Improving Addis Ababa Transport System by Using Transport Demand Management Strategy

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"The best teachers are those who show you where to look, but don't tell you what to see"

Alexandra K. Trenfor

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Abstract

Addis Ababa is challenged by providing access to safe, efficient and sustainable transport system. Congestion is becoming a common experience in different parts of the city due to the lack of consistent concentrated efforts from the various stakeholders. The city is critically inadequate to provide service for the increasing travel demand of the city. This research explores methods of minimizing Addis Ababa transport system problem by using transport demand management strategies. Transportation Demand Management (TDM) refers to the various strategies adopted to change travel behavior to increase the transportation system efficiency and also to achieve reduction in congestion, fuel conception, environmental pollution, while focusing on the safety and mobility of the road users.

In order to select applicable demand management strategy the first step is to identify behavior of major Addis Ababa transport problems. Primary and secondary data has been used to identify behavior of major transport problems. The behavior and effect of this problems have been described using system dynamics causal loop diagrams. After identification of Addis Ababa transport problems Qualitative comparative analysis is used to confirm applicability of transport demand management strategy. Applicable transport demand management strategy has been selected by considering correlation between Addis Ababa transport demand management barriers, transport demand management strategy and Addis Ababa transport problem behavior. Customized QFD analysis is performed to measure relative importance of selected transport demand management strategy with transport service quality measuring parameters and prioritize the transport demand management strategies.

Math lab Digital image process analysis is used to analyze traffic intensity of typical traffic congestion of Addis Ababa. Input of Math lab analysis is image collected form Online Google traffic monitoring webpage. Typical traffic condition data is collected for 17 hour per day for every week day. Math lab digital image analysis identifies traffic intensity of Addis Ababa with respect to week days and every season of the year. The result analysis shows decrease of traffic congestion by 17 % to 31 % .Finally based on result of analysis space (location) and time of application of selected transport demand management strategy is identified.

Key words: TDM, Digital image processing

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List of Abbreviations

AACRA-Addis Ababa road Authority

AACTA -Addis Ababa city transport authority

AACTMA -Addis Ababa city government traffic management agency

CCA-Connected component analysis

CSA- Central Statistics Agency

CS-Collector streets

FWAs - flexible work arrangements

GDP-Growth domestic plan

ITS - intelligent transportation systems

LOS -Level of service

LRT-Light rail transit

LS- Local Street

MOM -Ministry of Manpower

PAS- Principal Arterial streets

SAS-Sub-arterial streets

SMTE -Sheger Mass Transport Enterprise

TCQSM -Transit Capacity and Quality of Service Manual

TDM -Transportation Demand Management

TPMO -Traffic programs management office

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CHAPTER ONE

1.0 Introduction

Transport has a major impact on the spatial and economic development of cities and regions. The quantity and quality of transport infrastructure influences the attractiveness and desirability of urban regions [1]. All transactions require communications and most require transport of goods or people – to work, shopping, tourist sites, meeting locations. Thus, it is fair to say that transportation is central to economic activity. Most metropolitan areas in the world are experiencing traffic congestion during commuting hours. This can be resolved by infrastructure expansions. However, new roads or widening existing ones requires more land, and expansion costs are high. Moreover, such solutions may not be feasible in metropolitan areas because of lack of space or harmful effect on the environment. In addition, once roads are expanded and congestion is resolved, population will move from congested areas to less congested ones, and thus traffic demand for the latter will increase, which will in turn cause congestion again. [2]

As the population of urban cities increases rapidly, traffic problems in metropolitan areas such as lack of space and congestion as well as poor air quality increase. Public transportation therefore becomes a necessity to reduce traffic congestion, increase productivity, and reduce carbon emissions. In the west, more people are using public transport. For individuals, public transportation saves money and provides them with choices, freedom, and opportunities Transportation is a key driver of the development of cities by providing safe, efficient, and reliable transportation for people, goods, and services. When a city experiences rapid population growth, it will exert pressure on existing economic, social, and environmental structure including transportation and mobility. When countries are developing, most of economic activities are focused in urban cities. [3]

Sustainable development, which leads to a lasting improvement in the quality of human life uses three types of capital: economic, human, and natural. In the economical process, it is important that one capital should be not increased or used at the cost of others. This balance in local, regional, or global scale is necessary to ensure sustainable development. Unfortunately, the standard of economic efficiency causes this balance not to be properly appreciated and often-overlooked [4].

It is inevitable that rapid economic growth will lead to a simultaneous growth in economic activities. This will further contribute to an increase in urban population and income growth. Car ownership and usage will also increase with more road network infrastructures. The Fundamental Law of Road Congestion states that the travel speed on an expanded road reverts to its previous level before the capacity expansion. In other words, an increase in lane mileage is met by a proportional increase in traffic. This would then create a vicious cycle of more traffic congestion which affects many stakeholders in many ways. Traffic congestion creates serious urban transport problems such as parking difficulties, longer commuting, and difficulties for non-motorized transport, loss of public space, pollution, and accidents [4]. The social, economic, and environmental costs of auto-dependent cities are already high. Traffic accidents are on the rise with more than 1.2 million lives lost every year and would be the fifth-leading cause of death by 2030 [5]

Transportation Demand Management (TDM) refers to the various strategies adopted to change travel behavior to increase the transportation system efficiency and also to achieve reduction in congestion, energy and fuel conservation, savings in parking and road costs, while focusing on the safety and mobility of the road users.

TDM measures are social plans and their benefits encompass a vast sphere of social life. For example, a congestion reduction program might benefit not only from reductions in VMT, but might also gain from air quality improvements, decreased fossil fuel consumption, and reduced parking demand. Price changes can have a variety of impacts on travel, affecting the number of trips people take, their destination, route, mode, travel time, type of vehicle (including size, fuel efficiency and fuel type), parking location and duration, and which type of transport services they choose. All these are essential indicators in evaluating a TDM project.

The benefits associated with TDM are varied depending on the strategies employed and the context in which they are employed. Generally speaking, TDM facilitates increased travel via alternative travel modes, resulting in economic, social and environmental benefits. TDM benefits often include the following specific outcomes [6].

1.1 BACKGROUND OF THE STUDY

Traffic problems in urban areas continue to increase as a consequence of both higher mobility and increasing car ownership of people. On the other hand, the supply of transport infrastructure and facilities remains practically unchanged due to the high cost of land acquisition and construction of new roads. However, it is well known from basic transport economics that a higher level of supply will result to an increase of demand and finally the transport system will reach a new equilibrium point at a higher level. In the last decade's traffic engineers and practitioners had come to the conclusion that traffic problems can be mastered only through the introduction of appropriate Transport Demand Management (TDM) measures rather than through the provision of new highway infrastructure. [7]

Rapid and unconstrained growth of private vehicle use in developing cities create environmental impacts such as asthma and premature mortality. Many developed countries use demand management strategies for sustainable transport. Transport demand management is particularly effective in developing countries because of its low cost and multiple benefits. It is particularly appropriate in developing countries where resources are limited and major portion of residents relay on walking, cycling, ridesharing and public transport .In developing countries have budget constraints and they invest huge amount cost in infrastructure development. [22] Overall commitments to Africa's infrastructure from all sources increased to $81.6bn in 2017. As in previous years, transport accounted for the largest proportion of the combined infrastructure budget allocations across Africa, claiming two thirds of all funds in 2017, and a higher proportion than the 53% of Africa's budgets allocated to transport in the previous year. Spending on the transport sector grew by 23%, accounting for much of the 11% overall growth for infrastructure spending across all sectors from $66.9bn in 2016. From the funding Transport sector took $34.0bn and total East Africa $15.8bn (19.4%) [23]. This huge amount of transport infrastructure budget can be saved by effective transport demand management.

As per Ethiopian road transport authority Annual report on Dec 2018 4,546 citizens are died, 7,684 severe injure and 1, 189,447,240.88 ETB property was lost in Ethiopian roads [13]. This amount of citizen's life and injury has a major impact on citizen's wellbeing and country economy. The implication of data is quality of road transportation system is not safe, efferent, economical and sustainable. Much scientific Research has to be done on country level as well as city level. Hybrid strategy has to be developed to solve long term and short term.

Transport, one of these components of the urban system, which is responsible for bridging the gap between areas of production and consumption, as well as creating a medium for spatial interaction, continues to be in the thick of these challenges. The lack of properly planned urban transport in Addis-Ababa is manifested through the low degree of efficiency of urban mobility that is now observed in almost all of the city's center, sub-centers and other major traffic corridors.

The other point of view to solve city transport problem is to imagine Addis Ababa as huge manufacturing industry. Conceptual frame work to view city as huge manufacturing industry. When we view transport system from plant layout perspective we need to imagine Addis Ababa as huge product manufacturing plant. The basic components of plant layout are Product, Production lanes and material handling machineries. The basic problem in manufacturing plant are bottleneck and idle time. When this concept is converted to Addis Ababa city let's imagine people inside the vehicle as products in the material handling machinery or AGV (automatic guided vehicle). Lanes as roads and workstations as roundabouts or other activity areas. Products flow in manufacturing system to add value on themselves (shape, size etc..) humans also flow on the road to add value on themselves (adding knowledge, health, capital etc.). Both create bottleneck and idle time during their flow. The mitigation system of problem for both is the same that is distributing them into space and time (scheduling). Products flow in the desired direction within specified predicted time and direction human beings also flow within specified period of time within specified direction. The only difference Peoples make their own choices with regards to their transport modes (material handling machine). Influencing their choice of mode and their flow time is what this study deals about or difference with scheduling a product in manufacturing plant.

Human beaings choice mode can be influenced by transport demand management techniques. Most demand management strategies use carrot and stick method to influence transport mode choice of population.

1.3 Problem Statement

Addis Ababa is the capital and largest city of the Federal Democratic Republic of Ethiopia and diplomatic seat for many international organizations. Due to its historical and political importance and economic growth together with its suitability for living the size and population of the city increases significantly . The city has Rapid population growth of 3.6 % [63] per year and rapid motor vehicle growth of 15% in 2005 to 25 % in 2025. The city transport system is challenged by the increase in population size coupled with the economic growth and increase in the size of the city. The city need compatible urban transport supply and effective demand management strategy to meet the increasing demand and mobility needs of the people. The city has many transportation problems among the them poor access to work place, education, health and other services due to lack of public transport service, continuous increases in transport fair especially for low income Groups, lack of smooth traffic flow, lack of infrastructure for None Motorized Transport (NMT) (for walking and bicycle),high rate of traffic accidents, increasing air and noise pollution are the major ones identified by the Addis Ababa Transport Bureau [9].

As stated by [8] the existing public transportation system in Addis Ababa is critically inadequate to provide service for the increasing travel demand of the city. Addis Ababa faced huge challenges emanating from years of poor coordination between its existing urban systems. Congestion is becoming a common experience in all of the different parts of the city due to the lack of consistent concerted efforts from the various stakeholders. The lack of properly planned urban transport in Addis-Ababa is manifested through the low degree of efficiency of urban mobility that is now observed in almost all of the city's center, sub-centers and other major traffic corridors. Urban mobility, which is increasingly becoming inefficient in Addis Ababa and resulting in congestion.

Addis Ababa is challenged by providing access to safe, efficient and sustainable transport system. An increasing transport demand in the future could lead to politically unacceptable levels of congestion, air pollution, and traffic casualties if no additional policies were implemented. Thus, it is important for governments to know about possible future transport expectations in their region in order to be able to implement new policies in time [7]. Congestion is becoming a common experience in all different parts of the city due to the lack of consistent concerted efforts from the various stakeholders. It is also in part a result of the numerous socio-economic factors whose combined effect is to increase the pull factor of the city of Addis Ababa and hence resulting in an ever increasing population that in turn makes the battle to curb the gap between the demand for an efficient urban transportation system and the city's ability for its provision, a seemingly perpetual one.

As per Ethiopian road transport authority Annual report on Dec 2018 4,546 citizens are died, 7,684 severe injure and 1, 189,447,240.88 ETB property was lost in Ethiopian roads [10]. In

Addis Ababa a total of 28,289 Road Crashes and 456 fatal Crashes occurred in 2018 [95]. As per Addis Ababa city administration 2018 report by average Addis Ababa city population spend four hours in Addis Ababa roads during transportation. Study by [48] showed that on average about 18,000 Veh-min or 38 Veh-day and about169,000 Per-min or 352-person-day are wasted at each major intersection entry and the city incurs annually about 5-8 Million Birr per intersection only for vehicle and fuel cost.

Finding ways to solve existing problems and at the same time achieving sustainable transport system and decreasing congestion in Addis Ababa through effective implementation of TDM strategy is necessary. Implementation of TDM is different from city to city because the efficacy of TDM strategy depends on the economy, demographics, culture and mind set of city and population of the city where it is implemented

1.4 Research Questions

1. How to decrease Addis Ababa transport problem ?
2. What are the challenges to implement TDM strategies in Addis Ababa?
3. What are applicable TDM strategies for Addis Ababa ?
4. How to implement TDM strategies ?

1.5. Research Objectives

1.5.1 General Objective

General objective of this research is finding method for minimizing Addis Ababa traffic problems.

1.5.2 Specific Objectives

- Identifying new strategies that can improve Addis Ababa public transportation system.
- Identify TDM strategies that is applicable to Addis Ababa.
- Identify challenges to implement TDM strategies in Addis Ababa.
- Identify location and time of TDM application.

1.6 Significance of the Study

Policy makers in the field of transportation face major fundamental uncertainties. One of uncertainties is to see the effects of policy measures. Therefore, Policy makers will use this research as one input tool to decide on policy alternatives. This research can also be used as an input to Addis Ababa transport infrastructure investment decision or budget prioritization decision. If this Research recommendations are used by policy makers as an input below results are expected outputs : Reduce traffic congestion. Reduce adverse effects on the environment or public health. decrease of road traffic accident and Improved mobility .

1.7 Scope of the Research

Due to broad and complex nature of the transportation problem it is difficult to find method of solving for every problem. In this research only demands side solution will be explored for Addis Ababa transport system problem.

Chapter two

Literature review

Major content of this research literature review are as follows Concept generation about TDM., transport management techniques, types and categories of TDM strategies, Road transport problems, Researches on Addis Ababa city transportation problem and international TDM strategy experience.

2.1 What is transport demand management (TDM)?

The principal focus of traffic management and control systems is to ensure the safe and efficient movement of traffic on roadways . There are two types of transport management techniques this are supply side and demand side management technique. Transportation Demand Management (TDM) refers to the various strategies adopted to change travel behavior to increase the transportation system efficiency and also to achieve reduction in congestion, energy and fuel conservation, savings in parking and road costs, while focusing on the safety and mobility of the road users. Supply-side Management is typically increasing capacity of road links, junctions, and whole urban networks by new road construction [40] .

From a conceptual standpoint, TDM is concerned with the ways in which people make optimal use of locally available transportation resources, with a strong focus on getting people out of single-occupancy vehicles and into more efficient modes of commuting. Transportation Demand Management (TDM) includes various strategies to encourage more efficient travel patterns. This can provide multiple benefits, including reduced traffic congestion, road and parking facility cost savings, user financial savings, increased road safety, increased travel choice (especially for non-drivers), increased equity, reduced pollution, and energy savings[67] TDM does not require everybody to give up driving. Rather, it encourages consumers to use alternatives when appropriate. Although most TDM strategies only affect a small portion of total travel, their cumulative impacts can be significant. Travel reductions of 20-50% are possible.

Vehicle flow is relatively easy to quantify, so many transportation plans focus largely on traffic volumes and speeds to measure of transportation quality. Mobility and access are more difficult to measure, so they are often ignored. This tends to skew planning decisions toward capacity expansion and away from management alternatives. [68] As a wider range of options are considered, including TDM, more efficient solutions can be identified and selected. Efficient transportation planning therefore requires focusing on access rather than vehicle flow as the measure of transportation service quality.

2.2 Objectives of Transportation Demand Management Strategies

Fundamentally, Transportation Demand Management is about more than just managing the way people get around; it's about the overall health and wellness of communities. As such, the field has evolved to include a number of specific objectives, all of which are supported by the use of better methods of transportation.

Changing the culture and attitude of commuters naturally comes with difficult challenges. It isn't something that can be achieved overnight. Yet, as TDM becomes an increasingly visible element of urban living, awareness naturally rises and people become more mindful about the impact of their transportation decisions. One of the most powerful ways to continue to foster and nurture change is to leverage technology. Modern user-facing TDM tools make finding and using better methods of transportation easier [17]. "It is commonly accepted that cities are the engines of growth in most developing as well as developed countries. More importantly, urban transport can be viewed as the oil that prevents this engine from seizing up" [18]

Economically, transport is an essential element of city development that, in turn, is a major source of national economic growth. Simply stated, poor transport inhibits growth. Furthermore, socially, transport is the means of accessibility to jobs, health education and social services essential to the welfare of the city residents. Deteriorating transport conditions affect all city residents; they impact particularly the poor through a decline in public transport service levels, increased length of the journey to work and other essential services and the negative impacts on environment, safety and security that the poor are least able to mitigate. [19]

"The urban sector in most developing countries accounts for at least 50 % of the gross national product and in some countries over 70 %. Cities in developing countries often devote 15% to 25% of their annual expenditures to their transport system and sometimes much more" [20].

2.3 Transport management techniques

Traffic management measures are those actions that can be implemented to enhance the person-carrying capability of the roadway system, without adding significantly to the width of the roadway and include a range of strategies Traffic management measures should be set within a defined traffic and regulatory policy and are most likely to be combined into comprehensive packages which will vary in type and extent in accordance with the function of the relevant road in the hierarchy [33]

The primary emphasis of traffic management measure is on the safe and efficient flow of vehicles over urban streets and highways. The means of promoting this can vary from simple improvement of local streets by installing traffic signs and road markings to constructing comprehensive motorway control systems. Such comprehensive systems use access-road meters to monitor and control motorway access; closed-circuit television surveillance to detect quickly any deterioration in traffic flow; and emergency services to provide aid in case of accident and injury. Other traffic-control techniques include the use of one-way streets, enforcement of traffic flow regulations, chanalization (building traffic islands, turning lanes and so on), and the use of traffic signals [15].

Traffic management measures according to [34] involves, a package of actions designed to optimize the available highway network in a well-focused manner. The package of action comprises a variety of techniques for dealing with traffic related issues. [33] points out among the relatively inexpensive techniques available for developing comprehensive traffic management practices that could be applied for efficient use of the available traffic infrastructure in the area are Road capacity, traffic sign (i.e. pavement markings, road sign, etc.), Guard rails, cross marking etc traffic calming, vehicle parking regulations and controls, pedestrian measures, accident reduction programs, bus priority measures and application of Intelligent Traffic System (ITS). So for effective traffic management the aforementioned traffic management techniques can be applied, this will enable them make efficient use of the available traffic infrastructure in the area [34]. Another technique /measure pine point by many scholars for effective and efficient management of traffic in the road are" Educational, Enforcement and Engineering measures".

Demand-side Management Measures

Demand-side congestion management measures are also important for relieving congestion problem as it reduces the demand for vehicle use. [36] suggested three related demand side management approach; access management, parking management and pricing policies. [36] also suggested ensuring that land use planning, and the community objectives it embodies, is coordinated with congestion management policies. Access management and parking management are regulatory measures and pricing policies are economic measures. So, ECMT actually describes three aspects of demand side congestion management; economic, regulatory and land-use. These three aspects are also described by [39] as effective demand side congestion mitigation measures.

Economic Measures

Economic measures are important demand side management measures which can alter human behaviors to avoid congestion. Various economic measures are found through literature search such as; taxation (Disincentives), subsidies (Incentives), mixed use tool roads, cordon charges, road tolls, congestion pricing/ Tax, area licensing scheme, electronic road pricing, cordon charges, linked based pricing system etc.

It is therefore important to plan complementary measures such as the modification of road infrastructure and traffic operations management. Parallel measures such as investments in public transport can also be employed to make pricing more acceptable and also fairer for people who cannot afford the charges or tolls and thus contribute to acceptability [36]

Regulatory Measures

Regulatory measures refer to administrative measures, policies, regulations or even legislations that directly alter the travelers' behaviors [39]. Regulatory measures include; access management, parking control, restrictions on vehicle use, traffic calming and flexible working hours. Regulatory measures have many constraints. First, to the public, these measures, especially the restrictions on automobile use, narrow down individual choices and are too rigid to human freedom. These may not be applicable to every community. Secondly, these measures often adversely affect economic well-beings by altering normal traffic flows [39].

Land use Policies

Transport and land use policies are closely related. Land uses gives rise to trip generation and influence regional trip patterns. So, it is necessary to co-ordinate long term land use and transport planning [36]. To address congestion problem in the long run, land use policies for adjusting that imbalance are necessary. Through planning, land uses should be re-located in such a way that the need and the amount to travel can be minimized. With optimal land use and development policies, the demand for travel can be reduced to the least level.

More than three dozen TDM strategies are available below table summarizes TDM strategies.

Table 2. 1 Summary of TDM Strategies

No	Type		Description
1	Reforms	Land Use Reforms	Higher density, mixed use, growth management.
2		Reform Parking Requirements	Reduce parking requirements in zoning laws.
3		Pricing Reforms	Comprehensive tax and price reforms.
4		Institutional Reform	Transport agencies and professionals consider and understand TDM.
5	Parking	Preferential Parking	Preferential parking for rideshare vehicles.
6		Cash Out Parking	Providing employees who do not drive the cash equivalent of parking subsidies.
7		Parking Pricing	Charge users directly for parking. Charge by the hour or day rather than the month.
8		Park and Ride	Parking at urban-fringe transit stops.
9	Urban planning	Access Management	Coordinate roadway and land use design
10		Neo traditional Planning	Develop neighborhoods that encourage walking, bicycling and transit use.
11		Least Cost Planning	TDM competes against capacity expansion in terms of cost effectiveness.
12		Location-Efficient Housing	Reduced parking requirements and favorable mortgages for housing in transit-oriented, accessible locations.
13	Incentive related	HOV Preference	Transit and rideshare lanes and other priority measures.
14		Transportation allowance	Provide commuters with a transportation allowance rather than free parking.
15		Free Transit Zones	Free transit in commercial centers.
16		Mileage-based Fees	Distance-based vehicle insurance and registration fees.
17		Guaranteed Ride Home	Provide a limited number of free rides home for transit & rideshare commuters.
18		Address Security	Address security concerns of rideshare, transit, cycle and pedestrian commuters.
19		Road Pricing	Road tolls and congestion pricing.
20		Increased Fuel Taxes	Increase federal and state fuel taxes.
21		Full Cost Pricing	Pricing reforms to encourage efficient transport.
22	NMT	Bicycle Improvements	Improved bicycle planning and facilities.
23		Intermodal Bike	Bike lockers at transit stops, bikeracks on transit vehicles.
24		Pedestrian Improvements	Improved pedestrian planning, facilities and services such as Wide walk ways and pedestrian over pass bridge,
25	Program	Campus Management Programs	Trip reduction programs on college, university and research park campuses.
26		CTR Programs	Employee commute trip reduction programs.
27		Rideshare Programs	Rideshare promotion and matching.
28	Telecommuting		Working at home to avoid commute trips.
29	Alternative Work Hours		Flex time and alternative work weeks (such as 4 days for 10-hour per days)
30	Vehicle Rentals		Encourage car share cooperatives and neighborhood vehicle rentals.
31	Transit Improvements		Improved public transit service.
32	Traffic calming		Use strategies to reduce vehicle traffic speeds when appropriate.
33	Monitor TDM		Perform surveys and other monitoring of TDM program effectiveness.
34	Transportation Management Associations (TMAs)		TMAs provide trip reduction services in a commercial or employment center.
35	TDM Marketing		Provide public information and encouragement programs.
36	Manage Special Transport Activities		Manage special types of transport and special events for efficiency.
37	Push pull		Push out single occupant and pull into public transport services such as buses and mass rail transit.

Source: Compiled from different journals.

2.4 Road Transport problems

Urban traffic faces many challenges which are mainly caused by rapid urbanization and an increase in car ownership which then influence both the flow of traffic and the environment. The main challenges are traffic congestion, pollution and road accidents [24] Similarly [25] highlights the negative effects of urban traffic as it contributes to accidents, noise and air pollution as well as traffic congestion on the roads. Traffic also contributes to global warming through the gases which are emitted.

The increase in car ownership means also an increase in the number of trips per person per day. This continuous movement of people causes more traffic jams and more parking spaces will be used during the process. According to [26] cities are dynamic hence there is also need to constantly modify transport systems in order to cope up with the changes. Road transport costs arise from the external effects of traffic system, particularly accidents, congestion, consumption of public space, air pollution, noise, and disruption of social and economic interaction [27]. These externalities of traffic are especially pertinent in urban areas because here spatial densities are high and the infrastructure networks are most intensively used. The current status of road traffic in many countries is extremely unpleasant. Road traffic is dangerous, expensive and has a high pollution rate. Accidents injure or kill thousands of people every year. Traffic congestion in many big cities has gone almost out of control. Environmental damage is another issue. CO2 emissions from transportation in general and road transportation in particular have been rising faster than emissions from all other major sectors of the economy [28]

2.4.1 Congestion

Although there is traffic congestion in most major cities of the world, there is no standard definition of it. In general, congestion occurs when the number of vehicles using the road is greater than the capacity of the available road space, impeding the efficient movement of traffic [29]. [30] 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. [30] 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.

[31] 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 cited [30] 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.

In traffic engineering, flow is an important parameter that shows the state of the traffic movement. In terms of traffic flow, congestion is usually considered as the state where the speed & flow graph is reverted or sloped positive. Hence, congestion can be defined as a state in the traffic flow pattern which represents the condition at which demand exceeds capacity or the speed is below acceptable value[80]

Depending on its occurrence congestion can be classified as recurring and non-recurring congestion. Recurring congestion includes congestion due to bottlenecks, traffic signal, and persistent higher demand etc and they are predictable. Whereas non & recurring congestion is includes those congestion caused by mainly accidents and unprecedented events [81]

2.3.2 Road Traffic Accidents.

The Global status report on road safety 2018, launched by WHO in December 2018, highlights that the number of annual road traffic deaths has reached 1.35 million. Road traffic injuries are now the leading killer of people aged 5-29 years. The burden is disproportionately borne by pedestrians, cyclists and motorcyclists, in particular those living in developing countries. The report suggests that the price paid for mobility is too high, especially because proven measures exist. Drastic action is needed to put these measures in place to meet any future global target that might be set and save lives [32].

2.3.3 Transport and the Environment air pollution.

As well as being a leading source of greenhouse gas (GHG) emissions, the transport sector is responsible for a large proportion of urban air pollution. An estimated 3.7 million premature deaths are attributed to ambient (outdoor) air pollution, based on WHO data from 2012. Overall, higher urban air pollution concentrations increase the risk for cardiovascular and respiratory disease, cancer and adverse birth outcomes, and also are associated with higher death rates.

Transport is a significant and growing contributor to particulate air pollution exposures. Road transport is estimated to be responsible for up to 30% of particulate emissions (PM) in European cities and up to 50% of PM emissions in OECD countries – mostly due to diesel traffic. However, the total contribution of transport to particulate air pollution can vary widely, from 12%-70% of the total pollution mix. Low- and middle- income countries suffer disproportionately from transport-generated pollution, particularly in Asia, Africa and the Middle East. In part, this is due to the use of old and inefficient diesel vehicles and a lack of public and active transport networks. [32]

2.4.1 Transport management for decreasing traffic problems

The principal focus of traffic management and control systems is to ensure the safe and efficient movement of traffic on roadways. This is indeed a challenging task since incidents, of varying degrees of magnitude, can routinely impact the flow of traffic. These incidents need to be identified, and responded to in a timely fashion.

[33] stressed that urban traffic management use to make the most productive use of the existing road based transport system by adjusting, adapting, managing and improving the system. Specifically, traffic management is designed to improve the movement of people and goods; to improve the quality and safety of the traffic and transport system; and to contribute to the improvement of the urban environment. Traffic management can assist poverty reduction by improving travel for "people" and it also improves the flow of traffic and enhances mobility, thereby reducing emissions and fuel consumption.

[35] Studies describe the benefit of traffic management in two perspectives i.e. for the public and individual. Hence the public will profit from the measures because the road infrastructure is used more efficiently through traffic management, congestion can be addressed and, thus, negative impacts of traffic (e.g. pollution, noise, accidents) can be reduced. This is possible without investing in new road infrastructure. If breakdowns occasionally occur in the transport network or large scale events are taking place, traffic can be re-routed accordingly. Unnecessary mileage driven searching for available parking spaces is reduced. Access and parking management measures can be enforced more efficiently and, therefore, the positive effects of these actions will be enhanced. Also the reliability and the quality of service of public transport can be improved, affording passengers time savings. Furthermore, the road safety can be improved when dangerous locations and situations that can cause accidents are identified and improved with the help of the tools described. Individuals can benefit from less congestion and

reduced travel times effected by the improved traffic management. Fewer people are injured in traffic accidents, reducing personal harm and associated costs.

2.5 Traffic congestion and accident

There are only limited researches available on the relationship between traffic accident and congestion as it relates to the performance of the transportation system .However, Cambridge Systematic [42] showed some evidences that traffic congestion is related with traffic accident. The evidence is mixed on the degree to which congestion reduces the number of traffic accident on a congested road segment. In some cases, traffic accident shows a reduction in less congested road section. The study concludes that shifting vehicle travel from congested to less congested condition tends to reduce traffic accident but increases the accident severity.

Relationship between traffic congestion, mobility and road safety and productivity.

[76] Use Bayesian spatial model and the mixed logit model to study the relationship between traffic congestion, traffic accident and mobility. The study concluded that traffic congestion overall has a negative impact on road safety. The results indicate that mobility and safety can be improved simultaneously, and therefore there is significant additional benefit of reducing traffic congestion in terms of road safety. This study contributes to knowledge in terms of the relationship between traffic congestion and road accidents, showing that mobility and safety can be improved simultaneously. A new hypothesis is proposed that traffic congestion on major roads may increase the occurrence of serious injury accidents.

[78] It is expected that the effects of congestion on safety depend on the extent to which drivers are surprised by the congestion. This may, in its turn, depend on the type of congestion, the location of the queue and the use of variable message signs. Traffic congestion has a negative impact on the economy and on the quality of people’s lives. Road users experience delay and stress, and environmental pollution increases.

In this [77] study the relationship between road traffic congestion and mobility have been studded The result from the study concludes that mobility is restricted due to congestion, causing excessive travel delays, particularly, during peak hours and negatively affecting productivity. [78] Traffic congestion has a negative impact on the economy and on the quality of people’s lives. Road users experience delay and stress, and environmental pollution increases. The effects of traffic congestion on traffic safety, however, are less obvious. [79] Urban air quality is generally poor at traffic intersections due to variations in vehicles’ speeds as they approach and leave. Traffic congestion on roads not only increases the fuel consumption but consequently leads to increase in carbon dioxide emissions, outdoor air pollution as well as increase in the exposure time of the passengers

[80] use Ordered Response Models to study the relationship between congestion and safety. The result suggest that the level of traffic congestion does not affect the severity of road crashes. In Addis Ababa at Meskel squeare , Ayat , Megenena and kality the cause of traffic congestion is pedestrian crossing to use LRT. In the study [55] suggested pedestrian underpass or overpass crossing is necessary Near Anwar Mosque, Near Mexico Square, Torhayloch to avoid traffic accident and congestion.

2.6 Cost of traffic congestion

Many transport engineers and economists have been interested in costing traffic congestion for long period and different studies have been done to estimate the cost of traffic congestion. As all planning and congestion mitigation measures decisions require a quantified cost benefit analysis, costing traffic congestion is a critical task in traffic congestion management process. Traffic congestion costs nations for their transportation activities, negatively impact their national economy, impair the quality of life by costing traveler's time and money, degrading the environment and causing accident [43] reports the principal economic and social costs of traffic congestion.

Estimating the social and environmental cost is much difficult and different from area to area; but, some literatures try to estimate person hourly cost as a function of considering all trips to work place. However, the [44] determined the cost of congestion in United States of America as a function of delay time and wasted fuel cost of 2009. Accordingly, the result shows that: [45] The congestion cost for extra time and fuel for 439 urban areas were 24 Billion, 58 Billion and 115 Billion for the years 1982, 2000 and 2009 respectively.

Similarly, the congestion cost estimated for Toronto and for major Australia's cities estimated to be 3.3 Billion and 9.39 Billion per year respectively [43]. The above results show how the traffic congestion costs individual travelers and a nation in general. In Addis Ababa cost of congestion was studied [83] by taking one intersection MEKANISA - JEMO road. The total cost of congestion for specific approaching distance was estimated to be above Birr 210,805.87 per year during off peak time and Birr 343,597.99 per year during peak time. The total loss due to congestion will be above Birr 132,792.12 per year on single selected approach. Another study [47] reported the city incurs annually about 5-8 Million Birr per intersection only for vehicle and fuel cost.

2.7 Researchers conducted to solve Addis Ababa city transportation problem

Many researchers have studied problems of Addis Ababa transportation system. Most of the scholars are from Addis Ababa university. From them Quality of mass transport service providers has been studied by [46]. The study evaluates the quality of services of the public bus transportation system on three major routes of the Sheger Mass Transport Enterprise (SMTE) in Addis Ababa and come up with improvement strategies that would increase the quality of services. The findings of study revealed that the variation of headways and passenger loading vary depending on the period and direction of travel. Another study, [47] researches the level of the traffic congestion in Addis Ababa city was quantified using travel time approach. The result showed that on average about 18,000 Veh-min or 38 Veh-day and about169,000 Per-min or 352-person-day are wasted at each major intersection entry and the city incurs annually about 5-8 Million Birr per intersection only for vehicle and fuel cost. The result also showed that the city's traffic accident rate correlated with travel rate better than traffic volume and the congestion spots identified from questionnaire data consider with the black spots identified by the national road safety agency.

Location of black spots and their relation with delay has been studied by [48]. It also evaluated the aggravating factors such as proportions of heavy trucks with the performance measures in the route. The study proposed High, Medium and Low cost engineering counter measures which are recommended to reduce the level of Road Traffic Congestion and its associated impacts either through traffic management procedures or building better infrastructure development along the segment.

The impact and extent of public transport in Addis Ababa on urban mobility has been studied by [49]. The research assesses the possible strategies and approaches that can be devised to enable this mode play a significant role in mitigating the worsening level of congestion that we see in the city. The overall findings of this study revealed that despite the fact that an efficient public transport system is the best way to maximize urban mobility, in reality this mode of transport is in a critical condition to begin with in Addis Ababa. Impact of traffic congestion due to the new LRT system has been studied by [50].The result revealed that there is an additional delay to the normal control delay at the three junctions (Beshale Hotel Round About, CMC Round About and Ayat Round about) where the LRT crosses at-grade. Researcher concludes with meaningful suggestions have been briefed that can help better harmonization of LRT systems and principal arterial streets for the future development of the city. Car plate recognition system for Ethiopian vehicles is proposed by [15] on the basis of connected component analysis (CCA) for plate region extraction in conjunction with template matching technique for character recognition. The experimental results showed that by adjusting the influencing factors, the system can perform in a good way.

Reason and assessment zoning of Minibus service have been studied [52]. The overall findings of this study portrayed that the purpose of taxi zoning transport system was to improve transport service and resolve its problem as well as giving standard transport service for the people. However, the taxi zoning system failed to achieve its purpose due to lack of correct implementation, lack of well-trained institutional leaders, weak management and follow-up mechanism and the stakeholders failed to fulfill their responsibilities. Finally the paper puts forward suggestions and particular solutions to some existing realities of the public transport.

The suitability of cycling as additional means of transportation for Addis Ababa has been studied [53] . In order to do this around 9048 streets in Addis Ababa are evaluated to find out the best road for cycling. Factors such as slope, traffic density and pavement surface condition were considered to assess the suitability of roads for bicycle. The study was conducted in two steps. The first step involved evaluation of the entire roads of the city. When considering all factors, the result indicated that riders can use bicycle only on 9% of the roads. The data analysis showed that the factor ‘pavement surface’ condition was the most infantile to limit the suitability of roads for cycling. Using this factor alone about 65% of the total roads is found to be unsuitable.

Mode choice behavior of employees and students in a specific area of Addis Ababa has been studied [54] which is from Ayat to Megenagna. Finally it was identified that the significant factors for mode choice of employees were travel time, travel cost, work type and income. For the case of students the significant factors were found to be travel time, travel cost, service cost and gender. It was also found that both workers and students who travel longer distance choose Higer and Anbesa than taxi to decrease the transition time and energy wastage during transferring from one taxi to another. The main modal shift to LRT is found that from Anbesa, Higer followed by taxi the least interest is shown from private car users.

Effects of introducing LRT system in urban transport design on pedestrians and public transport users has been studied [55] travel distance and time to cross crossways of LRT. It is finally concluded that introducing LRT affects both pedestrians and public transport users’ mobility by creating walk distance increment, time delay and mode choice delay. It is recommended that affordable overpass bridges, pedestrian refuge area and integrate other transit locations with LRT crossways can potentially reduce the impact.

Cause of air pollution in Addis Ababa city related with urbanization, increment of motor vehicle population and transport system in the city has been studded [56]. The result shows that development of Addis Ababa lead to increased greenhouse gas pollution caused by the growth in vehicular traffic, energy use, and other activities. Transportation is the fastest growing major contributor to global climate change, Low carbon transportation strategies are better transportation means to reduce environmental air pollution. Road traffic crashes, particularly in roads from Gelan to Tukurwuha is studied by [97] with particular reference to the magnitude, risk factors, interventions and counter possible solutions has been recommended by the researcher.

2.8 International TDM strategy experience.

Many world cities have managed to build on their well performing urban transport to increase competitiveness and attractiveness. Their urban transport system structure shows the best direction to follow for providing citizens with good access to economic and social opportunities and enhanced quality of life, and enable businesses to efficiently access labor and markets. These cities offer valuable lessons for transition and developing countries. Cities in transition and developing countries are experiencing simultaneous growth of urban population, income, and private vehicle ownership, which, combined with resource constraints, creates a challenging environment for their urban transport systems.

2.8.1 Researches that are done to solve transportation problem using TDM in other cities around the world.

Modal choice of passengers is studied in the North of France [57]. They compute demand elasticizes to price and time to analyses mobility solutions. They simulate the impact of different transport policies to shift mobility behaviors towards more sustainable ones. The results show a strong inertia in the demand for car use. Only extreme mobility policies lead to a significant increase of the share of public transport. Conventional economic variables are not sufficient to increase the demand for public transport. Other tools need to be implemented. Social tariffs seem to be a relevant solution.

In Dhaka city, acute traffic congestion kills hours every day. The research [58] discusses the effects of undertaking some specific traffic demand management measures like car sharing, passenger car pricing, movable divider for peak periods. Car sharing increase the occupancy of any car and it directly decrease the percentage of car growth. Car pricing will also encourage the people into car sharing. In Dhaka city, the combination of these three measures will be very effective in reducing congestion created by passenger cars.

The tests of TDM measures [59] in Greece make us believe that traffic congestion problems can be better solved by implementing mixes of such measures. In any case the implementation of various TDM measures must be part of a comprehensive transport policy encompassing potential new infrastructure, other push and pull measures and finally publicity and promotion campaigns.

Table 2. 2 International TDM Success Stories.

TDM strategy [reference]	Description and advantage of TDM	City
Compressed Workweek	TxDOT maintenance crews in the Austin District. Participating crews work Monday through Thursday for 10 hours a day. Employees and supervisors cite improved morale, reduced stress, increased family time, and the ability to make personal appointments without taking time off. [70]	Texas
Compressed Workweek	In Texas Department of Insurance More than 28% of the employees now work a compressed workweek implemented. They reported that the program has aided in employee recruitment, retention, and morale, reduced congestion in the agency's parking garage and helped alleviate employee stress and burn-out. [43]	Texas
Compressed Workweek	95% ARCO Products Cherry Point Oil Refinery of employees use flexible work scheduling. Managers appreciate the increased production and savings. Many employees appreciate saving commute time and travel costs, and enjoy the increased quality of time off. This no-cost strategy not only improves employee morale, but it also increases production efficiency and administrative employee effectiveness. The longer working days in-crease the 4/10 maintenance crews' productivity by reducing about 10% of their non-productive time spent moving between jobs, getting parts, putting tools away, cleaning up, or attending meetings. For operating crews, a 3/12 schedule decreases the time. [40]	Seattle
flexible work options	DDB Seattle advertising offer flexible work options and observed that their employees work harder, produce better work, and stay with the company longer when allowed some freedom in how and when they work. The company relies on a teams-based structure to complete projects, but flexible work scheduling has not hindered team work. In fact, teams with members using flexible work options tend to exchange more information and are more willing to cover for their teammates. [69]	Seattle
Teleworkers	Holland America Line (HAL), a tour and cruise company has full-time teleworkers and teleworking management staff. The telework program has increased productivity, increased employee retention, improved coverage, and reduced absenteeism. Employees at HAL appreciate the flexibility that telework affords, and enjoy the extra time that was previously spent commuting. [69]	Seattle
PROPERTY FEES/TAXES	This instrument aims to eliminate the tariff and financial benefits currently in place This is important in order to balance out the real costs of vehicle ownership and use as well as limit the number of vehicles on the road. [71]	Singapore and Shanghai
PAY-PER-USE	The primary objective of this instrument is to assign a value to the use of roadways in the most congested areas. The urban toll requires drivers to pay for roadway use, particularly in city centers and other congested areas during specific high-volume traffic hours. This measure ensures faster travel and enhanced flow of traffic in these areas.[72]	Singapore and London.
DISTANCE-BASED CHARGING (PAY-AS-	Distance-based charging requires the driver to pay a fee (to the government or a private entity, such as a car insurance company) based on the distance driven in that vehicle. The logic behind this instrument is that by driving fewer	British

YOU-DRIVE)	kilometers there will be less wear on infrastructure, reduced risk of car accidents, and other positive impacts. [73]	
CAR-SHARING	car-sharing would be considered a mode of transportation intermediate between those who own and those who do not own a vehicle. [74]	Victoria
ENVIRONMENTAL RESTRICTIONS	This TDM instrument is somewhat similar to pay-per-use for access to roadways, although the charge is based on vehicle emissions. There are zones in the city in which only certain levels of emissions are permitted and, therefore, only cars that comply with emissions standards may enter. The aim is to phase out old gas guzzling cars and to encourage citizens to acquire less-polluting cars [75]	Berlin, Hanover, Cologne, and Stuttgart
BASIS FOR ON-STREET PARKING	Parking policy is most commonly employed to: reduce illegal parking, reduce circulation while searching for a parking space – which leads to undesired congestion and increased air pollution, increase or generate revenue, mitigate disruptions in the urban fabric, and re-think land allocation among users of all types of transportation	USA
PARKING REQUIREMENTS	This city has mandated maximum and minimum parking requirements for the sale of offices, government buildings, and universities. The minimums were reduced for sites close to public transportation, sites that share parking, sites that provide affordable housing, and sites in close proximity to public or commercial parking. The planning board allows developers to exceed the maximum in cases of high demand for parking. [75]	UNITED STATES: CAMBRIDGE, MASSACHUSETTS
parking compromise	If a new space is built off-street within a zone with a defined limit, an on-street space has to be removed to maintain the supply cap. This policy has enhanced public spaces, such as the development of new public squares. [72]	SWITZERLAND: ZURICH
LICENSE PLATE RESTRICTIONS	measures have taken on various forms, from restrictions based on whether the license plate number ended in an odd or even number, or by groups of numbers. Very complex reformulation schemes have come about to counter the many driver strategies to bypass the system. This measure has been used for two specific reasons: to reduce air pollution and to reduce traffic congestion. [84]	Mexico City, Bogota, Medellin, Sao Paulo Colombia, Quito
CONGESTION CHARGE	This instrument has had positive effects in the short-, medium-, and long-terms, and has generated significant revenue for these cities (after deducting operating costs). As such, the congestion charge approach is being proposed in many places as a TDM option. [84]	Singapore, London, and Stockholm
CAR-FREE DAY	The event is also intended to raise awareness among urban planners and politicians to promote prioritizing alternative modes of transportation, such as walking, biking, or using public transit instead of personal cars.[85]	European Union's, Ethiopia also started
vehicle restriction	Restricts the use of personal vehicles in the micro-center from 11 a.m. to 4 p.m. Buses and taxis are authorized to circulate in the micro-center, as are motorcycles, emergency vehicles, funeral vehicles, mechanic service vehicles, armored vehicles, daily distributors[86]	Buenos Aires

cordon pricing scheme	The cordon pricing scheme uses automatic number plate recognition in an 8 mi square area (21 km square area zone). Vehicles are registered automatically by cameras that photograph the number plates. The system consists of overhead gantries, cameras at all entrance points, pavement markings, and street signage. Reduce congestion Improve air quality and public health Improve journey time reliability for car users Create a long-term funding source for public transit improvements	
Staggered hours schemes	Since 1985 several successful cases of staggered hours' schemes are found in Singapore, to avoid traffic congestion has often caused long commuting times.[98]	Singapore
flexible work arrangements	Ministry of Manpower (MOM) have started an Enhanced Work-Life Grant that allows companies to provide flexible work arrangements for its employees. Under this scheme, employees are free to choose their starting and ending work times daily, provided they complete a stipulated number of work hours within the day. Singapore ministry of man power give incentive for those who implement flexible work arrangements (FWAs). [99]	Singapore

Source : compiled from different research papers

Literature Gap

As per knowledge and found literatures two main gaps are identified. The first gap is method of transport demand modeling this gap is found in both international and local research papers. When they study behavior of transport to model transport demand they used survey and questioner. Most of this questions are private (confidential) questions (At what time you start to go to work ? , Where do you work ? and What did you do after work ?) and respondents are not willing to answer or they will not give true reliable data. Additionally this method consume more time and laborious. Use of unreliable data will lead to unreliable conclusion. In this research combination of online Google map surveillance and Mathlb digital image analysis is used to study transport behavior Addis Ababa city or to prepare transport demand model. The second gap is found in local studies that focused on Addis Ababa transport problem. This research is different from other local researches because it focused on selecting transport demand management strategy. Most research focus single component of transport system and the solutions they suggest didn't consider effect the whole transport system (bigger picture) but this research first study the bigger pictures of the transport problem and go down to specific solution.

2.9 Bench Mark city selection

Advantages of Bench marking

Benchmarking, in the context of urban transport provides comparative information and management tools that enable:

- Government to assess, monitor, and fine-tune urban transport policies and to better exercise their regulatory role.
- Citizens to hold governments and service providers accountable through better information;
- Urban transport service providers to identify performance gaps and set realistic targets and measures to fill them.
- International development and financial institutions to design targeted and result-based development programs and to draw and share lessons from the experience of better performing cities.

The main objectives of benchmarking are To set realistic target, to avoid pilot test and to avoid policy measure output uncertainty and select TDM strategy that can be applicable to Addis Ababa. For identification of best practices and to Adapt these good practices and processes for improvement based on Addis Ababa existing situate To learn from top performers and adopt best practices for effective transport system improvement.

The steps that followed during selecting bench mark city are as follow.

1. Identify city, which has world's best transportation system.
2. Identify important bench marking parameters that are the same as Addis Ababa.
3. Select benchmark country.
4. Observe (visit) transportation system of selected benchmark country.
5. Collect important data's, take best practices and TDM strategy they used for effective transportation system improvement.
6. Identify and select TDM strategy that can be adapted to Addis Ababa by considering current Challenges (barriers) for implementation of TDM strategy, Capacity constraints, future opportunities and challenges and trend of increase in demand of transport.

7. Categorize TDM strategy that can be applied in Addis Ababa with short term and long term strategy by considering barriers (challenges) and current capacity constraints such as budget and future opportunity of Addis Ababa.
8. Suggest implementation for TDM strategy and mechanisms and Policy. Select city with best world best transportation system.

Top ten cites have been selected by research conducted [102], [103],[104],[105]’[106] are also appreciate Singapore transport polices and strategies. Recent research conducted in 2018 compares approximately 13,500 cities around the world and filtered them into 37 then 24 cites. The report provides a comprehensive view of transportation systems in 24 major cities around the world and compares these cities on five metrics such as availability of transportation, affordability, efficiency, convenience, and sustainability that directly affect the lives of billions of people. This data is then synthesized to identify the world’s top ten cities by how well they serve the mobility needs of their residents.. Summary of compression of the cities are available in Fig 2.1.

To identify top ten cites, the report relies on a combination of extensive quantitative analyses, the opinions of experts, and the perceptions of urban residents. The philosophy behind this approach is that the specifics of how city transportation systems function is important, as is the satisfaction their users have with them.

2.9.1 Selecting bench mark country from top ten best cities

No two cities are alike, of course but some are more similar than others. Singapore is selected as bench mark country for Addis Ababa because Major transport parameters are near same value. Major transport system parameters are number of population, Land area size and road coverage. This parameters are almost the same as Ethiopia. The comparison is shown in figure Table 7.1 Creation of best-in-class transport systems requires significant investments: development and maintenance of roads and rail infrastructure, renewal of the public transport fleet, investments in intelligent transportation systems (ITS), and digitization, to name a few. As expected there is a clear trend in general, richer cities have more opportunity to build impressive transport systems. However, there is a more compelling insight wealth neither definitively limits development of transport systems, nor guarantees its success. The GDP of Ethiopia and Singapore is shown in below Fig . The GDP of Ethiopia is less than Singapore but they have positive trend.

The goal the research was to assess comprehensively how urban transportation systems affect the quality of urban life. We identified five factors—availability, affordability, efficiency, convenience, and sustainability.

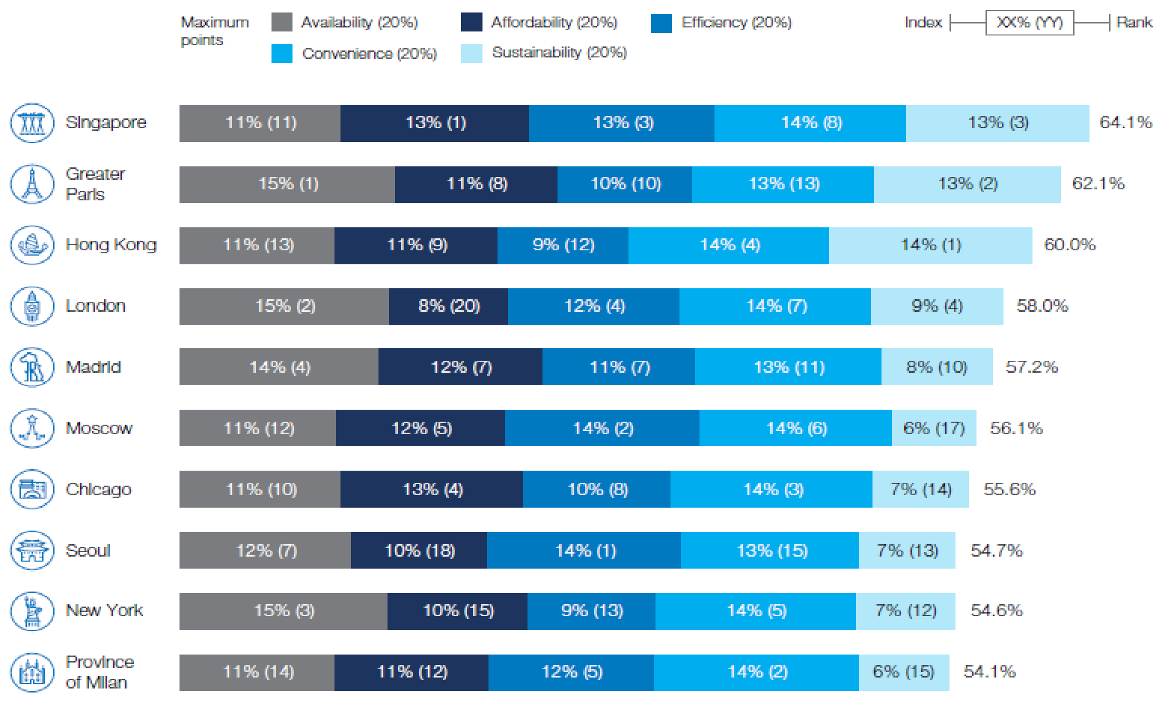


Fig 2. 1 : Top ten cities: Overarching urban mobility ranking.

Source [102]

The selection rank was as follow Singapore, Metropolis of Greater Paris, Hong Kong , London, Madrid ,Moscow , Chicago, Seoul, New York, Province o

Observation (visit) of selected benchmark country transportation system.

Singapore, Hong Kong, Beijing and sangha transport system have been studded and observed.

Addis Ababa and Singapore are the same with major transport parameters. Except two things

1. All observed best cites such as Singapore, Beijing ,Hong Kong ,sanghya and most developed cites around the world equipped with efficient underground MTR system. Singapore public transport handle 7 million commuters riding each day. [99]

2. Transport demand management policy.

Singapore transportation system

Singapore is among the most densely populated countries in the world. Like other urban cities, they face the challenges of growing transport demand and the constraints of physical space. Singapore has a vibrant economy, high-income levels and high car ownership. There is a distinctly pragmatic political culture, and the power structure is centralized. This may have made it easier for Singapore to be the first-ever country to successfully establish road pricing. Singapore land transport is working towards a more people-centered land transport system that meets the diverse needs of an inclusive, livable and vibrant global city.

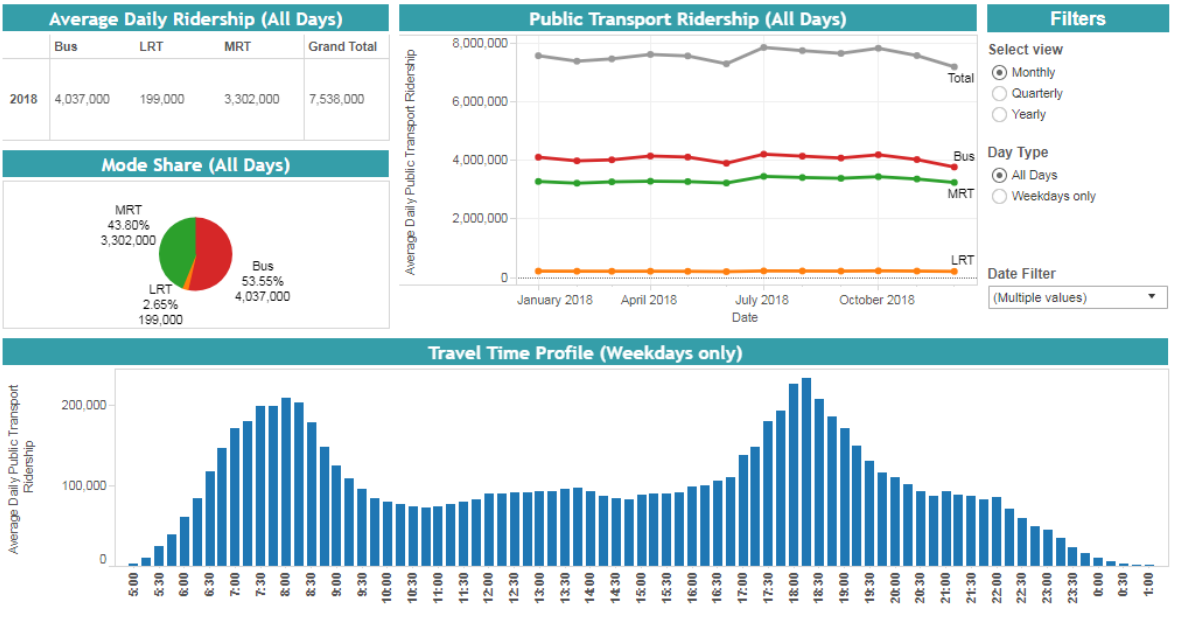


Fig 2. 2 Singapore transport system data

Source: Singapore Land Transport Authority website [114]

Singapore MTR

Singapore MTR opened in 1987 with 6 MRT stations and the system has grown to 170 MRT station & 51 LRT station in 2018.The routes are shown in the figure 4.34 . Singapore MTR transport 3.4 million commuters riding each day.

Advantage of MTR system

Disadvantages of MRT

Short-term drags on profits. Operators will incur start-up losses in the initial years before ridership gains traction. Hiring, training and utility costs are usually incurred ahead of ridership growth. For example, the Northeast Line of Singapore took three years to break even. More startup costs for government can absorbed by different strategies such as public private partnership (PPP), and others

Incentives for public to use public transport.

Promote Flexi-Travel Early Travel Free

We are also promoting flexi-travel. We extended the Free Pre-Peak Travel on MRT Scheme to June 2015, encouraging commuters to travel early before the peak periods. For employers, we are launching new Travel Smart Network, providing grant of up to $160,000 for companies to support the adoption of flexi-travel arrangements.

Important lessons and TDM strategies

Electronic road pricing (ERP)

ERP is successfully applied in Singapore, London and Stockholm. The primary goal of ERP was to Reduce congestion , Improve air quality and public health, Improve journey time reliability for car users , Create a long-term funding source for public transit improvements . The government uses huge amount of generated profit for another infrastructure development. Payment and cost and other related is summarized in below table [48]

Bus infrastructures

In Singapore, there are four public bus operators – Go-Ahead Singapore, SBS Transit, SMRT Buses and Tower Transit Singapore. In Addis there are 3 public bus operators Anbesa, shger and Alinace . The two new bus operators (Tower Transit Singapore and Go-Ahead Singapore) were brought into the industry with the transition to the Bus Contracting Model (BCM) in September 2016. With the BCM, the Government owns all depots and buses, and retains fare revenue, while bus routes are open to competitive bidding in packages. The two latest bus packages, namely Seletar and Bukit Merah, were awarded to SBS Transit.

Since end 2017, all public buses are equipped with the common fleet management system (CFMS), a sophisticated system that allows bus operators to track bus fleets in real-time. It monitors bus movement and shows the time that a driver needs to reach certain bus stops, so buses are on schedule for commuters. Commuters are also be able to enjoy the convenience of on-demand dynamically routed public bus services. This means commuters could request via a mobile application for pick-ups and drop-offs at any bus stop within an operating area, instead of relying on fixed timetables or routes. In the first phase of the trial, a dynamic matching and routing algorithm was developed to enable buses to be deployed according to real-time commuter demand, as well as pick-up and drop-off points.

Under the Bus Service Enhancement Programme (BSEP), the Government has partnered the bus operators to significantly increase bus capacity and enhance bus service levels to benefit commuters to grow the bus fleet by 35% within five years, with the Government contributing 1,000 buses by 2017. Besides enhanced connectivity, bus frequencies is also improved to reduce the feeder waiting time to 6-8 minutes during peak periods, and reduce bus loading.

Complementing its bus planning role, under the new model, LTA will contract operators to run bus services through a competitive tendering process. LTA will determine the bus services to be provided and the service standards, and bus operators will bid for the right to operate these services. Operators who are awarded the contracts will be paid fees to operate the services, while fare revenue will be retained by the Government.

Roads take up 12% of Singapore city land area today [114]. With limited road space and a growing population, there is a need to optimize public transport to efficiently carry and move more people. Therefore, it is important to enhance the speed and reliability of our bus system.

Bus Priority Schemes

Surveys by LTA have shown that the two most important aspects of the bus journey for commuters are waiting time and travelling time. To improve, LTA has been expanding the coverage of normal and full-day bus lanes, expanding the mandatory give-way-to-buses scheme to give buses a greater right of way along busy roads, and increasing the number of bus hubs to reduce the time buses spend at bus stops to shorten waiting and boarding times for commuters, improving overall journey times.

Integrated Fares payment system

Before the Distance Fares system was implemented, commuters making transfers (between bus and MRT, and between buses) had to pay a boarding charge each time they board. Hence, commuters paid more to make a transfer journey compared to a direct journey, even if he travelled on a comparable route over the same distance. This additional cost of making a transfer discouraged people from making transfers even when it made more sense to do so. A distance-based fare structure was thus introduced in 2010 to further improve the connectivity of the public transport system. Commuters only need to pay a fare based on the total distance travelled from origin to destination, regardless of the number of transfers they make. This fare system removed the previous fare penalty associated with bus-MRT or bus-bus transfers and made transfers more seamless and convenient.

intelligent transport system center

Providing real time information about traffic condition by using Green Link determining system technology responds to traffic demand .To increase choice and convenience for commuters, LTA has launched its next generation e-payment system for public transit, Symphony for e-Payment (SeP) in December 2008.With this new e-payment system, commuters are able to use cards issued by any card issuer for transit purposes, as long as the cards comply with the CEPAS technology standard and include the transit application. These new CEPAS-compliant cards can also be used for retail and non-transit payments such as those for Electronic Road Pricing (ERP) and Electronic Parking System (EPS) car parks.

Bike infrastructures

Riding an e-bike or e-scooter on a cycling path, or brisk-walk to the nearest train station. Walking, cycling, or the use of personal mobility devices offer commuters more choices for first-mile and last-mile connectivity – taking you from your home to your destination conveniently. In a combined effort to enhance enforcement action against inconsiderate parking, bike-sharing operators are also share with LTA the location of bicycles and the details of users who park indiscriminately. Users of shared bicycles have to scan a quick response (QR) code located at designated parking areas before they will be able to end their journey, thereby ensuring that users park properly. [109]

Singaporeans target to achieve a 75% public transport modal share during both the morning and evening peak hours by 2030, up from today's 64%. We will continue to enhance the public transport services and connectivity to encourage the use of public transport. We plan to expand the rail network to about 360 km by 2030 (up from 182 km today).[110]

Singapore Transport Academy's

Singapore set high Investment on research and development which is $25 million for mobility-related research and technology trials for the next five years (starting from 2019). Transport Academic institutions are available for transport system such as Singapore Rail Academy (SGRA) , Land transport Academy , Singapore Bus Academy. The Singapore Rail Academy (SGRA) will lead and collaborate with public transport operators to prepare the industry for the challenges ahead.

Singapore key Transport demand management strategy

Singapore's experience should be viewed in a holistic approach, i.e. from the integrated perspective. This encompasses urban planning, land use, transportation planning and environmental planning.

Singapore use many TDM strategies from them the major are:

1 Integrated urban, land-use and transportation planning.

2 Private vehicle ownership restriction by high import duty

3 Promote Flexi-Travel : Free Pre-Peak Travel on MRT Scheme , encouraging commuters to travel early before the peak periods. For employers singapore launching new Travel Smart Network, providing grant of up to $160,000 for companies to support the adoption of flexi-travel arrangements. Therefore demand is distributed through time and space,

4 Intelligent transport system centre : Providing real time information about traffic condition by using Green Link determining system technology responds to traffic demand

5 Car pool lanes

6 Ride the green wave Adjacent traffic lights controlled to be green

7 Encouraging Walking and cycling .

8 Bus Priority Schemes Roads.

9 Bus Contracting for the Public Bus Industry

10 High Investment on research and development: Singapore LTA set $25 million for mobility-related research and technology trials for the next five years (starting from 2019). Transport Academic institutions are available for transport system such as Singapore Rail Academy (SGRA), Land transport Academy, Singapore Bus Academy

Chapter three

3.0 Methodology

To improve city transportation system managing the demand is one of the sustainable system that many developed countries used to solve their city transportation problem. TDM strategy is selected because it's used by researchers [57, 58,59,60,61] to effectively solve transportation system problems around. Additionally, demand managements strategies have virtuous cycle behavior whereas supply side management strategies have viscous cycle behavior.

3.1 Data collection method.

- Quantitative data collection methodology.
  - Collecting quantitative data about transport infrastructures in Addis Ababa such as number and Type of public transport vehicle and road infrastructure.
  - Modal share of transport infrastructures by the population.
  - Extracting quantitative data from collected qualitative data.
  - Collecting existing documents of Addis Ababa Transport system components.
  - Collecting existing traffic condition of the city.
- Qualitative data collection methodology.
  - Observation, direct field observation of traffic congested places in the Addis Ababa. Taking pictures of traffic condition.
  - Collecting existing traffic condition of the city using online Google maps.
  - interview with Addis Ababa road transport concerned employees such as Addis Ababa road Authority, Addis Ababa transport authority, Addis Ababa traffic management agency .

3.2 Major primary and secondary data source

Primary and secondary data is collected for this research. Primary data are collected through field observation and interview with concerned transport authority offices such as Addis Ababa transport authority, Addis Ababa road transport authority and Addis Ababa traffic management agency. Secondary data also collected from these authorities is summarized in below table 3.1 and primary data such as interview questions are available in appendix C and D

Table 3. 1 Major primary and secondary data collection sources .

Data Type	Source
Addis Ababa city road Network data	Addis Ababa road Authority
Addis Ababa Vehicles Data	Addis Ababa transport authority
Addis Ababa traffic condition data	Addis Ababa traffic management
Addis Ababa city socio- economic and demographic data.	Addis Ababa city Administration transport Authority , Survey study for city transport problem , 2017/18
Addis Ababa City transport providers data	Addis Ababa Transport Addis Ababa city Administration transport Authority monthly report March 2019.
Road safety related data	Addis Ababa road safety Annual report 2017-2018, Blumberg initiative
Singapore transport system data	Singapore land transport authority and Singapore police report
Singapore, Hong Kong, and Beijing transport system overview	Visit (Field observation) and Singapore land transport minister.

3.3 Data analysis Method

To select effective TDM strategy for Addis Ababa qualitative and quantitative data are collected. Qualitative comparative analysis is used as confirming mechanism for existence of sufficient condition for implementation of TDM strategy. Quality function deployment analysis is used to measure relative and absolute importance of Selected TDM strategy with respect to transport service sector quality measuring criteria's and prioritize the TDM strategy with respect to relative and absolute importance. Math lab analysis is used to measure and analyze typical traffic condition of the Addis Ababa in different days of the week and different seasons of the year. In put for math lab analysis is online google map data collected. Space (location) and time of selected TDM strategy is analyzed by using Online Google map and Math lab analysis. Additionally Impact and other effect of selected TDM strategies are described using System dynamics close loop causal effect diagram.

3.4 Study Area

Addis Ababa, the capital of Ethiopia is not only the political, social, economic and geographic center of the country but also it is the seat of governments ever since the day of its emergence as a city, 1886. It is the home to African Union, the Economic Commission for Africa, Council of the Oriental Orthodox Churches and many other international organizations. Addis Ababa has an area of 540 kilometer square (54000ha) and average elevation of 2500m above mean sea level. It is located almost in the central part of the country. The city is a cultural mosaic of all Ethiopian ethnic groups due to its position as capital of the country. The current administration of Addis Ababa constitutes 10 sub-cities, 'KefleKetemas' and 116 "Woredas". Addis Ababa contributes a lot to the economic development of the country and it is where most significant changes in the socio- political sphere of the land emanate from.

Addis Ababa has been manifesting to be a fast growing city in recent decades and contributes about 40% to the national GDP. 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. [9]. Being the center of country, it has a wider role in economic, social, political and administrative perspectives. Addis Ababa is the economic center of Ethiopia where most financial and commercial institutions and about 85 percent of manufacturing industries are located. About 80 percent of the national vehicle fleet is registered in Addis Ababa [65]. The expansion of the city, increasing population size coupled with the economic growth has required respective transport service supply for the increasing mobility needs of the People [66].

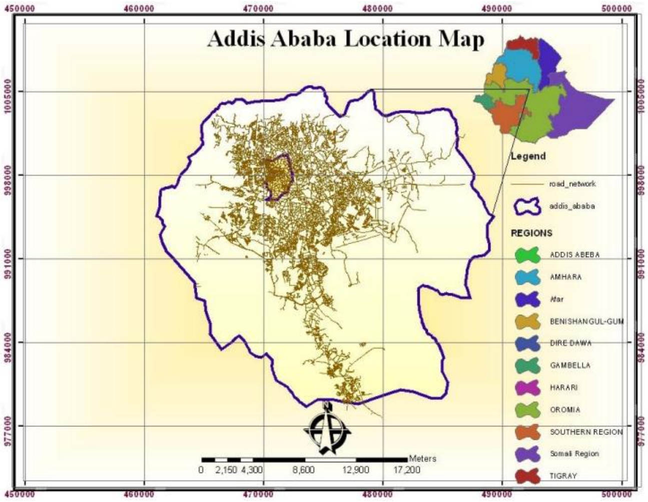


Fig 3. 1 Addis Ababa Location Map

Source: Addis Ababa city government transport Authority report 2018.

3.5 Study population

Addis Ababa had a population of 65,000 in 1912, which grew to 100,000 in 1935. In a little over three years it had increased to 143,000 [62]. According to Central Statistic Authority [63], the population of Addis Ababa has grown from 443,728 to 2,112,737 in 1994. Population of the city in 2011 is stated to be 3.4 million [64] (Table 2). The growth of population is because of the decline in death rate and the rapid pace of rural urban migration

Table 3. 2 size and average annual population growth rate of Addis Ababa (1961–2011).

Year	Population	Growth rate
1967	683,530	7.6
1978	1,167,301	4.9
1984	1,423,111	3.5
1994	2,112,737	4.0
2000	2,495,000	2.9
2007	2,738,248	2.1
2011	3,400,000	3.0

Source: CSA (2007)

Population Forecast for Addis Ababa

Duplication time is about 20 years. The range of the low, medium and high population estimate for 2000-2020 is given below.'

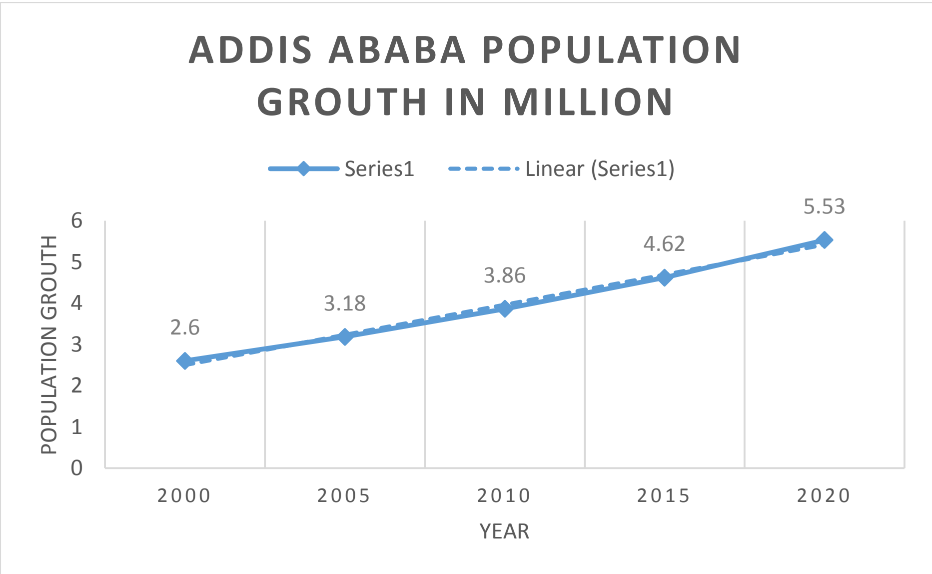


Fig 3. 2 - Addis Ababa Population forecast variations for 2000-2020.

Source – CSA 2007

A population of Addis Ababa is 3,194, 999 with annual growth rate 2.5 (CSA, 2014). This huge population causes a tremendous pressure of the demand for municipal services including road traffic services and motorization for the city. Addis Ababa motorized public transport demand is offered by the public owned Ambessa City Bus enterprise, privately owned mini buses, long distance buses, and the Para transit vehicles (taxies of various forms) including, recently, three wheeled vehicles (Bajaj) [63]

3.6 Political context of Study area

Addis Ababa is capital city of Ethiopia. The present institutional structure of the Federal Democratic Republic of Ethiopia is 28 years. The country had been ruled by an autocratic monarchy until 1974 when this was overthrown in a military coup. The ensuing regime, known as the Dergue, became increasingly dictatorial and repressive and was in its turn overthrown in 1991. A Transitional Government was then formed that laid the basis for the current constitutional arrangements. These were ratified by a Constitutional Assembly in late 1994, and took effect in 1995.

The president of FDRE is the head of the republic and the highest executive powers of the federal government are vested in the Prime Minister and the Council of the Ministers who are accountable to the House of Peoples' Representatives. This has the mandate to fix the term of the Prime Minister and to approve the ministers who are nominated by the Prime Minister.

The Federal Democratic Republic of Ethiopia (FDRE) comprises the Federal government and the governments of the Regional States. Addis Ababa is by far the most significant. The City of Addis Ababa is wholly surrounded by the State of Oromia, but forms no part of this.

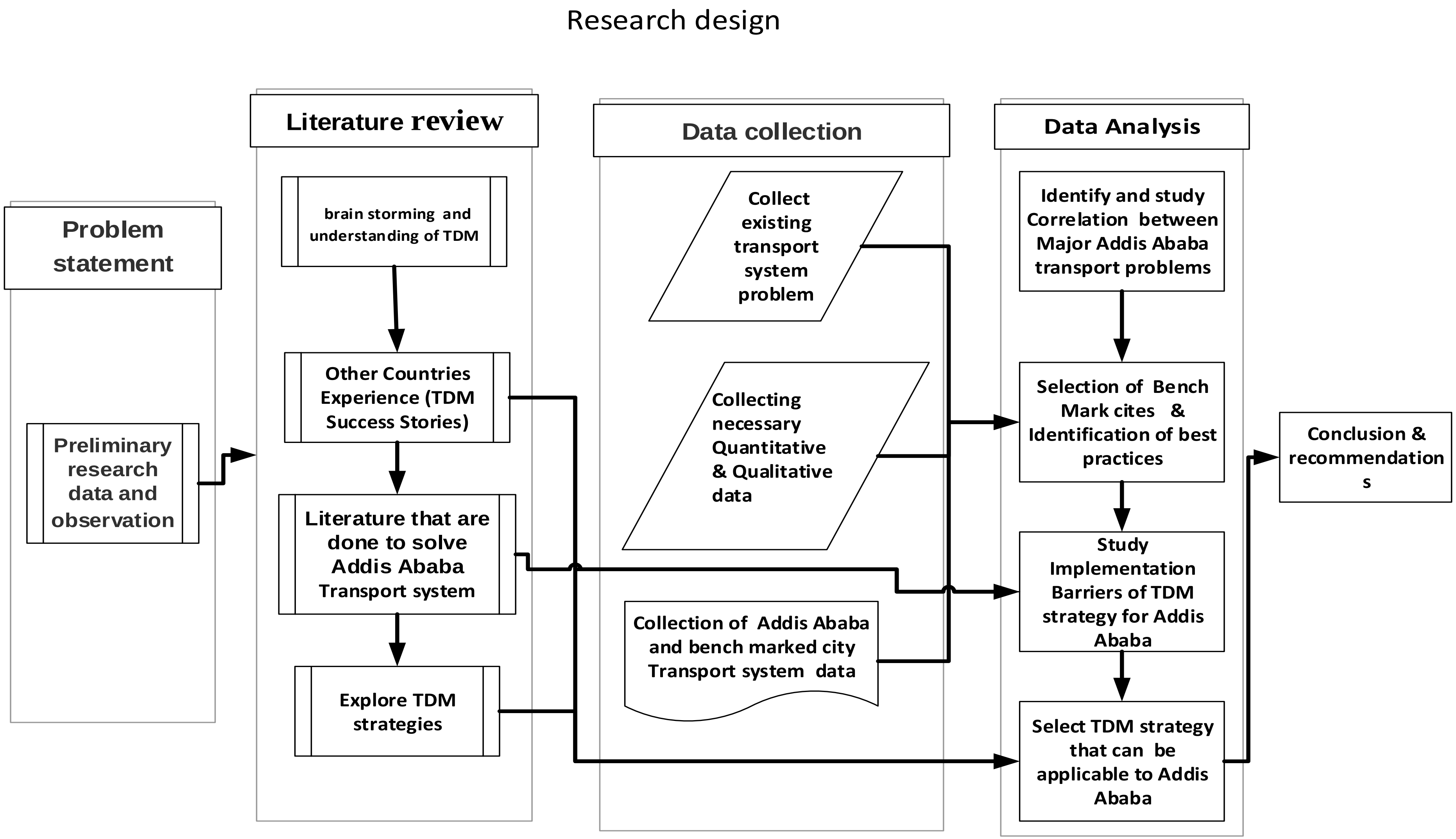


Fig 3. 3 research design

Chapter four

4.0 Data Collection, presentation.

Every Public transport system has four major component road infrastructure, Vehicle, user and administrator. For efferent and effective transport system this major components must be at optimum level of integration.

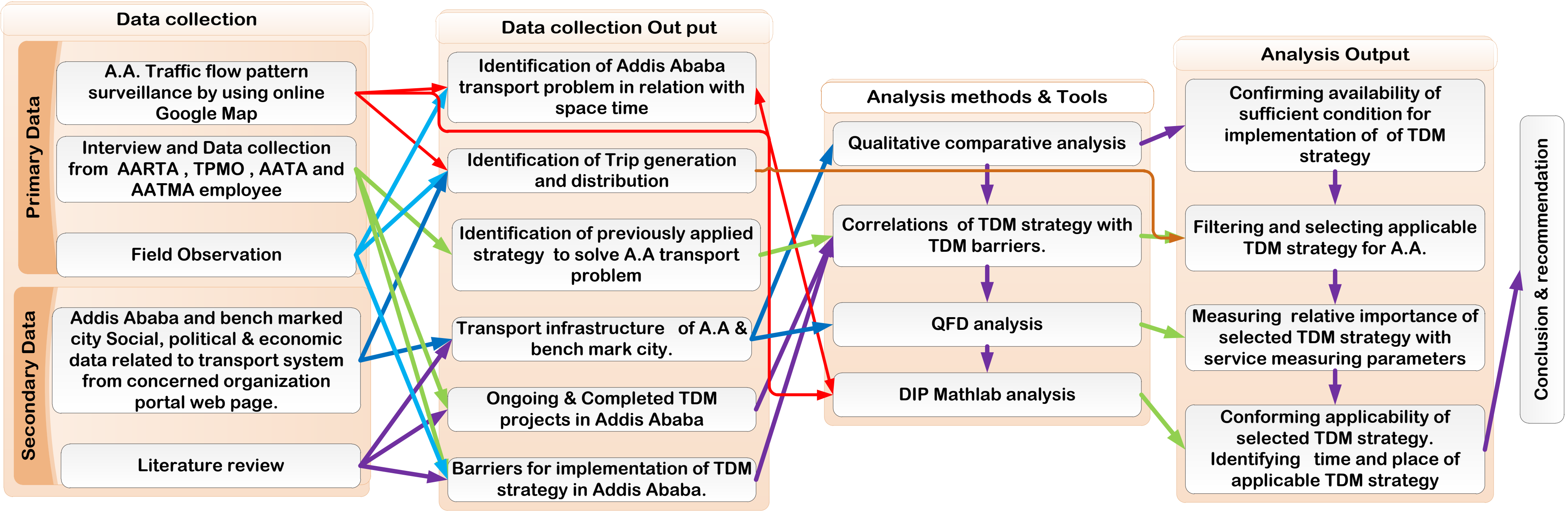


Fig 4. 1 summery of data collection, presentation and analysis

4.1 Existing transport system infrastructure of Addis Ababa.

To analyze and understand every transportation system problem the first step is to study existing transport infrastructure capacity and the challenges within it. In this section Addis Ababa infrastructures such as road infrastructure general condition, transport providers general condition and other social service general condition with respect to transportation system is studied.

4.1.0 Addis Ababa road infrastructures.

Ever since Addis Ababa City Road Authority has been established in 1990, various remarkable Changes have registered in the cities road asset. These have took place via different. Road inventory is one of an information about that basic engineering and traffic characteristics of road Networks.(TRL, 1995) .The cities road Authority has organized under five regions to implement road asset management through road inventory. The central regions has divided in to three sub-city. Accordingly; the aggregated results show 13.71%. road coverage. Therefore the progress has shown at some extent. However, the necessary intervention should be taken for the improvement of the road network coverage in the central region.

The construction of the first roads in Addis Ababa dates back to the foundation of the city in November 1886 by Emperor Menilik II and Etegie Taitu. The first roads served to link Sefers (villages within bigger settlements) by non-motorized modes of transport. The construction of modern roads was intensified during the beginning of the reign of Emperor Haile Selassie. The construction of roads during that period was carried out by the Public Works Department of the Municipality of Addis Ababa. The road construction had further been strengthened during and after the brief Italian occupation.

The total length of roads in the city before 1983 was 1,503Km, while the share of asphalted roads was below 20%. Following the establishment of the Addis Ababa City Road Authority (AACRA) in 1998, large scale road construction had commenced. The total length of roads in the city almost doubled (to 3,731km) between 1992 and 2012, and road density reached 12.9%.

Street Network

The city currently has mainly radial and orbital road pattern where main roads radiate from the center to the 5 outlets; and the ring road encircles the core and intermediate parts of the city, serving to link the peripheral areas of the city. According to the City Development Plan of Addis Ababa (2002-2012), road hierarchies are classified into five:

1 Express way (the ring road 40m width and above) with controlled access and high speed;
2 (PAS) Principal Arterial streets above 30m width (East –West, and North – South axes);
3 (SAS) Sub-arterial streets 20m – 25m width;
4 (CS) Collector streets 15m-19m width; and
5 (LS) Local Street (<15m width) and other exceptions such as Bole Michael to RR foot Bridge.

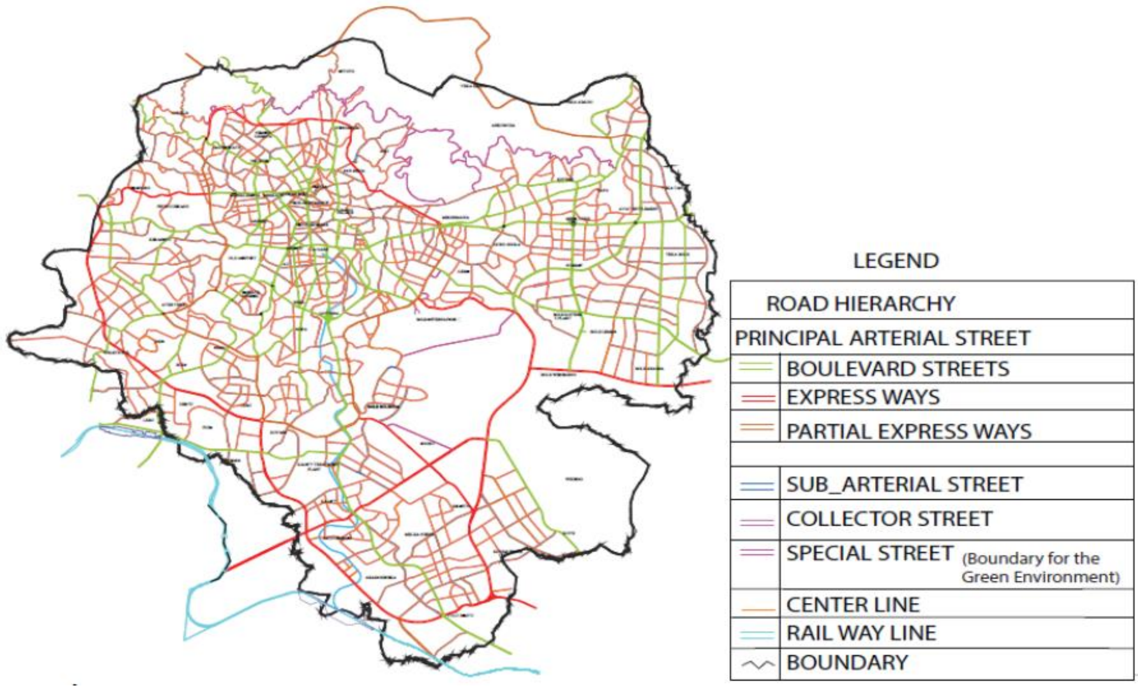


Fig 4. 2 Addis Ababa road network hierarchy.

Source: Addis Ababa Road Transport Authority Master plan.

Table 4. 1 Constructed Vehicular road coverage.

Road Hierarchy	Length of Varying width (KM)	Length in terms of 7m width (km)	No of bridges
Arterial	250	336	93
Sub Arterial	95	133	34
Collector	151	181	44
Local	167	167	30
Total	336	817	201

Source: - Addis Ababa City Road Authority

The total roads of the city (of 7m width and above) are 3,731km. Out of these 1,807km (48.4%) is asphalted, 1,777km (47.63%) is gravel and 147km (4%) is cobblestone. There are currently around 214 roads of arterial level (PAS and SAS) that structure the city. The total length of the major roads (PAS, SAS and CS) constructed in the past ten years is about 468.63km. 38 major roads were proposed by the pervious city development plan to be built in the planning period. Out of these, 42% have already been implemented (constructed). The rest either under construction, under design or in the process of entering into contracts. Few have yet to be implemented. At present, the existing road density is below the universally accepted standard of 25%. Road density of the total built up area is about 13%. On the other hand, the total urban space is about 54,000ha. This makes the gross density less than 10%, and the area covered by road is about 5199ha. The road infrastructure is insufficient and not comfortable for smooth vehicle movement. Most of the intersections are very narrow and prone to traffic congestion.

Addis Ababa is linked with the surrounding towns and beyond mostly by single-legged roads, except for the southern (a new toll road) and western corridors (an alternative road via Tatek). The south outlet carries about 73% of incoming and outgoing traffic, and is connected by a toll road that extends to Adama. Contrary to the areas along these regional outlets, those rural and suburb areas located inside and far from roads (although out of Addis) have not benefited.

4.1.1 Public transport services providers in Addis Ababa

There are few public transport companies this are ACBSE, Sheger public transport enterprise, Alliance bus and Public Service

4.1.1.0 ANBESSA city bus service enterprise

With a motive to provide public transport service in Ethiopia, ACBSE (Anbessa City Bus Service Enterprise) was started in 1933E.C. currently, though the enterprise has large coverage in and around the city of Addis Ababa, it faces a lot of challenges in providing adequate service, service satisfactions of its customers. Thus the enterprise has a burden to maintain a good quality service.

As of 2016, the service is provided from 3 central depots, 4 bus terminals, 124 routes, 29 check points and 1,640bus stops throughout the city. The numbers of buses operating are fluctuating due to maintenance problems. As of the same year, the company has an active fleet of 623 buses. Among these there are 253DAF, 219 Bishoftu rigid buses with a seat capacity of 30 passengers with 70 standing and 151articulated locally assembled buses with a seat capacity of 50 passengers with 100 standing.

The enterprise dispatches the buses from Legahar, Merkato, Piazza and Megenagna stations. It also has four service centers at Yeka, Shegole, Makanisa and Akaki on construction, where there are workshops, gas stations, stores and offices. Anbessa gives bus transport service for the city of Addis Ababa and the surrounding areas from 12:00AM up to 3:00PM. These buses cover a collective distance of 121,000 km daily and provide services to 132 million people per 2015/16 year.

SHEGER public transport enterprise

Sheger Mass Transportation Service Enterprise was established with a view to addressing the acute shortage of transport service in Addis Ababa City Administration at a cost of two billion Birr. Features of the Sheger express bus include ease of access for elderly, physically challenged, pregnant woman and children air conditioning and a GPS. Passenger can expect a faster commute, with buses arriving at limited stops about every 10minutes. At the moment, the bus travels around 29,000 commuters per day using 48 buses and it is planned to increase the number of buses to 300.

Alliance bus

Alliance transport service S.C was established in 2009 and has 2,100 shareholders with 35million birr in paid - up capital, bought 25 buses, at a cost of 36 million birr, before tax. Half of the cost was financed through a loan from dashen bank. Alliance is the first and only private city bus to join the sector and deliver transportation services for 17 different routes in the city. The current service of the company was faced problems like serving commuters out of known routes, contract service works and a decrease on the number of buses. Government is subsidizing private companies (Alliance transport service Share Company) investing on public transport to introduce 300 new buses. Alliance buses transport about 11,072 travelers every day.

Public service

Transportation service for federal and Addis Ababa city civil servants was launched 410 buses, which transport civil servants to and from work, provide a paid service for the general public during the rest of the day (morning and evening time). Lack of transportation service has been a critical problem in Addis Ababa city. It is very common to see people queuing up for a long time on the main roads of Addis as they try to race for time. This was particularly a source of worry for civil servants who had to report at their offices on time and provide services to clients waiting for them. The public employee service is working on 263 routes. The 51 lines working during morning time and 32 lines in the evening are travelling 31,000 passengers per day. Apart from giving services to civil servants, the bus is working on 56 routes and transporting 30,000 passengers using 156 buses. In general, the public service is giving services for 61,000 passengers per day.

The LRT

The LRT (electrified light rail transit) has a total length of 34.25 Km (North-South line 16.9km and East- West line 17.35 km). These two lines (N-S & E-W) use a common track stretching for about 2.7Km (Higher Court- Stadium), and total passenger capacity is 60,000-80,000 passenger per hour. Based on passenger transport survey, the passenger flow of East-West route in Addis Ababa LRT is estimated to be 734.4 thousands persons/day and 536.9 thousands person/day in the North-South direction.

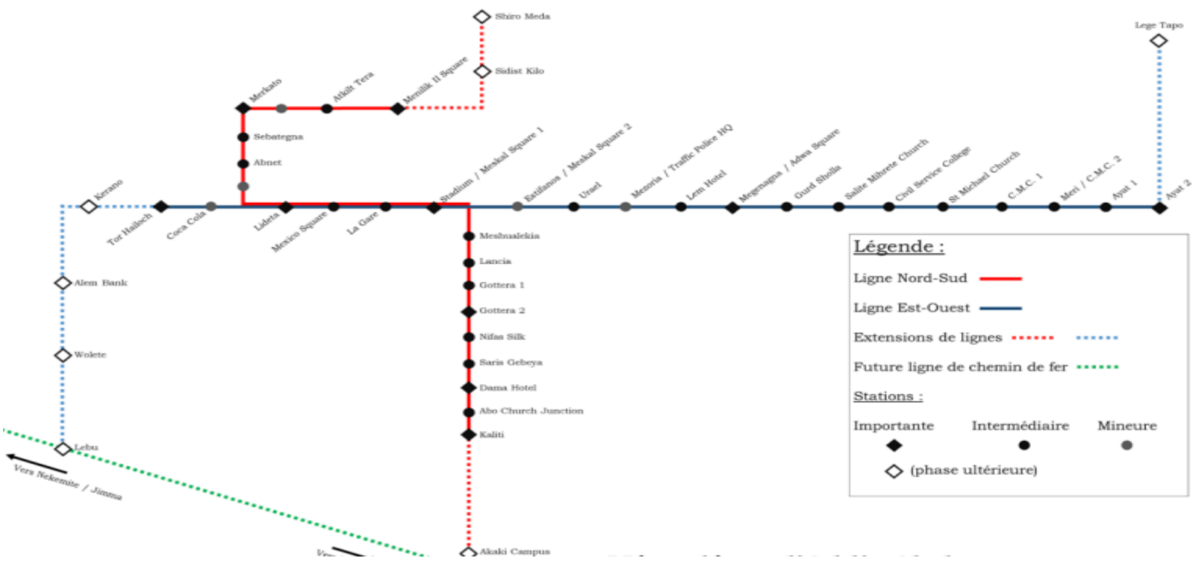


Fig 4. 3 Electrified light rail transit line.

Source [93]

Sheger Mass Transport Enterprise

The Sheger Mass Transport Enterprise was launched to provide public transportation service on free trial on May 28, 2016 with 10 buses for 10 days. During this period, 112,000 passengers were acquiring the service on the route from Mexico to Shiromeda. Each bus is 12.5 m in length with a capacity of 70 passengers - 40 seated and 30 standing. The buses are equipped with global positioning systems (GPS), security cameras, televisions, e-ticketing and other facilities to help passengers with disabilities, pregnant women and children for entering the bus easily

4.2 Mode of transport in Addis Ababa.

Addis Ababa has many different modes of public transport. These include Light rail transit, governmental owned bus, salon taxi and mini-bus. Some public transport services are run by private companies or public corporations wholly owned or partially owned by government. Competition exists between different public transport modes. These individual modes charge different fares and provide different levels of service to passengers. Public transport operators (minibus and salon taxi) run their business without any government direct subsidy. They need to generate sufficient revenue to cover all their expenditures and to survive they need to be profitable.

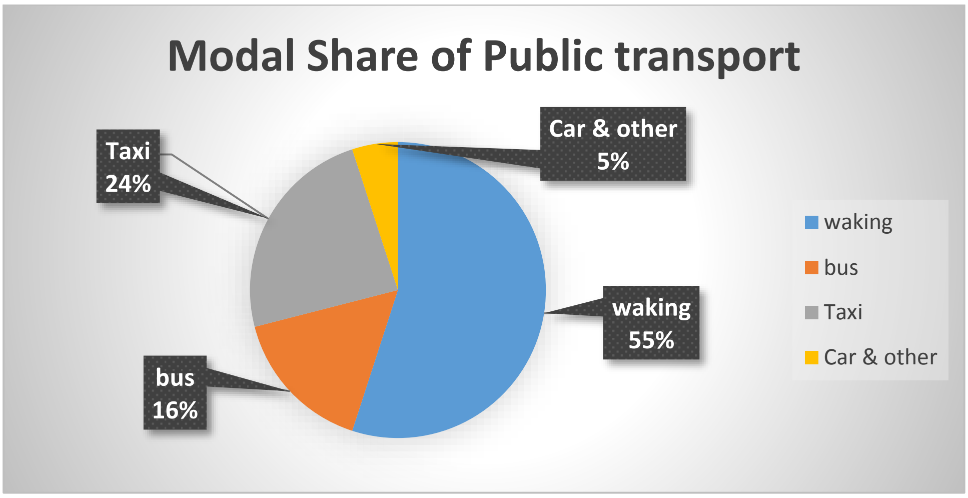


Fig 4. 4 Public transport share

Source Addis Ababa transport Authority report (2018)

Walking constituted the largest modal share in 2005 (60.5%). According to the household survey by CES, average walk trip is estimated to be 1.49km (CSA, 2005). Walking was still the dominant mode accounting for 55% of modal share in 2011.

According to travel demand projections, the share of walk trips is estimated to be around 45% in the year 2020.

In Addis 2.2 million people in Addis Ababa are using public transport of which 4.3 million trips happen in the city on daily basis. The modal share service providers is shown in the figure 4.9 At present, there are 8,500 minibus taxies, 442 midi buses, 1006 Anbessa city-buses and other 6,000 support vehicles that provide public transport service in the city and its immediate environs. Fleet availability has declined from 85% ten years ago to 64%. Due to various reasons, only 650 of Anbessa busses are presently working in 119 different routes. Maximum passenger carrying capacity of Anbessa city bus ranges from 100 to 150 persons. Recent data from Addis Ababa City Road Authority (AACRA) and Transport Bureau shows that there are about 488,028 passengers per day travel by Anbessa city bus, and a slightly smaller amount (479,182 passengers per day) by mini bus taxis. Nonetheless, the overall public transports system in Addis Ababa.

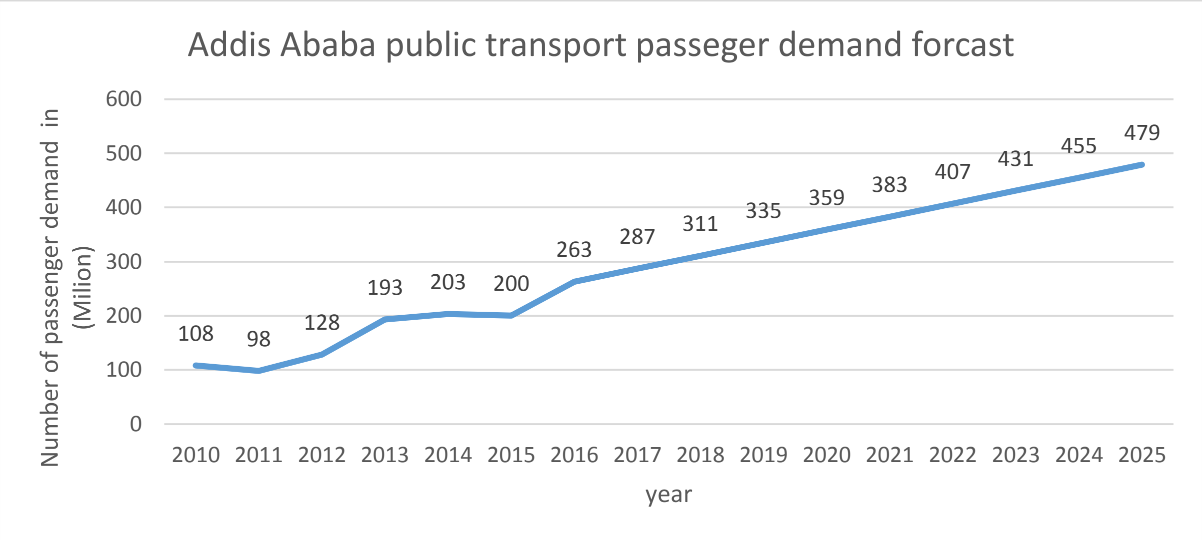


Fig 4. 5 Addis Ababa Transport forecast.

Source: Addis Ababa Transport Authority 2018.

public transport demand is increasing from previous. we can see the trend in Fig 4.10. Demand of Addis Ababa transport depends on time of the day as shown in fig 4.11Ababa is critically inadequate to provide service for the existing travel demand. The modal share of private car in Addis Ababa is 5%, as the number of private cars reached 40,344 in 2011 (CSA, 2011). The car-people ratio is estimated to be 17:1000 in 2016 as there are a total of 200,000 cars in the city

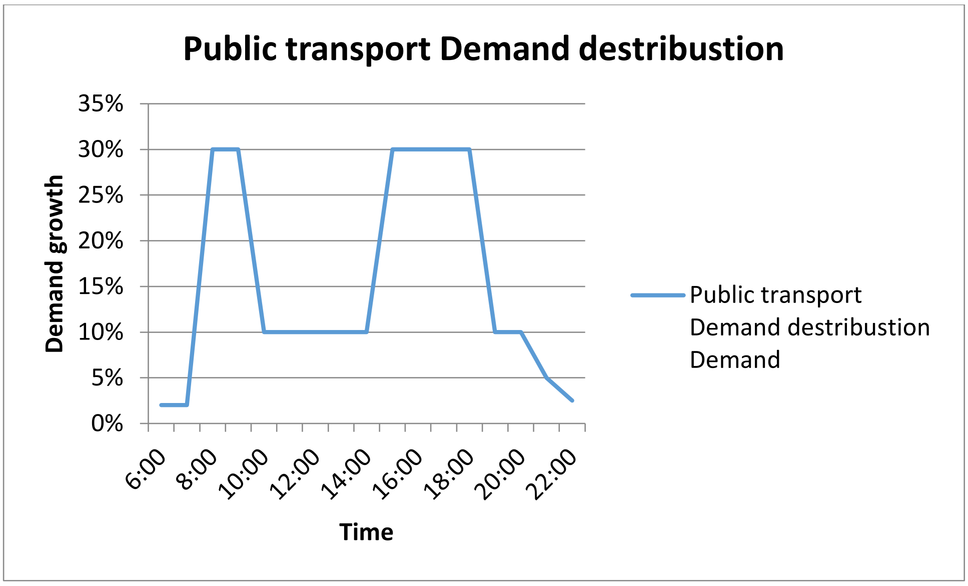


Fig 4. 6 Public transport demand distribution through time.

Source: Addis Ababa Transport Authority 2018.

4.3 Existing Services in Addis Ababa

Social services are one of basic criteria for modern city. Addis Ababa has many social service centers. Some trips are generated with the need of this social services. Specially recreating events are one of the cause of transport congestion in Addis Ababa.

4.3.1 Educational Service:

According to data obtained from the Educational Bureau of Addis Ababa, educational services were being provided by 1000 kindergartens, 767 primary, 188 secondary, and 85 preparatory schools as well as by 380 colleges & TVETs and five higher educational institutions in 2012. The majority of the schools in the city (76% of the KGs, 61% of the primary, 46% of the secondary, 51% of the Preparatory, 85% of the TVET and 91% of the Higher Institutions) belonged to the private sector. This is due to government policy to encourage the involvement of the private sector in the provision of education services. Data obtained from the same source showed that a total of 755,928 students were enrolled, including those in KGs (118,840), primary (484,517), secondary (109,731) and preparatory (42,840) schools in 2012.

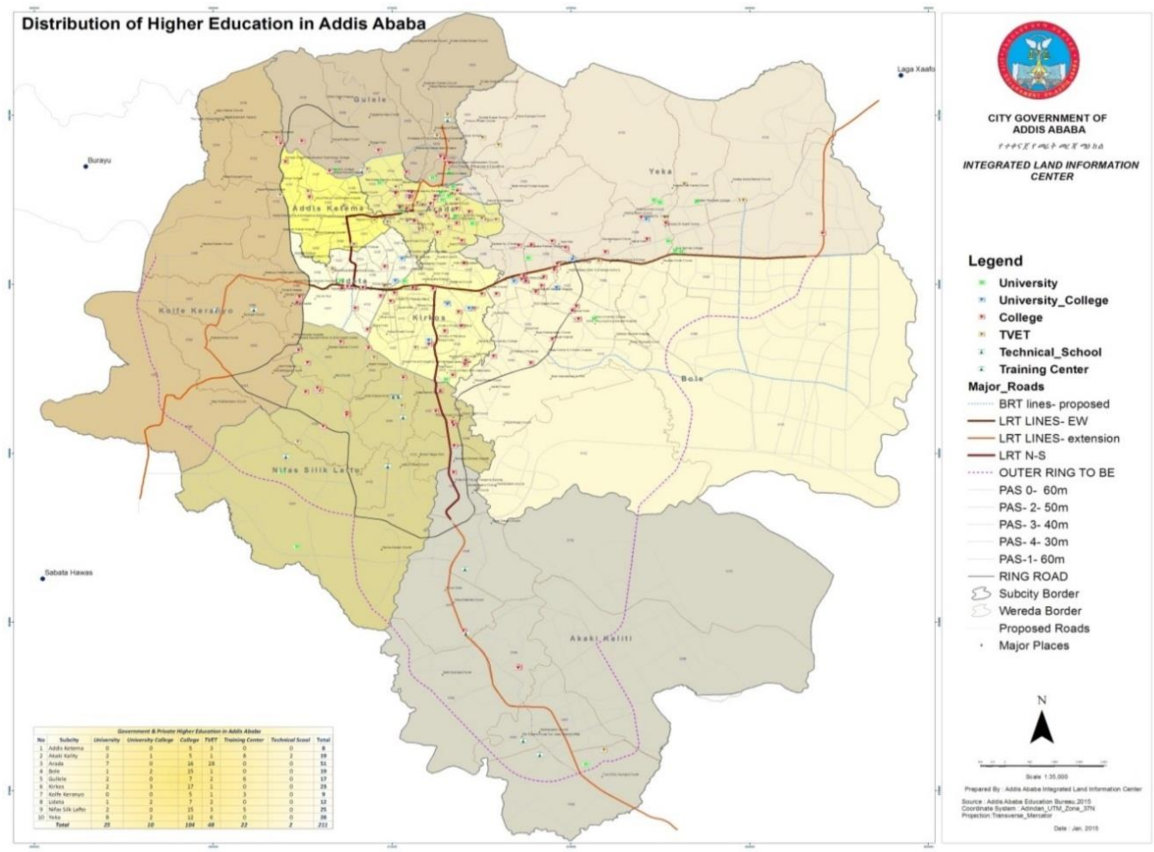


Fig 4. 7 Higher Education distribution in Addis Ababa. Source [87]

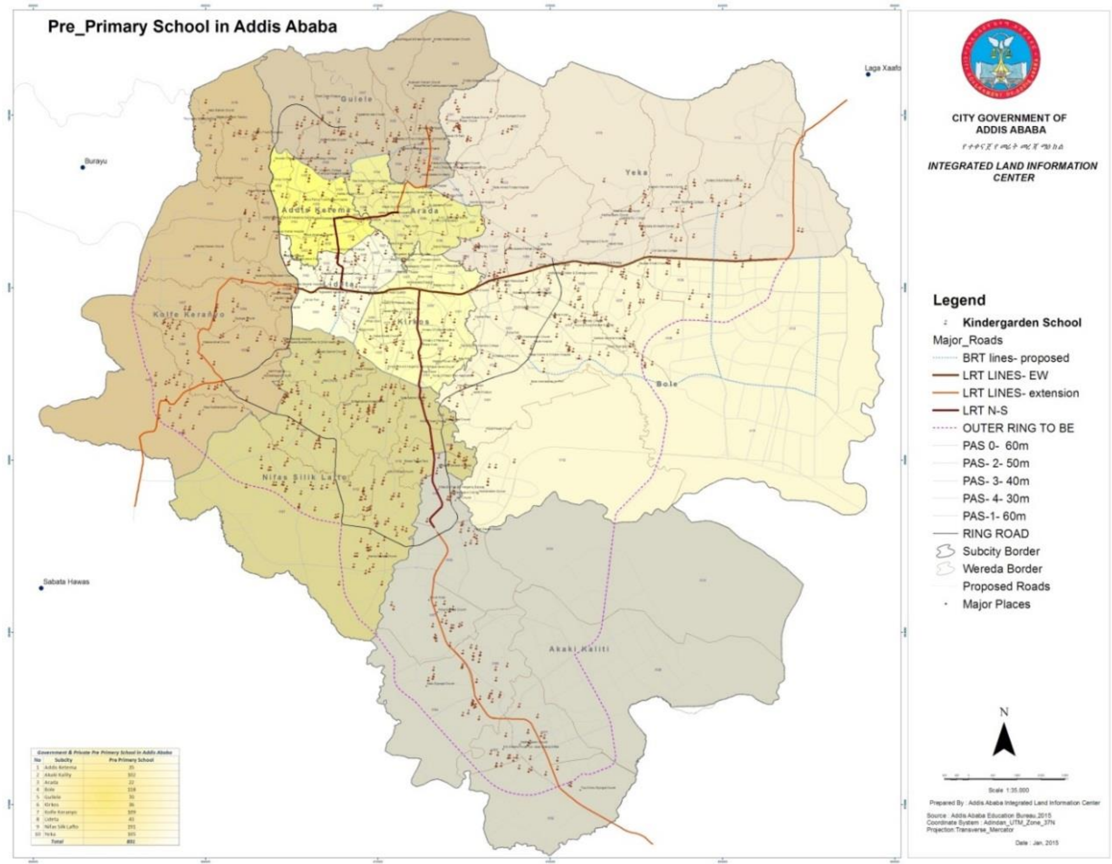


Fig 4.13 Pre-primary school distribution in Addis Ababa. Source [87]

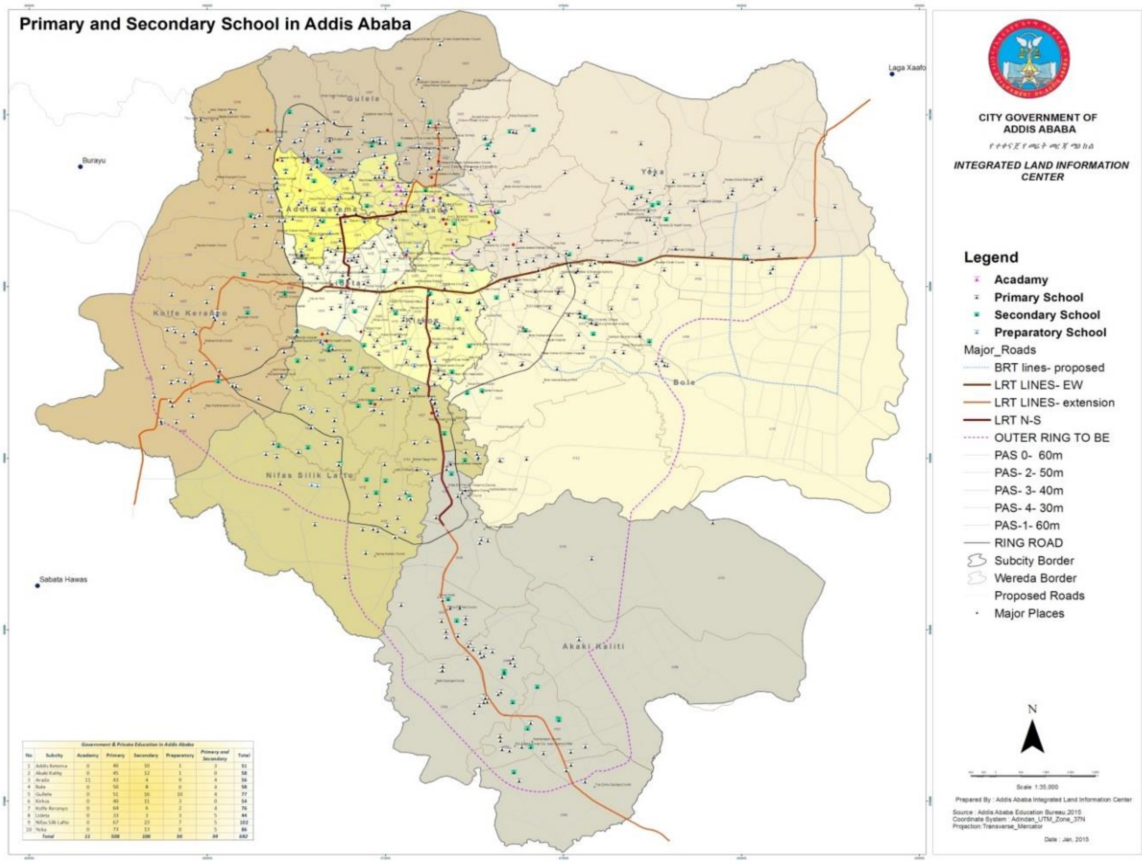


Fig 4. 8 Primary and secondary school distribution in Addis Ababa. Source [87]

There is generally a more or less uniform distribution of schools as calculated by the school-population ratio at the sub-city level. Lideta and Addis Ketema are the exceptions. When disaggregated by grade level, the distribution appears to be uneven especially in case of secondary schools for which the ratios vary from the highest in Arada Sub-city (1:12,091) to the lowest in Lideta Sub-City (1:64,488).

4.3.2 Health Service

There were in total 48 hospitals of different levels in 2013 of which, 36 were privately owned. Out of the 48 hospitals 5 (all of which are government owned) were Specialized Hospitals (Black Lion, Torhailoch, St. Paulos, Amanuel, and St. Petros Hospital), whereas the remaining 43 (which include all of the 36 privately owned hospitals) were General Hospitals. The seven General Hospitals that belong to the government are Ras Desta, Yekatit 12, Ghandi Memorial, Zewditu, Balcha, Police and Tirunesh Beijing. Even though these hospitals provide city-level service, the concentration of most of these hospitals in and around the centre makes them far from some parts (esp. expansion area settlements)

In addition to the hospitals, there were 96 government health centres (only 70 were functional, while the remaining 28 were under construction). There were also a total of 676 privately owned clinics of different level: higher level (138), medium level (259), lower level (159) and special clinics (90), and dental clinics (29). In addition, 293 pharmacies and 235 drug vendors were providing service (AACAHB, 2012). The majority of the general hospitals and almost all of the lower level health institutions (clinics, pharmacies and drug vendors) belong to the private sector and this has created more access to health service at neighborhood level, even though affordability is always an issue.

4.3.3 Sport Facilities

Currently, there are about 359 sport fields of different type in the city which include football, volley ball, basketball, ground tennis fields, gymnasiums (AACGSC, 2012). The figure on sport fields includes all facilities which are found in government institutions, schools, and military camps. In addition, there are three stadiums (i.e. the Addis Ababa Stadium, Abebe Bikila and Akaki Stadiums). The first two are equipped to hold international competitions, although their standard is low compared to other stadiums in Africa. The Akaki Stadium, even though it occupies a large plot, does not have any facility. At present, efforts are underway to upgrade the Akaki Stadium.

4.3.4 Worship and Cemeteries Places

Orthodox, Protestant and Catholic Christians, and Muslims are the major religious groups in Addis Ababa. According to data obtained from the Land Development and Administration Agency of Addis Ababa City as well as from religious institutions, the total number of worship that existed in 2013 was 723. Some religious groups have very large number of worship places as compared to the number of followers they have. Worship places are also being constructed in areas not reserved for religious functions. Shortage (for some religious groups) and uneven distribution are also existing challenges.

4.3.5 Housing

The magnitude of the need for social services and infrastructure such as housing depends, among others, on the size of the population and its growth. The population of Addis Ababa will reach at least 4.4 million at the end of the plan period. Since urbanization is unavoidable particularly in light of the transition the country is making from a predominantly rural towards an urban-based economy, one of the immediate challenges is "how to provide affordable and adequate housing within a liveable environment". This chapter presents a short summary of the housing strategy of the plan for the next ten years.

4.4 Existing transport problems

As per Addis Ababa city Administration transport authority report there are three Major Addis Ababa city transportation problems these are congestion, Mobility and traffic accidents. Congestion is related to the other two major problems mobility and traffic accident. The negative impact of traffic congestion is huge in Addis Ababa. Constraints in road transport infrastructure, lack of efficient public transport system and increase in private vehicle ownership have all contributed to high traffic congestion. In addition, the city is facing problems of road traffic accidents and air pollution.

The growing usage of motorized private vehicles coupled with the increasing congestion levels led to increased fuel consumption, thereby making the transport system expensive and economically unsustainable. The multi-dimensional effect of lack of integration between urban land use and urban transport has given rise to unnecessary trips, congestion, costly fuel consumption, pollution and low productivity. This is also partly due to poor transport planning and implementation.

4.4.1 Traffic Congestion

According to road transport authority report of 2019 by average every Addis Ababa city population spent four hour in road traffic every day . The current situation of Addis Ababa traffic congestion can be seen on figure 1-2. Studies shows when the level of traffic congestion increases availability and frequency of public transport facilities such as buses and taxi will decrease therefore long queue will be crated at waiting stations. This can be shown in fig 1-3.Another finding of data collection and observation is that, the level of congestion at morning pick hours from 7:30 to 4:30 and afternoon 17:00 to 19:00 is high. Collected data and studies show 45 % congestion starting points are bottlenecks such as such as roundabouts and road intersections. This phenomenon is occurred due to every Addis Ababa city population activity starting and ending time is the same. If the activity of the city population spread through time and space level of congestion will be decreased. Other cites traffic congestion pattern where the same as Addis Ababa but they solved the problem by spreading the population through time and space.

Traffic congestion data of the city is collected with Google map, field observation and interview of Addis Ababa traffic management employees . Data from Google map is counted in one hour interval of every seven day. The data is then categorized into highly congested road and moderately congested roads. Summary of collected data can be shown in fig 4.15 and fig 4.16.Sample collected data is shown in fig 7.4 .and 4.16 . Full traffic condtion data of the city is found at in the appendix A of this paper. The data shows number of congested road is decreased and increased as a function of time. The other collected data is cause of traffic congestion . As per the number of counted data 45 percent of traffic congestion is started at round about and road intersection (bottleneck roads) . This Can be shown in figure 4.14.

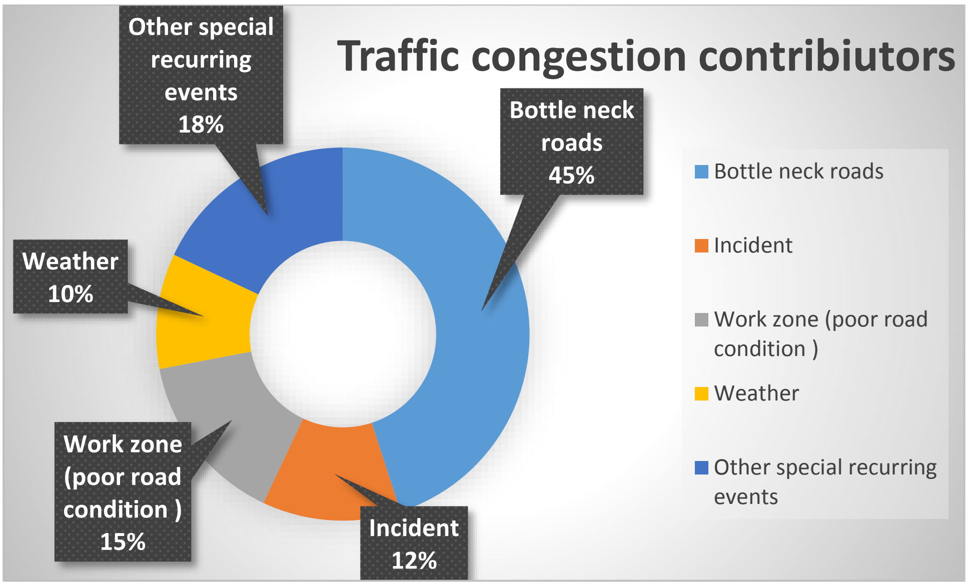


Fig 4. 9 Traffic congestion causes

4.4.2 Relationship between traffic congestion, traffic accident and mobility

The correlation between traffic accident and traffic congestion can be seen in in this literatures [76], [78],[77],[55]. In Addis Ababa the relation sheep between traffic congestion, mobility and accident are high. From field observation and interview of Addis Ababa traffic management Employees below relations are observed

1. Measures taken to reduce traffic accident increase traffic congestion. Roads with speed brakes are one of the means to reduce traffic accidents in the city. This speed breakers slow create traffic congestion at peak hour. The other problem on of speed brakes is they are not suitable for patents in emergency ambulance.

2. In congested roads minibus taxi drivers are not willing to give transport service to passengers in some congested roads this will create more queue for minibus at waiting station. Some drivers of mini bus take another Alternate route and they will increase the price of that specific root . When price of root is increase passengers will be dissatisfied this is creating conflict between the passengers and minibus taxi crews.

The other effect of congestion on mobility is as shown in fig 23 more transport service vehicles are unable to move in congested roads this will decrease cycle time of vehicles. The decrease in cycle time of vehicle will add more queue in waiting station. . Low operating speeds lead to low productivity for operators, reducing their gross revenues and recovery of their fixed costs related to the vehicle and of their semi-variable costs related to the road crew. Further, traffic congestion increases both fuel consumption and wear on the vehicle driveline. Both effects impact negatively on profitability and so lead to the need for higher tariffs.

3. At round about and road intersections specially at LRT stations pedestrians cross the road this situation decrease speed of the car and increase traffic congestion as well as traffic accidents. Some researchers [55] suggest to use underpass in major crossings but the concerned authority is not building this underpass crossing. Underpass crossing will decrease traffic congestion and traffic accident by avoiding crossing of passengers on road. Major cause of traffic congestion has direct relation with other transport problem of the city such as traffic accident, mobility of people, Air and sound pollution.

4.4.3 Traffic accident

The vehicle ownership per capita of Ethiopia is the lowest in the world Opposite to Vehicle ownership car accident is very high in number of fatalities. As per Ethiopian road transport authority Annual report on Dec 2018 4,546 citizens are died, 7,684 severe injure and 1, 189,447,240.88 ETB property was lost in Ethiopian roads [13]. This amount of citizen's life and injury has a major impact on citizen's wellbeing and country economy. One of the interesting information stated on Urban Transport study final report is that about 80% of the total vehicles in the country are believed to be in Addis Ababa only. In case of Addis Ababa the number of traffic accdent by category is shown below Table 4.2

Table 4. 2 Addis Ababa Road Traffic Crash, Injuries & death in the year

Description of Accident	Number
Total Road Crashes	28289
Injury Crash	2905
Injury Victims	3133
Fatalities	478
Property Damage Only crash	24928
Fatal Crashes	456

Source : Addis Ababa road safety Annual report (2017-2018)

The real safety issues with regard to urban transport relate to pedestrians. In order to have safe pedestrian movement, there should be provided with adequate pedestrian cross walks provide. In most of Addis Ababa roads, where sidewalks are provided, it is occupied by parked cars and road side sellers which are obstructing movements of people and forcing them to the roadway. Road crossings are also problematic, with few signalized junctions having adequate pedestrian provisions, but the rest are have no signal. Crossings mostly ignored by motorists; there are very few pedestrian over-bridges and underpasses. Further problems exist at public transport stops and terminals, with inadequate isolation of movements and little consideration being given by drivers.

Fig 4.23 shows the trend in road traffic accident deaths for the last ten years from 2008 to 2018. The number of road deaths increased by one from 477 to 478 the smallest increase in the last 5 years.

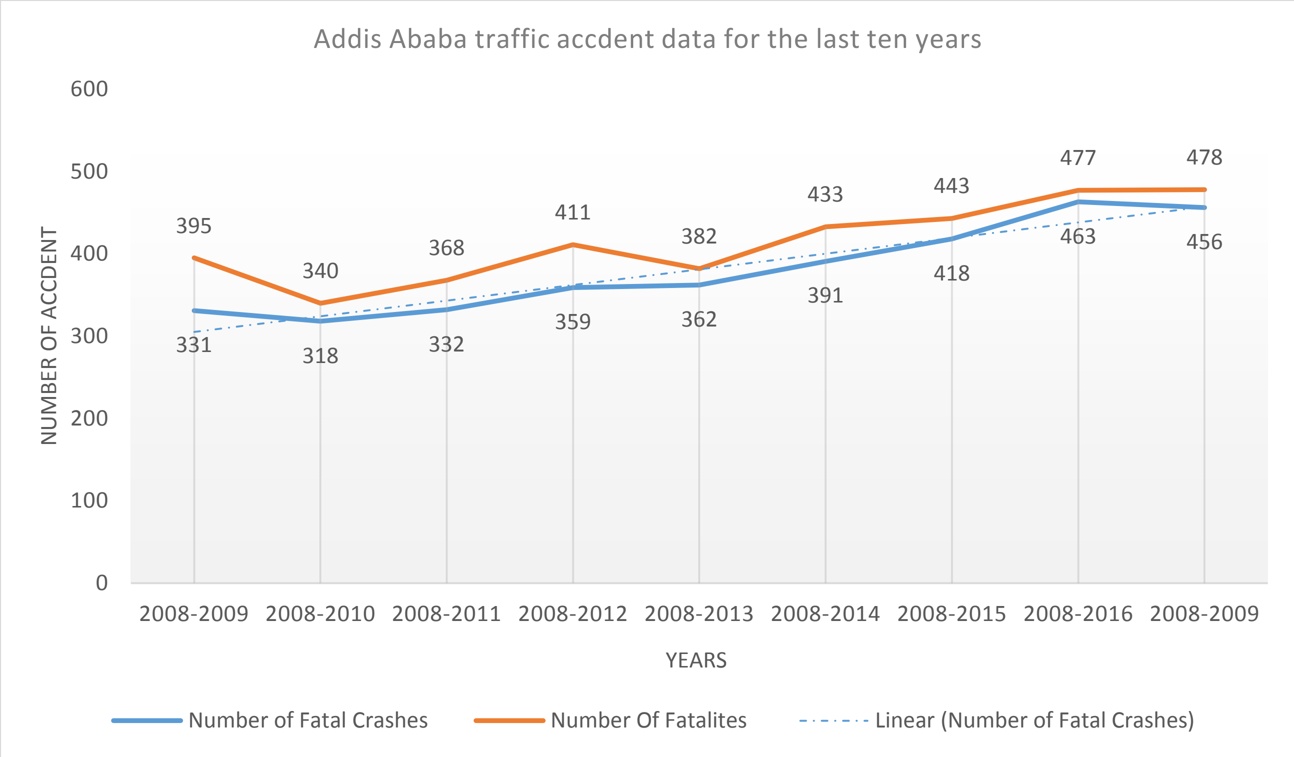


Fig 4. 10 Number of fetal Crashes in Addis Ababa for the last ten years.

Source : Addis Ababa road safety Annual report (2018)

Walking is the main ode of modality in Addis Ababa , accounting for an estimate of 70 % of trips , followed by public transport (26 %) and private motorized transport (4 %). Although the proportion of pedestrians death has dropped from 82 % to 76 % in the past year, Pedestrians still make up the overwhelming majority of fatality . following are 4 wheeled vehicle passengers (12 %), 4- wheled

vehicles drivers 7 percent motorist 5 % . fig 4.24 Prcentage of traffic deaths based on the activity

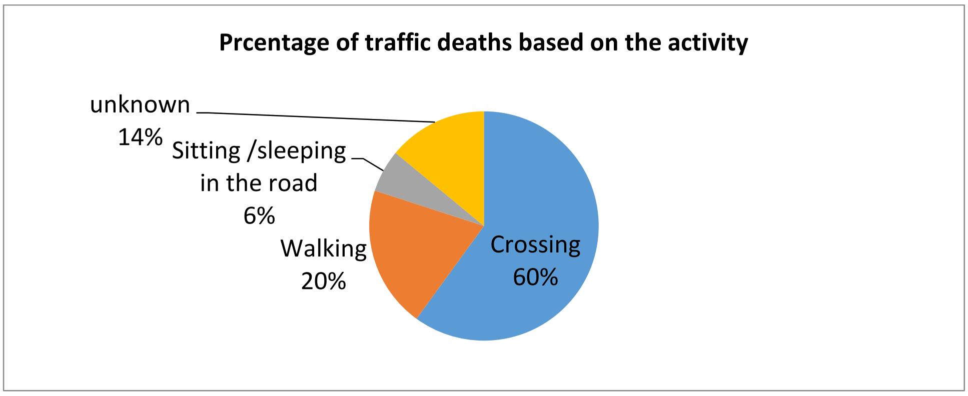


Fig 4. 11 road traffic deaths by road user type 2017-2018 .

Source : Addis Ababa road safety Annual report (2018)

Most road deaths and injures victims were among pedestrians particularly young and middle aged men (78 %) than two-third of fatal and injuries victims are 18 to 54 years old men. Disability and death in this productive and reproductive age have profound social and economic impact. On families .

Figure 4.25 shows road deaths and in by time of the day. Rate increased sharply from 6 am counting into the evening, with a drop starting around 8 p.m. Table in the appendix F shows the relationship between day of the week and time of the crash. The highest number of injuries occurred during rush hours in the morning 6 to 10 am and evening 6 to 8 pm Thursday and Friday recorded the highest number of injuries.

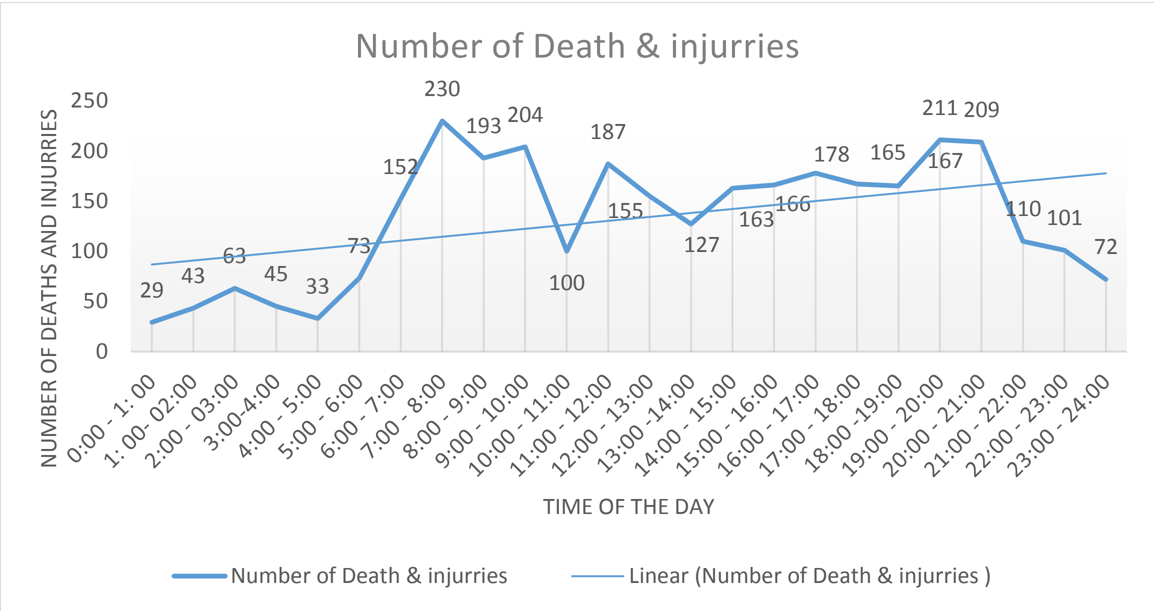


Fig 4. 12 Death and injury by the time of the crash.

Source : Adapted from Addis Ababa road safety Annual report. 2018

60 % of pedestrian deaths occurred while crossing the road, down 70 % in 2017, this may indicate some improvement in crossing safty design and speed interventions in the past year. For non-fatal pedestrian injuries ,most (57 %) occurred during crossing but a substantial proportions (39 %) occurred while walking or standing on the road this is summarized in below table 4.3

Table 4. 3 Road traffic deaths and injuries by pedestrian activates at time of Crash.

Activity	Death	Injury
Crossing	60%	57%
Walking	20%	39%
Sitting /sleeping in the road	6%	3%
Unknown	14%	1%

Source : Addis Ababa road safety Annual report. 2018

The most common causal vehicles for deaths and injures was minibuses, which provide much provide much of the public transport in the city. They account for 28 % of death and injuries followed by private automobiles (26 %). For passengers the common causal vehicles for death and injuries was also minibus followed by automobile. For drivers the most common causal vehicles were automobile this data is shown in appendix G.

4.4.4 Mobility problems

Urban population in the developing countries is characterized by lower mobility rates than in the richer countries. While the trips/person/day is higher than 2 for cities in developed countries and high income developing countries, the trip rates is just one for cities of very low income developing countries. Lower mobility rates are related to lower incomes of the cities of the developing countries [88] Mobility rate for Addis Ababa is low and the urban transport study report of Addis Ababa (Ethiopians Road Authority [89] estimated a trip rate of 1.07 trips/person/day for 2005 and projected a mobility rate of 1.4 trips/person/day for 2020. By and large, high poverty rates (50% of the population of Addis Ababa living in absolute poverty), high unemployment rate (28% of the total city's population being unemployed) and high proportion of people in the lower age groups (15% below the age of 10) characterized by weaker mobility could explain the low mobility rate for the city. The total daily volume of trips increased from 600,000 in 1986 to 2.1 million in 2001 (an increment of 250 % in just 13 years), 3.35 million trips in 2005 (an increment of 160% in 4 years) and projected to be 5.6 million daily trips in 2020 (ORRAMP, 2005, & FDRE, 2008b). Most of the trips are generated in the city and occur within the city. Trips to and from central areas of the city including the Sub Cities of Kirkos, Lideta, Arada and Addis Ketema are considerably high [88] In Addis Ababa working hour and school starting time is the same. Transportation facility utilization is not staggered. If public facility utilization is not staggered to the public scarcity will be created . As per observation in Addis Ababa public transport facilities such as taxi will be used by students at working stating time. If working hour or students class starting time is staggered this problem will be eliminated and additional revenue will be generated by taxi drivers.

Table 4. 4 Mode split of Students

Mode Type	Frequency	Percent
Walk	20	17
Private Car	24	20
Taxi	45	37
Anbessa bus	6	5
Higer bus	12	10
School Service	13	11

Source : [90]

In the study area Taxi is the most predominantly used mode for School trips followed by private car, walk, school service and higer the least chosen mode is Anbesa which is (5%) only.

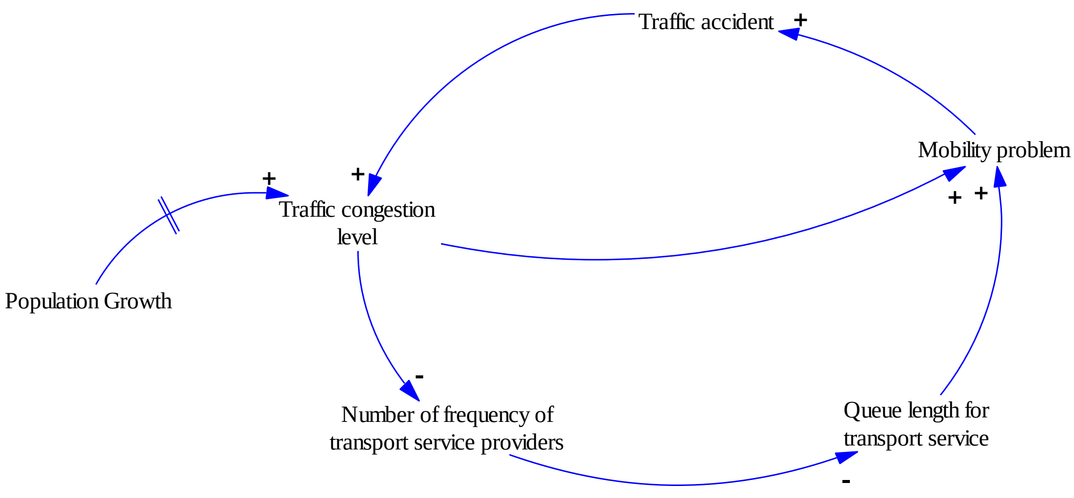


Fig 4. 13 system dynamics diagram Causal loop diagram showing relationship between traffic congestion , traffic accident and mobility.

Source : own diagram drawn by venism software

Fig 4.12 shows behavior of demand management strategy. Demand managements strategies have virtuous cycle behavior and they lead to desired goal or efficient transport system whereas supply side management strategies have viscous cycle behavior this means they solve the problem but the problem will reinforce it self and reoccur again to an endless cycle.

4.6 Barriers for TDM strategy implementation in Addis Ababa.

To select applicable TDM strategy from bench mark city or other city first barriers of for implementation must be identified and correlated to TDM strategy. below discussed TDM barriers collected from primary data and secondary data sources such as interview and documents provided from different Addis Ababa transport service stakeholders.

4.6.1 Poor Service Quality

Most of the problems encountered in the case of a minibus taxi service is overloading. The nominal capacity of minibus is 12 passengers; but during peak hour they load up to 17 passengers. The study on improving transport and the urban transport commented on lack of facilities provided for passengers, both at the terminals and at stops along the routes.

Passenger information is also lucking throughout the system. Most bus stops do at least show the route numbers being served, but there are no timetables or indication of destination for casual passengers. Information standards are better at the terminals and interchanges, but these seemed to attract little interest from passengers. Either passengers already know the system well, or the information provided has proven not to be credible.

Problems with the vehicles centered on their general cleanliness, the condition of their seats, water leaks during the rains, and the attitude of the crew. Focus group discussions identified cleanliness as a very real issue when the vehicle was also used for the carriage of produce or market goods, as sometimes happened in periods of low passenger demand. However, the general standards in the sector are not acceptable, based both on the typical age of the vehicle and a repair culture that tends to focus on its mechanical aspects rather than the passenger saloon.

4.6.2 Shortage of transport infrastructure.

There are many barriers to implement TDM strategies. This Barriers can be divided into 3 essential public transport components this are road infrastructure, Available mass transport Vehicles capacity , effective transport management system and users.

4.6.3 Improper mass transport vehicle management.

Most service providers not operate with full potential. As per March 2019 Addis Ababa Road transport Authority report most of them operate with low capacity due to Maintenance of vehicles . performance transport services in each sub city is shown in Fig 4.20. And Fig 4.21 The chart shows available vehicles versus provided (operated) vehicles in percentage. The available public transport vehicle performance and service quality must be high in order to implement TDM strategies such as push pool strategy.

Concerning the physical condition of the vehicles, this reflects both the maintenance culture in the industry and the lack of effective enforcement capacity at the government level. As the industry is effectively self-regulated, the owner associations could also do more to raise the standards expected of their members

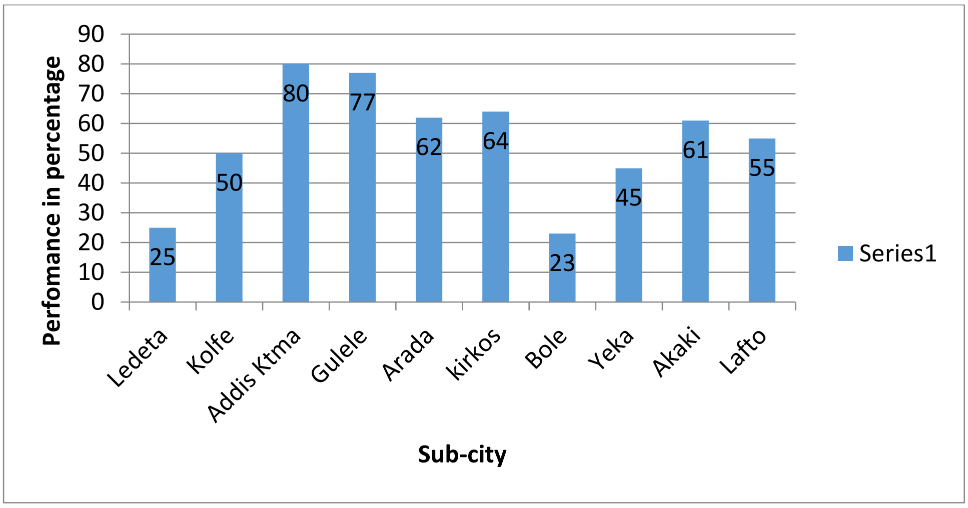


Fig 4. 14 Code 3-taxi Actual performance of March 2019 with the respective sub-city.

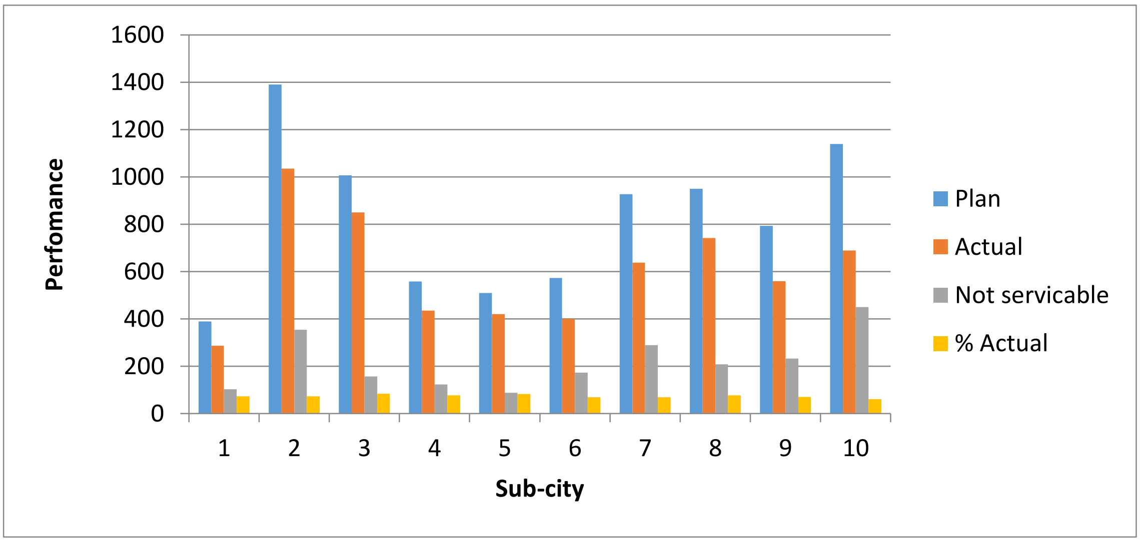


Fig 4. 15 Code 1 taxi Actual performance of March 2019 with the respective sub-city

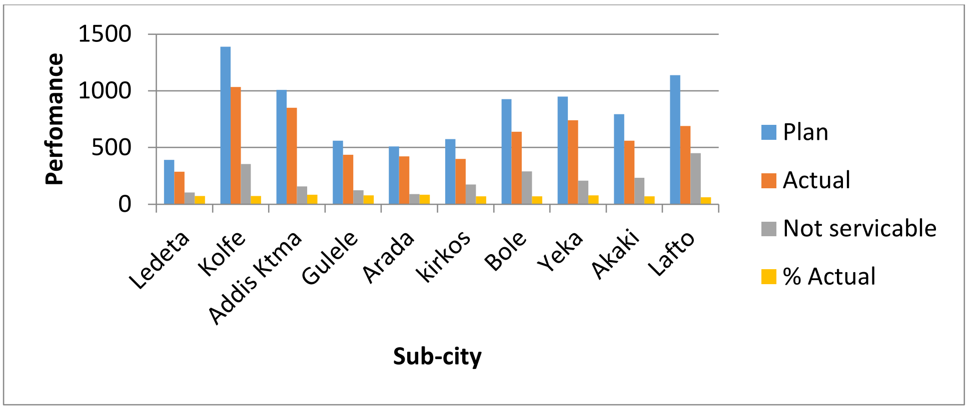


Fig 4. 16 Performance sum for code 1 & 2 taxi , hayger bus, IZUZ and public transport service providers

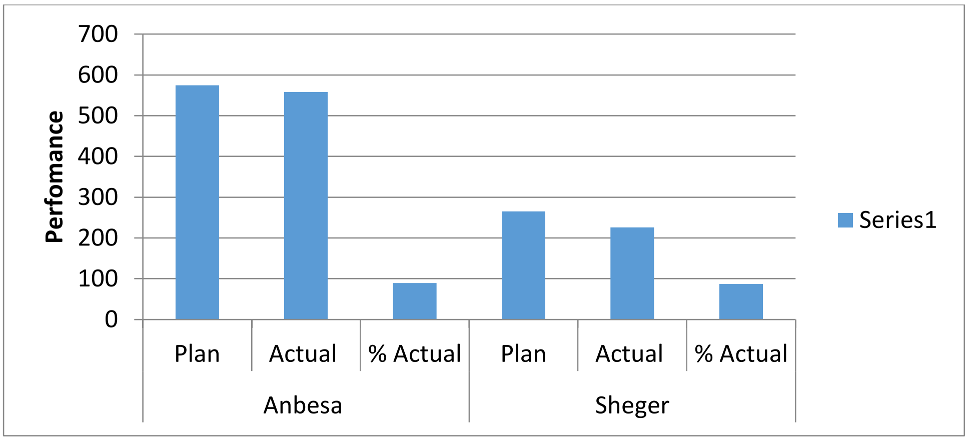


Fig 4. 17 Anbsa & Shger bus public transport providers March 2019 performance.

4.6.4 Poor operating standards and inadequate enforcement

Casual observation indicates a relatively low level of driving standards in the road passenger transport industry, and the urban transport planning study identified that driver indiscipline was a main problem. Driver behaviour, especially in the vicinity of passenger pick-up points and around interchanges, has impacts not only within the sector but also affecting general traffic congestion. Competition between vehicles operating on common routes provides incentives for blocking at the stops and / or aggressive driving in order to reach these first. Vehicles stop in the roadway to allow waiting passengers to board, and sometimes even while a load is being assembled. It is quite common for such behaviour to block the two nearside lanes of a dual-carriageway.

4.6.4 Low Quality of public transport service

the physical condition of vehicles operating in the urban passenger transport industry in Addis Ababa often leaves much to be desired. However this does not only concern their passenger saloons, but also their general mechanical condition. Casual observation of the vehicleparc shows many vehicles with damaged lights and smooth tyres, as well as some with dense exhaust smoke.

AS per collected Data quality of public transport services such as Anbesa, alliance and public bus are not preferable by Majority of the Addis Ababa population. The reason for dissatisfactions Low conformability, Frequency Time is very longer than small minibus, Confined space or loading above allowable limit. During observation of transport system at TORHALOCH as shown in the figure transport users are queued for taxi service for go to Mexico but public transport bus was also calling to Mexico but they ignored it even there is available seat. Some of the users are interviewed why they ignored public bus transport bus they respond that its not comfortable and its speed is low. This shows that public bus providers must work on creating awareness to public and they must increase the frequency of the trip.

4.6.8 Lack of empowerment of transport users

In assessing the problems of the urban transport sector, it becomes increasingly clear that the voice of the consumer is not being heard. They have no representation on development bodies, and are powerless in the face of the operating industry effectively controlled by the marshals. As a result of the latter, they are forced to access services at points that may not be convenient and to use the next available vehicle irrespective of its condition. At times of lower demand, they may be forced to wait an unreasonable time until any service is offered at all.

The introduction of a degree of regulation into the urban passenger transport market would potentially redress the balance of power between the consumer and the producer. Not only could regulations be set in passenger interests, such as the maximum headways on routes, but passengers could also be empowered as a first-level enforcement agency.

4.6.9 Attitude

The scope of 'attitude' in social development issues as it pertains to the plan is limited to lack of sense of ownership and concern. Disposal of waste on roads and rivers, defecation and urination in public spaces, intentional tampering with or vandalism on public and communal property, and destroying green plants, etc. is common in Addis Ababa. This may be linked to lack of sense of ownership or negative attitude towards the 'public'.

4.6.10 Lack of awareness.

Most of respondents say owning vehicle is sign of high social status. Even some of peoples specially young females are not willing to use public transport buses they only want to use taxi (mini bus). From observation (see FIG 4.24) it is visible in the picture that people queued waiting for taxi but public service bus is available with lower price and high safety but they prefer to wait taxi.

Fig 4. 18 Condition of passengers depot at TORHYLOCH

Source: own picture

4.6.11 Low level of standard

The driver of a commercial passenger vehicle of any size is required to have a degree of maturity and experience reflected in a Class 3 license. With regard to the standards expected from road crew, these have no strong basis in law and lack effective enforcement. However the Transport Authority reports that existing licenses can easily be tampered with, and hence that possession of the appropriate license is not a necessary indicator of capability.

Minibuses carry an ‘assistant’ to collect fares and manage passengers, but no conditions are set down with regard to the wearing of uniform or other relevant standards of behaviour. In most cases the driver employs the assistant on a daily basis, with the main criterion for his selection only being his honesty in declaring all fares paid

4.6.12 Low integration between stakeholders

During personal conversation with public and Addis Ababa transport authority, they respond that it is not easy to implement TDM strategies because they need coordination of different sectors. The other reason is the during design and construction of roads and houses this TDM strategies are not considered. Even most of the settlements are not planned. Most the city roads and homes are not properly designed and constructed for adjustment.

4.6.13 Narrow roads

According to Addis Ababa, road transport authority report road coverage of the city is below minimum standard level 30 which is set by master plan other developed cities Experience . Road coverage of the city is 13.5 % which is below standard. The other challenge is Addis Ababa road networks design is not suitable to take options during congestion at pick hour and roads are not wide enough to use lane based TDM strategy.

4.6.14 Inappropriate ownership structures or company size

As has been noted earlier, the large majority of public transport vehicles in Addis Ababa are in single unit ownership with fleet sizes of four or more being extremely rare. Further, in many cases the vehicle owner is a semi-passive investor with no direct involvement in its day-to-day operation. His commitment to the industry is not strong, and he may withdraw from it when faced with major expenditure whether for technical or accident repairs. Not only does such an ownership pattern restrict the likely level of capital investment that may be made, but it also produces incentives for maximizing short-term cash flows.

4.6.15 Suitability of roads for non-motorized mode of transportation

Many modern and attractive cities, both in the UK and throughout Europe, incorporate high levels of cycling. They recognize the benefits that this brings in terms of pleasant streetscapes, simplicity of moving around, and healthy lifestyles. These cities offer a compact yet spacious environment that attracts families to live there.In these cities, where 30 to 40 per cent of journeys are by bike, cycling is a normal, everyday activity. Because the cycle network coexists with the road network, people can still choose to drive for other journeys. Both adults and children appreciate the independence and ease of travel that cycling provides. Cycling is completely mainstream. Cycle transport is negligible; terrain and absence of cycle lanes have contributed to discouraging its use. Lack of attention given to this mode by policy makers and planners over the years seems to have shifted since there are now 3 cycle routes in the city.

With ITDP's technical guidance and support, AARTB has unveiled an ambitious ten-year Non-Motorized Transport (NMT) Strategy to create a better urban environment for all city residents. With ITDP's close partnership, the city is working to make its roads more hospitable to thousands of daily pedestrians, cyclists, and public transport travelers. NMT infrastructure will lead to lower pollution and will better connect people to educational, cultural, and economic opportunities. This NMT Strategy follows a multifaceted approach to street design and management, calling for traffic calming features, larger pedestrian walkways, crosswalks, and cycling paths. These improvements will be particularly significant for children who are currently unable to travel beyond their local neighborhoods due to the hostile road environment across Addis Ababa.

Many modern towns and cities throughout Europe recognize that providing space for cycling creates efficient and attractive places to live. They experience the benefits that this brings, in terms of attractive streetscapes, economic use of land, simplicity of moving around, and healthy

4.6.16 Inappropriate vehicle type and size for the existing demand trend.

Public transport in Addis Ababa is provided by high-capacity standee buses, with a nominal capacity of 100 passengers, or by minibus and modified taxis with a capacity restricted to only 11 passengers. Shared sedan taxis are a very low proportion of the modal mix, and there are no MRT rail services at present.

4.6.17 Administrative Barriers

Most developed cites have integrated city administration system, associations for demand management and designated transport demand management authority. Corrupt practices and inadequate training are some of the challenges of Addis Ababa city administration problem.

4.6.18 Poor urban planning

Poor Market Area Development.

The expansion of business activities has resulted in congestion of existing market places and their spilling over along major roads, impairing traffic movement. Moreover, small trading activities and street vending are mushrooming haphazardly along major streets and around transport terminals. Central market areas, working places are not well connected with residential areas by public transport. People are obliged to travel to city centers and recreation areas which give rise to unnecessary trips. These places are almost always congested by private cars and commercial vehicles during the day. Hence, market and business areas are not suitable areas for walking.

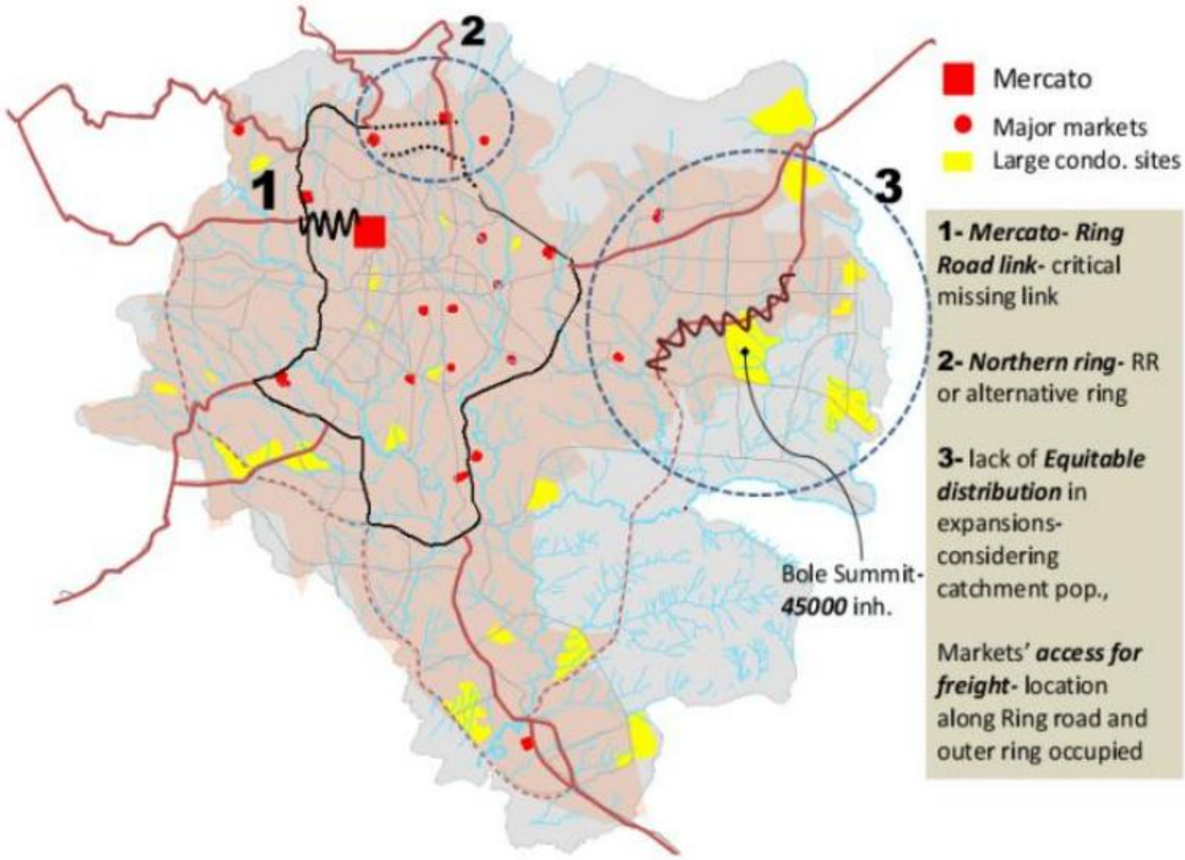


Fig 4. 19 Existing major markets and challenges

Source A.A road transport Authority study 2017

4.6.20 Other problems that aggravate Addis Ababa city transport problem.

Poor level of integration and coordination among authorities on Land Use Policy.

Addis Ababa Master Plan shows spatial segregation of different activities within the city boundary. It is indicated that most of the fringe areas of the city are earmarked as expansion areas mostly for residential development. Besides, even if there are few transport elements given emphasis in the new master plan of the city, the general view shows a very poor level of integration and coordination among authorities as evidenced by the consequences of the land use as well as transport decisions made by the authorities with out consulting each other, from time to time, that resulted in mobility chaos. This could be the result of lack of clear institutional arrangement, specially related to responsibilities, with in the administration. Furthermore, the Federal Transport Authority doesn't recognize land use effects on transport as proved by the policy that gives almost no attention to land use elements that have impact on transport services now and in the future. Thus, the crucial role of cheap and efficient public transport in poverty alleviation purging the disadvantages of the urban poor living at the fringes couldn't be realized. To make matters worth, the land use-transport interaction in the city is made even complex as the result of the involvement of the Oromiya Region and the Federal Authorities in land use allocation and infrastructure provision, respectively.

4.6.21 Air pollution due to customs policy gap.

people prefer to drive cars as long as they afford one, no matter how old it is, rather than taking public transport. This was explained while the interview as most of them replied that car ownership is an indicator of quality of life in addition to the freedom and independence it provides. The policy promotes import of old vehicles by taxing lower price than new vehicles.. More than 60 % of vehicles are 10 years old therefore level of pollution will increase if more old vehiclesn are in the fleet. As per some respondents more old cars are available because of tax system of Ethiopian customs authority policy.

4.6.22 Correlations of TDM strategy with barriers.

To identify which TDM strategy are applicable for Addis Ababa TDM strategy with its barrier has to be studied. TDM strategy that has less barrier is applicable to Addis Ababa. Based on interview , field observation and secondary data from Addis Ababa city transport Authority some barriers of TDM strategy are identified and listed in the above sections . Relationship of TDM strategy with their barriers has identified and summarized in in Fig

4.57. In this analysis TDM strategies which have less barrier will be applicable to Addis Ababa. The other consideration for selection of TDM applicable TDM strategy is their effect in the long run, there effect in environmental air pollution, Economic and cultural background of the city. In Fig 4.6 summarized or categorized form of TDM strategy and barriers is used in order to ease the for analysis. Table 6.1 shows summery of the relationship between TDM strategy and their number of barriers. .

From the above analysis and other consideration such as environmental air pollution, Economic and cultural background of the city and sustainability consideration. The exploded list of this strategy are found in literature review section or table 2.2. By considering above analysis selected TDM strategies theses are staggering school class starting time with work starting time, TDM monitoring, Electronic road pricing, pedestrian improvements, mass rail transit system.

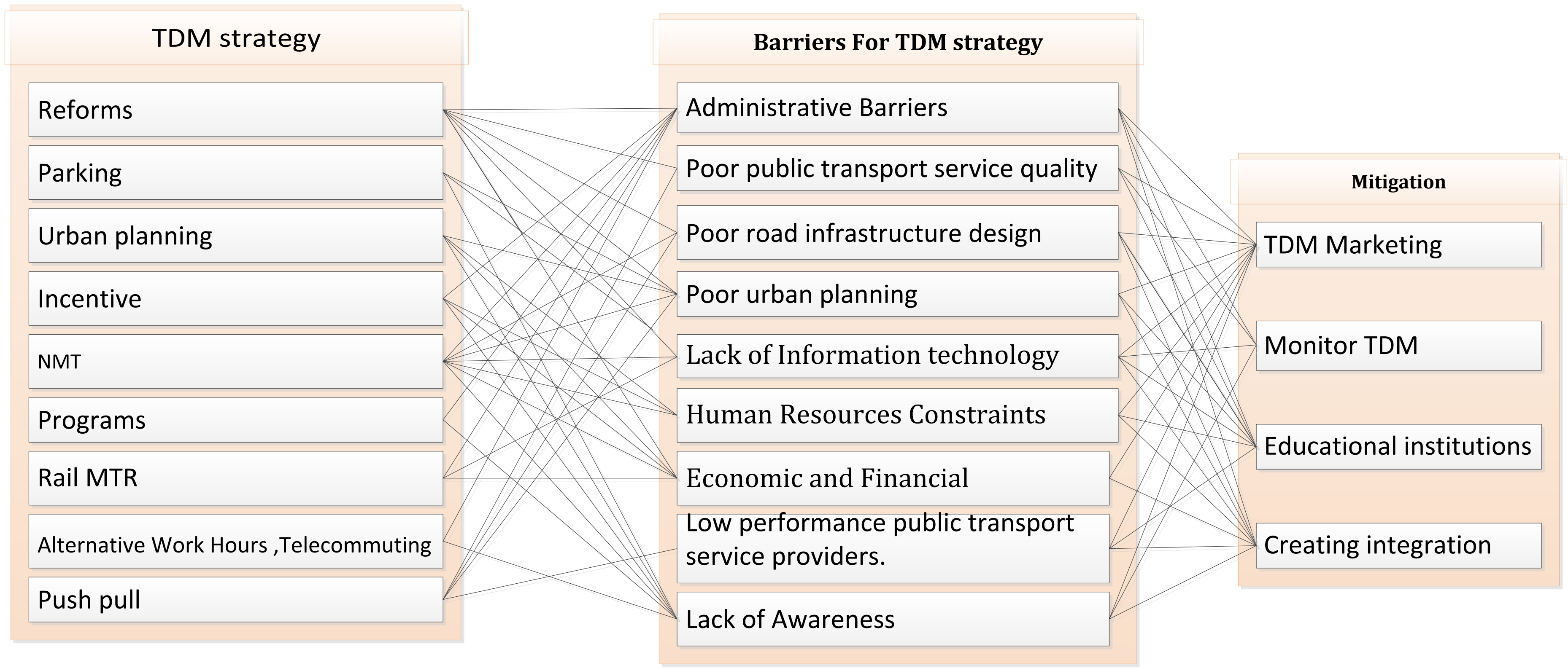


Fig 4. 20 summery of TDM strategy with related barrier and its mitigation method.

Source: own work using MS visio

4.7 Plans and Actions taken to mitigate Addis Ababa transport problem by concerned Authority

To mitigate Addis Ababa city major transport sector problems such as road traffic accident , traffic congestion and mobility Addis Ababa city government authority done a lots projects are launched and some are under implementation and some are not starting. To mitigate traffic accident Addis Ababa city government and Bloomberg initiative for global road safety (BIGRS) ,

4.7.1 Ongoing TDM strategies in Addis Ababa

One of ongoing TDM strategy is dedicated bus lane. The project is at good start up but low level of enforcement is observed during field observation. The bus lane is marked to show it is only used for bus but as shown in below figures 4.27 even some cars park on the dedicated lane. Therefore this observation data shows either parking space is not available for private cars or poor enforcement of TDM strategy.

Fig 4. 21 showing dedicated bus lane and its problem in Addis Ababa.

Source own pictures

Addis Ababa and other cities across Ethiopia are starting to celebrate car Free Day. Car-free days are known to reduce certain types of air pollution by 20 to 78%. [100].The measure was implemented by the government of Prime Minister Abiy Ahmed, who was came to office last April after his predecessor resigned.

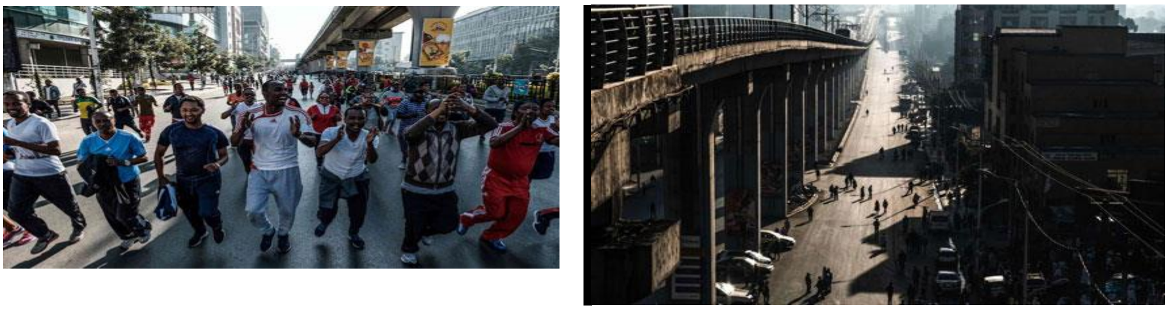


Fig 4. 22 Addis Ababa car free day. Source : Daily nation 2019

Chapter Five

5.0 Data Analysis

This research uses 3 analysis tools. This are qualitative comparative analysis tool, Customized quality function deployment and mathlab analysis. Qualitative comparative analysis is used as confirming mechanism for existence of sufficient condition for implementation of TDM strategy. Quality function deployment analysis is used to measure relative and absolute importance of Selected TDM strategy with respect to transport service sector quality measuring criteria's. Math lab analysis is used to measure and analyze typical traffic condition of the Addis Ababa in different days of the week and different seasons of the year. In put for math lab analysis is online google map data collected.

5.1 Qualitative comparative analysis.

Qualitative comparative analysis is analysis methodology that has independent variable (condition) and dependent variable outcome. Interaction and configurations and relations sets such as sufficiency (If A then Y), Necessity (Only if A then Y). QCA is used in this study to see necessary and sufficient conditions are fulfilled in Addis Ababa to create an outcome of efficient world class transport system.

Necessary and sufficient condition to create best transportation system can be derived from bench mark city (Singapore). The necessary conditions to create best transport system is a combination of the following major transport influencing factors this are city population, size of city , road coverage number of public bus operators and buses , Total number of Vehicle's and Modal share. From table 4.33 it is clear that Addis Ababa has fulfill the necessary conditions than Singapore . Sufficient conditions are less available than Singapore this conditions are implementation of transport demand management strategy.

Table 5. 1 Compression of Addis Ababa and Singapore.

Comparisons of necessary conditions to create best transport system between Singapore & Addis Ababa.						
Necessary conditions		**Singapore**	**Addis Ababa**	**Similarity**	**Sufficient condition for implementation of TDM strategy.**	**Reference for the data**
Population (Million)		5.8	5.43	93.62%	Addis High opportunity with 6%	[23]
Size of city		719 km².	527 km²	73.29%	Singapore higher opportunity 26.71 %	CSA [12], [LTA 2018
Road coverage		12.8	13.5	94.80%	Addis has Higher opportunity 9.2 %	[LTA 2018],[AACRA]
Number of public bus operators.		3	3	100%	Equal	LTA 2018],[AACTA]
Number of public transport buses		19,379	26,408	73%	Addis Higher Advantage 27 %	[AACTA]. [LTA 2018],
Total number of vehicles		957,006	553,938	58%	Addis Higher opportunity 42 %	[LTA 2018],[AACTA]
Modal share	**NMT**	27 %	60 %	45 %	Addis is better by 33 %	[LTA 2018],[AACTA
	Public transport	44 %	40 %	90.9%	Addis is better by 4 %	[LTA 2018],[AACTA
	Private vehicles	29 %	5 %	17 %	Addis is better by 24 %	[LTA 2018],[AACTA

Source : Compiled from different government web pages and official reports .

Though a city's wealth and history define the options for transport system development, its authorities' focus on and commitment to development and implementation of a clear transport strategy can significantly influence the outcome. If wealth of cites neither limit the transport system nor guarantee its success Singapore can be a good bench mark city for Addis Ababa. From top ten cites Singapore is almost the same as Addis Ababa with population size and surface area coverage which is 93.62 % and 73.29 % respectively. The comparison is shown in table 5.1.

The other selection criteria are development time or fastest growing city. Singapore and other Asia country development time is small. Singapore, china and Hong Kong MTR built within 40 years' period. MTR is what is makes common for best top ten city transportation system as shown in Fig 2.3 If we see Singapore city growth its fastest from other cites as shown in in Fig 4.33 Singapore is one of the fastest growing city in the world take this to home and enter it into this. The above comparative analysis result show Addis Ababa has more sufficient conditions than Singapore by average percentage of 19.1 %. Therefore, the necessary sufficient conditions are available what required is the scheduling and organizing of those strategy.

5.2 Quality function deployment analysis.

In this study quality function deployment is required to measure the relative importance of selected TDM strategies. The how part of QFD is filled with customer requirement. These requirements are universally accepted transport customer requirements. These customer requirements are as follows Availability, Efficiency, Convenience, Sustainability. The what requirements are filtered selected TDM strategies theses are staggering school starting time with work starting time, TDM monitoring, TDM marketing , Electronic road pricing, pedestrian improvements, Mass rail transit system. The customer requirements are considered the phase of the travel that is before, during, and after each trip. Before means criteria answers availability of travel options within and outside of the city and how affordable is transportation for residents. During the travel assessed efficiency, defined as speed and predictability of commuting time, and convenience of different transportation system elements. After the travel we analyzed sustainability of the transportation system in terms of safety and environmental impact. Source of other cities status information value a study conducted by [102] target value for Addis Ababa is set from best cities achievements this values are found in Fig 2.1

The availability index represents the set of indicators measuring the variety of transit options available to residents. The overall availability index is split into four sub dimensions: Rail infrastructure, Road infrastructure, Shared transport, and External connectivity. The affordability index represents the relative cost of available transit options compared to average residents' income. The overall availability index is split into two sub dimensions: Public transport affordability, and Cost of and barriers to private transport use.

We defined efficiency as how quickly and reliably a trip can be done by either public or private transport. Convenience complements efficiency to fully describe the quality of service provided by cities' transport systems. The overall convenience index is split into four sub-dimensions: Travel comfort, Ticketing system, Electronic services, and Transfers. Physical comfort during the trip is one of the key considerations for people choosing between using public and private transport.

Sustainability in Transportation system should not only provide a great experience before and during the trip, but also be safe and environmentally responsible.

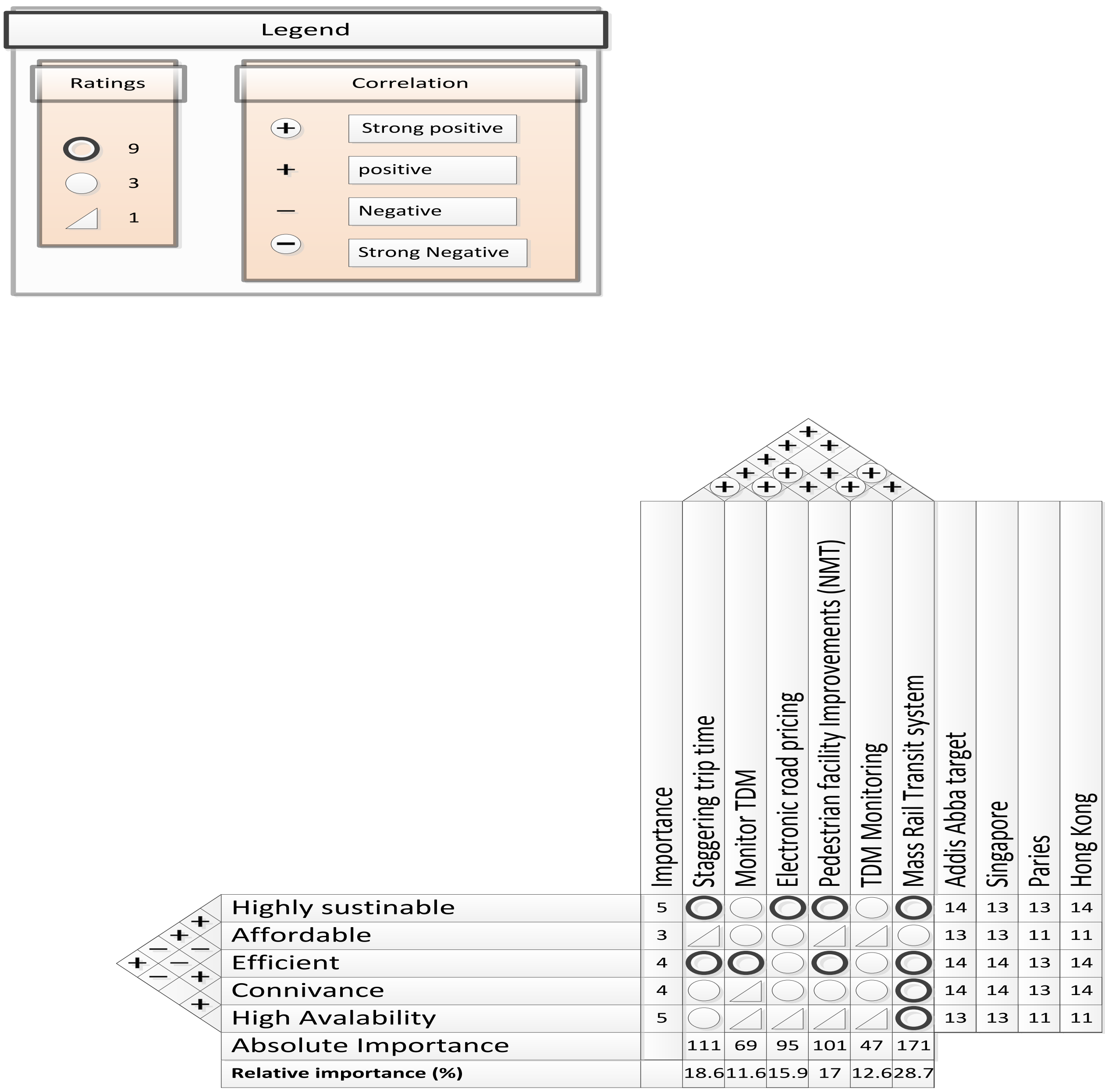


Fig 5. 1 QFD analysis to select and prioritize TDM strategy

5.3 Digital image processing Analysis using Math lab

In this research Math lab digital image processing is used for analyzing traffic condition of Addis Ababa. Math lab digital image processing has many applications such as Medical imaging, surveillance ,robotics, low enforcement such as number plate recognition for speed cameras/automated systems, Finger print recognition Automotive safety ,Customer electronics ,Machine vision and more as shown in the below figure 4.44

Fig 5. 2 Applications of digital image processing in Mathlab.

Digital image processing has 3 levels this are low level process , Middle level process and high level process as shown in fig 7.3 In this research middle level image processing is used to calculate traffic congestion intensity. The analysis is used math lab 2010 software

Digital images are made up of pixels , where each pixel is represented in 2-D as f(X,Y) which is the amplitude or the intensity of the pixel at (x,Y) location. In this analysis Red Green value of Google map data is analyzed. To identify traffic intensity of the map only red value of image used and segmented.

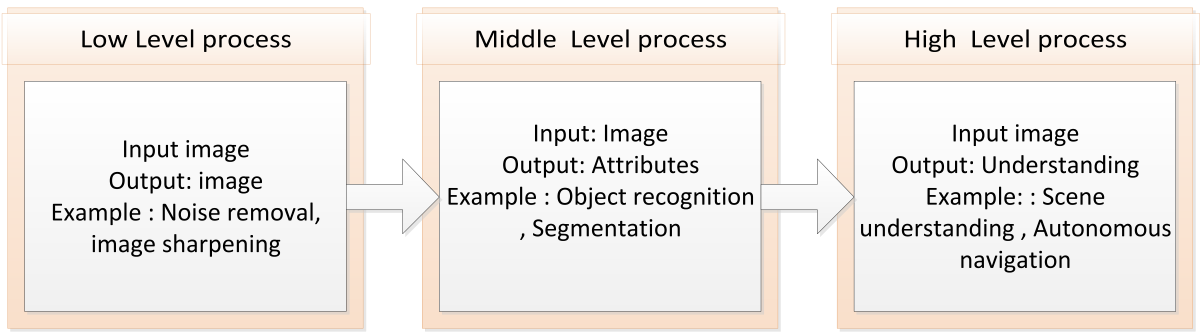


Fig 5. 3 Digital image processing levels.

In this research middle level image processing is used to calculate traffic congestion intensity. The analysis is used mathlab 2010 software

Steps followed during Matlab analysis for traffic congestion intensity.

1. Collect typical traffic congestion intensity of Addis Ababa from Google earth for 17 hours with 1 hour interval for every 7 days a week. Sample Google earth traffic

condition is shown in fig 7.4 to 4.19 and all collected data is shown in appendix of this research.

2. Typical traffic condition is collected from the month June to September and from October to May.
3. Collected traffic intensity data entered into Mathlab analysis to change the descriptive qualitative data into quantitative data
4. Relative traffic condition of each day and is calculated and then compared to each other .

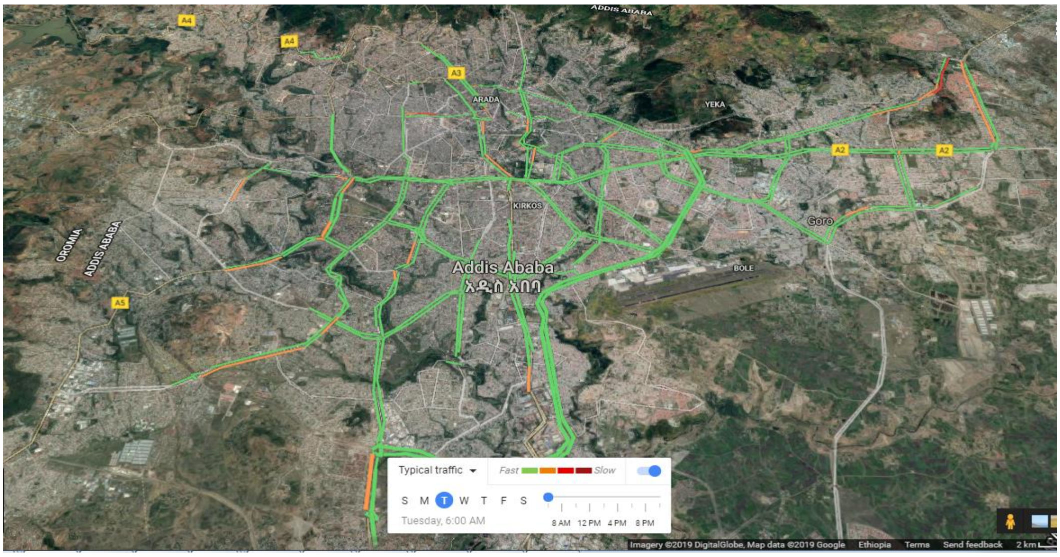


Fig 5. 4 sample traffic congestion condition of the Addis Ababa Monday at 06:00 morning

Fig 5. 5 sample traffic congestion condition of the Addis Ababa Monday at 9:00 morning

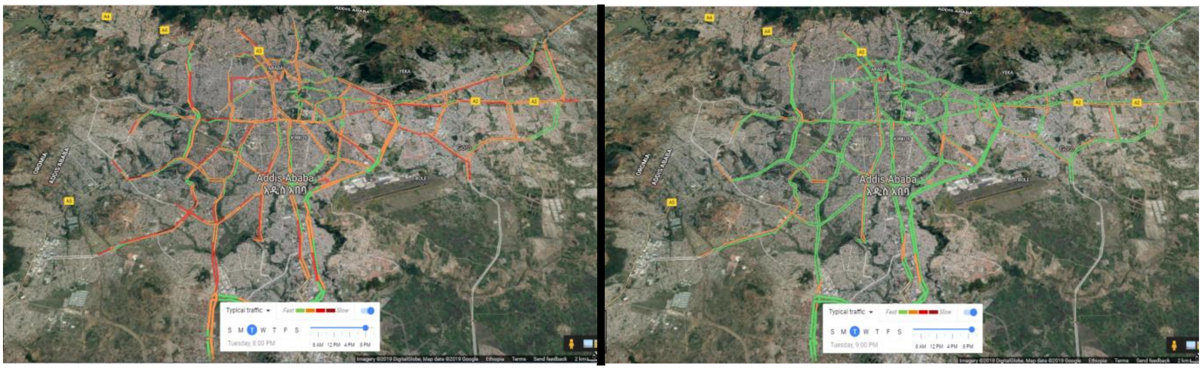


Fig 5. 6 Sample collected traffic condition of the city on Thursday Evening

Digital images are made up of pixels , where each pixel is represented in 2-D as f(X,Yc) which is the amplitude or the intensity of the pixel at (x,Y) location. In this analysis Red Green value of Google map data is analyzed. To identify traffic intensity of the map only red value of image used and segmented.

Table 5. 2 Typical Traffic intensity of Saturday relative other days

Typical Traffic intensity of Saturday relative other days					
Monday	Tuesday	Wednesday	Thursday	Friday	Time
27%	36%	27%	26%	20%	6:00
23%	46%	40%	41%	33%	7:00
14%	32%	34%	26%	31%	8:00
10%	1%	13%	12%	14%	9:00
-7%	1%	9%	4%	2%	10:00
-31%	-8%	-11%	-1%	-6%	11:00
-20%	-23%	-15%	-7%	-4%	12:00
-22%	-20%	-7%	-6%	-10%	13:00
-12%	-16%	2%	-4%	-2%	14:00
10%	0%	8%	18%	11%	15:00
3%	5%	10%	17%	19%	16:00
15%	22%	9%	22%	12%	17:00
-2%	12%	9%	10%	9%	18:00
-31%	10%	16%	7%	14%	19:00
-38%	33%	-1%	26%	-3%	20:00
-70%	-34%	-81%	-87%	-76%	21:00
	5%	28%	26%	42%	22:00
15%	17%	17%	20%	19%	Average
		Average		17%	

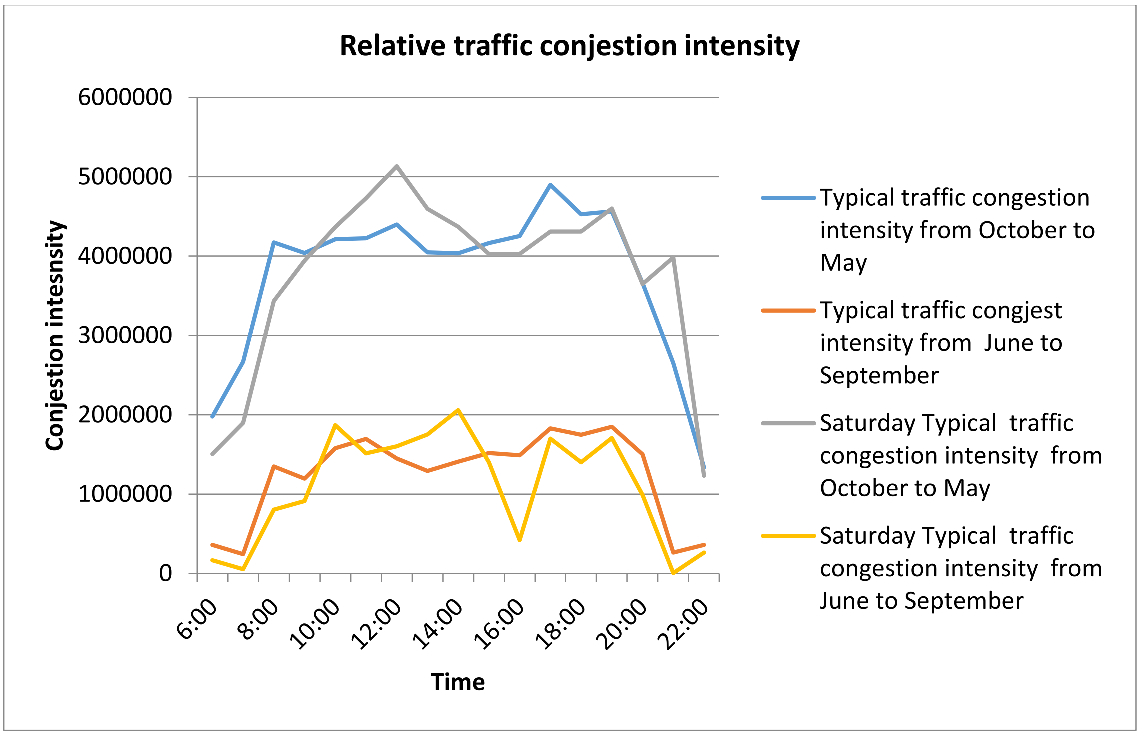


Fig 5. 7 relative typical traffic congestion intensity.

Table 5. 3 Typical Traffic intensity of Saturday relative other days

Typical Traffic intensity of Saturday relative other days					
Monday	Tuesday	Wednesday	Thursday	Friday	Time
55%		59%	51%	68%	Time
42%	-131%	19%	56%	91%	6:00
47%	43%	31%	43%	55%	7:00
8%	35%	21%	18%	42%	8:00
-15%	-3%	-22%	-36%	-48%	9:00
-16%	-12%	23%	29%	21%	10:00
-12%	-81%	1%	4%	-7%	11:00
-172%	-28%	-47%	-13%	-41%	12:00
-40%	-55%	-88%	-74%	-55%	13:00
15%	6%	-15%	12%	20%	14:00
77%	66%	74%	79%	77%	15:00
7%	-23%	4%	29%	11%	16:00
29%	29%	5%	32%	13%	17:00
12%	20%	4%	5%	1%	18:00
25%	54%	40%	10%	44%	19:00
-43%	100%	94%	45%	98%	20:00
-88%	81%	-1%	-45%	-273%	21:00
32%	36%	26%	14%	14%	
		Average		24%	

Table 5. 4 Relative typical traffic congestion intensity of October to May with June to September

Relative typical traffic congestion intensity of October to May with June to September						
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Time
18%	50%	20%	17%	28%	23%	Time
7%	1%	6%	12%	22%	3%	6:00
38%	28%	22%	30%	36%	23%	7:00
23%	35%	26%	25%	34%	23%	8:00
35%	41%	32%	30%	28%	43%	9:00
36%	31%	46%	45%	43%	32%	10:00
33%	21%	36%	35%	30%	31%	11:00
17%	36%	28%	36%	30%	38%	12:00
38%	35%	24%	28%	31%	47%	13:00
37%	37%	28%	32%	39%	35%	14:00
44%	29%	36%	42%	36%	10%	15:00
36%	25%	37%	43%	39%	39%	16:00
47%	40%	31%	43%	34%	32%	17:00
55%	42%	32%	36%	32%	37%	18:00
50%	40%	46%	22%	50%	27%	19:00
39%	41%	4%	0%	10%	0%	20:00
20%	45%	15%	11%	54%	21%	21:00
34%	32%	28%	29%	34%	27%	22:00
			Overhaul average		31%	

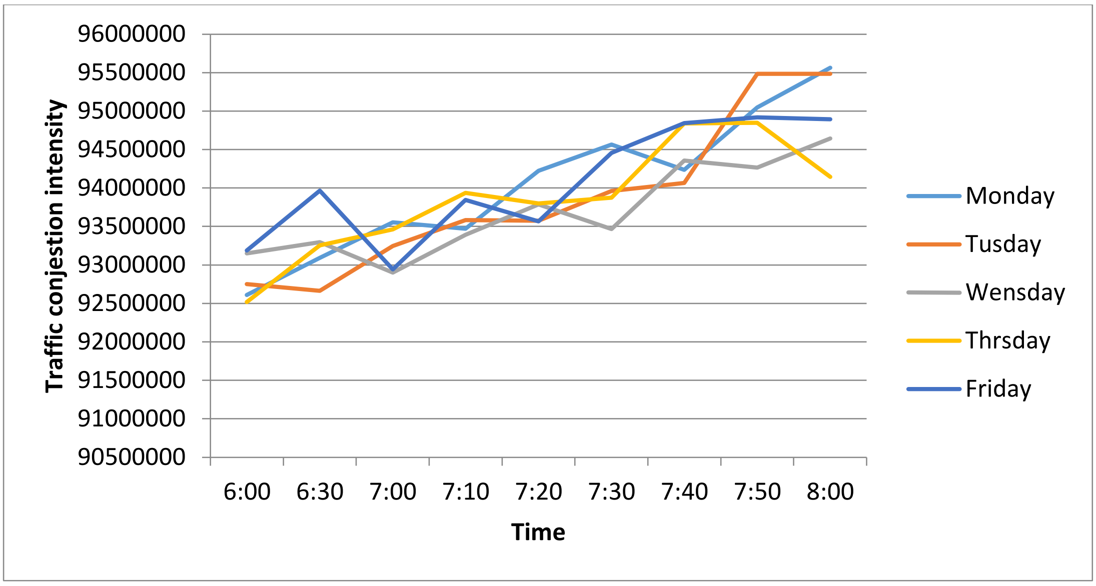


Fig 5. 8 Typical traffic intensity of morning from 6: 00 to 8 am with shorter interval

5.4 Analysis interpretation

5.41 Applicable TDM strategies for Addis Ababa and method of implementing selected TDM strategy

Based on barriers of transport demand management strategy, field observation, Economy of the city and output data of Math lab analysis the following transport demand management strategies are selected. This strategies will decrease Addis Ababa traffic congestion and related problems by spreading the population through time and space.

5.42 Staggering Student School starting time with work starting time.

As it shown in the Fig 4.9 Math lab analysis output data graph shows traffic congestion pick hour starts between 7:00 am and 8:00 am . If school starting time government employee work starting time is changed to 7:30 am. Dispatch(trip) starting time will be will be lower than 7:00 am. Traffic congestion level below 7:30 is lower than above 7:30. This transport demand management strategy will lower the number vehicles at roundabout and road intersections and the road will not be above capacity. The other advantage of This strategy is it enables us to use transport infrastructures and vehicles at optimum level. Students use Mini bus taxi as transport service mechanism to school during pick hour. This situation pullout taxi service during pick hour when other populations need it . When taxi services are used by students other public transport users will not get taxi service and long queues are created in many transport service stations. To increase utilization capacity of Addis Ababa transport infrastructures and public transport vehicles utilization hour must be staggered. If all students and government employees transport service is completed at 7:30 all transport vehicles such as mini bus taxi and other transport vehicles will serve other population with the full capacity this will decrease queue length at pick hour.

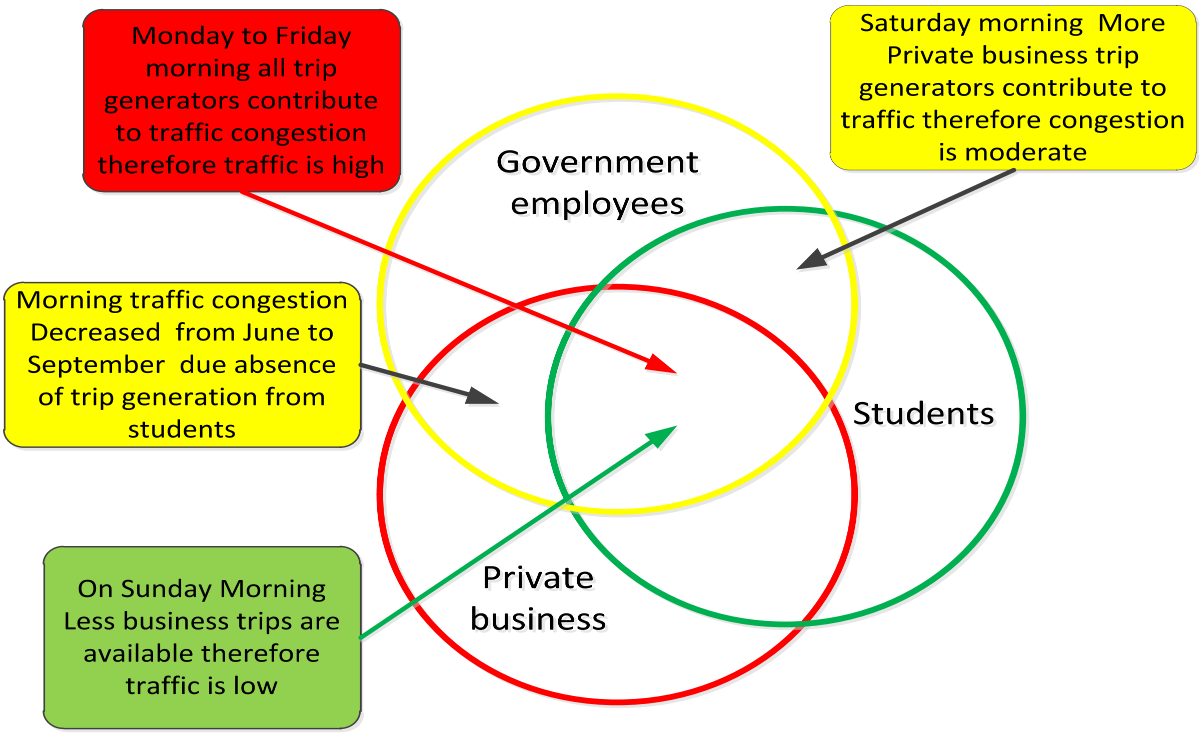


Fig 5. 9 Summery of Math lab analysis output result with Ven diagram.

showing the relationship between road transport users and trend of traffic congestion on different seasons of the year and days of the week.

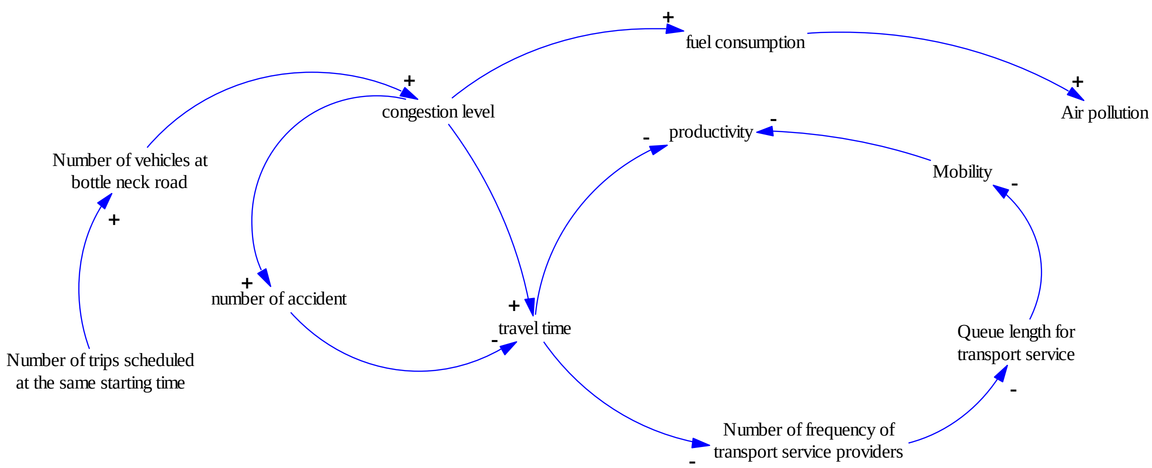


Fig 5. 10 Causal loop diagram Showing the impact and effect of staggering.

Source : own work using Vensim software.

As per math lab analysis typical traffic congestion intensity will decreased by 17 % by staggering student school starting time with other business trips. Overall effect of staggering student school starting time is summarized by above fig 4.53. As the staggering time or number of trips scheduled at the same time increased congestion level will decrease because number of vehicles at same junction at the time will decreased. The decreased in congestion level will decrease travel times, fuel consumption, traffic accident and air pollution. Decrease in travel time will increase productivity and mobility of travelers.

Fig 5. 11Students share mini bus service during pick hour.

Source : Own picture.

The other advantage of staggering student school starting time is to increase utilization and comfort of public transport services such as taxi bus. As shown in the above fig 7.12 and table 4.4 students have signifcat amount of modal split share of public transport vehicles. Students share taxi service during pick hour this effect will pull the amount of transport service during pick hour. This effect can be rebalanced staggering school starting time from other business trips. As shown fig 4.12, 4.13 and 4.14 schools are distributed at major corridors or roads of Addis Ababa this has impact of increasing level of congestion in Addis Ababa but staggering is applied congestion level will decreased.

5.43 Electronic road pricing (ERP)

ERP is successfully applied in Singapore, London and Stockholm. The primary goal of ERP was to Reduce congestion, improve air quality and public health, improve journey time reliability for car users, Create a long-term funding source for public transit improvements. The government uses huge amount of generated profit for another infrastructure development. Payment and cost and other related is summarized in below table 7.5

Table 5. 5 Financial parameters of ERP.

City	Payment	Hour	Initial investment	Annual operating cost	Annual net revenue
London Transport for London	Flat daily fee of £11.50 (US $15.21)	7:00am 6:00pm Monday-Friday	£161.7 million (USD $214 million)	£130 million (USD $172 million)	£137 million/year (USD $182 million)
Stockholm Swedish Transport Administration	Variable pricing based on time of day. 35 krona (US $4.14).	6:30am-6:30pm Monday-Friday	2 billion krona (USD $236.7 million)	100 million krona (USD $11.8 million)	1.3 billion krona/year (USD $155 million)
Singapore Land Transport Authority	Variable pricing	7:00am-8:00pm Monday-Saturday	$200 million (USD $110 million)	S $25 million (USD $18.5 million)	S $150 million/year (USD $100 million)

Source [112]

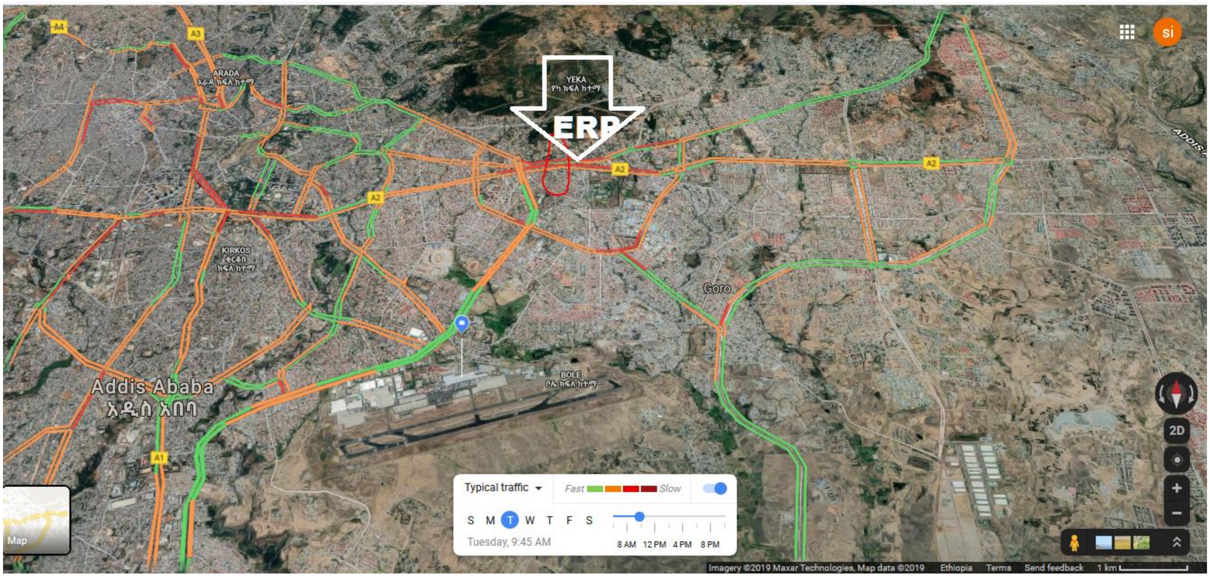
Source : own work using vensim software.

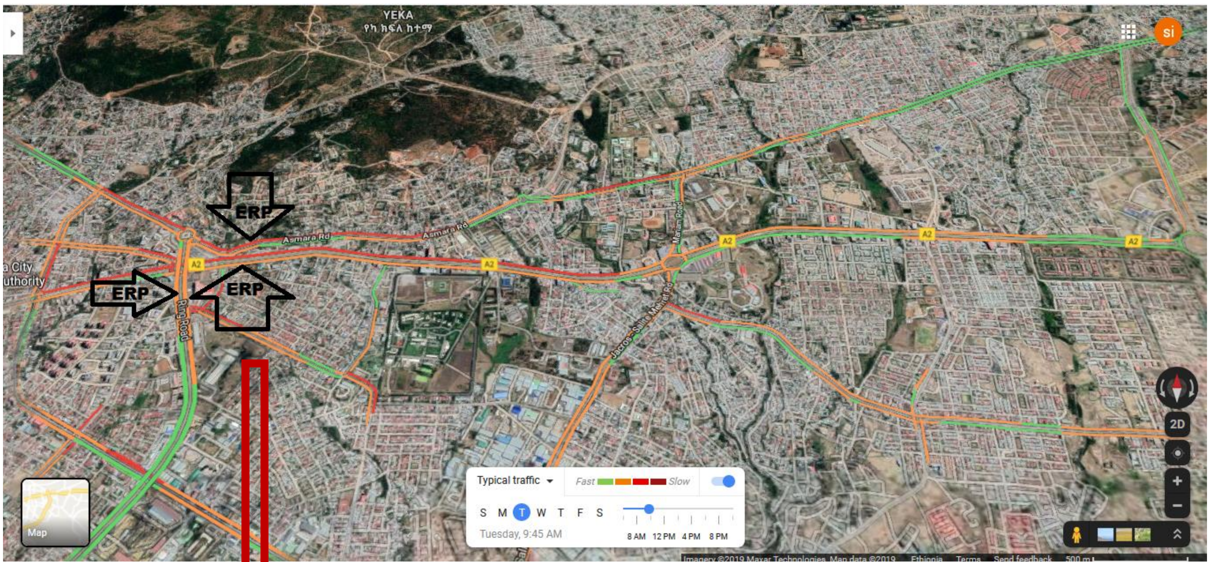
In London resulted in a reduction of almost 20% in congestion levels [112]. London has also experienced environmental and public health benefits as a result of less traffic in the inner city. From 2002-2003, carbon dioxide (CO_2) emissions declined by 16%, nitrogen oxide (NO_X) emissions declined by 13.5%, and particulate matter (PM_{10}) declined by 15.5%.16. Effect and benefit of ERP for Addis Ababa is also summarized in the above causal loop diagram. The effect and benefit of ERP is almost the same as Addis Ababa because number of vehicles and population are the same as shown in Qualitative comparative analysis table 5.1.

As a result of these reduced vehicle emissions, there is a reduced risk of serious illnesses such as asthma, bronchitis, and heart attacks. According to a recent study, 1,888 extra years of life have been saved among London’s more than eight million residents who are now breathing cleaner air.17 Protecting the environment and improving public health continues to be a major priority for Transport for London.

Electronic road pricing locations

In Addis Ababa Electronic road pricing can be installed in the following roads as pilot test. This roads are selected because they are most frequently congested roads and they provide service to large amount of population due to geographical location. This roads are entrance to the city or exits from resident areas. They are also bottleneck roads because more roads are merged in this roads. Therefore it is necessary to spread the demand in space and time by installing ERP in this location. This method is one of the method from carrot and stick method. Vechile owners must be charged when they enter this location at pick hour from 8:00 am to 10: 00 am in the morning and 4:00 pm to 12 :00 pm in the afternoon. The locations are as follows. Megenana, Jacros ,Zenebework and Gofa sefer As shown in the below Google map pictures.


YEKA
ERP
ARADA
KIRKOS
BOLE
Goro
Addis Ababa
Typical traffic
Fast
Slow
S M T W T F S
Tuesday, 9:45 AM
8 AM 12 PM 4 PM 8 PM
Map
2D


YEKA
ERP
ERP
ERP
Asmara Rd
Ring Road
Typical traffic
Fast
Slow
S M T W T F S
Tuesday, 9:45 AM
8 AM 12 PM 4 PM 8 PM
Map
2D

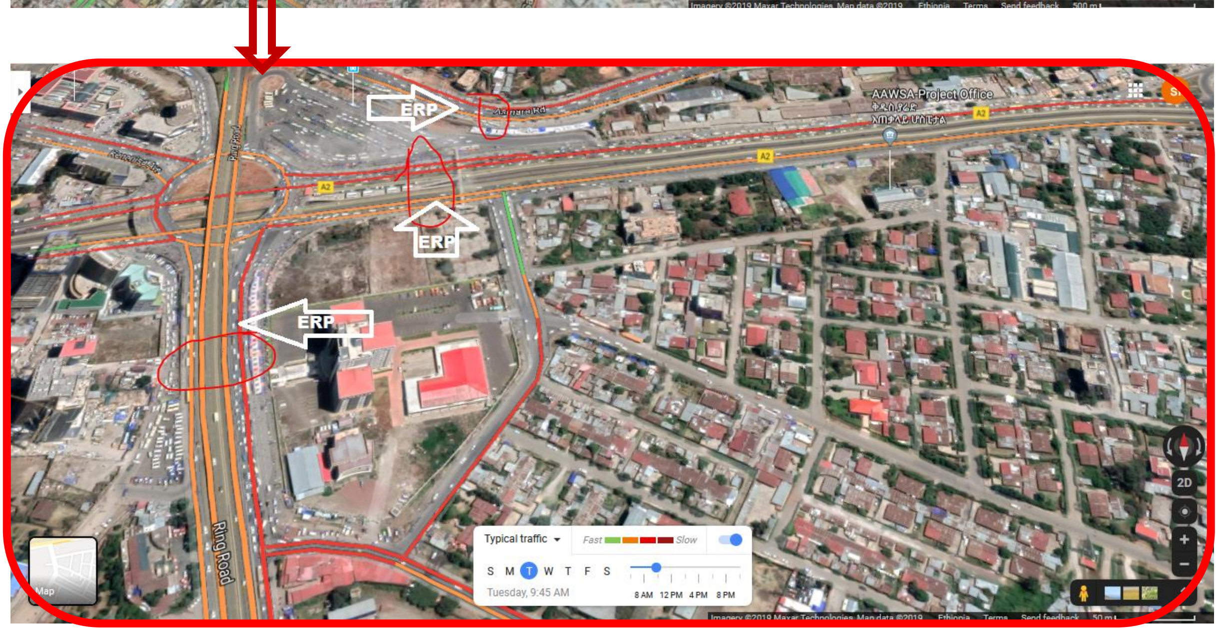

ERP
ERP
ERP
AAWSA Project Office
Ring Road
Typical traffic
Fast
Slow
S M T W T F S
Tuesday, 9:45 AM
8 AM 12 PM 4 PM 8 PM
Map
2D

Fig 5. 12 ERP location at MEGENANA.

Fig 5. 13 Location of ERP at GOFASEFEER.

Fig 5. 14 Location of ERP at ZENEBEWORK.

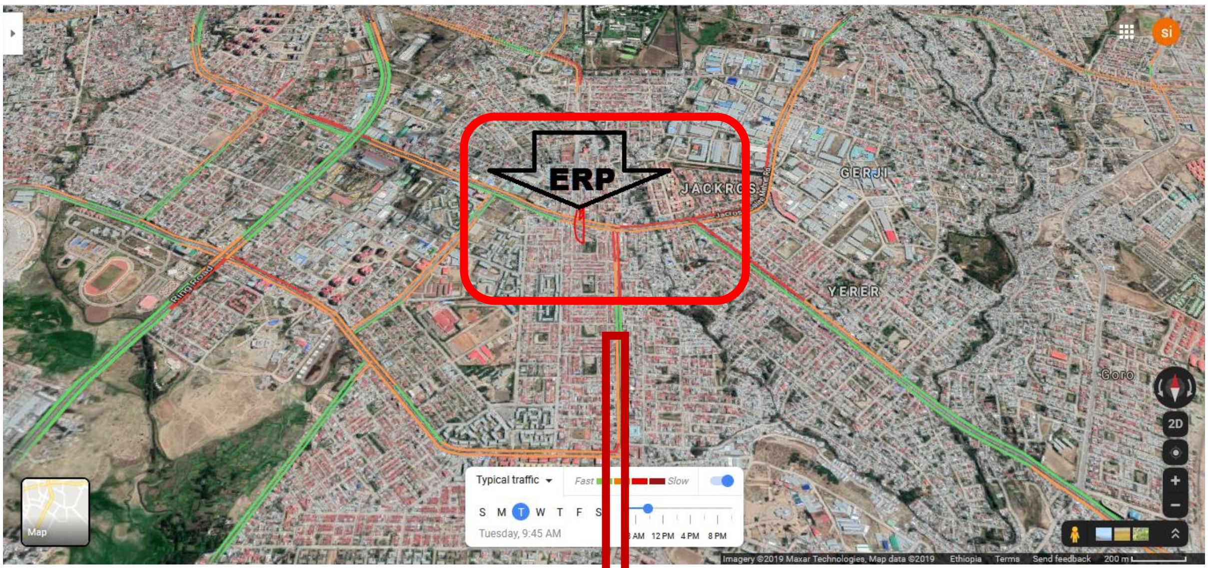


Fig 5. 15 Location of ERP at Jacros .

5.44 Pedestrian over pass bridge construction.

Pedestrian facility is one of transport demand management strategy which is categorized under non motorized transport system such as walking and biking. Some Addis Ababa locations are hazardous to walking because they are prone to traffic accident and traffic congestion. Location that require pedeserian overpass bridges are identified using google map data and filed observation. These locations are congested in all week days except Sunday. This locations are the following Gojam berenda , Atikelt tera and Megena and TORHAYLOCH. In this locations there is high number of pedestrian movement. Movement of pedestrian is cause of traffic interruption and traffic accident. When pedestrians cross the street they interrupt traffic flow and interruption of traffic flow is creating phantom traffic jam or traffic shock wave. Therefore traffic shock wave created by pedestrian movement can be easily avoided by constructing pedestrian overpass bridges. Conditions of these locations are as shown below figures.

5.19 shows traffic condition of GOGAM BERENDA. At this location many pedestrians cross the road for access to market and access to light rail transport service. Pedestrians have no available choice to cross the rail and road because the location to cross the road is long way. Because of this situation many pedestrians are prone to accident and traffic congestion is increasing significantly at this location because when vehicle movement is interrupted by traffic movement traffic phantom or traffic shock wave is crated. Traffic shock wave will continue to increase traffic congestion along the road. This phenomena can be removed by constructing.

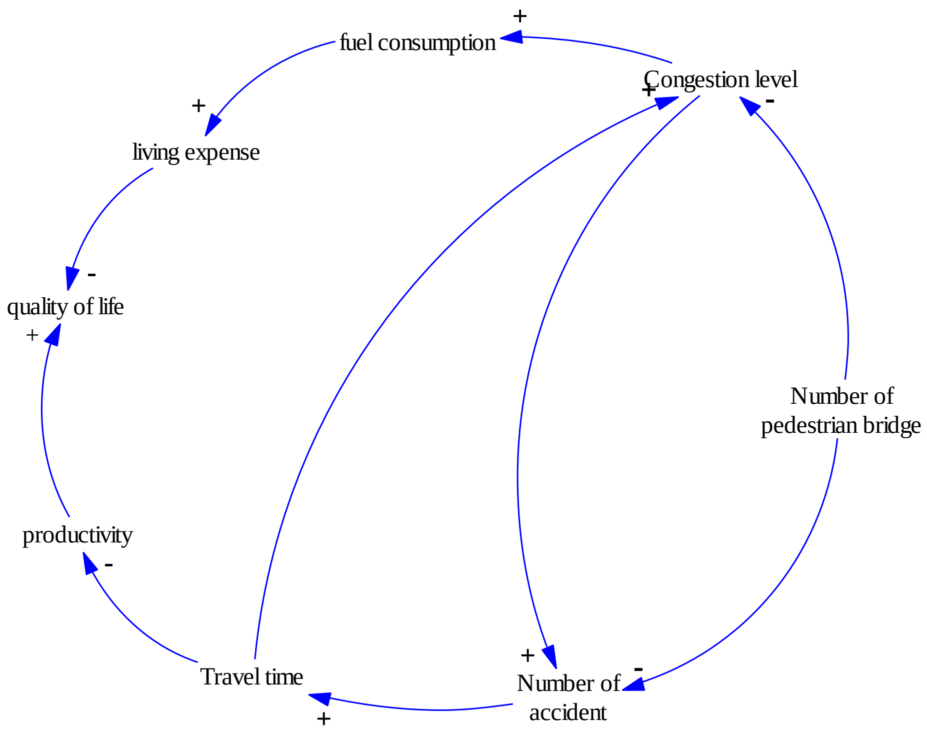


Fig 5. 16 Effect of pedestrian overpass bridge construction using causal loop diagram.

Source : own work with visim software

Number of pedestrian bridge and number of traffic accidents have indirect relationship. Data shown in appendix K and J shows inverse relationship of traffic accident and number of overpass bridges. As shown in field observation absence of Pedestrian Overpass Bridge is creating traffic phantom jam or traffic shock wave. The number of traffic shck wave will increase as the number of pedestrians is increased during pick hour. Traffic phantom jam phenomena create long traffic jam. This long traffic jam has effect or impact on the city by increasing number of accident , fuel consumption ,travel time and living expense. To avoid traffic phantom jam caused by pedestrian is to build simple cost effective overpass bridges. Pedestrian overpass or underpass bridges will avoid traffic congestion and accident by separating vehicles and pedestrians. This bridges will remove accidents caused by mechanical component of vehicles and drunk drivers. As shown in fig 2.24 60 % road traffic deaths occurred during crossing the road. Therefore building pedestrian overpass bridge will decrease traffic accident as well as traffic congestion by avoiding phantom traffic jam.

Gojam berenda and Atekilt tera traffic condition

Fig 5. 17 Traffic congestion caused by absence of pedestrian AUTOBUS TERA and GOGAM BERENDA.

Fig 5. 18 Traffic congestion caused by absence of pedestrian bridge at ATKELT TERA.

Source : Own pictures

5.19 shows traffic condition of GOGAM BERENDA. At this location many pedestrians cross the road for access to market and access to light rail transport service. Pedestrians have no available choice to cross the rail and road because the location to cross the road is long way. Because of this situation many pedestrians are prone to accident and traffic congestion is increasing significantly at this location because when vehicle movement is interrupted by traffic movement traffic phantom or traffic shock wave is crated. Traffic shock wave will continue to increase traffic congestion along the road. This phenomena can be removed by constructing simple pedestrian overpass bridge. The same phenomena is occurred in all other 3 selected locations.

Fig 5. 19 Traffic congestion caused by absence of pedestrian bridge at ATKELT TERA.

Fig 5. 20 Traffic congestion caused by absence of pedestrian bridge at MEGENA.

Fig 5. 21 Traffic congestion caused by absence of pedestrian bridge at TORHAYLOCH.

5.45 Mass transit rail system

Metro system is essential for city transport system performance. To cop up with future increase in demand of transportation system as shown in figure 4.10, it is neccecery to build mass transit rail system. Metro system is necessary for Addis Ababa for the following reasons It is sustainable and environmental friendly transport system Transports hug Amount of population, It takes less number of years to construct, It has low Accident rate , It will reduce environmental pollution at the same time save foreign exchange by reducing imported amount of fuel. The most essential components of metro system is its power source. Ethiopia is the power house of Africa and has bright future in terms of energy sector. This can be seen in below Table 7.5. Exploited percent of Ethiopia energy sector is very low the cautery has huge potential.

Table 5. 6 Ethiopia energy potential.

Resource	Unit	**Exploitable Reserve**	**Exploited**
Hydropower	MW	45 000	<5%
Solar/day	kWh/m2	Avg. 5.5	<1%
Wind: Power Speed	GW m/s	1,350	<1%
Geothermal	MW	7000	<1%
Wood	Million tons	1120	50%
Agricultural waste	Million tons	15-20	30%
Natural gas	Billion m3	113	0%
Coal	Million tons	300	0%
Oil shale	Million tons	253	0%

Source : [111] .

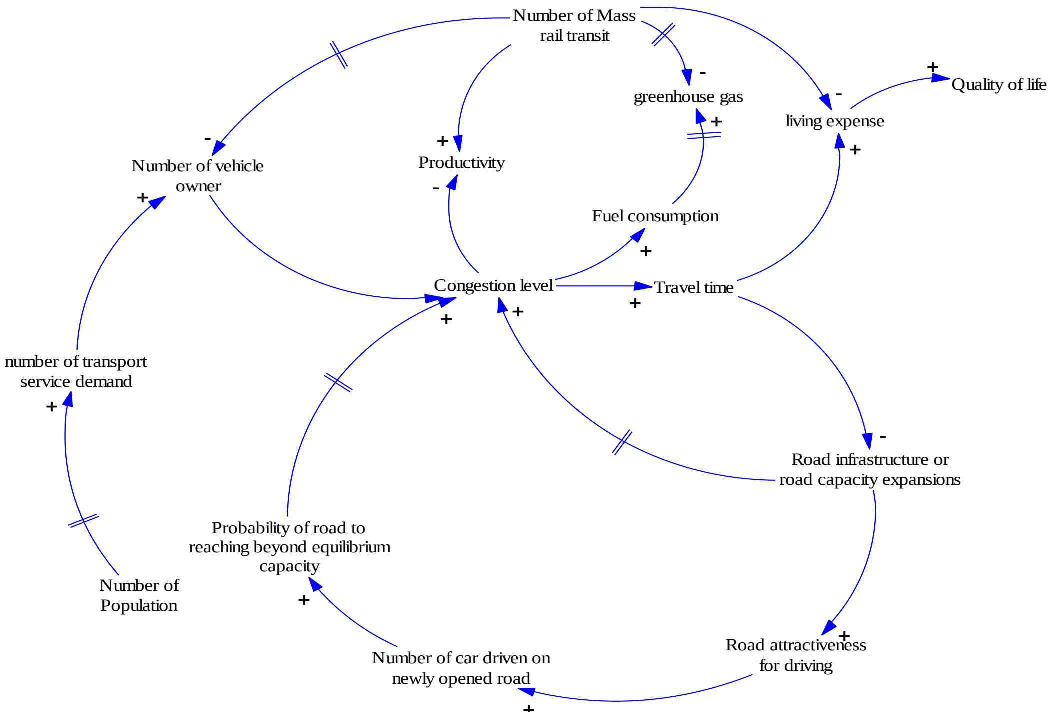


Fig 5. 22 Close loop cause and effect diagram for Mass Rail Transit system.

Mass rail transit is one of the sustainable way of transport service. As shown in the above fig 4.7 constructing mass rail transport system has effect of decreasing private vehicles users because travel time and cost of travel using MRT is lower than private vehicles. Decrease in travel time and travel cost will attract more passengers to MRT than private vehicles. Decrease in personal vehicles users will decrease level of congestion, fuel consumption and pollution. The main point of above causal loop diagram is to show behavior of virtuous cycle pattern created by constructing rMRT behavior whereas supply side management strategies have viscous cycle behavior.

5.46 TDM marketing and monitoring.

One TDM strategy was implemented in Addis Ababa but due to luck of TDM monitoring and marketing the project was unsuccessful .Therefore future TDM project prerequisite is TDM marketing and TDM monitoring.

Chapter six

6.0 Conclusion and Recommendations

6.1 Conclusions

Applying demand management strategy will lead Addis Ababa to the desired goal or to lower road traffic related problems. Comparative analysis result shows Addis Ababa is fully capable to apply transport demand management strategies. Causal loop diagram identifies supply side management strategy such as new road construction has viscous cycle behavior but applying Transport demand management strategies such as staggering student education starting time and government employee work starting time with other private business trip generation , Constructing simple pedestrian over pass bridge, Installing Electronic road pricing at selected roads, To shift to Mas rail transport system have virtuous cycle property.

As Mathlab Typical traffic congestion intensity analysis using math lab show Addis Ababa traffic is lower on Saturday morning with a minimum average value of 17 % . During july to September traffic congestion intensity is reduced by minimum average value of 31 % relative . This decrease of traffic congestion is the result of decreased trip generation of students and some government industries . Feasibility of staggering student school starting time from other business trips are proofed math lab analysis and causal loop diagrams. The other 2 strategies are selected by using online Google surveillance map data and by field observation. Selected roads for Electronic road pricing and pedestrian overpass bridges are selected by intensity of congestion. Bench mark city experience shows Electronic road pricing is a source of income for constructing other transport infrastructure additionally it reduce a around 20 % of road congestion on applied roads. As per Qualitative comparative analysis the same output is expected from Addis Ababa Electronic road pricing.

Transport demand management strategies that can improve Addis Ababa traffic condition are identified this are staggering student education starting time with work starting time, Constructing simple pedestrian over pass bridge, Installing Electronic road pricing at selected roads, To shift to Mas rail transport system , transport demand management monitoring and transport demand management marketing. Selected transport demand management strategies decrease major Addis Ababa transport problems such as traffic congestion , traffic accident and mobility. This strategies have additional benefits such as decreasing fuel consumption, decreased green house gas and air pollution.

6.2 Recommendations

For successful implementation of TDM strategy below, actions are highly recommended.

- Addis Ababa city government should create integration mechanism between different stockholders to successful implementation of TDM strategy. Addis Ababa traffic management agency must create collaboration with Addis Ababa education office and Addis Ababa workers association to create a policy that can change work and school starting time to 7:30.
- Addis Ababa city road transport office must create action plan on installing Electronic road pricing machines on the entrance and exit of selected roads. Selected roads are as follows GOFA SEFER road shown in blow figure 95 , ZENEBWORK road As shown in blow fig 7.16, JACROS road As shown in blow figure 98 .
- To construct pedestrian overpass bridge at selected roads. These roads are as follows GOJAM BERNDA light rail crossing station, ATEKITLT TERA light rail crossing at station, TORHAYLOCH Light rail crossing station.
- Addis Ababa city government plans to increase percentage of road coverage to 12 % to 30 %. As shown in from comparative analysis road coverage of Addis Ababa is almost equal as bench marked city (Singapore). Therefore, investment decision must be changed to develop TDM infrastructure such as Mass rail transit system and other TDM investments.
- MTR system need high amount of investment therefore first it is necessary to use low cost TDM strategies the first strategy is to stagger student and employee time. The second task will be to create awareness about selected strategies and to follow below Fig 5.1 recommended frame work for implementation of TDM strategy. Bus lane and NMT strategies where implemented in Addis Ababa these strategies failed because of luck of TDM marketing and monitoring. To avoid this, void its necessary to introduce TDM marketing and TDM monitoring before implementation of other strategies.
- From bench marked city and other developed city observation found that the most fundamental necessary condition for building sustainable development in transport sector and any other sector is availability of committed professional citizen. Addis Ababa must educate traffic engineers to be capable to use the complex planning and simulation software tools fast enough, where “fast enough” relates to the growth rate of their cities. Educational institutions must be established to solve future demand growth problem.

6.3 Future research direction

Mass rail transit is back bone of transport system for developed cities. Mass rail transport system is one of transport demand management strategy under the category of push pull strategy. It is applicability for Addis Ababa is confirmed in this research in terms of sustainability with growth rate of transport demand. Causal loop diagram shown in Fig 7.25 shows mass rail transport is the balancing mechanism of future transport demand growth. Constructing Mass rail transit is applicable for Addis Ababa because it has low rate of accident , environmental friendly, No fuel consumption because It uses electrical power and decreases environmental air and sound pollution. In the future Ethiopia will be the power house of Africa because the country has high potential for renewable energy generation as shown in Table 7.5. This high electrical power capacity, can be used to transport large amount off population using mass rail transport system.

Draw back of mass rail transit system is its initial investment for construction. Developed cites absorb Initial investment construction by different kinds of strategies such as public private partnership (PPP) . Future research is required on the feasible financial model for constructing mass rail transit system to absorb initial investment. The other research direction is designing efficient network that can address major population trip distribution. The network must be designed by considering Trip generation and distribution of Addis Ababa population.

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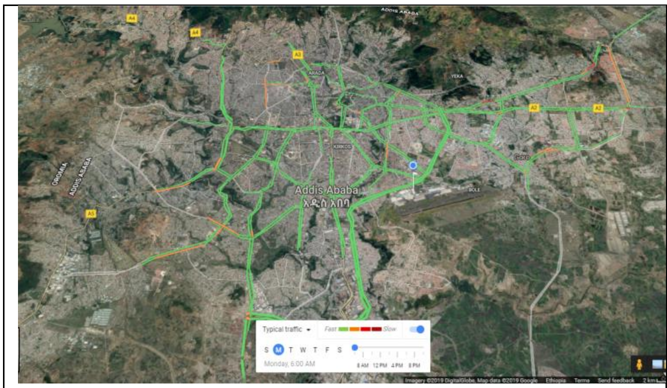
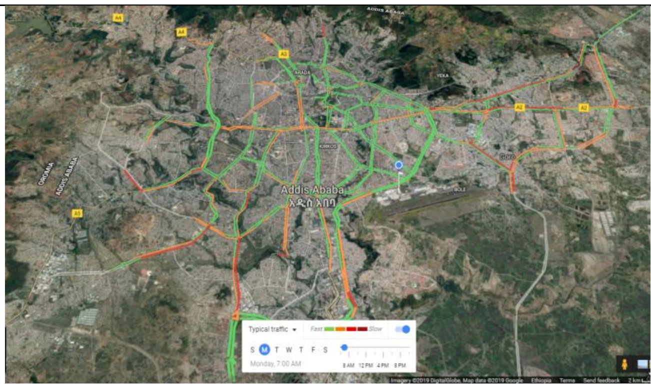
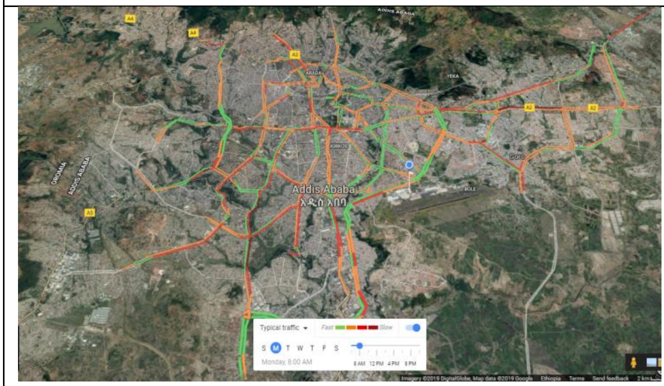
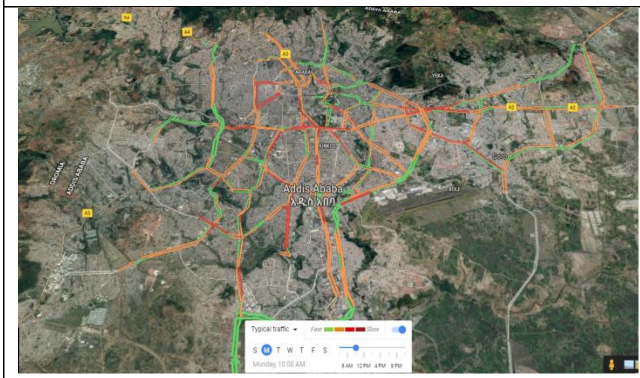
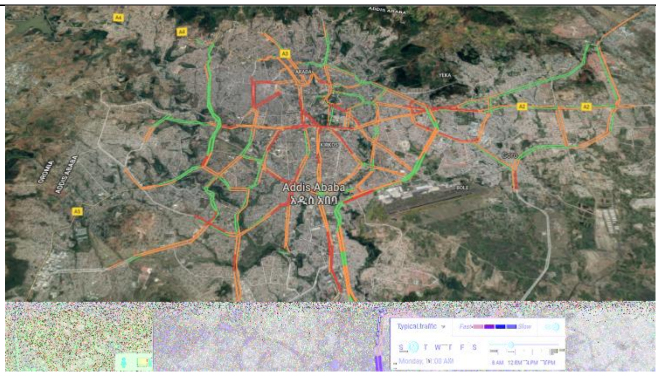
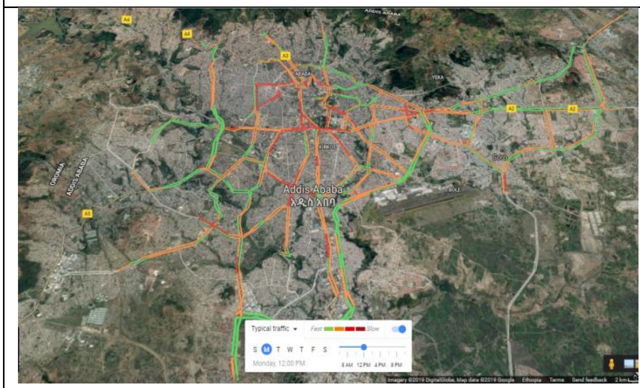
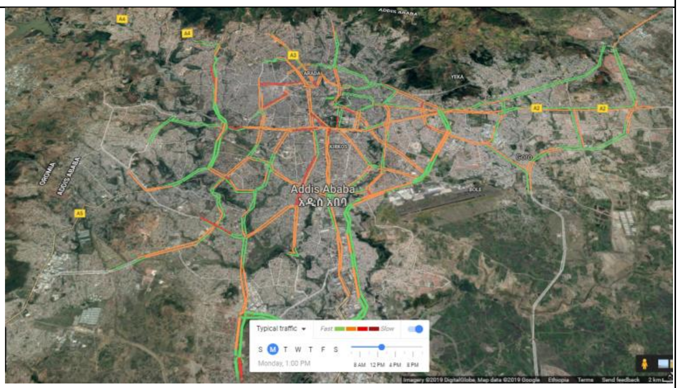
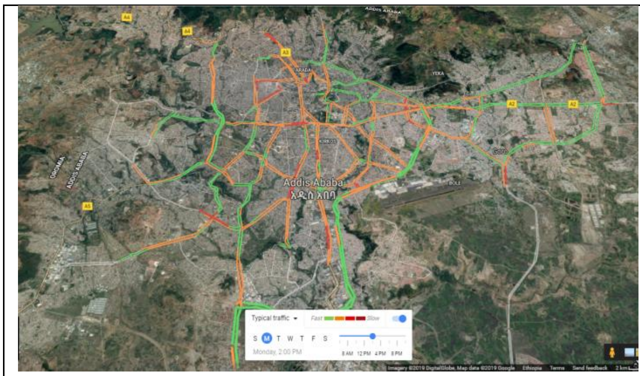
Appendix A

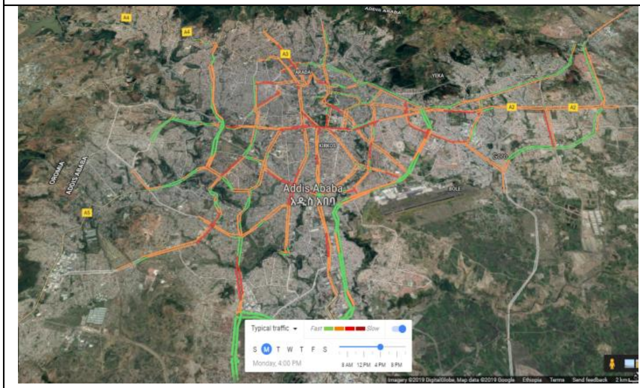
Data of traffic congestion in Addis Ababa in different day of the time

Table typical Monday traffic condition.


Addis Ababa
Typical traffic


Addis Ababa
Typical traffic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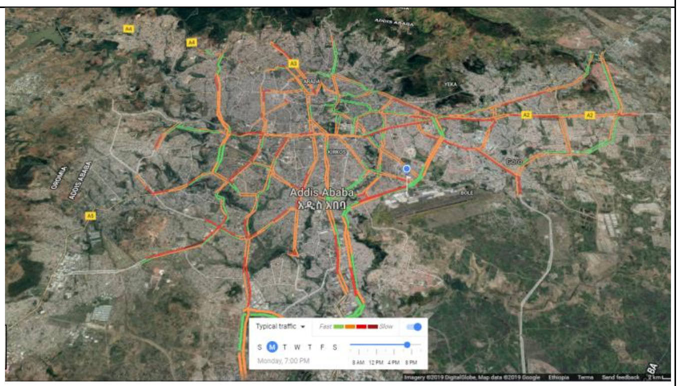
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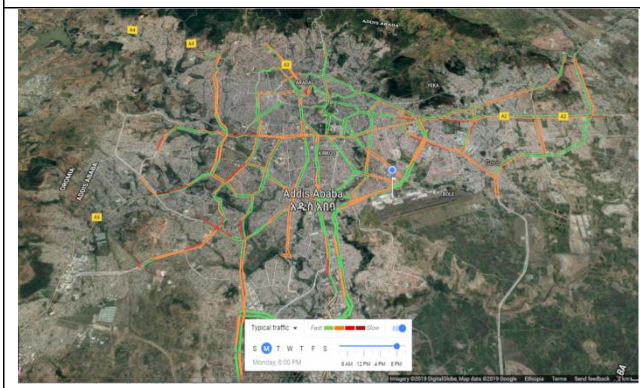
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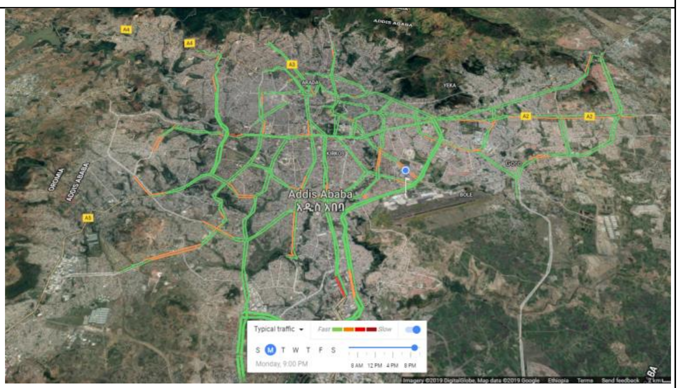
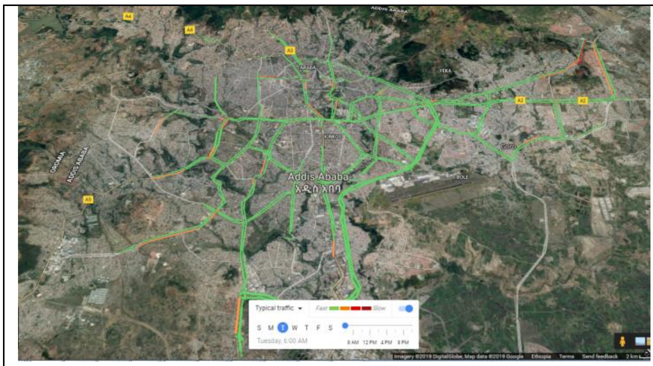
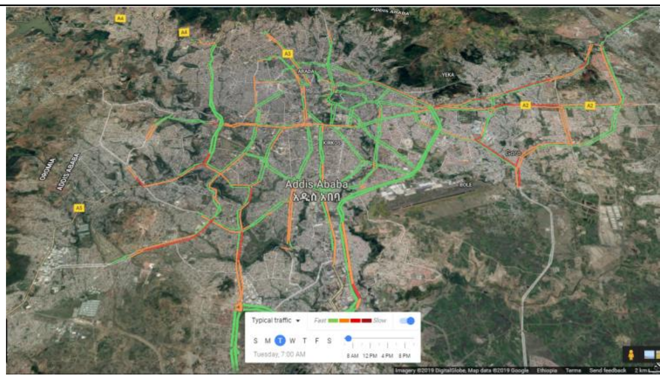
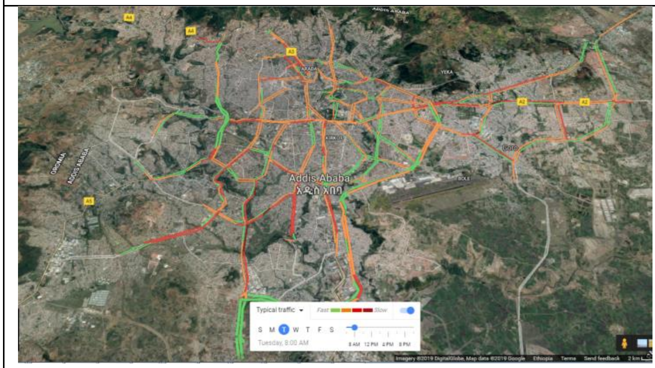
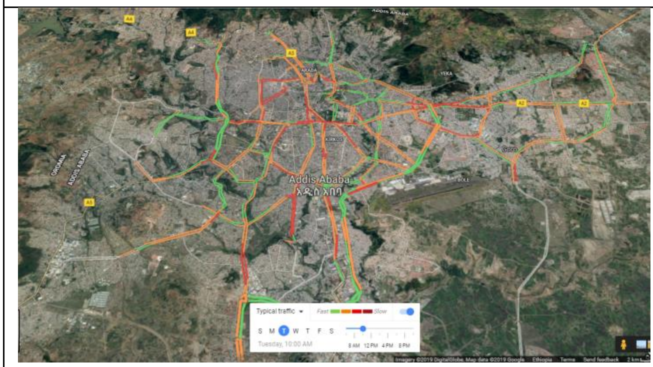
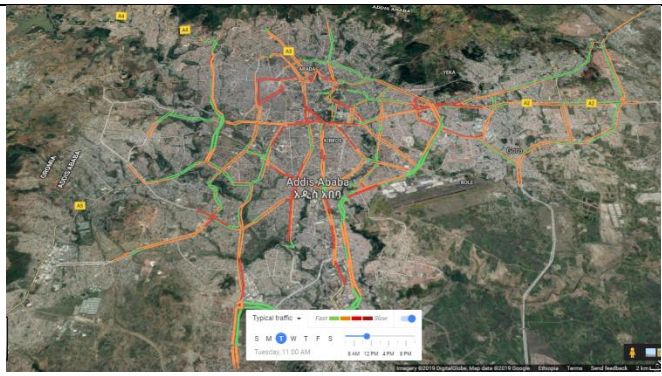
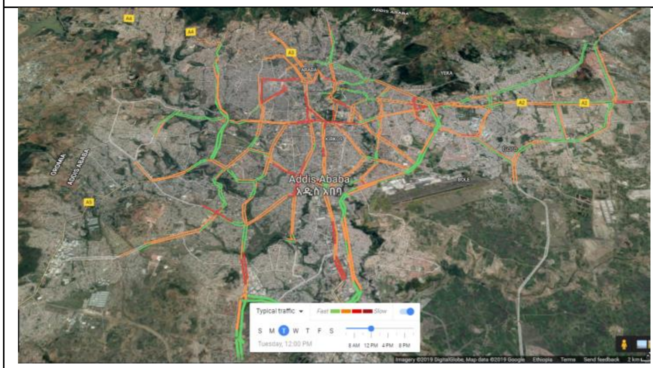
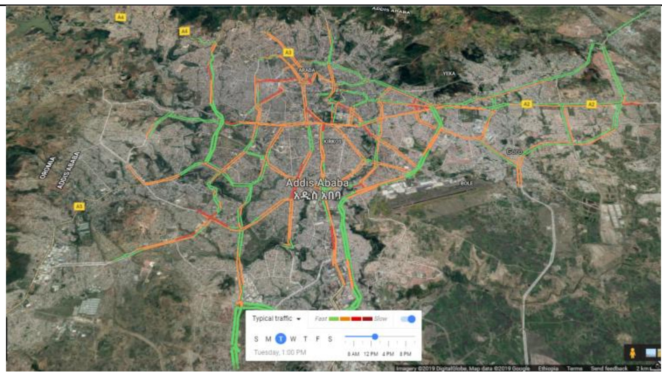
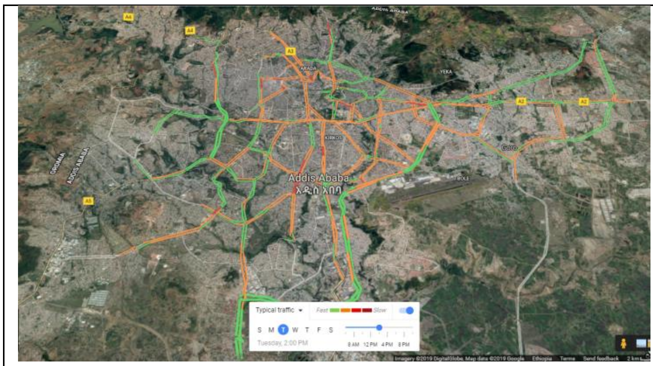
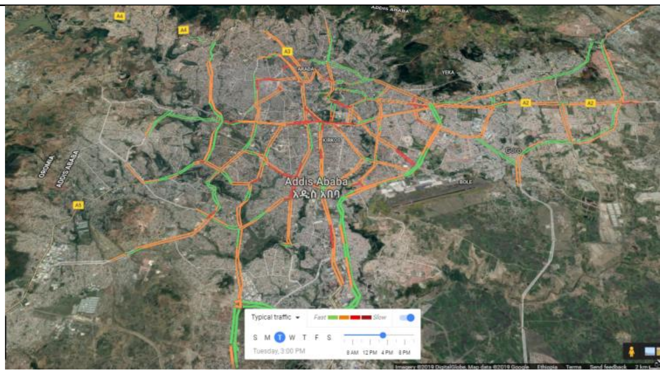
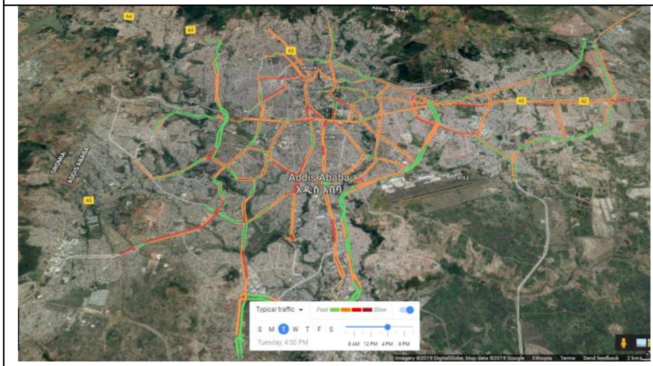

Addis Ababa
Typical traffic

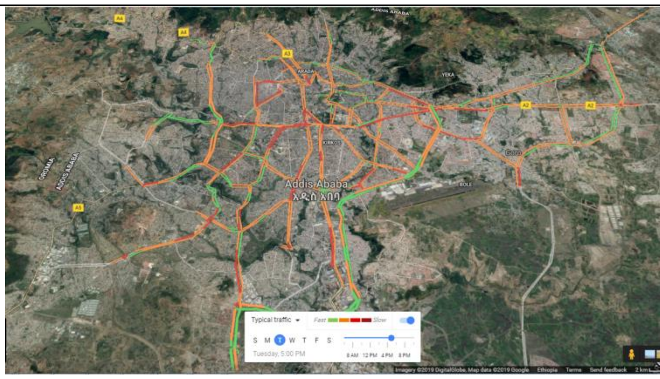
Table typical Tuesday traffic condition.


Addis Ababa
Typical traffic


Addis Ababa
Typical traffic


Addis Ababa
Typical traffic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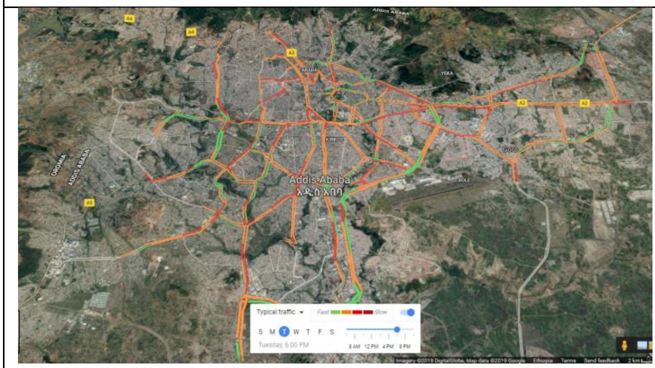
Typical traffic


Addis Ababa
Typical traffic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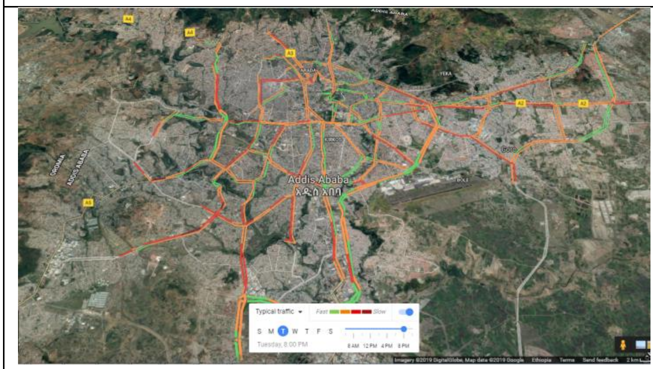
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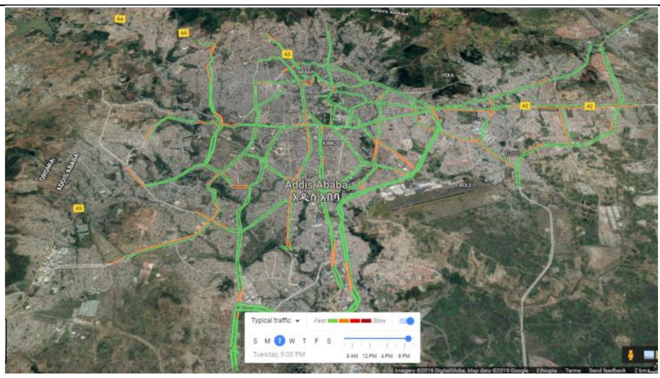
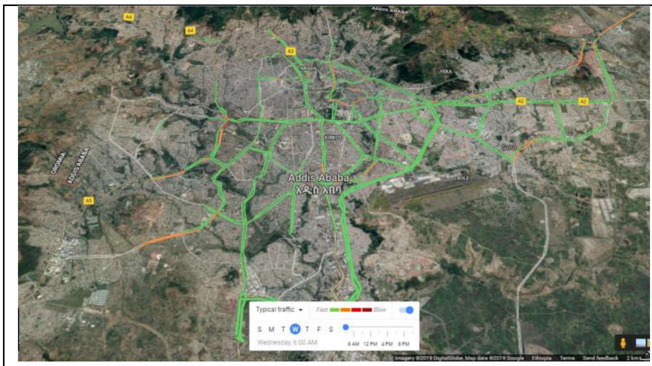
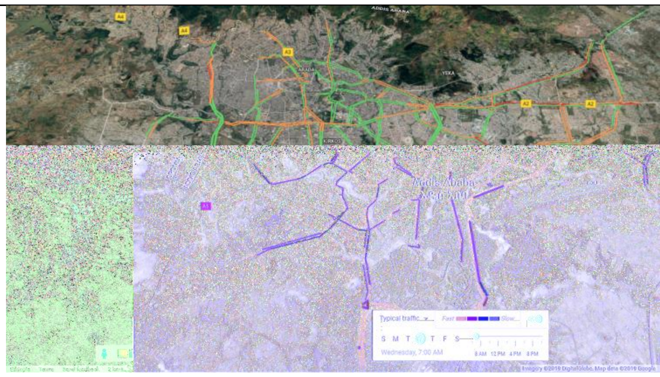
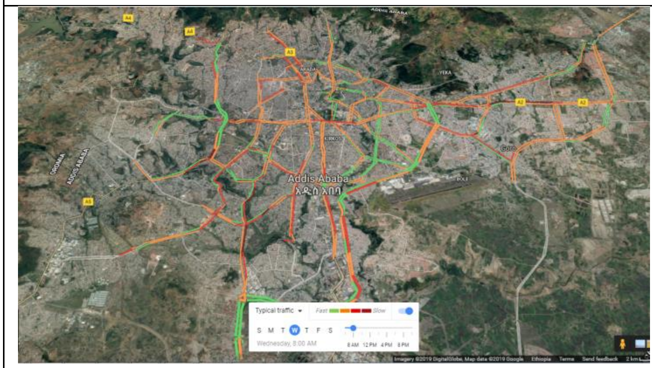
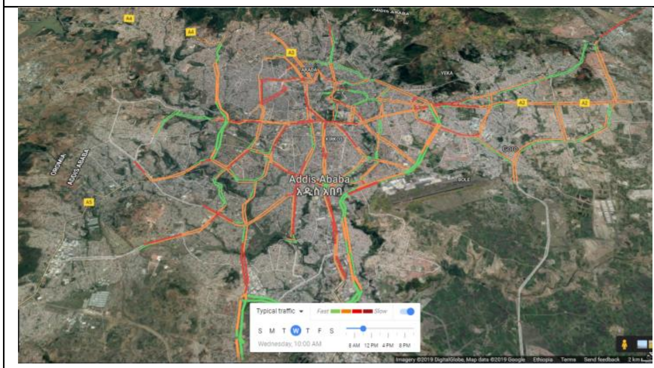
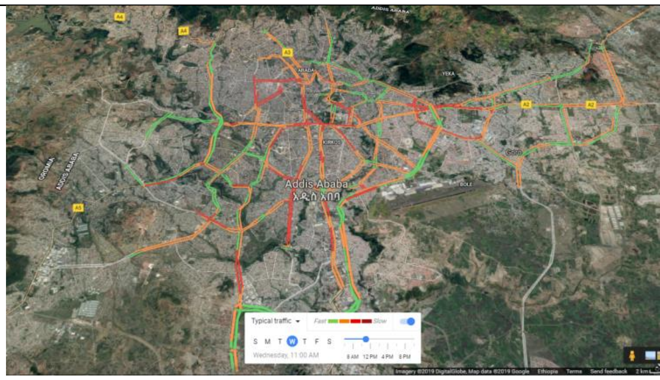
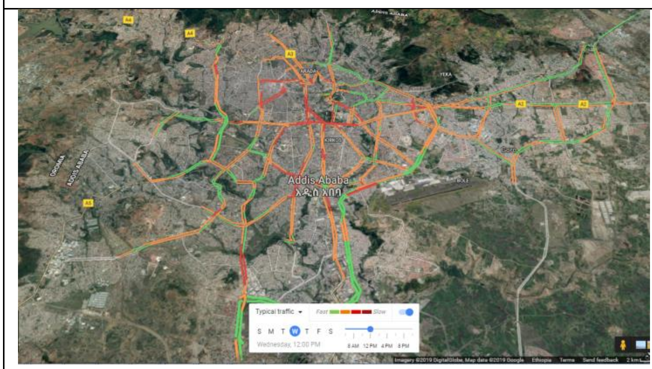
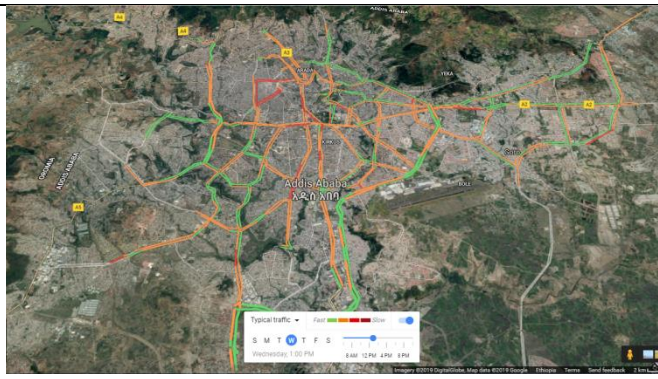
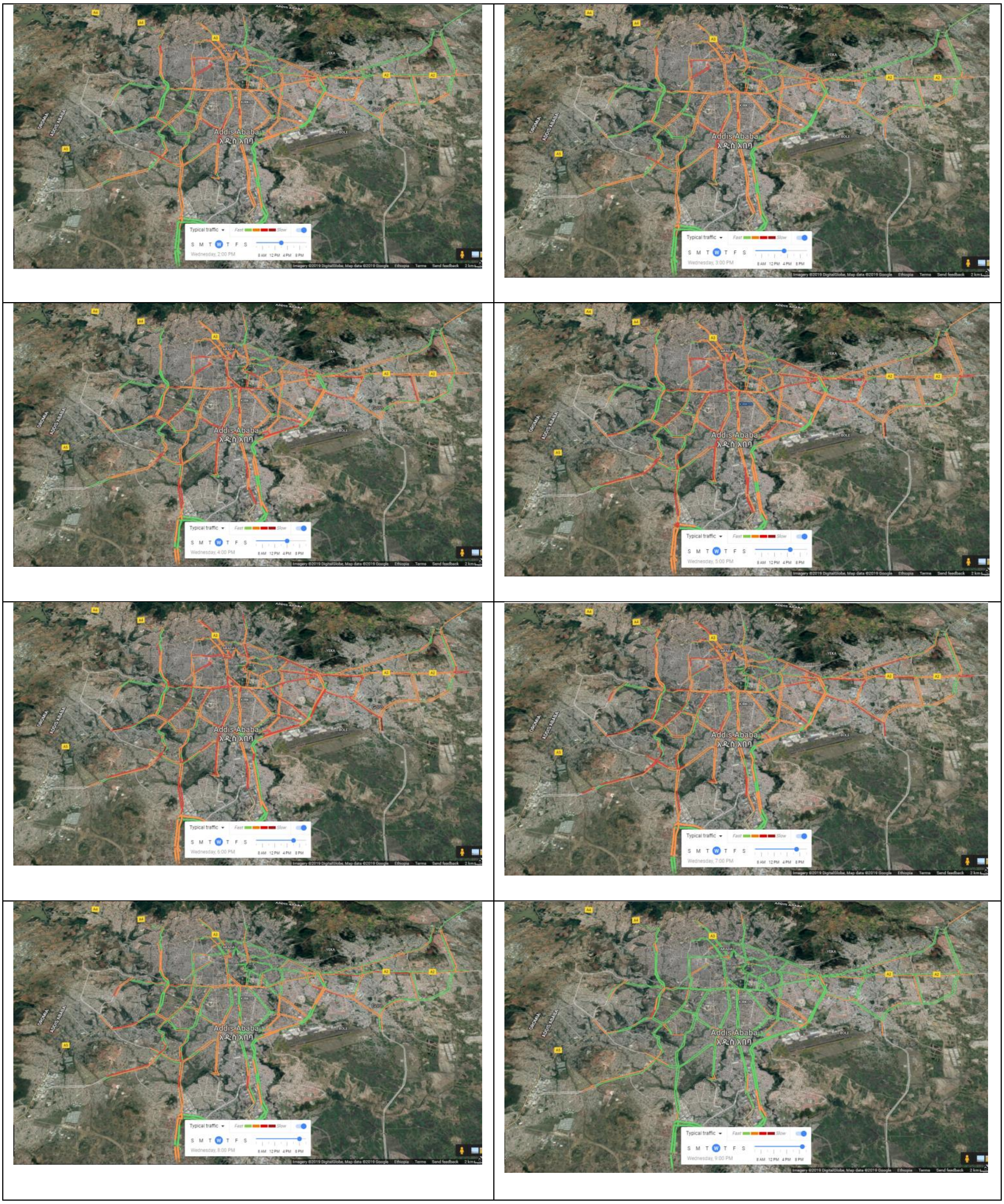

Addis Ababa
Typical traffic

Table typical Wednesday traffic condition.



Appendix E

Addis Ababa registered number of vehicles in 2018.

Number of Vehicles in Addis Ababa	
Vehicle description	Number of Vehicles
Automobile	184,227
Dry Cargo (>1000 Kg)	109,952
Field Vehicle	45,081
Dual Purpose Vehicle	44,954
Dry Cargo (< 1000 Kg)	37,384
Bus	26,408
Trailer	25,336
Motor Cycle	22,931
Not Specific	18,154
Bus (> 11 Seat)	15,242
Other	9,912
Liquid Cargo	6,341
Gotach	5,598
Tractor	1,059
Vehicle with Machinery	543
Three Wheel Public Load	375
Ambulance	198
Construction Vechiles	243
Sum	553,938

Appendix F

Traffic Injuries by day and time of crash in 2017-2018

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total	Percent
00:00 - 02:00	9	15	12	16	11	23	17	103	4%
02:01 - 4:00	3	11	11	8	9	7	9	58	2%
04:01 - 06:00	21	24	26	25	21	29	22	168	6%
06:01 - 8:00	52	69	68	56	56	42	32	375	13%
8:01 - 10:00	49	39	59	49	68	39	45	348	12%
10:01 - 12:00	44	36	42	48	51	52	40	313	11%
12:01 - 14:00	37	36	30	38	28	38	38	245	9%
14:01 - 16:00	48	38	33	49	37	41	59	305	11%
16:01 - 18:00	40	36	44	43	55	31	41	290	10%
18:01 - 20:00	56	40	41	47	55	59	61	359	13%
20:01 - 22:00	25	23	21	24	24	34	26	177	6%
22:01 - 00:00	4	6	8	9	7	8	6	48	2%
Total	388	373	395	412	422	403	##	###	

Appendix G

Addis Ababa Deaths and injuries by causal vehicles in 2017 -2018

	Pedestrian	Passenger of Vehicle	Driver Of Vehicle	Cyclist	Motorcyclist	Total
Automobile	513	85	50	3	19	670
Bajaj	109	103	12	0	2	226
Bicycle	33	1	0	3	1	38
Bus	72	26	3	0	1	102
Construction Machine	6	0	1	0	0	7
Lada	49	7	2	0	3	61
Light truck	239	69	23	1	5	337
Minibus	542	131	26	2	12	713
Motorcycle	149	7	7	0	42	205
Truck	115	37	19	1	6	179
Other	7	0	0	0	0	7
	1834	466	143	9	91	2545

Appendix I

FATALITIES IN ROAD ACCIDENTS BY ROAD USER GROUP (2008-2017)

Year	Total	Pedestrian	Cyclist and Pillion [1]	Motorcyclist and Pillion Rider	Motorcar Driver/ Passenger	Goods Van and Pick-Up Driver/ Passenger	Lorry, Tipper Truck and Trailer Driver/ Passenger	Bus Driver/ Passenger	Others
2008	221	62	22	108	23	0	5	1	0
2009	183	45	17	92	12	5	8	3	1
2010	193	55	16	89	14	3	9	2	5
2011	195	49	15	99	15	1	15	1	0
2012	168	44	16	76	14	0	11	4	3
2013	160	43	15	73	16	3	9	1	0
2014	155	45	15	74	12	2	6	0	1
2015	151	43	17	72	7	2	8	2	0
2016	141	47	20	62	8	1	3	0	0
2017	121	45	15	44	9	2	5	1	0

Appendix J

Singapore PEDESTRIANS CASUALTIES IN ROAD ACCIDENTS BY AGE GROUP (2013 - 2017)

Age	**2013**			**2014**			**2015**			**2016**			**2017**		
	Total	**Fatalities**	**Injured**	**Total**	**Fatalities**	**Injured**	**Total**	**Fatalities**	**Injured**	**Total**	**Fatalities**	**Injured**	**Total**	**Fatalities**	**Injured**
Under 18	122	1	121	133	0	133	129	1	128	136	0	136	120	1	119
18-19	27	0	27	27	1	26	28	1	27	22	0	22	25	1	24
20-24	106	3	103	94	2	92	102	1	101	94	1	93	102	0	102
25-29	101	2	99	95	3	92	115	1	114	127	2	125	103	2	101
30-34	111	3	108	99	3	96	93	2	91	113	3	110	110	2	108
35-39	76	2	74	74	2	72	66	3	63	83	4	79	71	3	68
40-44	83	5	78	61	2	59	68	1	67	57	0	57	66	3	63
45-49	57	0	57	46	1	45	57	1	56	69	3	66	49	2	47
50-54	54	4	50	57	2	55	70	4	66	60	5	55	56	4	52
55-59	67	6	61	47	3	44	59	5	54	78	1	77	64	1	63
60 & above	228	17	211	195	26	169	229	23	206	273	28	245	277	26	251
Total	**1,032**	**43**	**989**	**928**	**45**	**883**	**1,016**	**43**	**973**	**1,112**	**47**	**1,065**	**1,043**	**45**	**998**

Appendix K

Road, Traffic & Commuter Facilities source [Singapore land transport 2018]

	VEHICULAR			PEDESTRIAN				TRAFFIC		COMMUTER FACILITIES			
Year	Flyovers	Vehicular Bridges	Vehicular Underpasses & Tunnels	Pedestrian Overhead Bridges	Pedestrian Underpasses	Footbridges	Covered link way	Traffic Lights	ERP Gantries	Bus Interchanges	Bus Terminals	Bus Stops	Taxi Stands/Stops
1994	79	180	10	336	48	15		1,256					
1995	83	196	12	350	49	15		1,308					
1996	86	196	12	359	50	16		1,381					
1997	93	200	14	369	50	17		1,463					
1998	95	202	18	380	51	22		1,528					
1999	95	202	18	385	53	22		1,624					
2000	95	203	18	390	54	22		1,697					
2001	95	203	18	390	54	22		1,745	33				
2002	95	203	18	390	54	22		1,799	41				
2003	98	205	21	393	54	22		1,850	42				
2004	103	207	23	408	59	22		1,886	42				
2005	104	208	24	415	59	25		1,933	45	22	21	4,509	133
							14.00km		45	22	18	4,397	133
							14.39km		45	21	17	4,375	174
							15.60km		48	22	18	4,440	199
2006	111	214	25	446	55	29	21.20km	1,967	48	22	15	4,544	198
2007	111	214	27	449	55	29	21.10km	2,010	58	22	15	4,560	210
2008	112	214	27	466	54	28	21.20km	2,051	66	22	13	4,572	230
2009	114	213	28	480	54	28	22.22km	2,080	66	22	13	4,581	232
2010	114	213	28	484	54	29	22.22km	2,127	69	22	15	4,591	255
2011	116	212	28	491	54	26	24.00km	2,150	70	22	15	4,615	268
2012	119	212	29	498	54	27	35.00km	2,185	72	22	15	4,608	269
2013	119	212	29	513	54	27	35.30km	2,227	74	22	16	4,638	270

Appendix L

Interview Questions

My Name is Sisay Weheyaga I am Addis Ababa a student in Addis Ababa University., I am. Currently, studying industrial engineering in school of mechanical and industrial engineering. I am working on my thesis in title of transport demand management for Addis Ababa. You Are selected for the interview, and the information you give me is used for only for educational purpose. If you are willing, please reply to my questions carefully. Thank you for your acceptance.

Questions

Interview questions for minibus drivers and Anbesa bus , public bus drivers

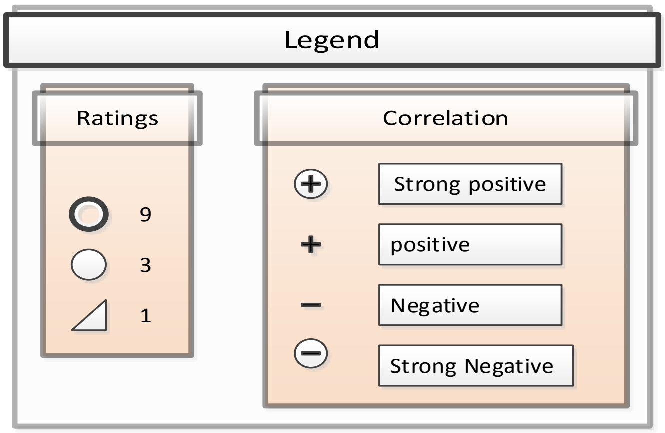
1. What are the major transportation system problem of Addis Ababa?
2. What is the cause of traffic congestion and mobility in Addis Ababa?
3. From your experience what is the major cause of Mobility in Addis Ababa?
4. What do you think is feasible and manageable to improve the system?
5. What is the main reason for taxi shortage particularly at rush hours?

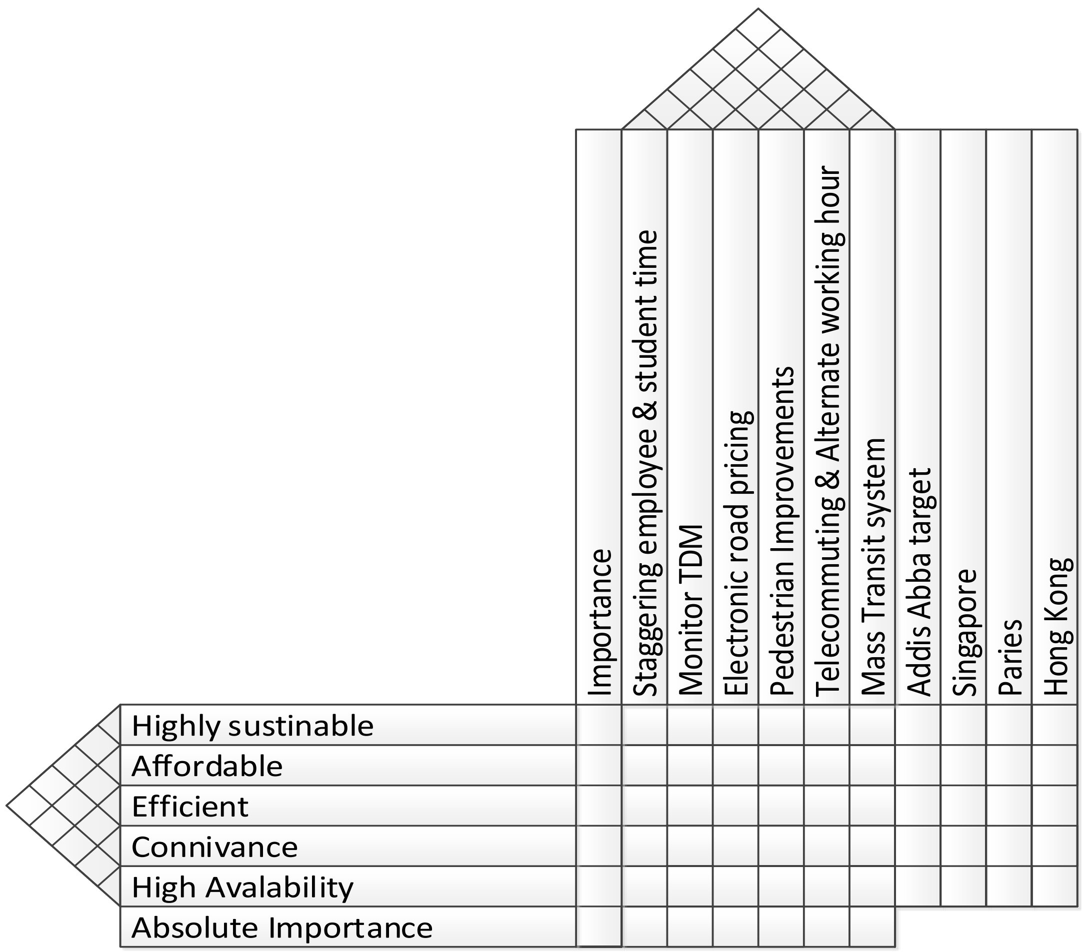
Interview Questions passengers on the queue for Minibus ?

1. Which transport service is more comfortable?
2. Why are you're criteria for selecting transport mode ?
3. Why do you prefer Mini bus than public bus or from Ambesa bus ?

Interview questions for Addis Ababa road Authority, Addis Ababa Transport Authority and Addis Ababa traffic management agency.

1. What are the major problems of Addis Ababa transport system?
2. What are the major causes of traffic congestion in Addis Ababa?
3. Is there any study done to solve Addis Ababa transport system problem?
4. Which roads are highly congested roads in Addis Ababa?
5. What are the main challenges for improving public transport?
6. What urgent improvements are needed in the public transport sector?
7. What are the current Demand verses supply side approach you use for Addis Ababa city?
8. What are the existing conditions of transportation of transportation facilities such as road, vehicles and administration system?
9. What barriers prevent from implementation of TDM strategy.
10. Please fill the relationship between below selected strategy.


Legend
Ratings
9
3
1
Correlation
Strong positive
positive
Negative
Strong Negative


Importance
Staggering employee & student time
Monitor TDM
Electronic road pricing
Pedestrian Improvements
Telecommuting & Alternate working hour
Mass Transit system
Addis Abba target
Singapore
Paries
Hong Kong
Highly sustinable
Affordable
Efficient
Connivance
High Avalability
Absolute Importance

Appendix M

Typical Sample Mathlab analysis for traffic congestion intensity.

>> % This step is used to calculate intensity of road congestion on Monday at 09:00 o'clock

>> % The first is to read

The First step is to view the RGB values of m

%This analysis is used for analyzing traffic condition of Addis Ababa city

%Every steps of analysis will be shown in this Matlab but in this paper every analysis of every hour

%traffic condition day is not shown because the steps are the same .

%The first step of the analysis is to see congestion level of Addis Ababa. In this sample analysis

% congestion level on Monday 09:00 will be analyzed

>> i=imread('09.png'); % to read Addis Ababa traffic condition map

>> imshow(i):

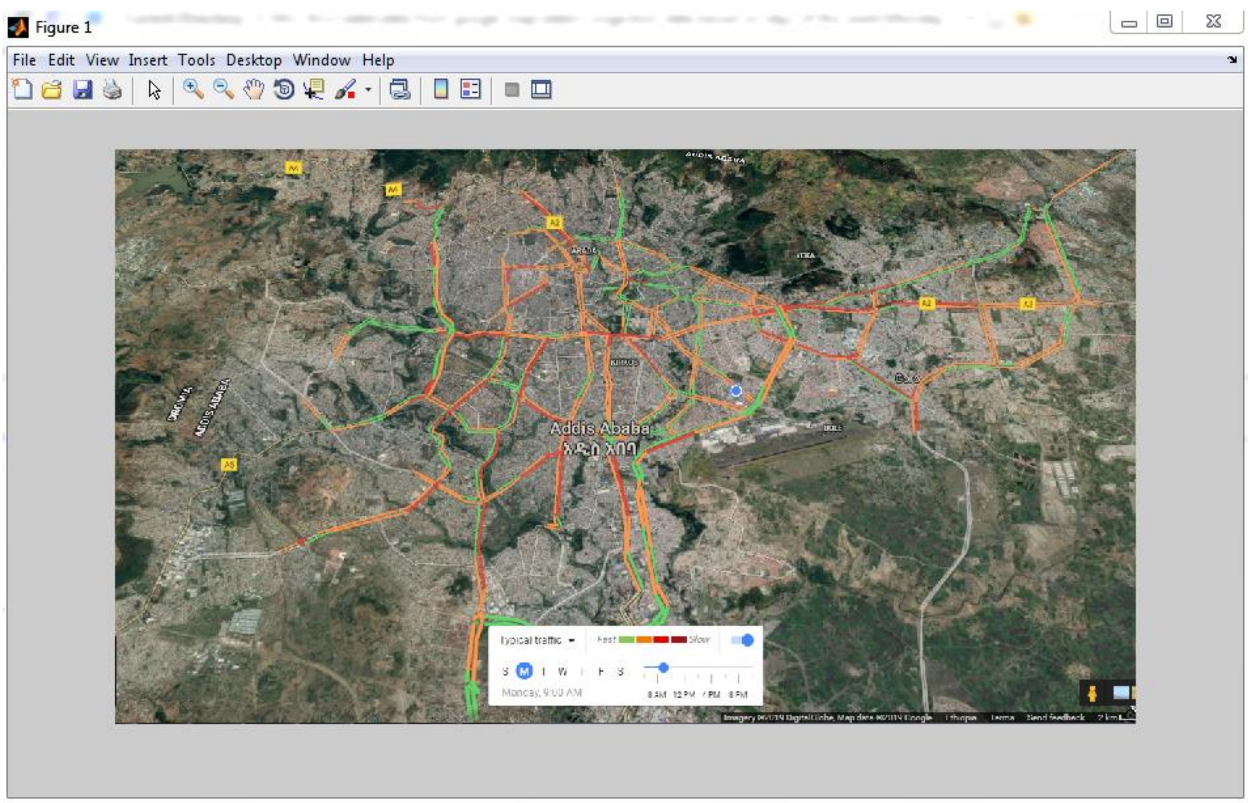


Fig 4.46 Math lab window that show traffic map of Addis Ababa by using Imshow function.

Imtool(i):

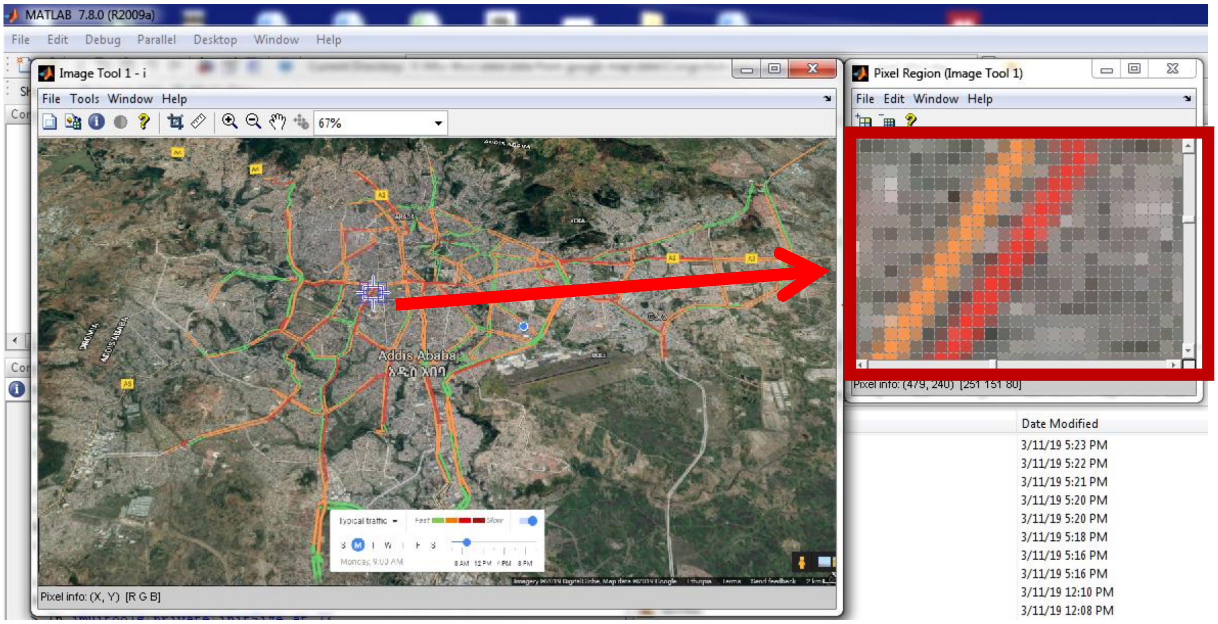


Fig 4.47 Math lab window that show pixele value of RGB image using iamtool function.

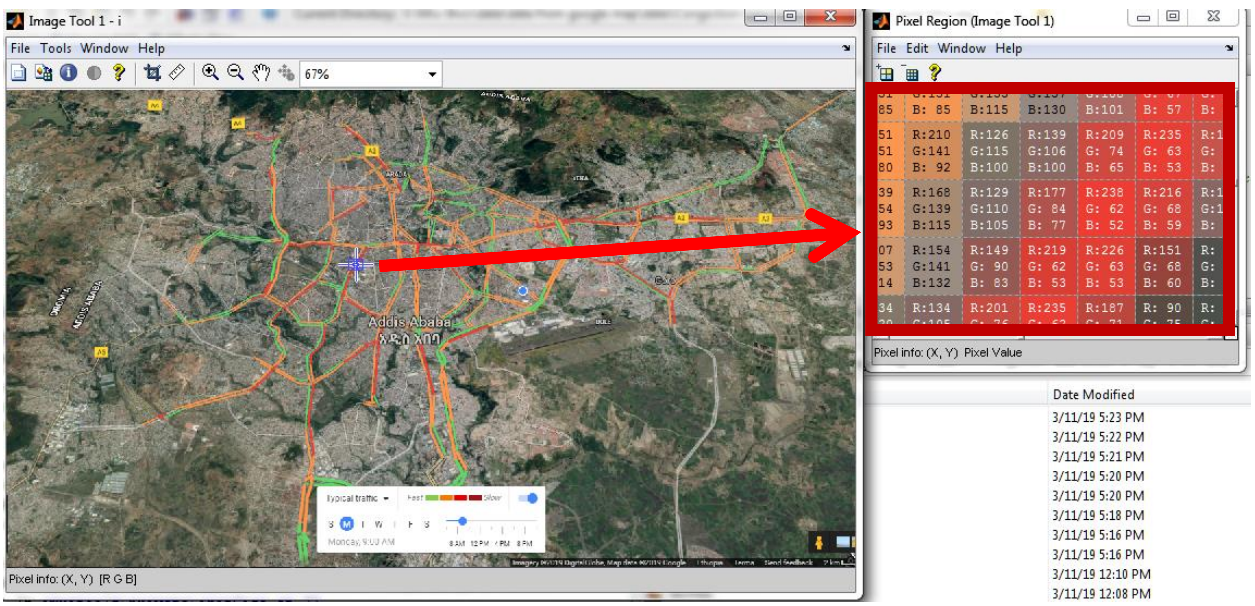


Fig 4.47 Math lab window that show pixele value of RGB image using imtool function.

```
R=i;
R(:,:,2)=0;
R(:,:,3)=0;
Imshow(R);
```

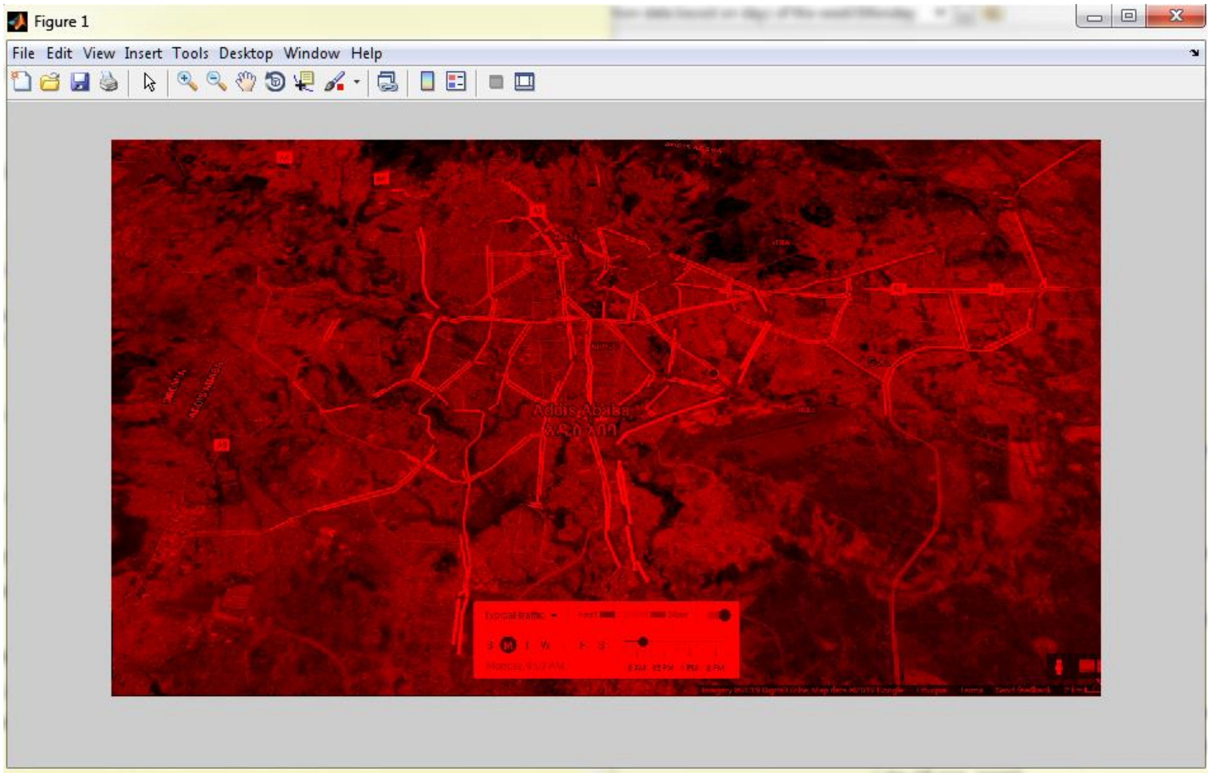


Fig 4.49 Math lab window that show only red color of an image.

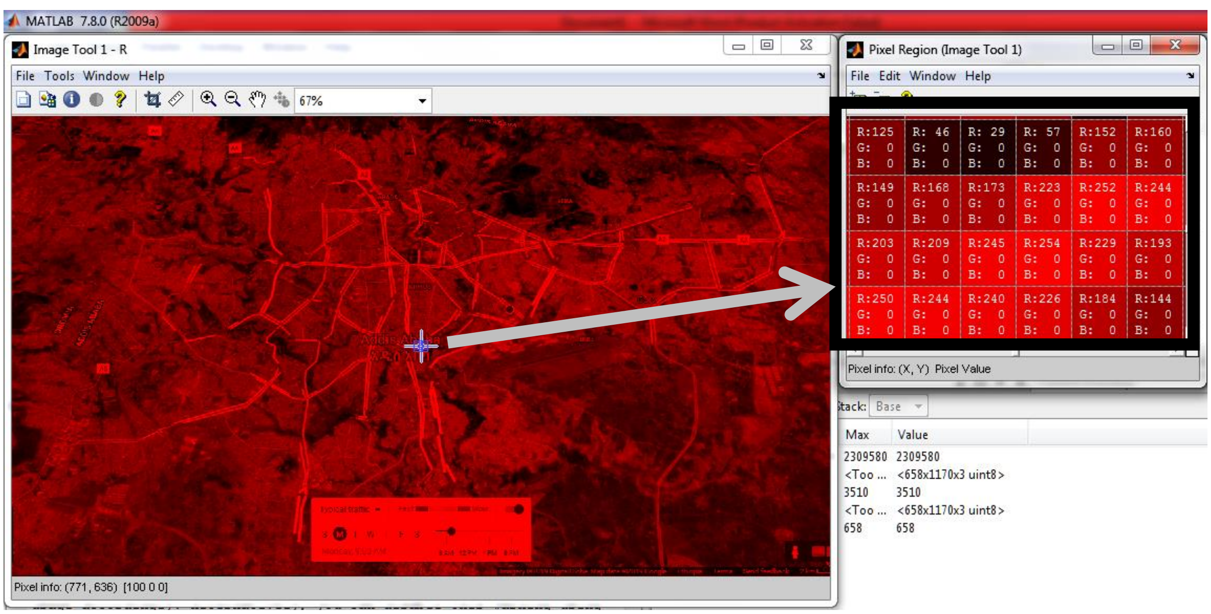


Fig 4.50 Math lab window that show only red value of an image.

%This analysis is used for identify traffic intensity of Addis Ababa of each day of the week and at %every 1 hour interval.

%The analysis identify RGB values of the traffic image obtained from Google map. Red value on the %on Google map identifies value of traffic congestion intensity.

% This analysis extracts red color intensity from Google map.

% below analysis is traffic intensity of Addis Ababa in summer on Sunday within every 1 hour for

% 17 hour surveillance.

```
>> i=imread('06.png');
>> sum(i);
>> q=sum(i);
>> sum(q)
```

% below analysis is sample analysis of traffic intensity of Addis Ababa during morning with starting from 06:00 %am.The analysis identify RGB values of the traffic image obtained from Google map. Red value on the %on Google map identifies value of traffic congestion intensity. % This analysis extracts red color intensity from Google map.

```
>> i=imread('6.png');
sum(i);
q=sum(i);
sum(q)
ans(:,:,1) =
      94562917
ans(:,:,2) =
      94581128
ans(:,:,3) =
      82890402
```

94083131

ans(:,:,3) =

82387181

```
>> i=imread('12.png');
```

ans(:,:,1) =

93244214

ans(:,:,2) =

93949769

ans(:,:,3) =

82312453

```
>> i=imread('13.png');
```

ans(:,:,1) =

93244214

ans(:,:,2) =

93585329

ans(:,:,3) =

82088137

```
>> i=imread('14.png');
```

93581176

ans(:,:,2) =

94153245

ans(:,:,3) =

82480111

```
>> i=imread('15.png');
```

ans(:,:,1) =

93572609

ans(:,:,2) =

94979567

ans(:,:,3) =

83108877

```
>> i=imread('16.png');
```

ans(:,:,1) =

93963142

ans(:,:,2) =

94900877

ans(:,:,3) =

82674099

>> i=imread('17.png');

ans(:,:,1) =

94066368

ans(:,:,2) =

95548049

ans(:,:,3) =

83108363

Math lab Output summery

Reference 86732898

Average traffic congestion intensity from October to May Math lab output								Average
Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	
6:00	88781652	89068104	88780188	88763447	88613157	88237079	88735369	88711285
7:00	89208069	90233984	89899684	89971771	89558961	88628278	88315215	89402280
8:00	90738325	91754366	91902993	91402058	91735673	90165660	88644685	90906251
9:00	91090714	90709291	91240650	91231717	91318907	90673987	89139910	90772168
10:00	90801552	91134319	91556602	91279606	91173296	91099130	89586558	90947295
11:00	90353087	91096873	91010934	91407564	91207207	91462593	90171719	90958568
12:00	91023181	90901619	91212234	91510685	91652203	91866876	89745989	91130398
13:00	90501324	90573845	91048861	91090213	90897349	91330929	90025914	90781205
14:00	90618729	90488793	91204204	90926963	91011713	91101524	90036442	90769767
15:00	91198981	90758357	91114612	91672526	91236746	90759112	89546160	90898071
16:00	90864563	90951366	91218067	91596905	91696243	90759112	89815295	90985936
17:00	91817475	92265052	91475035	92258855	91644164	91041500	90927985	91632867
18:00	90963431	91646550	91453968	91526989	91478588	91041500	90709554	91260083
19:00	90245560	91842670	92233513	91675857	92087636	91332634	89646876	91294964
20:00	89384421	92176659	90329674	91694627	90263484	90382567	88519207	90392948
21:00	89075797	89710684	88936551	88867808	88989933	90715958	89394730	89384494
22:00	86732898	88026331	88443281	88400850	88849535	87964573	88069677	88069592

Table 4.9 Math lab out traffic intensity output typical traffic congestion intensity from October to May.

Typical traffic congestion intensity from October to May with less back ground effect							
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Average
2048754	2335206	2047290	2030549	1880259	1504181	2002471	1978387
2475171	3501086	3166786	3238873	2826063	1895380	1582317	2669382
4005427	5021468	5170095	4669160	5002775	3432762	1911787	4173353
4357816	3976393	4507752	4498819	4586009	3941089	2407012	4039270
4068654	4401421	4823704	4546708	4440398	4366232	2853660	4214397
3620189	4363975	4278036	4674666	4474309	4729695	3438821	4225670
4290283	4168721	4479336	4777787	4919305	5133978	3013091	4397500
3768426	3840947	4315963	4357315	4164451	4598031	3293016	4048307
3885831	3755895	4471306	4194065	4278815	4368626	3303544	4036869
4466083	4025459	4381714	4939628	4503848	4026214	2813262	4165173
4131665	4218468	4485169	4864007	4963345	4026214	3082397	4253038
5084577	5532154	4742137	5525957	4911266	4308602	4195087	4899969
4230533	4913652	4721070	4794091	4745690	4308602	3976656	4527185
3512662	5109772	5500615	4942959	5354738	4599736	2913978	4562066
2651523	5443761	3596776	4961729	3530586	3649669	1786309	3660050
2342899	2977786	2203653	2134910	2257035	3983060	2661832	2651596
0	1293433	1710383	1667952	2116637	1231675	1336779	1336694

Table 4.10 Summery of Math lab output for typical traffic congestion intensity from October to May with less back ground effect.

Reference 94388428

	Typical traffic congestion intensity from June to September							
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Average
6:00	94752991	94388428	94794009	94726011	94906827	94552935	93996317	94621515
7:00	94557223	94411800	94571732	94787658	95007474	94442370	93488428	94466669
8:00	95913041	95789569	95548909	95802403	96165824	95190862	93897592	95472600
9:00	95384918	95793368	95548909	95506444	95958640	95301320	94177274	95381553
10:00	96007337	96195822	95921620	95762283	95647074	96256891	94327879	95731272
11:00	95689877	95742516	96352500	96510361	96294271	95900507	94209244	95814182
12:00	95819002	95274241	95998242	96051307	95887714	95989996	94533644	95650592
13:00	95031747	95755573	95581951	95940456	95632562	96141292	94809316	95556128
14:00	95859194	95714331	95480314	95570368	95719410	96446220	94578573	95624059
15:00	96045022	95871995	95607993	95980685	96141953	95790236	94591577	95718494
16:00	96213397	95622732	96014499	96416190	96187765	94810100	94161495	95632311
17:00	96213397	95770098	96155579	96778086	96291738	96089434	94422135	95960067
18:00	96363732	96367354	95863577	96452159	95987348	95787302	94686734	95929744
19:00	96335979	96514235	96166074	96189092	96115950	96094363	95118444	96076305
20:00	95706716	96559577	96035684	95491174	96167639	95378490	94898254	95748219
21:00	94392216	95622732	94485417	94398218	94624691	94393855	93675340	94513210
22:00	94390465	95770098	94647151	94568941	94458412	94649525	93669378	94593424

Table 4.12 Summery of Math lab output for typical traffic congestion intensity from June to September to May.

Typical traffic congestion intensity from June to September with minimized back ground effect.							
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Average	Time
364563		405581	337583	518399	164507	358126.6	6:00
168795	23372	183304	399230	619046	53942	241281.5	7:00
1524613	1401141	1160481	1413975	1777396	802434	1346673	8:00
996490	1404940	1160481	1118016	1570212	912892	1193839	9:00
1618909	1807394	1533192	1373855	1258646	1868463	1576743	10:00
1301449	1354088	1964072	2121933	1905843	1512079	1693244	11:00
1430574	885813	1609814	1662879	1499286	1601568	1448322	12:00
643319	1367145	1193523	1552028	1244134	1752864	1292169	13:00
1470766	1325903	1091886	1181940	1330982	2057792	1409878	14:00
1656594	1483567	1219565	1592257	1753525	1401808	1517886	15:00
1824969	1234304	1626071	2027762	1799337	421672	1489019	16:00
1824969	1381670	1767151	2389658	1903310	1701006	1827961	17:00
1975304	1978926	1475149	2063731	1598920	1398874	1748484	18:00
1947551	2125807	1777646	1800664	1727522	1705935	1847521	19:00
1318288	2171149	1647256	1102746	1779211	990062	1501452	20:00
3788	1234304	96989	9790	236263	5427	264426.8	21:00
2037	1381670	258723	180513	69984	261097	359004	22:00

Table 4.13 Summery of Math lab output for typical traffic congestion intensity from June to September to May with less back ground effect.

	Traffic condition in the morning				
	Monday	Tuesday	Wednesday	Thursday	Friday
6:00	92610048	92750086	93151336	92519004	93186089
6:30	93093116	92663331	93296410	93254136	93966278
7:00	93553011	93244214	92901730	93463031	92940675
7:10	93469362	93581176	93392781	93936332	93846762
7:20	94223906	93572609	93785954	93799838	93567209
7:30	94562917	93963142	93466511	93874387	94457179
7:40	94234243	94066368	94355647	94839064	94845210
7:50	95046923	95483699	94265613	94845620	94918321
8:00	95562990	95483699	94644914	94144662	94891509

Table 4.14 Typical traffic intensity of morning from 6: 00 to 8 am with shorter interval