Traffic Congestion Hot-Spots area and Traffic Demand Analysis by using Travel Demand Modeling, in Downtown Adama City.

Minichil Molla Sitotaw

A Thesis Submitted to the Department of Architecture, School of Civil Engineering and Architecture.

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Urban Planning and Design.

Office of Graduate Studies
Adama Science and Technology University

June, 2023

Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled "Traffic congestion hot-spots area and traffic demand analysis by using travel demand modeling, in downtown Adama City" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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Name of the student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “Traffic congestion hot-spots area and traffic demand analysis by using travel demand modeling, in downtown Adama city” prepared under my guidance by Minichil Molla Sitotaw submitted in partial fulfillment of the requirements for the degree of Mater’s of Science in urban planning and design.

Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Major Advisor/Supervisor	Signature	Date

APPROVAL PAGE OF M.SC. THESIS

I, the advisor of the thesis entitled "Traffic congestion hot-spots area and traffic demand analysis by using travel demand modeling, in downtown Adama city" and developed by Minichil Molla Sitotaw, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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Major Advisor/Supervisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis Minichil Molla Sitotaw have read and evaluated the thesis entitled "Traffic congestion hot-spots area and traffic demand analysis by using travel demand modeling, in downtown Adama city" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in urban planning and design.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADT--------------------------------Average daily traffic

ADWT-----------------------------Average daily weekday traffic

APHT------------------------------Average peak hour traffic

CBD-------------------------------Central business district

HBNW----------------------------Home-based-none –work

HBW------------------------------Home-based-work

HHD-------------------------------Household

HMC------------------------------Highway manual capacity

LOS--------------------------------Level of service

NHB-------------------------------None-home-based

O-D--------------------------------Origin-destination

PHV-------------------------------Peak hour volume

TA---------------------------------Trip attraction

TAZ-------------------------------Traffic analysis zone

TDM-------------------------------Travel demand model

TG---------------------------------Trip generation

TP----------------------------------Trip production

TTI---------------------------------Travel time index

VO---------------------------------Vehicle occupancy

4WD-------------------------------Four-wheel driver

Abstract

Nowadays almost all over the world especially in developing countries, the influence of rapid urbanization results in rapid motorization that leads to traffic congestion in urban mobility. Traffic congestion hotspots are a dynamic phenomenon in urban life characterized by a high traffic delay in the transportation system. Traffic demand is the over-dependence of people in transportation. Adama has experienced an alarming rate of urbanization and growth. Over the past years, the city has observed an amazing expansion and an increment in population size. Traffic congestion and traffic demand in the city are due to rapid urbanization, increased transport demands, and increment of private vehicle ownership, leading to significant motorization in the urban center. The study aims to analyze traffic congestion hotspots and traffic demand in Adama City's downtown using travel demand modeling. Cordon count which is a manual field count of traffic volume was employed to identify the most congested route in the traffic analysis zone. Survey, interview, and questionnaire was the major instrument for primary data collection for origin-destination analysis, household travel survey, and for travel demand modeling analysis. The study carries out a trip generation and attraction model analysis to examine the volume of trip production in the study zone of Gurmmu Kebele. Households, private car owners, and public transport users who commute regularly to the central business district are the representative target of this study. A sample of 210 was chosen which was stratified into 70 samples for each target group. Data were analyzed by using descriptive statistical tools, network analysis, and analysis of relationships. For all chosen routes in the traffic analysis zone, the study found that the route from Franco to Posta Bet was extremely congested especially at peak hour (morning and evening), with a total peak hour volume of 1946 vehicles per 15-minute interval, resulting in a Level of Service grade of F (constrained maneuverability at peak hour). The Franco to Posta Bet route experiences increased travel times and decreased speeds during morning and evening peak hours, with a higher travel time in the evening compared to the morning. During evening peak hours, covering the distance takes an average of 250.5 seconds. The overall origin-destination trips of households are held within the traffic analysis zone, with an average work distance of 1.5km. The study found that a trip of household origin-destination in the traffic analysis zone made an average of 7.8 trips per weekday and household members averaged 3.0 trips per weekday. The trip production and attraction results show a total trip production of 9007 per weekday across the four study zone. The highest trip production was in Gurmmu Kebele's zone two, with 3,236 trips generated in weekday travel. As a mitigation measure modeling traffic and flexible work schedules can spread traffic volume across the day, reducing peak-hour demand and improving overall traffic conditions.

Keywords: Congestion, hot-spot, households, origin-destination, transportation, and travel demand modeling.

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Nowadays almost all over the world especially in developing countries, the influence of rapid urbanization results in rapid motorization that leads to traffic congestion in urban mobility (Edwards, J. D. 2012). Traffic congestion hotspots are a dynamic phenomenon in urban life characterized by high traffic delays in the transportation system in urban mobility (Downs, A. 2000). This phenomenon is dominated in some particular areas in the city we call the congestion hot spot area (Bast, Funke et al. 2007). In addition, these hotspots are usually located in the city Centre, with high motorized movement which magnifies the problem (Solé-Ribalta, Gómez et al. 2018).

Human activities have been delayed by traffic congestion in the city center which harms the mobility of the urban and development of the city (Afolabi, Oluwaji et al. 2017). Therefore, rapid urbanization in the city had been affect traffic congestion (Nurdden, 2007).

Traffic demand nexus urbanization and mobility, traffic demand is a crucial aspect of nexus urbanization and mobility planning. As urban areas grow and evolve, the demand for transportation services increases, leading to greater pressure on existing infrastructure and systems (Ibrahim–Adedeji, K. J. J. o. E. I. et al. 2014). Understanding and managing traffic demand is essential to ensure efficient and sustainable mobility in the urban environment (Bose, R. K. 2019).

Travel demand analysis is a systematic process of understanding and forecasting the travel pattern and behavior of individuals or groups within a geographic area (Smith, J. 2022). It involves studying the factor that influences travel demand such as population characteristics, socioeconomic factors, land use pattern, transportation infrastructure, and policies (Kanu, K. E. 2015).

The current global traffic congestion levels (condition) increased slightly compared to previous years. The city with the world's worst traffic congestion was Bengaluru, India, followed by Manila, Philippines, and Bogotá, Colombia. Daily, weekly, and annual patterns of congestion vary greatly depending on the region, city, and local conditions (Houyengah, M. 2020).

Traffic congestion in developing countries is primarily due to factors such as rapid urbanization, economic growth, insufficient transportation infrastructure, illegal parking, inadequate land use planning, and a mismatch between traffic demand and route capacity (Nurdden, A. M. 2007). This issue is particularly prevalent in developing countries where transportation systems are not designed in accordance with future population forecasts (Kumar, R. &. 2021). The most congested African city was Cairo, Egypt, followed by Johannesburg, South Africa, and Cape Town, South Africa. Traffic in Lagos, Nigeria, has also become notoriously problematic (Organization, 2021).

Modeling traffic flow had been a hot field since the late 1970s for congestion analysis in worldwide congestion studies. Gipps' model and other car-following models, Treiber, Hennecke, et al. (2000) have evidenced the necessity of modeling traffic flows to improve road network efficiency. Consequently, varied suggestions have been made by various scholars on how to reduce the effects of traffic congestion. Some of these suggestions include the expansion of the road network (Ibrahim–Adedeji and Countries, 2014). Improved traffic management and staggering working hours Dor, (2019) improvement in public mass transportation.

Adama is one of the largest cities in Ethiopia. It has an alarming rate of urbanization and growth in the city. Over the past years, the city of Adama has observed an amazing expansion of the city size and an increment in population size. As the city is growing fast to the surrounding of the city, the mobility and traffic demand of the people also increased significantly. People prefer to use private vehicles to go work in the center of the city. Despite this urban expansion the city face delay and congestion of transportation in the TAZ. The concentration of workplaces in areas like Central Business Districts (CBDs) leads to morning rush hours.

Previous studies had been conducted in developing countries, such as Nigeria's Lagos-Ikorodu Road, congestion in this research corresponded only to link-based analyses, this research is just on the congestion segment level (Kanu, K. E. 2015). Here, this research was done based on the idealized model using travel demand model analysis for transportation analysis in traffic analysis zone by disaggregating the trip source area for traffic congestion and travel demand assessment. This research aimed to identify congestion hotspot locations in the city by measuring the level of congestion on the selected route and utilizing travel demand model analysis to examine the travel behavior and pattern of households.

1.2. Statement of the Problem

Addis Ababa, the capital of Ethiopia, has experienced urban growth, resulting in increased traffic congestion. Inadequate transportation infrastructure and high growth in vehicle ownership contribute to this congestion. The Ethiopian government has initiated projects to alleviate congestion in Addis Ababa, including the construction of a light rail and the expansion of road networks.

Traffic congestion in Adama is caused by rapid urban expansion and the increment of the traffic demand, rapid motorization, an increasing number of private car ownership, an imbalance between traffic demand and road capacity, population growth, diverse activities (economic, administrative, social), and incompatibility of land use.

Adama has experienced significant urban expansion, leading to increased demand for transportation. Many people prefer using private vehicles to travel to the city center for work, causing congestion and delays on major traffic routes during morning rush hours. The availability of working areas that concentrate on the CBD brought congestion that the individual commuting there in the morning rush hour by using a similar route leading to the work at the same peak hour. The increment in transport demand has a significant influence on transportation because the city's existing road network, which was constructed and built before the period of mass automobile ownership, is grossly insufficient to satisfy travel demands. Traffic congestion in the city greatly impacts residents, workers, students, and people commuting to the central business district. Delays and long travel times result in loss of working hours and missed events. Passengers relying on taxis, public transport, and private vehicles are most affected by this issue.

The researcher initiates addressing the severe vehicle congestion in downtown Adama by developing traffic management strategies. The study uses a unique approach, involving detailed transportation analysis, trip analysis of people's origin-destination, and household travel survey analysis.

Similar research was conducted in numerous developing nations, including Nigeria and Ghana. Traffic congestion in the Lagos metropolis specifically within the Ikeja Local Government Area is a result of the imbalance in the number of vehicles which has increased geographically. They only analyze congestion at a specified link in the area's road network by assessing the available level of mobility congestion in the road to investigate traffic volume.

Previous research which has been done only in the link-based assessment of congestion without assessing the trip nature and their demand for transportation by the level of traffic analysis zone in some developing countries like Nigeria has taken as a gap and was used and answered by this research. Especially including traveler characteristics in addition to population and land use character and traffic zone analysis of congestion rather than link-based were the base of this research. Trip source area assignments in other land use were carried out rather than only in the residential zone.

1.3. Objectives

1.3.1. General objective

The general objective of the research is to assess traffic congestion hot-spot areas and traffic demand by using travel demand modeling in traffic analysis zones in Adama City downtown.

1.3.2. Specific objective

The specific objective of the study is to:

- Investigate the current traffic volume and movement pattern in Adama City;
- Analyze the origin-destination pattern of people trips in the study area;
- Estimate the study area travel demand using a travel demand model; and
- Identify traffic congestion hot spots by measuring the level of congestion in a selected network of traffic analysis zone.

1.4. Research Question

- What is the current traffic volume and movement pattern in Adama City?
- What is the origin-destination pattern of people's trips in the study area?
- How can the study area travel demand be estimated using a travel demand model?
- How can traffic congestion hot spots be identified by measuring the level of congestion in a selected network of traffic analysis zones?

1.5. Significance of the Study

The research will have to make its own empirical and theoretical contributions, as well as fill a research gap on the subject.

This research will have developed an in-depth understanding of the theory and concept of transport analysis especially in travel demand analysis for the study of road conditions that mitigate the problem of congestion and how to identify its hot-spot region through this travel demand analysis. And fill the gap in earlier research about congestion that is only link-based.

This study will have to make beneficial to the policymakers, transportation planners, road infrastructure, urban planner and local government. It helps for Policy development, it informs the development of transportation policies, strategies, and regulations to reduce congestion and improve mobility. Based on the impact assessment of this finding, this transportation analysis finding can be used by the transportation sector in planning suggested development plans and it can make beneficial to policymakers and transportation planners for transportation planning. Moreover, this research finding can be used as a reference for future research, and it contains academic contributions that guide anyone who initiates traffic congestion analysis. Furthermore, it serves as a guideline for numerous transportation sectors' planning processes for demand assessment.

1.6. Scope of the Study

The research has been confined to Adama City's downtown, with a focus on the downtown traffic network. The analysis takes advantage of the existing road network in the city center, which includes all types of access in the analysis zone. The research was carried out with a major selected network of traffic analysis named as, route from Franco to Posta bet, route from Addis Ababa Meneharia to Posta bet, route from Tikur Abayi to Posta bet, route from Amede Gebeya to Posta bet, and route from mebrat hail to Posta bet. Moreover, the research focuses on the vehicle which enters and departs from the analysis zone and moves within the TAZ.

The purpose of the study is to identify congestion hotspot areas and analyze traffic demand by carrying out a transportation analysis and travel demand modeling of existing transportation facilities in the city center. The themes of this research are to investigate the volume of traffic flow to identify hotspots in the traffic network and assess the travel behavior, origin-destination, and household travel survey in the study area. Further, the research examines the significant impact of traffic congestion on stakeholders. It evaluates the average driving speed and time to explore the transportation system's road design capabilities.

1.7. Operational Definition

Traffic congestion: Traffic congestion is a road condition characterized by slower speeds, longer trip times, and increased queuing. It occurs when roadway demand is greater than its capacity (Kayithi, 2020).

Hot spots: The locations or those areas of the city, which are regularly congested and where the flow of traffic is very slow. In hot-spot areas a condition of breakdowns in the traffic flows. Queuing and congestion are the norm for this area.

Travel demand: according to Hougendoorn and Bovy (2001) observe that traffic flow, traffic growth, and congestion are some of the main economic and societal problems related to transportation.

Transportation analysis: A transportation study examines the flow of traffic on a network of roads. A unique application of the "network flow issues," which are a component of linear programming theory, is a road network. Determining a static maximum flow from one point to another in a network, subject to network capacity restrictions, is the mathematical foundation of network analysis (Fulkerson & Ford, 2012).

Traffic Analysis Zones: A study area is divided into areas, instead of points. Those areas are called Traffic Analysis Zones (TAZs).

O-d analysis: Traffic flows between TAZs are normally expressed in an origin-destination (O-D) matrix. Origin-destination flows (O-D flows, i.e. the number of trips between two locations.

1.8. Structure of the Research

The research has been organized into five chapters. Chapter One explores the study's background and provides a broad introduction to the subject, focusing on the paper's goal. It illustrates the objective of the research. The second chapter covers the literature review, which includes both a theoretical and empirical examination of the subject. The third chapter is on the research method, which is the study's blueprint. Some sections in this chapter include the study area description, research design, study approach, data type and source, study population, and sample technique. This chapter majorly explores methods for data collection, processing, and data analysis. Chapter four presents the result and its brief discussion. The last chapter, chapter five describes the general conclusion and recommendation of this study. This is the overall structure of this paper.

1.9. Limitation of the Study

Some of the most common challenges faced during these research operations include:

This researcher primarily relies on manual field counting to measure traffic volume, travel time, and speed. This approach is due to the incapability of automatic recording machines in capturing these parameters accurately in the study area. Consequently, these factors present significant challenges in conducting this research effectively.

Access to information and data: Gathering sufficient and relevant data from primary or secondary sources was difficult, as certain information is inaccessible due to privacy, security, or logistical reasons. One of the significant challenges faced while gathering information from representative households is their reluctance to share information freely. This reluctance stems from concerns regarding security issues associated with disclosing personal information. To address this challenge, it becomes essential to incorporate a mediated approach when interacting with respondents to build trust and ensure the privacy of the information being shared.

Time constraints: Adequate time is required to carry out thorough research, and present and analyze data.

Funding and resource allocation: Limited funds and resources was a big challenge in the research process leading to inadequate facilities, information, and for recruiting data collector.

Due to time and budget constraints, researchers often focus on trip generation and attraction models to assess travel behavior and the volume of trips produced in specific zones.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Theoretical Review

2.1.1. Travel demand modeling

A travel demand model is a quantitative tool used by urban planners, transportation engineers, and policymakers to estimate and analyze travel behavior and patterns within a specific region or city (Sivakumar, 2007). The model forecasts the demand for transportation infrastructure and services by simulating the decision-making processes of individuals and households related to various travel choices, such as modes of transport (private cars, public transit, walking, biking), trip origin-destination, travel routes, and time of travel and speed. These models help in understanding and predicting transportation usage, evaluating the impacts of various transportation policies and infrastructure investments, and supporting the planning and management of sustainable transportation systems (Ortúzar, 2011).

2.1.2. Hot-spot

Hot-spot areas are where there is frequent traffic congestion, collapsed urban mobility, and restricted right of way. It is the point where motorized movements are impossible and it is a location where vehicular queuing occurs (Colak, 2018). Congestion is the issue of planning and transportation analysis which study about the road condition of the city. Stuck in traffic and peak hour traffic congestion in the street network and nodal point of the city is becoming a serious problem for the urban environment (Downs, 2000).

The failure of the public transportation system in the cities has led to an increment in private motorization. cities have been characterized by overcrowding and the use of already overused and rickety vehicles imported from other parts of the world, incessant traffic congestion due to continuous deteriorating conditions of roads that inadvertently slow down traffic, and increasing vehicular and pedestrian accidents (Badejo, 2008).

2.1.2. Traffic congestion

Harriet, Poku et al. (2013) states that congestion can be perceived as an unavoidable consequence of scarce transport facilities such as road space, parking area, road signals, and effective traffic management. They argue that urban congestion mainly concerns two domains of circulation, passengers and freight which share the same infrastructure.

Downie, (2008) 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 several specific circumstances that cause or aggravate congestion. The over-dependence on cars has tremendously increased the demand for transport infrastructure. Consequently, several vehicles spend most of their time in traffic as a result of traffic space limitations (Yan, 2010).

In the cities of the developing world, traffic congestion is worse than those in developed countries with many times vehicles. The situation in developing countries however is at the peak of collapse, because increasing urban drift is still far from being under control and the problem of providing transport facilities is not in sight in developing countries as the case in developed countries (Bose, 2019).

Ikporukpo & Filani. (2000) Vehicular traffic problems in intra-urban mobility became significant in some areas, especially in trip destinations such as work zone, central business districts, and other government institutions. Nodal (roundabout), intersection and junction are the area of this congestion take place. Hudson. (2010) in his study on bicycles, planning pointed out that integrating bicycles into the transportation system will make a greater contribution to the solution of the problem of traffic in towns.

2.1.3. Traffic demands and delays

According to Houyengah, (2020) traffic flow, traffic growth, and congestion are some of the major economic and societal concerns associated with transportation in developed countries. This is due to the city's fast growth. These issues appear as environmental pollution, delays and accidents, and land use severance, among others. Ayeni. (2013) also supports this view and observes that these problems are some of the most pressing and perhaps most visible urban problems

The Need for Demographic Analysis:

Population projections are the base for many planning activities, such as producing land use and transportation plans, determining the direction of future economic development, and guiding housing, school, and shopping center developments. Population projections often become the centerpiece of comprehensive plans and the future vision of localities (Fernández-Martín, 2021).

Transportation planning: Growing cities and metropolitan regions face the challenge of coping with increases in transportation demand. More automobiles on the streets and highways and higher demands for public transportation systems have their origins in growing populations (Kumar, 2021).

2.1.4. Transportation analysis

Transportation analysis is one of the four planning analytical methods. Various economic activities for a given population in an area occur at different locations, which are associated with different land uses (Deal, Brian et al. 2013). The interaction of those activities requires a network to connect places for moving people and goods. The function of such a system is the focus of transportation analysis (Edwards, 2012). In addition to the mode of transportation, a transportation system consists of networks such as roads, and supporting facilities, such as traffic lights (Murray, Davis et al. 2014).

Transportation planners estimate the amount of traffic associated with the planned land use allocation, the options of travel modes, the alternative routes, and the required roadway features to support the estimated traffic volume (Banister, 2001).

The time of departure, mode of transportation, and route may be used to categorize people's travel preferences. Morning rush hours are the busy times when many people drive to work. People may decide to go to work in their vehicles or via public transportation. This leads to route choice as the only major factor affecting the traffic volume (Beirão & Cabral, 2007). Travelers can easily switch routes on the way. This switch of routes, modes, and time is called “triple convergence” (Downs, 2000).

2.1.5. Basic concept in transportation analysis

A transportation study examines the traffic conditions on road networks. Road networks represent a specific application of "network flow problems," which fall under the domain of linear programming theory (Ford & Fulkerson, 2015). The fundamental concept in network analysis involves calculating the maximum steady flow between two points in a network while considering the capacity constraints of the network (Ford and Fulkerson, 2012).

A node is the termination of a street or a junction where two or more streets converge. For example, in Fig.2-1, four street intersections are labeled as nodes 1 through 4.

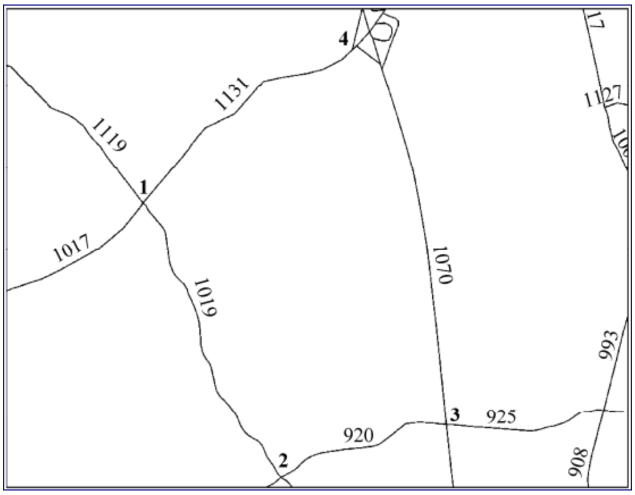

Figure 2.1: Illustration of a Street Network (source: research method in urban and regional planning book,page 329)

2.1.6. Traffic analysis zones

A study area is divided into areas, instead of points. Those areas are called Traffic Analysis Zones (TAZs). A traffic analysis zone is delineated as the smallest area of the study region. Although there may be numerous residential locations in a TAZ, including each location in the model would be rather difficult in practice. Therefore, travelers within a TAZ are treated in the same way as an aggregated group (Oppenheim, 2015). Traffic generated from a TAZ or ending at a TAZ is connected to street networks through one or more connectors.

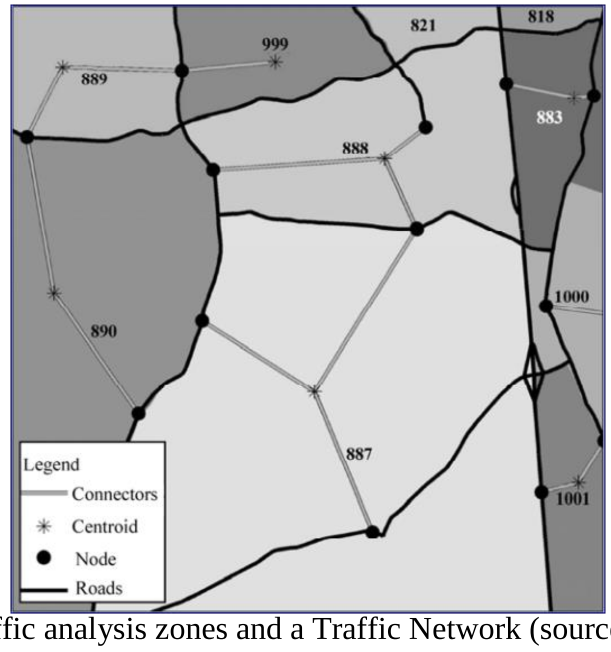

Figure 2.2: Traffic analysis zones and a Traffic Network (source: research method in urban and regional planning book, page 331)

One end of a connector is a node on the street network (Binetti & Ciani, 2002). The other end is the centroid of a TAZ. Connectors may not be real roads. Figure 2.2 illustrates TAZs and their connectors to the street network.

A trip is normally the focus of a transportation analysis. It represents the path people make from one place to another, for instance, from home to office (Hensher, D. A., & Reyes, A. J. J. T. 2000). One type of trip is a vehicle trip-the number of automobile trips traveling in a transportation system. Another type of trip is a person trip-the number of people traveling through the transportation system, Hensher & Reyes, (2000). The two places connecting a trip are called trip ends (origin-to-destination).

2.1.7. Origin-destination (o-d) analysis

Traffic flows between TAZs are normally expressed in an origin-destination (O-D) matrix. Origin-destination flows (O-D flows, i.e. the number of trips between two locations in a certain period) and traffic volumes (the number of vehicles that cross a street over a given time interval (Imai, Ryuichi et al. 2021). Traffic volume can be observed through measurement devices, while O-D flows are usually estimated by household travel surveys. Several mathematical models have also been proposed to estimate parameters for these two variables, such as models to estimate mean O-D flows based on observed traffic flows and traffic assignment methods to estimate mean routes (Wright & Ashford, 2019).

2.1.8. Basic terminology of transportation analysis

Table 2.1: Basic Transportation Planning Analysis Terminology

Terminology	Description	Measure
Design capacity	The maximum number of vehicles that can pass the end of a link.	Vehicles per hour, such as 1,000 vehicles per hour.
Design speed	Maximum travel speed for a given link when there is no delay.	Kilometer per hour
Number of lanes	Represents the lanes available for travel	number of lanes
Volume	The actual number of vehicles going through the link	Daily volume (24-hours) or one-hour volume
Average Daily Traffic (ADT)	Represents the typical daily traffic volume for a link	Weekday and weekend volume.

Average Peak Hour Traffic (PHV)	Traffic data are collected only during peak hours on multiple days.	The average is calculated from the data
Vehicle occupancy	Some people travel together in one mobile vehicle.	Number of travelers divided by the number of traveling

Source: A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, Washington, DC 1994.

2.1.9. Trip purpose

In transportation analysis trips are normally classified by trip purpose based on the location of the origin and destination.

Table 2.2: Origin -Destination of a Trip based on Trip Purpose.

Trip purpose	Description	Example
Home-based work (HBW)	One of the trip ends is home and the other trip end is a workplace	Home to work in the morning or vice versa
Home-based-non-work (HBNW).	One of the trip ends is home and the other trip end is not a workplace	When a family goes to a restaurant for dinner
Non-home-based (NHB)	Neither of the two trips ends is home, the trip	A person to go shopping during lunch break. One trip end is the office and the other trip end is the store.
Round trip	Two trips between two trip end (back and forth)	A person goes to work from home in the morning and returns home

Source: Research method in urban and regional planning book, (Transportation analysis)

The above-discussed trips can be called simple trips. As the trip-making behavior becomes more complex, people may make intermittent stops on a trip. Trip chaining is the succession of trip segments (Hensher & Reyes, 2000).

2.1.10. Overview of transportation analysis

Transportation planning consists of two tasks. The first task is to estimate the traffic flow based on population and economic activities. Human activities are normally reflected in land use composition. The second task is to evaluate the social, economic, and environmental impacts of transportation projects (Rosenbloom and Black, 2014).

Traffic demand analysis (freight and passenger) aims to derive the traffic volumes of a traffic network. The volumes are calculated from a set of origin-destination matrices related to a proper traffic analysis zone subdivision (Winkler, Mocanu et al. 2020). Computer models are often developed to simulate traffic demands (Gibson, 2013).

2.1.11. Level of Service to measure the level of congestion

The travel quality of a road is normally expressed with the measurement of the level of service (LOS) (Maitra, Bhargab et al. 1999). In the United States, there are six LOS categories represented by the letters "A" to "F", where A is for the best traffic condition and F, is for the worst. It can be used to measure different modes of transportation. It should be noticed that LOS measures the quality of traffic flow or the levels of congestion by volume/capacity ratio (Imran 2015).

Table 2.3: Level of Service Classification

Level of service	Description
A	Represents free-flow operations. A traveler can travel at the designed speed almost completely unimpeded.
B	A condition in which a motorist still can experience reasonably free flow at free-flow speeds.
C	The ability to maneuver is noticeably restricted.
D	Depicts a condition in which motorists can experience reduced travel speeds. The ability to maneuver is severely limited.
E	A condition in which traffic is at its design capacity. There is no room for any disruption of traffic flow.
F	A condition of breakdowns in the traffic flow. Queuing and congestion are the norms for LOS F.

Source: Research method in urban and regional planning book (Transportation analysis)

2.1.12. Travel demand modeling

A travel demand model is used to forecast the transportation arrangement. To estimate the traffic associated with different human activities, a region is divided into TAZs, and the TAZs are connected to the transportation network. TAZs are the smallest unit of analysis in travel demand modeling (Oppenheim. 2015). Two general rules are normally used in delineating TAZs:

(1) A zone should be bounded by the transportation network or natural boundaries, such as rivers.

(2) The zone boundaries enclose a relatively homogeneous area in terms of land use characteristics and traffic conditions and separate the areas that are different. TAZ boundaries may follow community or neighborhood boundaries.

This travel demand modeling encompasses significant travel behaviors influencing travelers' decisions regarding travel choice, destination, mode of transportation, and route selection. The modeling procedure comprises four distinct components, often known as the four-step travel demand forecasting model (Chang & Meyers, 2014).

1. Trip Generation: Forecast the number of trips that originated from and attracted to each TAZ.
2. Trip Distribution: Allocate the trips within and between the TAZs.
3. Mode Choice: Divide trips among different modes of travel.
4. Trip Assignment: Assign the trips to different routes connecting the TAZs. These four steps were developed in the 1950s and 1960s.

Trip generation

A trip is defined as a connection between an origin (O) and a destination (D). Consequently, trip generation is a process to determine the number of trips from and to a particular site or area. Trip generation establishes the connection between transportation analysis, demographic analysis, and economic analysis (Gazis, 2002).

To predict trip generation, an assessment of land use types is necessary. For instance, the Institute of Transportation Engineers releases information on trip generation rates corresponding to distinct land use categories (Engineers, 2003). The trip generation rate can be calculated as daily trips or peak-hour trips. Trip generation rates are presented as vehicle trips or personal trips. A vehicle occupancy variable can be used to convert the two rates:

$$TGv = TGp / VO \quad (1)$$

Where, TGv-vehicle trip generation rate; TGp -person trip generation rate; VO -vehicle occupancy rate.

Trip Production

A common practice of estimating trip production from a TAZ is based on variables related to the population in the zone. The most commonly used variable is number of households.

Some of the variables commonly used in calculating trip production are as follows (DOT, 2016).

1. Workers per household: Workers are the most likely people who travel. The more workers in a household the more trips will be made.
2. The number of households: Trips are generated by residents. The more households in a zone the more trips will be made.
3. Family income: Costs are associated with travel. The higher the family. income, the more trips will be made.
4. Number of automobiles available: People with a car likely travel more than those without a car.
5. Family size: Large families likely travel more than smaller-sized families.
6. Residential density: The residential density on the one hand reflects the number of residents in a zone.

Two methods are used most often in estimating trip production from traffic analysis zones. The first method uses aggregated zonal characteristics.

Trip Production =*f* (median family income, residential density, the mean number of automobiles per household) --- (2)

The second method, the cross-classification method, addresses this deficiency by classifying zonal households based on socio-economic characteristics.

Normally, no more than three to four variables such as family size, automobile ownership, or household income, are used in household classification.

Trip Attraction

Trip attraction predicts the number of trips to be attracted to (end in) each zone. The attractiveness of a zone is related to the size and type of land use that are the destination of trips (Yulianto, Purnomo et al. 2020). The majority of such land uses are non-residential land, such as stores, offices, libraries, etc. The trip attraction is normally expressed as the number of vehicle trips per household or unit area of non-residential land use (Taplin & Qiu, 2015).

All trip-attracting zones in a region compete for the number of trips produced in the region. More attractive zones will attract more trips than the zones that are less attractive.

2.1.13. Congestion measure

Traffic congestion is a persistent problem faced by urban areas worldwide, resulting in longer travel times, increased fuel consumption, and environmental pollution (D. Erath, M. A. 2018). This literature review aims to discuss some of the most significant congestion measures, including the level of service (LOS), volume-to-capacity (V/C) ratio, travel time, and delay, based on existing literature (Kim, 2020).

Level of Service (LOS)

Level of Service (LOS) is a congestion measure defined by the (Manual, 2016). The measure categorizes the performance of a transportation facility into six letter grades (A to F), considering factors such as speed, density, and delay. LOS is a widely accepted measure among transportation planners and researchers in assessing roadway congestion (Chester, 2013). However, the limitation of LOS is that it does not take road users' perceptions into account.

Volume-to-Capacity (V/C) Ratio

The V/C ratio is another congestion measure used to compare the demand (volume) to the available supply (capacity) in a transportation system (Gonzales, 2017). A V/C ratio greater than one signifies that a roadway is oversaturated, leading to higher congestion levels (H. N. Koutsopoulos, 2008). However, like LOS, the V/C ratio may not always accurately reflect users' experiences due to its static approach and assumption of equilibrium in travel demand (Henderson, 2019).

Travel Time

As a congestion measure, travel time is a direct indicator of mobility, reflecting the time required by road users to traverse a specific distance (D. Erath, 2018). Using travel time data can provide insights into congestion patterns and help prioritize transportation improvements (Jin, 2018). While travel time is an essential measure, it is dependent on various data sources like GPS data and manual field surveys, affecting its accuracy and reliability (Zheng, 2016).

Travel speed

Travel speed refers to the rate at which a person or vehicle moves from one point to another while covering a distance. It is usually measured in units of distance per time, such as kilometers per hour (km/h), miles per hour (mph), or meters per second (m/s). Travel speed helps determine the time it takes to reach a destination and plays a significant role in transportation planning, route optimization, and traffic management (Baiocchi, 2021).

The World Health Organization (WHO) has published a set of global speed recommendations. For urban roads, speed limits of 30-40 km/h (19-25 mph) are suggested, while limits of 50 km/h (31 mph) are suitable for non-urban arterial roads, and 80-100 km/h (50-62 mph) for highways (Organization, 2021).

2.1.14. Summary of literature review

Table 2.4: Literature Review

Title of the paper	Description
Solé-Ribalta, A., Gómez, et al. (2016). A model to identify urban traffic congestion hotspots in complex networks	The study proposes an idealized model, based on the critical phenomena arising in complex networks, that allows to analytical predict congestion hotspots in urban environments.
Nijkamp, P., & Blaas, E. W. (2012). Transportation analysis for transportation planning	This paper presents an estimation of the amount of traffic associated with the planned land use allocation, the options of travel modes, the alternative routes, and the required roadway features to support the estimated traffic volume for travel demand.
Tripathi, J. P., & Garg, D. G. (2010) Algorithm for detection of hot spots of traffic through analysis of Gps data	This report presents the method of detecting these areas, which we call 'Hot-Spots' in terms of road traffic, and analyses the impact of these 'Hot-Spots' on traffic, both in terms of time and space. In the report, we present algorithms for the detection of the 'Hot-Spots', based on the speed of the probe vehicle and clustering (Fuzzy c-means algorithm) algorithm.
Yao, L. et al. (2008). Trip Generation Model Based on Destination Attractiveness	This paper gives a method for calculating the trip efficiency and the effect of traffic zones combined with a destination selection model based on disaggregate theory for a trip generation.
Jain, V., Sharma, A. et al (2012, March) Road Traffic Congestion in the Developing World	In this paper, we first present a simple automated image processing mechanism for detecting the congestion levels in road traffic by processing CCTV camera image feeds. Our algorithm is specifically designed for noisy traffic feeds with poor image quality.
Pulugurtha, S. S. et al. (2013). Traffic analysis zone level crash estimation models based on land use characteristics	The objective of this paper is to develop crash estimation models at the traffic analysis zone (TAZ) level as a function of land use characteristics.

Barroso, J. M. F., Albuquerque-Oliveira, J. L. et al (2020). Correlation analysis of day-to-day origin-destination flows and traffic volumes in urban networks	This study analyzed the autocorrelation of a set of day-to-day series of traffic volumes and OD flows generated from a large collection of traffic sensors, identifying the data's correlation structure over different locations and OD pairs in an urban network.
Mei, B. (2002). Development of trip generation models of hurricane evacuation.	In this study, alternative trip generation models for hurricane evacuation movement were developed using logistic regression and neural networks. The southwest Louisiana post-Andrew survey data were used for model estimation, validation, and comparison.
Ibrahim–Adedeji, K. B. (2014). Traffic Demands and Delays on Lagos - Ikorodu Road in Nigeria	This survey assesses the nature of passengers' traffic demands and delays to identify its effects on the users of Lagos Ikorodu Road.
Harriet, T., Poku, K., et al. (2013). An Assessment of Traffic Congestion and Its Effect on Productivity in Urban Ghana	This study attempts to assess the extent to which congestion affects worker productivity. The study focuses on the transportation system in Kumasi Metropolis, Ghana.

Source: Own computation 2015, E.C.

2.2. Empirical Literature Review

Previous work has been done related to traffic congestion hot spot area analysis by analyzing the nature of population and land use characteristics for mitigation of traffic congestion. Some research has been conducted in the analysis of congestion in link and segment levels of traffic networks. Moreover, this trip production-attraction model and origin-destination analysis of trips have also been performed in prior studies for the analysis of traffic congestion by estimating the volume of traffic in the analysis zone. Traffic analysis zone for congestion study is performed in some research like level of crash estimation in traffic analysis zone. They develop a model of traffic to increase the efficiency of traffic management for the transportation sector. In this study, we have divided the study area into traffic analysis zone which is surrounded by the transportation system, assigned other trip source area, and assessed traveler characteristics in addition to population and land use characteristics. The trip production-attraction model of this research address this assignment and assessment, so the motivation of the study is just to see the limitation of the previous work and theoretical gap and then develop an effective model for the traffic demand of travel for the study area.

Table 2.5: Summary of Related Work and their research gap

Author	Title	Method	Research Gap
Ibrahim–Adedeji, K. B, (2014)	Traffic Demands and Delays on Lagos - Ikorodu Road in Nigeria	Traffic count and interview of passengers on the selected junction on the network	The traffic demand study is limited to the Ikorodu Road section, which is a link-based analysis. This is just concerned with the segment network's traffic flow. It does not conduct origin-destination analysis.
(Engineers, 2003).	Case Study For Estimation of Trip Production and Trip Attraction in Boone County	Assign several workers to trip attraction zone, Airports, and light industrial facilities.	This model is based on population profiles and land use kinds. This computation may contain inaccuracies since it does not account for other crucial elements influencing people's travel habits. Trip source areas are limited to residential areas only.
YAO Liya, GUAN Hongzhi et al. (2008)	Trip Generation Model Based on Destination Attractiveness	A method of trip efficiency and destination selection model based on disaggregate theory for trip generation.	The behavior of each traveler was studied instead of the characteristics of the traffic zone population and land use. But still lack assigning multi-trip source areas.
Takyi Harriet, Kofi Poku et al. (2013)	An Assessment of Traffic Congestion and Its Effect on Productivity in Urban Ghana	The study adopted a survey strategy on five major road links in the metropolis.	This assessment only focused on the effect of traffic congestion on worker productivity. But it does not consider the cause for the delay of workers which means land use characters, travelers, and the nature of the path. Work zone analysis in the metropolis is also not analyzed which is usually located in the CBD of the city.
Srinivas S. Pulugurtha a et al. (2013)	Traffic analysis zone level crash estimation models based on land use characteristics	Socio-economic characteristics and trip generation and attraction model as traffic indicator for the level of crash analysis in TAZ	This survey lacks some other considerations for driving behavior difference and the difference in vehicles' accelerations between the moving state and the starting state are not taken into account at the model level.

Source: Own computation 2015, E.C.

The primary gap identified in the review shows that the majority of traffic demand studies concentrate on a single road section by analyzing traffic flow within the segment network, without taking into account origin-destination analysis and household travel behavior. The traffic model, which is based on population profiles and types of land use, may include inaccuracies because it does not consider other factors that influence travel habits. However, these studies used a unique approach to analyzing traffic congestion by utilizing detailed transportation analysis starting with a trip analysis of people and their origin-destination and household travel survey analysis by utilizing one of the four-step travel demand analysis, which is the trip production and attraction model. This review aids in gaining a deeper understanding of traffic congestion and traffic demand assessment.

2.3. Conceptual Framework for Travel Demand Model

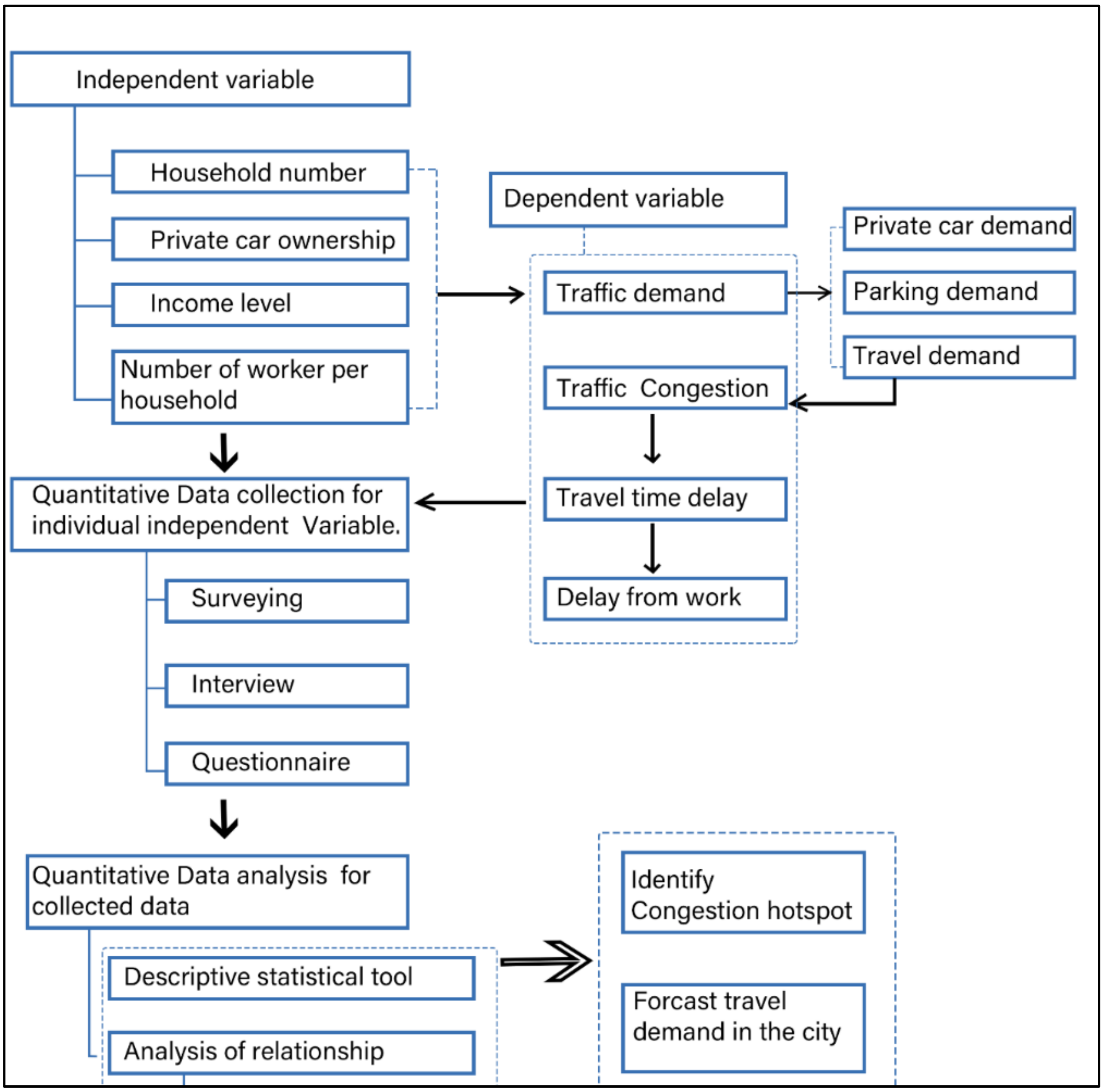

Figure 2.3: Conceptual Framework for Travel Demand Model Analysis

CHAPTER THREE

3. DESCRIPTION OF THE STUDY AREA AND RESEARCH METHODS

The purpose of the research is to identify the congestion hotspot area by measuring the level of congestion in the majorly selected traffic routes in the analysis zone and conducting a travel (transportation) demand analysis model to estimate the volume of trips generated in the study area and to estimate the volume of vehicular traffic on the selected routes. Traffic congestion in the area is due to the increase in private vehicle motorization and the enormous demand for transportation and private car demand. The problem that arises from the incompatible organization of land uses, unsystematic growth, illegal parking, unbalanced traffic demand, and existing route capacity, and rapid urbanization has brought increasing travel demands and preferences for using private vehicles.

3.1. Description of the Study Area

3.1.1. Location of the study area

Adama, also known as Nazret or Nazareth, is a city in central Ethiopia. It is located in the Oromia region, about 100 kilometers southeast of the capital, Addis Ababa. Adama is the administrative center of the East Shewa Zone and is a major transportation and economic hub for the region. It has an Elevation, Adama is at an elevation of approximately 1,713 meters (5,620 feet) above sea level.

Adama City, which was officially established as a transportation hub along the Addis Ababa-Djibouti railway, has economic ties with various regions and municipalities. Djibouti port is a destination for agricultural supplies, manufacturing, and commercial items. Arsi, Bale, and Borana contribute grain and animals to the city, while Kereyu and Afar are the key suppliers of natural resources (fuel wood, charcoal). According to the 2015 Census, the estimated overall population is 324,000. Adama's economy was built on hospitality and the Eth-Djibouti port transit infrastructure. Hospitality and Eth-Djibouti transportation are becoming back bone of Adama economy, it is a hub of several congress in the town from Addis Ababa and other part of the country. Despite its recent rapid expansion, Adama's urbanization is moving toward the rural region, and the city has numerous industrial zones in comparison to other cities.

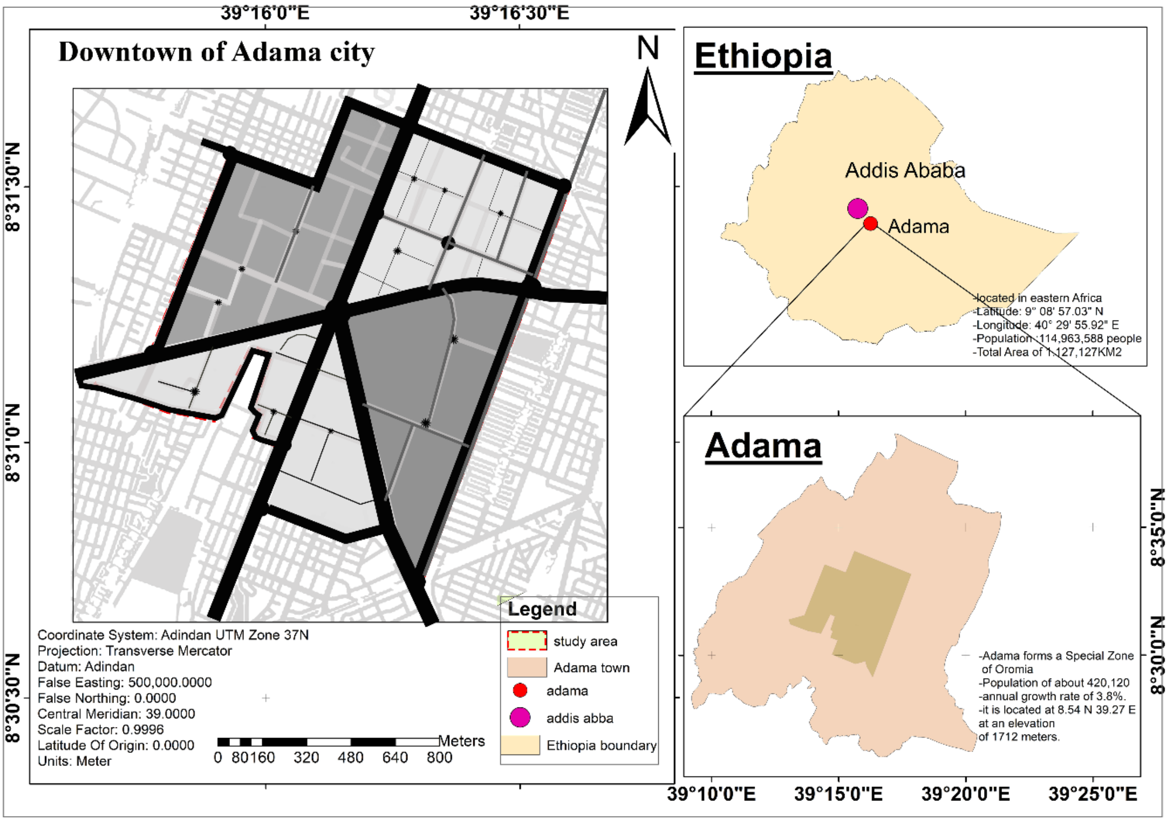

Figure 3.1: Location Map of Study Area

3.1.2. Physical environment

- Topography

The topography of Adama is fairly flat with slight undulations. The area is composed mainly of plains with occasional hills and mountains in the surrounding regions. To the west, the landscape rises to the Ethiopian Highlands which are part of the Great Rift Valley system. Adama has a geographical wide area of approximately 29.86 square kilometers (11.53 square miles). Adama has an elevation of approximately 1,712 meters (5,617 feet) above sea level. Adama lies alongside the Awash River, which provides essential water resources for agriculture and human consumption.

- Climate

Adama has a tropical savanna climate with a pronounced wet and dry season. The hot and wet season runs from June to September, while the drier season spans from October to May. The average annual temperature in Adama is around 18.5°C (65.3°F), with average monthly highs ranging from 25-27°C (77-80°F) and lows of 11-15°C (52-60°F).

The natural vegetation surrounding Adama mainly consists of mixed savanna grasslands and scattered acacia trees.

3.1.3. Socioeconomic conditions

- Population

Adama has a population size of around 300,000 to 400,000 people according to the 2015 census, it ranks among the most populous cities in the country. The city is an important commercial, transport, and industrial center.

The population density of Adama, Ethiopia, according to the 2007 census, the city had a population of approximately 220,000 people. The area of Adama is roughly 29.86 square kilometers. Based on this data, the population density would be approximately 7,366 people per square kilometer.

- Economic activity

Adama serves as a major hub for transportation and trade, and its economy largely revolves around commerce and industry. There has been significant investment in infrastructure in recent years, including the development of the Eth-Djibouti Railway which passes through the city, thereby enhancing the city's connectivity and economic importance within Ethiopia.

The economic activity in Adama is driven by a mix of agriculture, manufacturing, trade and commerce, and the service(hospitality) industry. Its strategic location and proximity to Addis Ababa further strengthen its economic growth and development prospects.

- Administrative condition

Adama serves as the capital of the East Shewa Zone and is a key administrative center. It has 6 sub-cities' administrative centers with sub kebele or woreda. The administrative condition of Adama involves governing affairs related to urban planning, provision of public services, infrastructure development, and management of public utilities. It operates under the jurisdiction of the Adama City Administration, which is accountable for the overall administration and policy direction in the city.

3.2. Research Methods

3.2.1. Approach and research design

The study employed a quantitative and qualitative research approach. quantitative approaches aim to collect and organize relevant data which are number based that help to answer the research question and to address the objective of the study. These studies assess the condition of the issue by conducting a stepwise data collection process quantitatively.

The research focused on a quantitative approach that is deductive and begins with theory to realize a world scenario about the subject. In this study, statistical data is relevant, which describes the objective of the study. This research approach clearly describes the quantity of the household characterstics that is the cause of the increase in the traffic congestion. Although, qualitative data from the questionnaire were also used to determine whether the congestion in the center of Adama city is significant or not, select routes, and assess other related parameters.

The research design consists of the following process, evaluating the overall travel behavior of households within the study area. This involves examining various aspects of traveler behavior, including residential location, trip origin, trip destination, mode of transportation, departure and arrival times, and chosen travel routes, as illustrated in Figure 3.2. A single-method (quantitative) research approach was employed to quickly analyze the issue's status. To gather relevant data for the study, the researchers utilized an objective data collection method and strategy.

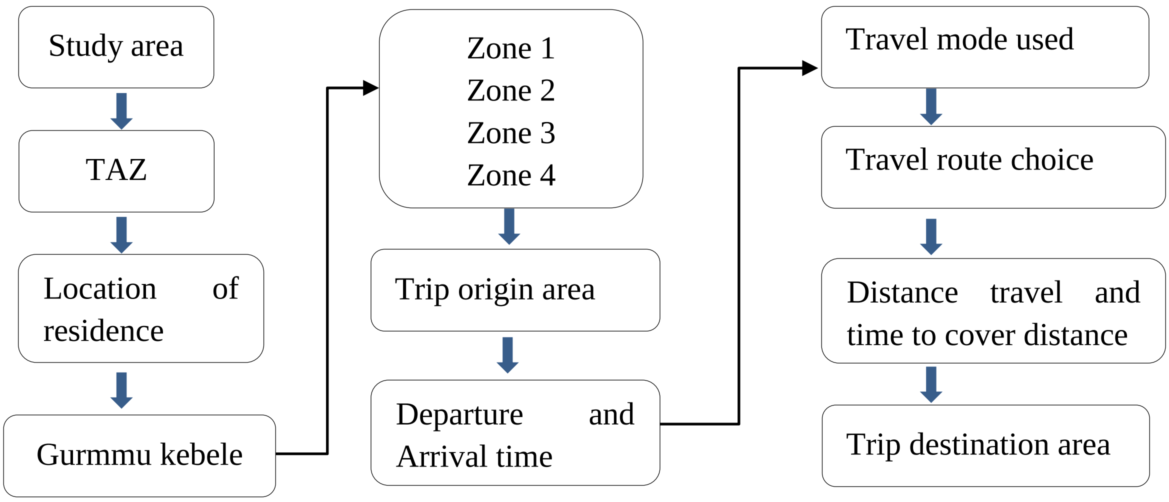

Figure 3.2: Workflow for Evaluation of Household Trip Behavior

3.2.2. Data type and source

The study was focused on primary and secondary sources of data. Primary sources of data necessarily require an on-site survey of the problem or issue to obtain accurate information about the real-study area phenomena. Secondary data, such as census data and data from the sub-city that are relevant to the study were collected. To collect data wisely, the necessary method and technique had been established. For example, survey data was obtained by distributing formal questionnaire paper for representative households to obtain information about their trip behavior and obtaining the population number of the study area from the census.

The necessary data for each objective of the study are categorized as follows: For the first objective, information on traffic volume on the selected route of the TAZ is needed. The second objective requires data on the origin-destination trips of people, as well as the locations of their residences and the purpose of their trips. For the third objective, essential data includes household travel patterns, times of day for travel, modes of transportation, trip purposes, and origin-destination information. Lastly, the fourth objective relies on data related to congestion level in the selected network. These are the primary data types used and required by this research.

The primary source of data

Data for traffic congestion assessment and travel demand analysis, such as population characteristics, land use data, traffic volume, travel time data, and the TAZ component (trip production and attraction) for the year 2015 EC, were obtained through surveying, interviews, and questionnaires in the study area. Traffic volume data at the selected route is used to detect hotspot areas of vehicle volume. Origin-destination analysis data in the TAZ that help link level volume calculation were conducted, which raise a question such as, where is the source of origin (land use), destination node, and work zone (attraction) in TAZ? In this study, trip production and attractiveness of a traffic analysis zone were used as traffic indicators for modeling purposes of traffic.

The secondary source of data

Population data, land use, number of vehicles and Traffic data from the transportation office, and census data which are counted and surveyed at a particular period were collected from the Aba Gada sub-city. These were used as input for traffic volume study in the area of research, this is based on population number and variety of activity of land use character. Examples Map data like the boundary of the study area, code of land use, percentage of land use classification, street network number, name of selected routes, and socio-economic data of the area.

Study population

The study area population size and the number of households were determined from census data and the household survey. According to the 2015 census, the total population of study woreda, Aba Gada sub-city-Gurmmu Kebele is 12,214. The total number of households in Gurmmu Kebele is 1,492 and the median family size is 4-5 and most of their work zones are located in downtown. The household that lives in Gurmmu Kebele, Aba Gada sub-city is the representative target of this study. Especially People who work in the central business district of the city, and private vehicle owners that regularly commute by using the selected network in TAZ are the representative target of this research. The representative target of this study is households which gives information regarding travel patterns. Households, private vehicle owners, and public transport users in this study are sample frames that represent all elements in the target population.

Sample size

The researcher chooses Aba Gada Sub City, located in the center of Adama. Aba Gada Sub City consists of four kebele: Badahatu, Gadaa, Gurmmu, and Odaa. The researcher further selects Gurmmu kebele, which is divided into four zones. From these zones, a representative target is randomly selected based on their geographical location to form a sample size within the stratum (zone). According to Neyman, J. (1934), the method of stratified sampling principle was used for sample size determination. A stratified random sampling technique was used to get representative targets. The following diagram illustrates the method of stratification in the study area.

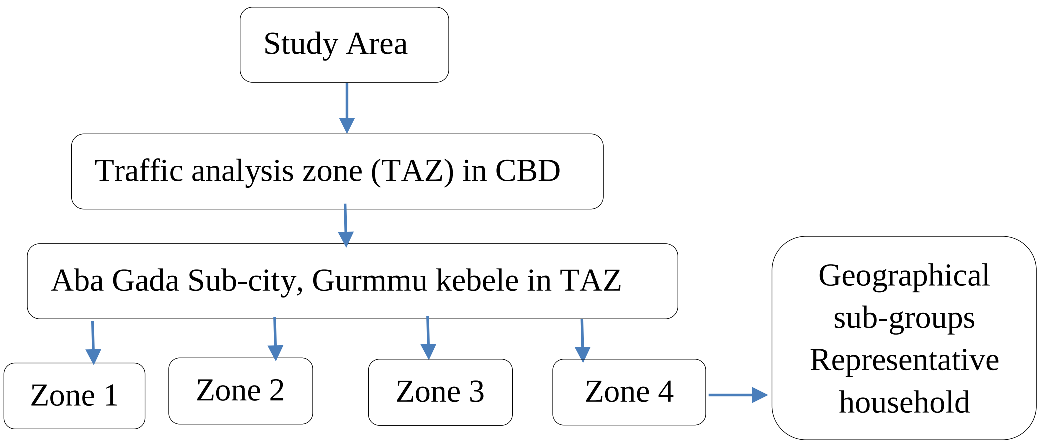

Figure 3.3: Sample Determination of Representative Target by Stratifying Study Area to Zone.

Based on Neyman, J. (1934) Sample size determination for stratified sampling, samples were chosen from Gurmmu kebele from each stratum or zone by the following formula.

n-h = (N-h / N) * n-- (3)

where:

n-h = Number of households to be chosen from stratum (zone) h

N-h = Number of population in stratum h

N = Total number of population

n = Total number of households to be chosen in the sample

The researcher aims to get a total of 70 representative samples from each target group of households, private car owners, and public transport users in Gurmmu Keble which became a total of 210 sample sizes from a population of 12,214 which is from each stratum (zone).

Sample for zone 1= (N-zone 1 / N) * n= (2,565/12214) *70=15

Sample for zone 2= (N-zone 2/N) *n= (4,275/12214) *70=24

Sample for zone 3= (N-zone 3/N) *n= (2,443/12214) *70=14

Sample for zone 4= (N-zone 4/N) *n= (2,931/12214) *70=17

Finally, the sample size of=15+24+14+17=70, For each target group.

In this situation, the number 70 is the desired total number of representative samples that the researcher wants to obtain from each target group of households, private car owners, and public transport users in Gurmmu Keble. This number was likely chosen by the researcher based on their judgment considering the population size, resource constraints, or desired level of precision for the study.

The researcher intends to collect a total of 210 sample sizes, with each of the three target groups providing 70 samples. In order to achieve this, the researcher uses a stratified sampling method and the formula mentioned above. This ensures that the samples are proportionally representative of the population across the different zones (strata) in Gurmmu Keble. The samples from each zone are calculated using the provided formula and then summed up to obtain a total of 70 for each target group with a total of 210 sample sizes.

Sampling technique

Stratified random sampling techniques were used to get the sample size. This technique was used by dividing the population into geographical locations, or strata. It involves random selection from each stratum (zone) proportionately, allowing you to make strong statistical inferences about the whole group. Taking a sample from a sample frame of households (especially workers), private car owners, and public transport service users to gain relevant data.

3.2.3. Method of data analysis

Quantitative data analysis techniques were employed to address the study's objective as follows:

The traffic volume and movement pattern in Adama City were investigated using a Data analysis method of descriptive Statistics and network analysis. The cordon count of traffic data was collected at different routes and road sections in Adama City. Descriptive statistics such as mean, median, and range were used to summarize traffic volume data. GIS software was used to create a traffic flow map that visualized movement patterns and identified trends and patterns in traffic volume during different times of the day and week. Divided the city center into different traffic analysis zones based on movement patterns.

The origin-destination pattern of people's trips in the study area was analyzed using a data Analysis Method of Survey Data Analysis and Matrix Analysis. Household travel surveys were conducted to collect origin-destination data for individual trips. The data was organized in an origin-destination matrix, with rows representing origins and columns representing destinations. The matrix was analyzed to identify patterns and trends in trip distribution.

The study area's travel demand was estimated using a travel demand model, which was developed through a data analysis method of relationship analysis and travel demand modeling. To create this model, variables such as land use, population, employment, and infrastructure were used.

Traffic congestion hot spots were identified by measuring the level of congestion in a selected network of traffic analysis zones, using a data analysis method of traffic flow analysis and LOS analysis. This involved measuring traffic flow at various points in the selected network using cordon counts of traffic at each selected route, calculating a congestion index based on the ratio of traffic volume to the capacity of the road, and identifying sections of the network with a high congestion index as traffic congestion hot spots. GIS software was used to visualize the locations and severity of the identified hot spots on a map. In general, the study employed Excel software to present the graphical and tabular representations of the results.

3.2.4. Method of data collection

Quantitative data collection was employed for a primary source of data as follows:
To address the specific objective of the inquiry and to answer the question, data has been collected from primary and secondary sources. For the collection of the primary source of data, the recommended technique and steps have been followed to minimize inquiries.

The primary data were collected using the following techniques; Surveys, Questionnaires, Manual traffic volume counts, Interviews, Manual travel time measures, Cordon count (cordon point traffic count survey), and photography for vehicle count.

Questionnaires were distributed randomly to road users (workers in the household member, private car owners, and public transport users) to gather information on the perception of road users about the traffic congestion level and severity especially in peak hour movement of people at major select routes or corridor in the CBD area. The questionnaire response helps to determine possible causes of congestion and to identify the most congested six routes in the central business district transport network.

The cordon count is a method of counting traffic volume manually on the field. For this research cordon counts were used for traffic volume count on the major selected routes in the traffic analysis zone by locating collection points on these routes (refer to Figure 3.6 below). Traffic volume counts, travel time and speed data were gathered manually for the analysis zone. These measurements were obtained using a stopwatch and field survey sheet operated by a driver and a recorder, the researcher also documented the information by pen and paper method.

Household travel surveys by questionnaire, and household interviews survey were used for the survey of household characteristics, trip details, and origin-destination for both public transport and private vehicles movement was conducted in the traffic analysis zone to investigate their travel behavior.

The secondary data which are; household numbers, the total population of the study zone (Gurmmu kebele), and the employment status of households are obtained from the Aba Gada sub-city. The reason that the researcher choose Aba Gadaa sub-city is because it is located in the central business district area. The resident in this sub-city access all the selected routes. The total number of the vehicle is obtained from the city transportation sector.

Survey design

Surveying for primary data collection to address the objective and answer the question, surveying the study area was conducted for the level of service analysis, origin-destination analysis, and household travel survey. To acquire necessary information, define the study area, divide the area into TAZ, TAZ to a zone of residents, and discuss the characteristics of households and their trip pattern in TAZ.

The exterior cordon, often known as the cordon line, defines the study area's boundaries.

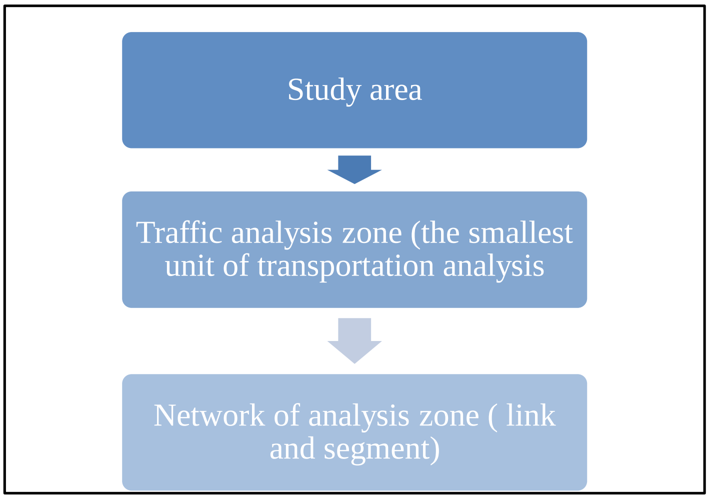

Figure 3.4: Study Area to Traffic Analysis Zone

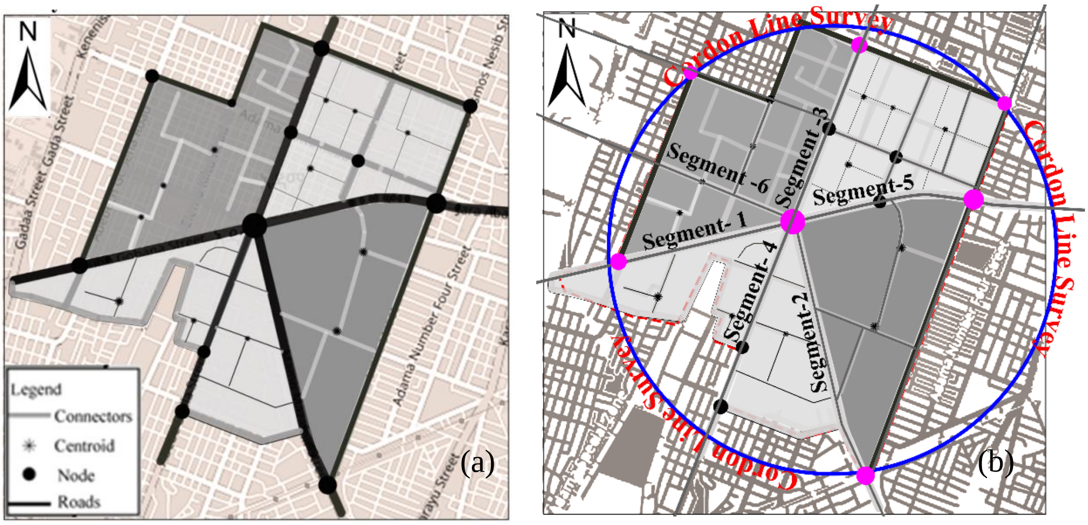

Figure 3.5: Traffic Analysis Zone of the Study Area (a) and Cordon line Survey of the Study Area (b).

The large point in Figure 3.5 (a) in the center of the city indicates the roundabout around the post office in downtown Adama City. A total of four nodes and six-segment are available in the TAZ

Zones, particularly traffic analysis zones, should correspond to other administrative divisions. Zones should have homogeneous characteristics, especially in land use. Population etc. Once the study area is defined, it is then divided into some small units called traffic analysis zones (TAZ) or simply zones. As you can see in Figure 3.4 the study area is divided into four traffic analysis zone.

3.2.5. Traffic volume surveys

Traffic volumes were inventoried on all selected major routes by manual field surveys. The Required traffic surveys are described in Table 3.1 as follows.

Table 3.1: Survey Items for Traffic Volume Surveys

Survey method	Description
Cordon Survey	A cordon survey is a manual field traffic count survey on a major cordon line or point that shows the volume of traffic entering or departing a target area or a city center.
Survey of route movement	Measures vehicular movements at selected routes during the morning, midday, and evening peak hours.
Travel Speed and Time Survey measure	Conduct travel speed and time surveys on main corridors in TAZ refer to Figure 3-5 above and strategically important roads to assess the efficiency of the road network at both peak and off-peak times.
Level of service of the existing transportation system	Levels of congestion or quality of traffic flow were checked by measuring the LOS of the selected route.

Source: Own computation 2015, E.C.

Description of traffic analysis zone or central business district (CBD) cordon count

A cordon survey is a traffic count survey on a major cordon line (point) that shows the volume of traffic entering or departing a target area or Adama city center. This central business district cordon count is done manually on the field to count the mobility inside and outside the CBD. This data involves both volumes by different modes of transportation. It is an important performance metric used to monitor changes to travel in to and out of the city's downtown. The field data was collected manually at the selected location (refer to Figure 3.6 below), it was involving 15-minute time interval recording by pen and paper counting method at peak hours (morning peak, midday peak, and evening peak) for 6 days with five other data collectors. Since Sunday is not a working day and few individuals commute to work on this day, it was not included in the data collection for the five regular working days from Monday to Friday and Saturday from non-working days. The focus of the traffic count is primarily on weekdays. Pedestrian walking has changed to a vehicle-by-vehicle occupancy rate of people per vehicle (Gan, 2005).

The cordon count traffic volume survey on six major selected routes in TAZ is discussed in chapter four and the recorded row data can be found in the attached Appendix A.

This cordon count is focused on the major travel mode of travelers (Automobile, Mini-bus, Bajaj, public bus, other 4WD, and walking). The tabular data presentation about the traffic volume on the selected major route named; Nuho Gobena Street, Abebe Bikila Street, Mamo Mazamir Street, Jira Aba Gada Street, Auraro Street, and Aba Jifar Road which are the main link leads from neighborhood to the center of the city from the different area were summarized by the percentage of the user for each mode.

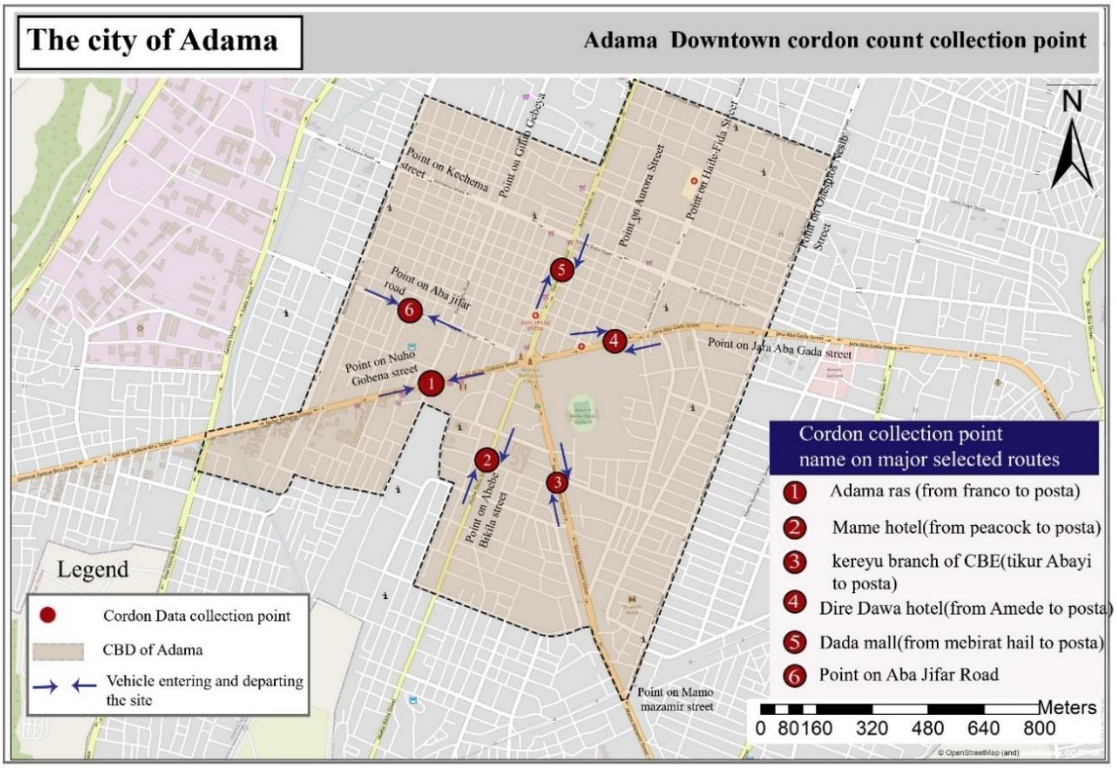

Figure 3.6: Adama Town Central Business District Cordon Count Collection Point

Description of the level of service of a major selected network of the study area

Level of Service (LOS) is a measure of congestion levels on major traffic routes. LOS data is collected by examining traffic flow quality in specific analysis regions. This information is gathered through cordon counts of total traffic volume on selected routes, as shown in Table 3.2. This data helps identify hot spots of congestion.

Table 3.2: Major Selected Segments of the Analysis Zone for LOS Analysis

Segment	Name of the route
From Franco to Posta bet (segment-1)	Nuho Gobena Street
From Tikur Abayi to Posta bet (Segment -2)	Mamo Mazamir Street
From mebrat hail to Posta bet (Segment-3)	Derartu Tulu Street
From A.A Meneharia to Posta bet (Segment -4)	Abebe Bikila street
From Amede Gebeya to Posta bet (Segment -5)	Jara Aba Gada street
From Abebech Gobena Street to Posta Bet (segment 6)	Aba Jifar Street

Source: Own computation 2015, E.C.

Description of the selected routes in the traffic analysis zone of the study area

A route in a Traffic Analysis Zone (TAZ) is a road or pathway connecting different TAZs, which are used for transportation planning and analysis. These routes help analyze travel patterns, demands, and various scenarios related to congestion, safety, and efficiency. The major selected routes are found in the central business district of Adama, as listed in Table 3.3 below.

Table 3.3: Name of Major Selected Route in Downtown the City and its Rank of Congestion

No	Name of route	Level of congestion (rank)
1	From Franco to Posta bet (Nuho Gobena Street)	1st
2	From Tikur Abayi to Posta bet (Mamo Mazamir Street)	2nd
3	From mebrat hail to Posta bet (Derartu Tulu Street)	3rd
4	From Peacock Meneharia to Posta Bet (Abebe Bikila Street)	4th

5	From Amede Gebeya to Posta bet (Jara Aba Gada street)	5th
6	From Abebech Gobena Street to Posta bet (Aba Jifar Street)	6th

Source: Respondent survey

The congestion ranks of the major selected six routes in Table 3.3 were based on the road user experience through a questionnaire in the study zone.

The study focuses on understanding road user perceptions of traffic congestion and determining major route selections. This is done through questionnaires distributed to daily commuters to the CBD, who provide information about road conditions and rank routes based on their experiences. The gathered data represents users' perceptions, transportation dependencies, and real-life experiences on the roads.

The primary motivation for inviting the populations to participate in the study is because the definition of traffic congestion is largely dependent on the interpretation of individual road users (Lomax, 1997). According to the report by Lomax et al. (1997) the extent of traffic congestion relies heavily on the perceptions of various road users. With this in mind, the researcher sought to examine the viewpoints of different road users through the use of questionnaires.

The study analyzes movement at key routes in the area by examining the behavior of these routes. Data was collected by assessing traffic on major selected routes within the traffic analysis zone. Surveys were conducted at peak hours to accurately capture the mobility patterns of people.

Description of the route from Franco to Posta Bet, the most congested route in the CBD, based on respondent value, is the Franco to Posta Bet route. This 1.5-kilometer route goes through a busy roundabout near the city center, connecting several roads. The Posta Bet area, 250 meters from the roundabout, is a bustling hub for shops, services, and government institutions. Expect heavy traffic and possible delays during peak hours or public holidays. Figure 3.7 provides a plain view of the route.

Figure 3.7 Route from Franco to Posta bet

Description of the route from Tikur Abayi to Posta bet, this route ranks as the second most congested route on the main road leading to Assela. During peak periods, traffic flow on this route becomes significantly congested. Bajaj vehicles are prevalent along this route, as well as a higher presence of 4WD trucks than on other routes. The traffic density increases during peak hours, consisting of a mix of private vehicles, buses, and pedestrians. A plain view of the route is shown in Figure 3.8 below.

Figure 3.8: Route from Tikur Abayi to Posta bet

Description of a route from mebrat hail to Posta Bet (Derartu Tulu Street), this route is moderately busy, as it connects residential areas with commercial establishments like the Post Office (Posta Bet) in Adama. Traffic volume can vary depending on the time of the day, with peak hours being more congested as people travel to and from work or school. the traffic movement of the route is low as compared with the first two. The route is the third congested one according to the questionnaire result. A plain view of the intersections is shown in Figure 3.9.

Figure 3.9: Route from Mebrat hail to Posta Bet (Derartu Tulu Street)

Description of the route from Peacock Meneharia to Posta Bet (Abebe Bikila Street). It is the fourth congested route and it is the narrow and one-way lane. Bajaj is the common mode of transportation on this route. At peak hour mobility traffic volume reaches higher and several Bajaj are observed crowding on the route. A plain view of the route is shown in Figure 3.10.

Figure 3.10: Route from Peacock Meneharia to Posta Bet (Abebe Bikila Street)

Description of the route from Amede Gebeya to Posta Bet (Jara Aba Gada Street). This route is the fifth congested route based on the field traffic volume count and respondent rank. Traffic volume on this route is moderate compared with the above route. It is a two-way road with moderate peak-hour traffic movement. A plain view of the route is shown in Figure 3.11.

Figure 3.11: Route from Amede Gebeya to Posta bet (Jara Aba Gada Street)

Travel Time and Speed Survey

Travel speed and time were conducted on the main corridor of the traffic analysis zone to check the efficiency of the road and the quality of traffic flow based on travel time and speed. The data collector has set significant initial point on the selected route and destination street with the help of the driver who drive the vehicle and the other two people for stopwatch control to measure the travel time and speed by traveling from the initial area to the destination place in peak hour and off-peak hour.

Data was recorded using a pen and paper and electronic devices like smartphones. A stopwatch was started when the chosen vehicle passed the starting point to measure travel time and speed. The collected data was then analyzed to determine average travel times and speeds for the chosen routes. The names and distances of the major selected routes are listed in Table 3.4.

Table 3.4: Major Corridors and their Length

Name of major Corridor	From street	To street	Length in (m)
Nuho Gobena	Franco	Posta bet	1,110
Abebe Bikila	Peacock Meneharia	Posta bet	1,170
Mamo Mazamir	Tikur abayi	Posta bet	1,660
Jara Aba Gada	Posta bet	Amede Gebeya	1,110
Derartu Tulu	Posta bet	Mebrat hail	600
Aba Jifar	Abebech Gobena	Posta bet	900

Source: An open street map

The recorded data for each route in weekday travel are collected both in peak hour and off-peak hour traffic movement to identify long travel time routes with low travel speed this implies that the route having short distances with high travel time indicates there is delay or congestion on that route. The travel time and speed recorded data in typical weekday travel (i.e. Tuesday, Wednesday, and Thursday) are attached in Appendix- B.

To perform a travel time and speed analysis, the researcher initially chose a single route with the highest traffic volume. Specifically, the researcher selects the route from Franco to Posta, which is situated on a major highway with the greatest number of large mini-busses. Subsequently, data collection was carried out using the pen and paper technique.

The stopwatch and pen-to-paper recording technique is repeatedly done in another field by resetting the stopwatch. These processes are conducted to the whole process until the major corridor data are collected at the site. This data collection has been conducted for three days due to the insufficiency of time and budget. The travel time and travel speed on each selected route are collected during the morning, midday, and evening peak periods on “typical weekdays” (i.e. Tuesdays, Wednesdays, and Thursdays)

3.2.6. Origin-destination (o-d) survey

O-D surveys to establish travel patterns (where people are moving to/from) were carried out by questionnaire for households and by household interview survey. The results of these surveys were used to develop O-D matrices. Household and roadside O-D surveys were conducted and the result is presented in chapter four. Table 3.5 summarizes the characteristics of these surveys.

Table 3.5: Description of Origin-Destination Survey

	Household O-D Travel Survey	Roadside O-D Travel Survey
Objective	To identify the travel activities of residents.	To clarify the travel movements between locations outside and inside the study area.
Method and technique	Questionnaire and Interview survey of sampled household	Interview sample of workers on target roads.
Survey Area	Aba Gada sub-city, Gurmmu kebele in TAZ target area.	On a major selected route (the same as the cordon line traffic count survey).
Zoning	Four survey zone in Gurmmu kebele Aba Gada Sub-city.	Zoning should be consistent with that in the household O-D survey.
Questionnaire Forms	Ask household members (workers) through the distributed questionnaire.	Formal written questionnaire interview for transport users.

Source: Own computation 2015, E.C.

Origin-destination survey is the classic method of obtaining transportation trip data (chapleau, Trepanier et al. 1996). The household origin-destination trip data were collected by questionnaire from representative households in the study area. The questionnaire is mainly focused on a worker in member of a household who is regularly commuting to the CBD and private vehicle owners who frequently use the selected route.

For this research trips have been classified for analysis according to the following general pattern concerning the “linked trip” origin and destination; Within a traffic analysis zone, to an adjoining zone, to the industrial park at the edge, To a university, college, and high school out of the traffic analysis zone and other areas.

3.2.7. Transport demand surveys

Traffic demand data such as origin-destination (O-D) and household travel data are essential for urban transport analysis. The following surveys were carried out.

Information such as population, travel behavior, and employment distribution is essential in transport demand modeling. This type of information relates to the travel pattern of households in the study area. The following data (Table 3.6) were collected.

Table 3.6: Survey item for Transport Demand data

Survey Items	Description
Population and Socio-economic Conditions	Collect population and socio-economic indices in traffic analysis zone. Data such as household number, household income, automobile ownership, family size, and the number of workers per household.
Household Travel surveys	Origin-to-destination travel survey at households and traffic data from cordon lines. The direction of travel, the destination, the trip purpose, and the cost of the travel.
Land use inventory	Residential density; shopping, business, or trade establishments; institutional; transportation service (bus station and node, which is the trip end) establishments in commercial and industrial zones; This information is particularly useful for trip-generation models.
Vehicle Ownership Survey	Collect vehicle ownership data for traffic analysis zone as above.
Travel demand analysis	Trip generation and attraction analysis of traffic analysis zone

Source: Own computation 2015, E.C.

This transport demand analysis is conducted by questionnaire and household interview survey responses from the respondent.

A household travel survey was conducted in downtown Adama's traffic analysis zone to analyze household characteristics and travel patterns. The study assessed transportation demand by evaluating demographics, trip data, and origin-destination information while considering factors like income, trip purpose, and employment status. The main focus was on residents living in the central business district. Data item in household travel survey in the study area traffic analysis zone was conducted by analyzing the basic variable of travel nature and household characteristics and structure. This can be summarized in Table 3.7 as follow.

Table 3.7: Household travel survey categorization

No	General Description of Travel Patterns and Trip Rates	Travel by different Types of Households
1	General Travel	Household Size
2	General Origin/Destination (O/D) Patterns	Household Income
3	Modes of Travel	Vehicle Ownership
4	Reasons for Travel: Trip Purpose	Household Structure
5	Travel Distance and Travel Times	Household number
6	Time of Day and Other Variations in Travel	Number of workers per household

Source: Own computation 2015, E.C.

The study was conducted in a specific region of Gurmmu Kebeles which is part of Aba Gadaa sub-city, which was divided into four Zones. Gurmmu kebele was chosen above other kebele in this sub-city because it is close to the post office and on a significant route from Mebrat haile to Posta Bet. This assists in locating persons who regularly use the selected network in the CBD region during the weekday. Data collection took place by gathering information from households located within the Gurmmu kebele. The sample size was determined to meet statistical reliability, with a target of at least 210 households in the TAZ. to achieve a margin of error of +/- 5 percent at a 90% confidence level for proportional measures.

The secondary source of data, data regarding the household demography of the study area was obtained from a secondary source provided by the relevant local authority sector in the central Adama-Aba Gada sub-city, Gurmmu Kebele.

Table 3.8: Demography Information from Aba Gada sub-city

No	Name of kebele	No. of Zone (ketena) for each kebele	Household	Total population	No of block
1	Bedahatu	6	5,924	11846	22
2	Gada	7	2,045	18109	22
3	Gurmmu	4	1,492	12214	16
4	Odaa	6	1,890	17319	20

Total		23	11,351	59,488	80

Source: Aba Gada sub-city in Adama town.

Table 3.9: Number of Households and total Population in Gurmmu Kebele, Aba Gada Sub-city

Kebele-Gurmmu	Number of households	Total population	Percentage
Zone 1	333	2,565	21%
Zone 2	522	4,275	35%
Zone 3	298	2,443	20%
Zone 4	358	2,931	24%
Total	1,492	12214	100%

Source: Aba Gada sub-city in Adama town.

Household vehicle ownership data were gathered through a questionnaire survey of 70 households in each zone within the TAZ. Significant variables affecting the proportion of vehicle ownership included household size, income, travel mode, and household structure. Moreover, vehicle ownership also influenced the results of the household travel survey.

3.2.8. Traffic movement survey

To complement the above surveys, the survey shown in Table 3.10 was conducted.

Table 3.10: Outline of Traffic Movement Survey

	Public Transport Vehicle Movement Survey	Private Vehicle Movement Survey
Objective	To identify the travel movements of buses, school buses, and medium buses.	To identify private vehicle movements
Method and technique	Questionnaire and Interview survey of public transport vehicle users.	Questionnaire survey of the privet car owners.
Questionnaire Forms	Ask public transport users by written questionnaire and oral interview.	Formal questionnaire for private car ownership.
Sampling	A sample of 70 public bus users was chosen.	A sampling of 70 private car owners was chosen.

Source: Own computation 2015, E.C.

Questionnaire

The questionnaires were simple and direct, was take the least amount of time, and were place the least amount of burden on the respondent. The household survey has three major sections: household characteristics, personal characteristics, and trip details.

Table 3.11: The basic Questionnaire for Data Collection about Household and Trips

	Questionnaire
Household characteristics	The number of members in the house; no. of employed people; no. of unemployed people; age and sex of the members in the house, etc.; some two-wheelers in the house; the number of cycles; the number of cars in the house, etc.; house ownership; and family income.
Personal Characteristics	Classify the household members (older than 5) according to the following aspects: relation to the head of the household (e.g., wife, son), sex, and age, possession of a driving license, educational level, and activity.
Trip data	Origin and destination, trip purpose, trip start and end times, the mode used, walking distance, public-transport line, and transfer station or bus stop (if applicable).

Source: Own computation 2015, E.C.

3.3. Ethical Consideration

The rights of study participants were protected by preserving scientific integrity and increasing research validity. This research was to preserve the willingness and safety of participants in case of delivery of the data. The individual's permission is necessary to carry out the task. This research was not having a psychological or physical impact on society while it is being carried out.

- Privacy and Confidentiality

Guaranteeing that information provided was unidentifiable by anybody other than the researcher. Ensuring they were knowledgeable that if any of the information resulting from the research is to be used for presentations or reports, all identifying information was changed to maintain privacy and confidentiality.

Safety

Eliminating any risk elements, ensuring safety was consistent over time and confirming that the research was not harmful to participants, and certifying proper use of information.

- Autonomy

The researcher ensured that the participant's contribution is completely voluntary and that they may withdraw from the research at any time. From here there was no further collection or analysis of data and all existing data was removed.

- Dignity

All participants have the freedom to make their own fully informed decisions.
All participants were treated with great respect.

Methodological framework

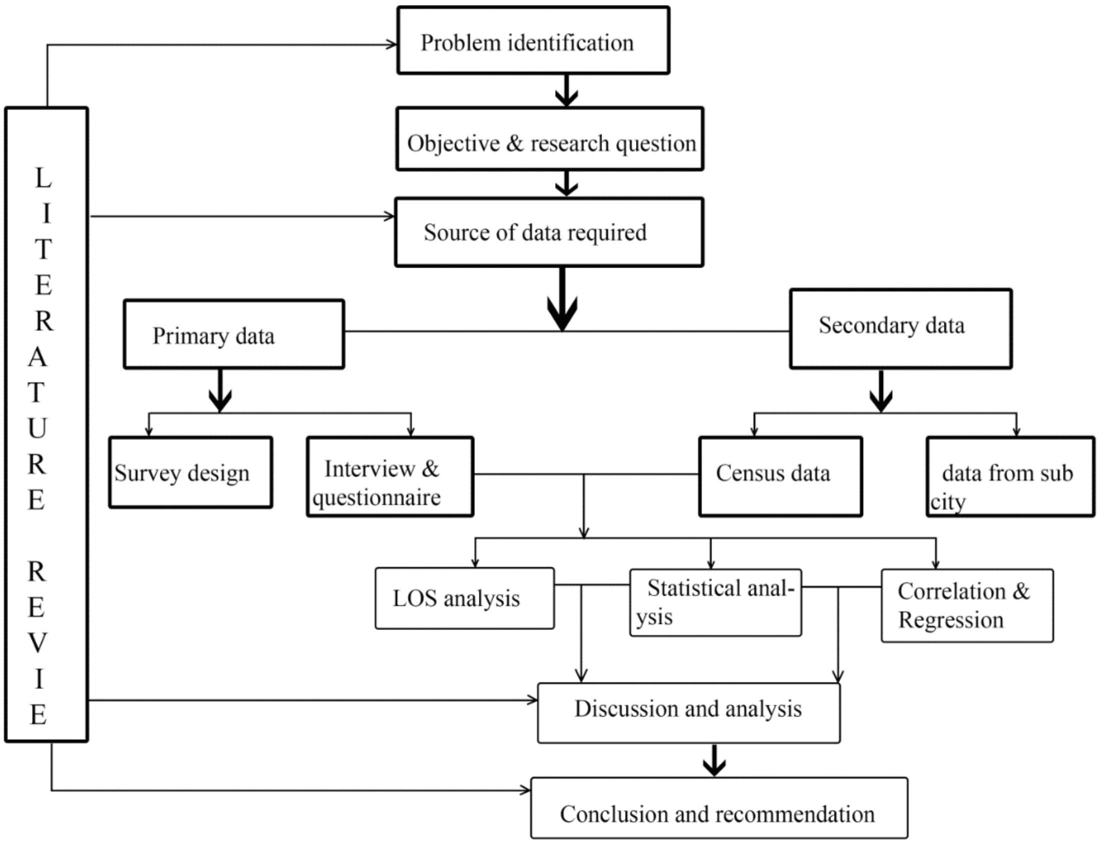

Figure 3.12: Methodological Framework of the study

The methodological framework for this research adopts a structured approach, encompassing a set of principles, methods, and criteria employed by the researcher in designing, conducting, and evaluating the research. This framework employs a flowchart to offer a systematic method for assessing, analyzing, and interpreting information or data. Utilized as a guiding model, this framework outlines the key components, such as research questions, methods, techniques, and data analysis, that are employed in a specific study.

CHAPTER FOUR

4. RESULT AND DISCUSSION

The analysis was carried out on major chosen routes within the traffic analysis zone and Gurmmu kebele in the Aba Gada sub-city, which is part of the TAZ for household travel surveys. The appropriate and most effective methods were applied for analyzing the collected data. The findings from this analysis are presented and briefly discussed in the following sections.

The questionnaire was distributed randomly to the representative households to evaluate the level of travel(transportation) demand, and the existence of traffic congestion and to examine their travel behavior by the road user experience in the traffic analysis zone. Out of the distributed 210 questionnaires 95% of it was returned.

4.1. Respondents Demographic Features

Regarding the respondents' demographic characteristics, Table 4.1 shows that majority of the respondents are male representing 61.4% and the remaining 38.6% are female respondents. Concerning the age structure of the respondents overwhelming share of them are in adult and younger age, which consists 73.7% whereas very little portion of the respondents (26.3%) are in the old age greater than 40 years.

Table 4.1: Questionnaire Respondents' Profile

		Number	Percentage
Sex	Male	129	61.4%
	Female	81	38.6%
	Total	210	100%
Age Distribution	15-20	19	9%
	20-30	52	24.7%
	30-40	84	40%
	40-50	31	14.7%
	Above 50	24	11.4%
	Total	210	100%

Source: Respondent survey

4.2. Current Traffic Volume and Movement Pattern

4.2.1. Cordon count on major selected routes collection point

The cordon count traffic volume survey on six major selected routes in TAZ is discussed in this section and the recorded row data were found in the attached Appendix A.

This cordon count result is presented in Table 4.2. Based on the data revealed in Table 4.2, mini-buses have emerged as the primary mode of transportation for individuals entering and exiting the central business district (CBD), accounting for approximately 76% of the travel mode share. During the morning peak hours, the total traffic volume entering the CBD within a 15-minute interval is higher, with around 1540 inbound vehicles. However, the overall traffic movement, which includes both inbound and outbound traffic, is more significant during the evening peak hours in the traffic analysis zone (TAZ) and the CBD. There is a significant increase in the preference for automobile travel mode within and around Adama's downtown area, with a percentage of 57.3%. This suggests a rising demand for the use of private vehicles in the region.

Table 4.2: Modal Split Percentage of Travel Movement across all Selected Routes

Mode	Morning peak 1:30-3:30		Midday peak 6:00-8:00		Evening peak 10:30-12:30	
	Entering	Departing	Entering	Departing	Entering	Departing
Minibus	76%	69.3%	67%	67.5%	75.8%	71.5%
Automobile	57.3%	54%	37.4%	30%	58.3%	55%
Bajaj	51.8%	51.5%	46.8%	44%	54.5%	52%
Public bus	8.4%	8%	5.5%	6.1%	9.8%	8.3%
Walking	35.8%	33%	34.5%	34.3%	37.3%	33.8%
Other 4WD	38.8%	31.8%	46.6%	42%	38.2%	33%

Source: Manual field count (survey).

The percentage of each mode share was calculated from 100% for the listed mode across each selected route at peak hours (morning, midday, and, evening).

Transportation Mode Usage (Modal Split) on CBD cordon count representing the proportions of different modes employed by people going inbound and outbound to Adama's CBD during peak travel hours are depicted in Figure 4.1 below. The figure, thus, demonstrates the proportion of individuals utilizing various modes of transportation to and from the downtown area. Mini-busses are the most popular choice, accounting for a significant 76% of primary transportation mode, while automobiles come in second place with 57.3% mode share for traveling to Adama downtown during morning peak hours. Both mini-buses and automobiles are the most commonly used modes of transportation in the Central Business District (CBD) area, with a higher percentage of mode travel than other options.

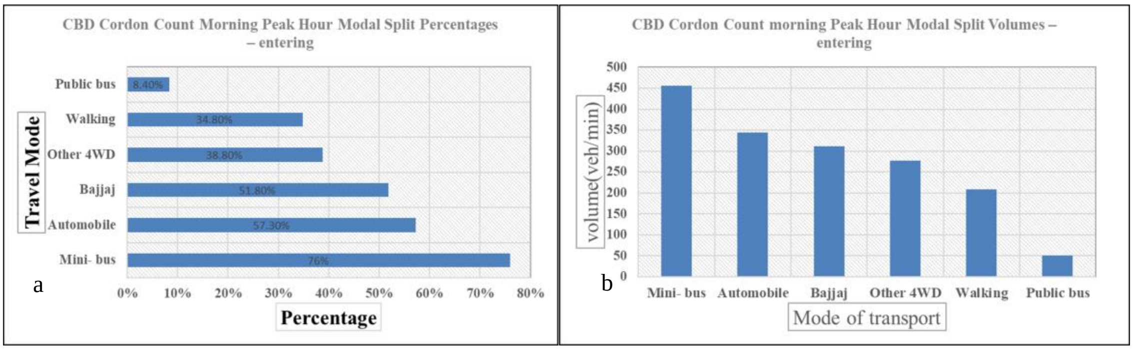

Figure 4.1: CBD Cordon Count Morning Peak hour a) Modal Split Percentages – Inbound and b) Volumes – Entering across all route

At the Morning peak hour, there is a large percentage of people are using minibuses and automobiles to enter the CBD across all selected rout, so here traffic volume is dominated by Minibus mode. Midday peak hour modal split -Exiting in the middle of the day during rush hour, traffic is relatively moderate as compared to the morning and evening peak hours. Numerous people leave downtown utilizing different modes of transportation. This increase in activity is due to individuals taking lunch breaks, running errands, or simply traveling around the area at this specific time.

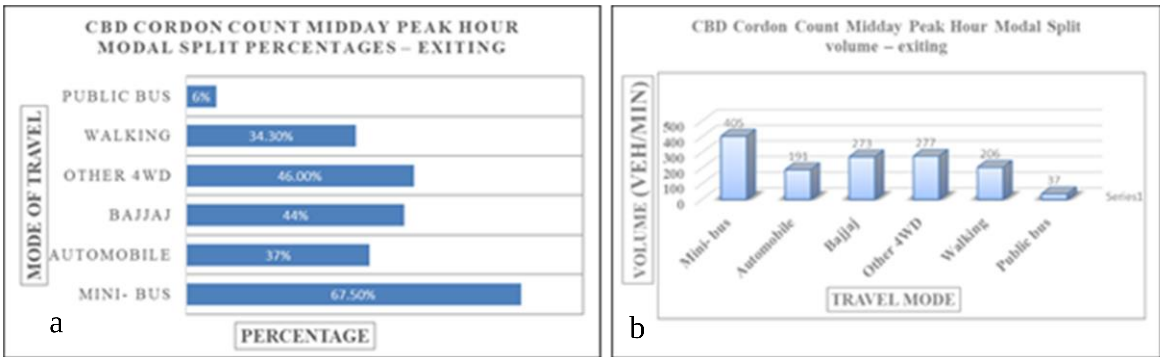

Figure 4.2: CBD Cordon Count Midday Peak Hour Modal Split a) Percentages – exiting across all routes and b) volume – Exiting across all routes

4.2.2. Result for the level of service of selected routes of the traffic analysis zone

The quality of traffic flow or level of congestion of the selected route (refer to figure 3.6) was measured by the CBD cordon point location with the highest volume per mode of transport. The overall volume of people traveling into and out of Adama downtown can be measured by adding a volume of traffic for each route at peak hour traffic. The selected network ranked according to this volume entering and exiting at peak hour movement. Table 4.3 provide the rank with volume below.

Table 4.3: CBD Cordon Locations with the Highest Entering Volumes at peak hour per Mode of Transportation.

Rank		Automobile	Mini-bus	Baja	Public-bus	Walking	Other 4WD
1	Location	Mebrat Hail - Posta Bet	Franco-Posta bet	Posta bet - Addis Ababa Meneharia	Posta bet - Tikur abay	Franco - Posta bet	Posta bet - Tikur Abay
	volume (veh/min)	251	433	432	30	146	125
2	Location	Franco - Posta bet	Posta bet - Amede	Posta bet - Tikur abayi	Posta bet –Amede	Posta - Mebrat Hail	Abebech Gobena Street - Posta bet
	volume (veh/min)	246	275	235	26	116	107

Source: Field survey

Figure 4.3 below depicts the location of the CBD cordon on the primary selected route, with the highest volume of entry into the CBD via various modes of transportation across all major routes. During peak hours, the minibus is the most prevalent mode of transportation on the route from Franco to Posta, while automobiles dominate the route from Posta to Mebrat Hail. The route from Posta to Peacock Meneharia, on the other hand, experiences significant congestion due to the high usage of Bajaj vehicles.

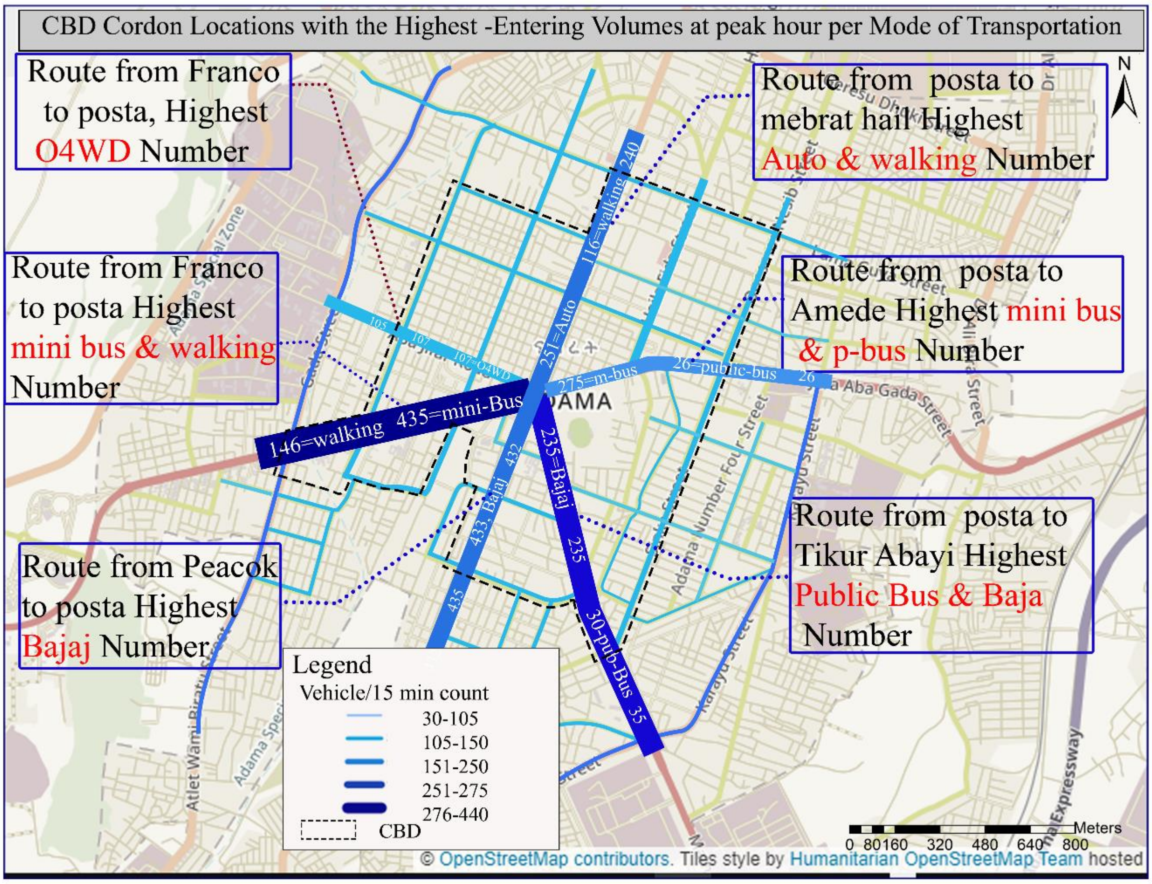

Figure 4.3: Cordon Location on the Selected Route with the Highest Entering Volume per mode of transportation

Table 4.4 below shows the highest exiting traffic volume for each travel mode in 15-minute intervals from CBD cordon locations. Automobiles dominate the route from Posta to Mebrat, minibuses are common from Posta to Franco, and Bajaj is prevalent on the way from CBD to Peacock Meneharia. During peak hours, Bajaj becomes crowded on the route from Posta to Peacock due to narrow, one-way streets. Different travel modes are preferred depending on the route, with automobiles, minibuses, and Bajaj being the top choices.

Table 4.4: CBD Cordon Locations on Selected Route with the Highest Exiting Volumes per Mode of Transportation

Rank		Automobile	Mini-bus	Baja	Public-bus	Walking	Other 4WD
1	Location (refer to section 3.3.3)	Posta - mebrat haile	Franco - Posta bet	Posta bet - Peacock Meneharia	Posta bet - Tikur abay	Franco - Posta bet	Posta bet - Tikur Abay

	volume (Veh/min)	235	433	497	33	121	126
2	Location	Franco - Posta bet	Posta bet -Amede	Posta bet-Tikur abayi	Posta bet - Amede	Posta bet-Tikur abay	Franco - Posta bet
	Volume (Veh/min)	227	256	203	27	107	125

Source: Field survey

On the other hand, Peak-Hour Total Inbound and Outbound Travel Volumes Across All Transportation Modes for Each Route. Figure 4.4 below shows that the total inbound and outbound travel for all modes of transportation within the traffic analysis zone of Adama's downtown core is displayed, focusing on the selected travel route and corresponding LOS. The Franco to Posta Bet route experiences a higher volume of traffic, with approximately 1946 vehicles per minute recorded in a 15-minute cordon count. During peak hours, mobility along this route is constrained, resulting in restricted maneuverability, limited vehicle speeds, and increased travel times.

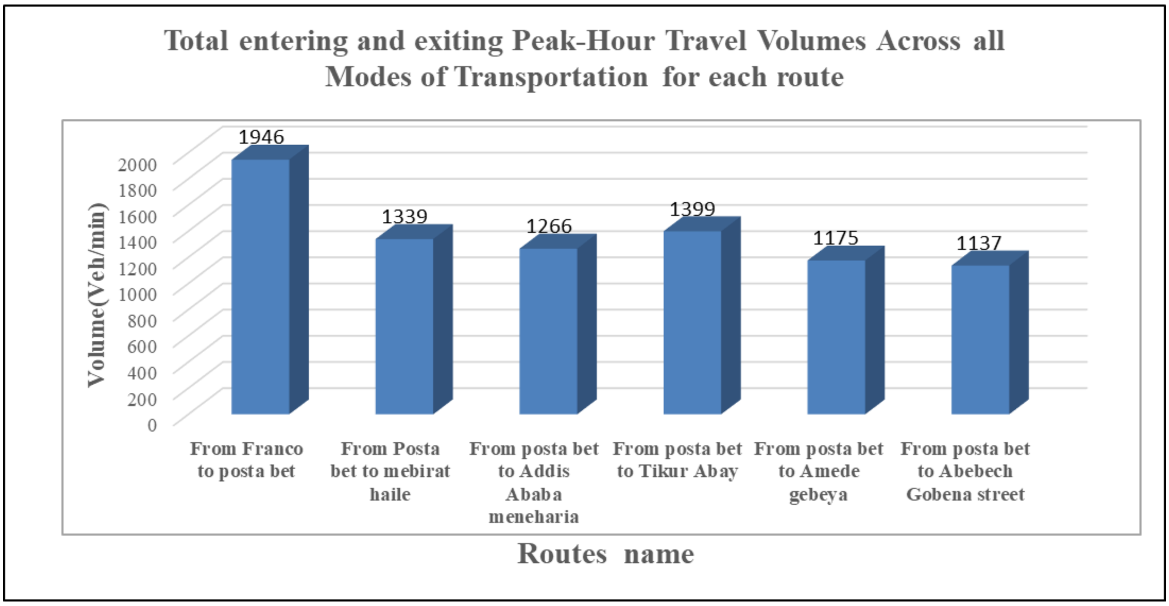

Figure 4.4: Total Entering and Exiting Peak hour Travel Volume across all Modes of Transportation

The results of the cordon count are supported by the findings of questionnaire results collected from the respondents of daily users. This questionnaire assesses road users' perceptions of congestion levels for each segment, enabling the ranking of the selected routes, and ultimately identifying the most congested route.

The following streets were ranked by the respondents based on their experiences of the traffic flow and volume on the selected roots. The first rank was given to Nuho Gobena Street, stretching from Franco to Posta Bet. The second rank was awarded to Mamo Mazamir Street, which runs from Posta Bet to Tikur Abay, followed by the third rank for Derartu Tulu Street, running from Posta Bet to Mebirat Haile. The fourth rank went to Abebe Bikila Street, connecting Posta Bet to Addis Ababa Meneharia, while the fifth rank was given to Jara Aba Gada, leading from Posta Bet to Amede Gebeya. Lastly, the sixth rank went to Aba Jifar Street, which runs from Posta Bet to Abebech Gobena Street. Table 4.5 described it below.

Table 4.5: Percentage of Congestion level on the Selected Routes by Road users

No	Name of route	Percentage (100%)
1	From Franco to Posta bet (Nuho Gobena Street)	32 %
2	From Tikur Abayi to Posta bet (Mamo Mazamir Street)	23%
3	From mebrat hail to Posta bet (Derartu Tulu Street)	18%
4	From Peacock Meneharia to Posta Bet (Abebe Bikila Street)	11%
5	From Amede Gebeya to Posta bet (Jara Aba Gada street)	9%
6	From Abebech Gobena Street to Posta bet (Aba Jifar Street)	7%

Source: Respondent survey

The total peak hour entering and exiting traffic volume data across each route per each mode of transportation into the CBD area are summarized and discussed in Table 4.6 below and the row data by cordon count are attached in Appendix-A. The traffic volume data are at morning, midday, and evening peak hour.

Table 4.7 below presents the total inbound and outbound travel for all transportation modes within the traffic analysis zone of downtown Adama, with an emphasis on the selected travel route and its corresponding Level of Service (LOS). In the United States, the letters "A" to "F" denotes the six LOS classifications, with A being the best traffic condition and F representing the worst, HMC (2010). The LOS system, in general, depicts a user's actual travel experience in relation to desirable travel situations. The route between Franco and Posta Bet counts a higher traffic volume, with an average of 649 vehicles per minute (Veh/min) recorded during a 15-minute cordon count, resulting in a LOS of F. Mobility along this route is particularly constrained during peak hours, especially in the evening, leading to reduced maneuverability, limited vehicle speeds, and increased travel times. Link-6, the route from Posta to Abebech Gobena Street, has a LOS of C with an average entering and exiting volume of 379 veh/min.

This finding is supported by the LOS measure of the congestion level and traffic flow quality of the selected route was assessed using the Level of Service (LOS) standard from the Highway Capacity Manual (2010). Highway LOS is calculated according to the volume/capacity ratio as shown in Table 4.6.

Table 4.6: Highway level of service classification

LOS	Volume /capacity ratio	Description (TRB 2000)
A	Less than 60%	Free-flow operation
B	60% to less than 70%	Reasonably free-flow
C	70 % to less than 80%	Flow at or near free flow speed
D	80% to less than 90%	Borderline unstable
E	90% to less than 100%	Operation at capacity
F	100% or greater	Breakdown

Source: Highway Capacity Manual (2010)

Table 4.7: Average Weekday Vehicular Traffic Volume at Peak hour in15 min intervals

Link (refer to section 3.3.3)	LOS	Total peak hour IB & OB volume (for all modes from cordon count)			Average Peak hour traffic vol.	Unit
		Morning	Midday	Evening		
Link-1 (Nuho Gobena street)	F	648	635	663	649	No. of trip/employee
Link-4 (Mamo Mazamir)	F	495	447	457	466	No. of trip/employee
Link-2(Derartu Tulu street)	D	468	384	487	447	No. of trip/employee
Link-3 (Abebe Bikila street)	F	271	490	506	422	No. of trip/employee
Link-5(Jira Aba Gada)	C	394	382	399	392	No. of trip/employee
Link-6(Aba Jifar street)	C	404	367	366	379	No. of trip/employee

Source: Field survey

The LOS grade of the selected route is based on the volume per capacity ratio standard in Table 4.6. the route from Franco to Posta, Posta to Tikur Abay, and Posta to mebrat hail are the most congested and grade LOS of F (breakdown operation at rush hour mobility).

4.2.4. Traffic movement survey private vehicle movement pattern

A private vehicle movement survey is one of the indicators of travel demand in traffic analysis. The analysis was done based on the weekday travel made by residents of the traffic analysis zone using private automobiles. This travel pattern analysis of auto helps identify the level of demand of individuals for transportation. Auto" is defined as driver and passenger, this is the representative group of this analysis. Questionnaire and household interview survey results regarding the private vehicle movement survey in this study area are summarized in the following section and the row data were presented in Appendix D. Because of that, the analysis takes in to consider Origin-Destination (O/D) Patterns, Time of Day, and Trip length and travel time.

Depending on the origin-destination result obtained from questioner response of the private vehicle owner, the general origin-destination pattern of travel for auto vehicle trips by kebele of trip origin in the traffic analysis zone is presented below in Table 4-8.

Table 4.8: Distribution of Auto Trips by O-D Market and zone of TAZ of Trip Origin (row %)

Trip origin Zone in CBD (Gurmmu kebele)	Within-traffic analysis zone	To adjoining zone	To the industrial park zone at the edge	To University, college, and high school out of the TAZ	To other zones
Zone 01	60%	26.6%	6.7%	6.7%	2%
Zone 02	66%	20.8%	4.1%	5.05%	4.0%
Zone 03	57.14%	21.4%	7.14%	14.3%	1.08%
Zone 04	58.3%	17.6%	11.8%	5.8%	6.5%
Total	60.36%	21.6%	7.4%	8.0%	2.64%

Source: Respondent survey

As per Table 4-8, the majority of auto trips took place within the traffic analysis zone (with an average percentage of 60.36%) and in an adjacent zone (21.6%). This travel pattern is common in the study area. Trips to industry parks and universities, colleges, and high schools accounted for a low percentage in the entire region with an average percentage of

7.4% and 8.0% respectively.

As far as the Time of Day analysis is concerned, according to the questionnaire survey and interview response results, the most common departure and arrival times of people were recorded. The time of day can be a useful indicator for evaluating the travel patterns of private vehicles, as it influences their travel behavior during weekdays travel. Figure 4-5 showcases the distribution of private vehicle trips on weekdays trips from the household travel survey, categorized by the hour of departure.

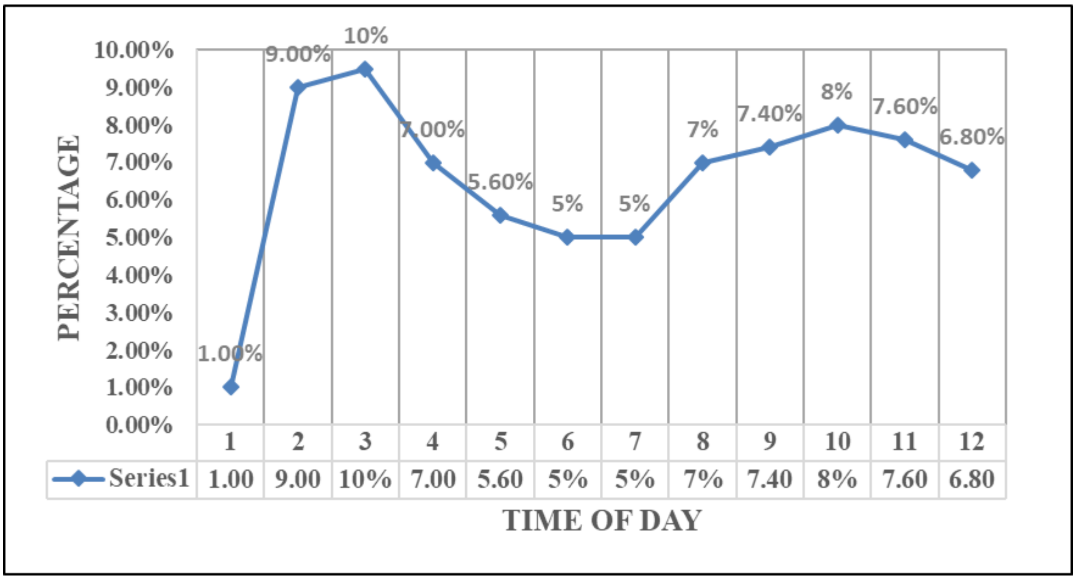

Figure 4.5: Distribution of Auto Trips by Departure Hour

Auto vehicle movement is higher in the morning and evening peak hours this is due to people moving to work and back home at this peak in weekday travel. During the midday peak, the most auto vehicle is seen in parking and they have made a moderate trip compared with other peak period.

Trip length and travel time were employed as efficient parameters for examining private vehicle movement within the traffic analysis zone in downtown Adama. Table 4-9 below displays the median travel times and trip distances for automobile journeys, categorized by the zone kebele of the trip analysis zone of the trip's starting point.

Table 4.9: Median Travel Time and Trip Distance by Trip Origin (zone) – Auto Trips

Trip origin	Duration(min)/day	Distance (km)/day
Zone 01	7.9	1.7
Zone 02	6.5	1.2

Zone 03	6.2	1.6
Zone 04	7.2	2.7
Overall	6.95	1.8

According to the table, a trip from Posta to Franco takes a long time to travel despite covering a short distance, which can be attributed to congestion in that area. On the other hand, a journey from Posta to Amede Gebeya takes less time even with a longer distance traveled, indicating that there is less congestion in that region during the travel period. Generally, the average distance to travel in TAZ is 1.8 km with an average duration of approximately 7 minutes in weekday travel.

Vehicle ownership is one of the variables used to assess private vehicle movement surveys in traffic analysis zone. measures of the auto movement were estimated and reported for the TAZ with the private vehicle owner travel data. Vehicle ownership rates by kebele of traffic analysis zone and by Work/non-Work trip purpose are found in Table 4-10 below.

Table 4.10: Average Vehicle Ownership for Work and Non-Work Trips by Purpose, Kebele of Traffic Analysis Zone (TAZ) of Trip Origin - Automobile Trips

Trip origin in TAZ	Trip Type		
	Work	Non-work	Total
Zone 01	1.8	0.9	2.7
Zone 02	1.1	1.0	2.1
Zone 03	1.4	1.0	2.4
Zone 04	1.7	1.3	3.0
Overall mean	1.5	1.1	2.55

Source: Respondent survey

Based on the provided data, a study was carried out to examine the total vehicle ownership and trip patterns for both work-related and non-work purposes. In Zone 04, the highest number of overall trips was recorded at 3.0, with 1.7 of these being work-related journeys and 1.3 being-non work journeys. Within the traffic analysis zone, the average number of vehicle trips for work-related activities came to 1.5, while the average auto rate for non-work trips stood at 1.1.

<u>4.2.5 Traffic Movement Survey Public Transport Vehicle Movement Survey</u>

Public transport vehicle movement surveys in the traffic analysis zone were used to analyze the level of people's demand for selected kebele in TAZ. Four zones are sampled in TAZ for a survey of public transport movement in weekday travel. In this section travel patterns by public transport were analyzed in their weekday travel. The common public transport that exists in the study area are buses, school buses, and medium buses. Typically, school buses are most active during morning and evening hours. During these peak times, students journey to and from school. Additionally, some university employees regularly commute during weekday mornings and evenings. According to the questionnaire response and public transport user interview survey, the result is summarized in the following section and presented in Annex-D. Accordingly, the analysis takes into consideration Origin-Destination (O/D) Patterns, Time of Day, Public transport trips survey by Purpose of Travel, and Trip Length.

The overall origin-destination pattern of public transport in the chosen kebele in the Traffic Analysis Zone (TAZ) is displayed in Table 4-11 below. The data is organized based on the kebele of the TAZ, which serves as the starting point for each trip.

Table 4.11: Distribution of Public Transport Trips by O-D and kebele of Trip Origin in TAZ.

Trip origin Zone in CBD (Gurmmu kebele)	Within the traffic analysis zone	To adjoining zone	To the industrial park zone at the edge	To University, college, and high school out of the TAZ	To other zones
Zone 01	40%	46.6%	6.6%	13.3%	2.3%
Zone 02	50%	25%	4.16%	12.5%	8.34%
Zone 03	50%	28.6%	14.3%	7.14%	0.1%
Zone 04	58.8%	17.6%	11.8%	5.89%	5.91%
Overall mean	49.7%	29.45%	9.25%	9.7%	4.2%

Source: Respondent survey

As per Table 4.11, most public transport movements take place within the traffic analysis zone (TAZ) and its surrounding areas, with average percentages of 49.7 and 29.45 respectively. Zone 01 generates a higher proportion of trips (46.6%) to the adjacent zone compared to other zones. Additionally, some trips, such as those for work-related purposes to universities and colleges as well as trips to industrial parks, occur outside the TAZ in the study area. The ideal time of day for assessing public transport in a transportation analysis zone (TAZ) was analyzed during the morning and evening peak hours, usually between 7 - 9 AM and 4 - 6 PM. This is when public transport networks are likely to experience the highest demands and be operating at or near capacity.

Based on the questionnaire response from 70 participating public transport users for weekday travel of public transport by hour of departure. The overall public transport movement regarding an hour of departure at peak hour mobility is presented in Figure 4. 6 below.

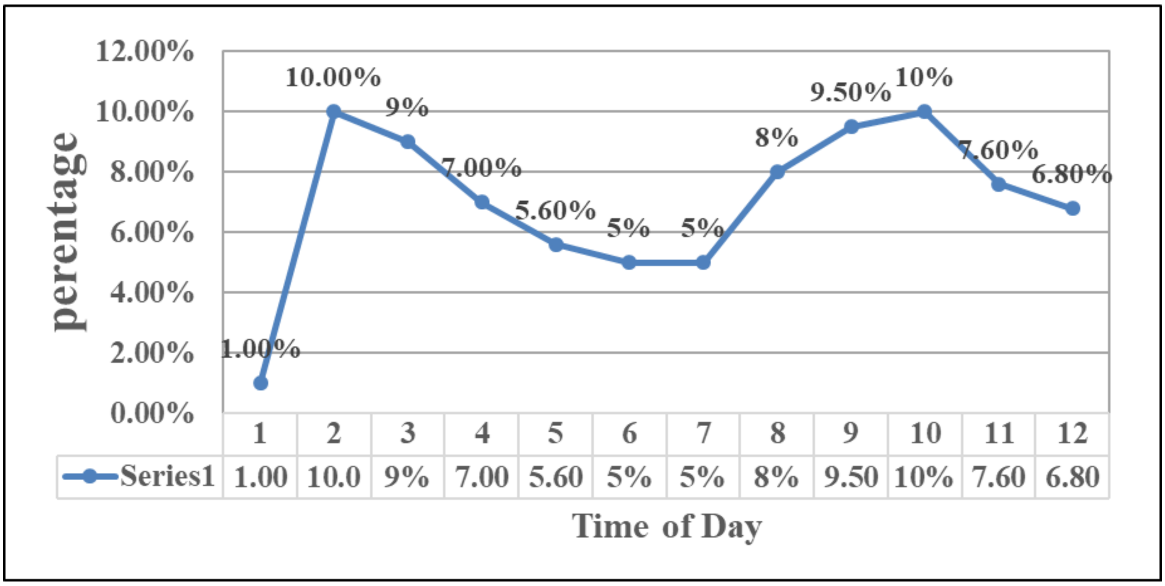

Figure 4.6: Distribution of Public Transport Trips by Departure Hour

The figure above illustrates that public transport usage is higher during morning and evening peak hours. School buses and public buses are the most popular transportation modes for students going to school and workers attending university, respectively, within the study area.

This survey is based on the purpose of travel in weekday travel. The destination or purpose of trips the household was determined. The overall distribution of work versus non-work public transport trips is presented in Table 4-12 below.

Table 4.12: Distribution of Trips by Public Transportation: Travel Mode and Trip Purpose (Work/Non-Work)

Mode	Trip Type		
	Work	Non-Work	average
Public bus	51.6%	10.0%	30.8%
School bus	10.0%	70%	40%
Medium bus	38%	20%	29%
Total	100%	100%	100%

Source: Respondent survey

Table 4-12 illustrates that in the selected traffic analysis zone, 70% of non-work-related public transport trips were made by school buses, while 51.6% of work-related public transport trips were made by regular buses. Overall, the percentage of work-related trips using public transport (regular public bus) is higher compared to non-work-related trips.

As to the Public transport trips survey by Trip Length assessment, the movement of public transport within traffic analysis zones was evaluated based on trip length and travel time. The recorded data from questionnaire responses provided information about the daily trip duration and distance traveled by public transport users during their weekday journeys. In Table 4. 13 below, the average reported travel times and trip distance for all trips made by public transport is displayed by the zone of trip origin in TAZ.

Table 4.13: Travel Time and Distance by Zone of Trip Origin – public transport Trips

Trip origin Zone in CBD (Gurmmu kebele)	Duration (minutes)	Distance (km)
Zone 01	9.9	1.4
Zone 02	9.5	1.4
Zone 03	10.9	1.8
Zone 04	10.9	1.9
Overall mean	10.3	1.6

Source: Respondent survey

The duration of public transport trips was significantly longer compared to those made by car with an average duration of 10.3 minutes. This is largely due to the additional time spent on activities related to using public transport, such as reaching the transit facility, switching between modes of transport, and waiting periods. When considering multi-modal trips with multiple stops, this further contributes to the extended duration of public transport journeys.

4.3. Origin-Destination (O-D) Travel Survey Result

4.3.1. General travel

The result of this section involved using both a respondents' origin-destination and the interview feedback about their weekday household origin-destination travel patterns. This process was conducted on a selected sample of 70 households in Gurmmu kebele of TAZ According to this, the overall result from the selected sample about the origin and destination of household travel which have made in the traffic analysis zone are presented in Figure 4.7 below. the researcher distributes questionnaires to 70 households for their O-D pattern on their weekday trip, the result of respondents is presented in the figure below.

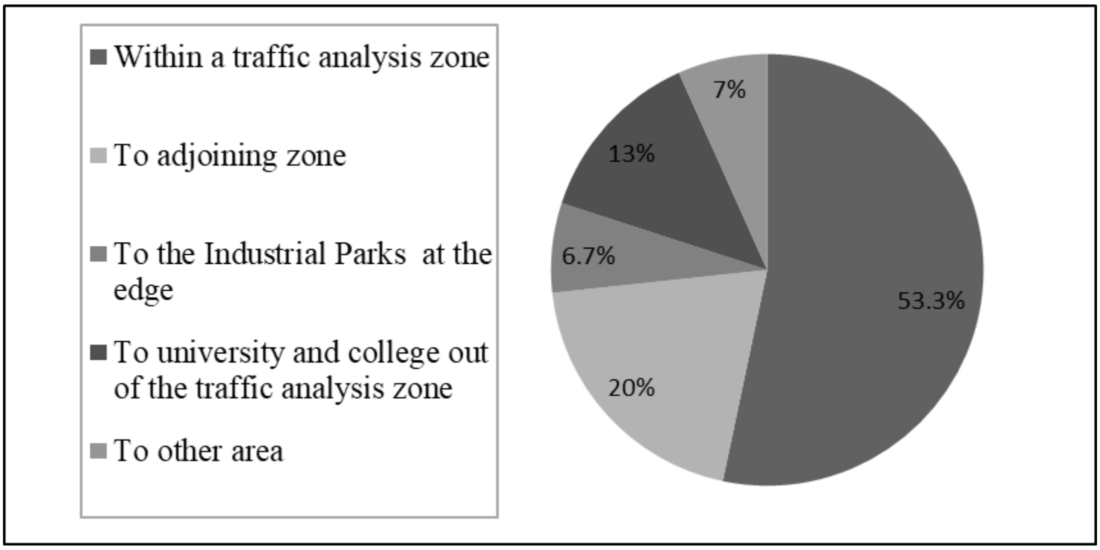

Figure 4.7: Distribution of Weekday linked trips of Households by Zone in the Study area.

Based on the figure, over 53% of all linked trips made by residents in the traffic analysis zone are within TAZ for shopping, business, market, and office, while just 20 % of trips are to the adjoining zone which is neighboring to the TAZ. Residents who commute to university, college, and high school out of the traffic analysis zone for work purposes are 13.3 % for work purpose.

According to the participating households, trips of households in the traffic analysis zone have made an average of 7.8 trips per weekday and household members averaged 3.0 trips per weekday. These mean household and person trip rate calculations are based on the travel number of households in the region who have made trips on weekdays.

Table 4.14: Weekday Mean household and Person Trip rate by Zone

Zone in the study area	Mean household trip rate	Mean person trip rate
Within the traffic analysis zone in the CBD area	10.5	3.9
To adjoining zone	8.8	3.4
To the industrial park at the edge	5.7	2.4
University, college and high school out of the TAZ	6.7	2.7
To other zones	7.3	2.8
Overall trip rate	7.8	3.04

Source: respondent survey

4.3.2. General origin-destination(O-D) pattern

The general origin-destination markets of a weekday household travel survey analysis typically involve Home-based trips, Work-based trips, and Non-home-based trips. Adama as it is a key transportation hub having several destination areas such as Adama Science and Technology University: Students, faculty, and staff would have O-D patterns associated with this institution for work, study, and daily activities, Industrial Parks and Markets, shops, and businesses which is becoming the daily O-D pattern in Adama's central business district and other commercial areas. However, the percentage of the summary of general origin/destination analysis of weekday travel is shown in Table 4-15 below. And the location of the zone in the center of the CBD is described in Figure 4.8 below.

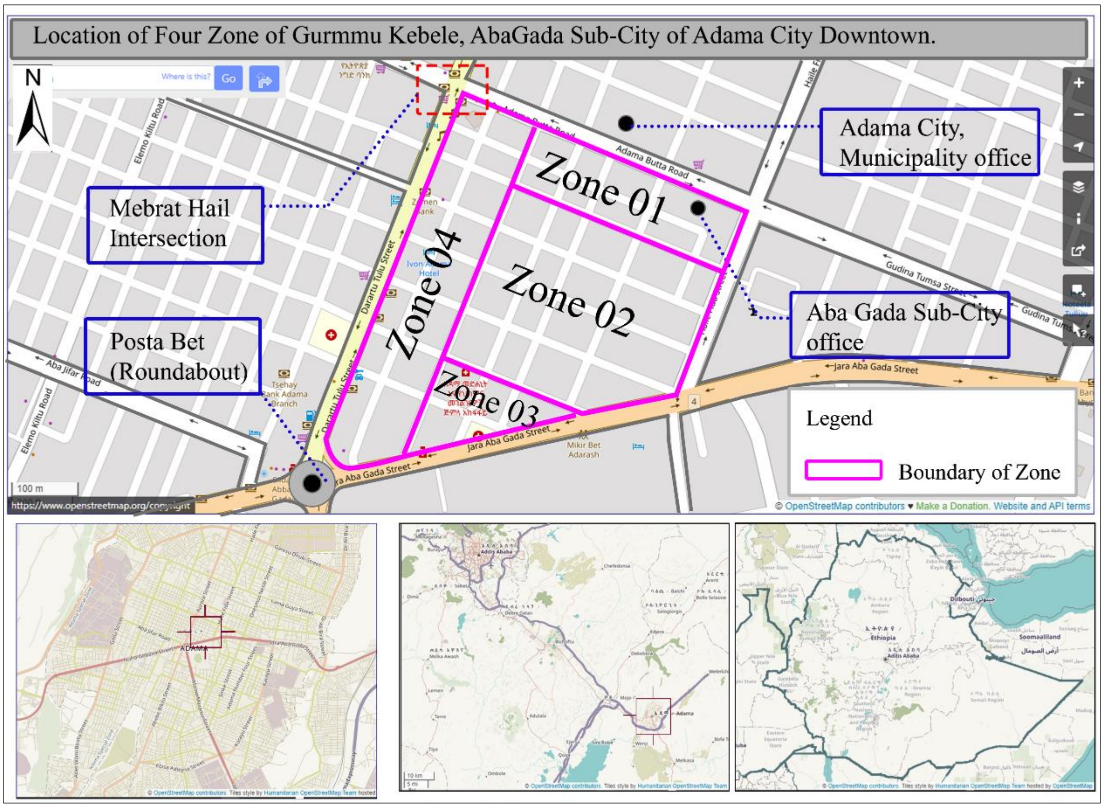

Figure 4.8: Location Map of Four Zones of Gurmmu Kebele of Aba Gada Sub-city, Adama

The above figure illustrates the zone area situated at the center of Adama, between the Posta Bet and Mebrat Hail intersection. The boundaries of the study zone include Mebrat intersection to the north, Posta Bet to the south, Mariam Orthodox Church to the east, and Eagle Hotel to the west.

Table 4.15: General Patterns of Origin-Destination (O-D) based on Trip Origin Zones during Weekdays – all Weekday Trips expressed as row percentages.

Trip origin Zone in CBD (Gurmmu kebele)	Within the traffic analysis zone	To adjoining zone	To the industrial park zone at the edge	To University, college, and high school out of the TAZ	To other zones
Zone 01	53.3%	20.0%	6.7%	13.3%	6.7%
Zone 02	54.2%	25%	12.5%	4.16%	4.14%
Zone 03	64.0%	14.0%	7.0%	14.0%	1.0%
Zone 04	52.9%	29.4%	11.7%	5.9%	0.1%
Total	56.2%	23.95%	9.51%	9.4%	2.74%

Source: Respondent survey

The majority of weekday trips (56.2% of all travel) occur within the traffic analysis zone. In comparison, 29.4% of household trips in Zone 04 are to the adjacent zone, which is higher than the total 23.95% and other zones. Additionally, 14% of trips in zone 03 are to universities and colleges in Adama city, which is a higher percentage compared to other zones.

4.3.3 General Origin-Destination Analysis by general trip purpose

Based on the questionnaire response result presented in Annex C, trips of households have several purposes. The overall trip made by households have their primary purpose, the researcher categorized those purposes into two; work and non-work.

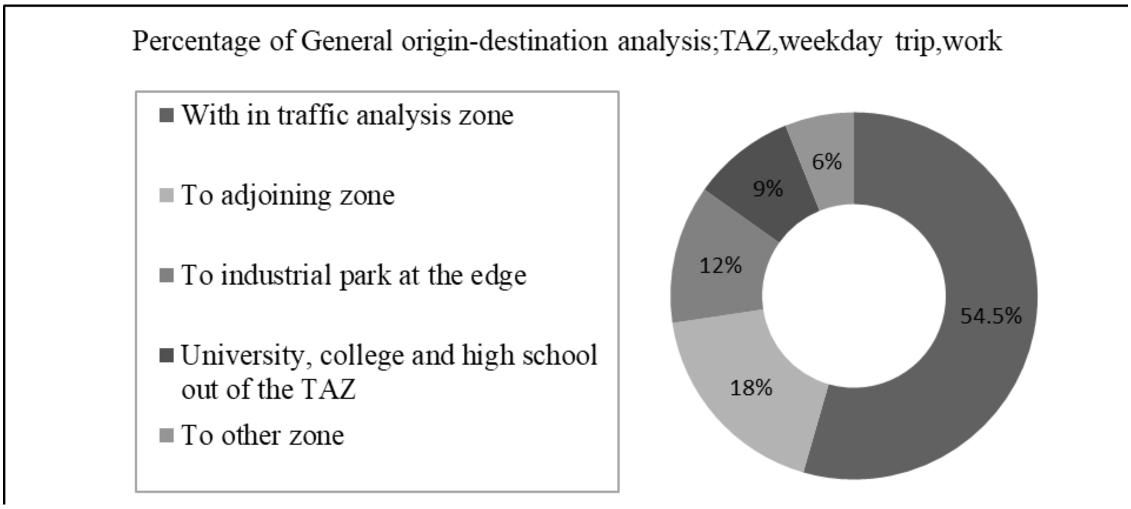

Figure 4.9: General Origin-Destination analysis: TAZ, Weekday Trips, Work

Figure 4.9 portrayed that about 54.5% of all linked work trips are within the traffic analysis zone with an average trip distance of 1.5 km. A trip to the adjoining zone counts 18% and a trip to the industrial park zone at the edge of the city counts 12% is the common origin-destination analysis for a work-related trip. 9.09%, of all work trips are destined for university, college, and high school and 6% of work-related trips are destined for other areas of the city.

As shown in table 4.16 below, the major non-work travel is made with a higher percentage of 62% within the traffic analysis zone and also non-work trips to the university, college, and high school with 5% which is the least percentage.

Table 4.16: General Origin-Destination analysis: TAZ, Weekday Trips, Non-work

Zone in the study area	Percentage
Within the traffic analysis zone in the CBD area	62%
To adjoining zone	24%
To the industrial park at the edge	4%
University, college and high school out of the TAZ	5%
To other zones	5%

Source: Respondent survey

The general origin-destination pattern of traffic analysis zone by work trip purpose has presented here in below Table 4-17. According to the questionnaire and household interview survey result presented in Table 4, Appendix-C, the overall work trip in each kebele in TAZ are presented in the below table.

Table 4.17: General origin-destination(O-D) pattern by zone of trip origin-work trips

Trip origin	Within the traffic analysis zone	To adjoining zone	To the industrial park at the edge	University, college, and high school out of the TAZ	To other zones
Zone 01	50 %	16%	16%	16%	0.1%
Zone 02	50%	20%	10%	20%	0.2%
Zone 03	62.5%	25%	12.5%	12.5%	0.1%
Zone 04	62.5%	12.5%	12.5%	12.5%	0.2%
Total	56.25%	13.5%	12.75%	15.25%	0.15%

Source: Respondent survey

According to the table mentioned above, the majority of work trips in each zone occur within traffic analysis zones that have a higher percentage. Additionally, trips to adjoining zones also have a higher percentage compared to other destination areas within the city. The work trips originating in zone 04 have the highest percentage of 20%, primarily directed towards universities and colleges located outside of the Traffic Analysis Zone.

4.4. Transport Demand Survey

4.4.1. Household travel survey

The household travel survey in the study area is influenced by several variables such as trip purpose, mode of travel, time of day, and vehicle ownership. The household weekday trip behavior survey is conducted by using the weekday household travel data obtained by questionnaire through surveys on 70 sampled participating households in the traffic analysis zone, Gurmmu Keeble. Accordingly, the assessment includes household and their weekday trip, trip purpose by general travel mode, travel distance and travel times, and time of day

Regarding household and their weekday trip Household use modes to travel for various purposes in the study region and they are depending on different travel modes according to their interest and economic level. The basic travel mode that Adama people used for their movement are Automobile, Mini-bus, Bajaj, public-bus, school bus, other bus, walking, and other 4WD. The travel mode percentage of household travel in the traffic analysis zone was analyzed. The overall trip behavior of household movement is within a traffic analysis zone and to an adjoining zone in weekday travel. The travel mode usage percentage is described below in Figure 4-10.

Overall, approximately 47% of trips were made by minibus in the traffic analysis zone, followed by auto and Bajaj, 24.3% and 10% respectively as depicted in Figure 4-10. Three years ago, the proportion of Bajaj services in the center of Adama was higher. However, due to current restrictions, Bajaj from operating on major routes leading to the Central Business District then the presence in the downtown area has significantly decreased.

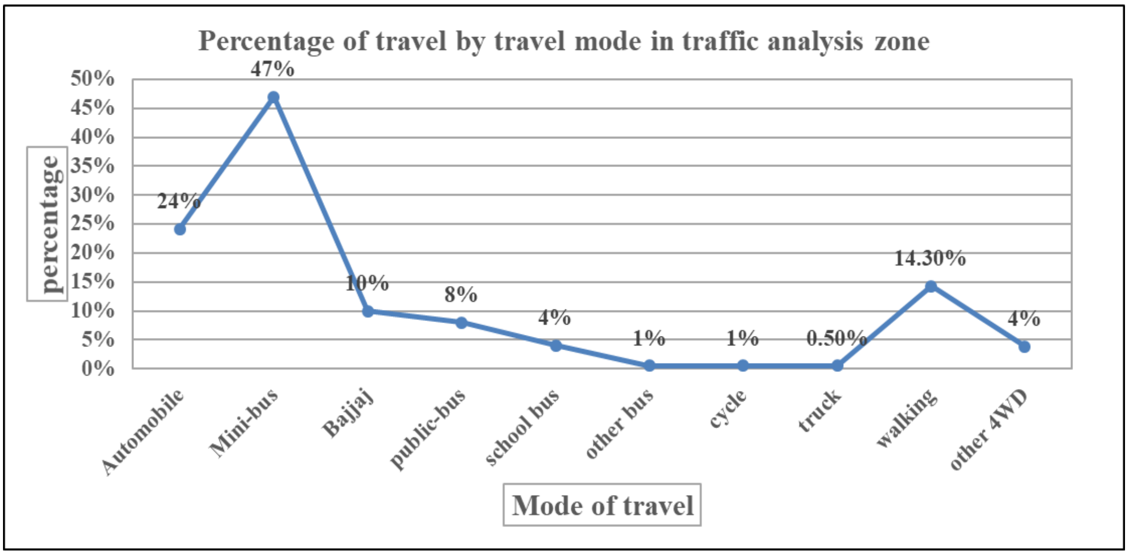

Figure 4.10: Percentage of Travel by Travel Mode in the Study Area

The result also presented in percentage of travel mode usage in Gurmmu kebele of TAZ based on the trip origin. Hence, based on the questionnaire and household interview survey result, responses gathered from participating households regarding the primary mode share of transportation used by household members for their trip origin, as well as their preferred mode of travel, has been compiled. Here Figures 4-11, illustrate the percentage of travel modes used by households in the zone of trip origin.

The minibus constitutes the largest portion of daily transportation mode within each zone of the traffic analysis zone. Automobiles serve as the second most common mode of transportation. Walking and non-motorized travel are also prevalent, particularly in the Central Business District (CBD) area, especially during the evening hours.

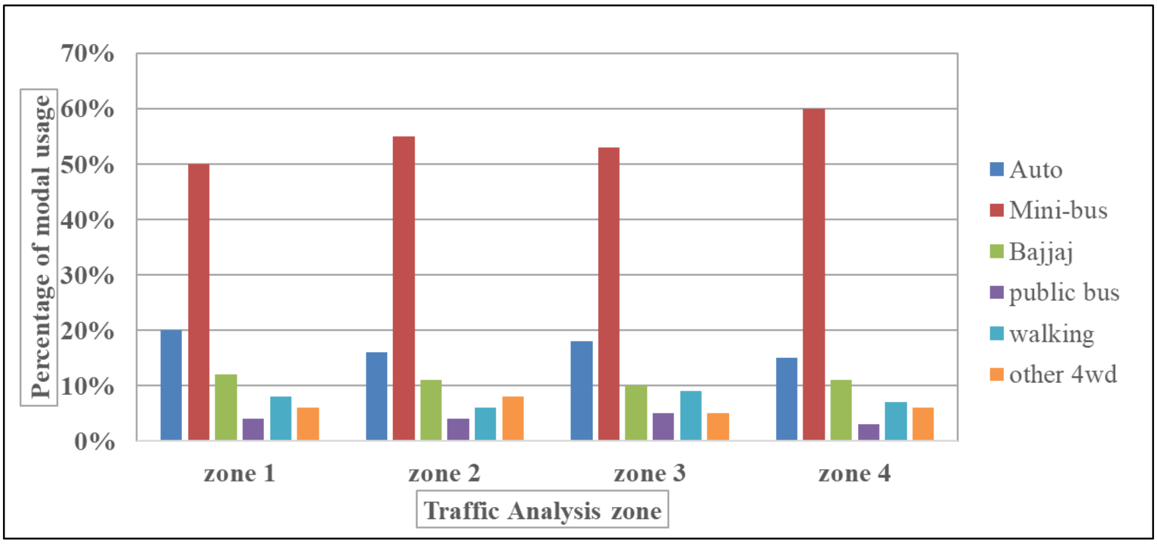

Figure 4.11: Percentage of Travel Mode used by zone (Gurmmu kebele) of Trip Origin

In order to analyze trip purpose by general travel mode the data is viewed with some category. As discussed in section 2.1.9 and presented in this section below, the general trip purpose is categorized by home-based work (HBW), home-based non-work (HBNW), and non-home-based (NHB). The trip data, derived from household travel surveys through questionnaire responses, provides insights about household common trip purposes and frequently used modes of transportation. Trips' purpose, type, and percentage of the mode used for individual purposes on their trip are presented in Table 4. 18 below.

Table 4.18: Trip Purpose by General Travel Mode

Trip purpose	General mode						
	Auto	Mini bus	Bajaj	public bus	Walking &non-motorized	Other 4WD	Total
Home to work	33%	41.6%	12%	7%	3.9%	2.5%	100%
Home to school	6%	17%	10%	43%	23%	1%	100%
Home to Recreation	20%	16%	10%	6%	44%	4%	100%
Home to Personal Business	38%	43%	4%	1%	8%	6%	100%
Home to shopping	14.3%	28.5%	11%	0.4%	45%	0.8%	100%
Home to Other	13%	27%	7.6%	1.3%	42.1%	10%	100%
Work to Home	26%	37%	19%	12%	8%	9%	100%
school to Home	8%	13%	11%	43%	23%	3%	100%
Social/Rec to Home	28%	38%	7%	2%	22%	4%	100%
Personal Business to Home	26%	44%	10%	1%	12%	5%	100%
Shopping to Home	16%	30%	11%	0.8%	38%	4.2	100%
Other to Home	14%	30%	6.6%	1.3%	40.1%	10%	100%
Work Related	25%	30%	14%	24%	6%	4%	100%
Other Non-Home/Non-Work	44%	13.5%	10%	4%	38%	5.5%	100%

Source: Respondent survey

The table above indicates that work trips primarily involve the use of mini-buses and automobiles, while school trips predominantly utilize school buses and walking or other non-motorized modes of transportation. Additionally, social/recreational and shopping trips largely rely on walking.

Household travel survey by trip purpose considers the zone. This section presents the result for the reason for travel made in the traffic analysis zone. The result of this is based on the questionnaire response of the respondent in the analysis zone. The overall trip data and their purpose are presented below in Table 4-19. Based on Table 4-19 below most of the residents travel for work-related purposes within TAZ, such as home to office and home to some other destination area like a university, college, and industrial park for work purposes. And the non-work trip is operated in low proportion when compared with work-related like shopping within TAZ.

Table 4.19: Percentage of Household Travel Survey by Purpose of Trip

	Percentage (100%)
Work	42%
School	13%
Personnel business	6%
Social or recreational	10%
Hospital	7%
Shopping	10%
Other	12%

Source: Respondent survey

Household travel survey by Travel Distance and Travel Times is also another measurement. The analysis of household travel distance and time was conducted. Table 4-20 presents the overall findings on the time taken to cover the distance for various purposes during weekday trips.

Table 4.20: Trip Duration (minutes) by Trip Purpose and zone of TAZ

Trip origin/residence	Trip purpose					
	Work	school	Social	Personal business	shopping	other
Zone 01	20	16	14	12	8	16
Zone 02	25	18	12	10	7	12
Zone 03	23	16	13	10	6	17
Zone 04	20	15	15	12	7	14
Overall mean	22	16.25	13.5	11	7	14.75

Source: Respondent survey

Generally, trip duration was higher for work-related trips with the median trip duration being 22.0 minutes for work-related trips on weekdays, as compared with 12.5 minutes for all trips which is the overall minute of school, social, Personal business, shopping, and other trip purpose. Areas like Posta bet to Franco had high trip duration, probably because they attracted trips from different routes within the traffic analysis zone. Table 4.21 illustrates that the median distance for trips was 0.9 km. Among all trip purposes, work-related trips had the longest median distance, which was 1.5 km on average.

Table 4.21: Median Trip Distance (in km) by Trip Purpose and kebele in TAZ

Trip origin/residence	Trip purpose					
	Work	school	Social	Personal business	shopping	other
Zone 01	1.5	0.8	1.2	0.9	0.6	1.4
Zone 02	2.2	0.9	1.1	0.6	0.5	1.3
Zone 03	1.6	1.0	0.9	1.0	0.7	1.2
Zone 04	0.9	0.6	0.8	1.1	0.8	1.5
overall	1.5	0.8	1.0	0.9	0.6	1.3

Source: Respondent survey

The time of day, the questionnaire, and the household travel survey which is presented in Annex-C, table 5, and discussed in this section. Analysis of departure and arrival times during peak hours for household journeys on weekdays was carried out. The study found that work-related trips accounted for a significantly higher proportion of weekday travel between 7:30 am and 1:30 PM with AM having the highest percentage of trips for work as it is described in table 4.22 below. Hour of departure is gained through questionaries' and on-site surveys of household trips. In addition, non-work trips also occurred throughout the day, with a noticeable increase during the midday hours.

At the midday peak period lower percentage of work trips are observed which account overall percentage of 26% because at this peak low amount of people are generating trips people from residence area most of people are stayed in CBD area. Non-work trip has occurred on midday peak with the overall percentage of 38.5% these are due to individual take a lunch break and simply move around the CBD area at this peak.

Table 4.22: Distribution of Trips by Time of Departure, Trip Purpose, and Trip Origin

Trip Origin	Work Trips			Non-Work Trips		
	Morning peak 1:30-3:30	Midday peak 6:00-8:00	Evening peak 10:30-12:30	Morning peak 1:30-3:30	Midday peak 6:00-8:00	Evening peak 10:30-12:30
Zone 01	40%	26%	34%	28%	39%	34%
Zone 02	42%	22%	37%	30%	37%	33%
Zone 03	39%	30%	31%	28%	40%	32%
Zone 04	40%	27%	33%	26%	38%	33%
overall	40%	26%	34%	28%	38.5%	33%

Source: Respondent survey

The overall distribution of trips through the traffic analysis zone by the time of departure is presented below in Figure 4.12. Based on the below figure trips by the time of departure had a higher percentage during the morning and evening period while in midday peak are low trips are departing from the home of residence.

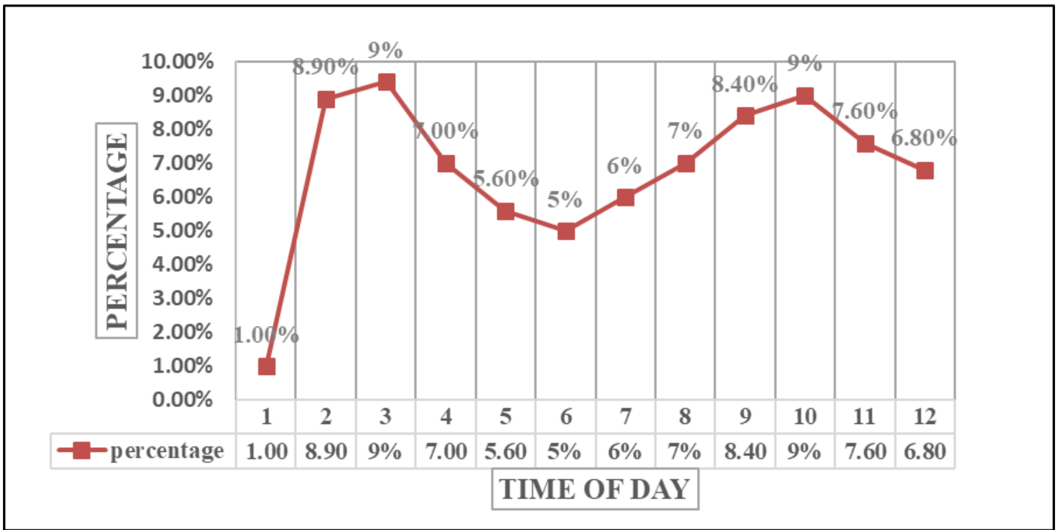

Figure 4.12: Distribution of Trips by Time of Departure overall in CBD

<u>4.4.2. Household travel survey by different types of households</u>

Household travel surveys, which analyze travel behavior, are highly dependent on household characteristics and structure. The assessment, thus, considered household size, household trip rates by household size, household income, vehicle ownership, and household trip rates by household structure and kebele of TAZ.

According to the questionnaire result from the representative target in the TAZ regarding the size of the family, the overall result shows that the households participating in the household travel survey had an average of 2.6, approximately three household members (see Table 4.23).

Table 4.23: Household Size by Zone in traffic analysis zone

Zone	Household Size				
	1	2	3	4 and 4+	Overall mean
Zone 01	20.6%	20%	26.6%	33.3%	2.5
Zone 02	17.4%	17.4%	21.7%	47.8%	2.6
Zone 03	14.3%	28.5%	35.7%	28.5%	2.5
Zone 04	16.7%	16.6%	22.2%	44.4%	2.5
Overall	17.25%	20.6%	26.5%	38.5%	2.5

Source: Respondent survey

In comparison to other zone in TAZ, zone 01 had the highest percentage of single-family households (20.6%). Meanwhile, kebele 02 had the greatest proportion of households with four or more members (47.8%). On average, households participating in the study across the entire area had three members. Generally, households having large families made more trips than families with a single family.

The transport demand is also determined by household trip rates by household size**.** Family size, it is likely that large families travel more than smaller-sized families. According to the questionnaire response result from the sampled household, this research analyzes the trip rate by a member of the household in each zone in TAZ. The overall trip rate result by household size is shown below in Table 4.24. The overall mean trip rate in the traffic analysis zone of the sampled zone was 5.5. Household size having four or more members and households with three members produce more trips in the region than lower family size groups while single-family groups produce lower trips.

Table 4.24: Household Trip Rates by Household Size and Zone of TAZ

Zone	Household Size				
	1	2	3	4+	Overall mean
Zone 01	3.6%	4.25%	6.25%	7.0%	5.3
Zone 02	3.0%	5.5%	6.0%	8.5%	5.75
Zone 03	4.0%	4.75%	5.75%	8.25%	5.7
Zone 04	4.3%	4.0%	5.0%	6.5%	5.0

Overall	3.7%	4.75%	5.75%	7.6%	5.5

Source: Respondent survey

Another important factor of travel demand of a household is the household income. Travel expenses are related to the number of trips taken. Families with higher incomes tend to take more trips on an average weekday trip. The study result shows that travel patterns in TAZ had influenced by the income of the resident. The overall result is presented in Table 4-25 below. In the below table, households having higher incomes produce more travel than the lower-income household. Zone 02 produces higher overall trips when compared with other zones. The overall trip rate is 5.8 per weekday trip. An income over 65$ produces more trips within the traffic analysis zone for several purposes such as recreation and shopping.

Table 4.25: Household Trip Rates by Household Income and Zone of TAZ

Zone	Under 25$	25-40	40-55	55-70$	Over 70$	Overall mean
Zone 01	5.0	5.4	6.0	7.2	7.0	6.1
Zone 02	4.0	5.5	6.5	7.0	7.7	6.3
Zone 03	3.0	4.3	5.0	6.0	7.5	5.2
Zone 04	4.0	5.0	6.0	6.2	6.25	5.5
Overall	4.0	5.05	5.9	6.6	7.2	5.8

Source: Respondent survey

Households' Vehicle Ownership is also an important determinant that influences the demand for transport in various ways. Based on the response to the questionnaire and household interview survey, the results for vehicle ownership were observed. Generally, larger households and those with higher incomes tend to have a greater number of owned vehicles. Therefore, both income and household size contribute to an increase in vehicle ownership which also increase trip made. As shown in Table 4. 26, households having 4 and 4+ vehicles had the highest trip rate with an average of 9.4 in weekday travel. The number of trips tended to increase in households with more vehicles. The overall trip generation rate by vehicle ownership is 7.02. Generally, households with private vehicles tend to produce more trips.

Table 4.26: Household Trip Rates by Number of Vehicles Owned in Zone of TAZ

Zone		Household Vehicles ownership				
	0	1	2	3	4 and 4+	Total mean
Zone 01	5.4	5.8	7.0	8.0	9.0	7.04

Zone 02	3.5	6.4	6.4	10.5	10.0	7.3
Zone 03	4.0	5.8	7.6	8.0	8.5	6.8
Zone 04	4.0	5.4	5.7	9.0	10.0	6.8
Overall mean	4.2	5.9	6.7	8.9	9.4	7.02

Source: Respondent survey

Household Trip Rates by Household Size and Number of Vehicles is one of the ways to evaluate its effect. Depending on the data collected from household responses, the household trip rate by household size and number of vehicles are presented below in Figure 4.13.

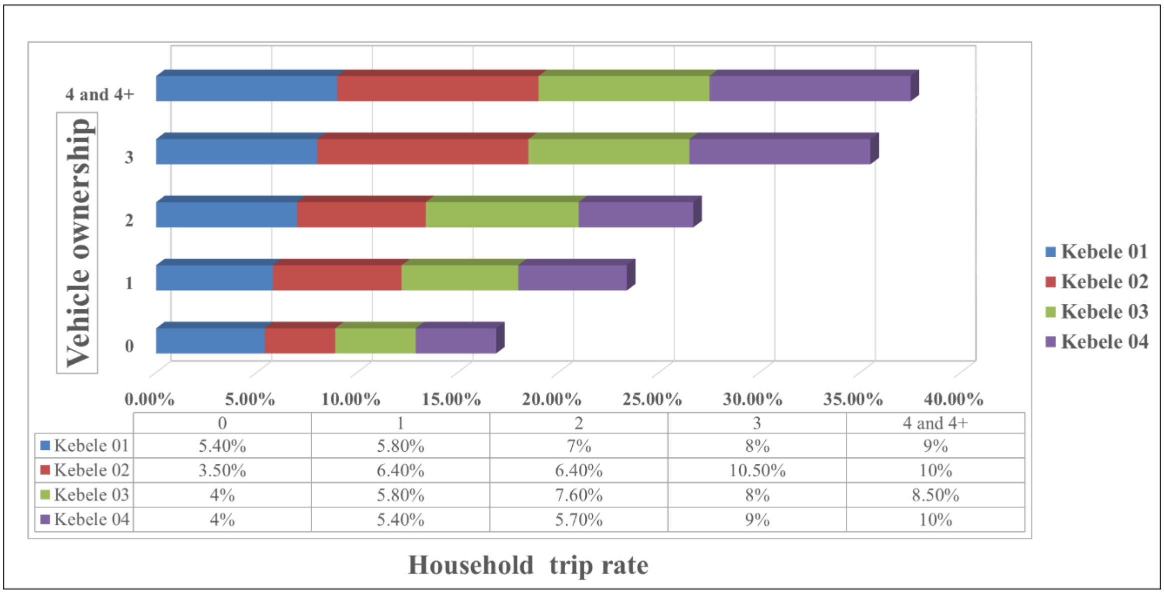

Figure 4.13: Household Trip Rates by Number of Vehicles Owned in Kebele of TAZ

According to Figure 4.13, households that own three or more vehicles generate a higher number of trips compared to those with fewer or no vehicles. For households without any vehicles, walking is the most common mode of transportation, and they also utilize other means such as minibuses and public buses. Households with vehicles tend to travel more frequently during weekdays than those who primarily walk.

Travel behavior of the family is also affected by the number of workers in the Household. The number of workers in a household is a key independent variable for analyzing travel patterns. Generally, employed households generate more trips than unemployed households during weekdays, as individuals with jobs travel daily for work.

Table 4. 27 represents household trip rates by household structure and kebele of TAZ. Based on questionnaire responses regarding the origin-destination of worker members of the household, linked weekday trip rates of household by home location and the number of worker/household structures are presented in Table 4-27 below. Home location was compared by a zone of traffic analysis zone. Households with three and four working members in the kebele of the traffic analysis zone generate a higher number of trips compared to those with two and one working members, with an average trip rate of 7.6 and 9.2 trips. In contrast, the overall trip rate based on the number of working members in the household is 6.7.

Table 4.27: Household Trip Rates by Household Member of Worker and home location

Zone	Number of workers					
	No worker	1 worker	2 worker	3 worker	4+ worker	Total mean
Zone 01	5.6	5.6	6.6	7.0	8.0	6.6
Zone 02	5.0	4.75	6.4	9.0	10.1	7.05
Zone 03	4.5	4.0	7.0	8.5	9.8	6.8
Zone 04	6.5	5.3	5.2	6.0	9.0	6.4
Overall mean	5.4	5.0	6.3	7.6	9.2	6.7

Source: Respondent survey

4.4.3. Travel demand modeling analysis

Travel demand modeling is a method used in transportation planning to estimate and analyze people's movement patterns across a region, studying factors that affect travelers' decisions on destinations, transportation modes, and routes. The process consists of four steps: Trip Generation, Trip Distribution, Mode Choice, and Trip Assignment, which help analyze and estimate traffic demands. In this study, travel demand analysis is based on population characteristics to estimate traffic demand. Data on household characteristics, such as the number of households, household income, household size, car ownership, and the number of workers per household, are collected through questionnaires. The model evaluates the impact of these variables on trip production within the study area.

Trip Generation Model

These models utilize secondary data and surveyed data from origin-destination analysis, household travel survey analysis, and land use analysis of the Traffic Analysis Zone (TAZ) in the study area. As mentioned in the previous section, this model estimates the volume of trip generation in the zone of Gurmmu kebele within the TAZ in the study region. To calculate trip generation and attraction, these models require information about variables such as household category (independent variable) and trip generation (dependent variable). The trip generation analysis focused on four zones in Gurmmu Kebele of the traffic analysis zone of the study region (refer to section 4.3.2).

Estimating trip generation consists of two interconnected aspects related to population and land uses at the Traffic Analysis Zone (TAZ) level. Trip production denotes the number of trips originating from a TAZ, while trip attraction signifies the number of trips ending within a TAZ. Table 4.28 below displays the number of households and their respective populations in the study zone. The number of households in each zone, as well as their corresponding population data, were obtained from local authorities.

Table 4.28: Number of households and total population in Gurmmu kebele of traffic analysis zone (TAZ) in the study area.

Kebele-Gurmmu	Number of households	Percentage	Total population
Zone 1	333	21%	2,565
Zone 2	522	35%	4,275
Zone 3	298	20%	2,443
Zone 4	358	24%	2,931
Total	1,492	100%	12214

Source: from Aba Gada sub-city in Adama town

Trip Production

The traffic analysis zone's trip production rate was estimated by considering variables associated with the population characteristics of the zone. The most frequently used variable for this estimation is the number of households. The commonly used variable (household category) to calculate trip production is the Number of households, Household income, Private car ownership, Workers per household, and Household size. The dependent variable is total trip production in TAZ.

The cross-classification model was used to calculate the trip generation in the traffic analysis zone. These techniques were used to analyze by classifying zonal households based on the population characteristics of TAZ. Trip generation rates were developed for each category in each zone. Data are organized from a field survey and questionnaire responses for household categories and trip behavior. The data for the chosen independent variable, used for the analysis of trip production from sampled households in each traffic analysis zone, is summarized and presented in the subsequent section and the recorded data are attached in Appendix F. After the researcher gathered the necessary data for the variable values, a variable analysis was employed to evaluate the relationship between the independent variables and the dependent variable, which in this case was the trip production for each household category.

Trip production and household characteristics analysis, the analysis of the relationship between the number of workers per household and the total trip production in the study area was conducted by analyzing trip production based on the number of workers per household. The data used for this analysis was gathered from the surveyed households and can be found in Appendix F and the result is presented in Table 4.29 below.

Table 4.29 Household trip production in TAZ by number of Workers per Household on a Weekday

Zone	Number of workers					
	No worker	1 worker	2 worker	3 worker	4+ worker	Total mean
Zone 01	4.0	5.2	5.5	8.0	8.5	6.24
Zone 02	5.5	4.2	6.9	9.0	9.2	7.0
Zone 03	4.0	5.5	6.5	7.0	9.0	6.4
Zone 04	6.0	4.6	6.6	5.0	8.0	6.04
Overall mean	4.87	4.87	6.4	7.3	8.7	6.4

Source: Respondent survey

The result of Table 4.29 demonstrates a positive direct relationship between the number of workers in a household and the trip production levels. This indicates that households with more members who are employed tend to generate a higher number of trips as each worker in the household has travel requirements, such as commuting to work, shopping, and leisure activities. As the household size increases with more workers, the overall trip production levels increase, showing the significance of employment as a factor contributing to travel demand.

In the specific context of the study area, zone two has the highest trip production, with an average household producing 7.0 trips per weekday. This could be attributed to the presence of a higher number of workers in the households of this zone as compared to other zones. In general, households with more workers tend to have a higher number of trips made.

Trip production and household income, an analysis of trip production and household income was conducted to examine the impact of household income on trip production in the study area. The analysis relied on data gathered from survey respondents through questionnaires. Table 4.30 below provides a summary of the overall results.

Table 4.30: Household trip Production in TAZ by Household Income on a Weekday

Zone	Household income					
	Under 25$	25-40	40-55	55-70$	Over 70$	Total mean
Zone 01	3.0	5.0	4.0	5.7	6.7	4.88
Zone 02	3.0	4.7	5.0	5.4	7.7	5.2
Zone 03	4.6	4.0	5.0	6.0	6.8	5.3
Zone 04	4.3	5.5	5.0	6.0	6.8	5.5
Overall Mean	3.7	4.8	4.8	5.8	7.0	5.2

Source: Respondent survey

The results presented in Table 4.30 demonstrate that as household income increases, there is a corresponding increase in trip production. This suggests that there is a direct relationship between trip production and household income. In the study area, the average number of trips made per person per weekday based on household income is 5.2.
This correlation between trip production and income indicates that households with higher incomes are likely to have more mobility and travel more frequently. This might be due to multiple factors, such as owning more personal vehicles, better access to public transportation, or the ability to afford more leisure activities that require more travel. In general, higher family incomes are associated with a greater number of trips made.

Trip production and private vehicle ownership, an analysis of trip production and car ownership was conducted to examine the relationship between trip generation and vehicle ownership. This is because private vehicle ownership has a substantial impact on trip production in the area under study. The analysis is based on the results of a questionnaire and a household travel survey, which is summarized and presented in Table 4.31, and the recorded data are attached in Appendix F.

Table 4.31: Household trip production in TAZ by car ownership on a weekday

Zone	Vehicle ownership					
	0	1	2	3	4 and 4+	Total mean
Zone 01	4.0	5.0	6.5	7.5	8.0	6.2
Zone 02	4.2	5.4	6.1	8.5	10.0	6.8
Zone 03	4.5	5.4	6.3	7.0	9.0	6.4
Zone 04	4.3	5.4	7.0	8.0	11.0	7.1
Overall mean	4.2	5.3	6.5	7.8	9.5	8.3

Source: Respondent survey

Based on Table 4.31, the findings demonstrate that household trip production in the study area is reliant on private vehicle ownership. There is a direct correlation between trip production and vehicle ownership, as the number of owned vehicles increases, the overall trip production in the area also rises. Within this study, Zone 04 has the highest trip production, generating an average of 7.1 trips per weekday travel. Generally, People with a car likely travel more than those without a car.

Another important factor for trip production is household size, the analysis was carried out to check the relationship and dependency of each other. According to the questionnaire result the summary of the result are presented in Table 4.32 below.

Table 4.32: Household trip Production in TAZ by Household size on a Weekday

Zone	Household Size				
	1	2	3	4 &4+	Total mean
Zone 01	3.5	4.3	5.5	6.6	4.9
Zone 02	3.6	4.8	6.2	7.7	5.6
Zone 03	3.8	5.0	5.6	7.6	5.5
Zone 04	3.7	5.5	5.5	7.4	5.5
Overall mean	3.7	4.9	5.6	7.3	5.4

Source: Respondent survey

Table 4.32 demonstrates that trip production is dependent on household size, as households with three and four family members generate more trips, with average values of 5.6 and 7.3 respective trips per weekday. This indicates that larger families tend to travel more than smaller-sized families. In particular, Zone 02 has the highest trip production, producing an average of 5.6 trips per household per weekday. The overall mean trip production for the study, based on household size, is 5.4 trips.

The traffic analysis zonal trip production, which presents the number of trips produced in each zone based on variable value discussed in the above section, and the actual trips generated derived from the questionnaire are detailed in table 4.33 below.

Table 4.33: Zonal Actual trip Production based on Total mean Trip Production value of variable

Zone	No. of HHD	Total mean of HHD income ($)	Total mean of Car Ownership	No. of workers per HHD	HHD size	Average mean TP per weekday	Actual trips per weekday
01	333	4.88	6.2	6.24	4.9	5.6	1,865
02	522	5.2	6.8	7.0	5.6	6.2	3,236
03	298	5.3	6.4	6.4	5.5	5.9	1,758
04	358	5.5	7.1	6.04	5.5	6.0	2,148
Total	1492						9,007

Source: Respondent survey

Based on the provided table, the trip production for each traffic analysis zone was assessed based on the characteristics of households Zone 2 appears to generate a larger number of trips, around 3236 on weekdays, due to its higher number of households and significant car ownership. In the study zone around a total of 9007 trips were generated per weekday in Gurmmu Kebele. A direct correlation exists between the total trip production in each zone and the respective independent variables. In the study area, Zone 3 has the lowest trip production.

Trip Attraction

The analysis of trip attraction in traffic analysis zones (TAZ) was conducted based on the amount and type of land use within the TAZ. The study gathered data from survey results and the Aba Gada sub-city, Gurmmu Kebele regarding the type and amount of land use in the study region to determine how many people are attracted to each zone.

The land use categories defined for this analysis of trip attraction include residential (housing units), retail (commerce), institutional (services), and other services. By considering these different types of land uses, the study was able to estimate the number of people attracted to each zone and gain insights into how land use patterns affect trip generation within the region.

The table below presents the percentage and amount of each land use type for each zone. In general, areas with a higher percentage of commercial land use, including retail, service, and office spaces, tend to attract more trips than other types of land. Conversely, residential land use typically draws fewer trips in comparison to commercial land use.

Table 4.34: Land Characteristics of the Selected Zone in the Traffic Analysis Zone.

Study zone (Gurmmu kebele)	Land use character	Amount Percentage	Population	Number of Employment
Zone 1	Residential (household unit)	35%	2,565	1200
	Commercial (retail, service, store, and office)	40%		
	Institutional(school & hospital)	25%		
Zone 2	Residential	65%	4275	900
	Commercial	25%		
	Institutional (service)	10%		
	Industrial	0.0%		
Zone 3	Residential	30%	2443	1800
	Commercial	50%		
	Institutional	15%		
	Industrial (service)	0%		
Zone 4	Residential	30%	2931	1500
	Commercial	55%		
	Institutional (service)	15%		

Source: Adama City municipality

The association between the overall trip attraction and the independent variable was ascertained. Here, trip attraction serves as the dependent variable that relies on the independent variable, which frequently includes factors such as population, employment, and land use features (residential, commercial, and institutional) within the TAZ.

Employment, commercial land use, and institutional or service land use share a direct relationship, as the majority of trip destinations tend to be concentrated in commercial districts. This is because these areas typically house businesses and services where people work or seek assistance. On the other hand, population and residential land use exhibit an inverse relationship, given that residential areas generally serve as the source of trips rather than their attraction. This is because people usually live in these areas and travel to other locations for work, services, or leisure.

The overall trip attraction concerning the corresponding independent variable in each traffic analysis zone is described in Table 4.35 below.

Table 4.35: Zonal trip attraction

TAZ (zone)	population	Employment	Residential Land Use	Commercial Land Use	Institutional land use	Total
1	2,565	988	35%	40%	25%	100%
2	4,275	2240	65%	25%	10%	100%
3	2,443	1230	30%	50%	15%	100%
4	2,931	1000	30%	55%	15%	100%
Total	12,214					

Source: Aba Gada sub-city and field survey

According to the provided table above, Zone 4 experiences a higher number of trips attraction due to its larger share of commercial land use, as there is a direct relationship between trip attraction and commercial land use types. On the other hand, Zone 2 has fewer trips as it has a smaller percentage of commercial land use and a greater percentage of residential land use but Zone two has a higher trip production zone as described in the above section. In travel demand analysis models, residential land use is more associated with trip production rather than trip attraction.

4.5. Traffic Congestion Analysis

The congestion analysis was carried out using the travel time method to identify various congestion indicators. These indicators comprise average travel time, delay, average travel speed, travel time index, and volume-to-capacity ratio (LOS). The assessment primarily concentrated on six chosen routes within the Traffic Analysis Zone (TAZ), which include the following: From Franco to Posta Bet, from Posta Bet to Tikur Abay, from Posta Bet to

Mebirat Haile, from Posta Bet to Addis Ababa Meneharia, from Posta Bet to Amede Gebeya, and from Posta Bet to Abebech Gobena Street.

4.5.1. Travel time

Travel speeds and travel times measured on any route vary by time of day, day of the week, and month of the year. In general, evening weekday peak hour traffic volumes and travel times were higher, and travel speeds lower, than those measured during midday periods or on weekends. Travel time and travel speed data were collected in 15-minute intervals along 6 major selected networks in the traffic analysis zone. In this study travel time and speed were conducted from 7:30 AM to 7:00 PM on peak and off-peak periods. Along each directional route, two runs were conducted for each hour. Travel routes are shown in Figure 4.14 and Table 4.36 below. A team consisting of a driver, two data collectors, and the researcher gathered the data. Travel time and speed data were recorded manually, using pen and paper along with stopwatches. In this research "average" or "typical" travel times and speeds, with a minimum of two-speed runs was collected on each route during the morning, midday, and evening peak hour on "typical weekdays" (i.e. Tuesday, Wednesday, and Thursday).

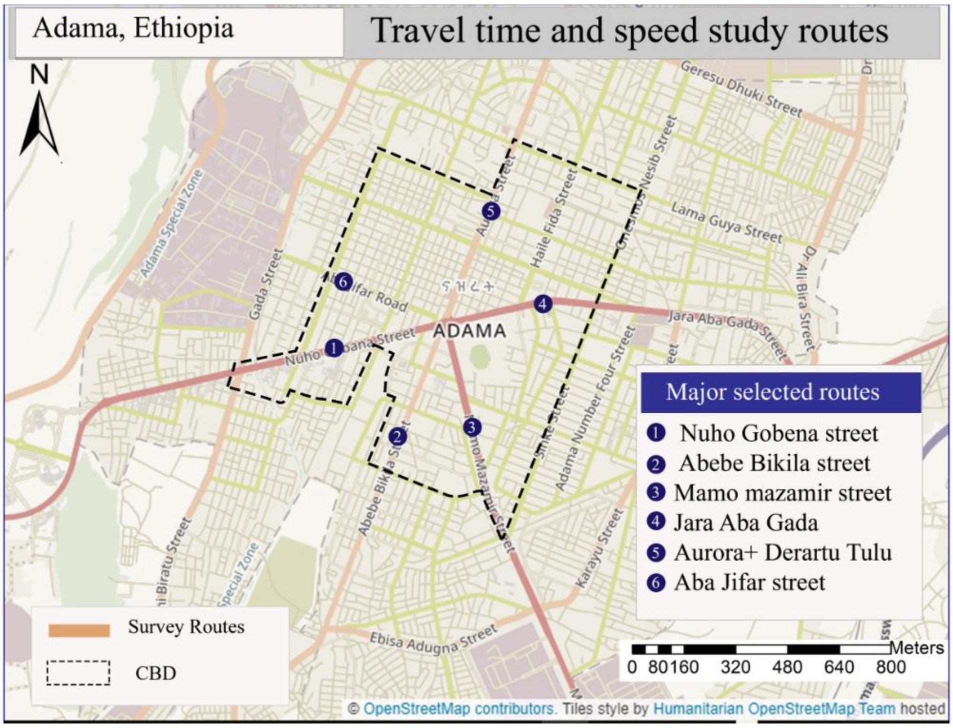

Figure 4.14: Travel route

Table 4.36 below provides an overview of the selected routes for congestion measure analysis in the traffic analysis zone. It includes the route names and their respective origin-destination information.

Table 4.36: Travel route for travel time and speed

No	Route Name	From and To
1	Nuho Gobena	From Franco to Posta bet
2	Derartu Tulu	From Posta bet to mebirat Hail
3	Abebe Bikila street	From Posta bet to Addis Ababa Meneharia
4	Mamo Mazamir	From Posta bet to Tikur Abay
5	Jara Aba Gada	From Posta bet to Amede Gebeya
6	Aba Jifar street	From Posta bet to Abebech Gobena Street

Source: field survey

Median peak hour travel time and average travel speed

Table 4. 37 presents the average surveyed travel time and speed across all chosen routes within the traffic analysis zone. To examine the impact of congestion on travel delays, both travel time and speed were surveyed during peak and off-peak hours on typical weekdays.

Table 4.37: Median peak hour and the off-peak hour travel time and average travel speed

Name of major Corridor	From street	To street	Length in (m)	Average				Travel time index	Run No.
				Peak hour TT in (sec)	Off peak hour TT in (sec)	Peak hour TS	Off peak hour TS(kph)		
Nuho Gobena	Franco	Posta bet	600	250.5	100.5	8.6	12	2.5	3
Abebe Bikila	Addis Ababa meneharia	Posta bet	600	100.7	59.4	21.4	30	1.69	3
Mamo mazamir	Tikur abay	Posta bet	600	200	90.2	10	21.4	2.2	2
Jara Aba Gada	Posta bet	Amede gebeya	600	91.5	60	20	30	1.5	3
Derartu Tulu	Posta bet	Mebirat haile	600	150.4	102.3	15	20	1.47	2
Aba Jifar	Abebech Gobena	Posta bet	600	80.6	55	30	40	1.46	2

Source: Field survey

The travel time and travel speed are analyzed by time of day and with the support of traffic volume data for each route and its LOS. The selected route which has measured travel time and speed has taken an equal length of 600m.

Figure 4-15. Illustrate, the route from Franco to Posta bet has high Travel time in morning and evening peak hours as it has high traffic volume at this peak hour while the travel speed is low this is due to the congestion of vehicles. The travel time on Jara Aba Gada (from Posta Bet to Amede Gebeya) and the route from Posta to Abebech Gobena Street have lower travel times with high travel speed which indicates the free flow of movement on this route.

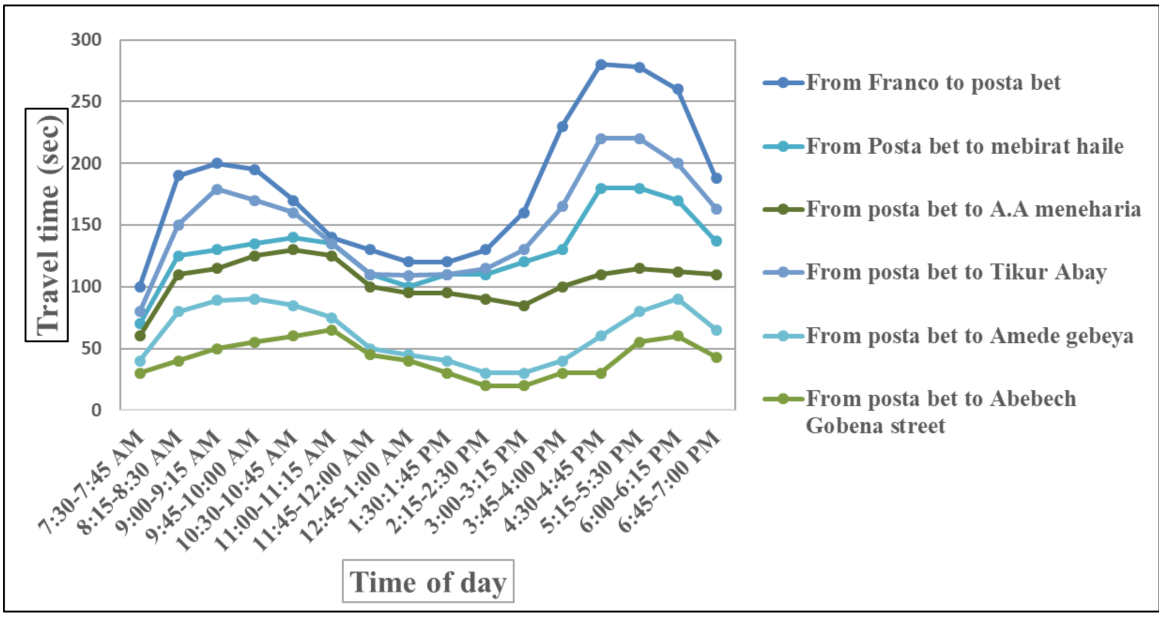

Figure 4.15: Travel time for the selected routes

Figure 4-15, the route from Franco to Posta bet has a higher travel time with lower travel speed during morning and evening peak hours similarly the evening travel time is also higher than the morning peak, it takes 250.5 seconds on average to cover the distance in the evening peak. Route from Posta bet to Abebech Gobena Street had the lowest travel time and high travel speed during the morning and evening peak periods.

4.5.2. Travel speed

Travel speed analysis has been performed at the selected route. These have been done based on the amount of traffic volume and significant travel starting location on selected routes with equal travel distance for recording speed. Figures 4-16 below illustrate the average speed distribution throughout the day for the selected route. As per the result during morning and evening peak the travel speed is lower up to 7 km/hr. but maximum speed occurs at the midday period.

Although the travel speed at the evening peak for the selected route is lower than that of the morning period. However, the route from Franco to Posta Bet performs at a constant speed during the midday period.

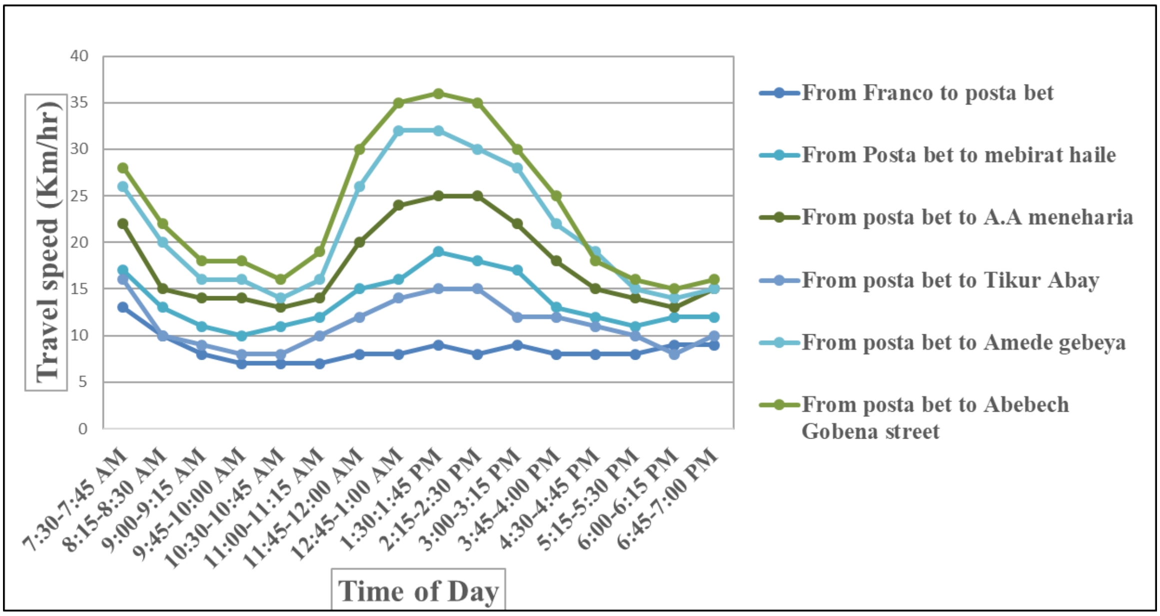

Figure 4.16: Travel speed for the selected route by time of the day

Traffic congestion hot spot area in the study area

Areas of congestion hot spots were identified by traffic volume results through cordon counts and utilizing time-lapsed photography from the tallest buildings along the selected routes during peak travel times as it is depicted in the above section. Figure 4-17 below illustrates the congestion hot spot areas within the traffic analysis zone of downtown Adama.

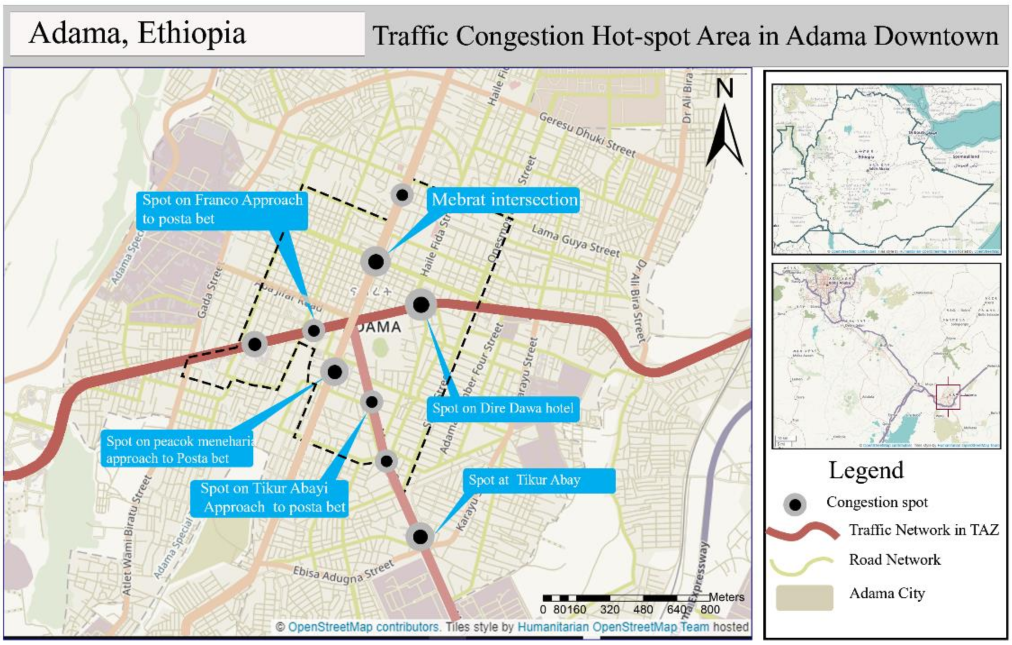

Figure 4.17: Traffic congestion hotspot area in Adama Downtown

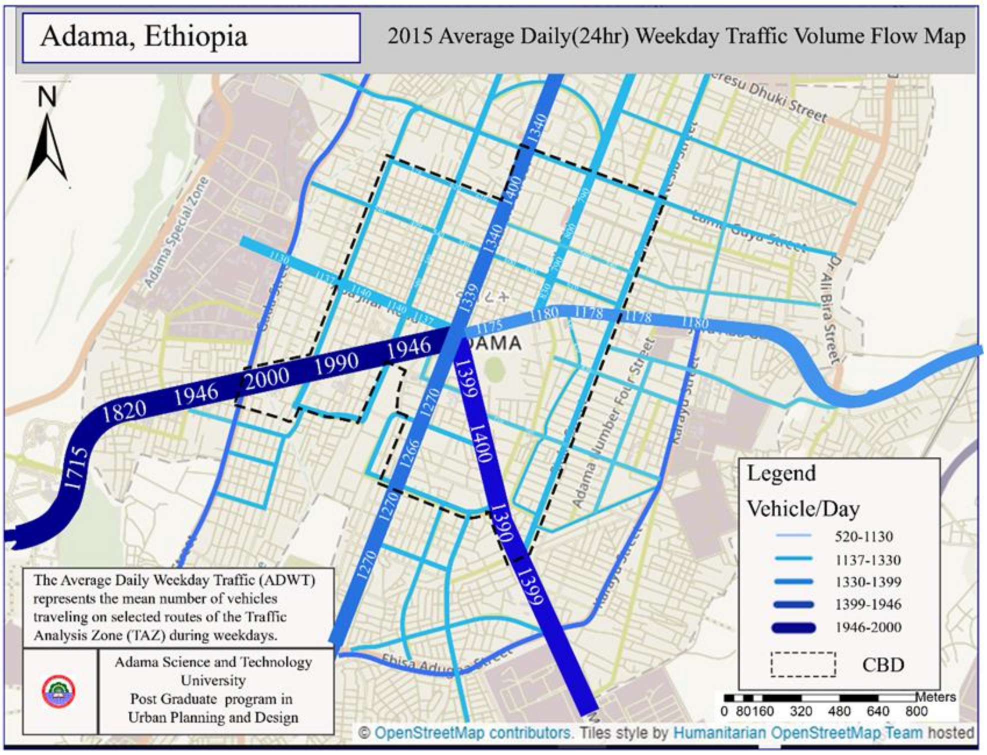

Figure 4.18: Average Daily (24hr) weekday traffic volume flow map.

Traffic volume flow map of the traffic analysis zone of Adama City downtown, the Average Daily Weekday Traffic (ADWT) represents the mean number of vehicles traveling on selected routes of the Traffic Analysis Zone (TAZ) during weekdays. As illustrated in Figure 4-18, this encompasses the total traffic flow of vehicles throughout all chosen routes in the Central Business District (CBD) area, with data collected at 15-minute intervals.

The research results on traffic volume in the major selected routes indicate that most of these routes are operating beyond their design capacity, particularly during peak hours. The routes, such as Franco to Posta, Posta to Tikur Abayi, and Posta to Mebrat, are all performing above capacity. The traffic demand among people is extremely high, leading to an over-dependence on transportation in these areas. These findings are supported by a study conducted at Addis Ababa University by Fasika. M (2012) unpublished MSc thesis, which focused on Adama City. This research also showed that traffic congestion was highly concentrated in the central business district (CBD), particularly along the major routes of Franco to Posta and Posta to Tikur Abay.

In this study, the congestion level and traffic flow quality of the selected route was assessed using the Level of Service (LOS) standard from the Highway Capacity Manual (2010). LOS evaluates the operating conditions of the chosen route. The routes from Franco to Posta, Posta to Mebrat Hail, and Tikur Abayi to Posta experienced overcapacity operation during peak hours, resulting in a LOS rating of F. This indicates that the roadways were operating beyond their capacity, leading to extreme congestion, stop-and-go traffic, and significantly longer delays.

4.5.3. Traffic congestion consequences and possible mitigation measures analysis

The significant traffic consequences can be defined as the potential adverse impacts on the traffic system due to factors like road capacity, vehicle speed, and travel time. These impacts may result from urban development, increased vehicle usage, or changes in the transportation infrastructure.

Road capacity: Increased traffic can lead to congestion and reduce the capacity of roads to accommodate vehicles. This can lead to longer travel times, increased vehicle emissions, and reduced access to other modes of transportation.

Vehicle speed: Congested roads can result in reduced vehicle speeds, leading to longer travel times and increased fuel consumption.

Travel time: Longer travel times due to traffic congestion can have various social, economic, and environmental impacts.

Increase in travel demand: refers to the growing need for transportation services in a particular area, often driven by factors such as urbanization and the preference for driving private vehicles in an urban environment.

To tackle these consequences, various mitigation measures can be recommended

Expanding and improving public transportation: Encouraging the use of public transportation can help reduce the reliance on private vehicles, thereby reducing traffic congestion and the associated impacts.

Traffic demand management: Implementing measures to reduce peak-hour traffic demand can help alleviate congestion. Measures like congestion pricing and flexible work schedules can spread traffic volume across the day, reducing peak-hour demand and improving overall traffic conditions.

Improved road infrastructure: Upgrading existing road infrastructure or constructing new roadways can help manage the increased traffic volume.

Promoting active transportation: Encouraging people to walk, cycle, or use other non-motorized modes of transportation can help reduce vehicle traffic. Providing safe and comfortable pedestrian and cycling facilities, like sidewalks and bike lanes.

Intelligent traffic management systems: Utilizing advanced technologies like adaptive traffic signals, real-time traffic information, and incident management systems can help optimize traffic flow and reduce congestion.

Land-use planning: Integrating land-use and transportation planning can help create communities with better access to public transportation, jobs, and services. Promoting mixed-use development, concentrating growth around transit nodes, and adopting transit-oriented designs can all contribute to a reduction in vehicle dependence.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The cordon counts traffic volume survey analyzed traffic patterns, congestion levels (LOS), and transportation demand for TAZ on selected routes. Congestion hot spots were identified through manual traffic volume counting. There were morning and evening peak traffic periods, with congestion during these times and moderate traffic during midday.

The study collected data on traffic flow and volume on all selected routes in TAZ and measured their LOS. High congestion was found on the route from Franco to Posta Bet, with 1946 vehicles per 15-minute interval and a LOS grade of F. In contrast, the route from Posta to Amede Gebeya had less congestion, with 1175 vehicles and a LOS grade of C. Overall, the selected network's level of service is over capacity.

The analysis of travel time and speed was conducted to evaluate congestion and transportation demand in traffic analysis zones, aiding the determination of road network efficiency, routes with the slowest speeds and longest travel times, and hotspots. The Franco to Posta Bet route experiences increased travel times and decreased speeds during morning and evening peak hours, with a higher travel time in the evening compared to the morning. During evening peak hours, covering the distance takes an average of 250.5 seconds.

As mitigation, Measures like congestion pricing, increasing road capacity, carpooling incentives, and flexible work schedules can spread traffic volume across the day, reducing peak-hour demand and improving overall traffic conditions.

An origin-destination study analyzing travel behavior in the Aba Gada sub-city, Gurmmu Kebele area, found that work-related trips were mainly within the central traffic zone with an average distance of 1.5 km. Households in the area made an average of 7.8 trips per weekday, while individual household members averaged 3.0 trips per weekday.

The study region conducted household travel surveys in two categories: general travel and different types of households. In general travel, a minibus and auto were the main modes of transportation within the Traffic Analysis Zone (TAZ), with auto being the secondary mode. Minibus trips accounted for over 47% of trips, and auto-generated trips made up nearly 25% of the TAZ.

The study analyzed travel demand in a specific region using travel demand modeling techniques of trip generation and attraction model concerning household characteristics. The study found that strong relationship between households and household categories such as household income, number of workers per household, household size, and car ownership. In the study zone, a total of 9007 actual trips were produced per weekday. The highest trip production was in Gurmmu Keeble’s zone two, with 3,236 trips generated in weekday travel, this is due to the highest number of households available in this zone and as it has a higher percentage of residential land use type. A lower portion of trips were generated from zone 3 with a value of 1,758 trips per weekday in the traffic analysis zone.

Implementing traffic models and staggering work hours to decrease peak hour traffic demand, particularly during mornings and evenings, for sustainable traffic management and alleviating traffic congestion.

5.2. Recommendation

To enhance the results of this study, it is recommended to implement the following suggestions:

It is recommended that further enhancements be made to this research by expanding on all aspects of the study, including the collection of additional data to improve the overall findings. In particular, data on traffic volume, travel time, travel speed, and travel demand should be prioritized.

- Implementing automatic traffic data collection and travel time recording methods will likely result in more accurate measurements and provide a better representation of a typical weekday.
- Implement congestion pricing to discourage private vehicles during peak hours, reducing traffic volume and easing congestion.
- Increase road capacity in areas identified as hotspots for congestion, such as Franco to Posta Bet, Posta Bet to Tikur Abay, and Mebrat Hail to Posta Bet.
- Encourage the utilization of public transportation options like buses and mini-buses, this is crucial as in the traffic analysis zone (TAZ), a sizable proportion of trips are made by minibus and auto, with public buses experiencing relatively low usage.
- Encourage flexible work schedules to distribute traffic volume throughout the day and further reduce peak-hour demand.
- Promote the use of alternative modes of transportation, such as cycling or walking and develop a pedestrian-safe walking environment for shorter work-related trips within the central traffic analysis zone.

- Develop targeted solutions for improving mobility in specific zones, such as zone two in Gurmmu Kebele, which generates the highest number of trips.
- Regularly conduct household travel surveys to monitor trends in travel behavior and preferences, and update transportation planning accordingly.
- Implement better land-use planning strategies to reduce work-related trip distances and increase the efficiency of the overall transportation system.
- Decentralized working areas especially office buildings of government institutions.
- Developing mixed-use neighborhoods: Encouraging a mix of residential, commercial, and business developments in the central traffic zone would allow people to live closer to their workplaces. This can help to reduce both the number and distance of daily trips made.
- Conducting transportation (traffic demand) demand analysis on this study region for better analysis of the travel demand of households which is needed to study congestion and people's travel choice in the study area.
- Employ the regression model and sophisticated traffic congestion model methods to effectively assess and enhance transportation policies and strategies. This proactive approach will address traffic congestion and boost mobility within the Traffic Analysis Zone (TAZ).
- The researcher only completed the trip generation and trip attraction model components of the four-step travel demand modeling process. Therefore, to further improve this research, I recommend developing the remaining three steps: trip distribution, mode choice, and trip assignment. Completing these steps will allow for more reliable predictions through the calibration and validation of the comprehensive four-step travel demand model.

Plan for the major selected congested route

The proposed plan for the major selected congested route such as the route from Franco to Posta, Posta to Tikur Abay, and the route from Posta to Mebrat hail to distribute the traffic volume and reduce peak hour traffic demand in the CBD area are as follow:

- Encourage non-motorized movements such as cycling and pedestrian sidewalk, this reduces the dependency of people on transportation.
- Follow the 5-minute walking distance service availability by decentralizing the work zone for long-distance work in the CBD area.

- Increase the Road capacity of the existing transportation system by increasing the width of the carriageway, constructing additional lanes, and separating roads by mode of transportation.
- Master plan design revision by incorporating basic solutions such as street width, additional lane, restriction of mode (Bajaj) from operation in major routes, and connectivity of route.

Design recommendation

The design proposal for the improvement of design capacity and encouraging non-motorized movement for short work purpose distance in the CBD area along with the main route from Franco to Posta. The plain view of the proposed street design of the congested route is presented in Figure 5.1 below.

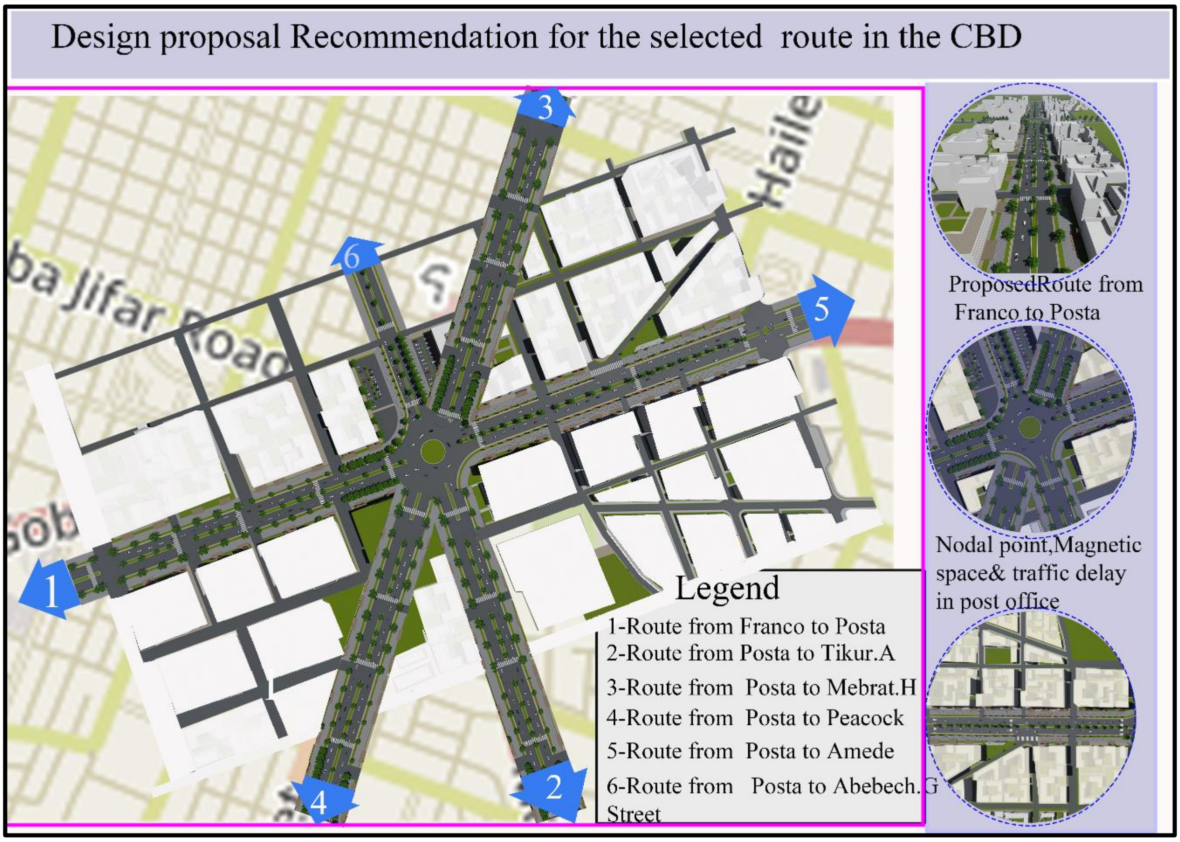

Figure 5.1: Proposed route design of the six selected routes in the CBD

Cycling and pedestrian sidewalk

Encouraging cycling and a pedestrian-free way for short-distance movement, especially in the CBD area to reduce motorized movement. Traffic volume is distributed while people are preferring to walk rather than utilized motorized mode share, this is by providing a pedestrian-friendly environment and creating a walkable environment. Short working distance in the central business district is highly utilized in this infrastructure.

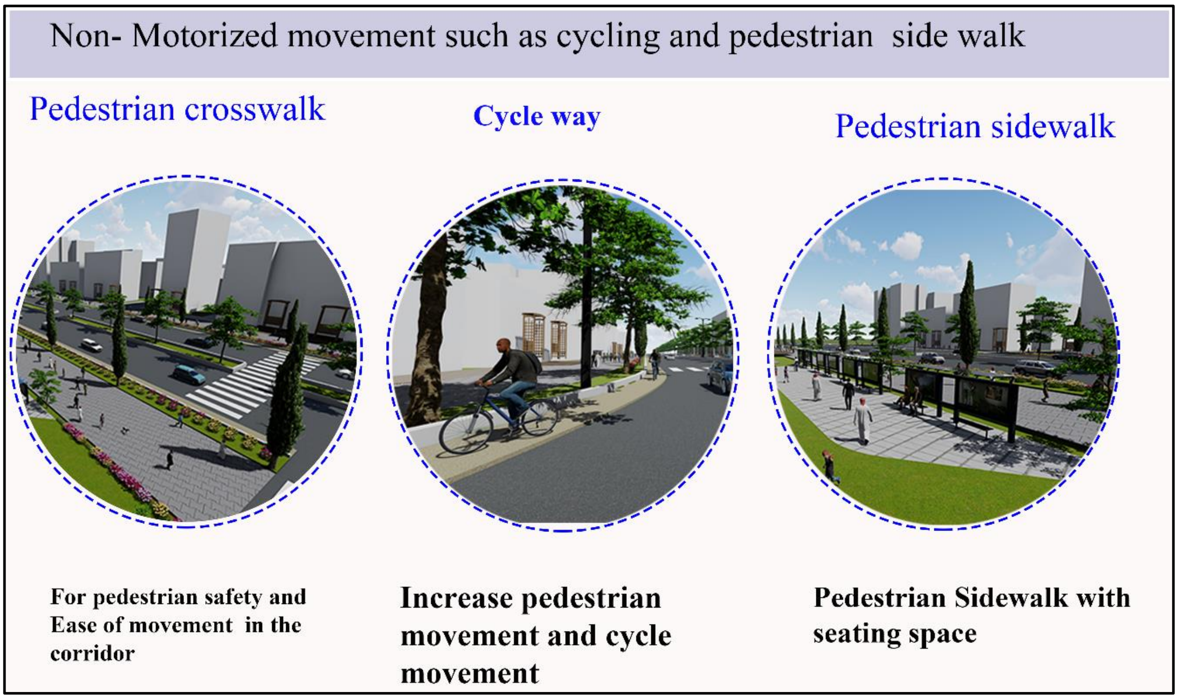

Figure 5.2: Proposed cycleway and pedestrian sidewalk

This proposal design of the congested route reduces the observed traffic volume in the CBD area, especially on the route from Posta to Franco. The design proposes a safe and convenient sidewalk and increases the width of the carriage to hold the traffic at rush hour mobility. People prefer to walk when the facility is safe in the working area, especially at evening peak hours when people are back home at this peak.

The dominance of minibus mode share is reduced through walking for short-distance mobility and increased usage of public mass transportation for long-distance movement for work and non-work purposes in the traffic analysis zone.

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REFERENCE

Afolabi, O. J., Oluwaji, O. A., et al. (2017). Socio-economic impact of road traffic congestion on urban mobility: A case study of Ikeja local government area of Lagos, state, Nigeria. *18*(246-255).

Baiocchi, G. D. (2021). *A review of travel speed prediction methods in urban environments: From regression models to machine learning-based approaches.* Journal of Traffic and Transportation Engineering (English Edition), 8(2), 185-220.

Banister, D. (2001). Transport planning. In *Handbook of transport systems and traffic control*: Emerald Group Publishing Limited.

Barroso, J. M. F., Albuquerque-Oliveira, J. L. et al (2020). Correlation analysis of day-to-day origin-destination flows and traffic volumes in urban networks. *Journal of Transport Geography*, *89*, 102899.

Bast, H., Funke, S., et al. (2007). Fast routing in road networks with transit nodes. *316*(5824), 566-566.

Beirão, G., & Cabral, J. S. J. T. p. (2007). Understanding attitudes towards public transport and private car: A qualitative study. *14*(6), 478-489.

Binetti, M., & Ciani, E. (2002). *Effects of traffic analysis zones design on transportation models.* Paper presented at the Proceedings of the 9th Meeting of the Euro Working Group on Transportation, Bari, Italy.

Bose, R. K. (2019). *Sustainable urban transport in emerging cities: Challenges, CO2 emission impact, and cost. In Urban Energy Systems for Low Carbon Cities (pp. 59-77).* Cham: Springer.

Chang, C. L., & Meyers, D. T. J. T. p. h. (2014). Transportation models. *2*, 174-206.

Chester, M. N. (2013). An energy-economic-environmental life cycle perspective on the impact of consumer preferences for vehicle automation. t*ransportation Research Board 92nd Annual Meeting, No. 13-3930.*

Colak, H. E. (2018). Hot spot analysis based on network spatial weights to determine spatial statistics of traffic accidents in Rize, Turkey. *Sevket %J Arabian Journal of Geosciences*.

D. Erath, M. A. (2018). *"Travel Time as a Congestion Measure: A Direct Indicator of Mobility for Road Users over Specific Distances," Journal of Transportation Research, vol. 69, pp. 231-248, 2018.* Journal of Transportation Research.

Deal, B. e. (2013). Complex urban systems integration: The LEAM experiences in coupling economic, land use, and transportation models in Chicago, IL. 107-131.

Dor, E. E.-E. ((2019)). Can staggered working hours reduce traffic congestion? Empirical evidence based on Ethereum. *Case Studies on Transport Policy,* , 8(2), 546-555.

DOT, U. J. W. D. G. P. O. (2016). Department of Transportation, Federal Highway Administration, Highway Statistics Summary to 2016.

Downs, A. (2000). *Stuck in traffic: Coping with peak-hour traffic congestion*: Brookings Institution Press.

Edwards, J. D. (2012). *Transportation planning handbook*: Prentice Hall.

Edition, H. C. (2016). Highway Capacity Manual 6th Edition: A Guide for Multimodal Mobility Analysis. *Transportation Research Board. Washington, D.C.*

Engineers, I. o. T. (2003). *Trip Generation: Trip generation rates, plots and equations [cont'd* (Vol. 3): Institute of Transportation Engineers.

Fernández-Martín, L. (2021). Population growth, land use changes and urban sprawl in Western Attica (Greece): the case of Mandra and Elefsina municipalities. *Journal of Environmental Planning and Management, 64(12),* , 2260-2283.

Ford, L. R., & Fulkerson, D. R. (2015). Flows in networks. In *Flows in Networks*: Princeton university press.

Fulkerson, D. R., & Ford, L. R. (2012). *Flows in networks*: Princeton University Press Princeton.

Gazis, D. C. J. T. T. (2002). Traffic Generation, Distribution, and Assignment. 185-243.

Gan, A. E. (2005). Vehicle occupancy data collection methods.

Gibson, D. J. T. A. O. T. S. M., TRB Special Report. (2013). Available computer models for traffic operations analysis. *194*.

Gonzales, E. (2017). Transportation Systems Analysis: Performance and Optimization Methods. Springer International Publishing.

Harriet, T., Poku, K., et al. (2013). An assessment of traffic congestion and its effect on productivity in urban Ghana. *4*(3).

Henderson, R. (2019). Level of Service Vs. Volume-to-Capacity Ratios: Understanding the Differences and Their Use in Evaluating Transportation Performance. *Journal of Transportation Planning and Engineering, 5(2).*, 53-59.

Hensher, D. A., & Reyes, A. J. J. T. (2000). Trip chaining as a barrier to the propensity to use public transport. *27*(4), 341-361.

H. N. Koutsopoulos, a. M. (2008). Simulation-Based Integration of Demand and Supply for Efficient and Sustainable Traffic Management, Transportation Research Record. *Journal of the Transportation Research Board, No. 2041, Transportation Research Board of the National Academies, Washington, D.C.*, pp. 13–20.

Houyengah, M. (2020). Traffic growth in developed countries: Analysis, explanations, and future prospects. . *Transportation Research Part A: Policy and Practice, 137,* , 143-154.

Hudson, M. (2010). *The bicycle planning book*.

Ibrahim–Adedeji, K. J. J. o. E. I., et al. (2014). Traffic Demands and Delays on Lagos-Ikorodu Road in Nigeria. *6*(1), 37-46.

Ikporukpo, C., & Filani, M. J. T. N. G. J. (2000). Transport Co-ordination in Nigeria: Trend and issues. *3*, 29-42.

Imai, R. e. (2021). Origin-destination trips generated from operational data of a mobile network for urban transportation planning. *Koichi %J Journal of Urban Planning,vol, 147*.

Imran, M. S. (2015). *Modeling freeway level-of-service based on travel time and travel time reliability.* The University of North Carolina at Charlotte.

Jain, V., Sharma, A., & Subramanian, L. (2012, March). Road traffic congestion in the developing world. In *Proceedings of the 2nd ACM Symposium on Computing for Development* (pp. 1-10).

Jin, J. Z. (2018). *Using travel time data can provide insights into congestion patterns and help prioritize transportation improvements.*

Kanu, K. E. (2015). Road Traffic Demand Management and Improvement of Mobility – A Case of Lagos-Ikorodu Road. *International Journal of Engineering Research & Technology (IJERT), 4(05). Retrieved from*.

Kayithi, V. &. (2020). Traffic congestion: A review. *Journal of Urban Management, 9(4).,* 234-246.

Kim, N. K. (2020). Traffic congestion measures using advanced cellular vehicle-to-everything (C-V2X) technology based on virtual queue model. . *Journal of Advanced Transportation*.

Kumar, R. &. (2021). *Transportation Planning in Growing Cities: Challenges and Solutions for a Sustainable Future. In Sustainable Solutions in Transportation Systems.* Singapore: Springer.

Lomax, T. T. (1997). Quantifying Congestion. *Washington, DC: National Cooperative Highway Research Program, Transportation Research Board of the National Academies.*

Maitra, B. e. (1999). Modeling congestion on urban roads and assessing level of service. *Journal of transportation engineering,vol,125*.

Manual, H. C. (2016). A Guide for Multimodal Mobility Analysis. (2016). Transportation Research Board. Washington, D.C. *Transportation Research Board.*

Mei, B. (2002). *Development of trip generation models of hurricane evacuation*. Louisiana State University and Agricultural & Mechanical College.

Murray, A. T., Davis, R., et al. (2014). Public transportation access. *3*(5), 319-328.

Nijkamp, P., & Blaas, E. W. (2012). *Impact assessment and evaluation in transportation planning*. Springer Science & Business Media.

Nurdden, A. M. (2007). Traffic congestion in major cities of developing countries: the situation in greater Khartoum. *Journal of Engineering Sciences, 2(1), 1-11.*

Ojide, M. G., Oyedele, O. A., et al. (2016). Evaluating the Effect of Road Infrastructure on Household Income in Ogoni Community, River State, Nigeria. *1*(1), 93-105.

Okpala, D. (2014). *Residential mobility in Nigerian cities: An exploratory analysis*: Nigerian Institute of Social and Economic Research.

Oppenheim, N. (2015). Urban Travel Demand Modeling: From Individual Choices to General Equilibrium. *Wiley.*

Organization., W. H. (2021). *Global Speed Recommendations. Retrieved from.*

Ortúzar, J. D. (2011). Modelling Transport.

Passenger and freight transport demand in Germany. *87*, 102476.

Phillip, D., Nkonya, E., et al. (2009). Constraints to increasing agricultural productivity in Nigeria: A review.

Pulugurtha, S. S. et al. (2013). Traffic analysis zone level crash estimation models based on land use characteristics. 678-687.

Rosenbloom, S., & Black, A. J. T. p. o. l. g. p. (2014). Transportation planning. *2*.

Sivakumar. (2007). Modelling transport: a synthesis of transport modelling methodologies. *Aruna %J Imperial College of London*.

Smith, J. (2022). Travel demand analysis: Understanding and forecasting travel patterns and behavior. *Transportation Research, 45(2),*, 123-137.

Solé-Ribalta, A., Gómez, S., et al. (2018). Decongestion of urban areas with hotspot pricing. *18*(1), 33-50.

Solé-Ribalta, A., Gómez, S., & Arenas, A. (2016). A model to identify urban traffic congestion hotspots in complex networks. *Royal Society open science*, *3*(10), 160098.

Taplin, J. H., & Qiu, M. J. A. o. T. R. (2015). Car trip attraction and route choice in Australia. *24*(3), 624-637.

Treiber, M., Hennecke, A., et al. (2000). Congested traffic states in empirical observations and microscopic simulations. *62*(2), 1805.

Tripathi, J. P., & Garg, D. G. (2010). *Algorithm for detection of hot spots of traffic through analysis of GPS data* (Doctoral dissertation).

Winkler, C., Mocanu, T. J. T. R. P. D. T., et al. (2020). Impact of political measures on (n.d.).

Wright, P. H., & Ashford, N. J. (2019). Transportation engineering.

Yao, L. (2008). Trip generation model based on destination attractiveness. *Tsinghua Science,5,13.*, 632-635.

Yan, X. (2010). Modeling the Overdependence on Cars. _Urban Traffic and Transport_. 26(3), 306-318.

Yulianto, B. P. (2020). Study of standard trip attraction models of various land use in the Surakarta City. *Journal of Physics: Conference Series*.

Zheng, L. S. (2016). *The Role of Data in Planning Future Cities. In The City of Tomorrow (pp. 281-301).* Yale University Press.

APPENDICES

Appendix-A: Traffic Volume by Cordon Count at the Major Selected Route in TAZ

Table 1: Average 15 min interval Cordon count result on selected routes collection point

Point on major selected routes	Data collection day at peak hour		Travel mode													
			IB-Auto	OB-Auto	IB-mini-bus	OB-mini-bus	IB-bajjaj	OB-bajjaj	IB-public-bus	OB-public-bus	IB-4WD	OB-4WD	IB-walking	OB-walking	IB-Total	OB-Total
		April 01/8/15														
Nuho Gobena street (From Franco to posta bet) on Adama ras	Morning peak 1:30Am-	1:30Am-1:45Am	87	82	155	138	5	5	7	10	45	40	49	40	348	315
		1:45Am-2:00Am	86	80	153	140	4	6	6	9	46	41	48	41	343	317
		2:00Am-2:15AM	86	81	154	141	3	5	8	8	47	39	47	39	342	313
		2:15Am-2:30Am	88	83	156	139	2	4	6	7	46	37	46	38	344	308
		2:30Am-2:45Am	89	80	157	140	4	7	9	8	44	37	49	40	352	312
		2:45Am-3:00Am	87	82	152	141	3	6	7	10	45	38	50	37	344	314
		Morning average	**88**	**81**	**153**	**139**	**3**	**6**	**8**	**9**	**44**	**39**	**191=48**	**156=39**	**344**	**313**
	Midday peak 6:00Am-8:00 Pm	6:00Am-6:15:Am	76	75	145	145	1	4	5	7	50	45	49	40	326	316
		6:15Am-6:30Am	77	76	143	146	2	4	6	6	49	44	48	41	325	317
		6:30Am-6:45Am	78	74	142	145	3	3	4	8	48	43	50	39	325	312
		6:45Am-7:00AM	79	73	142	144	2	4	5	7	47	42	48	38	323	308
		7:00Am-7:15Pm	76	72	143	143	3	3	6	6	50	45	47	41	325	310
		7:15PM-7:30PM	75	74	142	144	1	2	4	7	49	46	46	42	317	315
		7:30PM-7:45PM	79	76	141	145	2	3	6	6	48	45	47	39	323	314
		7:45PM-8:00PM	77	75	142	143	2	2	5	7	47	43	50	40	323	310
		Midday average	**78**	**74**	**140**	**144**	**2**	**3**	**5**	**6**	**46**	**44**	**196=49**	**163=41**	**323**	**312**
	Evening peak 10:30Pm-12:30Pm	10:30PM-10:45PM	88	73	138	152	5	5	8	8	45	43	48	42	332	323
		10:45PM-11:00PM	86	72	142	151	6	4	9	7	47	45	49	40	339	319
		11:00PM-11:15PM	88	74	140	150	5	3	10	6	48	43	50	42	341	318
		11:15PM-11:30PM	87	72	141	153	6	4	8	8	44	43	48	40	334	324
		11:30PM-11:45PM	85	73	142	152	5	5	9	7	46	42	47	39	334	318
		11:45PM-12:00PM	89	71	143	148	5	4	8	9	45	45	48	38	338	315
		12:00PM:12:15PM	88	73	139	149	5	6	7	10	44	43	49	40	332	321
		12:15PM-12:30PM	86	74	141	151	4	4	8	9	47	44	50	39	336	321
		Evening average	**85**	**72**	**140**	**150**	**6**	**5**	**9**	**8**	**46**	**43**	**197=49**	**165=41**	**335**	**319**
		Total	**251**	**227**	**433**	**433**	**11**	**14**	**22**	**23**	**139**	**126**	**146**	**121**	**1002**	**944**
		overall total													1946	
		April 03/8/15														
Abebe Bikila street (From posta bet to Addis Ababa meneharia) on Mame hotel	Morning peak 1:30Am-3:00Am	1:30Am-1:45Am	27	25	19	26	184	169	5	3	16	15	23	23	274	261
		1:45Am-2:00Am	25	23	20	25	182	173	6	2	15	16	24	25	272	264
		2:00Am-2:15AM	24	22	23	24	183	172	4	4	14	14	21	20	269	256
		2:15Am-2:30Am	25	24	19	26	185	167	5	5	13	13	20	19	267	254
		2:30Am-2:45Am	23	26	18	23	180	168	7	3	15	16	23	20	266	256
		2:45Am-3:00Am	25	25	20	24	182	171	5	5	14	15	20	21	266	261
		Morning average	**26**	**24**	**21**	**25**	**183**	**170**	**6**	**4**	**15**	**16**	**88=22**	**91=23**	**271**	**262**
	Midday peak 6:00Am-8:00 Pm	6:00Am-6:15:Am	17	15	20	28	167	160	5	3	13	16	23	22	245	244
		6:15Am-6:30Am	15	14	23	27	169	163	4	6	15	14	22	24	250	248
		6:30Am-6:45Am	16	13	19	26	170	165	3	3	12	13	20	21	240	241
		6:45Am-7:00AM	14	15	20	28	167	164	4	6	11	15	19	20	235	248
		7:00Am-7:15Pm	15	12	18	29	165	160	5	4	12	16	24	24	239	245
		7:15PM-7:30PM	13	13	17	24	169	159	3	3	14	14	23	25	241	238
		7:30PM-7:45PM	14	15	22	25	168	161	4	4	10	17	22	26	240	248
		7:45PM-8:00PM	17	16	21	26	166	163	5	5	11	14	20	23	240	247
		Midday average	**16**	**14**	**20**	**27**	**168**	**162**	**4**	**5**	**12**	**15**	**89=22**	**95=24**	**242**	**247**
	Evening peak 10:30Pm-12:30Pm	10:30PM-10:45PM	20	20	24	24	176	167	5	3	13	15	19	21	257	250
		10:45PM-11:00PM	19	19	26	23	174	164	4	2	14	13	18	23	255	244
		11:00PM-11:15PM	18	20	25	20	175	163	3	3	15	14	20	22	256	244
		11:15PM-11:30PM	17	18	27	19	173	167	5	4	12	15	22	24	256	247
		11:30PM-11:45PM	18	22	28	20	172	162	6	2	14	14	21	26	259	246
		11:45PM-12:00PM	16	20	22	18	175	163	4	3	11	15	23	27	251	246
		12:00PM:12:15PM	19	18	22	21	177	165	5	2	12	12	22	24	257	242
		12:15PM-12:30PM	20	19	24	23	175	163	6	4	13	14	19	23	257	246
		Evening average	**19**	**20**	**25**	**22**	**174**	**165**	**5**	**3**	**14**	**13**	**84=21**	**100=25**	**258**	**248**
		Total	**61**	**58**	**66**	**74**	**525**	**497**	**15**	**12**	**41**	**44**	**65**	**72**	**638**	**628**
		Overall total														**1266**

Mamo Mazamir street(From posta bet to Tikur Abay) on kereyu branch of CBE		April 05/8/15														
	Morning peak peak 1:30Am-3:00Am	1:30Am-1:45Am	49	48	47	30	85	74	10	12	38	43	32	37	261	244
		1:45Am-2:00Am	50	47	46	32	80	72	8	13	40	40	28	35	252	239
		2:00Am-2:15AM	47	46	45	35	82	68	9	14	36	38	30	34	249	235
		2:15Am-2:30Am	45	45	44	33	78	69	7	10	34	44	32	32	240	233
		2:30Am-2:45Am	46	44	43	35	81	73	8	12	39	39	29	35	246	238
		2:45Am-3:00Am	47	49	46	39	79	78	9	10	39	40	30	38	246	254
		Morning average	**48**	**47**	**47**	**33**	**80**	**72**	**10**	**13**	**37**	**42**	**124=31**	**139=35**	**253**	**242**
	Midday peak 6:00Am-8:00 Pm	6:00Am-6:15:Am	38	38	39	32	76	68	8	6	34	44	34	40	229	228
		6:15Am-6:30Am	39	39	38	31	74	70	9	5	32	40	33	38	225	223
		6:30Am-6:45Am	38	40	39	30	72	66	6	7	33	45	31	36	225	224
		6:45Am-7:00AM	35	41	40	28	78	67	8	4	31	38	28	37	220	215
		7:00Am-7:15Pm	36	42	41	27	75	68	7	5	36	39	30	35	225	216
		7:15PM-7:30PM	35	37	42	26	76	63	9	4	35	43	29	34	226	207
		7:30PM-7:45PM	38	38	43	30	73	65	7	8	37	42	30	38	228	221
		7:45PM-8:00PM	36	40	39	28	74	66	10	7	36	46	28	39	213	226
		Midday average	**37**	**39**	**40**	**29**	**75**	**67**	**9**	**6**	**33**	**43**	**128=32**	**147=37**	**226**	**221**
	Evening peak 10:30Pm-12:30Pm	10:30PM-10:45PM	38	40	42	34	83	66	12	12	34	43	30	37	239	232
		10:45PM-11:00PM	36	39	43	35	80	65	11	13	32	40	28	35	230	227
		11:00PM-11:15PM	34	38	38	35	79	62	10	15	35	38	32	32	228	220
		11:15PM-11:30PM	35	41	37	30	77	61	9	12	36	41	29	38	223	223
		11:30PM-11:45PM	34	36	41	28	80	63	12	16	31	39	31	36	229	218
		11:45PM-12:00PM	36	37	38	29	82	65	13	15	32	37	30	34	231	217
		12:00PM:12:15PM	34	42	41	27	79	64	10	14	35	42	27	32	226	221
		12:15PM-12:30PM	36	44	38	30	78	63	9	13	33	44	33	30	227	224
		Evening average	**35**	**41**	**42**	**31**	**80**	**64**	**11**	**14**	**34**	**40**	**122=30**	**143=35**	**232**	**225**
		Total	**120**	**127**	**129**	**93**	**235**	**203**	**30**	**33**	**104**	**125**	**93**	**107**	**711**	**688**
		Overall total														**1399**
Jira Aba Geda street (from posta bet to Amede gebeya) on Dire Dawa hotel		April 07/8/15														
	Morning peak 1:30Am-3:00Am	1:30Am-1:45Am	43	37	94	77	16	20	10	8	27	24	18	26	208	192
		1:45Am-2:00Am	42	39	90	80	17	18	11	7	24	23	21	24	205	191
		2:00Am-2:15AM	39	35	88	79	15	17	9	6	25	25	23	23	199	185
		2:15Am-2:30Am	38	36	95	74	16	16	13	9	28	22	19	21	209	178
		2:30Am-2:45Am	40	34	90	75	14	21	12	9	26	21	18	24	200	184
		2:45Am-3:00Am	45	38	91	78	18	20	10	6	23	24	22	23	209	189
		Morning average	**42**	**36**	**92**	**77**	**17**	**19**	**11**	**7**	**26**	**23**	**132=20**	**122=24**	**208**	**186**
	Midday peak 6:00Am-8:00 Pm	6:00Am-6:15:Am	35	29	90	94	8	7	8	7	38	29	22	18	201	184
		6:15Am-6:30Am	33	30	92	88	9	6	7	9	36	27	21	19	198	179
		6:30Am-6:45Am	36	32	87	95	7	5	6	8	34	26	19	17	189	183
		6:45Am-7:00AM	32	33	90	89	6	8	9	6	38	29	23	22	198	187
		7:00Am-7:15Pm	33	31	86	90	8	7	8	7	35	26	18	20	188	181
		7:15PM-7:30PM	36	28	92	94	9	6	7	6	33	24	22	21	199	179
		7:30PM-7:45PM	35	27	91	88	7	8	6	8	34	29	20	18	193	170
		7:45PM-8:00PM	32	34	88	94	8	9	7	7	37	30	19	20	191	194
		Midday average	**34**	**31**	**89**	**92**	**9**	**7**	**8**	**9**	**35**	**28**	**124=21**	**129=19**	**196**	**186**
	Evening peak 10:30Pm-12:30Pm	10:30PM-10:45PM	40	44	96	88	10	16	7	10	33	23	24	15	210	194
		10:45PM-11:00PM	38	42	94	87	9	14	6	12	32	22	22	17	201	194
		11:00PM-11:15PM	39	40	90	84	8	12	8	11	30	21	20	16	195	184
		11:15PM-11:30PM	37	39	88	86	10	15	9	13	31	24	21	16	196	194
		11:30PM-11:45PM	36	42	92	90	11	16	6	9	28	25	25	17	198	199
		11:45PM-12:00PM	35	38	93	92	8	14	7	10	30	21	23	18	196	193
		12:00PM:12:15PM	42	46	94	84	10	13	8	12	29	20	22	16	205	191
		12:15PM-12:30PM	44	43	92	88	12	12	7	9	34	22	24	17	213	191
		Evening average	**39**	**42**	**94**	**87**	**11**	**14**	**7**	**11**	**32**	**23**	**120=23**	**132=16**	**206**	**193**
		Total	**115**	**109**	**275**	**256**	**37**	**40**	**26**	**27**	**93**	**74**	**64**	**59**	**610**	**565**
		Overall total														**1175**
Auraro Street (From Posta bet to mebirat haile) on Dada mall		April 09/8/15														
	Morning peak 1:30Am-3:00Am	1:30Am-1:45Am	90	88	61	62	8	22	8	9	50	32	40	32	257	245
		1:45Am-2:00Am	88	86	58	60	7	20	10	8	52	30	37	33	252	237
		2:00Am-2:15AM	89	89	56	58	6	18	9	6	48	28	35	35	243	234
		2:15Am-2:30Am	86	84	54	63	9	24	6	10	47	29	34	34	236	244
		2:30Am-2:45Am	84	85	60	57	5	22	7	9	51	34	38	36	245	243
		2:45Am-3:00Am	87	84	62	62	9	19	6	7	49	32	40	30	253	234
		Morning average	**88**	**86**	**58**	**60**	**8**	**20**	**8**	**9**	**49**	**30**	**150=37**	**134=34**	**248**	**239**
	Midday peak 6:00Am-8:00 Pm	6:00Am-6:15:Am	70	70	40	38	6	9	4	6	44	24	44	36	208	183
		6:15Am-6:30Am	69	68	41	40	5	8	5	8	42	22	42	32	204	178
		6:30Am-6:45Am	72	66	39	37	7	7	3	5	46	20	40	30	207	165
		6:45Am-7:00AM	68	69	38	45	6	6	5	8	41	18	41	34	199	180
		7:00Am-7:15Pm	73	70	42	39	7	7	4	7	40	25	43	38	209	186
		7:15PM-7:30PM	66	65	36	41	9	9	6	6	38	24	39	37	194	182
		7:30PM-7:45PM	74	66	40	37	7	8	5	5	39	23	40	39	205	178
		7:45PM-8:00PM	75	71	38	45	5	10	4	7	45	21	41	35	208	189
		Midday average	**71**	**69**	**39**	**38**	**6**	**9**	**4**	**6**	**42**	**22**	**166=42**	**142=36**	**204**	**180**
	Evening peak 10:30Pm-12:30Pm	10:30PM-10:45PM	89	82	54	62	7	20	9	9	48	34	38	34	245	241
		10:45PM-11:00PM	86	80	50	58	8	18	6	8	46	30	37	36	233	230
		11:00PM-11:15PM	88	77	53	64	6	22	7	10	49	29	36	34	239	236
		11:15PM-11:30PM	85	86	56	61	9	16	8	6	47	33	40	38	245	240
		11:30PM-11:45PM	84	84	48	59	6	20	10	7	42	28	41	30	231	228
		11:45PM-12:00PM	89	76	50	64	8	18	6	8	44	30	38	37	235	233
		12:00PM:12:15PM	90	80	52	63	7	17	6	7	43	34	37	31	235	232
		12:15PM-12:30PM	86	78	51	55	9	20	7	10	48	32	39	33	240	228
		Evening average	**87**	**80**	**52**	**60**	**7**	**18**	**7**	**9**	**46**	**31**	**148=37**	**137=34**	**236**	**232**
		Total	**246**	**235**	**149**	**158**	**21**	**47**	**19**	**24**	**137**	**83**	**116**	**104**	**688**	**652**
		Overall total														**1339**

Appendix -B: Congestion Measure Analysis for Selected Route

Table 2: Tuesday travel time recorded data in second

Tuesday march 2/8/2015	Travel Time (sec.)																	
	From Franco to posta bet			From Posta bet to mebirat haile			From posta bet to A.A meneharia			From posta bet to Tikur Abay			From posta bet to Amede gebeya			From posta bet to Abebech Gobena street		
Starting and ending time	Length in (m)=600			Length in (m)=600			Length in (m)=600			Length in (m)=600			Length in (m)=600			Length in (m)=600		
7:30-7:45AM	250	246	238	151	149	150	99	100.5	188	198	200	199	91	88	93	78.6	80.5	81
7:45-8:00AM	240	146	246	140	135	140	110.5	88.6	80.7	200	190	181	80.3	78.1	100.2	80.2	90	70.2
8:00-8:15AM	241	258	246	135	118	130	82.8	110.5	102.5	188	206	188	72.1	87.2	80.9	90.2	96.2	80.8
8:15-:8:30AM	260	252	248	148	144	149	120.5	78.9	98.4	185	177	168	86.3	100.2	90.5	78.9	80.4	90.2
8:30-8:45 AM	243	245	241	152	126	127	104	112.5	120.1	190	199	211	70.3	66.2	60.1	55.6	67.6	80.8
8:45-9:00 AM	237	240	239	136	111	154	120.6	101.5	98.5	179	171	180	60.9	70.3	88.2	48.9	50.8	70.9
9:00-9:15 AM	240	199	209	116	122	115	94.5	120.2	111	120	112	130	55.3	62.1	58.9	50.6	40.5	60.6
9:15-9:30 AM	199	208	198	106	104	105	58.7	59	57.9	98.6	97.2	102	45	48	44	41	39	44
9:30-9:45 AM	188	159	177	99	113	120	66.4	60	56.2	107	98.2	88.4	40.5	50.8	56.3	60.4	45.5	40.8
9:45-10:00 AM	190	186	167	110	89	94	50.2	100.5	90.1	90.4	109	80.4	50.8	44.4	60.5	55.2	50.6	38.9
10:00-10:15 AM	178	198	200	100	98	80	101.2	77.4	48.5	78.3	70.9	112	58.9	60.9	54.5	50.2	60.1	48.9
10:15-10:30 AM	179	194	183	120	77	120	68.3	45.5	55.8	69.4	90.4	80.4	50.4	40	48.2	40.6	48.9	58.7
10:30-10:45 AM	184	186	200	82	118	80	48.5	51.6	64.1	112	99.1	101	58.4	50.2	60.2	55.9	50.6	4.6
10:45-11:00 AM	178	189	199	117	98	110	56.4	44.9	60.2	90.1	88.5	94.3	40.6	48.3	45.3	40.9	55.9	48.9
11:00 -11:15 AM	168	190	190	99	132	88	48.9	58.6	50	94.6	98.9	120	55	50.1	60.2	52.4	49.1	40.8
11:15-11:30 AM	194	209	200	128	78	121	55.3	48.1	42.4	100	107	124	88.9	77.5	80.9	39.6	46.8	50.6
11:30-11:45 AM	203	210	204	145	129	137	94	67.5	88.2	120	130	98	70.9	92.6	74.6	50.5	58.9	60.4
11:45-12:00 AM	216	220	208	109	150	104	88.6	90.3	78.4	160	170	180	100	70.9	86.1	70.6	66.6	72.6
12:00-12:15 AM	224	240	237	144	110	120	99.2	77.8	86	190	180	190	94.6	90.5	81.8	64.3	60	50.6
12:15-12:30 AM	248	250	248	115	124	150	105	82.6	90.8	200	198	209	88.4	74.9	70.9	76.5	70.6	68.3
12:30-12:45 AM	256	249	253	160	138	128	94.2	96.1	88.2	231	220	210	70.9	100	87.6	80.6	90.2	78.9
12:45-1:00 AM	247	250	246	122	119	156	78.2	75.4	87.6	180	169	178	88.9	92.5	79.8	74.6	82.6	70.3
1:00-1:15 PM	251	250	256	146	154	118	98.2	89.6	92.1	171	188	190	81.3	74.6	92.1	64.6	70.6	80.4
1:15-1:30 PM	246	248	248	152	126	149	105.6	96.4	108.4	210	176	195	109	96	80.4	75.5	99.1	88.3
1:30-1:45 PM	245	249	258	148	139	153	98	74.6	91.3	210	180	200	79.6	102.4	95.6	55.6	74.1	69.8
1:45-2:00 PM	260	252	250	154	150	147	71.2	80.2	70.2	190	181	170	88.6	99	100	50.9	48.9	50.4
2:00-2:15 PM	246	250	248	116	108	123	64.2	78.4	60.2	130	141	120	80.2	90.1	70.2	45.6	55.6	47.9
2:15-2:30 PM	251	245	235	106	114	112	58.9	61.2	56.2	99.2	113	98.4	70.4	70.9	99	40.3	42.3	35.4
2:30-2:45 PM	224	228	230	126	105	100	86.3	45.2	60.9	109	95.3	80.8	90.7	80.6	79.8	36.2	40.6	53.6
2:45-3:00 PM	235	231	199	99	112	88	50.2	61.6	54.3	90.2	101	114	90	74	112.3	46.3	50.1	35.1
3:00-3:15 PM	205	198	188	118	78	123	45.6	42.1	65.2	80.2	88.4	99.1	80.9	70.5	88.1	47.3	40.3	50.1
3:15-3:30 PM	194	184	209	102	122	98	50.8	60.2	57.8	98.1	109	110	90.3	88	99.4	38.2	46.4	39.4
3:30-3:45 PM	177	185	169	77.8	88.4	106	56.4	60.2	55.3	106	98.1	88.1	68.5	78.1	80.4	40	50.4	45.6
3:45-4:00 PM	184	179	190	110	120	90.8	53.7	45.1	50.8	80.1	90.1	78.9	88.6	94.2	68.9	55.6	42.3	50.6
4:00-4:15 PM	170	199	188	121	109	98.5	60.1	72.3	56.9	120	98.1	100	70	80.4	90.9	50.9	40.4	35.4
4:15-4:30 PM	184	197	178	113	124	108	61.8	57.9	42.8	84.2	112	82.3	100	99.4	88.1	48.3	52.1	44.6
4:30-4:45 PM	168	174	198	126	13.4	129	59	62.1	58.4	131	98.2	120	88.2	78.9	80.9	55.4	66.5	55.6
4:45-5:00 PM	203	198	178	144	139	142	70.2	55.4	77.4	141	119	113	120	99.7	112.4	62.4	58.9	60.4
5:00-5:15 PM	224	231	215	151	141	133	66.9	75.6	80.5	160	180	151	80.5	92.6	78.3	80.4	66.4	70.4
5:15-5:30 PM	205	246	255	142	136	150	98.7	108.9	95.6	190	161	190	103	80.4	99.8	76.4	88.4	80.4
5:30-5:45 PM	263	230	244	136	152	141	100.5	110.8	104	201	180	179	90.2	88	90.4	69.8	75.3	70.4
5:45-6:00 PM	211	231	220	151	144	137	99.6	78.9	112.3	186	178	194	101	80.4	78.4	75.6	80.6	86.1
6:00-6:15 PM	248	245	210	144	125	131	80.4	89.8	98.4	190	180	196	80.5	78.5	100.8	70.9	88.4	90.4
6:15-6:30 PM	199	252	244	138	151	138	100.2	90.7	80.5	181	190	171	90.4	88.4	90.1	80.4	74.6	82.4
6:30-6:45 PM	238	236	255	154	136	149	110.2	120	100.5	170	181	200	100	99	70.8	84.6	88.2	90.4
6:45- 7:00 PM	229	219	262	135	150	152	99.5	85.1	78.7	189	168	175	78.1	88.4	110.2	92.7	80.7	88.7
7:00-7:15 PM	238	241	252	152	148	146	89.2	87.4	98.2	182	199	188	98.5	112.4	90.2	100.4	78.9	80.6
7:15-7:30 PM	255	240	260	146	153	151	108.3	88.9	90.5	210	180	202	90.1	80.2	80.4	81.6	94.8	86.7
Median travel time	250			150			100			200			90			81		

Table 3: Wednesday travel time recorded data in second

Wednesday March 6/8/2015	Travel Time (sec.)																	
	From Franco to posta bet			From Posta bet to mebirat haile			From posta bet to A.A meneharia			From posta bet to Tikur Abay			From posta bet to Amede gebeya			From posta bet to Abebech Gobena		
Starting and ending time	Length in (m)=600			Length in (m)=600			Length in (m)=600			Length in (m)=600			Length in (m)=600			Length in (m)=600		
7:30-7:45AM	245	250	230	156	153	161	88	99.5	180	190	200	180	96	88	99	78.6	84	88
7:45-8:00AM	235	260	240	135	136	145	107.6	100	90.5	200	190	171	92.3	77.6	110.2	80.2	96.2	75.6
8:00-8:15AM	252	245	230	140	123	135	78.4	111.3	106.5	196	200	180	74.6	97.6	90.3	90.2	85.6	96.5
8:15-:8:30AM	260	252	255	139	150	155	110.5	70.8	100.6	182	198	160	80.6	99.6	80.4	78.9	90.3	80
8:30-8:45 AM	240	254	259	157	130	136	109.7	122.4	125.6	200	181	206	74.9	78.6	55.9	55.6	77.8	88.6
8:45-9:00 AM	240	250	243	142	117	155	115.6	120.8	95.6	179	171	180	60.9	70.3	88.2	48.9	52.1	79.5
9:00-9:15 AM	235	200	210	122	130	120	92.6	126.7	111	110	120	135	58.2	72.6	62.9	50.6	50.6	70.6
9:15-9:30 AM	199	188	198	120	116	110	62.6	58.9	62.1	90.8	90.7	120	55.2	52.1	66.4	41	36.8	40.8
9:30-9:45 AM	166	170	180	98	110	116	77.3	80	70.4	101	90.8	88.4	45.3	55.9	50.4	63.5	40.7	46.3
9:45-10:00 AM	187	167	155	110	89	90	62.5	110.4	78.2	99.6	129	80.4	65.2	40.5	56.9	55.2	50.6	40.6
10:00-10:15 AM	170	189	190	90	80	100	120.4	88.6	50.2	88.3	7.3	122	61.6	66.7	60.4	50.2	60.1	8.6
10:15-10:30 AM	165	175	180	122	74	110	77.9	40.5	65.2	78.6	108	92.4	45.6	48.9	57.6	40.6	50.4	58.7
10:30-10:45 AM	178	188	190	92	115	69	65.3	50.4	69.7	111	90.5	110	59.6	67.3	68.9	55.9	60.7	45.6
10:45-11:00 AM	168	178	199	117	98	110	56.4	44.9	85.6	80.4	88.5	80.3	60.2	58.6	45.3	40.9	55.9	50.2
11:00 -11:15 AM	179	180	200	108	130	98	50.9	66.5	55	104	94.8	122	50.3	56.3	62.1	52.4	46.7	40.8
11:15-11:30 AM	194	206	189	138	80	130	62.4	44.3	62.1	106	117	135	96.6	88.8	90.7	39.6	60	50.6
11:30-11:45 AM	190	200	199	155	133	140	96	74.6	84.5	126	132	92	80.4	98.6	79.6	50.5	55.3	66.3
11:45-12:00 AM	220	230	214	119	139	125	99.5	100.8	90.5	170	169	178	116	80.6	96.4	70.6	60.4	70.4
12:00-12:15 AM	224	240	237	140	109	132	102.5	55.6	96.4	181	168	204	80.4	98.6	91.4	64.3	50.4	55.3
12:15-12:30 AM	234	245	250	127	122	12	120	78.9	100.4	195	200	215	88.4	80.4	60.8	76.5	70.6	68.3
12:30-12:45 AM	244	266	255	155	140	133	90.4	90.6	88.2	240	222	218	80.6	110	92.4	80.6	96.2	70.9
12:45-1:00 AM	257	268	250	132	124	156	78.2	75.4	87.6	170	177	189	84.9	94.6	84.6	74.6	80.5	65.3
1:00-1:15 PM	256	260	250	140	160	118	98.2	89.6	92.1	181	192	175	90.4	80.4	100.5	64.6	90.4	80.4
1:15-1:30 PM	248	260	248	150	133	152	105.6	96.4	108.4	220	180	210	116	100	90.4	75.5	78	88.3
1:30-1:45 PM	260	251	249	145	146	163	98	74.6	91.3	218	208	220	86.4	108	100.8	55.6	88.4	70.6
1:45-2:00 PM	240	262	274	154	150	147	71.2	80.2	80.2	210	236	195	101	120.4	114.6	50.9	48.9	45.6
2:00-2:15 PM	247	245	254	131	112	129	64.2	78.4	60.2	146	151	128	90.7	96.3	60.4	45.6	50.7	40.4
2:15-2:30 PM	246	270	248	118	146	122	54.6	71.6	62.4	92.6	118	90.8	84.6	78.6	96.3	40.3	39.4	35.4
2:30-2:45 PM	218	230	241	130	109	120	96.5	48.5	90.5	110	96.8	90.7	99.6	80.6	84.6	36.2	40.6	50.6
2:45-3:00 PM	230	241	200	88	101	90	60.8	70.9	60.7	96.4	110	124	96.5	79	122.6	46.3	50.1	35.1
3:00-3:15 PM	210	200	199	110	78	123	55.6	48.6	70.5	88.6	98.4	96.5	84.7	65.8	88.1	47.3	36.5	42.6
3:15-3:30 PM	198	180	201	102	132	78	55.6	70.6	52.6	98.1	109	111	90.3	99.6	99.4	38.2	50.4	35.6
3:30-3:45 PM	188	175	179	66.8	99.5	105	76.7	60.2	55.3	111	103	94.1	60.7	70.8	80.4	40	44.6	52.4
3:45-4:00 PM	194	169	200	114	122	80.9	63.4	55.8	60.8	85.6	9.6	86.4	98.6	98.6	74.6	55.6	50.7	60.8
4:00-4:15 PM	160	230	178	132	120	100	45.6	82.1	60.2	128	102	116	80	90.4	90.9	50.9	40.4	35.4
4:15-4:30 PM	190	177	195	119	129	105	72.1	62.4	78.9	94.3	120	94.2	108	99.4	88.1	48.3	62.4	50.9
4:30-4:45 PM	178	159	189	136	145	133	62.4	66.4	64.5	136	97.4	122	86.7	74.8	80.9	55.4	70.6	55.4
4:45-5:00 PM	220	210	198	140	130	140	75.2	55.4	77.4	150	126	136	118	109.7	112.4	62.4	50.7	59.8
5:00-5:15 PM	229	235	220	222	132	125	66.9	80.2	90.4	165	179	155	90.6	99.7	78.3	80.4	60.4	80.8
5:15-5:30 PM	210	251	260	152	145	180	98.7	108.9	100	210	161	241	110	80.4	99.8	76.4	90.7	90.4
5:30-5:45 PM	255	23	249	136	152	141	105	114.2	109.7	210	189	185	96	80.7	82.9	69.8	70.9	60.7
5:45-6:00 PM	116	236	225	162	154	144	105.6	78.9	112.3	186	178	200	101	90.4	80.7	75.6	78	86.1
6:00-6:15 PM	253	250	236	150	156	136	90.4	88.4	100	196	189	205	80.5	84.2	100.8	70.9	93.5	92.7
6:15-6:30 PM	204	257	249	160	145	146	110	97.5	80.2	187	235	171	100	90.8	94.6	80.4	70.8	86.4
6:30-6:45 PM	222	239	260	168	126	152	120.3	120	100.5	177	190	200	110	80	60.8	84.6	98.7	90.4
6:45- 7:00 PM	238	228	250	136	142	132	99.2	80.7	78.7	195	172	184	67.9	99.6	120	92.7	96.4	86.7
7:00-7:15 PM	244	246	257	160	143	156	80.4	90.4	80.9	180	200	196	101	114	89.5	100.4	74.4	82.4
7:15-7:30 PM	253	235	255	140	163	156	100	80.7	92.6	220	176	186	93.6	83.4	80.4	81.6	92.4	88.6
Median travel time	255			145			95			190			95			80		

Table 4: Travel speed recorded data in Km/h

Tuesday march 4/7/2015	Travel Speed (Km/h)																	
	From Franco to posta bet			From Posta bet to mebirat haile			From posta bet to A.A meneharia			From posta bet to Tikur Abay			From posta bet to Amede gebeya			From posta bet to Abebech Gobena street		
Starting and ending	Length in (m)=600			Length in (m)=600			Length in (m)=600			Length in (m)=600			Length in (m)=600			Length in (m)=600		
7:30-7:45AM	8.6	8.6	7.9	15	14.8	15.2	21.4	20.9	21.8	10	9.8	10.2	20	18.2	22	30	32	31.5
7:45-8:00AM	8.8	7.4	8.7	14	15.6	14.6	21.6	21	22.5	10.2	11	8.9	20.8	20.4	19.4	28.4	30.6	32
8:00-8:15AM	7.9	8.2	8.6	13.7	14.4	16.4	20.6	18.9	23	9.2	10.1	11	18.9	17.9	20.4	27.6	31.4	29.4
8:15-:8:30AM	8.9	8.8	9.1	12.4	11.6	10.3	21.9	22.7	21.4	12	8.9	10.4	19.4	20.4	22.4	30.5	28.3	30.4
8:30-8:45 AM	8.2	7.9	9.4	15.8	16.2	14.7	20.4	22.2	20.4	14	13	15.3	20.4	22.1	18.7	26.3	32.4	27.6
8:45-9:00 AM	9.5	8.4	8.2	16.9	17	16	18.6	20.4	19.8	17.6	16.6	12.4	19.7	21.4	20.4	29.6	28	31.8
9:00-9:15 AM	10.1	9.5	8.6	18	19	18	24.6	26.4	23.4	19	20	17.8	26	22	24	34.6	38.4	34.6
9:15-9:30 AM	12	12.4	11.8	20	20.6	21.1	30	31.3	28.8	21.4	20.8	21.2	30	31.4	30.6	40	41.5	40.4
9:30-9:45 AM	11.9	10.6	12.5	20.6	22.1	19.8	29.8	30.4	30	20.4	20.8	20	28.9	31.4	30.6	38.6	42.1	39.4
9:45-10:00 AM	12.6	14.2	13	21.4	22.4	20.4	31.5	30.7	32.4	19.4	18.6	21	27.4	26.4	29.6	37.9	40.3	42.4
10:00-10:15 AM	13.1	10.4	11.6	20.4	18.9	17.9	28.9	28.9	33.4	22.3	20.6	22	30.4	33.9	23.4	40.3	38.4	40.4
10:15-10:30 AM	12.8	12.6	12.4	21.4	18.9	19.8	24.6	32.4	30.4	20.2	19.4	20.2	28.4	30.5	32.1	36.8	44.6	37.9
10:30-10:45 AM	12	12.6	11.9	22.9	21.5	20.4	30.7	35.4	27.9	22.1	16.8	24.2	34.1	27.8	30.4	38.4	38.9	42.4
10:45-11:00 AM	13	11.8	12	23	18.9	17	28.7	32.6	34.6	20.4	18.3	22.1	30.6	33.1	31.3	41.3	40.4	39.4
11:00 -11:15 AM	12.3	10.8	108	17	14.9	16.5	30.6	24.8	30.4	18	19	18.4	29.1	31.6	32.4	40.6	37.6	44.3
11:15-11:30 AM	10.5	8.9	9.8	15.3	14.7	12.9	28	20.4	26.1	14.6	15.3	16.6	34.9	28.4	30.4	37.6	40.2	38.4
11:30-11:45 AM	10.6	10	9	17.5	16.4	15.3	20.4	27.6	29.5	16.8	17.4	18.4	24.3	22.1	20.4	32.5	29.6	33
11:45-12:00 AM	10.6	9.4	8.3	16.4	17.5	19.4	21.9	20.6	23.4	15	15	12.4	26.4	28.7	22.4	31.2	30.4	28.3
12:00-12:15 AM	8.2	9.1	8.4	14	1	14.2	20.6	22.1	19.7	12	14	13	18.7	19.7	20.9	24.9	29	30.1
12:15-12:30 AM	7.8	9.8	8.7	12	15.6	13.7	18.6	20.4	22.3	14.7	15	11	15.4	20.4	18.7	30.5	27.6	28
12:30-12:45 AM	8.6	8.9	10.6	17.9	12.6	15	19.7	18.6	20.1	10	12	9.4	18.7	17.9	20.4	28.6	30.4	26.4
12:45-1:00 AM	8.4	9.6	8.7	15.4	14	13.9	17.9	18.4	19.7	14.9	10.5	12.6	20.4	21.6	16.9	29.5	32	32.4
1:00-1:15 PM	8.2	8.4	7.9	11.8	12	14	18.6	19.6	20.2	10.3	9.8	12.4	18	19	21	30	29	28.6
1:15-1:30 PM	9.5	8.7	10.5	12.7	14.6	14	20.1	22.4	20.3	7.8	10.6	8.7	17.9	22.1	19	32	34.3	32.4
1:30-1:45 PM	7.8	8.2	7.8	16.8	15	16	22	24	19.4	12.4	14.5	11.6	22	16	20.8	36.4	33.4	36.3
1:45-2:00 PM	11	10.7	9.8	17	18	17	26	27.6	25.4	17.6	16.2	14	26.4	24	27.4	39.4	37.6	38.2
2:00-2:15 PM	12.1	11.6	10.6	18.4	17.9	16.4	30.8	26.4	28.4	18.9	20.4	22.4	29	28.4	30.4	40.6	42.5	41.3
2:15-2:30 PM	13	12.5	11.5	20.2	19.4	21.6	32.1	28.4	30.2	20.4	22.1	20.4	32.4	30.7	28.9	42.2	40.6	39
2:30-2:45 PM	12.6	10.8	9.8	18.9	20.7	20.4	30.3	34.5	32.1	18.7	21.6	23.1	27	32	30.4	38.4	38.4	42.6
2:45-3:00 PM	10.8	12	11.3	17	19.4	20.4	32.4	36.4	30.1	20.4	19.8	20.4	29.7	30.8	28.4	36	42.5	39.4
3:00-3:15 PM	10	10.6	12	16.4	20	18.9	29.4	30.4	28.7	18.4	22.3	24.6	32.7	27.6	30.4	44	37.5	38.7
3:15-3:30 PM	11.8	12.6	14	19.7	20	21	26.4	24.6	28.4	19.7	20.3	21.2	27	30	31.6	36.4	43.8	41.7
3:30-3:45 PM	13	11	10	20	16	22	28.9	32.1	30.4	22.4	20.4	18.9	33	28.4	28	40.6	44.5	40.8
3:45-4:00 PM	10	11	9.7	15.6	17.2	14	32.6	28.1	29.6	20.6	19.4	24.6	26.8	30.8	33	38.9	38.4	42.1
4:00-4:15 PM	9.8	12	10.4	22.3	20	18	29	23	24	12	13	14	23	22	24	42.6	41.8	39.5
4:15-4:30 PM	12.3	8.9	9.4	18	16	17	24	19	18.6	10	14	12	20.4	23.4	20.4	36.4	33.5	34.6
4:30-4:45 PM	9.6	10.2	8.9	14.2	15	14	16.4	17.3	20.4	13.6	14	12.3	18	20.4	23.4	34.5	32.1	32.1
4:45-5:00 PM	7.8	8.9	9.5	12.7	13	11	20.1	18.7	15.6	19.5	10.1	10.1	16	18	15.6	30.5	31.4	28.4
5:00-5:15 PM	9.8	8.1	8.7	13.5	10.4	12.5	18.7	16.4	20.1	12.6	11	8.1	20	18	14.9	28.6	37.8	30.4
5:15-5:30 PM	10.4	10.2	7.6	10.2	13.4	10.1	16.7	17.6	19.4	12.7	12	8.9	16	17	22	32.1	26.9	30.4
5:30-5:45 PM	7.3	8.4	7.3	12.4	10.4	9.8	18.2	19.4	20.4	11	13	10.4	22	20.6	20.4	30.4	28.3	32.1
5:45-6:00 PM	8.6	9.6	9.8	11.6	10.4	14.7	20.5	16.4	18.4	22.4	8.4	7.8	18.7	19	21	29.3	31.5	26.8
6:00-6:15 PM	9.4	8.2	7.4	10.6	9.8	16.8	21.4	14.8	18.7	8.7	9.4	8.4	19.7	16.4	22	34.2	28.1	34.6
6:15-6:30 PM	8.2	9.6	7.8	12.4	11.3	14	18.4	22.4	20.4	15.6	10.2	9.8	20.1	24..7	18.7	26.2	30.4	28.4
6:30-6:45 PM	7.9	8	9.4	8.9	10.4	12	20.4	18.7	16.4	11	13	10.5	18.9	16.4	20.4	29.1	32.1	30
6:45- 7:00 PM	8.5	8	7.7	11.6	12.4	10.7	19.4	20.4	16.4	10.2	11.3	13.5	19	20.3	22	30.3	28.7	25.6
7:00-7:15 PM	9.8	6.8	8.6	12	14	10	22.4	18.9	23	12	10.7	8.9	20	18	18	29.4	30.4	32.5
7:15-7:30 PM	8.4	8.9	7.6	14.8	16.4	15	19.4	22	20.4	14	12	15	18.2	19.5	20.4	30.4	29.4	31.2
Median peak hour travel speed across selected routes	8.6			15			21.4			10			20			30		

Appendix -C: Transport Demand Survey of TAZ

Table 5: Origin-Destination (O-D) Travel Survey data

	weekday Household origin-destination travel survey															
	Household origin-destination and their travel behaviors															
ID	Residential location	Household_Size	Number_of_Vehicles owend	Departure travel time	Arrival Travel time	Origin	Destination	Total_Trips	Mode Share					Trip purpose	Total_Distance(km)/day	Average_Distance_per_Trip(km)=
									Private Car	PublicTransport	Taxi/Mini bus	Bajaj	Walk/Non motorized			
1	Zone 1	3	2	1:30 AM	2:00AM	home	Office	12	0.45	0	0.3	0	0.25	work	2.5	3.56
2	zone 2	2	1	8:00PM	8:20 PM	office	Industry park	10	0.5	0	0.2	0	0.3	Non-work	1.5	2.5
3	zone 1	4	1	3:20AM	10:45 AM	home	supermarket	9	0.3	0	0.2	0	0.5	non work	1.6	2.28
4	zone 3	4	0	1:30AM	8:30 AM	home	university	8	0	0.7	0	0.05	0.25	non work	2	2
5	zone 2	1	1	1:30AM	2:00 AM	home	school	14	0.01	0.75	0.05	0	0.2	Education	1	1.25
6	zone 4	3	1	1:00AM	1:45AM	home	industry	6	0.02	0.48	0.25	0.05	0.2	work	2.2	3.67
7	zone 1	2	2	4:35AM	5:00AM	home	shopping	5	0.6	0	0.1	0.1	0.3	leisure	0.8	1.33
8	zone 2	1	0	3:00AM	3:35AM	home	Adama G.hospital	3	0	0	0.5	0.2	0.35	non work	1.2	1.5
9	zone 2	1	1	9:00PM	9:45PM	HBNW	market	4	0.2	0	0.5	0.1	0.2	non work	2.4	2.4
10	zone 3	2	2	6:00AM	6:20AM	office	school	4	0.4	0	0.2	0.1	0.3	non work	2	1.54
11	zone 1	4	1	9:10PM	9:35PM	office	industry	3	0.5	0.1	0	0	0.4	work	1.6	2.67
12	zone 2	3	3	2:00AM	2:35AM	home	business	12	0.3	0	0.5	0.1	0.1	work	2.5	2.78
13	zone 3	2	0	3:30AM	4:00AM	home	p/business	10	0.1	0	0.6	0.1	0.2	work	2.6	2.6
14	zone 4	1	1	1:30AM	2:00AM	NHB	university	8	0	0.2	0.5	0.2	0.1	work	3	6
15	zone 1	5	0	10:20PM	10:50PM	home	social	2	0	0	0.5	0.3	0.2	leisure	1	3.33
16	zone 1	2	3	10:00PM	10:30PM	NHB	recreation	3	0.6	0	0	0	0.4	leisure	1.6	2.67
17	zone 2	1	1	11:00PM	11:15PM	office	shopping	8	0.3	0	0.2	0.1	0.3	non work	0.9	0.75
18	zone 3	1	1	1:30AM	1:45AM	home	school	12	0.05	0.65	0.05	0.1	0.15	Education	2	1.33
19	zone 2	5	0	11:00PM	11:20PM	home	sport	7	0	0	0.3	0.4	0.3	exercise	3	7.5
20	zone 4	4	1	6:10AM	6:30AM	NHB	Hospital	6	0.2	0	0.2	0	0.6	non work	1.4	1.55
21	zone 2	4	1	1:00AM	1:30AM	home	bus station	13	0	0.2	0.5	0.2	0.1	work	1.5	3.75
22	zone 2	6	0	7:30PM	8:00PM	home	university	10	0.05	0.75	0.1	0	0.1	work	2	2.85
23	zone 3	2	0	10:45PM	11:00PM	home	supermarket	5	0.2	0	0.1	0.1	0.6	work	1.3	1.3
24	zone 2	3	0	7:30PM	7:45PM	HBW	office	12	0.3	0.2	0.1	0.15	0.25	work	2.8	2.15
25	zone 1	2	0	6:00AM	6:20AM	office	restaurant	3	0	0.1	0.05	0.2	0.65	non work	2	2
26	zone 1	4	1	10:45PM	11:10PM	home	cultural	3	0.1	0	0.7	0.1	0.1	work	1	5
27	zone 2	1	2	1:00AM	1:25:AM	HBNW	gymnasium	4	0.4	0	0.2	0.2	0.2	exercise	1.4	3.5
28	zone 3	4	2	4:10AM	4:30AM	NHB	Industry park	14	0.7	0	0.2	0.05	0.05	work	2.2	4.4
29	zone 2	1	1	1:30AM	1:55AM	home	hospital	6	0.2	0.2	0.3	0.05	0.25	work	2	6.67
30	zone 2	2	1	4:30AM	4:45AM	HBW	market	10	0.1	0	0.6	0.1	0.2	work	1.6	1.78
31	zone 1	1	0	9:30PM	9:45PM	NHB	shopping	5	0	0	0.4	0.05	0.55	non work	0.7	0.75
32	zone 3	4	1	1:30AM	2:00AM	home	business	10	0.1	0.2	0.3	0.1	0.3	work	2.4	2.4
33	zone 2	3	2	11:00PM	11:30	HBW	gymnasium	6	0.3	0	0.4	0	0.3	exercise	1.7	5.67
34	zone 4	2	1	1:30AM	1:50AM	HBNW	college	12	0.05	0.65	0.1	0	0.2	Education	3	2.31
35	zone 4	1	3	7:30PM	7:50PM	HBW	office	14	0.61	0.19	0.1	0	0.1	work	3.2	2.13
36	zone 3	5	0	9:40PM	10:10PM	HBNW	recreation	4	0	0.1	0.2	0	0.7	leisure	2.2	3.66
37	zone 2	3	1	11:30PM	12:00PM	home	Office	8	0.1	0.1	0.6	0.2	0	work	2	5
38	zone 2	4	0	7:30PM	8:10PM	HBW	Industry park	9	0	0.2	0.6	0.05	0.25	work	2.6	5.75
39	zone 4	4	3	6:00AM	6:40AM	HBNW	university	12	0.2	0.6	0.1	0	0.1	Education	2	1.66
40	zone 4	3	1	11:00PM	11:25PM	NHB	sport	9	0.1	0	0.4	0	0.5	exercise	1.4	2.33
41	zone 2	7	1	6:45AM	7:00AM	HBNW	supermarket	6	0.2	0	0.4	0.2	0.2	non work	2.3	2.3
42	zone 2	6	0	6:30AM	6:45AM	office	shopping	5	0	0	0.3	0.1	0.6	non work	1.8	1.5
43	zone 1	8	1	11:30PM	12:00PM	NHB	university	6	0.1	0	0.3	0.05	0.25	non work	1	1.43
44	zone 3	5	1	12:00PM	12:30PM	home	hospital	7	0.1	0.3	0.2	0.2	0.1	work	1.4	3.5
45	zone 4	1	0	3:20AM	3:50AM	HBNW	cultural	4	0	0	0.6	0.1	0.3	work	0.9	4.5
46	zone 3	3	0	4:15AM	4:35AM	HBNW	supermarket	6	0	0.05	0.55	0	0.5	non work	1.6	1.77
47	zone 2	6	0	10:30PM	10:55PM	HBNW	school	10	0	0.72	0.1	0	0.18	Education	1.8	1.5
48	zone 2	7	0	1:30AM	2:00AM	HBW	industrial park	8	0	0.3	0.5	0.1	0.1	work	2.2	5.5
49	zone 1	3	1	10:20PM	10:45PM	NHB	other	6	0	0.05	0.35	0	0.6	non work	1.6	3.2
50	zone 3	2	2	8:30PM	9:00PM	NHB	service delivery	12	0.2	0	0.4	0.2	0.2	work	1.4	2.8
51	zone 4	1	2	7:30PM	8:00PM	HBW	office	14	0.65	0.15	0.2	0	0.1	work	1.2	1.2
52	zone 4	8	3	11:30PM	11:50PM	NHB	school	5	0.3	0	0.2	0.1	0.4	non work	1	1.67
53	zone 1	4	1	2:00PM	2:30PM	home	business	12	0.1	0	0.7	0	0.2	work	1.5	2.5
54	zone 2	3	0	9:45PM	10:00PM	HBNW	gymnasium	6	0	0	0.5	0.2	0.3	exercise	1.2	4
55	zone 4	5	1	10:30PM	11:00PM	HBNW	social	3	0.2	0.1	0.6	0	0.1	non work	1.6	5.33
56	zone 3	5	2	10:00PM	10:45PM	NHB	recreation	6	0.4	0.1	0.3	0	0.2	leisure	1	2.5
57	zone 2	1	1	11:00PM	11:20PM	office	shopping	4	0.3	0	0.2	0.1	0.4	non work	1	1.11
58	zone 4	2	3	1:30AM	2:00AM	home	office	12	0.65	0.05	0.2	0	0.1	work	1.5	1.87
59	zone 4	3	0	7:30PM	8:00PM	home	college	10	0	0.74	0.16	0.1	0.1	Education	1.2	1.2
60	zone 1	4	1	2:30AM	2:45AM	home	hospital	8	0.2	0.2	0.3	0.1	0.2	work	1	2.5
61	zone 1	5	0	7:45PM	8:20PM	HBNW	university	10	0	0.75	0.15	0.2	0	work	1.4	2.33
62	zone 3	**7**	3	1:20AM	1:55AM	home	college	9	0.4	0.2	0.3	0.1	0	work	2	3.33
63	zone 2	6	1	10:45AM	11:30PM	office	home	14	0.2	0.1	0.5	0.1	0.1	work	1.4	1.4
64	zone 4	3	1	1:30AM	2:10AM	home	store	11	0.1	0	0.6	0.2	0.1	work	1.6	4
65	zone 4	8	0	10:45PM	11:10PM	office	supermarket	6	0	0	0.3	0.1	0.6	non work	1	1.11
66	zone 2	2	1	6:00AM	6:20AM	office	restaurant	7	0.2	0	0.4	0.2	0.2	non work	1.2	1.5
67	zone 4	3	1	10:30PM	11:10PM	home	school	14	0.05	0.65	0.1	0.1	0.2	Education	1.3	1.44
68	zone 1	4	0	4:30AM	5:00AM	home	shopping	8	0	0	0.3	0.1	0.6	non work	0.8	1
69	zone 3	5	0	10:00PM	10:30PM	home	university	4	0	0.1	0.65	0.15	0.2	work	1.2	3
70	zone 4	3	1	1:30AM	2:00AM	home	hospital	8	0.2	0.2	0.4	0.1	0.1	work	1	2
	HBW= Home based work trip			NHB=None home based				HBNW=home based non work								

Table 6: Household and their weekday trip behavior survey data

Household ID	Residential location	Household size	Number of vehicle owned	Number of worker in family	Origin	Destination	Departure Time	Arrival Time	Trip Purpose	Mode of Travel	Income per month	Distance in (km)	Travel Time (min)	Travel Cost	Total - weekday Trips
Household and their weekday trips behavior survey															
1	Zone 1	3	2	2	home	Office	1:30 AM	2:00AM	work	Car	90$	2.3	25	0	6
2	zone 3	2	0	1	office	restaurant	8:00PM	8:20 PM	Grocery	taxi	70$	3.2	15	0	2
3	zone 2	4	1	3	home	supermarket	3:20AM	10:45AM	shopping	Taxi	115$	2.1	16	0	8
4	zone 1	4	4	2	home	university	1:30AM	8:30 AM	work	Bus	110$	2.1	20	0	9
5	zone 4	1	1	1	home	school	1:30AM	2:00 AM	non work	Walk	50$	3.4	10	10	7
6	zone 2	3	1	2	home	industry	1:00AM	1:45AM	work	Bus	50$	4.8	22	5	5
7	zone 3	3	0	1	home	shopping	4:35AM	5:00AM	marketing	Bajaj	40$	0.9	8	0	5
8	Zone 2	1	0	1	home	hospital	3:00AM	3:35AM	health care	walk	35$	3.5	12	10	3
9	Zone 3	1	1	1	HBNW	market	9:00PM	9:45PM	work	Taxi	40$	2	24	5	4
10	Zone 4	2	2	1	office	shopping	6:00AM	6:20AM	work	Car	60$	0.9	20	0	4
11	Zone 4	4	1	2	office	recreation	9:10PM	9:35PM	leisure	taxi	95$	2.6	16	0	7
12	Zone 2	2	0	0	home	business	2:00AM	2:35AM	buisiness	Taxi	30$	3.6	10	10	6
13	Zone 1	2	0	0	home	p/business	3:30AM	4:00AM	non work	Taxi	35$	2.6	11	5	5
14	Zone 4	1	1	1	NHB	industrial park	1:30AM	2:00AM	work	Taxi	25$	4.8	20	10	4
15	Zone 2	5	1	1	home	social	10:20PM	10:50PM	socializing	Taxi	40$	3.2	14	5	10
16	Zone 1	2	0	1	NHB	recreation	10:00PM	10:30PM	leisure	walk	25$	1.5	8	0	3
17	Zone 3	1	0	0	office	shopping	11:00PM	11:15PM	non work	taxi	35$	1.2	9	0	2
18	Zone 2	1	1	1	home	school	1:30AM	1:45AM	non work	Taxi	20$	3.4	20	0	4
19	Zone 4	5	2	2	home	sport	11:00PM	11:20PM	exersise	Car	100$	2.1	30	15	6
20	Zone 2	4	1	3	NHB	supermarket	6:10AM	6:30AM	work	Bajaj	95$	1.6	14	0	7
21	Zone 1	4	1	2	home	bus station	1:00AM	1:30AM	work	Taxi	99$	1.1	15	10	7
22	Zone 3	6	2	3	home	university	7:30PM	8:00PM	work	Car	120$	2.2	20	10	9
23	Zone 4	2	0		home	supermarket	10:45PM	11:00PM	non work	taxi	45$	3.6	13	0	3
24	Zone 3	3	1	2	HBW	office	7:30PM	7:45PM	work	Car	55$	1.8	18	0	6
25	Zone 1	2	0	2	office	restaurant	6:00AM	6:20AM	Grocery	Bajaj	55$	1.1	10	0	6
26	Zone 2	2	1	2	home	cultural	10:45PM	11:10PM	non work	Taxi	100$	2.9	12	5	6
27	Zone 4	1	0	1	HBNW	gymnasium	1:00AM	1:25:AM	exercise	Bajaj	30$	3.1	4	0	5
28	Zone 2	4	2	2	NHB	service delivery	4:10AM	4:30AM	work	Car	69$	3.7	18	0	7
29	Zone 1	1	1	1	home	hospital	1:30AM	1:55AM	work	Taxi	40$	2.3	18	10	3
30	Zone 4	2	1	2	HBW	market	4:30AM	4:45AM	work	Taxi	50$	2.3	16	5	5
31	Zone 2	1	0	4	NHB	shopping	9:30PM	9:45PM	non work	Bajaj	30$	0.8	7	5	3
32	Zone 2	4	1	2	home	business	1:30AM	2:00AM	non work	Taxi	68$	1.6	12	0	7
33	Zone 4	3	2	1	HBW	gymnasium	11:00PM	11:30	exercise	Taxi	70$	3.1	17	10	6
34	Zone 3	2	0	1	HBNW	college	1:30AM	1:50AM	School	Bajaj	25$	2.8	24	0	3
35	Zone 2	1	0	1	HBW	office	7:30PM	7:50PM	work	Taxi	20$	1.6	10	0	2
36	Zone 1	5	2	3	HBNW	recreation	9:40PM	10:10PM	leisure	Car	70$	1.8	22	0	7
37	Zone 4	3	1	2	home	ndustrial par	11:30PM	12:00PM	work	Taxi	98$	4.7	20	15	4
38	Zone 4	4	2	2	HBW	ndustrial par	7:30PM	8:10PM	work	Car	90$	4.6	26	10	4
39	Zone 2	2	2	2	HBNW	school	6:00AM	6:40AM	non work	Car	120$	4.5	20	0	6
40	Zone 1	3	3	1	NHB	sport	11:00PM	11:25PM	exercise	Taxi	97$	1.6	14	10	8
41	Zone 3	7	3	3	HBNW	supermarke t	6:45AM	7:00AM	non work	Car	130$	0.9	23	5	8
42	Zone 3	6	2	2	office	shopping	6:30AM	6:45AM	non work	Car	120$	0.8	18	0	9
43	Zone 2	8	3	3	NHB	restaurant	11:30PM	12:00PM	Grocery	taxi	115$	1.4	10	5	12
44	Zone 2	5	2	2	home	hospital	12:00PM	12:30PM	health care	Car	100$	2.5	14	0	7
45	Zone 1	2	0	0	HBNW	cultural	3:20AM	3:50AM	weeding	taxi	30$	2.3	9	10	6
46	Zone 2	3	1	2	HBNW	supermarket	4:15AM	4:35AM	work	Taxi	66$	4.6	16	5	5
47	Zone 4	6	2	0	HBNW	school	10:30PM	10:55PM	non work	Bus	120$	2.8	18	0	8
48	Zone 2	7	3	3	HBW	ndustrial par	1:30AM	2:00AM	work	taxi	130$	4.6	22	15	9
49	Zone 4	3	1	0	NHB	recreation	10:20PM	10:45PM	leisure	walk	90$	4.6	16	0	5
50	Zone 2	2	2	2	NHB	ervice deliver	8:30PM	9:00PM	work	Taxi	80$	3.4	14	10	4
51	Zone 1	1	0	1	HBW	office	7:30PM	8:00PM	work	Bajaj	20$	1.8	12	0	7
52	Zone 2	8	4	2	NHB	restaurant	11:30PM	11:50PM	leisure	walk	100$	2.7	10	0	10
53	Zone 3	4	1	0	home	business	2:00PM	2:30PM	non work	taxi	90$	1.6	15	10	7
54	Zone 2	3	1	0	HBNW	gymnasium	9:45PM	10:00PM	exersice	taxi	60$	2.9	12	10	4
55	Zone 1	4	2	1	HBNW	social	10:30PM	11:00PM	meeting	taxi	40$	1.7	16	10	7
56	Zone 2	3	2	2	NHB	recretion	10:00PM	10:45PM	leisure	Car	100$	4.6	10	0	8
57	Zone 1	3	1	0	office	shopping	11:00PM	11:20PM	non work	other	30$	0.4	10	0	6
58	Zone 3	2	1	2	home	office	1:30AM	2:00AM	work	Car	20$	1.8	15	0	8
59	Zone 4	3	0	1	home	college	7:30PM	8:00PM	school	Bus	56$	3.4	12	5	5
60	Zone 2	4	1	2	home	hospital	2:30AM	2:45AM	health care	taxi	50$	3.9	10	10	8
61	Zone 4	5	2	3	HBNW	university	7:45PM	8:20PM	work	Bus	70$	2.8	14	0	5
62	Zone 4	7	3	4	home	industry park	1:20AM	1:55AM	work	Car	135$	4.9	20	15	9
63	Zone 4	6	2	3	office	home	10:45AM	11:30PM	rest	Taxi	125$	3.4	14	10	7
64	Zone 3	3	1	2	home	store	1:30AM	2:10AM	work	Bajaj	79$	2.6	16	10	4
65	Zone 1	8	2	4	office	supermarket	10:45PM	11:10PM	marketing	Car	120$	0.6	10	0	8
66	Zone 3	2	0	1	office	restaurant	6:00AM	6:20AM	leisure	taxi	70$	0.8	12	5	6
67	Zone 2	3	1	0	home	school	10:30PM	11:10PM	non work	Bajaj	60$	4.3	13	0	7
68	Zone 4	4	1	1	home	shopping	4:30AM	5:00AM	non work	walk	60$	0.7	8	0	6
69	Zone 3	3	2	2	home	culture	10:00PM	10:30PM	meeting	Car	85$	2.9	12	5	8
70	Zone 1	3	1	2	home	hospital	1:30AM	2:00AM	health care	taxi	65$	1.6	10	10	5

Appendix -D: Traffic Movement Survey

Table 7: Private vehicle movement survey.

Private vehicle movement survey												
Owner ID	Residense location	Number of vehicle(s) owned	Year of Manufacture	Trip Start Time	Trip End Time	Trip Origin	Trip Destination	Average Km/Day	Average trip duration/day(min)	Total trip/day	Route Description	Purpose of Trip
1	Zone 1	2	2015	1:30 AM	2:00AM	home	Office	2.5	6	3	Main Road	Commute
2	zone3	0		8:00PM	8:20 PM	office	restaurant	1.5	5	2	Main Road	social
3	zone 2	1	2017	3:20AM	10:45AM	home	supermarket	1.6	5	1	City Streets	Commute
4	zone 1	1	2016	1:30AM	8:30 AM	home	university	2	10	3	Main Road	Commute
5	zone 1	1	2020	1:30AM	2:00 AM	home	school	1	7	2	collector street	school
6	zone 2	2	2019	1:00AM	1:45AM	home	industry	2.2	9	2	Main Road	Commute
7	zone 3	0		4:35AM	5:00AM	home	shopping	0.8	4	1	Main Road	shopping
8	Zone 2	1		3:00AM	3:35AM	home	hospital	1.2	6	3	Main Road	commute
9	Zone 4	1	2018	9:00PM	9:45PM	HBNW	market	2.4	4.5	2	Main Road	non work
10	Zone 3	2	2019	6:00AM	6:20AM	office	Industry	2	5	3	Main Road	commute
11	Zone 2	1	2016	9:10PM	9:35PM	office	recreation	1.6	6	2	Main Road	leisure
12	Zone 2	0		2:00AM	2:35AM	home	business	1	8	3	Main Road	non work
13	Zone 1	0		3:30AM	4:00AM	home	p/business	1.1	20	3	Main Road	non work
14	Zone 4	1	2017	1:30AM	2:00AM	NHB	industrial park	5.5	9	3	Main Road	Commute
15	Zone 3	1	2022	10:20PM	10:50PM	home	social	1.4	6	1	Main Road	social
16	Zone 2	0		10:00PM	10:30PM	NHB	recreation	0.8	6	1	Main Road	leisure
17	Zone 2	0		11:00PM	11:15PM	office	shopping	0.9	5	1	Main Road	shopping
18	Zone 1	1	2019	1:30AM	1:45AM	home	school	2	6	2	collector street	Education
19	Zone 4	2	2020	11:00PM	11:20PM	home	sport	3	7	2	local road	Exercise
20	Zone 4	1	2018	6:10AM	6:30AM	NHB	supermarket	1.4	6	1	Main Road	shopping
21	Zone 1	1	2021	1:00AM	1:30AM	home	bus station	1.5	8	2	Main Road	Commute
22	Zone 2	2	2019	7:30PM	8:00PM	home	university	2	9	3	Main Road	Commute
23	Zone 1	0		10:45PM	11:00PM	home	supermarket	1.3	6	1	Main Road	shopping
24	Zone 3	1	2022	7:30PM	7:45PM	HBW	office	1.8	7	3	Main Road	Commute
25	Zone 2	0		6:00AM	6:20AM	office	restaurant	1	6	2	local road	social
26	Zone 1	1	2016	10:45PM	11:10PM	home	cultural	1.2	5	1	local road	social
27	Zone 4	0		1:00AM	1:25:AM	HBNW	university	2.8	9	3	Main Road	Exercise
28	Zone 1	2	1999	4:10AM	4:30AM	NHB	Office	1.8	9	3	Main Road	commute
29	Zone 2	1	2002	1:30AM	1:55AM	home	hospital	1	7	2	Main Road	Commute
30	Zone 4	1	2001	4:30AM	4:45AM	HBW	office	1.6	6	3	Main Road	Commute
31	Zone 2	0		9:30PM	9:45PM	NHB	shopping	0.7	4	2	Main Road	shopping
32	Zone 1	1	2004	1:30AM	2:00AM	home	business	1.2	8	2	collector street	non work
33	Zone 3	2	2002	11:00PM	11:30	HBW	gymnasium	1.7	7	2	local road	Exercise
34	Zone 3	0		1:30AM	1:50AM	HBNW	college	2.4	6	3		Education
35	Zone 2	0		7:30PM	7:50PM	HBW	office	1	7	3	collector street	Commute
36	Zone 1	2	2006	9:40PM	10:10PM	HBNW	recreation	2.2	6	1	collector street	leisure
37	Zone 4	1	2008	11:30PM	12:00PM	home	office	4.8	10	3	Main Road	Commute
38	Zone 4	2	2019	7:30PM	8:10PM	HBW	Industrial park	5.6	9	3	Main Road	Commute
39	Zone 2	0		6:00AM	6:40AM	HBNW	school	2	5	3	collector street	Education
40	Zone 1	0		11:00PM	11:25PM	NHB	sport	1.4	6	2	local road	Exercise
41	Zone 4	3	2021	6:45AM	7:00AM	HBNW	supermarket	2.3	5	2	Main Road	shopping
42	Zone 3	2	2019	6:30AM	6:45AM	office	shopping	1.8	4	2	Main Road	shopping
43	Zone 1	3	2020	11:30PM	12:00PM	NHB	restaurant	1	4	1	collector street	leisure
44	Zone 2	2	2008	12:00PM	12:30PM	home	hospital	1.4	8	3	Along mebrat	health care
45	Zone 1	0		3:20AM	3:50AM	HBNW	cultural	0.9	7	1	collector street	meeting
46	Zone 3	1	2009	4:15AM	4:35AM	HBNW	supermarket	1.6	6	1	Main Road	shopping
47	Zone 4	2	2012	10:30PM	10:55PM	HBNW	school	1.8	4	3	collector street	Education
48	Zone 1	3	2014	1:30AM	2:00AM	HBW	industrial park	4.2	11	3	Main Road	Commute
49	Zone 3	1	2016	10:20PM	10:45PM	NHB	school	1.6	8	1	collector street	leisure
50	Zone 2	2	2014	8:30PM	9:00PM	NHB	service delivery	1.4	8	8	Main Road	non work
51	Zone 2	1		7:30PM	8:00PM	HBW	office	1.2	6	3	Main Road	Commute
52	Zone 2	4	2009	11:30PM	11:50PM	NHB	restaurant	1	5	2	collector street	leisure
53	Zone 3	1	2008	2:00PM	2:30PM	home	business	1.5	8	3	collector street	Commute
54	Zone 2	0		9:45PM	10:00PM	HBNW	gymnasium	1.2	9	1	local road	Exercise
55	Zone 4	2	2012	10:30PM	11:00PM	HBNW	social	1.6	7	1	local road	social
56	Zone 2	2	2014	10:00PM	10:45PM	NHB	recretion	1	5	2	Main Road	leisure
57	Zone 2	1	2022	11:00PM	11:20PM	office	shopping	1	4	2	Main Road	shopping
58	Zone 3	1	2021	1:30AM	2:00AM	home	office	1.5	7	3	Main Road	Commute
59	Zone 4	0		7:30PM	8:00PM	home	college	1.2	6	3	collector street	Education
60	Zone 4	1	2016	2:30AM	2:45AM	home	hospital	1	8	3	Main Road	health care
61	Zone 3	2	2020	7:45PM	8:20PM	HBW	university	2.4	10	3	Main Road	Commute
62	Zone 4	3	2019	1:20AM	1:55AM	home	Office	5	12	3	collector street	Commute
63	Zone 4	2	2014	10:45AM	11:30PM	office	home	1.4	7	2	local road	Commute
64	Zone 4	0		1:30AM	2:10AM	home	store	1.6	6	2	Main Road	Commute
65	Zone 2	2	2020	10:45PM	11:10PM	office	supermarket	1	2.8	2	Main Road	shopping
66	Zone 3	0		6:00AM	6:20AM	office	university	1.2	4	1	Main Road	social
67	Zone 2	1	2018	10:30PM	11:10PM	home	school	1.3	6	3	collector street	Education
68	Zone 2	1	2019	4:30AM	5:00AM	home	shopping	0.7	3	1	Main Road	shopping
69	Zone 3	2	2012	10:00PM	10:30PM	home	culture	1.2	5	1	collector street	meeting
70	Zone 2	1	2010	1:30AM	2:00AM	home	hospital	1	8	2	Main Road	health care

Table 8: Public transport movement survey

	Public Transport Vehicle Movement Survey												
User ID	Residence location	Trip start time	Trip end Time	Public Transport Type	Trip origin	Trip destination	Vehicle Capacity	Occupancy Level	Congestion	Average Trip Length (km)/day	Average Trip Duration (mins)/day	Number of trip/day	User Satisfaction
1	Zone 1	1:30AM	2:00:AM	school bus	Home	School	70	50	low	1.2	6.5	2	100%
2	zone2	5:30:AM	6:00AM	Public bus	university	home	82	72	medium	3.4	12	2	95%
3	zone 2	1:00AM	1:30AM	Public bus	home	university	82	60	low	3.4	12	2	100%
4	zone 1	10:30PM	11:00PM	school bus	school	home	50	40	Congested	1.5	14	2	75%
5	zone 1	1:30AM	2:00AM	Medium bus	home	college	45	40	Congested	1.3	10	2	75%
6	zone 2	1:30PM	2:15AM	Medium bus	home	industry	50	50	Congested	4.2	18	2	75%
7	zone 3	11:00PM	11:30PM	Public bus	industry	home	50	45	medium	4.2	18	2	90%
8	Zone 2	6:30AM	7:00AM	Medium bus	hospital	home	40	30	medium	1.4	9	2	90%
9	Zone 3	7:40PM	8:15PM	Medium bus	home	hospital	45	35	medium	1.4	9	2	90%
10	Zone 1	7:30PM	8:10PM	Public bus	university	home	70	60	medium	3.2	12	2	90%
11	Zone 2	1:30AM	2:00AM	Medium bus	home	hospital	40	40	Congested	1.4	9	2	75%
12	Zone 3	11:00PM	11:25PM	Medium bus	hospital	home	40	30	low	1.4	13	2	100%
13	Zone 2	1:30AM	2:00AM	Public bus	home	office	82	76	Congested	1.2	6	3	75%
14	Zone 4	6:30AM	7:00AM	Public bus	office	home	82	60	low	1.2	6	2	100%
15	Zone 2	1:30AM	2:00AM	Medium bus	home	office	45	35	medium	1.2	6	2	90%
16	Zone 1	6:00AM	6:30AM	Medium bus	home	recreation	40	30	medium	1	5	1	90%
17	Zone 2	1:30AM	2:00AM	Public bus	home	bus station	82	79	Congested	2.2	10	1	75%
18	Zone 2	10:30PM	11:00PM	Public bus	home	school	82	70	medium	1.3	12	2	90%
19	Zone 4	1:00AM	1:30AM	Medium bus	home	sport	40	40	Congested	1.6	6	2	75%
20	Zone 4	11:00PM	11:30PM	Medium bus	office	supermarket	40	25	low	0.9	9	1	100%
21	Zone 2	6:30PM	7:00AM	Public bus	university	home	82	80	Congested	1.5	12	2	75%
22	Zone 1	1:30AM	2:00AM	Public bus	home	university	82	70	medium	1.5	12	3	90%
23	Zone 2	4:30AM	4:50AM	Medium bus	home	Business	40	35	medium	1.4	9	1	90%
24	Zone 3	1:20AM	1:45am	school bus	HBW	School	45	42	Congested	1.2	8	2	75%
25	Zone 1	10:00PM	10:45PM	school bus	School	home	45	30	medium	0.9	12	3	90%
26	Zone 3	11:00PM	11:30PM	Medium bus	home	industru	40	30	medium	0.8	12	2	90%
27	Zone 2	10:00PM	10:30PM	Medium bus	HBNW	gymnasium	40	30	medium	1.2	14	2	90%
28	Zone 2	4:30AM	4:50AM	Medium bus	NHB	service	45	42	Congested	1.2	9	10	75%
29	Zone 1	7:45PM	8:15PM	Public bus	home	hospital	74	60	medium	1.4	10	2	90%
30	Zone 2	9:30PM	9:45PM	Medium bus	HBW	market	45	40	Congested	1	8	3	75%
31	Zone 4	1:30AM	2:00AM	Public bus	home	business	74	70	Congested	0.9	7	2	75%
32	Zone 2	6:00AM	7:20PM	Public bus	business	home	74	60	medium	1	9	1	90%
33	Zone 1	9:45PM	10:15PM	Medium bus	home	Gymnasium	40	30	medium	1.3	10	1	90%
34	Zone 3	1:30AM	2:00AM	Public bus	Home	college	74	50	low	1	8	3	100%
35	Zone 4	1:30AM	2:00AM	Public bus	HBW	office	82	76	Congested	1.2	9	3	75%
36	Zone 1	6:00AM	6:30AM	Medium bus	HBNW	recreation	40	30	medium	0.9	8	1	90%
37	Zone 4	1:30PM	2:15AM	Public bus	home	industry	82	70	medium	4.5	20	3	90%
38	Zone 4	11:00PM	11:30PM	Public bus	Industry	home	82	50	low	4.5	20	3	100%
39	Zone 2	1:30AM	2:00AM	school bus	home	school	70	65	Congested	0.8	9	3	75%
40	Zone 1	10:00PM	10:40PM	Medium bus	home	sport	40	35	Congested	1	10	2	75%
41	Zone 3	9:45PM	10:15PM	Medium bus	HBNW	supermark	45	30	low	0.6	5	2	100%
42	Zone 4	11:00PM	11:30PM	Medium bus	office	Restaurant	45	40	Congested	0.9	8	2	75%
43	Zone 2	1:30AM	2:00AM	Public bus	home	office	82	65	medium	0.9	7	1	90%
44	Zone 2	1:30AM	2:00AM	Medium bus	home	hospital	45	30	medium	1.2	10	3	90%
45	Zone 1	1:30AM	2:00AM	Public bus	home	industry	82	70	medium	1.2	9	3	90%
46	Zone 2	10:00PM	10:30PM	Public bus	school	home	82	80	Congested	1.2	12	1	75%
47	Zone 3	1:30AM	2:00AM	Medium bus	home	business	45	30	low	1.6	9	3	100%
48	Zone 3	1:30AM	2:00AM	Public bus	HBW	industry	82	80	Congested	4.4	18	3	75%
49	Zone 3	9:45PM	10:15PM	Medium bus	NHB	recreation	45	40	Congested	0.9	10	1	75%
50	Zone 2	1:30AM	2:00AM	Public bus	Home	college	82	65	medium	0.9	6	8	90%
51	Zone 4	1:30AM	2:00AM	Public bus	HBW	office	82	65	medium	1	8	3	90%
52	Zone 2	1:30AM	2:00AM	school bus	home	School	45	30	medium	1.2	7	2	90%
53	Zone 4	4:30AM	4:50AM	Medium bus	home	business	45	30	low	1.2	8	3	100%
54	Zone 2	12:20PM	12:45PM	Medium bus	HBNW	gymnasium	45	45	Congested	0.9	10	1	75%
55	Zone 1	11:00PM	11:30PM	Public bus	univesity	home	82	80	Congested	3.2	16	1	75%
56	Zone 2	9:45PM	10:15PM	Medium bus	NHB	recretion	45	30	medium	0.8	6	2	90%
57	Zone 1	1:30AM	2:00AM	school bus	home	School	45	30	medium	1	8	2	90%
58	Zone 3	1:30AM	2:00AM	Public bus	home	office	82	77	Congested	1.2	9	3	75%
59	Zone 4	7:30PM	8:00PM	Medium bus	home	college	45	30	medium	1.2	10	3	90%
60	Zone 3	1:30AM	2:00AM	Public bus	home	hospital	82	65	medium	1.4	10	3	90%
61	Zone 4	1:30AM	2:00AM	Public bus	HBW	university	82	77	Congested	3.2	14	3	75%
62	Zone 4	1:30AM	2:00AM	Public bus	home	industry	82	80	Congested	4.4	18	3	75%
63	Zone 4	11:30PM	12:00PM	Public bus	office	home	82	80	Congested	1.2	12	2	75%
64	Zone 3	11:00PM	11:30PM	Medium bus	store	home	45	42	Congested	1	8	2	75%
65	Zone 2	1:30AM	2:00AM	school bus	home	school	45	30	medium	1.2	9	2	90%
66	Zone 3	11:00PM	11:30PM	Public bus	home	university	82	78	Congested	4.2	16	3	75%
67	Zone 1	1:30AM	2:00AM	school bus	home	school	45	45	Congested	0.9	7	3	75%
68	Zone 4	10:15PM	10:45PM	school bus	school	home	45	42	Congested	0.9	10	1	75%
69	Zone 4	7:30PM	8:00PM	Medium bus	home	college	45	30	medium	1.2	10	3	90%
70	Zone 2	1:30AM	2:00AM	Public bus	home	hospital	82	65	medium	1.4	10	3	90%

Appendix -E: Questionnaire

Adama Science and Technology University

School of Civil Engineering and Architecture

Post-graduate program in urban planning and design

Postgraduate questionnaire

Questionnaire for households (particularly for workers, who regularly commute to commercial business districts)

Dear Sir/Madam

I am currently pursuing my Master of Science degree in Urban Planning and Design at the School of Civil Engineering and Architecture at Adama Science and Technology University. As a researcher and student, I am actively engaged in my studies within this esteemed academic institution. I am doing my M.Sc. research/thesis entitled “Traffic congestion hot-spots area and traffic demand analysis by using travel demand modeling, in downtown Adama City” to identify traffic congestion hot spots by measuring the level of congestion in selected route of traffic analysis zone, conducting origin-destination analysis of people trips in traffic analysis zone in downtown of Adama city.

Your authentic, truthful, and immediate participation in the survey will significantly contribute to the success of the research. Rest assured, your responses will remain confidential and your anonymity will be preserved. Additionally, the information you provide will be used solely for scholarly purposes. Completing the questionnaire should not require more than 10 minutes of your time. I deeply appreciate your time, effort, and thoughtfulness in completing this survey.

If you have any questions concerning the items of the questionnaire, please call on mobile: 09 30 58 04 92, or e-mail minichil1990@gmail.com

With Great Respect

Minichil Molla

Thank you in advance for scarifying the time to respond to this Questionnaire!!!

Respondents characteristics

1. Respondent's Name (Optional):--
2. Respondent's: Use (x)or (√) mark

Sex____________

Age: 15- 20___ 20-30___ 30-40___ 40-50___ above 50___

3. Respondent's occupation: _____________________________________

4. Education level

Degree----------------------Diploma-----------------(10+2) ------------------------

Grade twelve complete ---------------Below Grade 12----------------Other----------

5. Employment status. --------------------------------- Employed/ Unemployed

Part I: General question about their perception regarding traffic congestion

1. Do you have any knowledge about traffic congestion?

Yes_____ No_____

2. Do you think there is traffic congestion at the major route in Adama city downtown at some level?

Yes_____ No_____

3. If your answer to question number 1 is yes. What do you think is the level of traffic congestion in the network?

Very High------------High----------Moderate---------- Low----------Very Low--------

4. Rank the major causes of congestion.

High transportation demand ☐ concentration of working area in the central business district ☐

Increased love of driving private vehicle ☐ Inflexible working hour ☐

Imbalance vehicle volume and road capacity ☐ un-availability of mass transport ☐

Illegal on-street parking ☐ street vendor ☐

Incompatibility of land use and ☐ poor traffic management ☐

special events ☐ high parking demand ☐

Narrow street width ☐ poor condition of the road ☐

Traffic accidents ☐ poor traffic control signal ☐

Pedestrian interference with vehicle ☐ lack of sufficient lanes for mobility ☐

5. Which route is more congested in the central business district using posta-bet as a reference?

From Franco to Posta bet ☐ from Abebe Bikila street to Posta bet ☐

From Posta bet to mebrat hail ☐ from Tikur Abayi to Posta bet ☐

From Posta bet to Amede Gebeya ☐ From Abebech Gobena street to Posta bet ☐

Part II: Household characteristics

No	Household characteristics	Respondent answer				
		1	2	3	4	above
1	Number of members in the house					
2	No. of employed people in the house					
3	No. of unemployed people					
4	Number of two-wheelers in the house					
5	Number of cycles					
6	Number of cars in the house					

7. What is the status of your ownership? ------------------------------owner/renter occupant.

8. How much do you earn in birr? ----------------------------------Wks./monthly/year.

Part III: Personal characteristics

1. Household member number by age.

under 5 years ------5-14year------14-29 year------30- 39 year ------40-65----->65year ------

2. Number of Household members by sex.

Male ----------Female -----------

3. Head of the household member.

Husbands ----------Wife ---------- Son ------------

4. Number of household members having driving license---------------------------------------.

Part III: Trip data

1. Location of place of residence--.

2. Location of destination---.

3. How long do you travel the average distance from home to work in Km?

1- 5 km_____ 6-10km_____ 11-15 km _____ greater than or equal16 m _____

4. Total time spent each day traveling from home to work ------------------------min/hr.

5. Distance from house to the bus/taxi stop--km/mt.

6. The cost of a trip during peak hours -- Birr; and at off-peak hours ---Birr.

7. What mode of transportation you preferred?

Auto ------------------ taxi------------ Bicycle---

Bus-----------------Bajaj------------ walk-----------------other (specify)------------------

reason for the choice---

8. Have you switched modes (from one stop to another) on your commute to work?

No transfer ------------one stops----------two stop---------three stop --------above -------------

9. Where in the city are most people moving?

(a)Toward the central business district------------;(b) outward the central business district------------; (c) to the adjoining zone----------;(d) to the edge of the city----------;(e) to manufacturing area---

10. Give your opinion on the following:

(i) Waiting time for public transport:

Short---------------long-------------------too long---------------

(ii) Travel time by mode to destination.

Short---------------long------------------too long-------------------

(iii) Congestion of passengers in public transport

modes comfortable***;*** ----------------- congested ----------------------

too congested----------------------

(iv) Delays caused by traffic congestion during peak hours:

Okay-----bad-----------terrible---------------------------

11. What is the purpose of your trip?

Work -------------- business------------- social----------------school----------------------

Shop----------------culture-------------------- other (specify)------------------------

Location of trip---------------------------------------

12. When do you travel the most in a day (start and end hours in local time)?

Morning peak (1:30 am-2:30 am) ---------------- Midday peak (6:00-8:00) am --------------------Evening peak (10: 30- 12:30) ---.

13. Number of trips undertaken per day ---.

14.Total costs of trips undertaken per day -----------------------------Birr.

15. Location of where shopping is normally done -------------------------;

How often is shopping done---------------------------------/wks./month.

16. Location of the usual place for leisure ---.

17. Which form of transportation would you choose if you had the choice?

walking -------------bicycling-------- motor-cycling------------Taxi------------- bus-----------------Bajaj----------------private car-------------------------------------

18. Do you own any of the above modes? Yes --------- No ------

If Yes, specify--

Appendix-F: Household Categories Characteristics

Table 9: Household Categories information from 70 Participants.

Household categories data obtained from representative household						
House hold ID	Residential location	Household number(House hold size)	Car ownerhip	Household income ($)	Number of worker	Total daily trip production/day
1	Zone 2	3	4	90	2	10
2	zone 2	2	2	70	2	6
3	zone 1	4	1	115	3	9
4	zone 3	4	1	110	2	8
5	zone 3	2	1	50	1	7
6	zone 4	3	0	50	2	5
7	zone 1	2	0	40	1	5
8	zone1	1	0	35	1	4
9	zone 2	1	2	40	1	4
10	zone 2	2	2	60	1	4
11	zone 1	3	1	95	2	7
12	zone 2	3	0	30	0	6
13	zone 3	2	0	35	0	5
14	zone 4	1	1	25	1	4
15	zone 1	5	1	40	1	8
16	zone 1	2	0	25	1	3
17	zone 2	1	0	35	0	4
18	zone 3	1	1	20	1	4
19	zone 2	5	1	100	2	6
20	zone 4	4	1	95	3	5
21	zone 2	4	2	99	2	7
22	zone 2	6	3	120	3	9
23	zone3	1	0	45	1	3
24	zone 3	3	1	67	2	6
25	zone 1	2	0	56	2	5
26	zone 1	4	1	100	2	6
27	zone 2	1	0	25	1	3
28	zone 3	4	3	69	2	7
29	zone 3	2	1	40	1	4
30	zone 2	2	1	50	2	5
31	zone 1	1	0	30	0	3
32	zone2	4	1	68	2	7
33	zone 2	3	1	70	1	6
34	zone 3	1	0	25	1	3
35	zone 4	1	0	20	1	3
36	zone 2	5	2	78	2	7
37	zone 2	3	1	98	2	5
38	zone 2	4	2	90	2	5
39	zone 4	4	2	120	2	6
40	zone 4	3	1	97	1	4
41	zone 2	7	3	130	3	8
42	zone 2	6	4	120	2	10
43	zone 1	8	3	115	3	9
44	zone 3	5	2	100	3	7
45	zone 4	1	0	30	0	4
46	zone 3	3	1	66	2	5
47	zone 2	6	2	120	0	8
48	zone 2	7	4	130	3	10
49	zone 1	3	1	90	0	4
50	zone 3	2	2	80	2	4
51	zone 3	1	0	20	1	7
52	zone 4	8	4	100	2	11
53	zone 1	4	1	90	0	5
54	zone 2	3	1	60	0	4
55	zone 4	5	2	40	1	7
56	zone 2	5	2	100	2	8
57	zone 3	1	1	30	0	3
58	zone 4	2	1	20	2	6
59	zone 4	3	0	56	1	5
60	zone 1	4	2	50	2	4
61	zone 1	5	3	70	3	6
62	zone 3	7	4	135	4	9
63	zone 2	6	4	125	3	7
64	zone 3	3	1	79	2	6
65	zone 4	8	3	120	4	8
66	zone 2	2	0	70	1	4
67	zone 4	3	1	60	0	8
68	zone 1	4	2	60	1	6
69	zone 3	5	2	85	2	7
70	zone 4	2	1	65	2	5