to effective transportation system. This will improve energy efficiency, effective logistics system and increase productivity at both individual and national level.

2.3. Traffic Congestion

Traffic congestion is the existence of delays by the side of a substantial lane owing to the existence of additional road users.(Downie, 2011) argue that, This is the most important problem of transportation in metropolitan region. Because of this, each cause is delaying: road user insincerity achieve to the intention, be short of services on the period public require, be short of services scheduled the routes public necessitate. Owing to the traffic congestion in the unusual intersections the liberated stream of the vehicles speed is low compare to the design speed. This will effect socioeconomic development of the country. Environmental pollution increases due to traffic delay and congestion .

(Rodrique,et al.,2013) states that congestion can be perceived as unavoidable consequences of scarce transport facilities such as road space, parking area, road signals and effective traffic management. They argue that urban congestion mainly concerns two domains of circulation, passengers and freight which share the same infrastructure. Thus, traffic congestion condition on road networks occurs as a result of excessive use of road infrastructure beyond capacity, and it is characterized by slower speeds, longer trip hours and increased vehicular queuing.

(Downie ,2011) also opines that traffic congestion occurs when the volume of vehicular traffic is greater than the available road capacity, a point commonly referred to as saturation. He describes a number of specific circumstances which cause or aggravate congestion. Most of such circumstances are concerned with reduction in the capacity of road at a given point or over a certain length, or increase in the number of vehicles required for the movement of people and goods. (Downie, 2011) further argues that economic surge in various economies has resulted in a massive increase in the number of vehicles that overwhelms transport infrastructure, thus causing congestion on roads in cities. On other study (Rodnique, et al., 2013) note that congestion in urban areas is dominantly caused by commuting patterns and little by truck movement. They further attributed the causes of congestion to rise in population densities, road incidents and broken vehicles on the roads which restrict capacity of roads and impair smooth traffic flows.

Another contributing factor to congestion as suggested by (Downie ,2011) is parking. He is of the view that road parking, which consumes large amount of space has become a land issue that greatly inflates the demand for urban land, causing congestion in cities. He adds that high urban mobility rate also contributes to the congestion menace.On other study (Yan and Crooks, 2010)

study that, The massive use of cars does not only have an impact on traffic congestion but also leads to decline in public transit efficiency, thereby creating commuting difficulties in cities. Indeed the over dependence on cars has tremendously increased the demand for transport infrastructure. Unfortunately the supply of transport infrastructure has never been commensurate with the growth of mobility needs. Consequently, several vehicles spend most of the time in traffic as a result of traffic space limitation.

Furthermore, (Department of Urban Roads, 2014) Report that traffic congestion in Kumasi is attributable to limited road capacity, parking space, dysfunctional road signals, drivers' behavior, vehicle breakdown on roads and too many cars within the city. (Rodnique, et al., 2013) outline some measures that could help deal with the congestion menace. They mention traffic signal synchronization, incident management, congestion pricing and the use of public transit as possible effective strategies available in dealing with congestion situation, although not without their associated challenges.

2.3.1. Traffic Congestion and Productivity

Acording to (Yildirim ,2011), Any city that is economically dynamic and vibrant will rarely be free from traffic congestion. Congestion has become an inevitable part of everyday life and that it is the city authorities that have to devise policies to help manage congestion on affordable basis to relief commuters of the difficulties imposed upon them by traffic congestion.

According to him, there is little consensus on the type of policies that can be used to trade congestion in cities, and that it is unsure that congestion has any clear cut solution. Indeed people living in cities have come to accept traffic congestion as part of city dynamics and therefore have become used to getting along with it. They continue to argue that traffic congestion in cities is a symbol of a successful socio economic development, improved business activities, increase in employment and improved culture. These are factors that motivate firms to operate in cities to benefit from economic gains.

(May and Marshen, 2010) studied that, however argue that congestion impairs us from moving freely and that it disrupts business activities in cities and reduces productivity. Congestion affects speed and smooth traffic flow. This affects a wide range of activities, services, goods, markets opportunities in the cities which can best be delivered through transport mobility. The report

continues that congestion also reduces productivity through increased inventory holding by manufacturers and retailers as a result of unreliable travel conditions within cities. Business activities depend on timely delivery of logistics. However, freight movement in cities is impaired by traffic congestion, thus making productivity suffer.

(Weisbrod,et al.,2012) reinforce this assertion by saying that increased traffic congestion imposes cost upon commuters and affect business operations. They further affirm that businesses that have high needs for incoming deliveries are mostly affected by traffic congestion and thus reduce productivity. Thus traffic congestion increases the cost of businesses operations. For instance delay in delivering time-sensitive logistics can impose additional inventory and logistics cost. Indeed, congestion affects lean management system like just-in-time, making businesses less responsive.

(Weisbod, et al.,2012) conclude that congestion leads to reduced productivity through reduced worker access to job and shopper access to stores as a result of excessive delay in traffic. Cutting traffic congestion by half will bring huge economic benefit to economies. This statement lends credence to the fact that traffic congestion has negative impact on productivity.As (Hickman ,2010) tells us, Indeed in August 2010, Habee, one of the provinces of China experienced what is considered the world worst traffic jam ever, as traffic congestion stretched more than 100km from August 14 to 26 . Such situation has obvious implication on productivity and the socio economic development at large.

(Downie, 2011) further delineate that although the digital revolution enables twenty 21st Century industries to adopt just-in-time production, distribution and inventory management system, the challenges in the transportation system such as congestion, makes it difficult for them to be up to the task of ensuring reliable just-in-time deliveries for enhanced productivity and competitiveness.In addition (Eddington, 2009) argue that economic cost of congestion takes the form of time wasted through travel delays and unreliable transportation conditions, extra fuel, the environmental damage and related cost to human health.

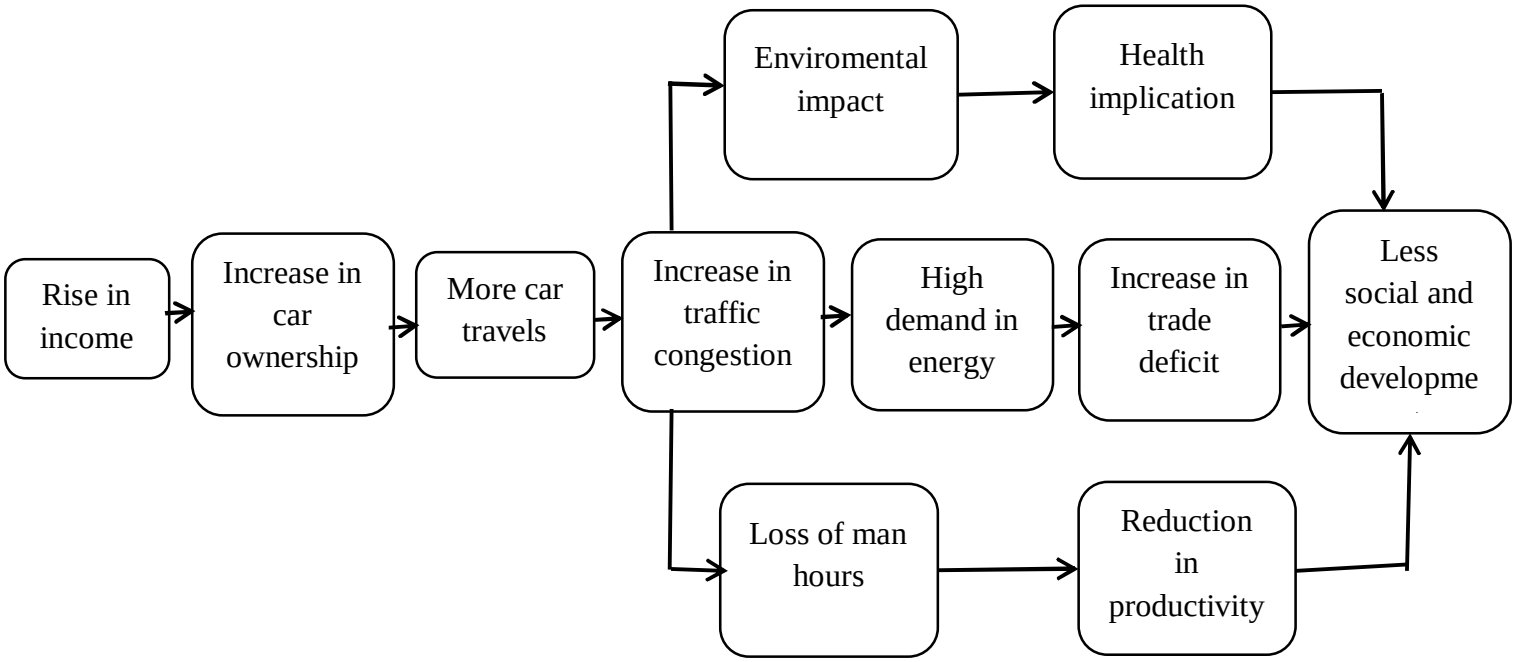


Chart 2: Rise in income as source of traffic congestion and its related problem.
Source: Adopted and modified from (Broadstock,et al., 2011)

The conceptual framework in chart 2 gives graphical model of transportation situation and its potential outcome. It seeks to explain that rise in income leads to increase in automobile ownership which will culminate in increased traffic congestion. The potential results of this situation are high energy demand, environmental implication and reduction in productivity, a situation that adversely affects the national socioeconomic development.

2.3.2. Root Causes of Congestion

Urban traffic congestion usually is defined as vehicles are blocked on the street and their average speed is lower than the designed standard. There are many causes of traffic congestion, which varies from city to city. In general, they could be summarized as the growth of vehicles and population, insufficient road space, mingling of different transport modes, poor quality of public transportation and infrastructures, and also low efficient management.

Congestion in urban or metropolitan areas may occur due to various reasons, such as excess demand, signal, incidents, and work zones, weather-related or special events. (Falcocchio and Levinsone,2015) Reported that, Depending on various root causes, generally, road traffic

congestion can be classified into two categories: (1) recurring congestion and (2) nonrecurring congestion .

Recurring Congestion

In most metropolitan cities, travelers experience congestion every day during daily peak hours. According to FHWA, roughly half of the congestion experienced by traffic users is recurring (FHWA, 2019).

The common reasons for recurring congestion are:

Bottlenecks and capacity: The most common cause of congestion is due to blockages. Bottlenecks generally occur during peak flow hours, where the number of lanes converging on a roadway, bridge, or tunnel exceeds the number of lanes these facilities have (Laval and Daganzo , 2016). It may also occur when the demand exceeds the capacity of a road. The capacity of any road indicates the maximum amount of traffic that can be handled. Capacity can be determined by the number and width of lanes, merging length at interchanges, and roadway alignment.

Insufficient infrastructure: is one of the most significant reasons for congestion, especially in highly populated areas. Because of the higher population rate, the number of vehicles also increases with it. When the existing number of infrastructure fails to occupy this increasing number of cars, congestion occurs (Wang, et al., 2013).

Variation in traffic flow: the variation in day to day traffic demands results in higher volumes in some days compared to others. When these variable demands do not match with the fixed capacity, a delay may occur (Falcocchio and Levinsone , 2015).

Inadequate traffic controllers: poorly timed signals or designs of traffic controller such as traffic lights, stop signs, speed reductions, or railroad crossings can disrupt a regular traffic flow, which leads to congestion and travel time fluctuation (Falcocchio and Levinsone, 2015).

Nonrecurring Congestions

Nonrecurring congestions generally occurred due to unpredictable events, such as traffic incidents, work zones, weather, or other particular circumstances (Falcocchio and Levinsone,

2015).Nonrecurring congestion can initiate new congestion in the off-peak periods, as well as can increase the delay due to recurring congestion.

Some common examples of nonrecurring congestion are:

Traffic incidents/accidents: The most common form of incidents is vehicular crashes, breakdowns, and debris in travel lanes. These events disrupt the normal flow of traffic, usually by blocking the travel lanes, which further results in capacity reduction (Haselkorn, et al., 2018).

Work zones: Work zones refer to the construction activities on the roadway by making physical changes to the highway environment. These changes lead to a reduction in the number or width of travel lanes, lane 'shifts', lane diversions, reduction or elimination of shoulders, and temporary roadway closures.

Weather: Changes in environmental conditions or weather can affect traffic flow and driver behavior. These may also modify the traffic control systems, such as signals and railway crossing, as well as road conditions. Due to bad weather induced road conditions, about 28% of all highway crashes and 19% of all fatalities take place (Mahmassani, et al., 2009). Besides, both vehicle speed and volume can be affected by high wind-gust, heavy rains, or snow.

Other special events: Demand variations of traffic flow about particular events that generally differ from the usual flow pattern. These events include sports events (game day), concerts, or other social events. A sudden spike in traffic demand during special occasions can overwhelm the system and create congestion.

2.3.3. Current Approaches to Measure Congestion

Different countries adopt different congestion measures to determine the congestion level. The Korea Highway Corporation considers traffic congestion when the average vehicle speed is lesser than 19 mph for more than 2 h in a day and 10 days in a month (Rao, 2012).And also he states that, In Japan, the speed threshold values are used to identify the congested areas. For examples, if the freeway travel speed falls below 25 mph, or there are frequent 'stop-and-go' flows for more than half a mile, or continues for more than 15 min, the state is called traffic congestion. Since approaches in different countries are not focus in this thesis, this section is kept concise and will not be further elaborated in detail.

To quantify the congestion level, numerous congestion measures have been developed by considering different performance criteria. Depending on these criteria, the congestion measures can be categorized in to five categories. (i) Speed, (ii) travel time, (iii) delay, (iv) level of service (LOS), and (v) congestion indices, as shown in the figure below.

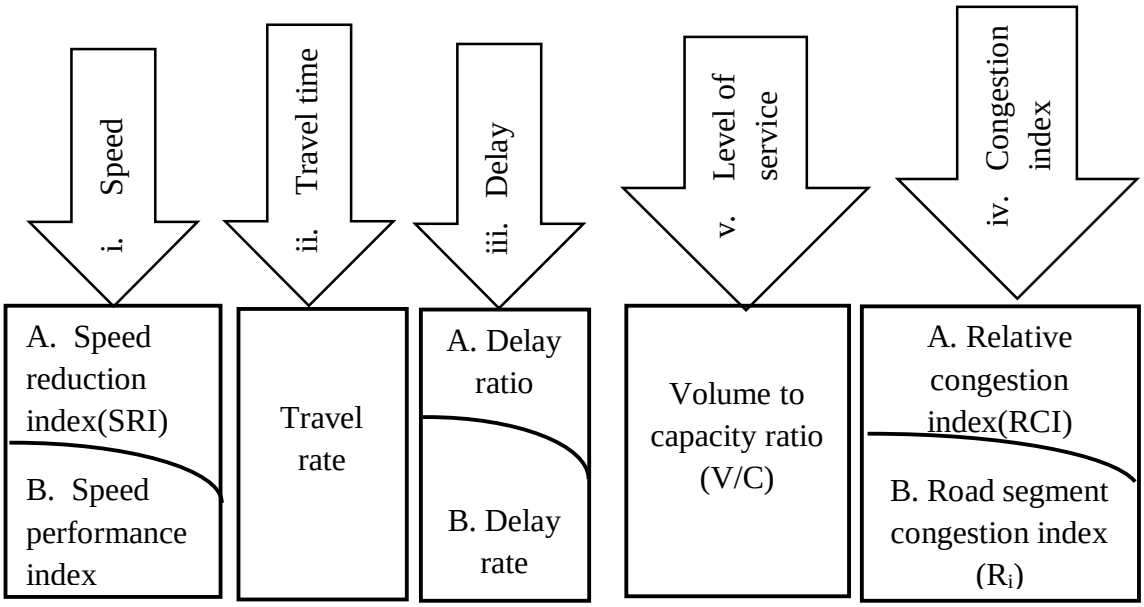


Chart 3: Approaches to Measure Congestion

i. Speed

A. Speed reduction index (SRI)

SRI is the ratio of the relative speed change between congested and free flow condition, as shown in equation 1 (He, et al., 2016) The SRI ratio is multiplied by 10 to keep the value of SRI in the range of 0 to 10. Congestion occurs when the index value exceeds 4 to 5. Values less than 4 indicate a non-congested condition.

$$SRI=(1-V_{ac}/V_{ff})\times 10 \quad (1)$$

Where SRI denotes the speed reduction index, V_{ac} indicates the actual travel speed, and V_{ff} means the free-flow speed.

The free flow speed generally refer to the average speed of the off peak period. In practice, the posted speed limit can also be considered as the free flow speed. In the FHWAs urban congestion report of 2019 (FHWA, 2019), the 85^{th} percentile of the off peak speed is considered as the free flow speed. According to the same report (FHWA 2019), the off peak period is

Monday through Friday, 9:00 a.m. to 4:00 p.m. and 7:00 p.m. to 10:00 p.m. and Saturday and Sunday 6:00 a.m. to 10:00 p.m.

B. Speed performance index (SPI)

SPI is developed to evaluate urban road traffic conditions (He, et al., 2016). The value of SPI (ranging from 0 to 100) can be defined by the ratio between vehicle speed and the maximum permissible speed, as shown in Equation 2. To measure the traffic state on the road with this index, the traffic state level can be classified with three threshold values (25, 50, and 75). The classification criterion of the urban road traffic state is shown in Table 1.

$$SPI=(V_{avg}/V_{max})\times 100 \quad (2)$$

Where SPI denotes the speed performance index, V_{avg} indicates the average travel speed, and V_{max} denotes the maximum permissible road speed.

Table1: Speed performance index with traffic state

Speed performance index	Traffic state level	Description of Traffic State
(0,25)	Heavy congestion	Low average speed, poor road traffic state
(25,50)	Mild congestion	Lower average speed, road traffic state bit weak
(50,75)	Smooth	Higher the average speed, road traffic state better
(75,100)	Very smooth	High average speed, road traffic state good

ii. Travel time

Travel rate

Travel rate refers to the rate of motion for a particular roadway segment or trip that can be represented by the ratio of the segment travel time by the segment length (Terhuurne and

Anderson, 2014), as shown in Equation 3. The inverse of speed can also be employed to quantify the travel rate.

$$T_r=T_t/L_s \quad (3)$$

Where, T_r denotes the travel rate, T_t is the travel time, and L_s indicates the segment length.

iii. Delay

A. Delay rate

The delay rate is the rate of time loss for vehicles operating during congestion for a specific roadway segment or trip (Aftabuzzaman, 2010). It can be calculated by the difference between the actual travel rate and the acceptable travel rate as

$$D_r=T_{Rac}-T_{Rap} \quad (4)$$

Where, Dr is the delay rate, T_{Rac} is the actual travel rate, and T_{Rap} is the acceptable travel rate.

B. Delay ratio

The delay ratio can be calculated by the ratio of delay rate and the actual travel rate. It is used to compare the relative congestion levels on different roadways (Aftabuzzaman, 2010).

$$D=D_r/T_{Rac} \quad (5)$$

Where D denotes the delay ratio, D_r is the delay rate, and T_{Rac} is the actual travel rate.

iv. Level of service (LOS)

LOS is extremely popular in practice (Tang and Heiniman, 2018). The LOS can be determined by various traffic quantities, such as density, speed, volume to capacity ratio, and maximum service flow rate. The LOS of a roadway can be determined by the scale intervals of the volume-to-capacity ratio (V/C), as shown in Table 2. The V/C ratio can be calculated by

$$V/C=N_v/N_{max} \quad (6)$$

Where, N_v is the spatial mean volume, and N_{max} denotes the maximum number of vehicles that a segment is able to contain as the capacity (Tang and Heiniman, 2018). It can be further quantified as

$$N_{max}=(L_s/L_v)\times N_l \quad (7)$$

Where L_s is the spatial segment length, L_v is the average vehicle length occupancy, and N_l is the number of lanes. L_v includes vehicle length and safety distance. In general, it is assumed that vehicle length is about 14 ft. (approximately 4.27 m), and safety distance is about 15 ft approximately 4.57 m (Tang and Heiniman ,2018).

Table 2: LOS based on the corresponding V/C ratio and operating conditions

LOS class	Traffic State and Condition	V/C Ratio
A	Free flow	0–0.60
B	Stable flow with unaffected speed	0.61–0.70
C	table flow but speed is affected	0.71–0.80
D	High-density but the stable flow	0.81–0.90
E	Traffic volume near or at capacity level with low speed	0.91–1.00
F	Breakdown flow	>1.00

v. Congestion indices

A. Relative congestion indices (RCI)

RCI is the ratio of delay time and free-flow travel time (T_{ff}) (Wan,et al., 2017). The RCI of 0 denotes a very low congestion level, and the values greater than two (> 2) show a significant congestion level. RCI can be calculated by

$$RCI=(T_{ac}-T_{ff})/T_{ff} \quad (8)$$

Where T_{ac} is the actual travel time, which is further quantified with the ratio of spatial length and spatial mean speed. The free-flow travel time (T_{ff}) can be calculated with the ratio of spatial length and free-flow speed.

B. Road segment congestion index (R_i)

The degree of road segment congestion, denoted by R_i, can be measured by using the normal road segment state and the duration of the non-congestion state in the observation period (He, et

al., 2016). The non-congestion state includes the traffic state where the speed performance index (SPI) is higher than 50. The R_i index value ranges between 0 and 1, and the smaller the value of R_i , the more congested the road segment is.

$$R_{i=}(SPI_{avg}/100)\times R_{NC} \quad (9)$$

$$R_{NC}=t_{NC}/t_t \quad (10)$$

Where R_i is the road segment congestion index, SPI_{avg} is the average of the speed performance index. R_{NC} and t_{NC} denotes the proportion of non-congested state and the duration of the non-congested state, respectively. t_t is the length of the observation period.

2.3.4. Possible counter measures for reduction traffic congestion

Traffic management is a proactive plan for influencing the flow of vehicles and pedestrians with the goal of minimizing delay or inconvenience. It may include measures like roundabouts, one-way streets, entry restrictions, speed limits, diversions during certain hours and parking policies.

Traffic management is the organization, arrangement, guidance and control of both stationary and moving traffic, including pedestrians, bicyclists and all types of vehicles. Its aim is to provide for the safe, orderly and efficient movement of persons and goods, and to protect and, where possible, enhance the quality of the local environment on and adjacent to traffic facilities.

When we try to solve the urban traffic congestion problem, we should take some principles, such as triple convergence and “offsetting by growth” into account. According to those principles, many efforts done by different instruments would be offset. Even so, it is worth trying those remedies, as they may reduce the potential added traffic congestions. The instruments for reducing traffic congestion can be divided into three parts: physical based instruments, market based instrument, and regulatory based instruments, which also could be listed as supply side approaches and demand side approaches. (Downs, 2013) list the instruments for reducing traffic congestion as shown in the table below.

Table 3: Classification of instruments for reducing traffic congestion

Made by author; based on Downs, 2013.

Instruments for Reducing Traffic Congestion	Supply side	Demand side
Physical instrument	Building more roads or expanding existing ones Building more transit facilities and increasing service and amenities in existing transit systems Improving highway maintenance Adding rowing response teams to remove accidents Upgrading existing city streets Developing means of transit feasible in low-density areas	Building special roads for trucks only Clustering high-density housing around transit stops Using traffic-calming devices to slow flows
Market based instrument	Converting free HOV lanes to HOT lanes	Road pricing with tolls set to raise peak-hour flows Commuting allowance for employees Charging high taxes on gasoline, parking during peak hours Eliminating tax deductibility for employers for providing free parking Increasing automobile license fees Cashing out free parking provided by employers

Table 3: (Continued)

Regulatory based instrument	Traffic management centers ITS mechanisms for speeding traffic flows Deregulating public transit activities Staggering work hours for more workers	Prohibiting certain license numbers from driving on specific days Changing deferral work laws that discourage people from working at home Ramp metering on expressways Encouraging more people to work at home Keeping minimum residential densities higher Limiting growth and development in local communities Improving the jobs/housing balance Concentrating jobs in a few suburban clusters Making some lanes HOV lanes

Physical based instruments

Physical instruments decrease traffic congestion usually by building something or improving something. Most used physical instruments are increasing road traffic capacity, building more transit facilities and increasing service and amenities, upgrading existing city streets and clustering high-density housing around transit stops.

A. Increasing road traffic capacity

When cities are trying to reduce urban traffic congestion, the first idea is often building more roads, to allow increasing traffic volumes. The more capacity of roads net, the more traffic flows in each period. Supplying more roads capacity or improving the old roads net seems feasible and

necessary in the areas at a rapid growing of population or vehicles. However, if the increasing of roads capacity does not catch up with the growing rate of population and vehicles, traffic flow would even go worse than before.

Once there is peak hour traffic congestion in a city's roads net, maybe the traffic congestion would be reduced by expanding road capacity in a short term. But this effect could be offset by many factors. First one is that rapid growing of population and number of vehicles could easily increase traffic loads, particularly in cities of developing countries. Also triple convergence could put much more pressure on expended roads net. When most of drivers realize new roads can save much time, they will switch their travelling time, travelling routes, and even travelling modes to this improved road, thus the intensity of traffic congestion will come back to the level as before in the near future. What's more, expanded road even induce more people settle down near those new roads in long term. By the influence of those reasons, reducing traffic congestion through enlarging road capacity is undefined. It is quite difficult to measure what extent the benefits of expanding a road will be offset by the added demands it induces in the long run (Downs, 2013).

When the whole capacity of the traffic system is enlarged, more travelers could travel during the peak hour. The total traffic flows in this area improve, since more vehicles can drive on the enlarged roads per time. So enlarging the capacity will bring benefits to whole society, no matter whether it reduced traffic congestion or not. Thus, the individual remedy of expanding the capacity of roads without other remedies is not a solution to reduce traffic congestion, but an approach to increase the whole traffic flows.

B. Improving public transport

Providing for convenient, safe, regular and reliable public transport is an essential requirement for any urban area. Buses, light rail or railways are the main public transport in most cities. According to various situations, there are different priorities in different cities.

Public transportation has quite different effects on reducing urban traffic congestion when compared with other kinds of instruments. Theoretically its huge capacity and high rate of using road resources makes it become the most efficient way to cut down traffic problems. Also a cheap price will make it affordable for almost everyone especially in developing countries' cities.

The figure 1 shows the efficiency of three kinds of means of using road resource; one bus' capacity corresponds to more than 50 cars' capacity, which shows us how traffic flow can be influenced by choosing different way of trips. If people choose public buses for commuting, it seems there would be no traffic congestion at all.

Notice: 160 cars = 3 buses = 1 tram

Figure 1: Comparison among the cars, buses, and tram system

On the contrary, a world without a public transportation would be a disaster. As (Bunting, 2010) said, replicating present American mobility everywhere would expand the world fleet of vehicle to 4.52 billion. And the vehicles on streets of metropolises would just block without moving. Public transport seems to be a savior in many cities filled with private cars.

So building more or improving existing public transits and facilities could be a useful way to reduce traffic congestion. But the development of public transport does not run smoothly in most of cities. One important reason is that most people prefer private cars to public transits, because of the flexibility and the accessibility of private cars. For example, drivers of private cars theoretically always have the advantages of saving time compared to people in public buses on the same route. People who choose to travel with public buses have to go to the bus station, wait for the bus, and the trip takes comparatively long time because the bus would stop at many stops before the destinations is reached, while drivers of private cars could save such time.

Bus Rapid Transit system may remove this disadvantages of public bus, since it has buses only right-of-ways, which were regulated only available for public buses. Through this bus only way,

buses could not be blocked on the normal routes with private cars, which encourage more people to choose Bus Rapid Transit instead of private cars.

C. Bicycle policies

Cycling is now considered by policy makers in many cities as a suitable way of city's transport. There are several good examples of cycling in cities, since it could be enjoyable, healthy and cheap to use. Since cycling is flexible and take much smaller space than other transport means, it could be reduce traffic congestion.

Market based instruments

Market based instruments has usually been used on the base of physical instruments, Since most of them are listed in demand side as shown in table 3, being used to depress people's desire to use private cars in specific time or specific area and encourage them to choose more efficient way for trips. Market instruments contain fuel taxation, road pricing, parking pricing and so on.

A. Taxes

Taxing has been used as an instrument to manage traffic demand in many cities around the world. (Litman ,2009) Transport demand consists of a group of factors generating the total volume of travel which contains travel length, travel modes, number of routes time of trips and so on. Instruments of tax for reducing congestion also involved in almost every factor of transport demand management.

The taxation instruments can be divided into three main parts: tax on the initial purchase of a vehicle; 'circulation' tax on the ownership of vehicles (annual registration tax and company car taxation); tax on the use of vehicles (fuel, tolls, road space and parking). Obviously, purchase tax has an influence on people's choice of travelling modes. Also circulation tax such as registration tax influences the choice of travelling modes. There are many more kinds of taxes on the use of vehicles compared with the purchase tax, which includes fuel, tolls, road space and parking taxes.

In many countries, purchase taxation instrument has been used mostly to reduce environmental impacts rather than to reduce traffic congestion. Consumers will pay higher tax when they choose big engine vehicle, which is encouraging people to choose vehicles with low emissions. Purchase taxation will discourage people to buy a vehicle when dealing with traffic congestion,

while it has no effect on people who have vehicles. Circulation tax has more influence on reducing the use of vehicles. It may encourage drivers to sell their vehicles when the circulation tax is high enough. And automobile ownership ratios will decrease.in this traffic congestion will decrease.

B. Road user charging

Road pricing is used in many cities to reduce traffic congestion in city centers or expressways through charging fees from drivers. The main argument for charges on express ways is normally not an ambition to reduce traffic congestion but to finance the investment in the express way. Since the road tolls, a large number of vehicles would not move onto those roads. Theoretically, the higher road pricing is, the less people would choose this pricing route. Thus, traffic congestion on those roads net would decrease. The traffic flows would be improved; more vehicles could use roads net per hour. According to this, traffic congestion would be reduced as soon as there is enough high road pricing. The road traffic flow would be more efficient, as more drivers switch travel time from peak hour to non-peak hour, even shift travel mode from vehicles to other transits, such as bus and light rail.

C. Parking policy on traffic congestion

There are various types of parking policies, which focused on different factors such as parking location, parking supply, and parking price. Thus the results of those policies usually vary between each other. Parking policy control and management can also influence on trip generation, trip distribution, travel modes and travel time. Thus parking could play an “active” role in the transportation system. (Litman, 2009) has the notion that more focus on parking management could increase the utilization of land and transport in urban areas. It can be used as a price instrument to influence transportation. Many parking policies are designed to control and reduce parking space in city’s downtown areas.

Regulatory based instruments

Like market instruments, most regulatory based instruments could be list in demand side approaches, being used to control the use of private cars in specific time or specific areas. Ramp metering on expressways, prohibiting certain license numbers from driving on specific days are most used regulatory instruments.

A. Ramp metering

Ramp metering is an instrument used to increase the traffic capacity of expressways or freeways. This method tries to control the number of vehicles per time that enter limited access expressways and highways through controlling traffic lights on ramps. Ramp metering was designed to make full use of expressways, and try to offer a highest traffic flows through ramp metering. Without such a control of traffic flow on ramps, vehicles would move onto those expressways and slow down former traffic flow. Especially in peak hour, they will reduce travelling speed automatically since there are too many vehicles. Such a slow-down leads to a lower vehicles passing rate per hour, then slow down further the road carrying capacity per hour.

In order to improve the efficiency of road carrying, ramp metering could reduce the number of vehicles passing road per hour. When there are fewer vehicles on the road, the interval between two vehicles is longer compare to a situation without ramp metering. So drivers will drive faster since the longer interval between two cars, which is a guarantee of safety.

B. Using High-Occupancy Vehicle (HOV) Lanes

High-Occupancy Vehicle lanes are designed only for those vehicles carrying more than two or three persons and for public bus. Most people prefer to drive alone, since it is more comfortable, more convenient. But road carrying capacity would drop to a very low level, if a large number of single drivers travel on the roads net. HOV lanes encourage those single drivers to participate in car pools, in order to reduce the number of vehicles without decreasing traffic capacity. Also with the improvement of traffic flows, there will be more vehicles attracted to move onto roads net especially during peak hour. Also this instrument would shorten the periods of peak congestion.

CHAPTER THREE

3. RESEARCH APPROACH AND METHODOLOGY

3.1. Introduction

This chapter is about the methods that were used for collecting information in the study. This chapter mainly explains how the study was conducted, the applied methods and techniques in data collection and the reasons as to why they were used according to the research aims and main objectives of the study. This chapter involves justification and sources of data, the selection of the study area and discussion of the research process used in the study. Analytical techniques used in analyzing the data for the study are also discussed.

3.2. 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 quantitative and qualitative approaches. Quantitative data and analysis were used to determine the level of service of the selected intersections. As a data source primary data or direct field measurements. Although, qualitative data from field survey were also used to assess the cause of traffic congestion and determine possible countermeasure to reduce the traffic congestion.

In order to achieve the objectives outlined in section 1.2, adopted organization of methodology for analyzing traffic congestion and suggest a solution is illustrated in the chart below.

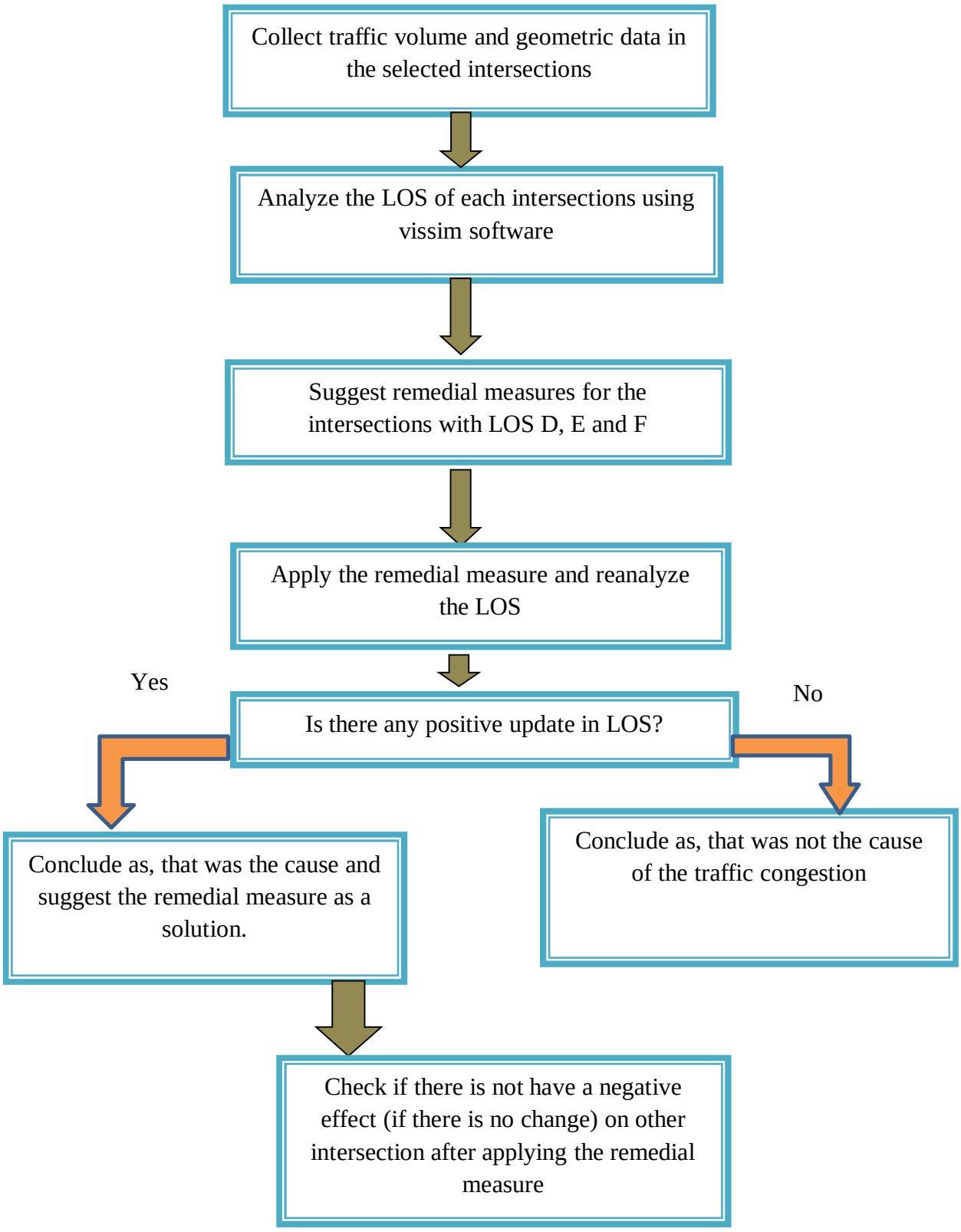


Chart 4: Flow chart of the methodology

3.3. Study Area

3.3.1. Description of study area

Mekelle is the capital city of the National Regional State of Tigrai, Ethiopia. . It is about 783 Kms away from Addis Ababa capital city of Ethiopia. Mekelle is the center of political, social, economic and geographic of the region. Mekelle has average elevation of 2,254 m above mean sea level. It is located almost in the central part of the region.

The current administration of Mekelle constitutes 7 sub cities known as Semien, Ayder, Hawelti, Kedamay Weyane, Adi-Haqi, Hadnet and Quiha. Mekelle has been manifesting to be a fast growing city in the region. However, the growth is accompanied with several constraints as it has not been provided with an equal growth in urban transport provisions is lagged behind the existing demand. Moreover, the sector is expressed by many traffic problems. In this research the study is done in kedamay weyane sub city.

3.3.2. Selected intersections

Based on traffic police office witness; almost all intersections in kedamay weyane sub city are congested and difficult to manage. In this study I select only 9 main intersections with the help of traffic police office; which are the most congested and new intersections still not assessed their LOS. Finding the LOS on the non-congested intersections is helpful to manage or balance traffic from the congested ones and see the change on them.

Intersection 1: Hawzen adebabay roundabout intersection

Hawzen adebabay intersection has four-leg approach namely, street to st.mariam church, street to Romanat adebabay (Hakfen street), street along post office (Alganesh Meles street) and street to Zeslase roundabout as shown below. Based on Adindan coordinate system, the intersection is located in UTM_Zone_37N at 551235 m Easting and 1491846 m Northing.

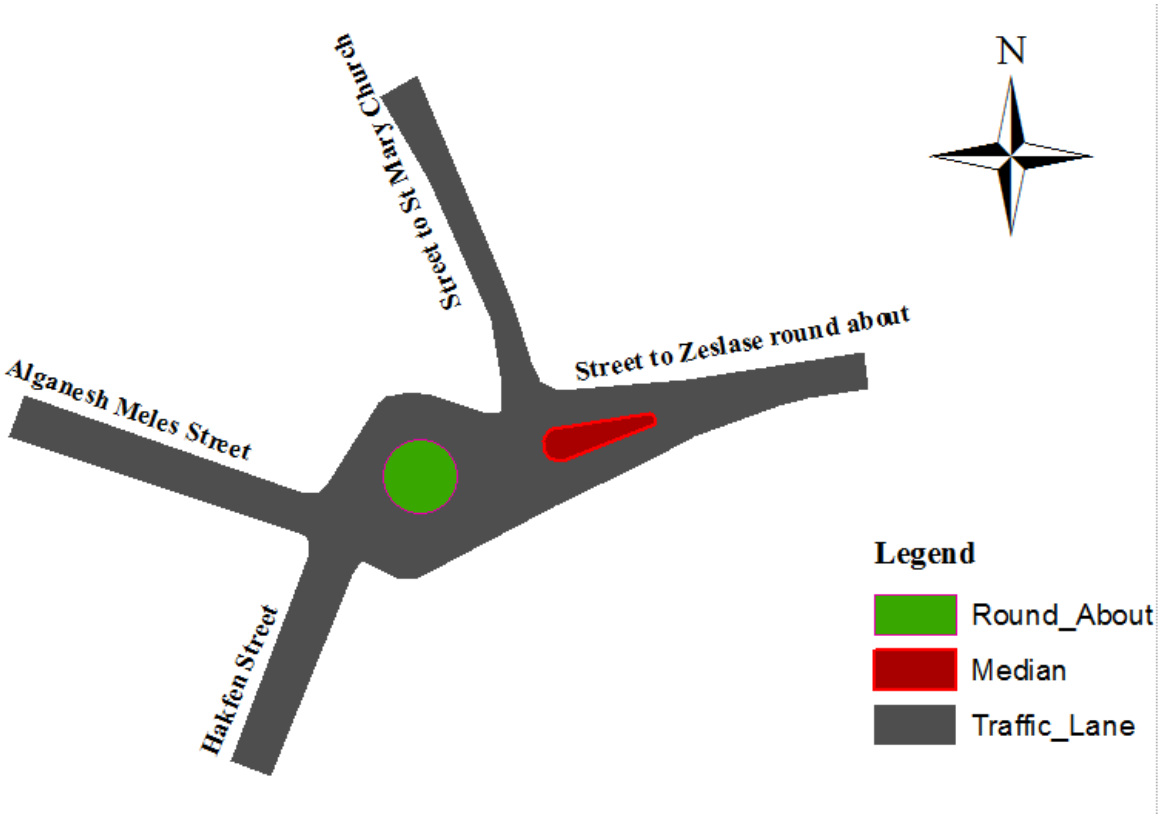


Figure 2: Hawzen adebabay roundabout intersection

Intersection 2: Millano roundabout intersection

Millano round about intersection has three-leg approach namely, street to old bus station (Eyasu Berhe street), street to Queha (Eyasu Berhe street), and street to Romanat adebabay (Agazi street) as shown below. Based on Adindan coordinate system, the intersection is located in UTM_Zone_37N at 551450 m Easting and 1491110 m Northing.

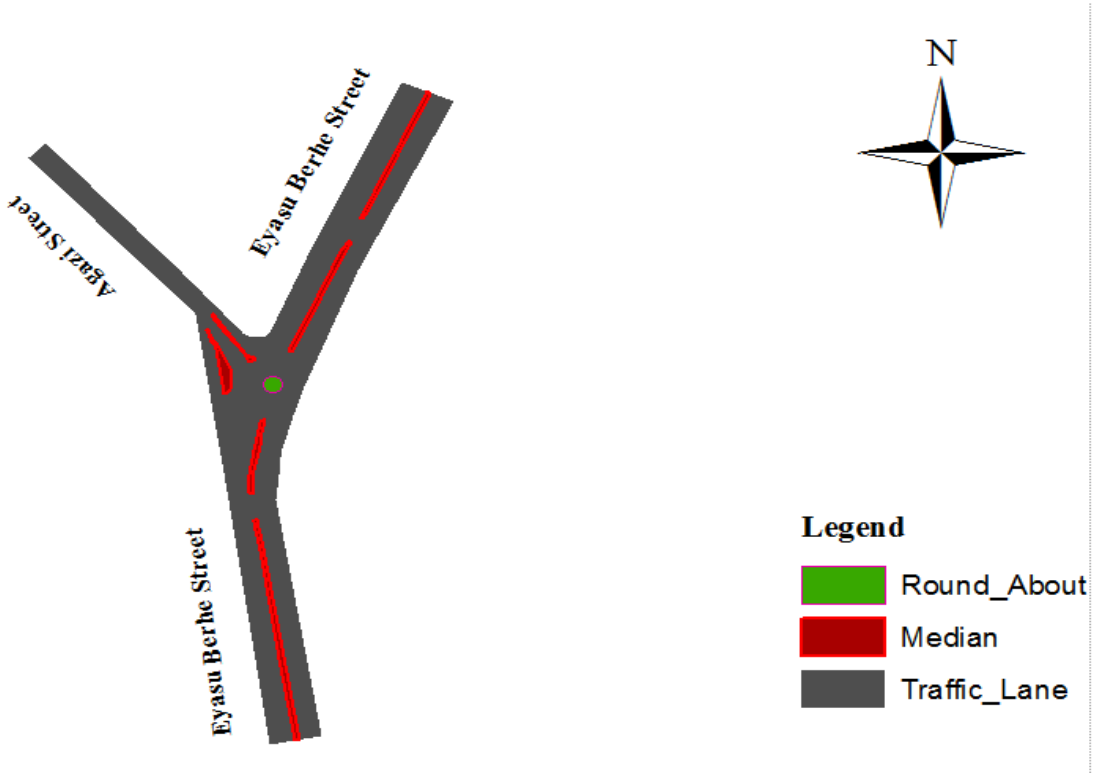


Figure 3: Millano round about intersection

Intersection 3: Romanat adebabay Intersection

Romanat adebabay intersection has four-leg approach namely, street to Hawzen adebabay (Hakfen street), street along Housing agency (Selam street), street to main CBE (Alula street) and street to Millano hotel (Agazi street) as shown below. Based on Adindan coordinate system, the intersection is located in UTM_Zone_37N at 551094 m Easting and 1491486 m Northing.

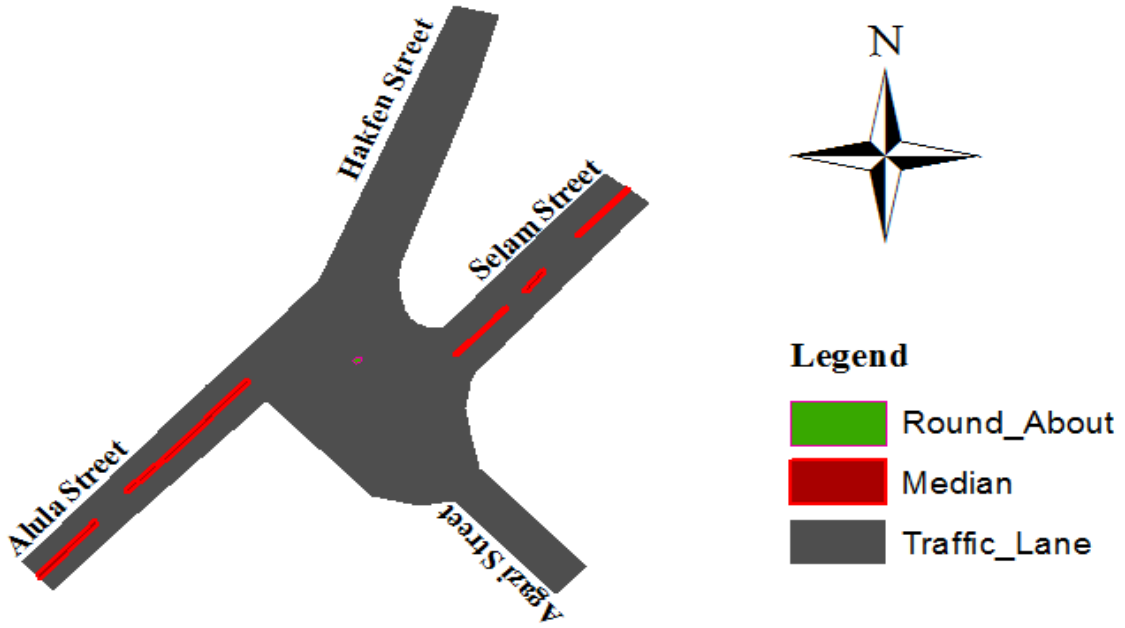


Figure 4: Romanat adebabay intersection

Intersection 4: Main CBE intersection

Main CBE intersection has four-leg approachs namely, street to Romanat adebabay (Alula street), street to Abrha castel (Alula street), street to micheal church and street to Sheba college as shown below. Based on Adindan coordinate system, the intersection is located in UTM_Zone_37N at 550710 m Easting and 1491125 m Northing.

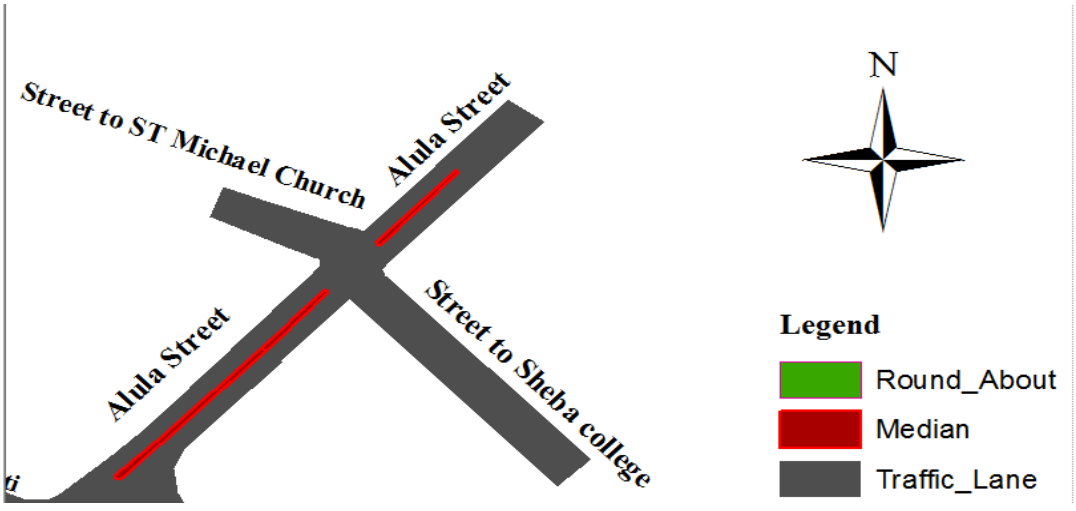


Figure 5: Main CBE intersection

Intersection 5: Abrha castel roundabout intersection

Abrha castel roundabout intersection has three-leg approach namely, street to Main CBE (Alula Street), street to Hawelti and street to awash restaurant as shown below. Based on Adindan coordinate system, the intersection is located in UTM_Zone_37N at 550613 m Easting and 1491024 m Northing.

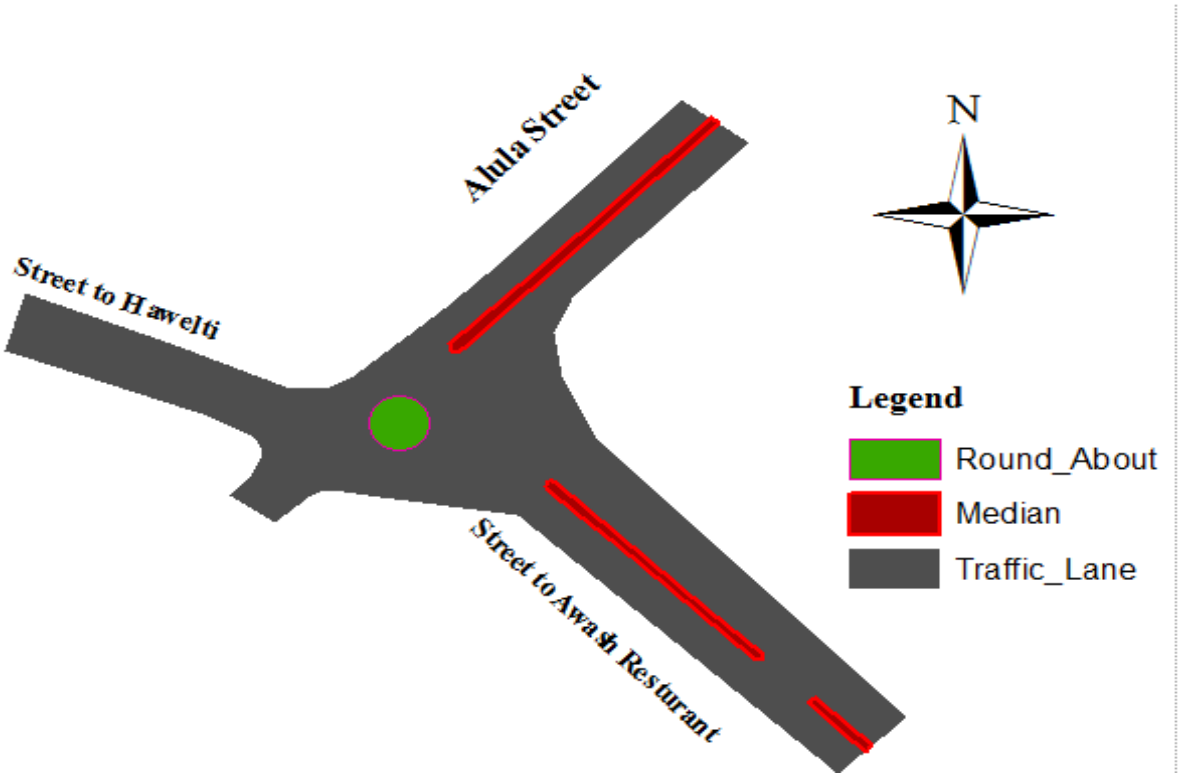


Figure 6: Abrha castel roundabout intersection

Intersection 6: Hashenge intersection

This intersection has four-leg approach namely street to Aider Hospital, street to Hawelti, street to Dedebit microfinance (Alganesh Meles street) and street to Hawzen adebabay roundabout (Alganesh Meles street) as shown below. Based on Adindan coordinate system, the intersection is located in UTM_Zone_37N at 550385 m Easting and 1492130 m Northing.

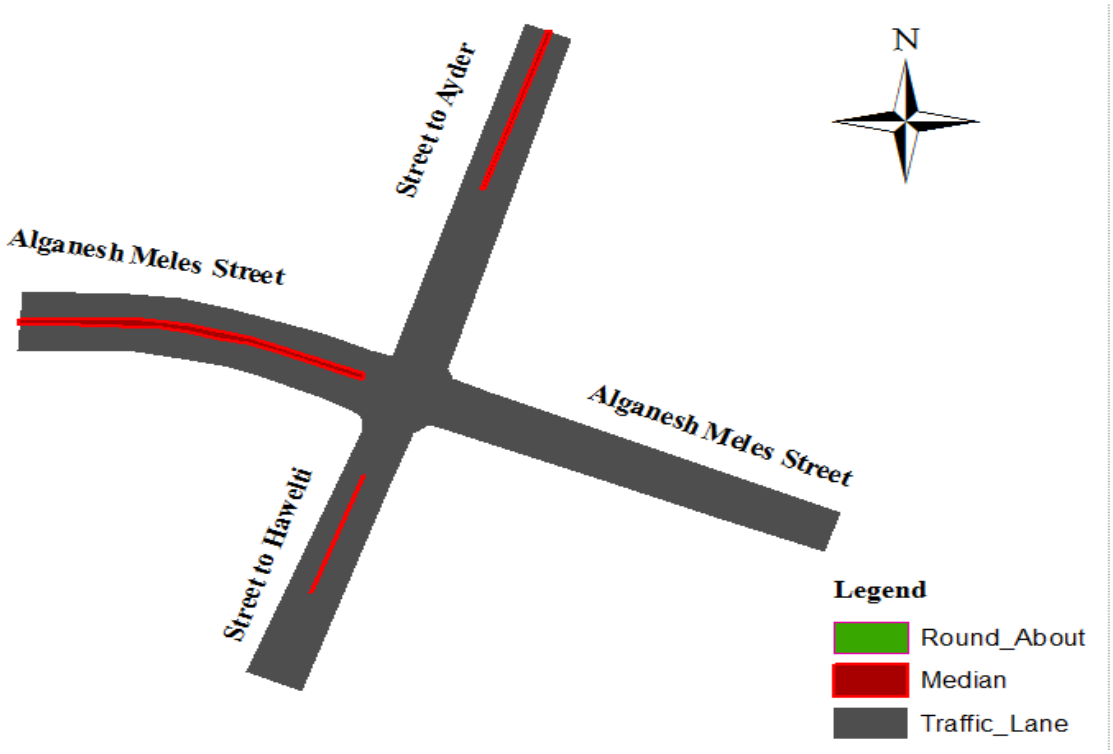


Figure 7: Hashenge intersection

Intersection 7: Mekelle tena tabya intersection

This intersection has four-leg approach namely, street to Hatsey Johannes elementary school (Guna street), street to 17 kebelle (guna street), street to Axum hotel and street to main CBE as shown below. Based on Adindan coordinate system, the intersection is located in UTM_Zone_37N at 550946 m Easting and 1490883 m Northing.

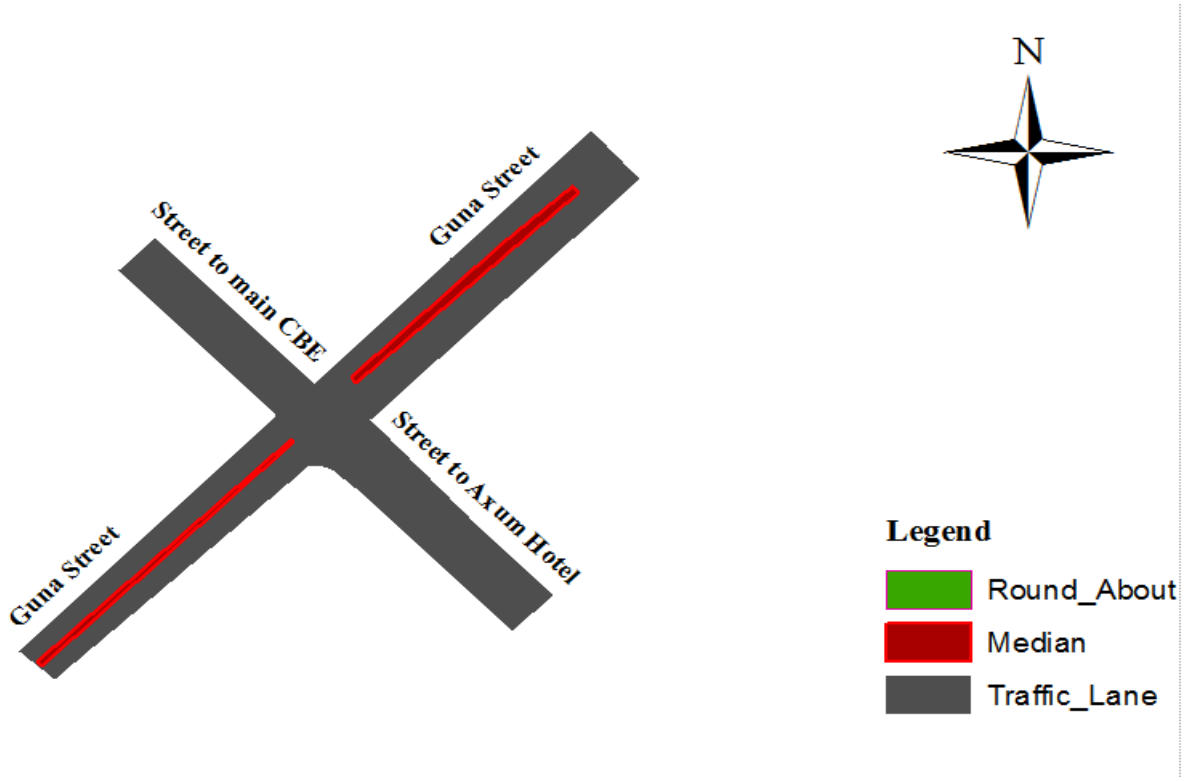


Figure 8: Mekelle tena tabya intersection

Intersection 8: Mekelle administration office round about intersection

This intersection has four-leg approach namely, street to Meserete elementary school (Daniel Asefa street), street to st.mariam Church (Daniel Asefa street), street to water supply office and street to Electric utility office. Based on Adindan coordinate system, the intersection is located in UTM_Zone_37N at 551022 m Easting and 1492435 m Northing.

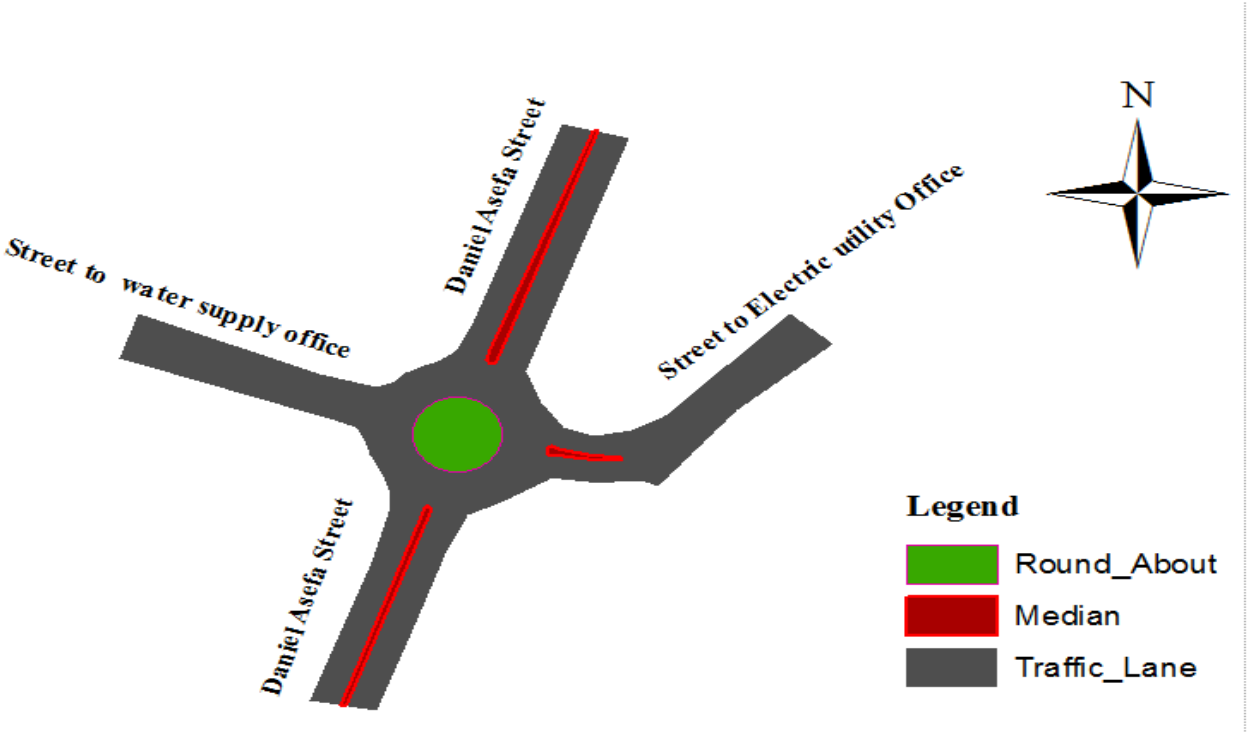


Figure 9: Mekelle administration office intersection

Intersection 9: Intersection around union dental clinic (#1)

This intersection has four-leg approach namely, street to Mekelle administration office (Daniel Asefa street),street to micheal church (Daniel Asefa street), street to Hashenge intersection (Alganesh Meles street) and street to Hawzen adebabay roundabout intersection (Alganesh Meles street). Based on Adindan coordinate system, the intersection is located in UTM_Zone_37N at 550928 m Easting and 1491934 m Northing.

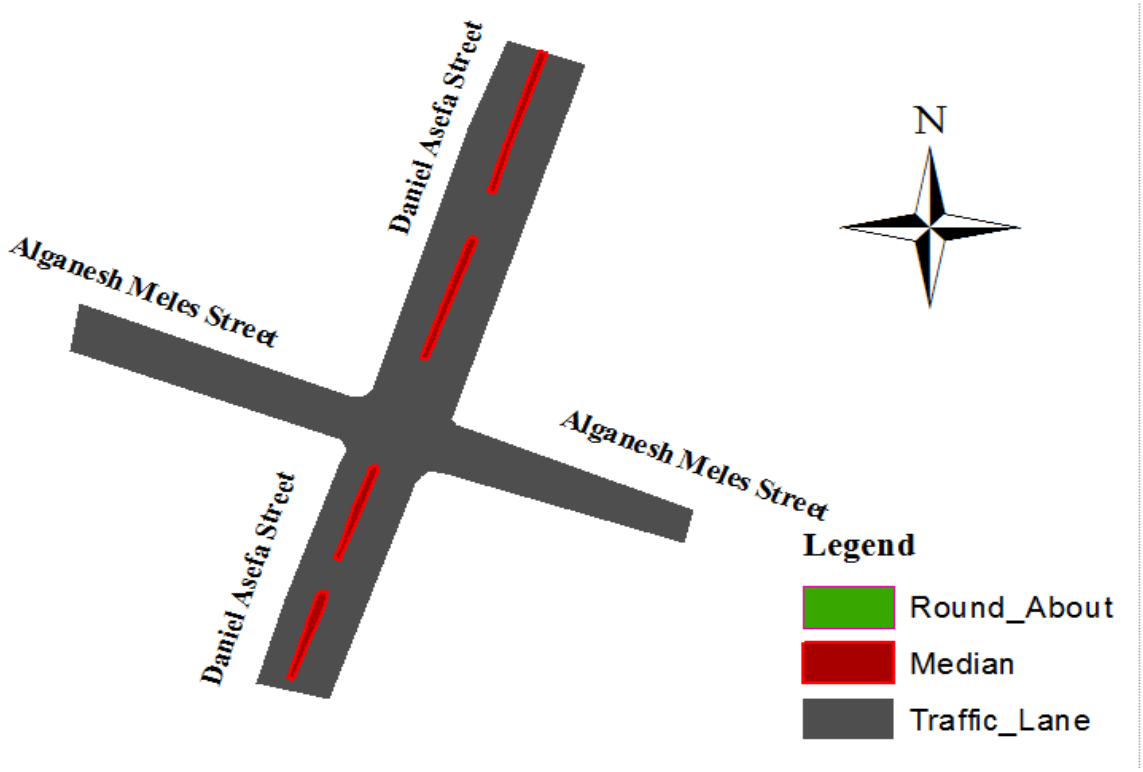


Figure 10: Intersection around union dental clinic (#1)

3.4. Methodology

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

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

- Field measurement and
- Manual traffic volume counts

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 and width of median. These measures were done for the 9 selected intersections. (Refer section 3.4.2.)

3.4.1. Traffic Data collection method

The primary traffic flow data collection technique used were

- Video recording and
- Manual traffic volume count**:**

Video recording

This method of travel data collection relies on video cameras to collect or capture the traffic flow in the field and human personnel to transcribe at the office after the actual time of data collection. Video capturing techniques is preferred over the manual collection (pen and paper method) because

- It provides a permanent, easily-review record and show the traffic conditions at any time;
- It permits the reading of required parameters in a controlled environment in which plate characters can be closely examined;
- It provides additional information about traffic flow characteristics such as traffic volume and vehicle headway; and
- It can provide a time stamp for accurate determination of arrival times.
- Have better accuracy than manual methods; and
- Able to capture a larger sample of the total number of vehicles

In this study; this technique uses to check and review the movements again at any time in office.

Manual Traffic Volume count

Traffic count is a count of vehicular or pedestrian traffic, which is conducted along a particular road path, or intersection. 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.

On this study for the analysis of LOS traffic volume has been counted on each intersection by using manual traffic volume count in addition to Video recording. This is done by considering different type of vehicles and movement mechanism (TH, LT and RT).

Traffic count in this study has been conducted in the selected locations during morning, afternoon and evening peak hour at 15 minutes interval on Monday, Tuesday and Saturday based on previous studies and traffic police office witness. The vehicles were counted in category as Animal of Push Cart ,Bicycle, motor bike, Auto rickshaw or Bajaj, LCV or mehandura, Pick up, cars and 4WD, Minibus taxi, Micro bus and Large or standard Bus, Small, Medium and Heavy commercial or truck vehicles. The total peak hour traffic volume for each approach is summarized in the following tables starting from table 5 to 13 by using PCU factor shown in table 4. The raw data of traffic volume for each intersection for the day with peak hour count is summarized in Annex-A.

Table 4: PCU factors

Sr. No	1	2	3	4	5	6	7	8	9	10	11	12	13
Vehicle Category	Heavy Truck	Mediumm Truck	Small truck	Large bus	Micro bus	Mini bus	Car and 4WD	Pick up	LCV	Auto rickshaw	motor bike	Bicycle	Animal/Push Cart
PCU factor	4	3	3	3	2.5	1.5	1	1.5	2	0.8	0.5	0.3	5

Table 5: Total traffic volume for Hawzen adebabay roundabout intersection

Date	Peak hour	Hawzen adebabay roundabout intersection				Total
		From st.Mariam church	From Romanat adebabay (Hakfen street)	From Alganesh meles street	From Zeslase roundabout	
	12:15 To 13:15	345	712	649	453	2159

Table 6: Total traffic volume for Millano roundabout intersection

Date	Peak hour	Millano roundabout intersection			Total
		From Old bus station (Eyasu Berhe street)	From Queha (Eyasu Berhe street)	From Agazi street	
	7:15 to 8:15	498	437	157	1092

Table 7: Total traffic volume for Romanat adebabay intersection

Date	Peak hour	Romanat adebabay intersection				Total
		From Hawzen adebabay (Hakfen street)	From Housing agency(Selam street)	From Main CBE (Alula street)	From Millano hotel (Agazi street)	
	12:30 to 13:30	462	312	817	449	2040

Table 8: Total traffic volume for Main CBE intersection

Date	Peak hour	Main CBE intersection				Total
		From Romanat adebabay (Alula street)	From Abrha castle (Alula street)	From Micheal church	From Sheba college	
	7:30 to 8:30	608	565	189	318	1680

Table 9: Total traffic volume for Abrha castel roundabout intersection

Date	Peak hour	Abrha castel round about intersection			Total
		From Main CBE (Alula street)	From Hawelti	From awash restaurant	
	5:00 to 6:00	597	552	437	1586

Table 10: Total traffic volume for Hashenge intersection

Date	Peak hour	Hashenge intersection				Total
		From Aider Hospital	From Hawelti	From Dedebit microfinance (Alganesh Meles street)	From Hawzen adebabay (Alganesh Meles street)	
	7:30 to 8:30	561	309	858	736	2464

Table 11: Total traffic volume for Mekelle tena tabya intersection

Date	Peak hour	Mekelle tena tabya intersection				Total
		From Hatsey Johannes elementary school (Guna street)	From 17 kebelle (Guna street)	From Main CBE	From Axum hotel	
	7:30 to 8:30	708	235	733	497	2173

Table 12: Total traffic volume for Mekelle administration office intersection

Date	Peak hour	Mekelle administration office intersection				Total
		From Meserete elementary school (Daniel asefa street)	From st.mariam church (Daniel asefa street)	From water supply office	From electric utility office	
	12:30 to 13:30	273	307	131	197	908

Table 13: Total traffic volume for intersection around union dental clinic (#1)

Date	Peak hour	intersection around union dental clinic (#1)				Total
		From Mekelle administration office (Daniel asefa street)	From Micheal church (Daniel asefa street)	From Hashenge intrsection (Alganesh meles street)	From Hawzen adebabay (Alganesh meles street)	
	11:45 to 12:45	407	543	606	640	2196

3.4.2. Field Measurements

The width of traffic lane and median measurement is done manually using measuring tape; 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 nine selected intersection.

Table 14: Geometry data for Hawzen adebabay intersection

Hawzen adebabay round about intersection				
Approach from	Number of lanes		Average lane width (m)	Median width (m)
	Entry	Exit		
St.Mariam church	2	2	3.5	Not available
Romanat adebabay (Hakfen street)	2	2	3	Not available
post office(Alganesh meles street)	2	2	3	Not available
Zeslase round about	2	2	3	6
Round about				
Number of Circulating lane	2			
Circulating width (m)	3			
Diameter (m)	20			

Table 15: Geometry data for Millano intersection

Millano roundabout intersection				
Approach from	Number of lanes		Average lane width (m)	Median width (m)
	Entry	Exit		
Old bus station (Eyasu berhe street)	2	2	5	1.5
Queha (Eyasu berhe street)	2	2	5	2
Romanat adebabay (Agazi street)	1	1	5	0.5
Round about				
Number of Circulating lane	2			
Circulating width (m)	3			
Diameter (m)	8			

Table 16: Geometry data for Romanat adebabay intersection

Romanat adebabay intersection				
Approach from	Number of lanes		Average lane width (m)	Median width (m)
	Entry	Exit		
Hawzen adebabay (Hakfen street)	2	2	3	Not available
Housing agency(Selam street)	2	2	3	0.7
Main CBE (Alula street)	2	2	3	1
Millano hotel (Agazi street)	1	1	3.5	Not available

Table 17: Geometry data for Main CBE intersection

Main CBE intersection				
Approach from	Number of lanes		Average lane width (m)	Median width (m)
	Entry	Exit		
Romanat adebabay (Alula street)	2	2	3	1
Abrha castle hotel (Alula street)	2	2	3	1
Micheal church	1	1	3	Not available
Sheba college	2	2	3.5	Not available

Table 18: Geometry data for Abrha castel intersection

Abrha castel intersection				
Approach from	Number of lanes		Average lane width (m)	Median width (m)
	Entry	Exit		
Main CBE (Alula street)	2	2	3	1
Hawelti	1	1	5	Not available
Awash restaurant	2	2	4	2
Round about				
Number of Circulating lane	2			
Circulating width (m)	3			
Diameter (m)	11			

Table 19: Geometry data for Hashenge intersection

Hashenge intersection				
Approach from	Number of lanes		Average lane width (m)	Median width (m)
	Entry	Exit		
Aider Hospital	2	2	3	0.3
Hawelti	2	2	3.5	0.3
Dedebit microfinance (Alganesh meles street)	2	2	3.5	1.5
Hawzen adebabay(Alganesh meles street)	2	2	3.25	Not available

Table 20: Geometry data for Tena tabya intersection

Tena tabya intersection				
Approach from	Number of lanes		Average lane width (m)	Median width (m)
	Entry	Exit		
Hatsey yohannes elementary school (Guna street)	2	2	3.25	1
17 kebelle (Guna street)	2	2	3.25	1
Main CBE	2	2	3	Not available
Axum hotel	2	2	3.5	Not available

Table 21: Geometry data for Mekelle administration office intersection

Mekelle administration office round about intersection				
Approach from	Number of lanes		Average lane width (m)	Median width (m)
	Entry	Exit		
Meserete elementary school (Daniel Asefa street)	2	2	4	2
St.Mariam church (Daniel Asefa street)	2	2	4	2
Water supply office	2	2	3.5	2
Electric utility office	2	2	3.5	2
Round about				
Number of Circulating lane	3			
Circulating width (m)	4.5			
Diameter (m)	30			

Table 22: Geometry data for Intersection around union dental clinic (#1)

Intersection around union dental clinic (#1)				
Approach from	Number of lanes		Average lane width (m)	Median width (m)
	Entry	Exit		
Mekelle administration office (Daniel Asefa street)	2	2	4	2
Micheal church (Daniel Asefa street)	2	2	4	2
Hashenge intersection (Alganesh Meles street)	2	2	3.25	Not available
Hawzen adebabay (Alganesh Meles street)	2	2	3.25	Not available

CHAPTER FOUR

4. RESULTS AND DISCUSSION

Analysis was done on the nine selected intersections using the collected data and the results are presented in the following sections.

4.1. Intersections Level of Service Analysis

In order to check whether the intersections are congested or not, analysis was made using PTV VIISSIM program. As only the level of service (LOS) is determined for an indicative result leaving the other out puts of the program.

4.1.1. Input data

Directional traffic hourly flow data, Vehicle composition, number of lane, lane width and median width were prepared as an input for the program used from field measure for the analysis of level of service. The input data's for the program for the nine selected intersections are summarized in the following Tables. The raw data of traffic volume for each intersection for the day with peak hour count is summarized in Annex.

The geometry for intersection around union dental clinic (#1), 3 m of the traffic lane from segment hawzen adebabay (Alganesh Meles Street) and 1.5m of the traffic lane from segment Hashenge (Alganesh meles street) is occupied by illegal on street trading and on road parking. So, consider this for the first analysis of the LOS.

Table 23: Input data for Hawzen adebabay roundabout intersection

Hawzen adebabay roundabout intersection						
Traffic volume			Vehicle composition			Geometry data
Approach (from)	To	PCU	S.no	Vehicle type	Veh comp	Described in section 3.4.2.
St.Mariam church	Romanat adebabay (Hakfen street)	150	1	Heavy Truck	0	
	Zeslase round about intersection	112	2	Medium Truck	0	
	Post office (Alganesh Meles street)	83	3	Small truck	0	
	Total	345	4	Large bus	0.031	
Romanat adebabay (hakfen street)	St.Mariam church	197	5	Micro bus	0.036	
	Post office (Alganesh Meles street)	243	6	Mini bus	0.111	
	Zeslase round about intersection	272	7	Car and 4WD	0.227	
	Total	712	8	Pick up	0.293	
Post office (Alganesh Meles street)	Romanat adebabay (hakfen street)	221	9	LCV	0.243	
	St.Mariam church	187	10	Auto rickshaw	0.045	
	Zeslase round about intersection	241	11	motor bike	0.013	
	Total	649	12	Bicycle	0.001	

Table 23 continued

	Romanat adebabay (hakfen street)	178	13	Animal/Push Cart	0	
	St.Mariam church (SB)	122				
Zeslase round about intersection	Post office (Alganesh Meles street)	153				
	Total	453				

Table 24: Input data for Millano round about intersection

Millano round about intersection						
Traffic volume			Vehicle composition			Geometry data
Approach (from)	To	PCU	S.no	Vehicle type	Veh comp	Described in section 3.4.2.
Old bus station (Eyasu Berhe street)	Queha (Eyasu Berhe street)	258	1	Heavy Truck	0.029	
	Romanat adebabay (Agazi street)	240	2	Medium Truck	0.06	
	Total	498	3	Small truck	0.006	
Queha (Eyasu Berhe street)	Old bus station (Eyasu Berhe street)	241	4	Large bus	0.077	
	Romanat adebabay (Agazi street)	196	5	Micro bus	0.098	
	Total	437	6	Mini bus	0.23	
Romanat adebabay (Agazi street)	Queha (Eyasu Berhe street)	83	7	Car and 4WD	0.205	
	Old bus station (Eyasu Berhe street)	74	8	Pick up	0.115	
	Total	157	9	LCV	0.088	
			10	Auto rickshaw	0.074	
			11	motor bike	0.013	
			12	Bicycle	0.005	
			13	Animal/Push Cart	0	

Table 25: Input data for Abrha castel round about intersection

Abrha castel round about intersection						
Traffic volume			Vehicle composition			Geometry data
Approach (from)	To	PCU	S.no	Vehicle type	Veh comp	Described in section 3.4.2.
Main CBE (Alula street))	Hawelti	315	1	Heavy Truck	0.007	
	Awash restaurant	282	2	Medium Truck	0.016	
	Total	597	3	Small truck	0.002	
Hawelti	Awash restaurant	218	4	Large bus	0.025	
	Main CBE (Alula street))	334	5	Micro bus	0.032	
	Total	552	6	Mini bus	0.149	
Awash resturant	Hawelti	209	7	Car and 4WD	0.182	
	Main CBE (Alula street)	228	8	Pick up	0.286	
	Total	437	9	LCV	0.208	
			10	Auto rickshaw	0.076	
			11	motor bike	0.015	
			12	Bicycle	0.002	
			13	Animal/Push Cart	0	

Table 26: Input data for Romanat adebabay intersection

Romanat adebabay intersection						
Traffic volume			Vehicle composition			Geometry data
Approach (from)	To	PCU	S.no	Vehicle type	Veh comp	Described in section 3.4.2.
Hawzen adebabay (Hakfen street)	Housing agency(Selam street)	0	1	Heavy Truck	0.001	
	Main CBE (Alula street)	240	2	Medium Truck	0	
	Millano hotel (Agazi street)	222	3	Small truck	0	
	Total	462	4	Large bus	0.01	

Table 26 continued

Housing agency(Selam street)	Hawzen adebabay (Hakfen street)	0	5	Micro bus	0.032	
	Main CBE (Alula street)	142	6	Mini bus	0.124	
	Millano hotel (Agazi street)	170	7	Car and 4WD	0.261	
	Total	312	8	Pick up	0.242	
Main CBE (Alula street)	Housing agency(Selam street)	244	9	LCV	0.215	
	Millano hotel (Agazi street)	278	10	Auto rickshaw	0.097	
	Hawzen adebabay (Hakfen street)	295	11	motor bike	0.017	
	Total	817	12	Bicycle	0.001	
Millano hotel (Agazi street)	Housing agency(Selam street)	158	13	Animal/Push Cart	0	
	Main CBE (Alula street)	138				
	Hawzen adebabay (Hakfen street)	153				
	Total	449				

Table 27: Input data for Main CBE intersection

Main CBE intersection						
Traffic volume			Vehicle composition			Geometry data
Approach (from)	To	PCU	S.no	Vehicle type	Vehcomp	Described in section 3.4.2.
Romanat adebabay (Alula street)	Abrha castle (Alula street)	300	1	Heavy Truck	0.005	
	Micheal church	84	2	Medium Truck	0.009	
	Sheba college	224	3	Small truck	0.004	
	Total	608	4	Large bus	0.025	

Table 27 continued

Abrha castle (Alula street)	Romanat adebabay (Alula street)	356	5	Micro bus	0.031	
	Sheba college	119	6	Mini bus	0.149	
	Micheal church	90	7	Car and 4WD	0.196	
	Total	565	8	Pick up	0.215	
Micheal church	Sheba college	61	9	LCV	0.234	
	Abrha castle (Alula street)	60	10	Auto rickshaw	0.112	
	Romanat adebabay (Alula street)	68	11	motor bike	0.018	
	Total	189	12	Bicycle	0.002	
Sheba college	Micheal church	82	13	Animal/Push Cart	0	
	Romanat adebabay (Alula street)	120				
	Abrha castle (Alula street)	116				
	Total	318				

Table 28: Input data for Hashenge intersection

Hashenge intersection						
Traffic volume			Vehicle composition			Geometry data
Approach (from)	To	PCU	S.no	Vehicle type	Vehcomp	Described in section 3.4.2.
Aider Hospital	Hawelti	127	1	Heavy Truck	0.005	
	Dedebit microfinance (Alganesh Meles street)	151	2	Medium Truck	0.038	
	Hawzen adebabay (Alganesh Meles street)	283	3	Small truck	0.02	
	Total	561	4	Large bus	0.031	

Table 28 continued

	Aider Hospital	78	5	Micro bus	0.042	
	Hawzen adebabay (Alganesh Meles street)	153	6	Mini bus	0.185	
	Dedebit microfinance (Alganesh Meles street)	78	7	Car and 4WD	0.178	
Hawelti	Total	309	8	Pick up	0.278	
	Hawzen adebabay (Alganesh Meles street)	410	9	LCV	0.155	
Dedebit microfinance (Alganesh Meles street)	Hawelti	172	10	Auto rickshaw	0.036	
	Aider Hospital	276	11	motor bike	0.012	
	Total	858	12	Bicycle	0.002	
	Dedebit microfinance (Alganesh Meles street)	352	13	Animal/Push Cart	0.018	
Hawzen adebabay (Alganesh Meles street)	Aider Hospital	283				
	Hawelti	101				
	Total	736				

Table 29: Input data for Tena tabya intersection

Tena tabya intersection						
Traffic volume			Vehicle composition			Geometry data
Approach (from)	To	PCU	S.no	Vehicle type	Vehcomp	Described in section 3.4.2.
Hatsey johannes elementary school (Guna street)	17 kebelle (Guna street)	106	1	Heavy Truck	0.009	
	Main CBE	269	2	Medium Truck	0.012	
	Axum hotel	333	3	Small truck	0.003	
	Total	708	4	Large bus	0.01	

Table 29 continued

	Hatsey johannes elementary school (Guna street)	75	5	Micro bus	0.023	
	Axum hotel	81	6	Mini bus	0.119	
17 kebelle	Main CBE	79	7	Car and 4WD	0.257	
(Guna street)	Total	235	8	Pick up	0.309	
	Axum hotel	252	9	LCV	0.167	
	17 kebelle (Guna street)	222	10	Auto rickshaw	0.081	
	Hatsey johannes elementary school (Guna street)	259	11	motor bike	0.008	
Main CBE	Total	733	12	Bicycle	0.002	
	Main CBE	166	13	Animal/Push Cart	0	
	Hatsey johannes elementary school (Guna street)	179				
	17 kebelle (Guna street)	152				
Axum hotel	Total	497				

Table 30: Input data for Mekelle administration office intersection

Mekelle administration office intersection						
Traffic volume			Vehicle composition			Geometry data
Approach (from)	To	PCU	S.no	Vehicle type	Veh comp	Described in section 3.4.2.
Meserete	St.mariam church	241	1	Heavy Truck	0.027	
elementary	Water supply office	18	2	Medium Truck	0.04	
school (Daniel	Electric utility office	14	3	Small truck	0.01	
Asefa street)	Total	273	4	Large bus	0.06	

Table 30 continued

St.mariam church	Meserete elementary school (Daniel Asefa street)	194	5	Micro bus	0.05
	Electric utility office	72	6	Mini bus	0.16
	Water supply office	41	7	Car and 4WD	0.152
	Total	307	8	Pick up	0.215
Water supply office	Electric utility office	27	9	LCV	0.145
	St.mariam church	55	10	Auto rickshaw	0.114
	Meserete elementary school (Daniel Asefa street)	49	11	motor bike	0.018
	Total	131	12	Bicycle	0.009
Electric utility office	Water supply office	24	13	Animal/Push Cart	0
	Meserete elementary school (Daniel Asefa street)	45			
	St.mariam church	128			
	Total	197			

Table 31: Input data for Intersection around union dental clinic (#1)

Traffic volume			Vehicle composition		
Approach (from)	To	PCU	S.no	Vehicle type	Veh comp
Mekelle administration office (Daniel Asefa street)	Micheal church (Daniel Asefa street)	142	1	Heavy Truck	0.008
	Hashenge intersection (Alganesh meles street)	136	2	Medium Truck	0.022
	Hawzen adebabay (Alganesh meles street)	129	3	Small truck	0.007
	Total	407	4	Large bus	0.023

Table 31 continued

Micheal church (Daniel Asefa street)	Mekelle administration office (Daniel Asefa street)	148	5	Micro bus	0.032
	Hawzen adebabay (Alganesh meles street)	232	6	Mini bus	0.134
	Hashenge intersection (Alganesh meles street)	163	7	Car and 4WD	0.206
	Total	543	8	Pick up	0.279
Hashenge intersection (Alganesh meles street)	Hawzen adebabay (Alganesh meles street)	242	9	LCV	0.185
	Micheal church (Daniel Asefa street)	178	10	Auto rickshaw	0.096
	Mekelle administration office (Daniel Asefa street)	186	11	motor bike	0.006
	Total	606	12	Bicycle	0.002
Hawzen adebabay (Alganesh meles street)	Hashenge intersection (Alganesh meles street)	297	13	Animal/Push Cart	0
	Mekelle administration office (Daniel Asefa street)	157			
	Micheal church (Daniel Asefa street)	186			
	Total	640			

Geometry data			
Approach from	Number of lanes		Average lane width (m)
	Entry	Exit	
Mekelle administration office (Daniel Asefa street)	2	2	4
Micheal church (Daniel Asefa street)	2	2	4
Hashenge intersection (Alganesh Meles street)	1	2	3.8
Hawzen adebabay (Alganesh Meles street)	2	1	3.3

4.1.2. LOS output of each intersections

Level of service (LOS) is a measure used to determine the effectiveness of elements of transportation infrastructure. LOS is most commonly used to analyze highways by categorizing traffic flow with corresponding safe driving conditions. The level of service was performed for

the nine selected intersections after collecting all the necessary data listed in section 4.1.1 and the output is shown in the following tables.

Table 32: LOS for Hawzen adebabay round about intersection

Hawzen adebabay round about intersection												
Approach (from)	St.Mariam church			Romanat adebabay (Hakfen street)			Post office (Alganesh Meles street)			Zeslase round about intersection		
To	Romanat adebabay (Hakfen street)	Post office (Alganesh Meles street)	Zeslase round about intersection	St.Mariam church	Post office (Alganesh Meles street)	Zeslase round about intersection	Romanat adebabay (Hakfen street)	St.Mariam church	Zeslase round about intersection	Romanat adebabay (Hakfen street)	St.Mariam church	Post office (Alganesh Meles street)
LOS	**D**	**B**	**D**	**D**	**E**	**D**	**C**	**D**	**D**	**D**	**A**	**B**
Overall intersection												
LOS	**D**											

Table 33: LOS for Millano round about intersection

Millano round about intersection						
Approach (from)	Old bus station (Eyasu Berhe street)		Queha (Eyasu Berhe street)		Romanat adebabay (Agazi street)	
To	Queha (Eyasu Berhe street)	Romanat adebabay (Agazi street)	Old bus station (Eyasu Berhe street)	Romanat adebabay (Agazi street)	Queha (Eyasu Berhe street)	Old bus station (Eyasu Berhe street)
LOS	**B**	**A**	**B**	**B**	**A**	**A**
Overall intersection						
LOS	**A**					

Table 34: LOS for Romanat adebabay intersection

Romanat adebabay intersection												
Approach (from)	Hawzen adebabay (Hakfen street)			Housing agency(Selam street)			Main CBE (Alula street)			Millano hotel (Agazi street)		
To	Housing agency(Selam street)	Main CBE (Alula street)	Millano hotel (Agazi street)	Hawzen adebabay (Hakfen street)	Main CBE (Alula street)	Millano hotel (Agazi street)	Housing agency(Selam street)	Millano hotel (Agazi street)	Hawzen adebabay (Hakfen street)	Housing agency(Selam street)	Main CBE (Alula street)	Hawzen adebabay (Hakfen street)
LOS	–	**D**	**D**	–	**D**	**B**	**D**	**C**	**D**	**A**	**C**	**C**
Overall intersection												
LOS	**D**											

Table 35: LOS for Main CBE intersection

Main CBE intersection												
Approach (from)	Romanat adebabay (Alula street)			Abrha castle hotel (Alula street)			Micheal church			Sheba college		
To	Abrha castle hotel (Alula street)	Micheal church	Sheba college	Romanat adebabay (Alula street)	Sheba college	Micheal church	Sheba college	Abrha castle hotel (Alula street)	Romanat adebabay (Alula street)	Micheal church	Romanat adebabay (Alula street)	Abrha castle hotel (Alula street)
LOS	**D**	**A**	**D**	**D**	**D**	**C**	**C**	**B**	**C**	**C**	**C**	**D**
Overall intersection												
LOS	**D**											

Table 36: LOS for Abrha castel intersection

Abrha castel round about intersection						
Approach (from)	Main CBE (Alula street)		Hawelti		Awash resturant	
To	Hawelti	Awash restaurant	Awash restaurant	Main CBE (Alula street)	Hawelti	Main CBE (Alula street)
LOS	**C**	**D**	**B**	**D**	**D**	**A**
Overall intersection						
LOS	**C**					

Table 37: LOS for Hashenge intersection

Hashenge intersection												
Approach (from)	Aider Hospital			Hawelti			Dedebit microfinance (Alganesh meles street)		Hawzen adebabay (Alganesh meles street)			
Movement	Hawelti	Dedebit microfinance (Alganesh meles street)	Hawzen adebabay (Alganesh meles street)	Aider Hospital	Hawzen adebabay (Alganesh meles street)	Dedebit microfinance (Alganesh meles street)	Hawzen adebabay (Alganesh meles street)	Hawelti	Aider Hospital	Dedebit microfinance (Alganesh meles street)	Aider Hospital	Hawelti
LOS	**D**	**C**	**D**	**D**	**C**	**C**	**D**	**C**	**D**	**D**	**C**	**D**
Overall intersection												
LOS	**D**											

Table 38: LOS for Mekelle Tena tabya intersection

Mekelle Tena tabya intersection												
Approach (from)	Hatsey johannes elementary school (Guna street)			17 kebelle (Guna street)			Main CBE			Axum hotel		
To	17 kebelle (Guna street)	Main CBE	Axum hotel	Hatsey johannes elementary school (Guna street)	Axum hotel	Main CBE	Axum hotel	17 kebelle (Guna street)	Hatsey johannes elementary school (Guna street)	Main CBE	Hatsey johannes elementary school (Guna street)	17 kebelle (Guna street)
LOS	**D**	**D**	**D**	**C**	**B**	**C**	**D**	**D**	**D**	**D**	**C**	**C**
Overall intersection												
LOS	**D**											

Table 39: LOS for Mekelle administration office intersection

Mekelle administration office intersection													
Approach (from)	Meserete elementary school (Daniel Asefa street)			St.mariam church (Daniel Asefa street)			Water supply office				Electric utility office		
To	St.mariam church (Daniel Asefa street)	Water supply office	Electric utility office	Meserete elementary school (Daniel Asefa street)	Electric utility office	Water supply office	Electric utility office	St.mariam church (Daniel Asefa street)	Meserete elementary school (Daniel Asefa street)	Water supply office	Meserete elementary school (Daniel Asefa street)	St.mariam church (Daniel Asefa street)	
LOS	**B**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	
Overall intersection													
LOS	**A**												

Table 40: LOS for Intersection around union dental clinic (#1)

Intersection around union dental clinic (#1)												
Approach (from)	Mekelle administration office (Daniel asefa street)			Micheal church (Daniel asefa street)			Hashenge (Alganesh meles street)			Hawzen adebabay (Alganesh meles street)		
Movement	Micheal church (Daniel asefa street)	Hashenge (Alganesh meles street)	Hawzen adebabay (Alganesh meles street)	Mekelle administration office (Daniel asefa street)	Hawzen adebabay (Alganesh meles street)	Hashenge (Alganesh meles street)	Hawzen adebabay (Alganesh meles street)	Micheal church (Daniel asefa street)	Mekelle administration office (Daniel asefa street)	Hashenge (Alganesh meles street)	Mekelle administration office (Daniel asefa street)	Micheal church (Daniel asefa street)
LOS	**D**	**C**	**D**	**D**	**D**	**D**	**D**	**C**	**D**	**D**	**C**	**D**

Overall intersection	
LOS	**F**

4.2. Proposed mitigation of the traffic congestion

There are a number of specific circumstances, which cause or aggravate congestion: rapid increase in urban population, economic growth, increase in number of cars and number of people using cars, low capacity of transport infrastructure, road layout, underinvestment in road infrastructure, poor traffic management, shortage of street parking, signal and equipment failure, non-adherence to traffic regulations, the rapid expansion of city boundaries, poor public transport, increased use of private cars, car accidents, special events gatherings, road works, and bad weather are some of them.

The congestion level 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.

The most serious cause of congestion is reduction in highway capacity, due to increase in traffic volume. Traffic congestion can be reduced by either reducing traffic flow or increasing road capacity. When in order to increase road capacity; is the whole capacity of the traffic system is enlarged, more travelers could travel during the peak hour. The total traffic flows in this area improve, since more vehicles can drive on the enlarged roads per time. Thus, the individual remedy of expanding the capacity of roads without other remedies is not a solution to reduce traffic congestion, but an approach to increase the whole traffic flows. So instead of building more roads, manage the existing traffic flow is the most remedies for traffic congestion.

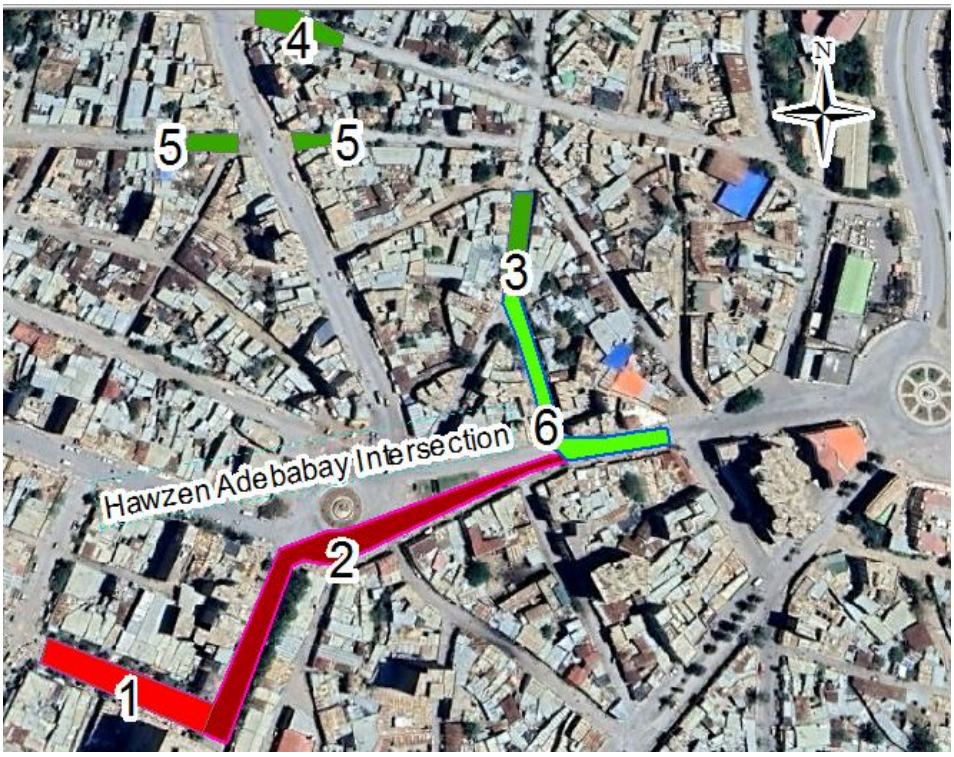
Most of congestion could be avoided with simple traffic management. On all intersections, on street parking near the intersection should be prohibited this will minimize excessive congestion near the intersection, the minibus taxi stations are almost concentrated to one area which is around kedamay weyane market center so try to rearrange to other free spaces ; similarly, take away the illegal on walkway and on traffic lane trading.

It's known that LOS A, B and are stable flow. LOS C is the target LOS for some urban and most rural highways. Due to time shortage the recommended counter measures are tested for intersection with movement LOS below D.

4.2.1. Forwarded countermeasure to Hawzen adebabay intersection

A. Make a regulation to avoid entrance of Auto rickshaw or Bajaj to the intersection.
B. Change mini bus taxi station of Lachi menaharia mini bus taxi station from 1 to 3, 05 kebelle from 3 to 4 and 03 kebelle from 4 to 5 as shown below; and also the route of Lachi bus station taxi from 2 to 6.This decreases the number of entering mini bus taxi to hawzen adebabay intersection from Romanat adebabay (Hakfen street) to Zeslase round about intersection approach and vice versa.

The number of Lachi minibus taxis is calculated from the directional flow as the number of minibus taxis from Hakfen street approach to Zeslase round about approach.



Legend

1: Current mini bus taxi station of Lachi

2: Current route of Lachi mini bus taxi

3: Current 05 kebelle mini bus taxi station

4: Current 03 kebelle mini bus taxi station

5: Free space

6: The recommend route for Lachi

Figure 11:Relocation of Lachi bus station mini bus taxi

Table 41: LOS after remedial measure for Hawzen adebabay intersection

Hawzen adebabay round about intersection												
Approach (from)	St.Mariam church			Romanat adebabay (Hakfen street)			post office (Alganesh meles street)			Zeslase intersection		
To	Romanat adebabay (Hakfen street)	post office (Alganesh meles street)	Zeslase intersection	St.Mariam church	post office (Alganesh meles street)	Zeslase intersection	Romanat adebabay (Hakfen street)	St.Mariam church	Zeslase intersection	Romanat adebabay (Hakfen street)	St.Mariam church	post office (Alganesh meles street)
LOS	**D**	**B**	**C**	**C**	**D**	**C**	**C**	**C**	**C**	**C**	**A**	**A**
Overall intersection												
LOS	**C**											

4.2.2. Forwarded countermeasure to romanat adebabay round about intersection

A. Make a regulation to avoid entrance of Auto rickshaw or Bajaj to the intersection.
B. Change mini bus tax station of Hawelti from 1 to 2 and the route from 4 to 3 as shown below; this decreases the number of enter mini bus taxi to romanat adebabay intersection from Hawzen adebabay (Hakfen street) to main CBE (Alula street) approach and vice versa.

The number of Hawelti minibus taxis is calculated from the directional flow as the number of minibus taxis from Hakfen street approach to Alula street approach.

Legend

1: Current Hawelti mini bus taxi station

2: The recommend taxi station for Hawelti taxi

3: The recommend route for Hawelti taxi

4: Current route of Hawelti taxi

Figure 12: Relocation of Hawelti mini bus taxi

Table 42: LOS after remedial measure for Romanat adebabay intersection

Romanat adebabay intersection												
Approach (from)			Hawzen adebabay (Hakfen street)			Housing agency(Selam street)			Main CBE (Alula street)			Millano hotel (Agazi street)
To	Housing agency(Selam street)	Main CBE (Alula street)	Millano hotel (Agazi street)	Hawzen adebabay (Hakfen street)	Main CBE (Alula street)	Millano hotel (Agazi street)	Housing agency(Selam street)	Millano hotel (Agazi street)	Hawzen adebabay (Hakfen street)	Housing agency(Selam street)	Main CBE (Alula street)	Hawzen adebabay (Hakfen street)
LOS	**–**	**C**	**B**	**–**	**C**	**B**	**D**	**C**	**B**	**A**	**C**	**B**
Overall intersection												
LOS	**B**											

4.2.3. Forwarded countermeasure to main CBE intersection

A. If Hawelti taxi route change as shown above; this decreases the number of enter mini bus taxi to main CBE intersection along Romanat adebabay (Alula street) and Abrha castle hotel (Alula street) approach.

The number of minibus taxis of hawelti is calculated from Abrha castle round about intersection, by take as the proportion of RT and LT minibus taxis from Alula Street approach. And multiply the RT proportion to the number of minibus taxis from Romanat adebabay (Alula Street) to Abrha castle (Alula Street) in Main CBE intersection.

B. Make a regulation to avoid entrance of Auto rickshaw or Bajaj to the intersection.

Table 43: LOS after remedial measure for Main CBE intersection

Main CBE intersection												
Approach (from)	Romanat adebabay (Alula street)			Abrha castle hotel Alula street)			Micheal church			Sheba college		
To	Abrha castle hotel Alula street)	Micheal church	Sheba college	Romanat adebabay (Alula street)	Sheba college	Micheal church	Sheba college	Abrha castle hotel Alula street)	Romanat adebabay (Alula street)	Micheal church	Romanat adebabay (Alula street)	Abrha castle hotel Alula street)
LOS	**B**	**A**	**C**	**C**	**B**	**C**	**B**	**B**	**B**	**C**	**B**	**D**

Overall intersection	
LOS	**C**

If Hawelti taxi route change as shown above; this decreases the number of enter mini bus taxi to Abrha castle round about intersection along Main CBE (Alula street) approach and Hawelti. This means the LOS of Abrha castle intersection also changes.

Table 44: LOS after relocation of Hawelti taxi for Abrha castel intersection

Abrha castel round about intersection						
Approach (from)	Main CBE (Alula street)		Hawelti		Awash restaurant	
To	Hawelti	Awash restaurant	Awash restaurant	Main CBE (Alula street)	Hawelti	Main CBE (Alula street)
LOS	**A**	**C**	**B**	**B**	**B**	**A**

Overall intersection	
LOS	**B**

4.2.4. Forwarded countermeasure to Hashenge intersection

A. Make a regulation to avoid entrance of Auto rickshaw or Bajaj to the intersection
B. Change mini bus taxi of Adi shmdhun to Mekelle administration line as shown in the figure below; this decreases the number of enter mini bus taxi to hashenge intersection along Dedebit microfinance (Alganesh Meles street) and Hawzen adebabay (Alganesh Meles street) and also; Aider minibus taxi are use Hawzen adebabay (Alganesh Meles street) approach and Ayder hospital approach; if this route is changed the number of enter mini bus taxi along Hawzen adebabay (Alganesh Meles street) approach again and Ayder Hospital approach is also decrease.

The number of Aider minibus taxi is calculated as the number of minibus taxis from Alganesh Meles (Hawzen Adebabay Street) approach to Aider hospital approach. And, the number of Adi shmdhun minibus taxis is calculated from one sixth of the minibus taxis from Hawzen adebabay (Alganesh Meles) approach to Dedebit (Alganesh Meles) approach because this route is used by taxis of six areas (adi shmdhun ,daero, adiha, adiha asphalt, adiha korokoj and biethntset).

1: Current Adi shmdhun mini bus taxi station

2: Recommend taxi station for Adi shmdhun

3: Current route of Adi shmdhun taxi

4: Recommend route for Adi shmdhun taxi

5; Current Ayder mini bus taxi station

6: Recommend route for Ayder mini bus taxi

Figure 13:Relocation of Adi shmdhun and Ayder mini bus taxi

Table 45: LOS after remedial measure for Hashenge intersection

Hashenge intersection												
Approach (from)	Aider Hospital			Hawelti			Dedebit microfinance (Alganesh meles street)			Hawzen adebabay (Alganesh meles street)		
Movement	Hawelti	Dedebit microfinance (Alganesh meles street)	Hawzen adebabay (Alganesh meles street)	Aider Hospital	Hawzen adebabay (Alganesh meles street)	Dedebit microfinance (Alganesh meles street)	Hawzen adebabay (Alganesh meles street)	Hawelti	Aider Hospital	Dedebit microfinance (Alganesh meles street)	Aider Hospital	Hawelti
LOS	**C**	**C**	**C**	**C**	**C**	**B**	**C**	**C**	**C**	**C**	**A**	**C**
Overall intersection												
LOS	**C**											

4.2.5. Forwarded countermeasure to Mekelle Tena Tabiya intersection

A. Make a regulation to avoid entrance of Auto rickshaw or Bajaj to the intersection.

B. Change mini bus taxi of arid to millano intersection as shown below; this decreases the number of enter mini bus taxi from Hatsey johannes elementary school (Guna street) approach to axum hotel .

Legend

1: Current arid mini bus taxi station

2: Current route of arid taxi

3: Recommend route for arid taxi

Figure 14:Relocation of arid mini bus taxi

Table 46: LOS after remedial measure for Tena tabya intersection

Mekelle Tena tabya intersection												
Approach	Hatsey johannes elementary school (Guna street)			17 kebelle (Guna street)			Main CBE			Axum hotel		
To	17 kebelle (Guna street)	Main CBE	Axum hotel	Hatsey johannes elementary school (Guna street)	Axum hotel	Main CBE	Axum hotel	17 kebelle (Guna street)	Hatsey johannes elementary school (Guna street)	Main CBE	Hatsey johannes elementary school (Guna street)	17 kebelle (Guna street)
LOS	**B**	**C**	**B**	**B**	**B**	**C**	**C**	**C**	**D**	**C**	**C**	**B**

Overall intersection	
LOS	**C**

Even the LOS of Mekelle tena tabya is modified; the LOS of millano intersection is decreased because of the relocation of Arid taxi. The change of the LOS is shown below.

Table 47: LOS after relocation of Arid taxi for Millano intersection

Millano round about intersection						
Approach (from)	Old bus station (Eyasu berhe street)		Queha (Eyasu berhe street)		Romanat adebabay (Agazi street)	
To	Queha (Eyasu berhe street)	Romanat adebabay (Agazi street)	Old bus station (Eyasu berhe street)	Romanat adebabay (Agazi street)	Queha (Eyasu berhe street)	Old bus station (Eyasu berhe street)
LOS	**B**	**B**	**C**	**C**	**C**	**A**

Overall intersection	
LOS	**B**

4.2.6. Forwarded countermeasure to intersection around union dental clinic (#1)

A. If Adi shmdhun and Aider mini bus taxi is changed as shown above the number of enter mini bus taxi along Hawzen adebabay (Alganesh Meles street) approach and Hashenge (Alganesh Meles) approach is decrease;
B. Make a regulation to avoid entrance of Auto rickshaw or Bajaj to the intersection.
C. Avoid parking along a road and on street trading along Alganesh Meles Street.this is considered by rearrange the reduced width of the traffic lane.

Table 48: LOS after remedial measure for Intersection around union dental clinic (#1)

Intersection around union dental clinic (#1)												
Approach (from)	Mekelle administration office (Daniel asefa street)			Micheal church (Daniel asefa street)			Hashenge (Alganesh meles street)			Hawzen adebabay (Alganesh meles street)		
Movement	Micheal church (Daniel asefa street)	Hashenge (Alganesh meles street)	Hawzen adebabay (Alganesh meles street)	Mekelle administration office (Daniel asefa street)	Hawzen adebabay (Alganesh meles street)	Hashenge (Alganesh meles street)	Hawzen adebabay (Alganesh meles street)	Micheal church (Daniel asefa street)	Mekelle administration office (Daniel asefa street)	Hashenge (Alganesh meles street)	Mekelle administration office (Daniel asefa street)	Micheal church (Daniel asefa street)
LOS	**C**	**C**	**C**	**C**	**C**	**D**	**C**	**C**	**B**	**C**	**C**	**C**
Overall intersection												
LOS	**C**											

The LOS of Mekelle administration office intersection is decrease due to change of adi shmduhun taxi to there. The change is shown below.

Table 49: LOS after relocation of taxi for Mekelle administration office intersection

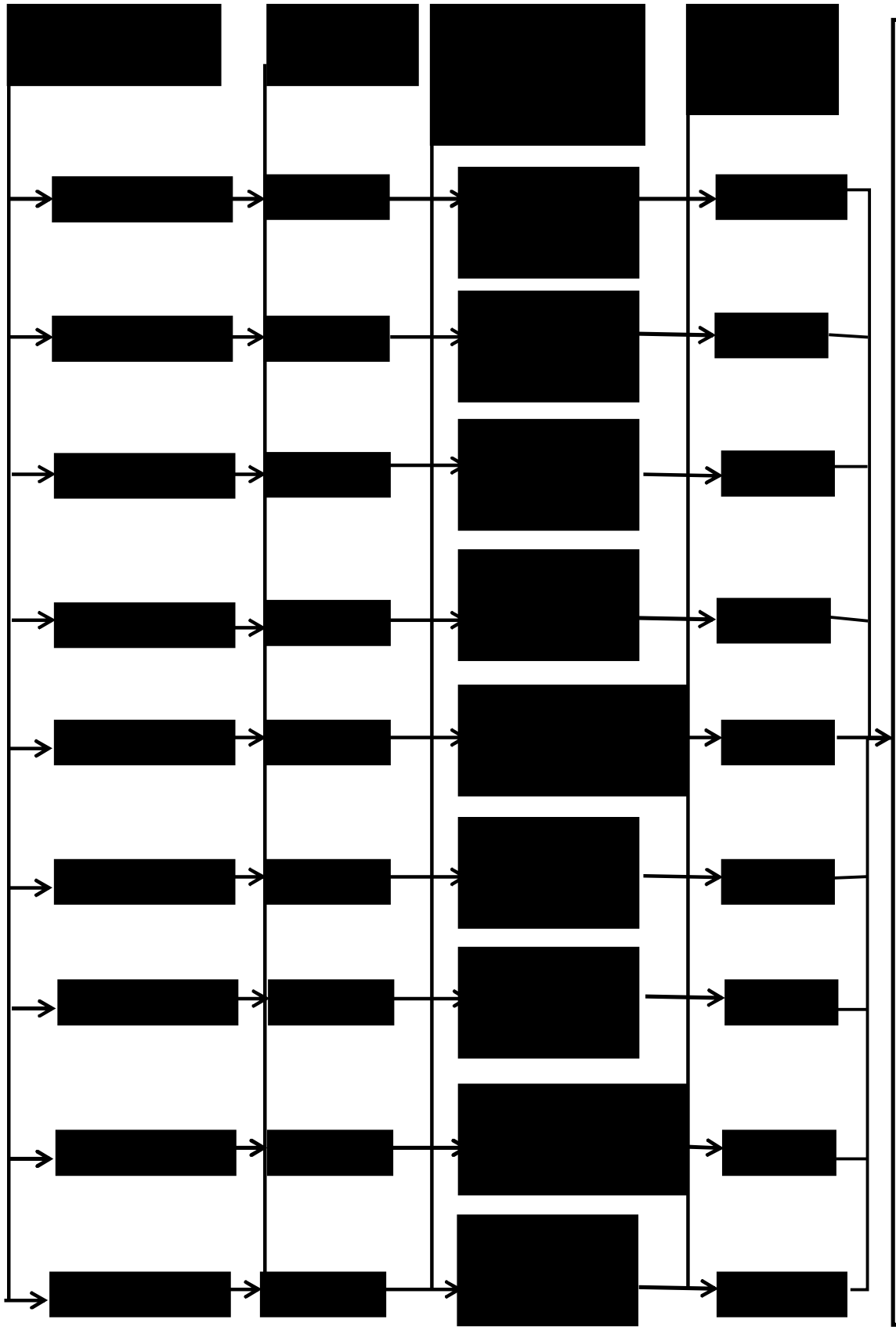
Mekelle administration office intersection												
Approach (from)	Meserete elementary school (Daniel asefa street)			St.mariam church (Daniel asefa street)			Water supply office			Electric utility office		
To	St.mariam church (Daniel asefa street)	Water supply office	Electric utility office	Meserete elementary school (Daniel asefa street)	Electric utility office	Water supply office	Electric utility office	St.mariam church (Daniel asefa street)	Meserete elementary school (Daniel asefa street)	Water supply office	Meserete elementary school (Daniel asefa street)	St.mariam church (Daniel asefa street)
LOS	**B**	**A**	**A**	**B**	**B**	**A**	**A**	**A**	**B**	**A**	**A**	**B**
Overall intersection												
LOS	**A**											

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This thesis discusses on assessment of level of traffic congestion, the regulatory counter measures, their change on the level of traffic congestion and identify the cause of thetffic congestion on the selected intersections of Mekelle city around kedamay weyane subcity. The selected intersections are (1) Hawzen adebabay round about intersection, (2) Millano round about intersection (3) Romanat adebabay intersection, (4) Main CBE intersection, (5) Abrha castle round about intersection, (6) Hashenge intersection, (7) Mekelle tena tabya intersection, (8) Mekelle administration office round about intersection and intersection around union dental clinic number one . The most typical used to assess the level of traffic congestion is LOS and used on this study. The simulation of the LOS is done by using VISSIM software using directional traffic flow and geometric feature of the intersection as input data.

And the suggested countermeasures are (A) make a regulation to avoid entrance of auto rickshaw or Bajaj to the intersection (B) relocation mini bus taxi station and route of some locations pass through the intersection And (C) Avoid vehicle stop near intersections and avoid illegal trading on the walk way and traffic lane. The current LOS of the selected intersections, suggested regulatory countermeasures to the intersections with LOS D,E and F, the change on the LOS after applying the counter measures and at the last identify the cause of the traffic congestion is summarized on the chart below.



Even though the LOS of Millano intersection and some turning movements in Mekelle administration office intersection are decrease after apply the counter measures; because some minibus taxi routes are changes to them, most LOS of the selected intersections around kedamay weyane are become to above LOS C. At final this thesis concluded that some of the key factors behind traffic congestion or the causes of traffic congestion include traffic overload on the same route (mini bus taxi routes), large numbers of LOV vehicles (in this case Bajaj), and parking along a road and on street trading.

Chart 5: Conclusion

5.2. Recommendation

Based on the discussion in the sections above, the following recommendations are made to help manage traffic congestion in order to improve the traffic operation:

- **For city administration**
  - Provision of adequate parking spaces
  - Relocate the mini bus taxis: most of minibus taxi routes are almost concentrated to one. So it must reroute the taxis in order to distribute the mini bus taxis to less congested intersections in order to decrease the congestion in more congested intersections or to minimize the gap of LOS between intersections.
  - Make relation with academic institutions to reduce traffic congestion: by doing more researches to find out different solutions that can reduce traffic congestion.
  - Strict enforcement of road traffic regulations like:
    - To avoid entrance of Auto rickshaw or Bajaj to the intersection because most of intersections are disturbed their traffic flow because of high number of Auto rickshaw or Bajaj.
    - To make minibus taxis to follow only the legal rout. Because some minibus taxi drivers are not following the regular/legal route of the taxi; they go as they want and this causes more congestion at some intersections only.
    - To make the taxi drivers follow traffic rules. and
    - Follow other important road traffic regulations recommended by other researchers by making relation with academic institutions as saying above. And not to be careless to regulate it may by employ some supporters to follow the regulations.
  - Make strict focus on the installed signals in order to give continuous function.
- **For academic institutions (universities, colleges)**
  - Carry out more studies to look at the reduction of congestion and to look at management the public transport or minibus taxis.
  - Make relation with the city administration to apply findings in different studies rather than for academic purpose only.

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Annexes

Annex-A: Traffic Volume in PCU

Table A1: Traffic volume at Hawzen adebabay Intersection

Hawzen adebabay intersection traffic volume count															Date: Oct 21/2019
		From St.Mariam church			From Romanat adebabay (Hakfen street)			From post office(Alganesh Meles street)			From Zeslase round about intersection			
Counted hour		To Romanat adebabay (Hakfen street)	To post office(Alganesh Meles street)	To Zeslase round about intersection	To Zeslase round about intersection	To post office(Alganesh Meles street)	To St.Mariam church	To St.Mariam church	To Romanat adebabay (Hakfen street))	To Zeslase round about intersection	To St.Mariam church	To Romanat adebabay (Hakfen street)	To post office(Alganesh Meles street)	Peak hour
Morning peak hour	7:00 - 7:15	36	30	23	33	31	25	41	35	23	51	42	23	
	7:15 - 7:30	47	51	35	46	41	20	32	30	19	54	33	30	
	7:30 - 7:45	61	47	39	52	35	21	47	41	34	66	58	46	
	7:45 - 8:00	53	39	22	57	43	37	36	30	25	70	63	50	
	7:15 - 7:30	47	51	35	46	41	20	32	30	19	54	33	30	
	7:30 - 7:45	61	47	39	52	35	21	47	41	34	66	58	46	
	7:45 - 8:00	53	39	22	57	43	37	36	30	25	70	63	50	
	8:00 - 8:15	57	46	38	50	35	26	42	34	21	81	72	63	
	7:30 - 7:45	61	47	39	52	35	21	47	41	34	66	58	46	
	7:45 - 8:00	53	39	22	57	43	37	36	30	25	70	63	50	
	8:00 - 8:15	57	46	38	50	35	26	42	34	21	81	72	63	
	8:15 - 8:30	33	24	19	50	48	26	39	34	21	73	50	41	
	7:45 - 8:00	53	39	22	57	43	37	36	30	25	70	63	50	
	8:00 - 8:15	57	46	38	50	35	26	42	34	21	81	72	63	
	8:15 - 8:30	33	24	19	50	48	26	39	34	21	73	50	41	
	8:30 - 8:45	37	29	22	46	40	24	42	30	24	28	20	19	
	8:00 - 8:15	57	46	38	50	35	26	42	34	21	81	72	63	
	8:15 - 8:30	33	24	19	50	48	26	39	34	21	73	50	41	
	8:30 - 8:45	37	29	22	46	40	24	42	30	24	28	20	19	
	8:45 - 9:00	31	26	15	46	33	26	40	31	26	42	37	25	

Table A1. (continued)

Afternoon peak hour	11:30 - 11:45	28	35	18	55	43	20	48	42	31	45	35	31	
	11:45 - 12:00	31	26	21	50	41	23	43	32	21	54	43	36	
	12:00 - 12:15	42	30	16	45	33	29	46	34	29	60	52	46	
	12:15 - 12:30	45	36	22	62	55	41	39	31	26	64	50	42	
	11:45 - 12:00	31	26	21	50	41	23	43	32	21	54	43	36	
	12:00 - 12:15	42	30	16	45	33	29	46	34	29	60	52	46	
	12:15 - 12:30	45	36	22	62	55	41	39	31	26	64	50	42	
	12:30 - 12:45	40	32	25	75	68	59	73	66	51	45	39	31	
	12:00 - 12:15	42	30	16	45	33	29	46	34	29	60	52	46	
	12:15 - 12:30	45	36	22	62	55	41	39	31	26	64	50	42	
	12:30 - 12:45	40	32	25	75	68	59	73	66	51	45	39	31	
	12:45 - 13:00	39	25	21	70	63	57	70	62	60	32	31	25	
	12:15 - 12:30	45	36	22	62	55	41	39	31	26	64	50	42	**Peak hour**
	12:30 - 12:45	40	32	25	75	68	59	73	66	51	45	39	31	
	12:45 - 13:00	39	25	21	70	63	57	70	62	60	32	31	25	
	13:00 - 13:15	26	19	15	65	57	40	59	62	50	37	33	24	
	12:30 - 12:45	40	32	25	75	68	59	73	66	51	45	39	31	
	12:45 - 13:00	39	25	21	70	63	57	70	62	60	32	31	25	
	13:00 - 13:15	26	19	15	65	57	40	59	62	50	37	33	24	
	13:15 - 13:30	30	20	13	37	46	24	51	42	37	45	37	33	
Evening peak hour	4:00 - 4:15	33	29	20	41	33	25	45	30	26	39	27	31	
	4:15 - 4:30	29	31	24	32	23	17	42	38	23	35	43	30	
	4:30 - 4:45	31	26	20	51	48	34	47	42	35	51	44	38	
	4:45 - 5:00	48	44	22	43	47	41	56	45	37	49	37	40	
	4:15 - 4:30	29	31	24	32	23	17	42	38	23	35	43	30	
	4:30 - 4:45	31	26	20	51	48	34	47	42	35	51	44	38	
	4:45 - 5:00	48	44	22	43	47	41	56	45	37	49	37	40	
	5:00 - 5:15	25	22	20	36	42	25	50	40	40	50	37	44	
	4:30 - 4:45	31	26	20	51	48	34	47	42	35	51	44	38	
	4:45 - 5:00	48	44	22	43	47	41	56	45	37	49	37	40	
	5:00 - 5:15	25	22	20	36	42	25	50	40	40	50	37	44	
	5:15 - 5:30	25	20	18	39	31	26	31	25	23	57	46	39	
	4:45 - 5:00	48	44	22	43	47	41	56	45	37	49	37	40	
	5:00 - 5:15	25	22	20	36	42	25	50	40	40	50	37	44	
	5:15 - 5:30	25	20	18	39	31	26	31	25	23	57	46	39	
	5:30 - 5:45	29	24	19	41	30	24	21	20	16	41	30	31	
	5:00 - 5:15	25	22	20	36	42	25	50	40	40	50	37	44	
	5:15 - 5:30	25	20	18	39	31	26	31	25	23	57	46	39	
	5:30 - 5:45	29	24	19	41	30	24	21	20	16	41	30	31	
	5:45 - 6:00	41	32	26	43	26	18	30	25	27	55	47	35	

Table A2: Traffic volume at Milano Intersection

Millano intersection		traffic volume count				Date: Oct 29/2019		
		From Old bus station (Eyasu Berhe street)		From Queha (Eyasu Berhe street)		From Romanat adebabay (Agazi street)		Peak hour
Counted hour		To Queha (Eyasu Berhe street)	To Romanat adebabay (Agazi street)	Romanat adebabay (Agazi street)	To Old bus station (Eyasu Berhe street)	To Old bus station (Eyasu Berhe street)	To Queha (Eyasu Berhe street)	
Morning peak hour	7:00 - 7:15	38	33	69	56	14	13	
	7:15 - 7:30	52	49	60	76	18	20	
	7:30 - 7:45	65	73	53	67	21	14	
	7:45 - 8:00	63	71	53	61	25	22	
	7:15 - 7:30	52	49	60	76	18	20	
	7:30 - 7:45	65	73	53	67	21	14	
	7:45 - 8:00	63	71	53	61	25	22	
	8:00 - 8:15	60	65	30	37	19	18	Peak hour
	7:30 - 7:45	65	73	53	67	21	14	
	7:45 - 8:00	63	71	53	61	25	22	
	8:00 - 8:15	60	65	30	37	19	18	
	8:15 - 8:30	32	23	36	34	20	21	
	7:45 - 8:00	63	71	53	61	25	22	
	8:00 - 8:15	60	65	30	37	19	18	
	8:15 - 8:30	32	23	36	34	20	21	
	8:30 - 8:45	30	27	40	39	13	20	
	8:00 - 8:15	60	65	30	37	19	18	
	8:15 - 8:30	32	23	36	34	20	21	
	8:30 - 8:45	30	27	40	39	13	20	
	8:45 - 9:00	39	31	36	45	16	18	

Table A2. (Continued)

Afternoon peak hour	11:30 - 11:45	47	33	44	53	18	20	
	11:45 - 12:00	52	41	50	39	18	15	
	12:00 - 12:15	50	39	43	36	17	13	
	12:15 - 12:30	41	44	32	27	20	16	
	11:45 - 12:00	52	41	50	39	18	15	
	12:00 - 12:15	50	39	43	36	17	13	
	12:15 - 12:30	41	44	32	27	20	16	
	12:30 - 12:45	37	30	33	42	31	22	
	12:00 - 12:15	50	39	43	36	17	13	
	12:15 - 12:30	41	44	32	27	20	16	
	12:30 - 12:45	37	30	33	42	31	22	
	12:45 - 13:00	47	37	34	40	27	25	
	12:15 - 12:30	41	44	32	27	20	16	
	12:30 - 12:45	37	30	33	42	31	22	
	12:45 - 13:00	47	37	34	40	27	25	
	13:00 - 13:15	30	39	46	51	22	23	
	12:30 - 12:45	37	30	33	42	31	22	
	12:45 - 13:00	47	37	34	40	27	25	
	13:00 - 13:15	30	39	46	51	22	23	
	13:15 - 13:30	39	45	59	50	30	17	
Evening peak hour	4:00 - 4:15	38	47	58	63	17	13	
	4:15 - 4:30	42	44	40	49	15	16	
	4:30 - 4:45	33	48	38	47	20	19	
	4:45 - 5:00	33	39	37	34	26	20	
	4:15 - 4:30	42	44	40	49	15	16	
	4:30 - 4:45	33	48	38	47	20	19	
	4:45 - 5:00	33	39	37	34	26	20	
	5:00 - 5:15	50	38	40	32	18	19	
	4:30 - 4:45	33	48	38	47	20	19	
	4:45 - 5:00	33	39	37	34	26	20	
	5:00 - 5:15	50	38	40	32	18	19	
	5:15 - 5:30	27	30	51	44	13	16	
	4:45 - 5:00	33	39	37	34	26	20	
	5:00 - 5:15	50	38	40	32	18	19	
	5:15 - 5:30	27	30	51	44	13	16	
	5:30 - 5:45	33	37	36	36	18	15	
	5:00 - 5:15	50	38	40	32	18	19	
	5:15 - 5:30	27	30	51	44	13	16	
	5:30 - 5:45	33	37	36	36	18	15	
	5:45 - 6:00	34	41	41	32	20	19	

Table A3: Traffic volume at Romanat adebabay Intersection

Romanat adebabay intersection		traffic volume count									Date : Nov 18/2019			
		From Hawzen adebabay (Hakfen street)			From Housing agency(Selam street)			From Main CBE (Alula street)			From Millano hotel (Agazi street)			
Counted hour		To Housing agency (Selam street)	To Main CBE (Alula street)	To Millano hotel (Agazi street)	To Hawzen adebabay (Hakfen street)	To Main CBE (Alula street)	To Millano hotel (Agazi street)	To Housing agency (Selam street)	To Millano hotel (Agazi street)	Hawzen adebabay (Hakfen street)	To Housing agency (Selam street)	To Main CBE (Alula street)	To Hawzen adebabay (Hakfen street)	Peak hour
Morning peak hour	7:00 - 7:15	0	45	51	0	32	36	52	46	47	40	34	37	
	7:15 - 7:30	0	72	80	0	40	31	49	30	57	41	33	39	
	7:30 - 7:45	0	62	75	0	33	38	45	54	46	57	50	54	
	7:45 - 8:00	0	75	70	0	28	36	41	37	55	52	47	50	
	7:15 - 7:30	0	72	80	0	40	31	49	30	57	41	33	39	
	7:30 - 7:45	0	62	75	0	33	38	45	54	46	57	50	54	
	7:45 - 8:00	0	75	70	0	28	36	41	37	55	52	47	50	
	8:00 - 8:15	0	79	72	0	33	29	47	41	53	63	51	58	
	7:30 - 7:45	0	62	75	0	33	38	45	54	46	57	50	54	
	7:45 - 8:00	0	75	70	0	28	36	41	37	55	52	47	50	
	8:00 - 8:15	0	79	72	0	33	29	47	41	53	63	51	58	
	8:15 - 8:30	0	55	50	0	42	30	48	45	61	57	49	54	
	7:45 - 8:00	0	75	70	0	28	36	41	37	55	52	47	50	
	8:00 - 8:15	0	79	72	0	33	29	47	41	53	63	51	58	
	8:15 - 8:30	0	55	50	0	42	30	48	45	61	57	49	54	
	8:30 - 8:45	0	43	49	0	44	29	43	39	54	42	34	39	
	8:00 - 8:15	0	79	72	0	33	29	47	41	53	63	51	58	
	8:15 - 8:30	0	55	50	0	42	30	48	45	61	57	49	54	
	8:30 - 8:45	0	43	49	0	44	29	43	39	54	42	34	39	
	8:45 - 9:00	0	54	53	0	33	36	41	38	45	32	29	36	

Table A3. (Continued)

Afternoon peak hour	11:30 - 11:45	0	48	59	0	32	33	53	47	59	37	32	35	
	11:45 - 12:00	0	65	59	0	26	32	51	45	62	38	33	37	
	12:00 - 12:15	0	53	59	0	29	27	57	49	62	41	39	38	
	12:15 - 12:30	0	53	57	0	22	24	47	41	49	38	40	41	
	11:45 - 12:00	0	65	59	0	26	32	51	45	62	38	33	37	
	12:00 - 12:15	0	53	59	0	29	27	57	49	62	41	39	38	
	12:15 - 12:30	0	53	57	0	22	24	47	41	49	38	40	41	
	12:30 - 12:45	0	69	61	0	32	36	68	58	56	44	41	43	
	12:00 - 12:15	0	53	59	0	29	27	57	49	62	41	39	38	
	12:15 - 12:30	0	53	57	0	22	24	47	41	49	38	40	41	
	12:30 - 12:45	0	69	61	0	32	36	68	58	56	44	41	43	
	12:45 - 13:00	0	62	48	0	39	52	78	58	82	45	37	41	
	12:15 - 12:30	0	53	57	0	22	24	47	41	49	38	40	41	
	12:30 - 12:45	0	69	61	0	32	36	68	58	56	44	41	43	
	12:45 - 13:00	0	62	48	0	39	52	78	58	82	45	37	41	
	13:00 - 13:15	0	54	50	0	36	41	74	61	69	34	27	31	
	12:30 - 12:45	0	69	61	0	32	36	68	58	56	44	41	43	Peak hour
	12:45 - 13:00	0	62	48	0	39	52	78	58	82	45	37	41	
	13:00 - 13:15	0	54	50	0	36	41	74	61	69	34	27	31	
	13:15 - 13:30	0	55	63	0	35	41	75	67	71	35	33	38	
Evening peak hour	4:00 - 4:15	0	49	58	0	35	38	45	38	48	42	39	40	
	4:15 - 4:30	0	42	57	0	32	30	49	35	54	44	41	46	
	4:30 - 4:45	0	57	43	0	31	34	46	40	51	41	36	38	
	4:45 - 5:00	0	46	53	0	34	35	42	39	48	48	41	46	
	4:15 - 4:30	0	42	57	0	32	30	49	35	54	44	41	46	
	4:30 - 4:45	0	57	43	0	31	34	46	40	51	41	36	38	
	4:45 - 5:00	0	46	53	0	34	35	42	39	48	48	41	46	
	5:00 - 5:15	0	66	40	0	35	32	46	40	49	46	41	49	
	4:30 - 4:45	0	57	43	0	31	34	46	40	51	41	36	38	
	4:45 - 5:00	0	46	53	0	34	35	42	39	48	48	41	46	
	5:00 - 5:15	0	66	40	0	35	32	46	40	49	46	41	49	
	5:15 - 5:30	0	65	52	0	28	32	51	43	49	41	32	39	
	4:45 - 5:00	0	46	53	0	34	35	42	39	48	48	41	46	
	5:00 - 5:15	0	66	40	0	35	32	46	40	49	46	41	49	
	5:15 - 5:30	0	65	52	0	28	32	51	43	49	41	32	39	
	5:30 - 5:45	0	55	49	0	25	29	56	48	53	44	39	41	
	5:00 - 5:15	0	66	40	0	35	32	46	40	49	46	41	49	
	5:15 - 5:30	0	65	52	0	28	32	51	43	49	41	32	39	
	5:30 - 5:45	0	55	49	0	25	29	56	48	53	44	39	41	
	5:45 - 6:00	0	48	54	0	34	37	59	49	57	47	41	44	

Table A4: Traffic volume at Main CBE Intersection

Main CBE intersection		traffic volume count								Date: Nov 25/2019				
		From Romanat adebabay (Alula street)			From Abrha castle (Alula street)			From Micheal church			From Sheba college			Peak hour
Counted hour		To Abrha castle (Alula street)	To Micheal church	To Sheba college	To Romanat adebabay (Alula street)	To Micheal church	To Sheba college	To Romanat adebabay (Alula street)	To Abrha castle (Alula street)	To Sheba college	To Romanat adebabay (Alula street)	To Abrha castle (Alula street)	To Micheal church	
Morning peak hour	7:00 - 7:15	54	5	27	72	14	17	16	13	17	42	35	31	
	7:15 - 7:30	78	13	47	81	13	15	14	12	16	43	31	21	
	7:30 - 7:45	81	20	56	89	26	23	19	17	22	27	24	31	
	7:45 - 8:00	86	25	64	78	15	16	15	11	13	26	27	21	
	7:15 - 7:30	78	13	47	81	13	15	14	12	16	43	31	21	
	7:30 - 7:45	81	20	56	89	26	23	19	17	22	27	24	31	
	7:45 - 8:00	86	25	64	78	15	16	15	11	13	26	27	21	
	8:00 - 8:15	88	24	67	91	26	30	15	17	9	34	29	31	
	7:30 - 7:45	81	20	56	89	26	23	19	17	22	27	24	31	
	7:45 - 8:00	86	25	64	78	15	16	15	11	13	26	27	21	
	8:00 - 8:15	88	24	67	91	26	30	15	17	9	34	29	31	
	8:15 - 8:30	45	15	37	98	38	35	19	15	17	25	22	21	
	7:45 - 8:00	86	25	64	78	15	16	15	11	13	26	27	21	
	8:00 - 8:15	88	24	67	91	26	30	15	17	9	34	29	31	
	8:15 - 8:30	45	15	37	98	38	35	19	15	17	25	22	21	
	8:30 - 8:45	41	11	35	69	8	10	18	14	19	33	25	28	
	8:00 - 8:15	88	24	67	91	26	30	15	17	9	34	29	31	
	8:15 - 8:30	45	15	37	98	38	35	19	15	17	25	22	21	
	8:30 - 8:45	41	11	35	69	8	10	18	14	19	33	25	28	
	8:45 - 9:00	65	13	43	73	8	11	14	17	11	38	34	36	

Table A4. (Continued)

Afternoon peak hour	11:30 - 11:45	62	11	46	89	19	23	18	16	21	35	31	29	
	11:45 - 12:00	57	8	43	86	17	21	16	18	19	36	33	27	
	12:00 - 12:15	48	10	42	81	14	11	15	17	8	41	32	36	
	12:15 - 12:30	51	12	43	78	11	9	19	14	11	29	26	24	
	11:45 - 12:00	57	8	43	86	17	21	16	18	19	36	33	27	
	12:00 - 12:15	48	10	42	81	14	11	15	17	8	41	32	36	
	12:15 - 12:30	51	12	43	78	11	9	19	14	11	29	26	24	
	12:30 - 12:45	48	11	38	81	8	13	21	15	13	44	46	41	
	12:00 - 12:15	48	10	42	81	14	11	15	17	8	41	32	36	
	12:15 - 12:30	51	12	43	78	11	9	19	14	11	29	26	24	
	12:30 - 12:45	48	11	38	81	8	13	21	15	13	44	46	41	
	12:45 - 13:00	65	12	41	83	7	14	16	18	12	41	44	39	
	12:15 - 12:30	51	12	43	78	11	9	19	14	11	29	26	24	
	12:30 - 12:45	48	11	38	81	8	13	21	15	13	44	46	41	
	12:45 - 13:00	65	12	41	83	7	14	16	18	12	41	44	39	
	13:00 - 13:15	62	8	35	85	14	11	18	15	14	26	24	18	
	12:30 - 12:45	48	11	38	81	8	13	21	15	13	44	46	41	
	12:45 - 13:00	65	12	41	83	7	14	16	18	12	41	44	39	
	13:00 - 13:15	62	8	35	85	14	11	18	15	14	26	24	18	
	13:15 - 13:30	75	16	45	83	11	13	21	17	16	24	25	21	
Evening peak hour	4:00 - 4:15	62	15	42	85	14	12	14	17	16	36	27	29	
	4:15 - 4:30	64	13	39	86	12	10	21	17	15	34	25	27	
	4:30 - 4:45	72	17	44	84	13	8	11	13	12	25	27	24	
	4:45 - 5:00	70	15	47	87	16	7	17	14	18	29	26	33	
	4:15 - 4:30	64	13	39	86	12	10	21	17	15	34	25	27	
	4:30 - 4:45	72	17	44	84	13	8	11	13	12	25	27	24	
	4:45 - 5:00	70	15	47	87	16	7	17	14	18	29	26	33	
	5:00 - 5:15	67	14	44	78	9	11	16	15	18	27	25	28	
	4:30 - 4:45	72	17	44	84	13	8	11	13	12	25	27	24	
	4:45 - 5:00	70	15	47	87	16	7	17	14	18	29	26	33	
	5:00 - 5:15	67	14	44	78	9	11	16	15	18	27	25	28	
	5:15 - 5:30	81	16	47	88	17	19	19	14	18	31	24	26	
	4:45 - 5:00	70	15	47	87	16	7	17	14	18	29	26	33	
	5:00 - 5:15	67	14	44	78	9	11	16	15	18	27	25	28	
	5:15 - 5:30	81	16	47	88	17	19	19	14	18	31	24	26	
	5:30 - 5:45	64	11	36	89	15	18	22	19	17	27	29	24	
	5:00 - 5:15	67	14	44	78	9	11	16	15	18	27	25	28	
	5:15 - 5:30	81	16	47	88	17	19	19	14	18	31	24	26	
	5:30 - 5:45	64	11	36	89	15	18	22	19	17	27	29	24	
	5:45 - 6:00	72	14	44	81	7	10	26	21	24	29	27	28	

Table A5: Traffic volume at Abrha Castle Intersection

Abrha castle intersection		traffic volume count				Date Dec 9/2019		
		From Awash resturant		From Hawelti		From Main CBE (Alula street)		Peak hour
Counted hour		To Main CBE (Alula street)	To Hawelti	To Main CBE (Alula street)	To Awash resturant	To Awash resturant	To Hawelti	
Morning peak hour	7:00 - 7:15	65	59	78	45	62	71	
	7:15 - 7:30	71	69	68	47	51	58	
	7:30 - 7:45	73	75	65	47	63	51	
	7:45 - 8:00	71	76	76	48	44	50	
	7:15 - 7:30	71	69	68	47	51	58	
	7:30 - 7:45	73	75	65	47	63	51	
	7:45 - 8:00	71	76	76	48	44	50	
	8:00 - 8:15	85	79	81	39	59	47	
	7:30 - 7:45	73	75	65	47	63	51	
	7:45 - 8:00	71	76	76	48	44	50	
	8:00 - 8:15	85	79	81	39	59	47	
	8:15 - 8:30	61	59	56	29	45	47	
	7:45 - 8:00	71	76	76	48	44	50	
	8:00 - 8:15	85	79	81	39	59	47	
	8:15 - 8:30	61	59	56	29	45	47	
	8:30 - 8:45	57	60	49	23	61	53	
	8:00 - 8:15	85	79	81	39	59	47	
	8:15 - 8:30	61	59	56	29	45	47	
	8:30 - 8:45	57	60	49	23	61	53	
	8:45 - 9:00	53	55	59	25	41	57	

Table A5. (Continued)

Afternoon peak hour	11:30 - 11:45	61	59	69	39	50	63	
	11:45 - 12:00	54	58	72	44	41	63	
	12:00 - 12:15	51	47	75	47	45	52	
	12:15 - 12:30	57	58	69	44	56	60	
	11:45 - 12:00	54	58	72	44	41	63	
	12:00 - 12:15	51	47	75	47	45	52	
	12:15 - 12:30	57	58	69	44	56	60	
	12:30 - 12:45	67	66	75	51	70	59	
	12:00 - 12:15	51	47	75	47	45	52	
	12:15 - 12:30	57	58	69	44	56	60	
	12:30 - 12:45	67	66	75	51	70	59	
	12:45 - 13:00	59	56	79	43	59	67	
	12:15 - 12:30	57	58	69	44	56	60	
	12:30 - 12:45	67	66	75	51	70	59	
	12:45 - 13:00	59	56	79	43	59	67	
	13:00 - 13:15	52	55	65	32	46	52	
	12:30 - 12:45	67	66	75	51	70	59	
	12:45 - 13:00	59	56	79	43	59	67	
	13:00 - 13:15	52	55	65	32	46	52	
	13:15 - 13:30	43	47	65	51	57	46	
Evening peak hour	4:00 - 4:15	61	56	78	46	74	57	
	4:15 - 4:30	59	66	65	41	54	70	
	4:30 - 4:45	56	61	84	47	49	55	
	4:45 - 5:00	58	54	63	24	52	69	
	4:15 - 4:30	59	66	65	41	54	70	
	4:30 - 4:45	56	61	84	47	49	55	
	4:45 - 5:00	58	54	63	24	52	69	
	5:00 - 5:15	53	51	86	49	67	78	
	4:30 - 4:45	56	61	84	47	49	55	
	4:45 - 5:00	58	54	63	24	52	69	
	5:00 - 5:15	53	51	86	49	67	78	
	5:15 - 5:30	57	54	85	55	79	86	
	4:45 - 5:00	58	54	63	24	52	69	
	5:00 - 5:15	53	51	86	49	67	78	
	5:15 - 5:30	57	54	85	55	79	86	
	5:30 - 5:45	47	44	79	57	67	81	
	5:00 - 5:15	53	51	86	49	67	78	Peak hour
	5:15 - 5:30	57	54	85	55	79	86	
	5:30 - 5:45	47	44	79	57	67	81	
	5:45 - 6:00	71	60	84	57	69	70	

Table A6: Traffic volume at Hashenge Intersection

Hashenge intersection traffic volume count														Date: Dec 28/2019
		From Dedebit microfinance (Alganesh meles street)			From Hawelti			From Aider Hospital			From Hawzen adebabay (Alganesh meles street)			Peak hour
Counted hour		To Hawelti	To Hawzen adebabay(Alganesh meles	To Aider Hospital	To Aider Hospital	To Hawzen adebabay(Alganesh meles street)	To Dedebit microfinance (Alganesh meles street)	To Dedebit microfinance (Alganesh meles street)	To Hawelti	To Hawzen adebabay(Alganesh meles street)	To Aider Hospital	To Hawelti	To Dedebit microfinance (Alganesh meles street)	
Morning peak hour	7:00 - 7:15	44	83	16	26	35	29	27	31	61	49	21	47	
	7:15 - 7:30	82	112	52	29	38	31	31	28	58	52	17	39	
	7:30 - 7:45	77	107	49	24	36	21	33	29	66	65	29	53	
	7:45 - 8:00	74	105	48	12	26	14	37	31	68	73	32	68	
	7:15 - 7:30	82	112	52	29	38	31	31	28	58	52	17	39	
	7:30 - 7:45	77	107	49	24	36	21	33	29	66	65	29	53	
	7:45 - 8:00	74	105	48	12	26	14	37	31	68	73	32	68	
	8:00 - 8:15	79	109	46	23	46	18	38	34	71	72	41	91	
	7:30 - 7:45	77	107	49	24	36	21	33	29	66	65	29	53	
	7:45 - 8:00	74	105	48	12	26	14	37	31	68	73	32	68	
	8:00 - 8:15	79	109	46	23	46	18	38	34	71	72	41	91	
	8:15 - 8:30	46	89	29	19	45	25	43	33	78	69	44	99	
	7:45 - 8:00	74	105	48	12	26	14	37	31	68	73	32	68	
	8:00 - 8:15	79	109	46	23	46	18	38	34	71	72	41	91	
	8:15 - 8:30	46	89	29	19	45	25	43	33	78	69	44	99	
	8:30 - 8:45	49	85	31	17	35	15	33	29	65	32	15	39	
	8:00 - 8:15	79	109	46	23	46	18	38	34	71	72	41	91	
	8:15 - 8:30	46	89	29	19	45	25	43	33	78	69	44	99	
	8:30 - 8:45	49	85	31	17	35	15	33	29	65	32	15	39	
	8:45 - 9:00	55	87	23	24	39	26	33	28	69	31	19	38	

Table A6. (Continued)

Afternoon peak hour	11:30 - 11:45	49	91	20	23	37	19	37	31	71	42	24	58	
	11:45 - 12:00	47	88	17	25	41	22	33	32	72	39	26	64	
	12:00 - 12:15	52	84	27	18	36	14	36	29	74	41	21	49	
	12:15 - 12:30	47	91	23	21	39	18	35	28	71	34	19	51	
	11:45 - 12:00	47	88	17	25	41	22	33	32	72	39	26	64	
	12:00 - 12:15	52	84	27	18	36	14	36	29	74	41	21	49	
	12:15 - 12:30	47	91	23	21	39	18	35	28	71	34	19	51	
	12:30 - 12:45	55	95	36	19	31	23	46	49	99	39	15	47	
	12:00 - 12:15	52	84	27	18	36	14	36	29	74	41	21	49	
	12:15 - 12:30	47	91	23	21	39	18	35	28	71	34	19	51	
	12:30 - 12:45	55	95	36	19	31	23	46	49	99	39	15	47	
	12:45 - 13:00	69	98	41	27	45	21	57	49	102	35	21	41	
	12:15 - 12:30	47	91	23	21	39	18	35	28	71	34	19	51	
	12:30 - 12:45	55	95	36	19	31	23	46	49	99	39	15	47	
	12:45 - 13:00	69	98	41	27	45	21	57	49	102	35	21	41	
	13:00 - 13:15	37	86	29	21	38	17	61	47	106	47	26	56	
	12:30 - 12:45	55	95	36	19	31	23	46	49	99	39	15	47	
	12:45 - 13:00	69	98	41	27	45	21	57	49	102	35	21	41	
	13:00 - 13:15	37	86	29	21	38	17	61	47	106	47	26	56	
	13:15 - 13:30	36	81	19	17	38	13	65	57	103	51	29	62	
Evening peak hour	4:00 - 4:15	51	89	34	23	37	14	39	28	59	57	31	65	
	4:15 - 4:30	49	83	36	21	38	13	45	39	83	51	28	55	
	4:30 - 4:45	51	85	34	17	29	14	41	46	64	49	26	59	
	4:45 - 5:00	55	88	31	27	41	21	44	42	72	43	23	56	
	4:15 - 4:30	49	83	36	21	38	13	45	39	83	51	28	55	
	4:30 - 4:45	51	85	34	17	29	14	41	46	64	49	26	59	
	4:45 - 5:00	55	88	31	27	41	21	44	42	72	43	23	56	
	5:00 - 5:15	52	84	28	32	49	29	49	41	76	52	34	59	
	4:30 - 4:45	51	85	34	17	29	14	41	46	64	49	26	59	
	4:45 - 5:00	55	88	31	27	41	21	44	42	72	43	23	56	
	5:00 - 5:15	52	84	28	32	49	29	49	41	76	52	34	59	
	5:15 - 5:30	49	83	24	37	54	31	44	39	74	49	36	59	
	4:45 - 5:00	55	88	31	27	41	21	44	42	72	43	23	56	
	5:00 - 5:15	52	84	28	32	49	29	49	41	76	52	34	59	
	5:15 - 5:30	49	83	24	37	54	31	44	39	74	49	36	59	
	5:30 - 5:45	57	87	32	35	56	34	49	45	79	41	27	49	
	5:00 - 5:15	52	84	28	32	49	29	49	41	76	52	34	59	
	5:15 - 5:30	49	83	24	37	54	31	44	39	74	49	36	59	
	5:30 - 5:45	57	87	32	35	56	34	49	45	79	41	27	49	
	5:45 - 6:00	61	97	41	14	27	11	51	43	91	39	19	55	

Table A7: Traffic volume at Tena Tabya Intersection

Tena tabya intersection		traffic volume count								Date: Feb 11/2020				
		From Hatsey johannes elementary school (Guna street)			From 17 kebelle (Guna street)			From Main CBE			From Axum hotel			Peak hour
Counted hour		To 17 kebelle (Guna street)	To Main CBE	To Axum hotel	To Hatsey johannes elementary school (Guna street)	To Main CBE	To Axum hotel	To Hatsey johannes elementary school (Guna street)	To 17 kebelle (Guna street)	To Axum hotel	To Hatsey johannes elementary school (Guna street)	To 17 kebelle (Guna street)	To Main CBE	
Morning peak hour	7:00 - 7:15	54	15	49	27	26	23	43	35	45	45	41	43	
	7:15 - 7:30	53	12	48	24	21	27	57	49	53	47	44	40	
	7:30 - 7:45	65	21	68	18	21	22	64	52	66	37	34	33	
	7:45 - 8:00	71	29	85	13	15	18	54	42	51	41	33	38	
	7:15 - 7:30	53	12	48	24	21	27	57	49	53	47	44	40	
	7:30 - 7:45	65	21	68	18	21	22	64	52	66	37	34	33	
	7:45 - 8:00	71	29	85	13	15	18	54	42	51	41	33	38	
	8:00 - 8:15	69	27	89	22	25	21	76	69	72	46	37	44	
	7:30 - 7:45	65	21	68	18	21	22	64	52	66	37	34	33	
	7:45 - 8:00	71	29	85	13	15	18	54	42	51	41	33	38	
	8:00 - 8:15	69	27	89	22	25	21	76	69	72	46	37	44	
	8:15 - 8:30	64	29	91	22	18	20	65	59	63	55	48	51	
	7:45 - 8:00	71	29	85	13	15	18	54	42	51	41	33	38	
	8:00 - 8:15	69	27	89	22	25	21	76	69	72	46	37	44	
	8:15 - 8:30	64	29	91	22	18	20	65	59	63	55	48	51	
	8:30 - 8:45	41	18	56	22	24	23	46	38	44	45	42	47	
	8:00 - 8:15	69	27	89	22	25	21	76	69	72	46	37	44	
	8:15 - 8:30	64	29	91	22	18	20	65	59	63	55	48	51	
	8:30 - 8:45	41	18	56	22	24	23	46	38	44	45	42	47	
	8:45 - 9:00	43	25	59	23	20	18	43	37	45	49	46	44	

Table A7. (Continued)

Afternoon peak hour	11:30 - 11:45	44	21	65	24	28	18	42	34	41	63	52	58	
	11:45 - 12:00	51	24	63	19	24	21	41	38	42	52	45	37	
	12:00 - 12:15	47	19	61	19	23	18	54	49	59	48	49	45	
	12:15 - 12:30	63	26	74	22	24	20	51	44	45	51	47	45	
	11:45 - 12:00	51	24	63	19	24	21	41	38	42	52	45	37	
	12:00 - 12:15	47	19	61	19	23	18	54	49	59	48	49	45	
	12:15 - 12:30	63	26	74	22	24	20	51	44	45	51	47	45	
	12:30 - 12:45	53	23	62	24	23	19	46	39	48	45	44	51	
	12:00 - 12:15	47	19	61	19	23	18	54	49	59	48	49	45	
	12:15 - 12:30	63	26	74	22	24	20	51	44	45	51	47	45	
	12:30 - 12:45	53	23	62	24	23	19	46	39	48	45	44	51	
	12:45 - 13:00	52	24	64	27	23	25	51	42	48	42	46	43	
	12:15 - 12:30	63	26	74	22	24	20	51	44	45	51	47	45	
	12:30 - 12:45	53	23	62	24	23	19	46	39	48	45	44	51	
	12:45 - 13:00	52	24	64	27	23	25	51	42	48	42	46	43	
	13:00 - 13:15	54	25	61	28	24	23	53	43	47	40	42	36	
	12:30 - 12:45	53	23	62	24	23	19	46	39	48	45	44	51	
	12:45 - 13:00	52	24	64	27	23	25	51	42	48	42	46	43	
	13:00 - 13:15	54	25	61	28	24	23	53	43	47	40	42	36	
	13:15 - 13:30	56	26	63	31	28	26	49	38	46	42	37	39	
Evening peak hour	4:00 - 4:15	44	24	59	25	27	23	45	43	51	51	45	43	
	4:15 - 4:30	56	32	76	19	22	21	41	37	46	57	51	48	
	4:30 - 4:45	59	28	62	26	29	24	51	48	54	42	41	46	
	4:45 - 5:00	49	21	67	19	21	17	49	44	63	48	38	45	
	4:15 - 4:30	56	32	76	19	22	21	41	37	46	57	51	48	
	4:30 - 4:45	59	28	62	26	29	24	51	48	54	42	41	46	
	4:45 - 5:00	49	21	67	19	21	17	49	44	63	48	38	45	
	5:00 - 5:15	46	24	55	21	19	17	48	39	43	58	61	51	
	4:30 - 4:45	59	28	62	26	29	24	51	48	54	42	41	46	
	4:45 - 5:00	49	21	67	19	21	17	49	44	63	48	38	45	
	5:00 - 5:15	46	24	55	21	19	17	48	39	43	58	61	51	
	5:15 - 5:30	47	27	63	22	18	21	55	46	50	58	55	61	
	4:45 - 5:00	49	21	67	19	21	17	49	44	63	48	38	45	
	5:00 - 5:15	46	24	55	21	19	17	48	39	43	58	61	51	
	5:15 - 5:30	47	27	63	22	18	21	55	46	50	58	55	61	
	5:30 - 5:45	54	26	69	23	19	22	52	53	45	61	54	64	
	5:00 - 5:15	46	24	55	21	19	17	48	39	43	58	61	51	
	5:15 - 5:30	47	27	63	22	18	21	55	46	50	58	55	61	
	5:30 - 5:45	54	26	69	23	19	22	52	53	45	61	54	64	
	5:45 - 6:00	48	15	55	29	25	26	57	48	51	62	66	56	

Table A8: Traffic volume at Mekelle Administration Office Intersection

Mekelle administration office intersection traffic volume count														Date: Feb 22/2020
		From Meserete elementary school (Daniel Asefa street)			From St.mariam church (Daniel Asefa street)			From Water supply office			From electric utility office			Peak hour
Counted hour		To St.mariam church (Daniel Asefa street)	To Water supply office	To electric utility office	To Meserete elementary school (Daniel Asefa street)	To Water supply office	To electric utility office	To Meserete elementary school (Daniel Asefa street)	To St.mariam church (Daniel Asefa street)	To electric utility office	To Meserete elementary school (Daniel Asefa street)	To St.mariam church (Daniel Asefa street)	To Water supply office	
Morning peak hour	7:00 - 7:15	62	14	12	31	5	29	17	14	12	3	21	5	
	7:15 - 7:30	54	11	6	35	4	30	6	11	8	4	26	6	
	7:30 - 7:45	59	12	6	38	6	28	8	9	7	7	39	3	
	7:45 - 8:00	57	9	5	34	8	24	9	12	8	4	31	3	
	7:15 - 7:30	54	11	6	35	4	30	6	11	8	4	26	6	
	7:30 - 7:45	59	12	6	38	6	28	8	9	7	7	39	3	
	7:45 - 8:00	57	9	5	34	8	24	9	12	8	4	31	3	
	8:00 - 8:15	69	11	5	28	3	21	11	12	7	6	29	3	
	7:30 - 7:45	59	12	6	38	6	28	8	9	7	7	39	3	
	7:45 - 8:00	57	9	5	34	8	24	9	12	8	4	31	3	
	8:00 - 8:15	69	11	5	28	3	21	11	12	7	6	29	3	
	8:15 - 8:30	84	12	6	26	4	19	7	8	3	8	37	4	
	7:45 - 8:00	57	9	5	34	8	24	9	12	8	4	31	3	
	8:00 - 8:15	69	11	5	28	3	21	11	12	7	6	29	3	
	8:15 - 8:30	84	12	6	26	4	19	7	8	3	8	37	4	
	8:30 - 8:45	46	4	2	33	7	18	13	9	11	7	29	5	
	8:00 - 8:15	69	11	5	28	3	21	11	12	7	6	29	3	
	8:15 - 8:30	84	12	6	26	4	19	7	8	3	8	37	4	
	8:30 - 8:45	46	4	2	33	7	18	13	9	11	7	29	5	
	8:45 - 9:00	51	5	3	45	6	37	11	9	8	5	28	5	

Table A8. (Continued)

Afternoon peak hour	11:30 - 11:45	56	7	4	49	8	34	9	15	5	9	33	8	
	11:45 - 12:00	65	6	5	39	5	17	13	15	9	7	25	6	
	12:00 - 12:15	57	4	7	35	8	11	9	13	8	4	21	2	
	12:15 - 12:30	55	5	3	38	4	13	5	7	3	5	28	3	
	11:45 - 12:00	65	6	5	39	5	17	13	15	9	7	25	6	
	12:00 - 12:15	57	4	7	35	8	11	9	13	8	4	21	2	
	12:15 - 12:30	55	5	3	38	4	13	5	7	3	5	28	3	
	12:30 - 12:45	69	5	4	37	11	16	13	15	4	11	31	5	
	12:00 - 12:15	57	4	7	35	8	11	9	13	8	4	21	2	
	12:15 - 12:30	55	5	3	38	4	13	5	7	3	5	28	3	
	12:30 - 12:45	69	5	4	37	11	16	13	15	4	11	31	5	
	12:45 - 13:00	65	6	3	53	12	21	9	13	8	9	36	4	
	12:15 - 12:30	55	5	3	38	4	13	5	7	3	5	28	3	
	12:30 - 12:45	69	5	4	37	11	16	13	15	4	11	31	5	
	12:45 - 13:00	65	6	3	53	12	21	9	13	8	9	36	4	
	13:00 - 13:15	48	3	5	49	8	18	12	16	7	10	28	6	
	12:30 - 12:45	69	5	4	37	11	16	13	15	4	11	31	5	Peak hour
	12:45 - 13:00	65	6	3	53	12	21	9	13	8	9	36	4	
	13:00 - 13:15	48	3	5	49	8	18	12	16	7	10	28	6	
	13:15 - 13:30	59	4	2	55	10	17	15	11	8	15	33	9	
Evening peak hour	4:00 - 4:15	81	4	6	54	8	14	8	6	8	11	31	5	
	4:15 - 4:30	63	7	3	37	9	14	9	7	5	9	23	3	
	4:30 - 4:45	45	2	3	41	4	13	12	9	5	14	29	6	
	4:45 - 5:00	66	4	3	49	3	15	8	12	6	4	24	6	
	4:15 - 4:30	63	7	3	37	9	14	9	7	5	9	23	3	
	4:30 - 4:45	45	2	3	41	4	13	12	9	5	14	29	6	
	4:45 - 5:00	66	4	3	49	3	15	8	12	6	4	24	6	
	5:00 - 5:15	59	3	4	45	6	17	15	11	13	11	21	5	
	4:30 - 4:45	45	2	3	41	4	13	12	9	5	14	29	6	
	4:45 - 5:00	66	4	3	49	3	15	8	12	6	4	24	6	
	5:00 - 5:15	59	3	4	45	6	17	15	11	13	11	21	5	
	5:15 - 5:30	41	0	4	33	7	7	11	9	4	8	19	6	
	4:45 - 5:00	66	4	3	49	3	15	8	12	6	4	24	6	
	5:00 - 5:15	59	3	4	45	6	17	15	11	13	11	21	5	
	5:15 - 5:30	41	0	4	33	7	7	11	9	4	8	19	6	
	5:30 - 5:45	64	1	5	47	8	24	8	9	4	7	32	9	
	5:00 - 5:15	59	3	4	45	6	17	15	11	13	11	21	5	
	5:15 - 5:30	41	0	4	33	7	7	11	9	4	8	19	6	
	5:30 - 5:45	64	1	5	47	8	24	8	9	4	7	32	9	
	5:45 - 6:00	69	4	7	44	12	14	11	14	9	9	29	8	

Table A9: Traffic volume of intersection around union dental clinic (#1)

intersection around union dental clinic (#1)		traffic volume count								Date: Oct 8/2019			
		From Mekelle administration office (Daniel asefa street)			From Hashenge (Alganesh meles street)			From Micheal church (Daniel asefa street)			From Hawzen adebabay (Alganesh meles street)			Peak hour
Counted hour		To Micheal church (Daniel asefa street)	To Hashenge (Alganesh meles street)	To Hawzen adebabay (Alganesh meles street)	To Mekelle administration office (Daniel asefa street)	To Micheal church (Daniel asefa street)	To Hawzen adebabay (Alganesh meles street)	To Hashenge (Alganesh meles street)	To Mekelle administration office (Daniel asefa street)	To Hawzen adebabay (Alganesh meles street)	To Mekelle administration office (Daniel asefa street)	To Micheal church (Daniel asefa street)	To Hashenge (Alganesh meles street)	
Morning peak hour	7:00 - 7:15	41	44	36	39	36	52	42	29	58	35	42	64	
	7:15 - 7:30	36	31	33	34	37	45	52	38	65	46	49	76	
	7:30 - 7:45	37	34	31	31	34	48	49	42	64	39	34	67	
	7:45 - 8:00	43	38	40	41	39	51	53	39	69	33	32	69	
	7:15 - 7:30	36	31	33	34	37	45	52	38	65	46	49	76	
	7:30 - 7:45	37	34	31	31	34	48	49	42	64	39	34	67	
	7:45 - 8:00	43	38	40	41	39	51	53	39	69	33	32	69	
	8:00 - 8:15	47	39	38	43	39	53	49	45	62	39	36	72	
	7:30 - 7:45	37	34	31	31	34	48	49	42	64	39	34	67	
	7:45 - 8:00	43	38	40	41	39	51	53	39	69	33	32	69	
	8:00 - 8:15	47	39	38	43	39	53	49	45	62	39	36	72	
	8:15 - 8:30	46	42	44	33	31	47	39	32	48	41	47	73	
	7:45 - 8:00	43	38	40	41	39	51	53	39	69	33	32	69	
	8:00 - 8:15	47	39	38	43	39	53	49	45	62	39	36	72	
	8:15 - 8:30	46	42	44	33	31	47	39	32	48	41	47	73	
	8:30 - 8:45	36	29	27	34	38	55	42	38	51	45	44	71	
	8:00 - 8:15	47	39	38	43	39	53	49	45	62	39	36	72	
	8:15 - 8:30	46	42	44	33	31	47	39	32	48	41	47	73	
	8:30 - 8:45	36	29	27	34	38	55	42	38	51	45	44	71	
	8:45 - 9:00	33	30	25	39	36	58	44	41	53	41	38	68	

Table A9. (Continued)

Afternoon peak hour	11:30 - 11:45	38	33	41	38	35	54	41	42	56	38	45	74	
	11:45 - 12:00	36	27	25	42	39	53	39	37	61	36	51	77	
	12:00 - 12:15	28	34	32	46	43	62	44	39	59	39	46	69	
	12:15 - 12:30	36	37	34	41	49	55	41	37	63	43	47	77	
	11:45 - 12:00	36	27	25	42	39	53	39	37	61	36	51	77	Peak hour
	12:00 - 12:15	28	34	32	46	43	62	44	39	59	39	46	69	
	12:15 - 12:30	36	37	34	41	49	55	41	37	63	43	47	77	
	12:30 - 12:45	42	38	38	57	47	72	39	35	49	39	42	74	
	12:00 - 12:15	28	34	32	46	43	62	44	39	59	39	46	69	
	12:15 - 12:30	36	37	34	41	49	55	41	37	63	43	47	77	
	12:30 - 12:45	42	38	38	57	47	72	39	35	49	39	42	74	
	12:45 - 13:00	31	39	29	54	44	62	39	32	47	34	39	65	
	12:15 - 12:30	36	37	34	41	49	55	41	37	63	43	47	77	
	12:30 - 12:45	42	38	38	57	47	72	39	35	49	39	42	74	
	12:45 - 13:00	31	39	29	54	44	62	39	32	47	34	39	65	
	13:00 - 13:15	29	27	34	33	39	49	33	39	55	36	44	63	
	12:30 - 12:45	42	38	38	57	47	72	39	35	49	39	42	74	
	12:45 - 13:00	31	39	29	54	44	62	39	32	47	34	39	65	
	13:00 - 13:15	29	27	34	33	39	49	33	39	55	36	44	63	
	13:15 - 13:30	38	33	36	35	36	52	45	37	66	35	39	61	
Evening peak hour	4:00 - 4:15	34	26	31	33	43	66	39	41	57	41	38	62	
	4:15 - 4:30	38	33	36	37	46	62	36	39	53	35	41	51	
	4:30 - 4:45	31	37	32	31	37	51	42	38	63	55	46	81	
	4:45 - 5:00	29	34	27	41	38	51	39	42	46	58	51	82	
	4:15 - 4:30	38	33	36	37	46	62	36	39	53	35	41	51	
	4:30 - 4:45	31	37	32	31	37	51	42	38	63	55	46	81	
	4:45 - 5:00	29	34	27	41	38	51	39	42	46	58	51	82	
	5:00 - 5:15	35	29	27	33	45	43	31	37	48	53	47	72	
	4:30 - 4:45	31	37	32	31	37	51	42	38	63	55	46	81	
	4:45 - 5:00	29	34	27	41	38	51	39	42	46	58	51	82	
	5:00 - 5:15	35	29	27	33	45	43	31	37	48	53	47	72	
	5:15 - 5:30	33	35	29	39	42	47	34	42	52	54	46	73	
	4:45 - 5:00	29	34	27	41	38	51	39	42	46	58	51	82	
	5:00 - 5:15	35	29	27	33	45	43	31	37	48	53	47	72	
	5:15 - 5:30	33	35	29	39	42	47	34	42	52	54	46	73	
	5:30 - 5:45	39	32	36	43	39	54	45	51	62	42	39	63	
	5:00 - 5:15	35	29	27	33	45	43	31	37	48	53	47	72	
	5:15 - 5:30	33	35	29	39	42	47	34	42	52	54	46	73	
	5:30 - 5:45	39	32	36	43	39	54	45	51	62	42	39	63	
	5:45 - 6:00	31	35	33	41	38	55	48	52	55	39	35	57	