ADDIS ABABA UNIVERSITY

INISTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

Performance measurement and analysis of Addis Ababa city taxi fleet network. Case site: megenagna fleet zone

By: ERMIYAS MISGANA

ADVISOR: ESHETE BERHAN (PhD)

Co-Advisor: Mr. FITSUM GETACHEW. (PhD. Candidate)

A Thesis Submitted to Addis Ababa University, Institute of Technology, school of mechanical and Industrial engineering in Partial Fulfillment for the Award of the Degree of Master of Science in Industrial Engineering

October , 2020

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Declaration

I hereby declare that the work which is being presented in this thesis entitled **“performance measurement and analysis of Addis Ababa Taxi fleet network with special reference to megenagna fleet zone ”** is original work of my own, had not been presented for a degree of in any other university, in any Research by any means, and all the resource materials used for this thesis had been accordingly acknowledged.

__________________ _________________

ERMIYAS MISGANA Date

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

Advisor signature __________________ _________________

ESHETE BERHAN (Phd) Date

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Finally yet importantly, I would like to thank all members of my family, especially my parents, my sisters, and my brothers; I owe a lot to their encouragement, support and prayers.

Dedication

(In memory of my father)

I dedicate this entire work to my beloved father a strong and gentle soul, whom I lost in the beginning my study for his guidance and extensive support throughout every step of my life am eternally grateful for everything you have done for me.

My mother and every members of my family, you have been an incredible inspiration till this moment. I am speechless for your relentless effort and sacrifice. May the almighty God comfort you in his abundant blessing.

Abstract

Analysis of public transport sector service level is an important procedure in creating a model capital which is experienced with a higher mobility rate and rapid urbanization. As Addis Ababa is a hub for many international organization and is also considered as African capital in addition being a diplomatic center, the level of its service industry plays an important role in transforming the capital to its intended destination. In this study a thorough analysis of the performance of the taxi fleet network has been made at megenagna fleet zone(considered as sample representative zone) the performance of the sector was measured in three distinctive indicator modes, namely financial, quantitative and practical indicators. Result obtained was compared to acceptable standards regionally acceptable and internationally considered and have been found average.

In addition a representative model was formulated to optimize the current trip allocation. Three constraint were considered for this study loading capacity, route distance and trip frequencies and using those constraints an LGP model was formulated and solved using QM for windows V5 2015 in linear optimization mode. The nature of the arrival rate of customers and the waiting line created at depots differ in the normal hour and peak hour a distinctive equation was formulated for the two time frames.

After optimization the results showed there is a room for modification on trip allocation which will improve both the quality of the service sector and provide an even and balanced demand based allocation.

Key word: performance analysis, linear goal programing, trip allocation

Table of content

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ACCRONYMS

EN --European Standards (ENs)

VRP ---vehicle routing problem

LGP --- linear Goal programing

GA --- Genetic Algorithm

ACBSE --- Anbessa City Bus Service Enterprise

TAPT -------------------------------------Trans africa - African Association of Public Transport (UTATP),

SMTSC--Sheger mass transport share company

AALRW---Addis Ababa light rail transit way

NCST--National Center on Senior Transportation

CREC---china rail way group limited c

CSA-- central statistics agency

PLF ---percentage load factor

TTD ---terminal to total distance

CMPV---Carrying mile age per vehicle

CHAPTER ONE
INTRODUCTION AND BACKGROUND

1. INTRODUCTION

1.1. Background and Justification

Travelling is a very common and inevitable day to day routine of almost every individual. Peoples started travelling from the very creation of day at their very infant stages of their lives most of the time around age 2 to 3 using their own feet. (Linda J. Murray, Baby center LLC-L, 2010). Then after in the course of civilization and urbanization humans have created different mode of transportation system to ease their daily activity and quality of life.

This days humans in most part of the world use almost all the available mode of transportation system starting from their own feet using animal backs, bicycles settings automobiles, public vehicles airplanes trains and etc. likewise in third world countries like Ethiopia ,where the advancement hasn’t been well entertained and financial capabilities are limited most of the population use the cheapest mode of transportation available most commonly Public buses and taxis in urban area and trains for longer town to town destination. As transportation is a main concern in a community’s day to day routine the quality of these services are vital since they are directly related to the majority of the population basic needs. (Agrawai, 2004)

Quality of life which is directly related to quality of service a customer obtains at any customer service window, has become very basic necessity in modern era communities. In Ethiopia where government has launched a serious phase of growth and development plan to pursue a development goals, (Graeme Currie, 2009)improving quality of life is a major concern to address. Yet the current scenario shows quite a difficulty specially in some sectors like transportation ,health care services public administration services and some other service providing institutions.

Of those services providing institution transportation service plays a vital role since it can be considered as a primary service station which assists a community by providing a service to reach a destination where other basic services can be obtained from. Especially in urban area where fore say every one is a passenger unbalance between the demand of service and service provider and its management has become a real headache. Seeing a very long queue of customers in major transportation routes has become common which indeed require expertise interference to the situation. (Aniyeri & Nadar, 2017)

Waiting line are common in urban transportation sites specially in job entering and leaving hour. (Niyonsenga, 2012) Hence a scientific approach to analyze these pitfalls has become mandatory. Several studies used queuing theory to model the passenger flow and further measure the performance of the available servers in similar cases so as to enhance efficiency and increase service throughput.

The capital city of Africa and Ethiopia, the city of Addis Ababa is one of the fast growing cities as the report of African business initiative in 2016. Due to this and some other additional reasons urbanization and frequent migration to the city has become a common scenario in the context of Addis Ababa which left a lots of side problems. The most common hot issues captured after the start of urbanization and massive migration to urban cities are shortages on transportation and shelters. It has been a common thing to hear individuals asking this question. “Is Ethiopian transportation crises a problem sourced from demand supply variation or fleet management problems and uneven allocations” it does look quite a research question itself which needs researching by concerned bodies and provide a controlling solution, otherwise the problem will persist for long duration.

Therefore this study deals with measuring the performance of the current transport service and providing a solution to the bottlenecks to be identified at north region of Addis Ababa city taxi line fleet network. The detailed sub procedures of this study include determining of demand in sample stations, simulating the arrival rate of customers to the service and determine the level of resource required for those customers, analyze the efficiency of the network, designing a fleet network and management system to efficiently use the resource available using vehicle routing problem solving software and finally simulation to analyze the new performance of the designed vehicle trip allocation.

1.2. Statement of the problem

Transportation is one of the most daily routines of human population , thus it can be said that it is related to our major day to day activities. Due to this fact any breakdown and underperformance in this sector, has a direct impact on peoples life.

Measuring a given performance of a service providing institution is a mandatory procedure specially in a system which requires frequent upgrade and continuous improvement. In Ethiopian public transport sector (road only) resources are relatively in scarce amount which is about 961 functional mass transport buses 3624 minibuses and 1136 other medibuses and special contract taxis servicing more than 1.9 million customers per day with approximate vehicle population ratio of 1:335 on daily basis. In such relatively scarce resource which is below the recommended standard public transport vehicle- population ratio of 1:96, efficient utilization of the available resource is a choice less measure. (PPIAF.org , 2013)

The sectors governing offices, ministry of transportation and Addis Ababa city road authority has indicated in their annual conference on 2016, that the current performance level of the Addis Ababa city fleet network has not been scientifically studied so far considering all necessary parameters yet focuses mostly on addressability or serviced passenger volume ignoring most of other necessary parameters that are required for effectively analyze the performance levels and help in taking further action plans to improve the service sector.

In addition to this as per a study made by Mr. bayou (mulat, 2001) on commercial road transport sector on the nature and quality of the transportation service here in Addis Ababa the capital of Ethiopia, the level of the quality of transportation service can be considered poor that it is unable to fulfill the demands of the ever increasing population or customers. Majority of the passengers of the city are obliged to spend more than one hour in the vehicle to rich a 20 minute driveway due severe congestion of the network. This condition gets even severe In job entering and leaving hours. (Demdime, 2012)

Thus this study opts to analyze the current performance level of the network line of the indicated route and tries to find a solution to the bottlenecks to be determined.

1.3. Objectives of the study

Main objective

The objective of this study is measuring and analyzing the current performance of the fleet network in megenagna fleet network and improving it by route optimization.

Specific Objective:

- ✓ To study the public performance measurement indicators and their relationship.
- ✓ To Measure the current performance level of taxi fleet network in the selected station and routes and indicating possible areas of improvement.
- ✓ To Develop mathematical models to assess the current trip allocation on the selected route network.
- ✓ To apply Route optimization in the selected network using Goal programming.
- ✓ To do a Comparative analysis of performance of the route before and after the optimized allocation.

1.4 Description of the study area

This study will be conducted in northern Addis Ababa region, the capital of Ethiopia on the selected sample stations and avenues.

North Addis Ababa is selected due to presence of multiple way branched networks and destinations in its geometry and is also the second most densely populated region according to the census Made in 2016 by city administration transport bureau . Northern part of Addis Ababa includes majority of Arada sub city and parts of Kirkos and Yeka sub city.

1.5 Research questions

I. What is the current performance or efficiency level of northern Addis Ababa taxi fleet network line.?

II. What are the bottle necks associated with the current performance and What can been done to address them in order to improve the efficiency of the service ?

III. Is Ethiopian public transport problem specifically in city of Addis Ababa, a problem sourced due to scarcity of resource or poor available resource utilization?

IV. How well this performance would be improved if route optimization concept is integrated Specifically a goal programming approach?

1.6 Scope

The scope of this study is limited to the capital city of Ethiopia Addis Ababa with special reference to the northern part of the city administration.

1.7 Limitation

- ✓ The pickup and drop of stations for the taxi service is not definite and is arbitrary (can be any given place on the coordinate)and could vary from passenger to passenger in any different time frames.
- ✓ The carrying capacity of different vehicles vary from one another which complicates the process of determination of customers serviced in a single trip by different vehicles
- ✓ The fleet assigning body in Ethiopian context is ministry of transportation which lacks an organized system to manage the taxi unions efficiently which makes it difficult in obtaining accurate organized information.

1.8 Significance of the study

- ✓ Suggest a way to increase the efficiency of the fleet network in the mentioned route and avenue.
- ✓ Improves the service rate and efficiency of the transportation system in the area
- ✓ Assists in an attempt of measuring the current performance status of the fleet networks of a given route
- ✓ Indicate ways to understand and analyze similar case scenarios in other areas
- ✓ Indicates ways of integrating route optimization to improve level of performance of public transport
- ✓ Incites a way to improve the level of the performance of the network in other areas with similar scenario.
- ✓ Benefits passengers drivers and service providers by indicating ways of effective resource utilization.
- ✓ Shows ways of reducing extra investment expenditures by optimized scarce resource utilization ways.

1.9 Thesis structure

The overall research is organized under six chapter and described as follows

Chapter one deals with brief introduction about the research area, identification of research problem, definition of research objectives and briefs on research questions.

Chapter Two focuses on brief review related literature on transport service performance analysis and factors used to evaluate the efficiency of a fleet network in addition vehicle routing problems and solution methods will be discussed

Chapter Three presents the methodology used in this research work in details like the research frame work details regarding site area selection methods of sampling and data collection, ways and tolls to be used to analyze the collected primary and secondary data's

Chapter four is concerned with data presentation and data analysis stage data's related with the performance of the selected route will be analyzed in detail.

Chapter five in this chapter linear programming model will be developed that can improve the current performance of the fleet network. In addition details regarding validation of the developed model, this model is validated by secondary data obtained from sources. Then after conclusion and recommendation are provided at the end.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Transportation

Transportation is an act or process of conveyance of goods, humans and animals from one place to another place known to be destination. It is a movement of entities away from a current location to a given destination place for different wide range of purposes. (L. Glover, 2011)

Transportation can be considered as one of the world's most dominating business activities. It is considered as a daily business activity that has to do with traveling, traffic and communication or with the movement of persons, service or goods and with the mechanical transmission of ideas as per the definition from scholars like Johnson, Transportation is a planned common daily routine activity performed by inhabitants both in metropolitan cities and rural areas. (Toride, 2007)

Transportation, as a general term, can be categorized in to three classes as traditional , intermediate and modern transport. The traditional way transport sector comprises of human back and portage/head-loading and equine or backs of animals (horses, donkeys and camels) as description of Jorgenson. The modem transport sector, on the other hand, is made up of engine-powered automotive-based means of transportation. Thus the intermediate transport sectors consists of all possible range of transport modes between direct head traditional and automotive-based vehicles. (Jorgenson, 1983) it include transportation modes like Hand trolleys, wheel barrows, ox-carts, and others.

It is obvious that in today's world, transportation is a key aspect of world economy in various ways.. It is directly related to health care, social life, business travels and etc. Ideal Transport System is a fully integrated safe transport network which supports social and economic regeneration and ensures good access for all which, is operated to the highest standards to protect the environment and ensure quality of life. (Richard J. lee, 2016)

Transportation sector and its network has a vital importance to development of a nation and affects all sectors through economic coordination and socio-financial linkages. Sound transportation system grants safely and timely travel of service or goods which in return encourages business related activities by reducing costs related to production and distribution hence cost of a product or service. A reliable transportation network also provides enhanced ease to reach destination in appropriate time which plays its part in labor productivity. In addition the industry itself is quite a source to of job opportunity which can accommodate huge employment opportunities. A well organized and managed transportation system also provide a great deal of advantages in both local and international business competitiveness among institutions and business firms (L. Glover, 2011)

2.2 Public transportation

Public transportation is one of the major forms of the vast transportation sector which focuses on transporting of the general public population to and from its residing or working place. It plays major role in a countries economic and social wellbeing by providing a back bone to the mobility of a town and being a medium to meet up of resources to demand areas and vice versa (Jonanson, 1970)

During the past few decades developing countries have experienced huge population growth the increase in population has led to the increase in the demand for urban transport especially in African cities but the transport infrastructure in these cities is appropriate for the current transport demand this has caused serious road congestions and public transport overloads. Most government have a lack of financial and human resource to meet these demands. There is shortage of public transport supply which has led the emergence and growth of informal transport (G. william, 2002)

2.3 Public transport in Ethiopia

Ethiopia as one of growing African countries has a growing range of public transportation sector. There are different modes of transportation service providing firms from mass transportation of cross country to city buses minibuses and personal taxis and rail way transits. As a survey made by Mr zerhiun in 2007 the public transportation is growing in reasonable manner that plenty of individuals and enterprises are introduced to the public transport sector annually

The current transport sector in Ethiopia is composed of about 46,000 km of roads (including about 11,800 km asphalt and 14,620 km gravel), 46 km light weight city railway, a 812- km railway line linking the capital city Addis Ababa with the neighboring country Djibouti, international airports and over 30 scattered airfields. (Mulat, 2002)

As per annual report of statistical agency of Ethiopia the contribution of the transport sector to the Gross Domestic Product, in spite of its great potential, is only around 8 percent. The transport system has often been identified as a bottleneck to an effective production and distribution system in most of the countries business sector.

As a rapidly urbanizing city Addis Ababa has been striving to provide a moderate transportation to around 3.5- 4.5 million inhabitants. yet the level of and quality of its service has been struggling to cope up with the ever increasing population size of the city in its very limited resource. (Mulat, 2002)

2.4 Public transport operators in Addis Ababa

The Addis Ababa taxi transport service, which is believed to have begun in the time of Emperor Hailesellasie I with hatchback models of Fiat 600, and hence started growing to reach level that can serve the ever increasing number of population.

Residents of the town uses one or some of the following modes of transportation in the town as they travel from place to place.

Some of the common modes of transportation used in the city are mentioned below.

- Bus service operators (Anbessa city bus, sheger buses Alians city bus (currently on bankruptcy)
- Medibuses
- Minibuses/taxi
- Collective Contract /hailing/ taxi
- city based light train
- private cars
- company service vehicles
- rickshaws
- pedestrians

2.4.1. Anbessa City Bus Service Enterprise

Anbessa city bus service enterprise is a bus operating company established in 1943 as a private enterprise holding an exclusive franchise for the provision of passenger transport services in Addis Ababa, which was nationalized in 1974. (Trans africa - African Association of Public

Transport (UATP), 2008) about one third of the buses are DAF model city buses which has a carrying capacity of about 90 passengers per single trip whereas the rest two third of the enterprise buses are assembled by Bishoftu automotive has an average carrying capacity of 85 passengers per a trip. (Y.E Roux, 2012)

The enterprise operates a fleet of 816 conventional large buses, with an average vehicle age of ten years, and provides scheduled services along about 116 routes transporting about 507200 passengers daily accounting for about 15% of the public transport market share, that is nearly 172 million passengers carried annually. (haile, 2016)

Over the past ten years, the enterprise has been gaining regular investment from the city council in financial and sustainable provision for reaching a millennia goal of serving 20% of the town residents. Tariffs and Fares are provided by city administration in consideration of subsidy for the low level income inhabitant of the town. For quite long time fares hasn't been revised which required the city administration to raise the annual budget deficient compensation for the enterprise. (haile, 2016)

2.4.2 Minibus-Taxi

As per the study conducted by Trans-Africa Consortium on public transport in sub Saharan African countries in 2014, The capital city Addis Ababa is served mainly by minibuses also known as "taxis" whose estimated number is about 12600. According to the Addis Ababa Transport Authority branch office, the number of minibus taxis is registered as 11,907 and their average daily operational capacity is estimated at 1,228,934 passengers. They are serving about 154,791 passenger trips a day.

They account to provide around 57% of the public transport trips despite their fares is about three folds than city buses and less than one tenth of fares of contract taxis. The common privately owned minibus taxies are the Toyota Jaguar, Haice and d4d models with a seat numbers that range from 12 to 15 as per the report from African association of public transport on statistical indicators of public transport. They are registered as code 1 taxi provider painted as blue and white or code 3 taxi provider with undefined color type. They are considered as the safest and comfortable modes of the city transport by many residents of the town due to their availability flexibility and relatively smaller size. (haile, 2016)

2.4.3 Medibuses

Those are another mode of transportation in the capital where vehicle seat number ranges from 21 to 32 passengers. They include Chinese made higer medibuses and refurbished Isuzu model buses commonly called as "kitkit" In 2008, the City government undertook the purchase of 500 Chinese model medibuses commonly known as" higer buses "at a cost of about EUR 10 million through a bank loan and distributed them to private operators for a five year repayment period(trans Africa 2010). Currently it is estimated that about 750 medibuses are providing service in the town for about 326000 passengers daily as per study conducted by (Mullu, 2016) The approximate modal share of the this provides is approximately about a little less than 10% from motorized transportation mean's.

2.4.4 Sheger Mass Transport

Sheger mass transport share company was established October 2009ec to support addressability of city buses service and play vital role in increasing accessibility and service quality in the sector.

This share company has introduced itself in the market with 65 Bishoftu assembled buses which later has grown to 131buses in 17 route initially. In the this fiscal year (2011 ec) sheger mass transport share company has announced it has provided service for over 62.4 million passengers per annum covering 9.8million km. the share company was servicing about 176250 customers per day with a modal share of around(5.2%) of the city public transport providers. (Bogale, 2018).

2.4.5 Collective Contract /hailing/ taxi

Collect hauling contract taxis are code 1 sedan type taxis which offer private contract taxi service from one destination to the other, fares are cut either on mutual agreement between driver and customer or fixed rate fare put by government transport bureau based on total kilometers travelled. Those private contract taxi service providers should be registered in a union of their choice or a dispatch company to operate in the city. There are about 6 private contract taxi unions providing service in and around the city they are ride taxi dispatcher pick pick taxi dispatcher, zayride taxi dispatcher, sheger meter taxi union, Lucy meter taxi union, MNS meter taxi union and conventional blue and white colored contract taxi unions. Total number of contract taxi operating in the city reaches around 2648 as of 2010 ec transporting more than 35000 passengers daily in different routes of the town.

2.4.6 Addis Ababa light rail transit way

AALRT was inaugurated in September 2015 in two directions south-north and east to west accounting of a total of 34 km of rail ways in 39 stations to provide service for the residents of the town. The rail way was contracted by china rail way limited after a fund from import export bank of china. The south- north route starts from Kality round about passing through meskel square to Atobis tera. transporting 8000 passengers per hour per direction/PPHPD/ whereas the east–west route circulates from ayat round about passing through meskel square to Torhailoch and vice versa servicing 7000 PPHPD. As shown in the survey by china rail way group limited commonly known as CREC the rail way carried an average 113500 daily passengers in both routes in 2016 which has grown to 194100 passengers per day in 2019.

2.4.7 Others

Other modes of motorized modes of transportation include private cars, rickshaws 2 tyre motor bicycles are also widely used by the residents of the town. Annual report made by Addis Ababa road authority in 2017 depicts that about 150000 private vehicles uses the roads of the city in a day which can help in estimating private car daily travelers would be around 150000 considering a single traveler per single vehicle. Other modes include motorized and non-motorized wheel chairs, horse carts bicycles.

It was pointed out on a study by trans Africa UATP on public transport on sub Saharan Africa on 2008 and 2014 pedestrians in the town are roughly estimated as 17-24% of the total population whereas survey by ministry of transport of FDRE on transport policy of Addis Ababa on august 2011 has indicated that there were about 620000 non-motorized transport users and about 500000 non travelers in the town. Considering 2.6 % annual growth rate of population provided by CSA of Ethiopia on national statistics abstract 2018, it can be predicted that pedestrians and non-travelers in the town would be around 819000 and 752000 respectively.

Summary of modes of transportation with passengers number is explained below in the table.

No	Modes of transport	Active No of vehicles	No of passenger(1000)
1	ACBSE	**816**	**507.2**
2	SMTSC	**131**	**176.3**
3	MEDI-BUSES	**756**	**326**
4	MINI BUSES	**12600**	**1928.9**
5	AALRT	**(14)**	**194.1**
6	CONTRACT TAXI	**2648**	**34.5**
7	PRIVATE CARS	**148000**	**150**
8	OTHER(RICKSHAWS, MOTO-CYCLES		**62.5**
	SUM		**3378.9**
9	PEDISTRIANS		**819**
	TOTAL		**4197.9**
10	NON TRAVELLERS		**752**
	GRAND TOTAL		**4950.5**

Table 1: Vehicle numbers and passenger proportion in Addis Ababa

2.5 Quality of public transport in Ethiopia

Quality is a general term which generally indicates the soundness of the level of the service to meet the levels of interest of a customer's (Richard J. lee, 2016) in this context quality of public transportation can be defined as the wellness of the sector to fulfill a given level of requirements by users or customers. Here in Ethiopia the ever increasing population size has been a critical factor in achieving a quality service to its users, studies of some scholars like bayou mulat, Eshetie, Birhane and wondimu 2012 has indicated that mass public transport specially city bus service is way under standard and low when compared to neighboring cities and towns in terms of addressability, safety, comfort and accessibility. An article from (mulat, 2001) depicts that it is either costly or time consuming and uncomfortable to use public transportation modes to travel from one destination in Addis Ababa , he also claims that there is huge gap between number of service providers and total number of passenger population.

Given the nature of transport sector in Ethiopia, there are four important qualities parameters of public transport

2.6 Quality parameters of Public Transport

2.6.1 *Affordability*

It refers to the extent to which the customer would be subjected to sacrifice financial in cost terms to travel from one destination to other. The need for the travel could be either job related to generate income or other socio curricular activities or journeys . the ease of paying for the service in a any given time of travel can differ from a given set of population to the other but considering the majority or middle to low income group population would provide a better analysis.

Researchers like (K. Robert, 2008) and (Dhingra, 2011)has pointed out on their studies that in most developing countries passengers are obliged to incur about 17% of their annual income in transportation where as in sub Saharan countries where Ethiopia is located the, the amount of investment passengers are paying reaches to 24%. While in central and west African countries metropolitan cities Dakar , Yaoundé, doula and Lagos the figure varies from eight to nineteen percent.

In these cities it appears that majority of the population is pedestrian or uses cheaper modes of transportation due to inability to pay the required amount of fares. (Robin Carruthers, 2005) Fares in these cities are in a strict watch by government bodies but due to huge difference in demand and supply, service providers are seen altering tariffs and fares in peak hours and weekends. The proportion of average seat number of a transport operating vehicles to number of passenger residents of a given village is less than 1:5 (Kumar A, 2008) which contributes to escalating of fares of a voyage in those cities hindering affordability to transport to a destination.

In the capital Addis Ababa private taxis service providers the commonly known as minibuses are usually seen requesting extra amounts in a single trip or sometimes cut trips to two or three parts to gain extra specially in peak hours like 8 am and 5 pm which force customers and passengers for extra expenditures and hence a dalliance to their destination (mulat, 2001)

2.6.2 Availability

Availability of transport is a term used to refer to presence of the required amount of transport providing service in a given time on specified route. (B. F. Tchanche, 2018) no matter what is the driving factor for the passengers to travel to a destination education, work, leisure, personal services or other her/his travel activities are constrained by the route and vehicle presence and the time it takes traveling to the specified destination.

Availability of a specified mode of transportation in some agreeable radius to a station is main factor for passengers to choose.

Even if an individual has a terminal or stop around in near distance, let's assume in less than 500 meter of their residence, how much that individual can be benefited entirely depends on their need to travel, how often and how long the entire journey is going to take. Timing and frequency are included since service came after need arise. ((National Center on Senior Transportation (NCST), 2011)

Presence of passengers taxi when required by a travel man as they reach taxi stations are only 31 percent and the rest do not get. On average, passengers are obliged to wait more than 27 minutes to get service at that or nearby station's. According to (Kumar A, 2008) on average, African passengers wait above 30 minutes to get taxi service at terminals. This is way much larger than some middle east cities like Riyadh, where passengers wait on average 6 minutes. (Algadhi, 1998). A lot has been said to determine the prime cause behind this scarcity of service for travelers but as for Addis Ababa city transport bureau survey made on 2015 one is even the bureau cannot tell for sure how many service providers operate in the routes of the city which will made it even difficult to manage them the other is there has not been an organized platform that could be used to control and manage the flit operation in and around the city.

2.6.3 Accessibility

Accessibility can be understood as the ease of a service demanding passenger can get a certain mode of public service providers in a reasonable distance in every depots. It is sometimes used to describe the ease of accessing the bus stop or station ((National Center on Senior Transportation (NCST), 2011). Scarcity of transport service providers like taxis and buses especially when compared to the ever growing and increasing demand has been common in developing countries like Africa and some Middle East countries for past century. The transformation of transportations modes from a ancient ordinary animal carts and back of animals to relatively modern one of a collective mass transport has been improving the addressability and the accessibility in time, yet even if the level and the quality of service has been improving, the demand of travelers has been also growing in same rate or even sometimes greater (Robinson, 1978).

Several studies in Transport industry in Addis Ababa city has shown a distinctive gap between the capacity of service providers and their respective potential customers or service requiring population size.

Even if the number of service providers in Addis Ababa are three or four times greater than that of the sub metropolitan cities in the country side like Bahirdar Hawassa and Adama /Nazreth the chance to access to public transport is still difficult to obtain in Addis Ababa as federal transport authority report in 2011. There are different factors that directly or indirectly affect accessibility of public transport among them some may have predominant impact while others share is insignificant. (poonam sharma, 2017) Some of the most commonly known factors are more elaborated in the picture below.

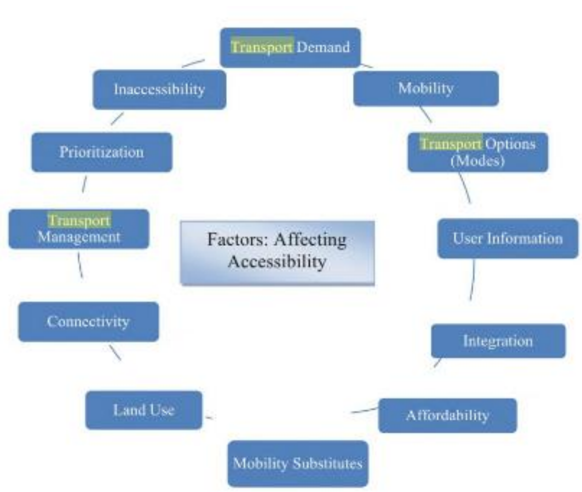


Figure 1: Factors that affect accessibility [source: poonam and Sharma compilation, pg 583]

2.6.4 Acceptability

Acceptability is the other basic public transport quality parameters which measure the willingness of potential users to accept to use that specific mode of transport without hesitation and fear of personal insecurity. Esteemed customers may be bothered by the state vehicle, safety comfort and road experience of the driver they had around to travel on. In addition passengers also consider age of driver, seat availability and sometimes how fast that specific vehicle would let them reach their destination.

In a study made by (asme, 2017) on passenger's preference of mode of public transport on 2010 a sub Saharan passenger commonly prefer to use cheaper modes instead of comfortable and fancy modes.

Comfort of public transport can be seen in different perspectives yet it is mainly controlled by worldwide accepted quality standards. One of these standards is EN 13816, (European standards 13816 accepted by the European Union), is a service standard in public transportation which evaluates the satisfaction level of passengers over a range of factors such as convenience, accessibility, informing, voyage time/duration, customer care, ride comfort, security and environmental effects. In other word Ride comfort is defined as usability of facilities, riding comfort, ambient conditions, complementary facilities, and ergonomic conditions. Another standard we should consider is, ISO 2631-1which is related to mechanical vibration and knock of human body in travelling to a destination which is really difficult to consider in developing countries where there might not be enough seat on vehicle and also the fact that majority of vehicles available are obsolete and are estimated to be aged in between 20 and 30 years. Comfort concept can be even widen to a concepts of ergonomics and ergonomically comfort while travelling for that matter yet still it would sound a bluff to call those parameters as a comfort indices in developing countries like sub Saharan countries.

These acceptability of public transport modes in general falls in a range of mid comfort zone vehicles and budget modes of transportation schemes which can address majority of the traveler population.

The Road network of Addis Ababa can be characterized by severely damaged routes, unmaintained rough roads, streets and uncomfortable sidewalks which are mostly overtaken by small scale street shops and stand selling spots yielding an effect use of pedestrians occupying a vehicle lane. In addition as per a study from (Yohannes, 2017) significantly poor road coverage commonly described as road density which is around 889km per 100km^2 in Addis Ababa paved and graveled which is way less than even neighboring countries capitals (1322km in Nairobi) and (1017 in Kigali) also contributes for the comfort level and which in other aspect affects the acceptability of a given modes of public transportations. (African Development Bank Group, 2013)

2.7 Performance indicators of public transport

Performance of service industries can be easily measured using key performance indices and indicators. Those indicators application may vary from situation to situation, a country to country and other condition but at least they give basic insight about the current status of the service sector. This days throughout world, public transport industry is dominated by the operations of the ‘disorganized’ informal sector (by this we mean market-based, unregulated, low capacity service offers). (Jaramillo P. et.al, 2013)

Amongst the wide ranges of performance indicators of public transportation studied through time Here under is the summary of some of the most commonly used public transport performance and evaluation criteria and indictors.

Total number of vehicles (unit: veh)

This is the total number of passenger vehicles (taxis, cars, buses automobiles and motorcycles) within a given metropolitan area privately owned or used in public transport. In this regard Only active vehicles are allowed to be counted in the, scraps and junkyard collections should be excluded even if they are registered under the regulatory body and bear license plate. (Jarboui, 2012)

Number of vehicles per mode (unit: veh)

This is the total number of motorized vehicles for sorted according to their family or known as mode which are effectively in activity and used for public transportation purpose

Private passenger vehicles per thousand inhabitants

This indicator can be explained as a ratio of active functioning private four wheelers to a thousand population in a community. on the other hand it can also be defined as the measure of the sum of the number of passenger using personal automobiles in and around metropolitan area to the inhabitants of that area which are potential travelers. (Jaramillo P. et.al, 2013) (Robin Carruthers, 2005)

Motorcycles per thousand inhabitants

As the name clearly indicate it measures the motor bicycle population in a predefined area of population. The number of motorcycles in the metropolitan area includes all motorized two wheelers vehicles belonging to households, administrations or companies resident or established another owning groups in the metropolitan area. (BERG, 2005)

Capacity offered per vehicle (unit: place)

This indicator is the average number of available places (seating and standing positions) per unit of each individual mode of transportation. (BERG, 2005)

Average occupancy rate per vehicle (unit: passenger)

The average occupancy rate is a measure of an annual utilization of the average carrying capacity of a given mode of transportation. (Dhingra, 2011)

Average annual mileage per vehicle (unit: km)

This is another indicator where the average annual distance travelled by a vehicle within the limits of the metropolitan area for a purpose of providing a service of public transport. Average annual mile age can also sometimes be known the term live mileage or average live mile age.it is named as live mileage because it excludes dead head runs or in other words dead mileage which is a distance covered by a public transport providing vehicle outside the service operation. (BERG, 2005) (Dhingra, 2011)

Average daily mileage per large bus (unit: km)

This is the Average number of distance in kilometers covered by each active bus in a day. (BERG, 2005) (Dhingra, 2011) (Robin Carruthers, 2005)

Average daily mileage per minibus informal transport (unit: km)

It indicates the Average number of kilometers covered by each minibus per day. (Dhingra, 2011)

Annual total number of passengers per unit per mode (unit: passenger)

This is another indicator which refers to the total number of passengers annually carried by each vehicle of each transport mode. (Dhingra, 2011) (BERG, 2005)

Daily unit trips per collective transport mode (unit: trips)

This is other indicator which is computed as the average number of daily trips carried out by each transport mode. (Hickman, 2007) (Dhingra, 2011)

2.8 Indicators relationship with fleet network

The aforementioned three broad categories of indicators directly or indirectly affects the fleet condition of individual routes in the cities. It’s obvious that each of the indicators have their individual effect on the fleet network yet beyond the weight of individual factors one can summarize that they all have their share on the overall fleet efficiency level. (Agency, 2011)

The point of determining and understanding thus indicators in the first place is to evaluate the current status of the system and in the other way it is to show possible improvement areas. The indicators as mentioned earlier were categorized to three broad categories as quantitative, practical and financial indicators where each of those categories represent plenty of their kinds Specifically. (Niyonsenga, 2012)

For instance considering some of the common qualitative indicators like average minibus fleet operating in a day, average annual mileage per vehicle and Passengers carried per day are directly related with the fleet situation. Whenever the fleet efficiency is improved one way or the other it affects average daily and annual fleets of vehicle to their respective routes and passenger carried annually in general.

considering also the other indicator group like the practical qualitative indicators for instance customer quality service satisfaction percentage would vary whenever fleet addressability shows change of figures. for routes where addressability is assured in appropriate fleet allocation and management the respective satisfaction rate will also be improved. Same effect will be seen in the financial indicators like operating expense per passenger and vehicle revenue per liter of fuel and per trip. Higher level of fleet efficiency which is sourced from effective control and management of trip allocation would guarantee improvement in the financial indicators mentioned above. (Dhingra, 2011)

2.9 Vehicle routing problems

The Vehicle Routing Problem abbreviated as (VRP) is defined as a system which aims in finding optimal routes for multiple vehicles visiting a set of locations. (When there's only one vehicle, it reduces to the Traveling Salesman Problem as (Irena okhrin, 2009). Other scholars also defined VRP as a system which is used to design an optimal route (resource and cist wise) for a fleet of vehicles to service a set of customers, given a set of constraints. It can also be used for application supply chain management, transport services and vehicle resource allocation in the physical delivery of goods and services as per (Bruce G, 2008)

In studying the science VRP it can found several variants of VRP. which are formulated according to the nature of the service or types goods to be transported, the required service quality and the status of the vehicles.

Vehicle routing problem (VRP) has been widely studied in the optimization and operation research science. Several studies like (J.Ramser, 1959) have given insights about routing problems in the late1950s. Since then a series of studies and publication of routing problems has been made and a significant upgrade has been achieved on the concept of VRP. The reason behind why VRP has been widely being studied was because of its vast application and its significance in determining optimum and efficient strategies for reducing costs in distribution networks.

This days size limit of exact VRP ranges from 50 to 100 orders depending variants of the problem and requirement of time response according to (Laporte, 1992) thus this days studies aims in finding an approximate algorithm which can be used to obtain variant solution in limited time which can in turn be used for day to day real life applications like oil depot vehicles and goods distributing scenarios.

Other perspectives from (G.clarke, 1964) and (P. Toth, 2002) define VRP as the problem of designing least cost delivery routes from a depot to a set of geo- graphically dispersed locations (customers) subject to a specified set of constraints.
Other perspective of VRP called Dynamic Vehicle Routing Problems (DVRP), some- times referred to as On-line Vehicle Routing Problems have become an interesting field of investigation for its versatility in processing a areal time inputs in DVRP, some of the orders are known in advance before the start of the working day, but as the day progresses, new orders arrive and the system has to incorporate them into an evolving schedule.

The classical VRP is defined as follows: Let $G = (V, A)$ be a directed graph where $V = \{0, \cdots n\}$ is the vertex set and $A = \{(i, j) : i, j \in V, i \neq j\}$ is the arc set. Vertex 0 represents the depot whereas the remaining vertices correspond to customers. A fleet of m identical vehicles of capacity Q is based at the depot. The fleet size is given a priori or is a decision variable. Each customer i has a non-negative demand q_i. (Beasley, 1993)

2.10 Variants of vehicle routing problems

There are several widely used types of VRP so far in operation science study which may vary according to the number of constraints and other conditions. VRP problems can be classified as a problem type which create taxonomy or a generalized framework that summarizes the existing models, and the objectives pursued and the theories associated with the analysis of the problem. (Reisman, 1992) Here under some of the common types of VRP are tried to be discussed.

Two-Echelon Vehicle Routing Problem (2E-VRP): in this kind of VRP problem goods are delivered from depots to various spots some time known as satellites, or in other word intermediate depots, and then back to the customers as per the discussion from (Cranic G, 2010) this scholars has also pointed out 2E-VRP is characterized by cutting global routing related costs. Other studies from (Gonzalez Feliu, 2008) and (Perboli, 2008) has also discussed about mathematical formulation using two echelon capacitated vehicle routing problems.

Asymmetric capacitated VRP (ACVRP): ACVRP is known to be NP-hard problem and has been in several practical applications like distribution of goods and scheduling of jobs worldwide. A symmetric capacitated VRP usually Indicates that the cost to travel from consumer A to consumer B is different from B to A.

This types of problems has been tried to be investigated in different studies to mention some of them for instance Pessoa et al has mentioned asymmetric capacitated problems can be treated using branch and bound techniques of algorithms (A.pessoa, 2008) other studies from a book entitled the vehicle routing problem latest advancement and new challenges by Bruce G et.al suggest that for this type of problems a robust BCP type of algorithm can be applied to harness a sound result. As clearly indicated in the book a Branch-cut and price(BCP) for the ACVRP can be adapted to its symmetric counterpart(CVRP) (Bruce G, 2008)

Dial-a-ride Problem (DARP): this type of problem is characterized by a need of routing a vehicle on call basis. Some of the common real life examples include ambulances, fire fighters, animal control services and privately owned on call conveyance. Scholars like (Bergvinsdottir, 2004) and (Cordeau J.-F. , 2003) has discussed dial a ride type of problem can be solved using genetic algorithm and branch and cut (Band C) algorithm respectively.

Distance-Constrained Capacitated Vehicle Routing Problem (DCVRP): in this type of VRP problem the commonly considered and usually used restriction on capacity of routes is replaced by the maximum length of the route or the time required to cover the route in the form arc based integer programming formulation according to studies of (Kara I, 2011)

The Emissions Vehicle Routing problem (EVRP): The main aim of this type of VRP is reducing the emission of environmental pollutant and the fuel consumption in the formulated cost function. Some scholars was using the term pollution routing problem(PRP) instead of EVRP (Figliozzi, 1998), (Kwon Y, 2013) some additional extensions have been also made to the formulated reduction of emission and fuel consumption

Generalized VRP (GVRP): this variant is also another extension of the classical vehicle routing problem where an application designing optimal route from the source to collective similar destination which are sometimes known as the node sets. This node sets consists of singular nodes from each of the collective node sets until reached a capacity limitation. This type of VRP has been applied in designing networks for communication and distribution purposes. studies from (R. Baldacci, 2008) has indicated the versatile application of the GVRP.

Location Routing Problem (LRP): this variety of vrp differs from the others it uses a system to solve three problems at a time to find an optimal solution. These three problems are the defining of routes, physical location of nodes and route assignment to available nodes or sometimes called depots. (Min H, 1996) . (Gabor Nagy, 2007) showed LRP can be effectively dealt using both exact and heuristic algorithms where us (Prins C., 2007) showed that Lagrangiean relaxation with granular search can be used to solve LRP. (Kara, 2012) has indicated new mathematical approaches that can ease obtaining of an optimal solution.

Multi-Depot Vehicle Routing Problem (MDVRP): this category of vrp is characterized by having diversified and multiple depots serving a customer. (J.W. Escobar, 2016) has studied the using of tabu search method to solve the multi depot VRP while (Y. Shimizu, 2014) have introduced metha heuristics to analyze larger set of multi depot problems in another level (Vidal et al., 2014) has developed a unified solution frame work to deal with multi-depot fleet mix problems with a relatively higher and unconstrained route or fleet size.

OVRP (Open VRP): this is also another variant where a service provider or a service source is not expected to fleet back to the initial depot after serving the last customer. This type of VRP is most common in food trucks providing home deliveries newspaper distributors and other similar mostly one way fleet systems (A.A.Rahmani H. et. al, 2016) the objectives in OVRP is designing a sets of an open routes to a customer destination. Different algorithms have been tried to solve open route vehicle route problems so far (Xiangyong Li et. al, 2011) introduced A multi-start adaptive memory-based tabu search algorithm for the heterogeneous fixed fleet of open route VRP where as (A.A.Rahmani H. et. al, 2016) used gravitational emulation local search algorithm.

Periodic Vehicle Routing Problem (PVRP): this variant is also common variant where the delivery of routes are only constructed for some time window frame or tie period. It may have about three simultaneous decisions that determine the end optimal solution. Thus are schedule selection for each node, assignment of nodes, routing of the vehicle for the specified time period according to (Peter M. Francis et.al, 2008). (Speranza, 2002) and (Valentina C. et al, 2012) have used heuristics to solve the periodic vehicle routing problems.

Real time dynamic VRP (RTDVRP): This type of VRP is another variant which exhibit an extension of time window and the parameters considered for the problem change from time to time. (Kenny Q. & Kar loon, 2000).Different solving techniques have been applied in course of time for real time dynamic VRP which can accommodate the dynamic nature of the problem parameters. according to (G. Ghiani et.al, 2003) indicated solution through Algorithm and parallel computing strategies.

Split Delivery VRP (SDVRP): this variant came up with a common objective function of minimizing total distance travelled like the classical vehicle routing problem and differs in a way that the necessity of visiting of each customer by exactly one vehicle is removed in the case of split delivery VRP allowing a split delivery (Claudia Archetti & M G Speranza, 2008). Different solving techniques can be applied to split delivery VRP (C. Archett et.al, 2006) used a tabu search algorithm for the split Delivery VRP whereas (J.M. Belenguer et.al, 2000) used exact algorithm of branch and bound approaches.

Stochastic VRP (SVRP): stochastic vehicle routing problem is another variant where constituents of the problem which are the customers visited. Demands at depots and the travel duration are characterized by stochastic behavior. (Chepuri, 2004), different solution approaches have been used to solve this types of problems (Marcella B & J.Pannek, 2018) have tried in two stages recourse model as minimizing of routing plan cost at first stage and minimization cost of corrective actions due to changes in inputs. (Z.shen et.al, 2009) have applied a tabu search heuristics to obtain an optimal solution for such problems..

Time Dependent VRP (TDVRP): this type of variants is distinguished as a vrp problem when a travel time between two nodes is dependent on the geographical distance between them and the time of the day. (M.S. Daskin & C. malandraki, 1992) Defined TDVRP as a vehicle fleet of fixed capacities serving customers of fixed demands at central station where as customers are assigned to routes and vehicles so that total time consumed on the routes could be minimized. (Y.Huang et.al, 2017) tried combining problems of path selection in the road network along with routing decision. Here in such problems any arc between two customers nodes will have multiple corresponding paths in the network.

2.11. Solution methods for VRP

There are reasonably plenty of methods to solve routing problems for vehicles ranging from exact type of algorithms to several types of heuristics and metaheuristics. Most widely used methods are heuristics for exact algorithm techniques don't guarantee finding optimal route in reasonable computing time when number of depots become significantly big.

Exact techniques

Exact algorithm techniques proposes to compute every possible solution until an optimal and best is solution is reached. This type of solution method varies according the result outputs.

Solving VRP was tried to be computed using exact algorithms in the first stages of solving using the likes of branch and bound, branch and cut branch bound and cut and branch cut price algorithms (Cordeau J.-F. , 2003) (Laporte, 1992) (M. Fischetti, 1994)

Exact algorithms have extensively studied in literature for a long time. Most scholars agree on the term that there are 3 commonly known categories of exact algorithms techniques. Thus are

- Direct tree-search methods
- Dynamic programming methods
- Integer linear programming methods

Direct tree-search methods

(Nicos Christofides et. al, 1981) has deeply discussed about direct tree search method and it application on its article for exact algorithm for rural postman problem. The study used nodes on a graph instead of using arcs. The researcher have proposed a formulation for the symmetrical VRP. A symmetrical VRP can be defined on a graph as vertices V and E or G = (V,E) with defined edges instead of arcs. The concept behind is dividing the edge set E in to many subsets , four in this example.

- Ei: Edges not belonging to the solution
- Eii: Edges forming a k-degree center tree where the depot has degree k, $k = 2m - y$
- Eiii: y edges incident to the depot.
- Eiv: $m - y$ edges not incident to the depot.

The objective of this model is to minimize the total cost of the edges satisfying all the demands

Branch-and-bound algorithms this approach of exact algorithm is most of the time used to solve most of the mixed integer programming formulations by relaxing property of the decision variables considered. The starting node for starting the solving procedure will be the solution of polynomial solvable linear programming problem. For every result based on decision variables branching will further proceed by adding additional constraint where variable is relaxed to the nearest integer. hence the upper and lower bounds will be reduced and updated to optimality which intern reduce the branched tree in general.

Branch-and-cut algorithms are other type of approach which are considered as the latest development in the exact solution approaches for the symmetric VRP (SVRP). it is a competitive algorithm for MIP mixed integer programming an exponential number of constraints such as the TSP and VRP. (Laporte G., 2007)

Dynamic programming methods

Dynamic programming is a common term used to describe a programming algorithm where a larger or complex problems is divided down to smaller portions of mini problems which are easier to be solved and in turn can be summarized to a final solution. This method most of the time guarantee optimality along with exact answer.

This programming method has been used to solve real time problem and obtain an optimal solution. Some of those scholars include (Bertsekas, 2007) and (S. Martello, 1999) and (Laporte, 1992)

Specially (Laporte, 1992) formulated a function for traveler sales man problem and optimized cost function. In this function V (S) is a node as the cost of a TSP visiting all customers in S. Then f(k, S) is considered as the minimum cost of serving all customers in S with k vehicles.

$$F(k;s) = \begin{cases} V(s) & K = 1 \\ \min l < s < v \, f\left(k-1, \frac{s}{l}\right) + V(l) & K > 1 \end{cases}$$

The optimal solution is then given by f(m, V). As cons this methods efficiency in terms of computation time is poor therefore it is most of the time it is recommended to add some constraints to reduce the size of the problem. For the above formulated equation the added constraints by (Laporte, 1992) are given below.

$$\sum_{i \in S} di - (k-1)D \le \sum_{i \in L} di \le D$$

$$\sum_{i \in V} di - (m-k)D \le \sum_{i \in S} di \le kD$$

Even if adding extra constraints helps reduce the size of the problem this method is still has its cons for larger sized problems and yet it is not mostly being used in recent researches.

Integer linear programming methods

An integer programming problem sometimes called as integer linear programming(ILP) is the third category of the known feasibility optimization methods where all the variables are restricted to integral denotations.

This type of programming has been also studied and used by several scholars like (Anderesen E, 1995) , (E. Balas, 1965) and (Bazzara MS, 1977). The idea used by those scholars is by preparing a set named J with all feasible routes j then by selecting a subset of routes from J where a customer is visited once with reduced route cost. The general denotation of ILP is expressed as

Maximize $\mathbf{C^t X}$

Subject to $\boldsymbol{Ax \leq b}$

$\boldsymbol{x \geq 0}$,

$\boldsymbol{x \in Z}$,

an in standard form

Maximize $\mathbf{C^t X}$

Subject to $\boldsymbol{Ax + s = b}$

$\mathbf{S \geq 0}$

$\mathbf{X \geq 0}$

$\mathbf{X} \in \boldsymbol{Z}$,

Where C and b are vectors and A is a matrix and S is slack variable

Heuristics

There are commonly mentioned three categories of heuristics for vehicle routing problem thus are: construction heuristics the two phase heuristics, and the iterative improvement.

Construction heuristics. This category of heuristic differs from the others in a way it starts from an empty solution from several feasible alternatives and go to a more optimal solution. It is known that The conventional way heuristics starts from a complete set of solutions and improve the optimality in a series of iterations. (Holger H. Hoos, 2005) used construction heuristics for travelling salesman problems using the concept of greedy heuristics.

The two-phase heuristics this category of heuristics works in principle of dissecting the given problem to two distinctive stages which are customer allocation to route and determining the order of a route visit (S.M.A.Suliman, 2002) used modified permutation flow-shop problem for the single machine scheduling problem two phased heuristics. this solution approach undergoes two stages of a generation of initial job sequence and second one is the generated sequence will be further improved by using a pair exchange mechanism with directionality constraint.

Iterative improvement heuristics.

This branches of heuristics is characterized by having a search method that starts with an initial solution and tries to improve this solution by "local" modifications. Different problem types like Knapsack, travelling salesman and scheduling problem has been tried to solved using this technique (Dorn, 1995)

While using this method it is tried to find an exchange or transfer of customers on a tour that intern improve the final solution in each step.

Metaheuristics

Metaheuristics are the other types heuristic approaches mostly used for complex and sophisticated solving optimization problems. There are different categories of most widely used metaheuristics like metaphor based and non-metaphor based heuristics

Metaphor heuristics consists of algorithms like (PSO) particle swarm optimization, Genetic Algorithm (GA) Water Waves Optimization (WWO), Clonal Selection Algorithm (CLONALG), Chemical Reaction Optimization (CRO), Harmony Search (HS), Sine Cosine Algorithm (SCA), Simulated Annealing (SA), Teaching–Learning-Based Optimization (TLBO), and others (Mohamed A.B. et.al, 2018). The other category which the non-Metaphor heuristics consists of the two most common varianats of Tabu Search (TS) and Variable Neighborhood Search (VNS) heuristics.

Other classification include improved metaheuristics, adaptive metaheuristics and hybridized metaheuristics which has been thoroughly used through time to obtain optimal solutions

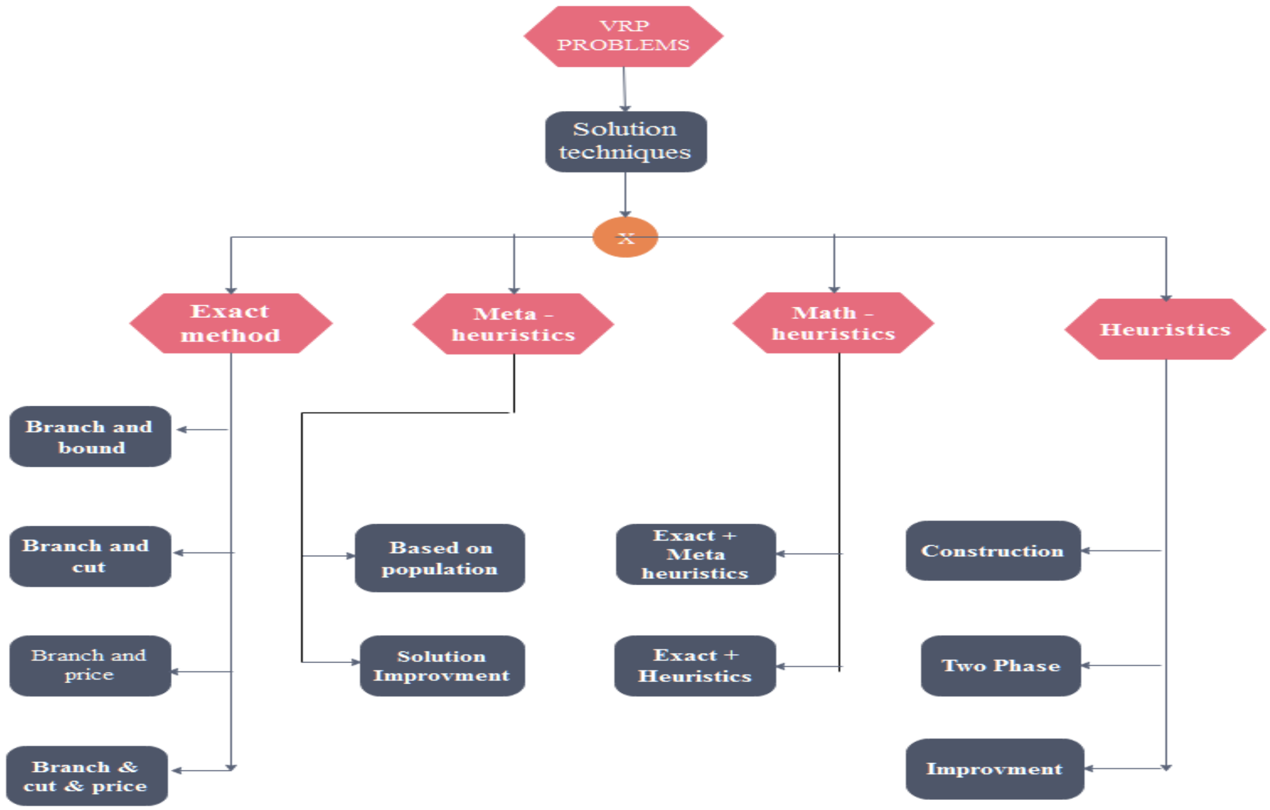


Figure 2 VRP Solution Techniques

Math heuristics

This type of heuristics are known as optimization algorithms made by combination of metha heuristics and mathematical programming techniques.

They include procedures and strategies from metha heuristics and procedures from exact algorithm techniques like branch and bound or branch and cut. Some scholars have tried lagragean relaxation of dynamic programing in math heuristics and has obtained a promising result (chrstian prins, 2007), (Markus leitner, 2008), (Beasley, 1993).

Goal programming

Goal programming can be defined as a branch of multi-objective optimization which itself is a part of multi- criteria decision analysis The rationale behind goal programming is that whether goals are attainable or not, an objective will be stated in which optimization gives a result which is near to desired goals sometime known as satisfying solution. (Lee S.M, 1972)

Goal programming differs from the common linear programing in a way that Goal programing focuses on reduction of deviation between the set or desired value and the final attained value whereas linear programing optimize a single function. (U.C. orumie & D.Ebong, 2014)

There are many time of goal programming among them one is Pre-emptive Goal Programming sometimes refereed as Lexicographic Goal Programming which is characterized by attaining the most important goals in the initial stage and goes down to attain Lesley important goal set. In other word the objective functions that are labeled in priority order in a way the most important goal comes at the top.

Min z = $\sum_{i}^{k} Pi(di\text{-} + di+$

For each of the objectives, a target value or goal would be given which is needed to be achieved. Finally, the undesired deviations d =(di^- ,di^+) from the given set of targets are minimized by using an achievement function (z). In effect, a deviational variable represents the distance (deviation) between the aspiration level and the actual attainment of the goal. Hence, the deviation variable d is replaced by two variables: d= di^- - di^+ where di^- ,di^+ >= 0

No	Goal	Deviation variable to be minimized in Z
1	$a_{ij}x_j \leq b_i$	d_i^+
2	$a_{ij}x_j \geq b_i$	d_i^-
3	$a_{ij}x_j = b_i$	$d_i^- + d_i^+$

Table 2: General structure of goal programing model

Source((U.C. orumie & D.Ebong, 2014))

The other type of goal programming is the weighted goal programming where weights will be attached to the list of objectives to categorize according to their importance.

Weighted goal programming can be used within each group in turn while pre-emptive goal programming is being applied to deal with each group in order of importance. Each priority level (each group) has a number of un-wanted deviations to be minimised. As per the study from (W.Ken et.al, 1996) the formulation of WGP is as follows

$minZ = \sum_{i}^{m}(widi -) + (Widi +)$ where Wi- and Wi+ are numerical weight averages

di- and di+ are deviational variables showing the distance of decision from the goal.

2.12 Route optimization of public transportation

Route optimization is the one of the significant perspective of vehicle routing problem where a fleet characteristics whether it be a number, size or schedule is solved using mathematical modeling to efficiently utilize resources addressing constraints. Efficient management of public transportation starts from planning of transit systems to mobilizing of resources and further engages in over control supervision of the system.

The planning of transit systems can be used for both short-term and long term goals desired to be achieved. The so called Short term plans sometimes called operational planning and a range of medium to long term plans some also known as strategic planning can be incorporated in the broad name of planning of public transit systems.

Most of the time the design of vehicle routes, frequencies and scheduling of vehicles are considered as short-term problems. This operational planning consists of several sequential steps as (Jaramillo P. et.al, 2013)

The first step is the Study of the demand of travels from the different origins to different destinations in the designated geographical location. Determination of Modal split is the next step on third step Design of the lines or routes are made while Frequency determination of the number of passengers for each line is done on fourth step, on the fifth step schedules will be determined while Vehicle scheduling follows and in the last stages Scheduling of drivers and other responsible on spot actors will be made. (Jaramillo P. et.al, 2013)

The first three steps are usually performed by the regulators like the municipality and higher policy developers whereas the last four steps are generally executed by the service operators. (Alberto B, 2003) Solving these routing problems involves a great deal of wide range of operation research methods of formulating a series mathematical models considering several significant constraints. Result obtained is further used addressing public transit planning and further support the process of decision making. The final solution obtained predominantly depends up on the solution of each stage in the series of problems. (Soumia L et.al, 2010)

Route optimization has been thoroughly studied since researches and investigations has started to be published in areas of vehicle routing problem back in 1960s. As mentioned above researchers has been optimizing either vehicle schedules or trip number trip/route distance in different studies the first type of schedule optimization is focused on finding an optimum fleet schedule so that a vehicle can address the demands on depot station where as the second type which is trip or route distance optimization is characterized by determining shortest part from starting depot throughout each node and back to the end depot covering maximum passenger demand in each sub stations. The last one is trip number optimization problem where an optimal trip number will be allocated to different stations having their own routes based on solution obtained after solving. (P k Reddy, 2015)

(Moka E et.al, 2018) has mentioned in his study that worldwide study of the main strategic and tactical steps of fleet planning which are designing and scheduling of network indicated a five step planning process including the network design, frequencies of trips a time table development and scheduling of both vehicle and driver. Basically public transport operational planning is considered to be a complicated multistep process. Thus one needs to dissect the overall situation and treat each complex steps separately and sequentially. Some of the basic steps include the route designing procedure, the time table development and vehicle and crew scheduling.

2.13 Literature summaries

In the course of this study nearly around 52 related conceptual and empirical literatures has been surveyed so as to gain concepts and theories regarding vehicle routing problems and performance measurement and optimization. The review mainly focused on understanding the main objectives of each literature observed along with their approach and their respective results.

Some of the main objectives in the literature typical focus on minimization of route duration, maximizing number of service users, minimization of number of dispatches ,minimizing route length and overall general effectiveness improvement and service quality optimization. For instance authors like (Desrosiers et al, 1986). (Cordeau J.-F. , 2003) (Golden B., 1972) and (Xiangyong Li et. al, 2011) has mainly focused on overall reduction of route duration or dispatch numbers to destination depot.

Those researchers has tried several methodologies to come up with results to fulfill those mentioned objectives some of the common methodologies used include application of Exact dynamic programing, cluster assignment heuristics, Vertex insertion heuristics , Data Envelopment Analysis (DEA) and Goal Programming.

The results obtained basically varies based on their respective objective but it was noted that overall operational efficiency improvement module has been developed in some studies where as some other results were seen by effectively increasing number of service users in the system without deteriorating the quality outputs. In Other more studies it was indicated that it was possible to reduce route duration or the amount of total time a service provider stays in a single service schedule. There was also a result found on reduction of route length covering all the required service with optimally reasonable cost expenditure.

Details of some of the surveyed literatures based on the their objectives, approaches study locations, time window references and results are given in tabular summary format in the appendix section B.

2.14 Literature gap

Enormous vast studies have been conducted on the vehicle routing problem and related fields for quite long time now. Especially after 1980's several scholars and academicians have engaged in studies related to optimization and modeling research areas. The study in transportation optimization sector has ranged from basic travellers sales man type problem in 1970's by pioneer scholars like (Golden B., 1972) to capacitated and time window referred vehicle routing problems to plenty of verities in recent times. The methods used to solve those the afore mentioned types of vehicle routing has also ranged from exact methods of relaxed constraint improvement and exchange to further incorporate heuristics.

One can argue that every detail aspect of vehicle routing problems has been thoroughly covered by different studies for the past 30 and 40 years the argument seems to hold true that plenty of studies can be traced for those varied types problems and solution methods. Scholars have also been even Integrating types of solution methods for versatile problem types. Problem scenarios has also shared their coverage on several studies, single depot to multi depot condition problems, simple to mixture genetic algorithm and further even to sweeping algorithms and ant colony hybridized algorithms have been addressed through times by literatures.

In reference to picking up and loading with multiple depots has also seen the light of different forms of investigations through times yet as far as this literature review was concerned simultaneous pick up and dropping along with presence of multiple depots has been treated as single depot by using Euclidian distance between customer lines using three distinctive stages, these stages include allocating customers or pickup and delivery items to a single delivery centers solving the capacitated time window VRP problem and solving the customer service improvement problems however most of public transport sector problems unlike distribution schemes follow a definite simultaneous pickup and delivery multiple terminal problems along with stochastic pick up and drop off scenarios, thus as complicated as it sound such type of problems should somehow need a considerable attention to be treated in a way considering the actual stochastic nature of simultaneous pick and drop off scenarios.

CHAPTER THREE

3. RESEARCH METHDOLOGY

3.1 Introduction

This chapter discusses about how the pointed objectives would be processed to achieve their required result at the end. It deals with where data will be collected from how they are going to be collected and organized and how it will be analyzed and processed to achieve the goal. Tools and systems to collect organize and analyze data will be briefly discussed in this chapter.

3.2 Case site area selection

Rapid urbanization and heavy migration of population to the capital city of Ethiopia Addis Ababa has led to increased travel demand in the city, triggering a transport crisis like congestion, pollution and others. Dealing with this situation has been a difficult task for the transport bureau and related offices due to ever increasing demand has not been well quantified and addressed. Government has been trying to mitigate the public transport crisis each year. some of the measures taken include introduction of public bus transport providing operators like sheger mass transport share company(SMTSC) and alliance transport service share company(ATSSC) to the market beyond strengthening the already sole operating Anbessa city bus enterprise(ACBSE).In addition Addis Ababa city light weight rail transit has been launched on 2015. The government has also relived custom related taxes for importing of vehicles for public transport sector. Yet the city fleet network related problem hasn't been optimal for the residents for a while now.

The city taxi service (the commonly known as mini-buses) are operated by private vehicle owners whose fleet and fares are controlled by the city transport bureau. Currently the city taxi fleet consists of more than 5000 blue and white painted twelve seated code 1 taxis and more than 6500 unpainted code 2 taxis mostly with 15 passengers seats. Thus taxis operate in currently developed taxi zonal system to cover the routes of the city appropriately. This zonal system consists of 5 zones each consisting of two sub cities with 13 taxi associations with each more than 900 members in them (office, 2017/18) .The details of the zonal system is shown in the table below.

No	Zone name	Regional area	No of subcities	Name of subcities	Routes
1	Megenagna zone	North-east area	2	Yeka and Arada	38
2	Asko zone	Western area	2	Gulele and A. ketema	42
3	Bole zone	Eastern area	2	Bole and kirkos	31
4	Torhailoch zone	South west area	2	Lideta and kolfe	24
5	Saris zone	South east area	2	Lafto and A/kality	31

Table 3: zonal distribution of Addis Ababa taxi network

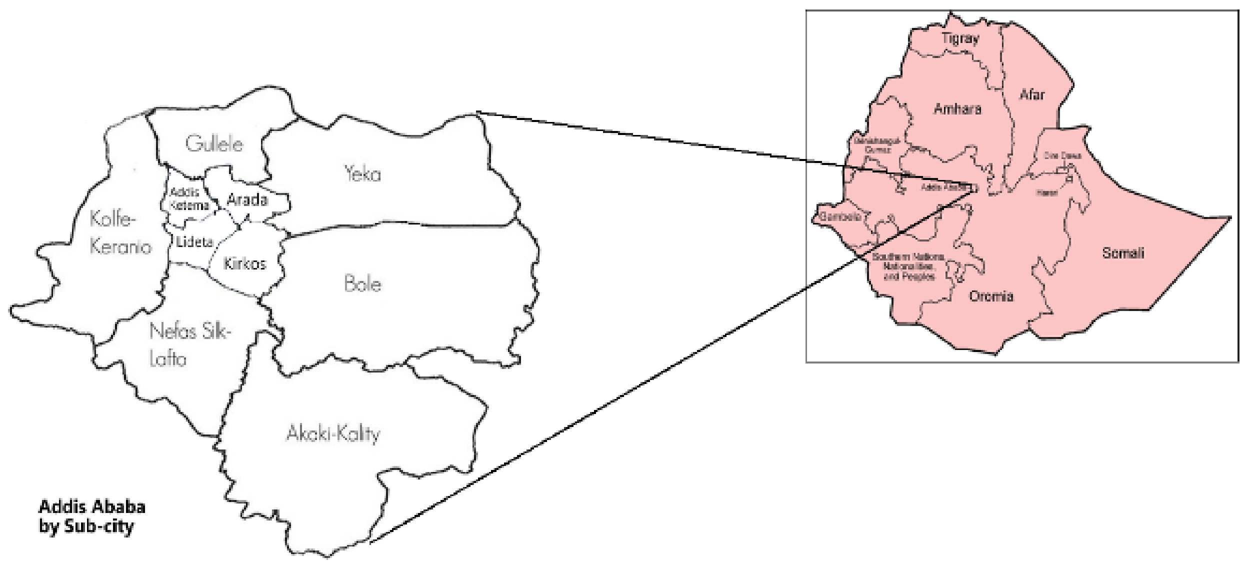


Figure 3 Map of Addis Ababa city and demarcation of the ten sub cities

These factors mentioned under are used to analyze different zones in the city

Here under some basic transport service analyzing factors are used to compare the status of the sample depots from ten sub cities of Addis Ababa. Thus factors are:

I. traveler population density
II. vehicle number proportion(public transport)
III. traveler queue proportion and utilization factor(utilization of vehicle resource)
IV. main Road length and route numbers

I. Traveler population density

Traveler population density refers to the proportion of a given population of an area who ought to travel from a depot to destination using one or many modes of transportation for different reasons.

The current population of the city of Addis Ababa is estimated to be above 5 million. The last census made in Ethiopia was made before 12 years by then the city population was about 2.77 million consisting of 51.8 percent of female and 48.2 and male population (ESA 2000) The annual growth rate was indicated to be about 3.2% in 2012 GC. Computing with this annual growth rate the current population number is believed to reach nearly 4.94 millions. The capital city is divided in to ten sub cities namely Addis Ketema, Arada, Bole, Kirkos, Lideta, Nifasilk Lafto, Yeka Gullele and Akaki kality sub cities. The table below describes the details about population size of the sub cities of the capital along with geographical area and population density.

sub city	Addis ketema	akaki kality	arada	Bole	Gullele	Kirkos	kolfe keranio	lideta	nifasilkl-afto	yeka	Total
Population	450929	324153	375158	545974	472876	390832	906724	356517	557328.4	560375	4940866
population density(psqkm)	60854.12	2745.2	37857	4472.26	15668.5	26733	14804	38836	8160.006	6557.2	
area(km2)	7.41	118.08	9.91	122.08	30.18	14.62	61.25	9.18	68.3	85.46	526.47

Table 4 : population distribution of Addis Ababa by sub cities

As indicated above in the table Bole Akaki Kality and Yeka sub city cover the largest geographical area in the city where as kolfe keranio ,Nifasilk lafto and Yeka sub cities are seen consisting of the top largest number of population size. From this we can also depict that Addis ketema Arada and Lideta sub cities are known for their highly dense population coverage.

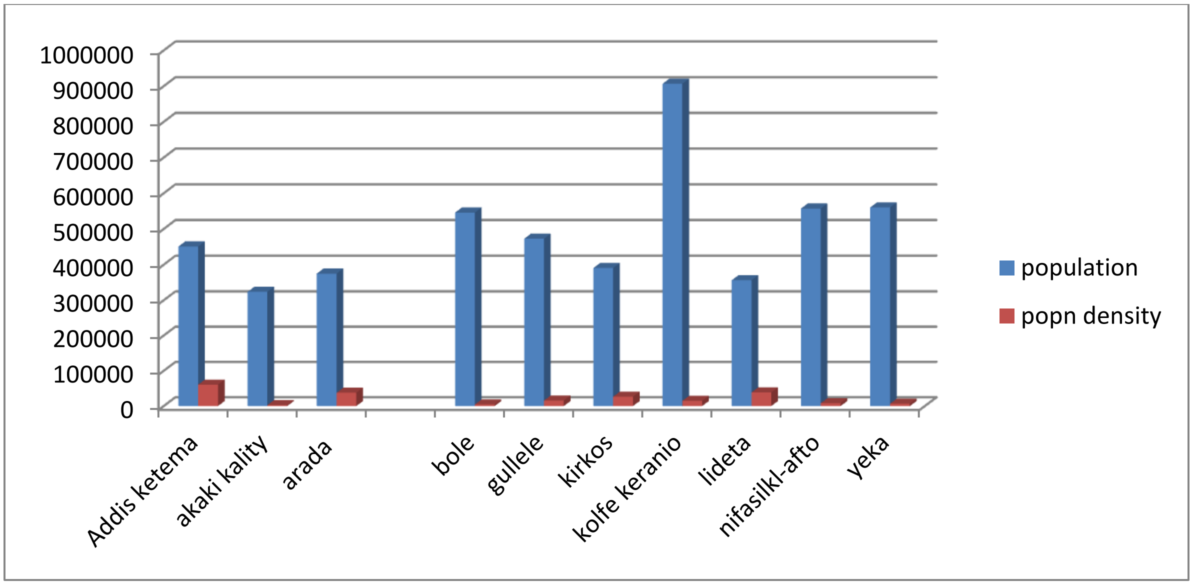


Figure 4 Addis Ababa city population size and population density by sub cities

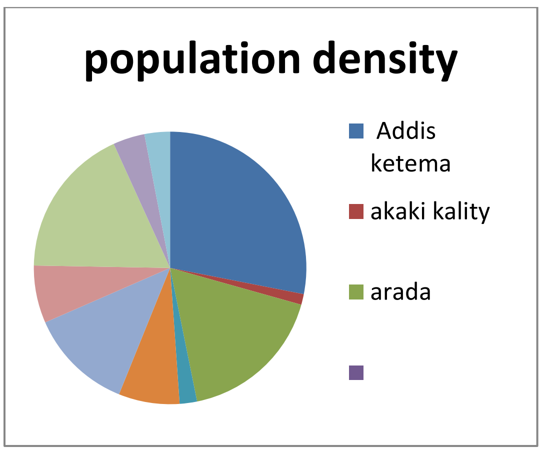


Figure 5. Addis Ababa population density by sub cities.

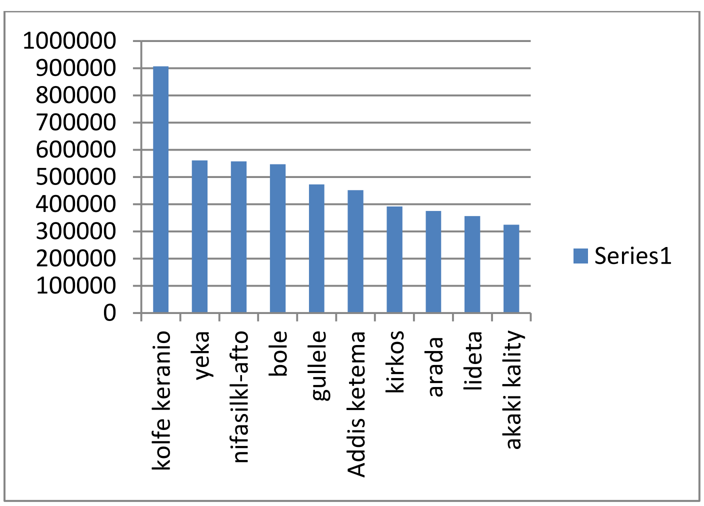


Figure 6 Rank of Addis Ababa sub cities by population size

Its common that population density is directly related with traveler population density thus the above graphs shows most of the travelling population are found in sub cities like kolfe keranio Yeka Nifasilk lafto and bole sub cities.

II. vehicle number proportion(public transport)

public transport vehicles size indicate the total number of public transportation providing vehicles allocated in that given area. Determining this figure is helpful in assessing the condition of the fleet network covered in the area. For this purpose the considered Road public transport providers are ACBSE, SMTSC, mini buses and medibuses since they cover more than 90% of the transportation service in the city private contract taxi light rail transits and private cars are considered insignificant for this purpose. Here under in the table number of vehicle(from ACBSE,SMTSC and medibuses) in the fleet networks of the city is given. Data's of ACBSE is sourced from the company annual report of 2016 whereas data for SMTSC is obtained from annual financial report of SMTSC for the fiscal year 2018.

Accurate data for fleet network of medibuses was difficult to obtain since regulation and assessment of fleets of medibuses is not registered accurately by neither the city transport bureau or sub city branch sectors. Therefore data of annual license renewal registration from the transport office is used as the fleet area of the vehicles.

Here it should be noted that variations in the numbers of total registered medibuses and numbers of vehicles in the fleet may vary accordingly. Since there is a probability of redundancy in a fleet assignment of vehicles as vehicles registered in a single sub city would be operating in another sub city and vice versa.

sub city	Addis ketema	Akaki Kality	Arada	Bole	Gulele	Kirkos	kolfe keranio	Lideta	Nifasilk-Lafto	Yeka
ACBSE	69	57	64	53	64	48	95	66	59	77
Midi-buses	61	49	73	77	51	63	109	84	68	91
SMTSC	13	9	13	12	10	10	16	12	14	15
TOTAL	143	115	150	142	125	121	220	162	141	183

Table 5 Number of operating vehicles in Addis Ababa (ACBSE,SMTSC and midi buses)

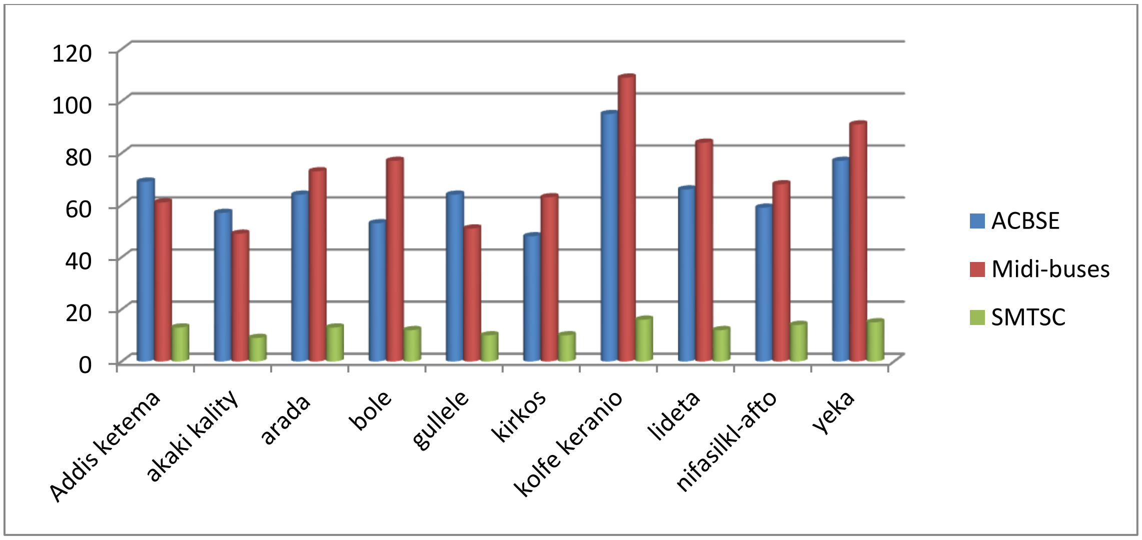


Figure 7 public transport vehicle distribution across the 10 sub cities (excluding minibuses)

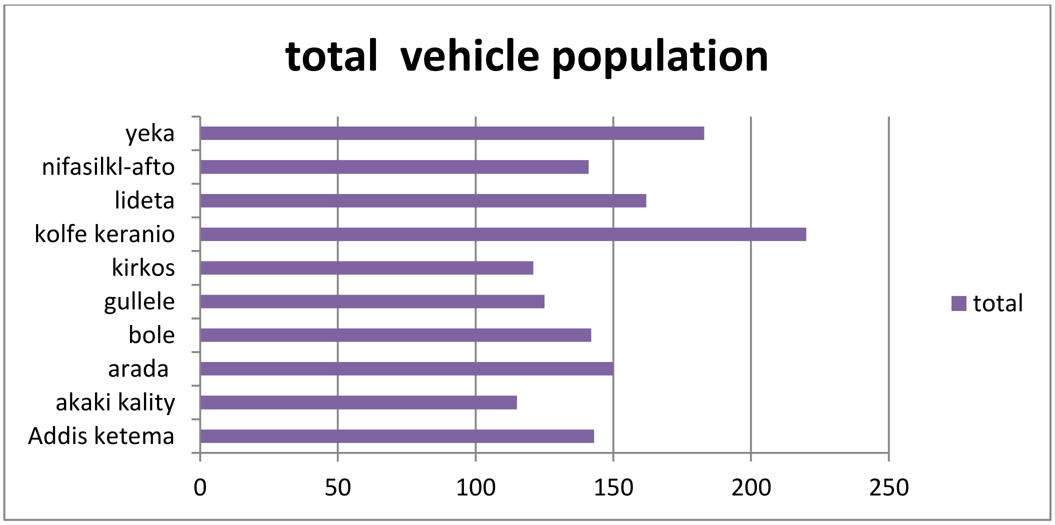


Figure 8 distribution of sum of public transport vehicles by sub cities

From the graph above we can summarize that the largest number of public transport operating vehicles are found in the kolfe keranio, Yeka Lideta and Arada sub cities.

The other main public transport provider are the minibuses which are commonly known as taxis which account more than half of the city transportation service. Currently the city taxi fleet consists of more than 5000 blue and white painted twelve seated code 1 taxis and more than 6500 unpainted code 3 taxis mostly with 15 passengers seats. Thus taxis operate in currently developed taxi zonal system to cover the routes of the city appropriately. The numbers of zones are five each consisting of two sub cities each with a total of 13 taxi associations .

These are mentioned below.

- **Torhailoch zone** : This zone covers fleet networks of south west area of Addis Ababa specifically fleet networks residing in Lideta and kolfe sub city. The zonal dispatch operates in 24 routes with about 1887 twelve seated and fifteen seated traveler van vehicles under two unions or associations.
- **Saris zone** this zone fleet networks of south east parts of the town specifically fleets networks operating in Akaki Kality and nifas silk lafto sub cities this zonal operates in 31 routes with about 2485 twelve and fifteen seated minibuses under three unions or associations
- **Bole zone** . This zone covers fleet networks of eastern parts of Addis Ababa specifically fleets residing in bole and Kirkos sub cities. The zonal dispatch operates in 31 routes with about 1509 twelve seated and fifteen seated traveler van vehicles under two unions or associations
- **Megenagna zone:** This zone covers fleet of north-eastern parts of Addis Ababa specifically fleets residing in Arada and Yeka sub cities. The zonal dispatch operates in 38 routes with about 2779 twelve seated and fifteen seated traveler van vehicles under three unions or associations
- **Asko zone:** This zone covers fleets of western edge parts of Addis Ababa specifically fleets residing in Gulele and Addis ketema sub cities. The zonal dispatch operates in 42 routes with about 2462 twelve seated and fifteen seated traveler van vehicles under three unions or associations

The table found below summarizes the numbers of fleet covered by each associations in their respective zonal dispatches

Zones	**Name of Associations**	**No of route**	**Operating vehicle**		
			Code 1	**Code 3**	**Total**
Asko zone	Selam	24/42	546	781	811
	Fikir	29/42	602		859
	Tila	26/42	533		792
Bole zone	Niser	21/31	497	541	844
	Blen	17/31	471		665
Megenagna zone	Addis hiwot	26/38	506	**1231**	1068
	Tsehay	24/38	617		894
	Zebra	25/38	425		817
Saris zone	Metebaber	20/31	492	996	746
	Bilichta	19/31	428		810
	Walta	22/31	569		929
Torhailoch zone	Goh	19/24	578	855	1044
	Biruhtesfa	15/24	454		843

Table 6 zonal distribution of minibuses in Addis Ababa

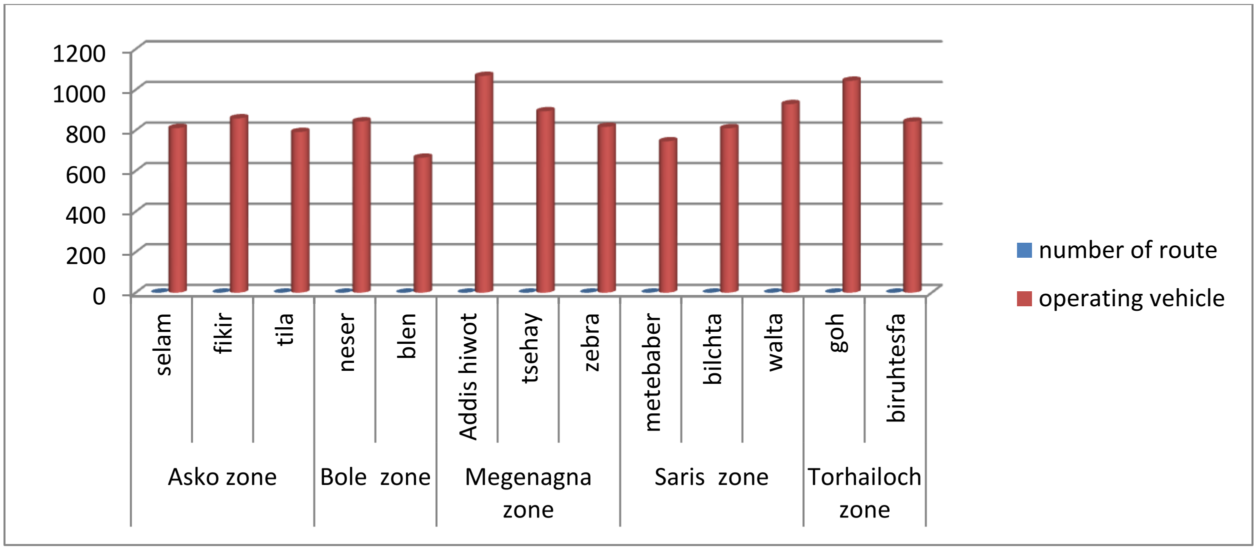


Figure 9 Graphical representation of vehicles zonal distribution in Addis Ababa

We can learn from this graph that fleets in the megenagna and tor hailoch zones are more than the other zonal areas which depicts that traveling demand is higher in those zones specifically the megenagna zone consisting of Yeka and Arada sub cities has larger fleet dispatch hence a larger demand of transport from the a travelling population is on ground.

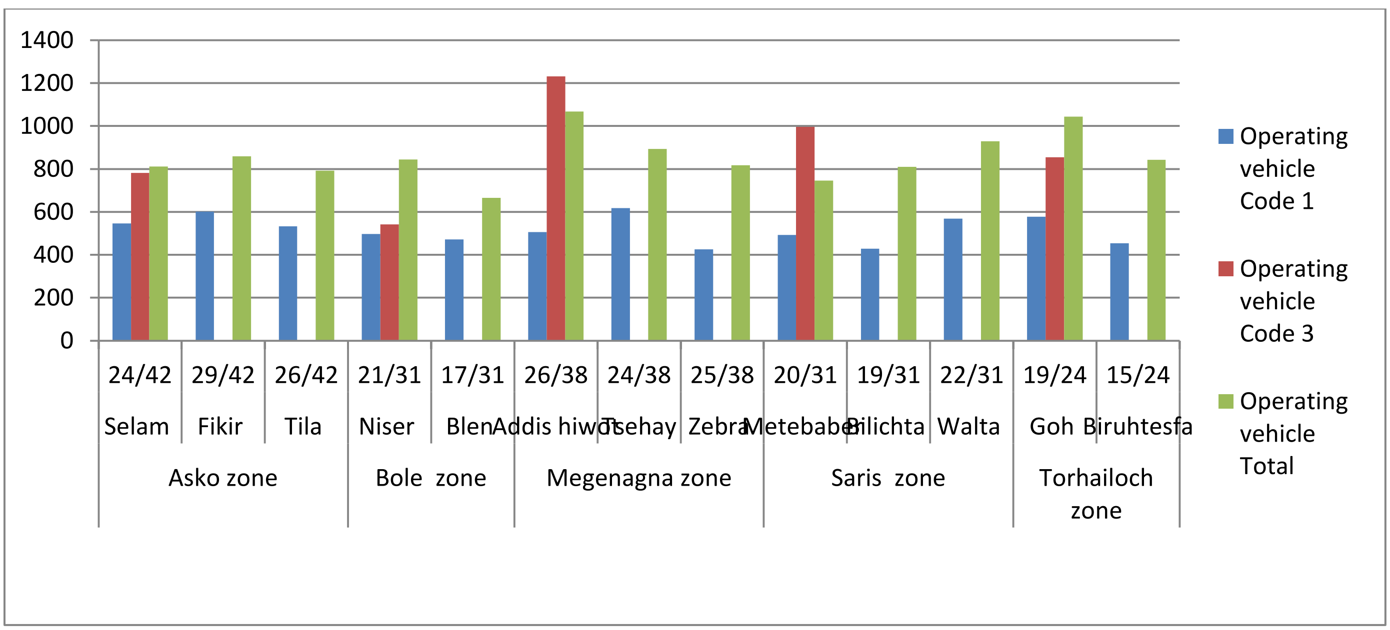


Figure 10 Graphical representation of operating public transport vehicles by fleet zones

Graphical representation from figure 8 and 9 also indicates that even if general population residing in the sub cities like Yeka and Arada are not the highest, public transport vehicle proportion to general population is higher which is mere indication of a larger travelling population is found in those areas!!

III. Utilization factor(U)

It is another factor which indicates how good the server in each depot is servicing its customers and indicating proportion of how much the server is occupied or is in short of. To compute utilization factor of the twelve seated and fifteen seated minibuses in city sample depots from each zones were selected randomly and service rate of the server and characters of the passenger queue was studied to determine the nature of the passenger demand and the ability of the server to meet their demand. Selected Sample depots are shown in figure below along with the route and destination.

				Arrival rate of passenger/hr (λ)		**mean service rate of minibuses /hr(μ)**		**utilization factor(U)**	
Zones	Sample depot/origins	Through	Desti nation	peak hr	normal hr	peak hr	norma l hr	peak hr	normal hr
Asko zone	atobis tera	gojam berenda	Mexico	65	44	48	60	135%	73%
	Asko	Yohannes	Piassa	94	61	66	69	142%	88%
	winget	Kolfe	Torhailoch	76	68	72	74	106%	92%
Bole zone	Bole	Yosef	saris abo	97	56	62	74	156%	76%
	kazanchis	Filwuha	Stadium	65	55	54	51	120%	108%
	Goro	arsema	tullu dimtu	59	48	48	56	123%	86%
Megenagna zone	megenagna	Kebena	Piassa	116	74	79	78	147%	95%
	Kara	Wesen	Lamberet	71	57	42	50	169%	114%
	Piassa	semen hotel	adisu gebeya	64	42	48	45	133%	93%
Saris zone	Saris	maseltegna	Kality	111	89	79	75	141%	119%
	Kality	Cheralia	Wuhalimat	68	55	47	49	145%	112%
	Lafto	Kera	Mexico	84	81	73	78	115%	104%
Torhailoch zone	atena tera	Amanuel	coka cola	45	42	51	49	88%	86%
	Torhailoch	Medida	Bethel	98	75	77	84	127%	89%
	Teklehaimanot	tikur anbessa	bole mickael	76	80	61	65	125%	123%

Table 7: sample Arrival rate and utilization factor of minibuses on fleets origins of the five zones

Then after a passenger arrival rate and server rate of the operators vehicles is recorded in both peak and normal hours since both passenger arrival and service rate differs in the two condition. Peak hour for this study used is time of the day from 7:30Am to 8:30Am and from 5pm to 6 pm and the normal hours taken was from 9:00Am to10:00AM to 2:pm to 3 pm. The passenger arrival rate ,inter arrival rate and service rate on the selected depots were recorded for 5 days and the result has been simulated in excel spread sheet to observe the trend for 200 days.

From the simulation spread sheet the following result were found and respective utilization factor are computed

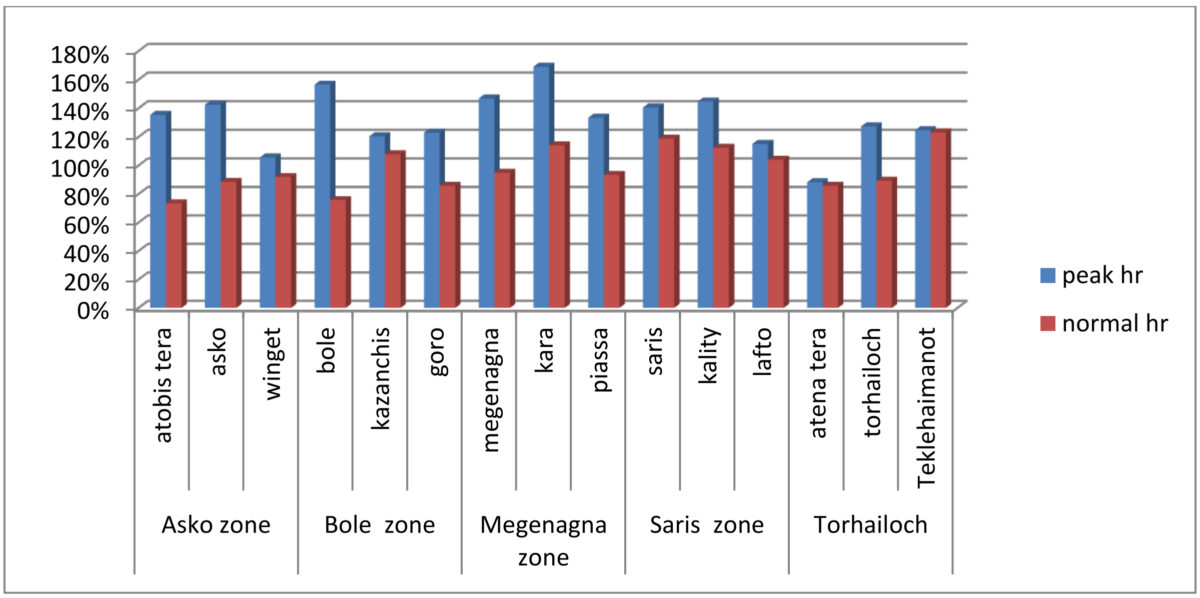
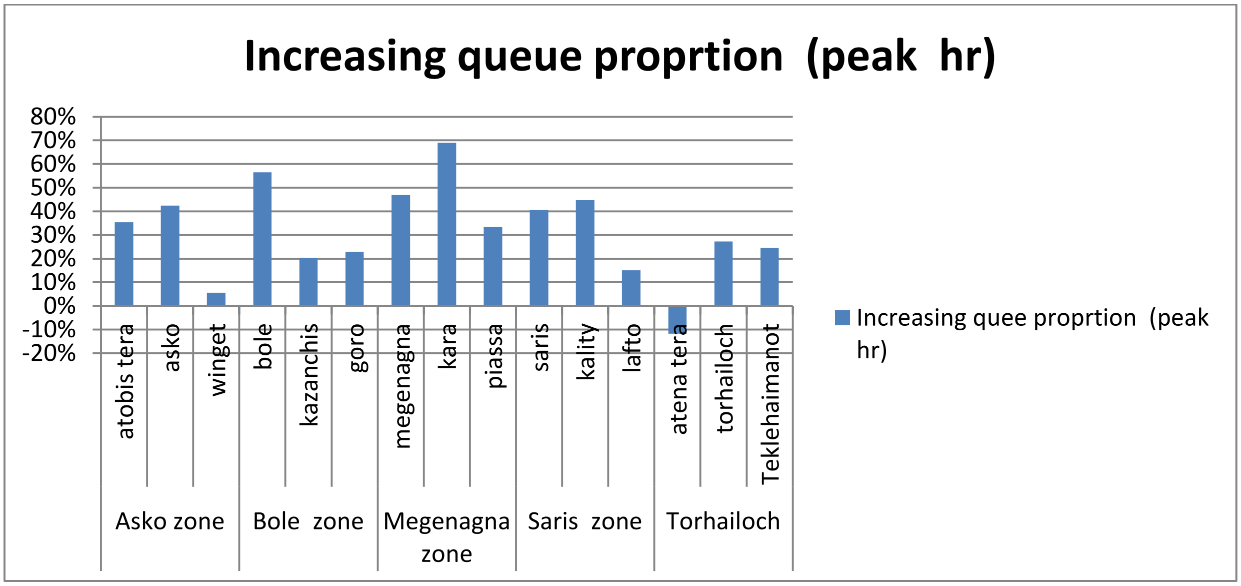


Figure 11 public transport vehicles utilization factor of sample depots in the five taxi zones of Addis Ababa

As shown in the table above the sample depots from the five taxi zones and the server(vehicles) servicing rate are in indicated both for peak and normal hours. Percentile expression above indicates the server is 100% occupied and the figure above the 100% indicates the unserviced remaining travelers which will be accumulated in a queue waiting to be served. For example in the bole-yosef – sarisabo route in the peak hour the utilization factor(U) is 156% this indicates that minibuses available to serve travelers are 100% occupied and there is remaining 56% un-serviced customer increasing queue in the depot or station.

Therefore sorting on the basis of the busiest stations, megenagna zone is the highest or the busiest in the peak hour and saris and megenagna zone are the busiest stations in the normal hours. Whereas Torhailoch zone is the least busiest zone in the peak hours and asko and Torhailoch zones are the least busy zones in the normal hours.



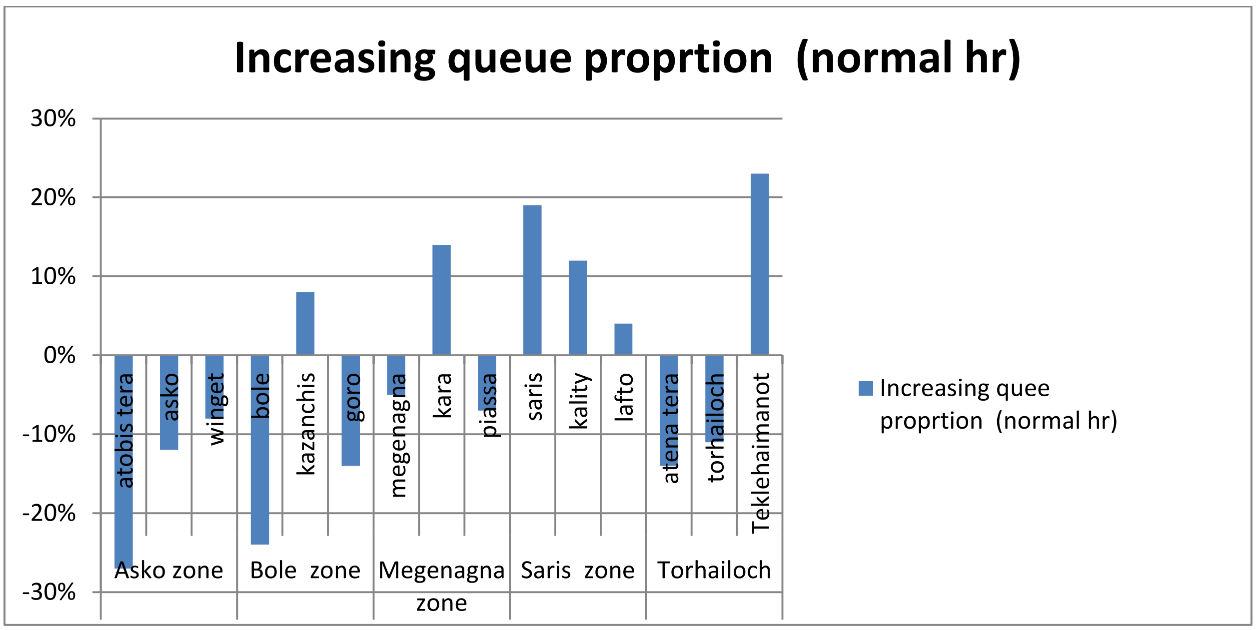


Figure 12: increasing queue proportion of sample stations (after server is occupied)

Iv route size

Taxis of the town operate in currently developed taxi zonal system to cover the routes of the city appropriately. The numbers of zones are five each consisting of two sub cities each with a total of 13 taxi associations .

The five zones along with total number routes they cover are compared below.

Torhailoch zone covers fleet networks of south west area of Addis Ababa specifically fleet networks operating in 24 routes whereas. Saris zone fleet networks covers south east parts of the town specifically fleets networks operating in Akaki Kality and nifas silk lafto sub cities operating in 31 routes. Bole zone covers fleet networks of eastern parts of Addis Ababa specifically fleets residing in bole and Kirkos sub cities. Operating in 31 routes where as Megenagna zone covers fleet of north-eastern parts of Addis Ababa specifically fleets residing in Arada and Yeka sub cities covering a total 38 routes last zone Asko zone covers fleets of western edge parts of Addis Ababa or fleets residing in Gulele and Addis ketema sub cities on approximately 42 routes.

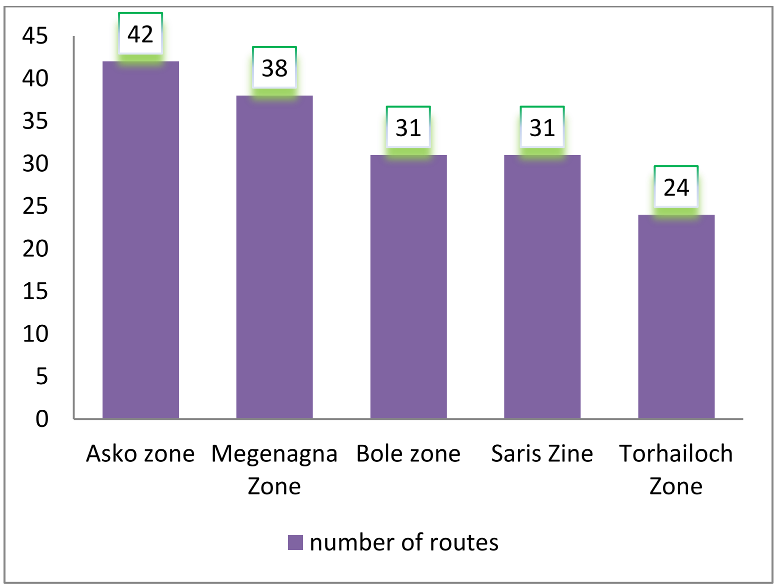


Figure 13 Number of routes of taxi fleets by zone

3.3 Summaries of zone selection

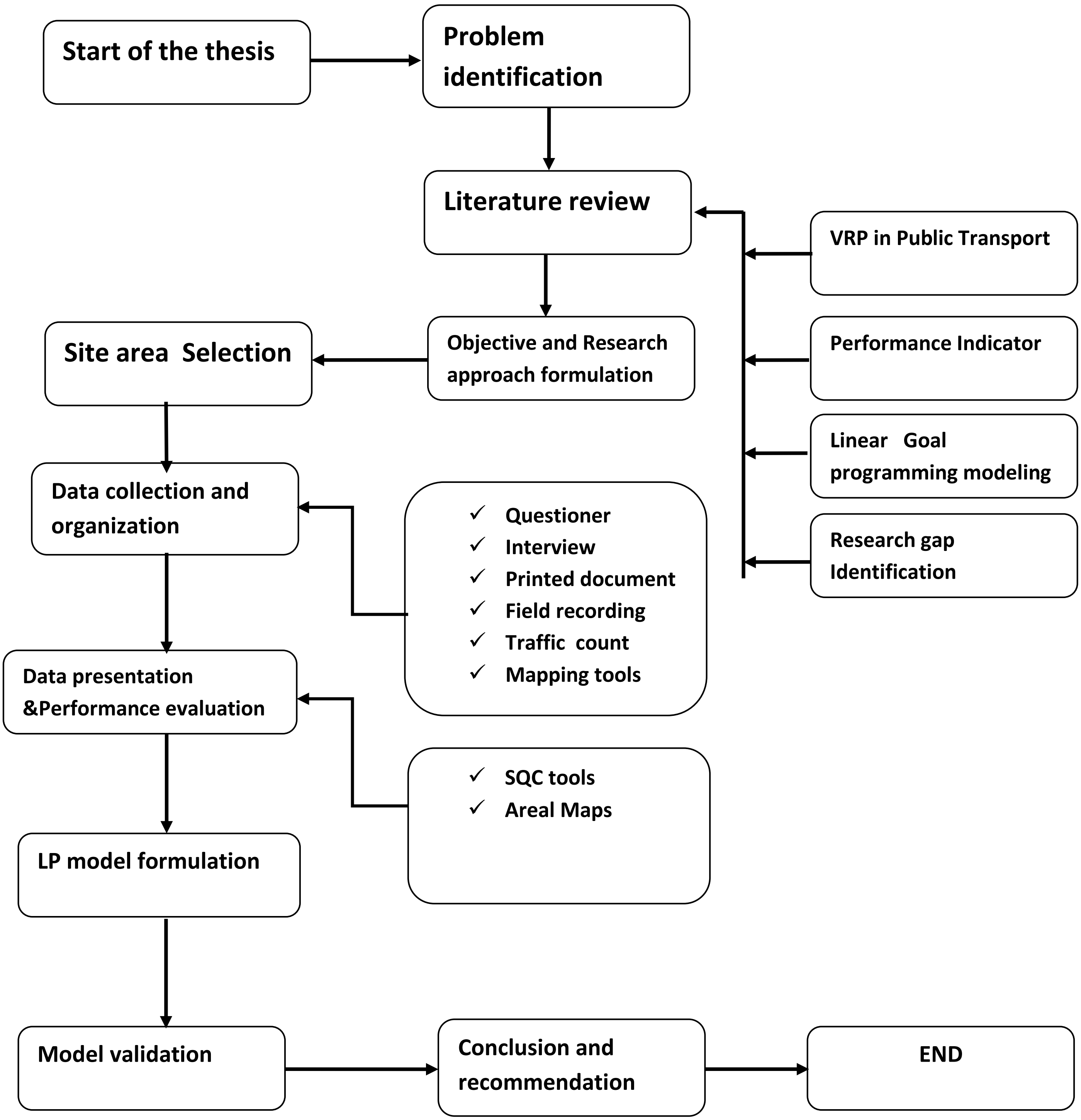
From the data's provided above the five zonal fleet network has been assessed based on traveler population density, geographical area route size or route coverage, server utilization factor or measure of business, and public transport providing vehicles size (buses medibuses and minibuses).

Therefore for the zonal area of megenagna that covers fleets networks under Yeka and Arada Sub cities is selected as case area due to it is among the places where three of the highest traveler population is present. In addition the zone is also characterized by having one of the two largest zones where largest fleets of Anbessa city busses service enterprise, sheger mass transport s.c. and medium sized buses occur.

The other contributing factor is the zonal area is a place for the busiest stations of minibuses fleets the commonly known as taxis and characterized by huge number of increasing number of traveler queue due to every available serving vehicle are utilized and demand exceeds resource specially in peak hours more than the rest zones as per sample study made in sample stations from every zones.

This zone is also a home for the second highest numbers available routes of taxi lines of the city after asko zone which has more than route lines.

3.4 Research approach



i. Problem identification.

The main problem to be studied in this research work is identified in due process of examining the general condition of the transportation service industry. Preliminary observation were made in prior to the start of the study and Indications to incompetence were sourced. Then after the problem was defined in a manner that can be thoroughly investigated in a study.

ii. Literature review

Different types of articles, journals, research papers, conference proceedings, books and related documents on the area were reviewed to gather the different perspectives of the situation. The survey has covered documents regarding vehicle routing problems and types, solutions methods to vehicle routing problems and related Techniques were assessed in addition survey has been made on the ways and experience regarding performance measurement of public transport industries. Programming and linear programming modeling were also given attention in the survey. Concepts regarding linear further more gaps related to the researches and the research area were also identified for better insights of the study.

iii. Objective formulation

Based on the findings of the literature survey research objectives were formulated to best suit the finding needed to be obtained. Both main and specific objectives of the research title were made to be comply along with the conceptual frame work provided for the study.

iv. Data collection and presentation

A. *Sampling Technique*

Based on the scope indicated the number of population that was taken to the study was determined by appropriate and standard procedures of sample size determination. Here the sample size determined include the number of population or customers using the service in the mentioned geographical area, with the respective number of serving vehicles and the fleet routes selected for the study.

B. *Data collection and site recording*

In this stage all the required input data is collected and recorded and further was categorized according to their nature. Two types of data’s were collected as primary and secondary, tools which were used for collecting and recording these raw data include, interview of respected concerned bodies, a structured questioner, an onsite data recording check lists, areal mapping tools and available printed documents from different governmental and nongovernmental organizations.

C. *Types of expected data*

During collection and recording phase, the types of data determined include empirical data regarding Number of taxi/ service providing vehicles, Number of route or network the vehicle are currently operating on Number of stations and terminals used on the network line, Number of pickup and drop off stations, volume of customer serviced in a given trip, operating cost incurred to provide a service per a given customer, time spent by a vehicle to reach a destination from starting terminal and etc.

No	Data collection method	Purpose	Source of the data
1	Literature review	To understand the different ways and approaches that has been used in a study of performance measurement and improvements of fleet networks in transport industry	Different articles and other printed documents
2	Interview	To determine the extent of problems associated with the passenger transport services, the significant factors that has contributed for the current level of quality of service	Different concerned officials passengers, taxi associations, fleet controllers and drivers
3	Questioners	To better assess the level and the extent of level of the service in addition to the addressability of the service sector	Transport service officials, passengers, fleet controllers
4	Observation and On site data recording	To determine the level of performance and the quality of the service like server service rate, queue nature of passengers, possible bottle necks and etc	Different selected stations and depots
5	Traffic count	To analyze the efficiency related to dispatch of taxis on a given route	Selected Sample routes
5	Areal mapping	To assess the geometry , distance and density of the fleet network of northern Addis Ababa and its related efficiency	Site recordings and Addis Ababa city transportation bureau Traffic and fleet management office

Table 8 Possible sources of data for the various data collection methods

CHAPTER FOUR

4 DATA PRSENTATION AND ANALYSIS

4.1 Over view of data collection

For the aim of collecting data from passengers and other related officials a structured questioner and an interviews were prepared and distributed to passengers in different terminal and stations drivers passing through the zonal dispatch area, taxi association officials and terminal attendants an also officials from Addis Ababa road authority and Addis Ababa administration Transport management offices. The interview contained 8 main questions that will help assess the conditions regarding the service quality of the sector, prioritize the main problems out of the whole, possible suggestions regarding bottle necks and others. It was given for 694 passengers 21 drivers, and 16 terminal attendants found in different days and terminals to assure randomness.

A structured questioner was also prepared and dispatched for about 60 personnel on sectors like quality related assessments, quality management techniques, resource allocation strategies and performance analysis guidelines and procedures.

4.2 Sampling technique and Sample size

Sampling is a key aspect in obtaining a convincing results in research and studies, both economically and time consumption wise, researchers are not able to collect data from every source rather they choose representative population from the total population to generalize the result to the entire population. Different types of sampling techniques and sample size determination methods exist in literature depending on the end result required and the nature of and the distribution of the target population. The steps that's should be followed when selecting the feasible sampling method includes defining target population ,selecting time frame , choosing sampling technique , determining sample size and finally collecting data. Hence among the broad category of sampling methods a simple random sampling-probability sampling has been chosen to be used in this study based on the concept of need of every case of the population should have an equal probability of inclusion in the sample.

In this study a proper sample size has been determined in the conventional way of determining a correct sampling approaches using the sample size determining equation

The commonly used sample size determination equation is as follows

$$S= (Z_{1-a}/2^2 P(1-p))/(D^2)$$

Where $Z_{1-a}/2$: is standard normal variate or sometimes called Z score(which can also read from Z score table)

P: expected proportion in a population

D: is absolute error or precision

Therefore using this equation the sample size for making an interview in the megenagna zonal fleet will be completed as such

Considering confidence level 99% or respective Z score of 2.576 and a margin of error as % the ideal sample size therefore will be **664**.

For distribution of questioners it is assumed a reduced value of 95% or respective Z score of 1.96 and margin of error 8% the ideal sample size will be found to be **151**

Finally an arrival rate customers and service rate minibuses in each depots should be determined in the study and since it's difficult to time measure the entire daily weekly and monthly flows of vehicles a proportionate sample time frame is calculated using the sample size determination formula which in turn will be simulated to obtain results on larger time frame basis. Therefore the active time frame for dispatch in the fleet network is considered as 15 hr a day or approximately 900 minutes and thus sample time frame is computed in the above formula with the assumptions of considered above 95% confidence level and 8% error margin, will became 120 minutes which is approximately **2 hrs a day.**

4.3 Primary data

Interview

Among the five zones, megenagna zone has been selected as Site area with its 38 routes 3 taxi association and more than 2700 taxis or minibuses providing service. A total 694 respondents were interviewed in 9 days in the starting depot or destination of the all 38 destinations. Contents of the interview include view of customers on the service quality of taxi transport service they are obtaining, main categories of problems they are facing regarding the condition of the network, sources of those problems, average time it takes them to reach their respective destination, opinions regarding route and road congestion and its contributing factors.

In addition managers of the five taxi associations, traffic controllers and drivers were interviewed about their opinion regarding the performance of the service with its main contributing factors and possible counteracting solutions to problems mentioned. Here its should be noted that Passenger respondent for the interview were interviewed both in normal and peak hours.

Responses from passengers were classified to six main categories as extremely long queues with averagely longer waiting lines., un balanced and biased allocation of vehicles to each route where some routes are very busy that allocated taxis fail to cover the demands of the route where as other routes had excess free vehicles waiting longer hours for arrival of customers. Other quality problem mentioned includes comforts related, road congestion related, and dividing of routes. Summary of the response from passengers about quality of the service is described below.

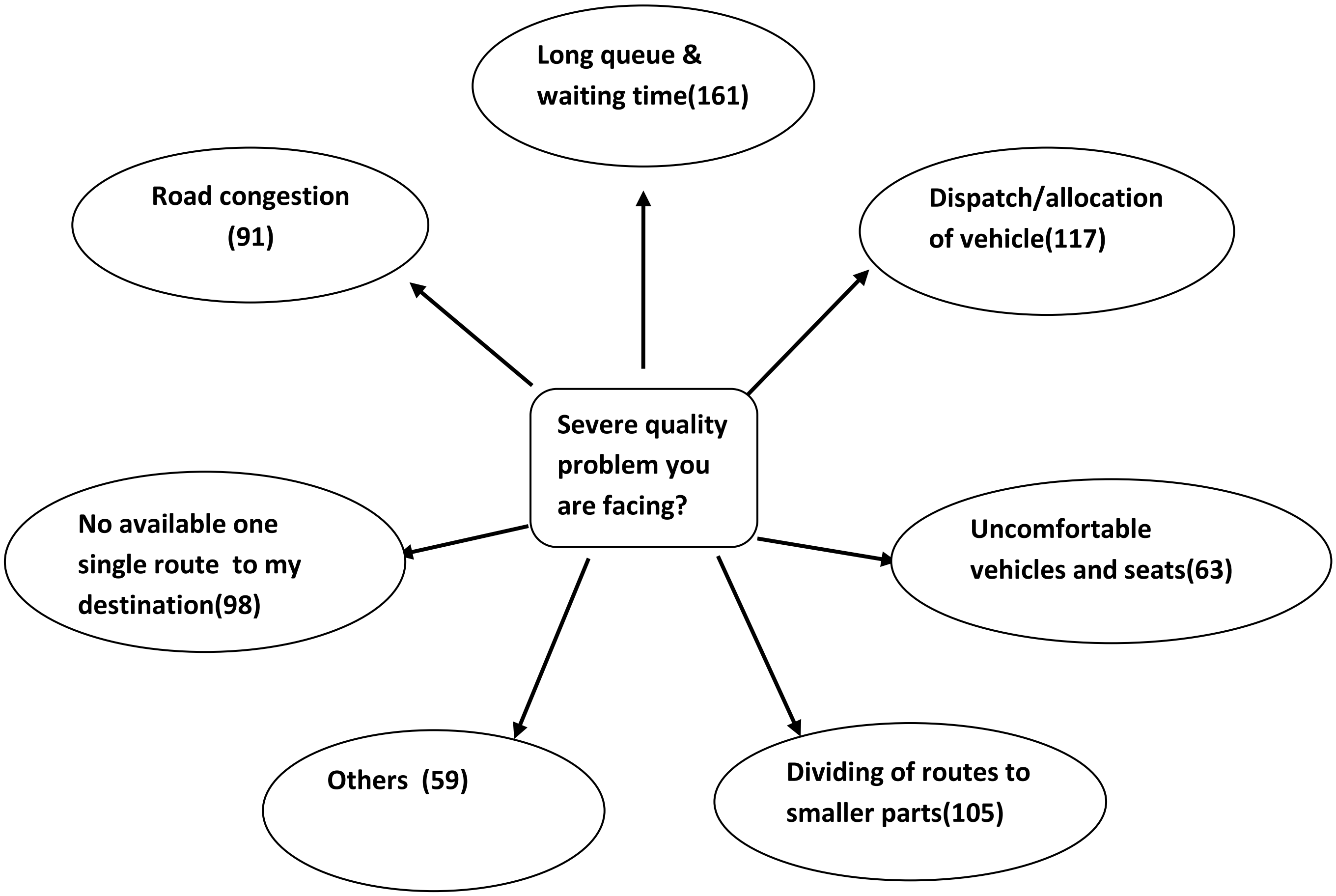


Figure 14: Response distribution of passengers for an interview

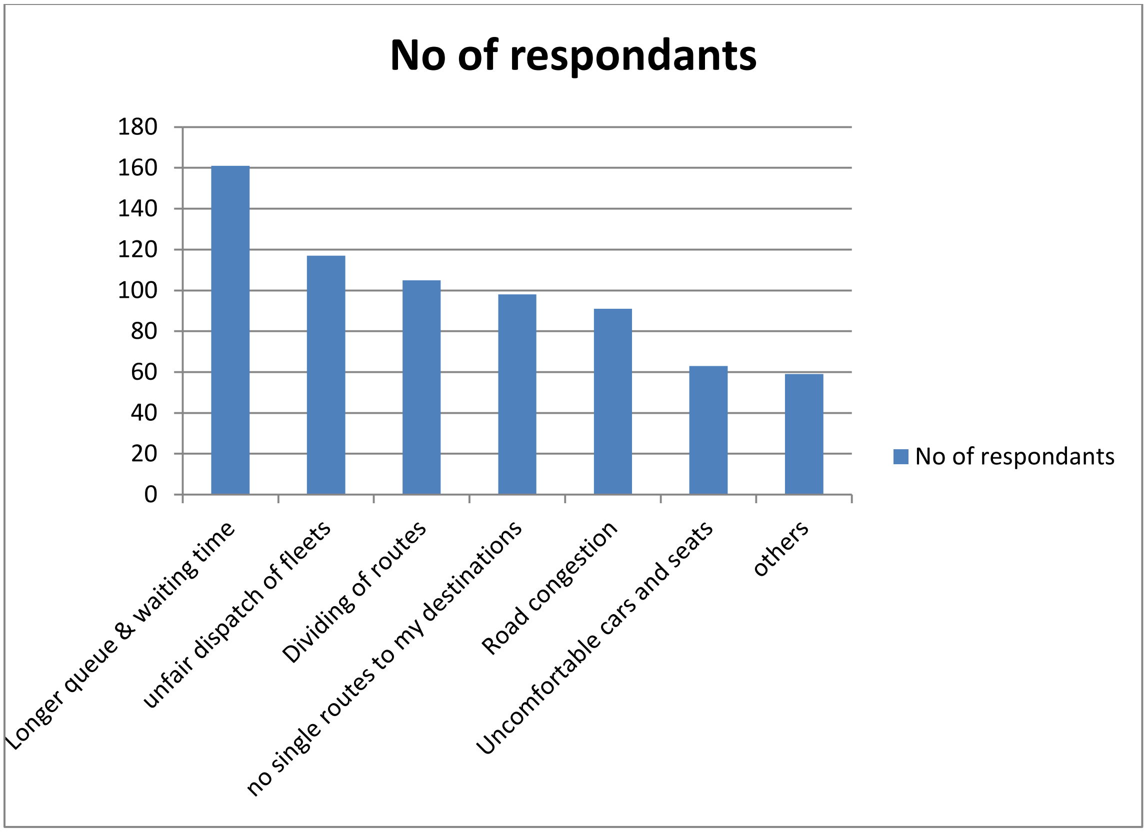


Figure 15 categorization of passenger response in descending order

As shown in the figure above the dominant quality issue of the taxi transportation service on the selected site resides on longer queue lines and a related excess waiting times to be served in addition to dispatch unfairness and dividing of trips to smaller routes by taxis.

Interview answers from officials from taxi associations and drivers on the quality of the service differs from that of the passengers. Most of the problems issued by those officials and drivers include problems related with road congestions, fares and tariffs and severe dispatch related issue in the case of code three minibuses where dispatch is made by respective sub cities transport management offices.

Questioner

A semi structured questioners were also prepared for different target groups from the transportation industry those concerned bodies include sub city transport management offices, taxi association officials and dispatch controllers,

Summaries from the questioner is indicated below

Respondent	**Contents**	**Responses**	**remarks**
AATMO Taxi associations	Common complaints	Minibuses Allocation, new route, tariffs, traffic and route selection related	
AATMO	Service evaluation	Is made twice a year Non scientific Analyze service performance evaluation by only active vehicle on the route. Vehicle and road maintenance problems	
AATMO Taxi associations	Feed backs from evaluations	New routes needed More vehicles needed Subsidies should increase to reduce tariffs	
AATMO Taxi associations Terminal attendants	Basis for Route dispatch	Personal preference by drivers Previous allocation schemes Arbitrary demand evaluation Vehicle flow Availability of other alternatives Road condition	
AATMO Taxi associations Terminal attendants	Opening of new route	Based on request from either driver or customer Field analysis of route cycle is done Trial for two month Making of Permanent route	

Table 9: Summaries of questions and responses on questioner for transport bureau officials

Data from site recording

The following data were collected from field on sample stations trips and destination depots.

- ✓ Arrival time of passengers and respective service rate
- ✓ Traveler profile
- ✓ Trip pattern
- ✓ Operating routes
- ✓ Number of operating vehicles and taxi associations
- ✓ Dispatch allocation
- ✓ Accident

4.4 Secondary data

Taxi associations for Addis Ababa taxi network

In order to provide taxi service in Addis Ababa specifically in code 1 minibus taxi service the city administration requires vehicles to be registered in taxi association of their choice and get route plate accordingly. Currently there are 13 taxi associations operating in Addis Ababa having more than 6500 code 1 minibus taxis. Each taxi associations assign based on the drivers and owners interest and control the fleet of their respective drivers. The five main zonal dispatch locations has from two to three associations operating in them. As indicated in table 7 the details of the 13 taxi association and their operating zone are describe.

From the table above it can be seen that asko and megenagna zone taxi association dispatch largest number of vehicles to the available routes more than the other zone. In the contrary associations from Torhailoch and bole zone are seen to be dispatching relatively lesser number of code 1 taxi minibus to the system here it is needed to be noted that code 1 taxis are dispatched on the basis of drivers or owners preference whereas code 3 taxis are allocated to each route by sub city transport bureaus.

Vehicles operating in megenagna zone

The sample zone which is megenagna station is one of the busiest stations of the town every modes of transportation is found in this zone larger buses, midi buses , taxis private contract and overhauling taxis trains and private vehicles, since the focus of this study is about only minibuses or the commonly known as taxis. There are about 38 routes under this zonal dispatch where most of them resides in the Yeka and Arada sub cities. Here for a given route to be considered in a specific zone the criteria behind is the origin of route to reside in on of the stations found in the zone and most of the voyages the vehicles make should be in the spatial area of that specific zone.

This zonal dispatch was started in 2003 e.c to tackle the very low performance of the then service industry which failed to address the demand of the population of the city. since then transportation service providers specifically minibuses and medibuses were dispatched based on this zonal dispatch program.

There are both code 1 and code 3 minibuses operating in those 38 routes where dispatch allocation for code 1 taxis easily distinguishable as being painted as blue and white is made by taxi associations formed by owners of the vehicles whereas for code 3 one which are not obliged to get painted to a specific color, the allocation was made by respective management offices.

For code taxis vehicle allocation to a given route is done according to the will of the driver of owners of the vehicles, thus they are made to provide choices of their own route to operate once every three month. Therefore accordingly they are given route plate to operate on. Whereas code 3 taxis' vehicle allocation is made by sub city transport management offices based on the flow of passengers. Drivers are obliged to cover their given route and are prohibited to jump routes which are not indicated on the route plate they receive from transport bureau.

There are totally 1548 code 1 taxis operating in three distinctive taxi associations and about 1231 code 3 taxis assigned by sub city transport offices. Actively operating taxi number varies from time to time even within a week since there are plenty of maintenance breakdowns and shifting of routes by vehicles is predominant.

The table under describes number of each taxis by their association and fleet coverage.

Zone name	Vehicle type	Taxi Association	Covering route	Taxi Numbers	
Megenagna	Code1	Addis hiwot	26/38	506	
		Tsehay	25/38	617	
		Zebra	24/38	425	
	Code 3	-	36/38	1231	
TOTAL				**2779**	

Table 10: Number of minibuses operating in megenagna zone

Route lines in megenagna zone

There are 38 distinctive routes consisting of about 60 terminal and more than 100 sub stations in megenagna zone dispatch area. Distance in each of the route lines varies from 2.8 km to 19.6 km while time of travels reach from 20 Minute to 90 minute. Here under the table details of each routes and respective allocation of vehicles by associations is described. For convenience each of the routes are denoted by a respective alphabetical code to distinguish one from the other.

No	Route	Denotion	Distance	code 1			Code 3	Total
				A. hiwot	Tsehay	Zebra		
1	4killo -6killo – ferensay - biretdildey	A	6.2	21	0	0	16	**37**
2	4 killo-6killo-41eyesus	B	4.6	0	2	9	19	**30**
3	minilikschool-6killo- bella	C	4.4	11	4	25	22	**62**
4	abakiros RA-nibu michael-bole arabsa	D	6	0	0	7	36	**43**
5	altad mikael - urael stadium	E	6.8	32	11	0	39	**82**
6	gursholla-balderas-biiherawi shebelle	F	10.2	18	0	12	47	**77**
7	bella-janmeda -6killo –raguel	G	6.4	26	21	0	28	**75**
8	ferensay -giorgis –raguel	H	7.3	19	25	0	14	**58**
9	hayat RA-abakiros RA-tafo-mishen	I	8	0	43	6	32	**81**
10	kazanchis - filwuha-t/haymanot - atobis tera	J	6.8	0	0	4	35	**39**
11	kazanchis total- 4killo-piassa - autobis tera	K	6.1	19	0	4	39	**62**
12	kazanchis -4killo-shiromeda	L	6.7	24	22	0	28	**74**
13	lamberet-kebena-4killo-piassa autobis tera	M	11.2	17	41	23	34	**115**
14	lamberet-bole michael-saris -kalitymeharia	N	19.6	4	6	0	26	**36**
15	megenagna-cmc-semit RA	O	7.4	18	48	0	44	**110**
16	megenagna-wesen-kara-yekaabado condo	P	12.2	0	17	0	36	**53**
17	megenagna - bole-saris kality meneharia	Q	17.8	26	0	14	29	**69**
18	megenagna - kazanchis total- 4killo- piassa	R	6.7	0	18	17	33	**68**
19	megenagna-shola-lamberet-kotebe- kara	S	6.3	26	16	26	37	**105**
20	megenagna mizan - gurd shola -meri-hayat	T	8.8	29	18	35	48	**130**
21	megenagna-mizan-stadium- tegbared	U	10.1	17	0	12	45	**74**
22	megenagna -kebena -silase -goirgis	V	7.3	29	31	24	33	**117**
23	megenagna- gurd shola-hayat- abakiros RA	W	11	0	0	15	43	**58**
24	megenagna -kebena-4killo-piassa- mesalemia	X	7.9	23	78	16	48	**154**
25	megenagna-aware-banko de roma-tana	Y	8.2	26	55	22	32	**146**
26	diaspora- adwa -aware-arbengnoch bulding	Z	5.1	0	39	11	25	**75**
27	minilik hospital -giorgis - autobistera	AA	6	0	24	49	21	**94**
28	minilik hospital-giorgis raguel	AB	5.1	18	0	15	28	**61**
29	shiromeda-silase- kuskuam	AC	2.8	6	0	1	8	**15**
30	shiromeda-4killo-estifanos-stadium	AD	6.8	27	22	0	47	**96**
31	shiromeda-giorgis autobis tera	AE	6.4	18	19	0	36	**73**
32	shiromeda-tabot maderia-kidanemihret	AF	2.8	14	4	0	17	**35**
33	shiromeda - menen - giorgis -raguel	AG	5.1	0	24	19	24	**67**
34	shola-kebena-piassa-19kutr mazoria	AH	6.4	29	0	38	38	**105**
35	shola-kebena-6killo-piassa	AI	4.1	6	16	0	44	**66**
36	megenagna signal-kazanchis - mexico	AJ	6.6	0	7	11	47	**65**
37	shiromeda-4 killo – filwuha -mexico	AK	7.2	3	0	0	35	**38**
38	4killo-tourist-filwuha-ambassador	AL	3.2	0	6	10	18	**34**
	TOTAL			**506**	**617**	**425**	**1231**	**2779**

Table 11: Summary of route lines and vehicle allocation of megenagna zone

(summarized from data from three association and yeka sub city transport office)

As per the table above code 3 minibus taxi are allocated in all 38 routes while code 1 taxis allocation range from 21 to 26 routes. Route lines from megenagna to Mesalemia has the largest vehicle allocation with around 154 minibus taxis from the rest of the routes where as Shiro meda to kuskuam mariam route exhibits the least vehicle allocation with only 15 vehicles operating. Generally the routes with largest vehicle allocation include route line like megenagna to semit, lamberet to autobis tera, megenagna to hayat RA, megenagna to Mesalemia megenagna to giorgis, shoal to 19 kutr mazoria and megenagna to Tana mall (mercato) each having more than 100 vehicle per route allocation. There are around 2779 total vehicle (code 1 and code 3) allocated for the 38 routes which brings as an average of 74 vehicles per route.

4.5 Data from site recording

Arrival pattern of passengers

Arrival pattern is a scheme that indicate the frequency of passengers arriving at depot or stations to get a service from a server. In this case a total 46 stations from 38 routes and 15 sub stations were selected to assess the arrival pattern of customers by time recording. For convenience purpose and due to significant difference in arrival pattern of passengers and service rate of medibuses differ in significant figure, the time gap has been divided in to two shifts namely normal hours and peak hours. The basis to divide the shift accordingly was the general assessment of mobility of the town in general.

A working hour considered for this study is from 6:00Am to 9 pm with a total of 15 hours. But as per responses from interview of many drivers actual working hour is between 8 and 9 hours a day. Thus out of the total 15 hour peak hour is labeled as the time from 7:00 AM to 10:00 AM and from 4:00 PM to 7:00 PM with a total range of 6 hours, whereas the remaining time from the total time frame 6:00 AM to 9:00PM is labeled as normal hour. A normal hour has a total of 9 hour span covering about 60% of the total time and the remaining 40% is peak hour span. Then after a time measurement was made for four hours per a route terminal in two days where 2 hours of arrival time of passengers were recorded in peak hour and the other 2 hours were allotted for normal hour arrival recording. The gap of arrival of one passenger from the next passengers ranges from second to minutes thus the measuring unit for arrival time recording used is the smallest unit which is second and later converted to minutes and hours.

Some routes has two or more sub stations therefore Arrival rate of that route is assumed to be the grand summation of arrival rate of each sub stations. For example a route from milinilik hospital to autobis tera through giorgis has three substation namely minilik hospital station, 6 killo and giorgis therefore Arrival rate of this route is found by grand summation of arrival rates in each of the sub stations.

Arrival time collected in each of 38 routes for 2 hours a day and 4 hours totally per route was used as initial data and used as an input pattern to simulate arrival rate of passengers for 60 hrs or nearly 4 equivalent working days. Generating data of the poison arrival rate for wider span of working hours helps in making the collected data reliable. The generation of data as per the collected pattern was made by Microsoft excel 2010 and result arrival rate is considered as the average arrival rate of that specific route. Here under in the table the computed final arrival route of the 38 route is indicated whereas the details of random data simulation is mentioned in appendix part.

Route denotation	Distance (km)	Arrival rate/hr (normal hour)	Arrival rate/hr (peak hour)
A	6.2	145.3	354.7
B	4.6	69.3	260.2
C	4.4	252.7	536.2
D	6	96.1	404.8
E	6.8	314	830.7
F	10.2	285.3	813.2
G	6.4	432	674.3
H	7.3	222.7	532
I	8	197.3	597.3
J	6.8	124.7	502.8
K	6.1	244	560
L	6.7	391.7	779.3
M	11.2	301.3	751.3
N	19.6	229	356.2
O	7.4	326	833
P	12.2	220	820.2
Q	17.8	268	479.5
R	6.7	398.3	675.5
S	6.3	476	1076.8
T	8.8	391.3	886.7
U	10.1	398.3	554.2
V	7.3	396	493.5
W	11	291.7	422.1
X	7.9	770.7	1293.2
Y	8.2	554.7	871.5
Z	5.1	279.4	563.5
AA	6	312.7	686
AB	5.1	366.7	498.2
AC	2.8	69.3	459.7
AD	6.8	354.7	905.3
AE	6.4	325.3	775.8
AF	2.8	152.3	329.3
AG	5.1	305.3	593.8
AH	6.4	375.3	757.3
AI	4.1	381.3	810.8
AJ	6.6	416.0	859.8
AK	7.2	309.3	602
AL	3.2	144	357

Table 12: Average Arrival rate of passengers in megenagna 38 routes

Service rate

Service rate is a measure of how much the server is meeting the demand of service at a work station. In this case the servers are code 1 and code 3 minibuses having carrying capacity of 12 and 15 passengers respectively. As mentioned above allocation of minibus taxis is made by personal preference for code 1 taxis and city transport management offices for code 3 taxis. For determining of service rate, stations used for recording arrival rate are again used. Like arrival rate distribution, service rate is also recorded in both normal and peak hours for 2 hours a day and 4 hours per route totally. Data obtained from recoding of service rate is used as a pattern to expand the time span to 40 days which equals 600 hours using Micro soft Excel 2010 that intern increased a confidence level of certainty in the collection of data.

In most routes origin station can be three or more since drivers breaks routes to several parts leading to creation of several sub routes. Therefore average service rate of a given route is considered as a summation of all small origins station in the main route.

The details of service rate computation and data generation for a span of 600 hours is found at last part of this paper under appendix section.

The table below indicates the average servicing rate of minibuses in the 38 routes

Route denotion	Distance (km)	Service rate/hr (normal hour)	Service rate/hr (peak hour)
A	6.2	154	252
B	4.6	84	154
C	4.4	252	336
D	6	168	280
E	6.8	280	504
F	10.2	252	448
G	6.4	210	420
H	7.3	224	392
I	8	266	434
J	6.8	98	336
K	6.1	378	406
L	6.7	322	476
M	11.2	392	504
N	19.6	182	182
O	7.4	406	504
P	12.2	196	420
Q	17.8	308	336
R	6.7	294	448
S	6.3	364	532
T	8.8	448	462
U	10.1	350	294
V	7.3	490	420
W	11	294	308
X	7.9	784	588
Y	8.2	616	532
Z	5.1	350	476
AA	6	336	420
AB	5.1	294	280
AC	2.8	84	308
AD	6.8	364	504
AE	6.4	280	336
AF	2.8	126	112
AG	5.1	280	266
AH	6.4	420	336
AI	4.1	406	294
AJ	6.6	350	378
AK	7.2	364	336
AL	3.2	182	210

Table 13 Average service rate of minibuses on the 38 routes

Trip pattern

Trip pattern is indicator which indicates where does most of passengers demand to go or travel or in another word it gives insight where is most passengers destination spot and where is the travel density is tilted to. it helps to analyze the demand distribution among different stations and terminals. Further it helps to make optimized and efficient allocation of limited resource to better use. Trip analysis was made in megenagna zone with the help of **ADOBE ILLUSTRATOR ®** with built in mapping tool. The result from trip analysis showed the weight of trip demand and directions where allocations should be focused. A total of 38 routes of megenagna zone were assessed with an input data of arrival time of passengers. The picture below illustrates the trip patterns of megenagna zone and its routes

Figure 16: trip pattern result from Adobe illustrator for megenagna fleet zone (illustrated on oct 2019)

After obtaining the average arrival rate of passengers on all 38 routes respective numbers of trip demands were computed. As computed above there are two types of vehicle whose carrying capacity is 12 and 15. For convenience purpose an average number of passenger seat which is 14 is used to determine the trip demands of passengers since arrival rate is different on normal hour and peak hour so does the trip demand in this context.

	TOTAL TRIPS		Trip demand		Trip Allocation	
	Demand	allocation	Normal hr	Peak hr	Normal hr	Peak hr
A	245	222	93	152	115	107
B	156	210	45	112	109	101
C	392	434	162	230	226	208
D	235	258	62	174	134	124
E	558	492	202	356	256	236
F	532	462	183	349	240	222
G	567	525	278	289	273	252
H	371	348	143	228	181	167
I	383	567	127	256	295	272
J	296	273	80	216	142	131
K	397	434	157	**240**	226	208
L	586	518	252	334	269	249
M	516	690	194	322	359	331
N	300	216	147	153	112	104
O	567	660	210	357	343	317
P	493	318	141	352	165	153
Q	378	345	172	206	179	166
R	546	476	256	290	248	228
S	768	630	306	462	328	302
T	632	780	252	380	406	374
U	494	444	256	238	231	213
V	466	702	255	212	365	337
W	368	348	188	181	181	167
X	1050	924	495	549	480	444
Y	730	816	357	374	424	392
Z	421	525	180	242	273	252
AA	495	564	201	294	293	271
AB	449	427	236	214	222	205
AC	242	120	45	197	62	58
AD	616	576	228	388	300	276
AE	542	438	209	333	228	210
AF	239	280	98	141	146	134
AG	451	402	196	255	209	193
AH	566	630	241	325	328	302
AI	593	528	245	348	275	253
AJ	636	390	267	369	203	187
AK	457	228	199	258	119	109
AL	246	272	93	153	141	131
Total	**17974**	**17472**	**7449**	**10526**	**9085**	**8387**

Table 14: Trip demand and vehicle allocation in the routes

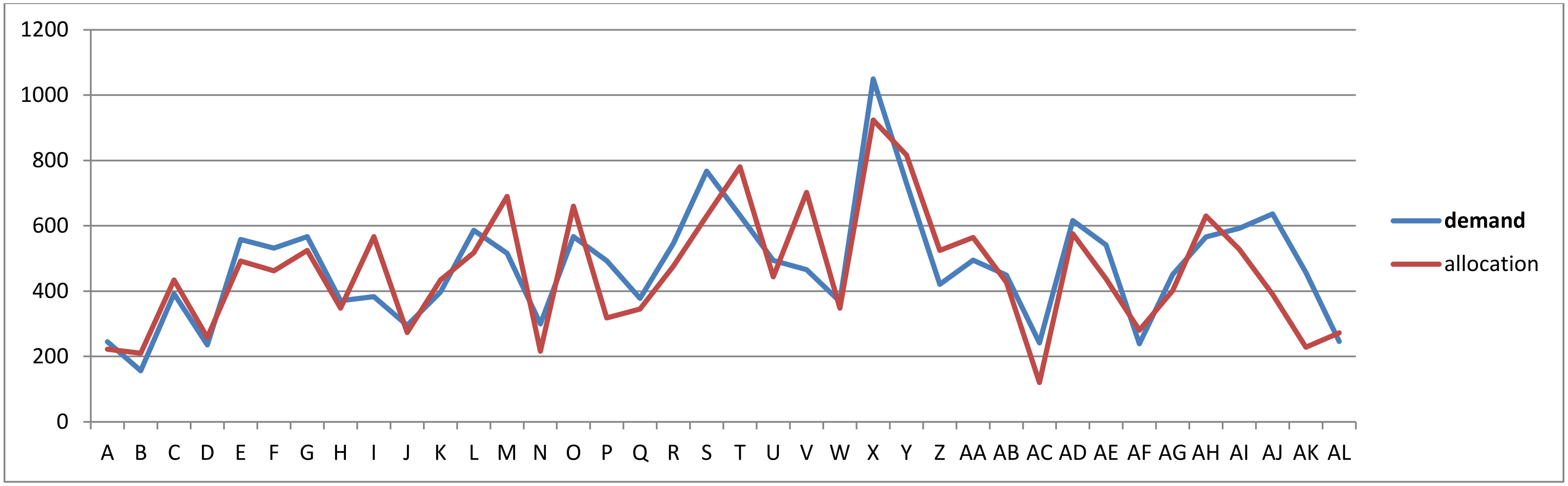


Figure 17: Trip demand and allocation distribution for all routes

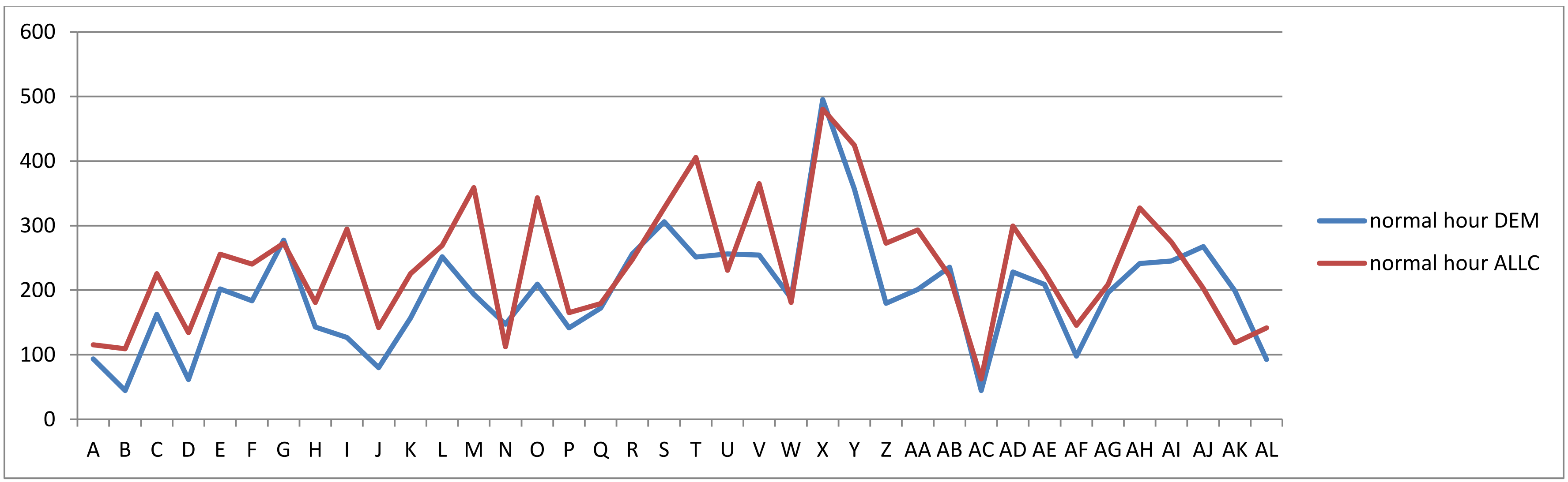


Figure 18: Trip demand and allocation distribution in normal hour

Figure 19: Trip demand and allocation distribution on peak hours

Observation from those three graphs indicates that there is significant difference between actual demand of trips by passengers and vehicles allocated to those routes. in routes like I ,M ,O ,T, Z and AH it is seen there are plenty of allocated vehicles in normal hour even if the demand in those areas are few where as in the routes like G, N, U and AB is demand is yet not covered by allocated vehicle. Let's for instance consider route H and I, in routes H demand is higher than I but when we see the allocation, route I allocation is higher than H. this case scenario is seen in most of the routes which indicate there is unbalanced and biased allocation of resources in those areas.

4.6 Performance analysis

Performance is a common term we use to indicate a measure of how well a server is functioning towards a defined goal. Performance of minibus taxi service and the fleet network can be measured in different ways like indicated in the literature review. Here under performance status of megenagna zone taxi fleet network is analyzed based on selected key performance indicators.

Quantitative indicators

I. Total vehicle population (TVP)

Total vehicle population (TVP) is a measure of the total amount of active public and private motorized vehicles used for transportation purpose only residing in a specific area. TVP excludes trains, heavy duty, construction oriented and other vehicles whose tyre number is below four like rickshaws.

The vehicle population is megenagna fleet zone residing on both Yeka and Arada sub cities is code 1 minibus(1548), code 3 minibus(1231) Anbessa bus(141) sheger bus(28) medibuses(164) and collective hailing taxis(311) and private cars (above 36000)(2010E.C) providing a total sum number of 39243 vehicles.

II. Average minibus fleet operating in a day

Average minibus fleet operating per day is a measure of mean of active transport providing minibuses code 1 minibuses and code 3 minibuses in Ethiopian context. Data obtained from Addis Hiwot, Tsehay and zebra taxi associations indicates that there are a total of 2779 registered minibuses on the route, though due to frequent maintenance breakdowns, and other personal problems the mean number of active minibuses were 2638 (nearly 94.5%)from May 2010 to February 2011 ec as per the associations 3rd quarter report.

III. Passenger vehicles per thousand inhabitants.(PVPT)-minibus

Passenger vehicles per thousand inhabitant is the ratio of public transport providing vehicles residing in a specific area to a size of one thousand population. here the indicated population is the total residing population which is a sum of travelling population and non-travelling population.

$$\text{PVPT} = (tot\ \ vehicle\ \ no\ x\ 1000)/(Total\ population)$$

$$\text{PVPT} = (19246\ vehicle\ x\ 1000)/935532.9 \quad = 20.57 \text{ vehicles}$$

When compared to PVPT of African cities like Nigeria (Lagos) 60, south Africa (cape town) 172 and Algeria (Algiers) 311 and international cities like Brussels (Belgium), Rome (Italy), London (united kingdom) and Madrid (Spain) 511,646,473 ,514 respectively, the capital Addis PVPT is shows significantly lower value and it needed to grow vigorously to cope with those African and international cities.

IV. Average occupancy rate per vehicle(unit passenger)

It is a measure of passenger carrying load capacity of different sized vehicle. In Addis Ababa context it is average carrying capacity of code 1 blue and white code 3 traveler vans. Code 1 blue and white minibuses' passenger carrying capacity is 12 travelers on 12 seats and code 3 traveler vans has a carrying capacity of seated 15 passengers. In actual case carrying load of these two types of traveler vehicles may reach to 19 passengers specially in peak hours, though according to regulations of federal transport bureau exceeding the pre-defined seats number is a violation of traffic regulation. Thus extra passengers carried in this manner is not considered for this study.

Carrying capacity = $(code\ 1\ CC + code\ 3\ CC)/2 = \frac{12+15}{2} = 13.5 \approx 14$ passengers

V. Total number of routes

It is a measure of the available functional main and sub road network designed according to traffic flow of passengers.

Sources from sub city Traffic management offices has reported that megenagna zone consists of 38 routes each having different size of route length. Route length of these routes range from 2.8 km to 19.6 km with a total sum of route length of 281.6km

VI. Total trip by vehicle

Total trip indicates the total amount of voyage made by one allocated passenger vehicle in a given scheduled time.

In most of 38 routes the operating 2779 code 1 and code 3 minibus taxis made from 5 to 8 trips daily which gives us a daily average of 6 trips this data was obtained from three sources

a. Terminal attendance: terminal attendance is a form carried by terminal attendants in each terminal for the checking up of the signing in of a scheduled vehicle at the scheduled time. In the megenagna zone there are 6 daily terminal attendants to control the voyages of minibuses and midi buses. data from those terminal attendants and their check list indicates that by average a vehicle sign in six times a day.
b. Traffic count: it is video aided counting of passing vehicles in a specific route in the daily operating time. In a traffic count made on some stations and routes, it was learned that an average of 6 -7 trips are made by single vehicle
c. Driver interviews and questioner: in a interview made for 32 minibus taxi drivers the average trip(or the commonly used term biajo) is about 6 – 7 in nearly 9 hours of their operating time of the entire 12- 15 hrs of the total shift time. Indicating that most of the time they will stay off service from 11Am to 3:pm

Thus daily trip on route A with 37 minibus taxis to serve becomes around 37x6= 222 total trips and daily trip on route B with 30 minibus taxis to serve is also around 30*6 = 180 total trips

Likewise the Total trips in all 38 routes is computed as such.

$$\sum TT = \sum TA + \sum TB + \sum TC \ldots . \sum TAL$$

Where TT is total trips

TA is tot trips on Route A

TB is total trips on route B and as such

$$\sum TT = 222 + 180 + 372 \ldots\ldots 204 = 16674 \text{ trips a day}$$

VII. Average annual mileage per vehicle(unit: km)(mpv)

Mileage per vehicle indicates the total length a passenger vehicle travels to serve the public annually. A daily average of 6 trips by a single vehicle gives as about 16674 trips daily on all 38 routes. In a single trip a vehicle covers from 2.8 km to 19.6 km depending on the total distance the route covers thus

Mpv = $(\sum \boldsymbol{RD\ x\ DT})/\mathbf{38}$ where RD is route distance

DT is daily trip made by a single car

Thus Mpv = (6.2 x 6) + (4.6 x 6) + (4.4 x 6). . . . . .(3.2 x 6)/38

Mpv = 54.6 km/day (excluding travel to depot from home and vice versa)

Annual MPV = 54.6km/day x 297 = 16216.2km/yr

VIII. Terminals to total route distance (TTD)

It's a measure of ratio of available terminals and the total route distance covered by vehicles

TTD = $\frac{\text{RD}}{\sum \text{a}-\text{an(Terminals no)}}$

Total terminal numbers is computed to be 172

TTD = 281.6/172 = 1.64km

Therefore there is 1 Terminal every 1.64 km

Here terminals number are assumed to include main terminal along with sub terminals and loading and unloading depots on that route.

IX. Passengers carried per day

It indicates the total amount of passengers that is able to be travelled by a minibus taxis in that specific zone .it is computed that multiplying the average carrying capacity of a single car by a total number of trips made in that zonal routes.

Therefore PCPD =TT x CCC

Where TT total trips

CCC is carrying capacity of a single car

As such PCPD = 16674 x 14 = 233436 passenger daily

X. Percentage load factor

It is a measure of comparison of passengers carried to un carried passenger in other meaning it is the ratio of total demand of passenger on the route to the actual transported passengers.

Percentage load factor(plf) can be expressed as ratio of carried passenger to uncarried passenger thus from above calculation we have obtained that daily carried passenger are indicated to be 233436 passenger whereas uncarried passenger is determined by computing uncovered trip demands due to short allocation. In mathematical expression it can be stated that

uncarried passenger =$\sum_{1}^{RN}(D - A +) * \ CC$

*= (23+66+70 ………..229)*14*

*=1888 trips * 14passenger*

=26432 uncarried passengers

Thus ratio of carried passenger to uncarried passenger is

CP:UCP 233436:26432 which is equivalent to

CP:UCP = 8.9: 1

Thus we can conclude that for every 89 carried passenger there is eleven uncarried passenger in this specific dispatch zone.

Or in other word out of every passenger who ought to be transported by minibus taxis 89% of them will be served while the rest 11 % will be obliged to look for alternative modes of transportation.

Summary

From the above performance indicator it has been seen that the public transport sector of the capital Addis Ababa is measured to be below average when compared to some international and continent wide standards. In the table below the summary of those mentioned indicators are given along with some national and international standards.

No	Indicator	Result	Standard	Remark
1	Total vehicle population (TVP)	39243		All type of public transportation vehicles
2	Average minibus fleet operating in a day	2638		nearly 94.5% of the available vehicle
3	Passenger vehicles per thousand inhabitants.(PVPT)-minibus	20.56 veh	Br(511)Ro(646) Uk(473)	Significantly lower than those cities
4	Average occupancy rate per vehicle(unit passenger)	14 passengers		
5	Total number of routes	281.6km		
6	Total trip by vehicle	16674 trips a day		
7	Average annual mileage per vehicle(unit: km)(mpv)	16216.2 km/yr		
8	Terminals to total route distance (TTD)	1.64 km	400-500meter (Asia)	
9	Passengers carried per day	233436 passenger daily		
10	Percentage load factor	*8.9:1.1 (CP:UCP)*	>=98%	*89.8% will be served while 10.2 will look for alternatives*

Table 15: Summary of quantitative indicators for public transportation

Practical indicators

I. % passenger satisfaction with public transport quality

II. Fare affordability

III. Modal share

I. % passenger satisfaction with public transport quality

Passenger satisfaction rate indicates whether the customers or specifically passengers of a specific mode of transportation felt satisfied with the service they are obtaining. This data has been obtained from interviewing 694 passengers and 58 drivers terminal attendants and 200 questioners distributed to officials of the sector and taxi associations.

As per the data obtained from those interviews and questioners,379 passengers has responded they are satisfied with the current service yet they also mentioned that an extra effort is needed on some sectors from the transport officials to make the service quality even better whereas 313 passengers has responded in a way that describes the current service quality they are getting from minibus taxi services is below average and it is way so far to feel satisfied with it mentioning all the drawbacks of the service. other 2 respondents were didn't give response to this very question. In other hand data from questioner indicates that from 127 passengers 74 of them mentioned they are satisfied whereas the rest 53 felt unsatisfied with the current performance of the sector

Therefore in a summary 55.2% of the sampled passengers were satisfied by the current service quality where as 44.5% has pointed out they were not satisfied.

Satisfied why	No	**Unsatisfied why?**	
Better mode of transportation(than bus, medibuses and trains)	290	Availability in my place is worse	298
Availability is good compared to other modes	439	Longer queue (waiting time)to get a service	376
Comfortable	378	Uncomfortable because taxis carry more than allowed numbers of passenger	277
Preferable for Short distance oriented travel	322	Not always accessible when wanted and differs from place to place or routes to routes	354
Accessibility(easily found near to my village)	414	Taxi drivers always divide single routes to parts	332
Fast and reliable	386	Fare is costly and increase in peak hours	285
Has many versatile routes	395	Most cars are old more than 25 yrs old so not safe	214
Can stop anywhere for loading unloading unlike buses and trains	273	Other reasons	18
My only option in my place	154		
Other reasons	39		

Table 16: responses of passengers on service quality satisfaction

II. Fare affordability

It a measure of the capacity of the majority of passengers to pay the cost A passenger need to incur to travel to a destination. The fare of a minibus taxi service is provided by the city transport offices yet some drivers develop their own fares especially in a route where there is less control from traffic attendants. From a questioner and interview made around 603 out of 821 respondents said fares are fair or affordable whereas the remaining 218 passengers disagrees with the ones who were saying fares are affordable but rather they are costly specially compared to others modes in addition where there is lesser control drivers add fares arbitrary specially in peak hours. Therefore summaries indicate that 73.44% passengers feel the fares are affordable whereas the remaining 26.55% passengers feel in contrary.

In other hand data from social affairs of the Yeka and Arada sub cities shows that about 38% of the population of the sub city leaves below poverty threshold. And the other 33% of the population are relatively a little higher than the low income population with earning less than 3000etb per month, but the rest population which accounts 29% is middle and high income which can afford any modes of transportation and Therefore we can summarize the above data as about for about 59.1% of the passenger and population the given fares area affordable where as for the remaining 40.9 % is a a little above than their pay grade to travel daily.

Given this in mind almost all drivers feel the provided fares are relatively very low and even not good enough to cover the leaving expense of them

III. Modal share

Modal share is measure of how much a given mode of transportation serves from the total

Above In the literature review data sourced from Addis Ababa transport bureau in 2010 the relative share of each of the transportation providing modes were indicated thus the modal share of minibuses is said to be around 57.1% which accounts the majority of different modes of public transportation providers.

No	Modes of transport	No of passenger (x1000) per annum	Out of Total population	Modal share
1	ACBSE	**507.2**	**10%**	**15.01 %**
2	SMTSC	**176.3**	**4%**	**5.2%**
3	MEDI-BUSES	**326**	**7%**	**9.6%**
4	MINI BUSES	**1928.9**	**39%**	**57.1%**
5	AALRT	**194.1**	**4%**	**5.7%**
6	CONTRACT TAXI	**34.5**	**1%**	**1.0%**
7	PRIVATE CARS	**150**	**3%**	**4.4%**
8	OTHER(RICKSHAWS,MOTO-CYCLES	**62.5**	**1%**	**1.8%**
	SUM	**3379.5**		
9	PEDISTRIANS	**819**	**17%**	
	TOTAL	**4198.5**		
10	NON TRAVELLERS	**752**	**15%**	
	GRAND TOTAL	**4950.5**		

Table 17: modal share of different modes of transportation vehicles in Addis Ababa

Financial indicators

Operating expense per passenger

Annual expense of a car is a total sum of different sub expenses of the car that are required to keep the car operating without a problem for a given period of time.

The main expenses of a car for operating are fuel , maintenance , insurance , depreciation

Mpv =16216.2km/yr

a. Annual Fuel expenses

No	Vehicle type	Engine	Fuel type	Fuel efficiency (km/ltr)	Average(km/ltr)
1	Toyota Hiace	1Y	Petroleum	7-8	**7.5**
2	Toyota Hiace	3L	Petroleum/diesel	9-10	**9.5**
3	Toyota Jaguar	2Y	Petroleum	8-10	**9**
4	Toyota van	1RZ	Petroleum	9-10	**9.5**
5	Toyota haice	5L	Diesel	11-12	**11.5**
6	Toyota traveler	2L	Diesel	9-11	**10**
7	Toyota traveler	2LT	Diesel	11 -12	**11.5**
8	Toyota traveler	D4D	Diesel	11-13	**12**
9	Others		Petroleum/diesel	7-9	**8**
	Average				**9.7**

Table 18: fuel efficiency of different vehicles

(sourced from Zebra taxi association)

Thus given annual mile age of a single car (mpv) of about 16216.2km/yr computed in the above section and extra of at least 30 km per day of voyage away and to home and unloaded driving and also the average fuel efficiency of vehicles indicated above in the table, we can compute annual fuel cost as

Annual fuel cost = MPV / fuel efficiency

Considering non carrying voyages (for refueling and to and from starting depot) as average of 20km per day

= (16216.2km/yr + (20km x 297))/ 9.7 km/ltr)

= 22156.2 km/yr/9.7km/ltr

= **2284.14ltr**

Converting to cost in birr considering the current price of fuel petroleum 21.53 and diesel with 18.75 giving us an average of 20.15br/ltr

Therefore annual fuel cost is 20.15br/ltr x2284.14 ltr = **46025.4ETB**

b. Maintenance and service

It's a cost incurred for the wellbeing of the vehicle to perform its design requirement without failure. This cost include maintenance shops costs tyres and changeable costs oiling costs and others. In general we can consider cost of maintenance and service of a vehicle about **10 - 14%** of the total revenue it makes as per (Cundill M et.al, 1997)

Total revenue of a single car is computed as a multiplication of total km it covers per year with fare price per kilometer. In this context, Addis Ababa transport bureau fare tariff scale is indicated below which will be further used to compute annual revenue of a single passenger vehicle.

No	Distance km	Service tariff	Tarrif br/km
1	Up to 2.5	1.5	0.6
2	2.5 -5	3	0.6
3	5-7.5	4.5	0.6
4	7.5-10	6	0.6
5	10-12.5	7.5	0.6
6	12.5 -15	9	0.6

Table 19: Addis Ababa city transport management office route tariffs for a single trip

Therefore total revenue (TR)

TR = MPV x fare/km X CC

= 16216.2 km x0.6birr X 14

= 136216.1 ETB

From this considering 12% for an average maintenance cost will give us 16345.9ETB

c. *Overheads (per-deem of door man, cleaning , terminal attendants)*

Total overheads can be approximately put as 7% (Bogale, 2018) of total revenue generated by a single vehicle therefore it will give us about 9535.17**ETB**

d. *Insurance and Depreciation*

Insurance and depreciations can be approximated to about 6% (Bogale, 2018) of total revenue obtained from a single vehicle thus depreciation and insurance from minibus taxis can be evaluated as 0.03*136216.2 which gives us about 4086.48 ETB

Therefore total expense is a grand sum of cost of fuel, cost of maintenance, cost of overheads and insurance related cost which bring us a total of **65992.96ETB**

With annually passenger serving capacity of 26712 persons total operating expense per passenger become a ratio of Total expense per yr to total passenger travelled thus the value is about **2.47** ETB per passenger for 10km.

Vehicle revenue per liter of fuel and per trip

Vehicle revenue per liter indicates the total amount of revenue obtained from a single car with use of 1 liter of fuel. Its computed as ratio of total revenue from a single vehicle to annual fuel liter used. Thus the above computed total revenue of 136216.1etb and annual fuel usage of 2284.2ltr the vehicle revenue per liter of fuel is calculated as

= Total annual revenue/annual fuel usage

Thus it will be 136216.1etb/2284.2ltr = 59.6 ETB. Which also mean for one liter of fuel a vehicle consume it makes a revenue of 59.6 ETB if total capacity of the vehicle is exploited

Whereas vehicle revenue per trip shows ratio of the total revenue made to total trips made by a single vehicle.

Thus it will be 136216.1/ 6 trips x 297 days = 76.43etb/trip

CHAPTER FIVE
5. MODEL FORMULATION AND OUTPUTS

5.1 MODEL FORMULATION

Having multiple goals desired to be attained specially in public transport sector one has to categorize and prioritize an objective or goal and address the most significant one (chosen by an formulator). This model was formulated in way to fit a linear goal programming based on trip allocation that has been discussed the literature.

In order to formulate an integer goal programming for optimization of trip/ vehicle allocation it is required to set the objective function and constraints for the specific function.

Basic Constraints we had for vehicle/ trip allocation optimization are

- ✓ Time frequency of trips
- ✓ Passenger demand distributions
- ✓ Loading capacities of vehicles
- ✓ Route distance

As an assumption taken all the constraints are given equal priorities

As such we can deduct our objective function as a function to minimize total trips a vehicle makes satisfying possible customer demands in other word it is minimization of negative deviation of sum of travels, route length and loading capacity constraints.

Let time frequency of trips be denoted by T thus number of trips in all routes will be T1 ,T2, T3…….Ti)

Let passenger demand distribution be denoted by D thus number of demands in each routes will be D1 ,D2, D3…….Di)

Let load capacity of vehicles be denoted by C thus number of vehicles load capacity in each route will be C1 ,C2, C3…….Ci)

Let route distance of trips be denoted by L distance of each route will be L1 ,L2, L3…….Li)

Therefore the objective function can be stated as

Min $T = d1^{-} + d2^{-} + d3^{-} \ldots\ldots\ldots\ldots + dn^{-}$ (minimization of negative deviation of sum of travels)

1. *Trip frequency constraints*

Let VN be Total vehicle number

CTR be cycle time ratio

CT cycle time of a single trip by vehicle

TT total operating time on the shift

Xi required number of trips for i[th] route

Thus VN $=\sum_{i=1}^{38} CTR * Xi - d1+ + d1-$ ---------------------Eqn 1

$VN=\sum_{i=1}^{38} \frac{CT}{TT} * Xi - d1^{+} + d1^{-}$

Normal hour

Of all total vehicle population residing in Addis Ababa (code 1 and code 3) 2769 on the normal working hour 60% of those vehicle will be on duty and 80% of the vehicle will be present in peak hours.

Therefore operating vehicle number at normal hour is computed as 0.6 x 2779 which is 1665

CTR(cycle time ratio) is computed as a ratio of single cycle time for one route to total time frame. Here an average of 45 minute is considered as extra waiting time in a queue and other factors.

CTR = (CT +WT)/TT

CTR1 =(58 + 45)/540 min = 0.19

CTR2 =(47 + 45)/540 min = 0.17 as such CTR is computed for all 38 routes

$1665 = CTR_1X_1 + CTR_2X_2 + CTR_3X_3 \ldots\ldots\ldots + CTR_iX_i - d1^{+} + d1^{-}$

$1665 = 0.19\ X_1 + 0.17\ X_2 + 0.16\ X_3 \ldots\ldots\ldots\ldots\ldots\ldots 0.15X_{38} - d1^{+} + d1^{-}$- - - - - - const 1

Peak hour

CTR = (CT +WT)/TT

Total operation time is 6 hour a day which is around 360 min

Here average of 35 minute is considered as extra waiting time in a queue and other factors like traffic stops.

CTR1 = (58 + 35)/360min = 0.26

CTR 2 = (47 + 35)/ 360 min = 0.23 as such CTR is computed for all 38 routes

$2223 = CTR_1X_1 + CTR_2X_2 + CTR_3X_3 \ldots\ldots\ldots + CTR_iX_i - d1 + d1$

$2223 = 0.26\ X_1 + 0.23\ X_2 + 0.21\ X_3 \ldots\ldots\ldots\ldots\ldots 0.19\ X_{38} - d1^{+} + d1^{-}$- - - - - - const 1

2. Route distance constraint

Let Li length of ith route in km

VN total number of vehicle

Xi required number of trips for the ith route

Lt distance to be covered by each vehicle(km)

Thus Lt*VN =$\sum_{i=1}^{38} Li * Xi - d2 + d2$ - Eqn 2

Lt = total distance/total no of route

=281.6km/38route = 7.41km

One vehicle covers an average of 7.41km per trip thus in a day which is approximately 6 trips distance covered by a single vehicle in a day is around 7.41km x 6 = 44.5km carrying a passenger and an average of extra around 30km to and from home or car night parking place.

Normal hour

1665*44.5km = $6.2X_1 + 4.6X_2 + 4.4X_3 \ldots 3.2X_{38} - d2^+ + d2^-$ - - - - - - - - - Const 2

Peak hour

Average distance = 7.41km

Daily average trip in peak hour 4

2223*4*7.41km = $6.2X_1 + 4.6X_2 + 4.4X_3 \ldots 3.2X_{38} - d2^+ + d2^-$ - - - - - - Const2

3. Loading Capacity constraint

Let Di passenger demand for i th route

CC carrying capacity of taxi in the route

Xi the required number of trip for the i th route

Thus $\sum_{i=1}^{38} Di = \sum_{i=1}^{38} CCi * Xi - d3 + d3$ -- - - - - **Eqn 3**

But since demand differs from normal hour to peak our we are required to split the mathematical formulation of demand to peak hour demand and normal hour demand therefore

Let Dni be passenger demand for i th route in normal hour

Dpi be passenger demand for i th route in peak hour

Normal hour

Thus $\sum_{i=1}^{38} Dni = \sum_{i=1}^{38} CCi * Xi - d3 + d3$ **(normal)- - - - - - - - - - - - -- - - - - Eqn 3**

Summation of passenger demand for normal hour is 7450 trips

$7450*14 = 14X_1 + 14X_2 + 14X_3 + \ldots\ldots 14X_{38} - d3^+ + d3^-$ - - - - - - - - - - -- - - - **Const 3**

Peak hour

And $\sum_{i=1}^{38} Dpi = \sum_{i=1}^{38} CCi * Xi - d3 + d3$ **(peak) -- - - - - - - - - - - - - - - -- - - - - - Eqn 3**

Summation of passenger demand for normal hour is 10525 trips

10525*14 = $14X_1 + 14X_2 + 14X_3 + \ldots\ldots 14X_{38} - d3^+ + d3^-$ - - - - - - - - - - - - - - - - const 3

The other constrain are demand based constraints which states that every allocation should at least be equal or exceed demand of each route.

CCiXi >= AR X TT

Where AR is arrival rate and

TT is total operation time frame

CCi carrying capacity of one vehicle on ith route

Normal hour	peak hour
CCiXi >= AR X TTn	CCiXi >= AR X TTp
14X1 >= 145.3pss/hr X 9hr	14X1 >= 354.7pss/hr X 6hr
14X1>= 1308 - - - - - - - - - - const 4	$14X_1$ >= 2128 - - - - - - - - const 4
$14X_2$ >= 624 - - - - - - - - - - -const 5	$14X_2$ >= 1561 - - - - - - - const 5
$14X_3$ >= 2274 - - - - - - - - - - const 6	$14X_3$ >= 3115 - - - - - - - const 6
$14X_4$ >= 792 - - - - - - - -- - const 7	$14X_4$ >=2429 - - - - - - - const 7
$14X_5$ >= 2826 - - - - - - - - - - const 8	$14X_5$ >= 4984- - - -- - - - const 8
$14X_6$ >= 2568 - - - - - - - - - - -const 9	$14X_6$ >= 4879 - - - - - - - - -const 9
$14X_7$ >= 3888 - - - - - - - - - - const 10	$14X_7$ >= 4046 - - - - - - - - - const 10
$14X_8$ >= 2004 - - - - - - - - - - const 11	$14X_8$ >= 3192 - - - - - - - - - const 11
$14X_9$ >= 1776 - - - - - - - - - - const 12	$14X_9$ >= 3584 - - - - - - - - - const 12
$14X_{10}$ >= 1122 - - - - - - - - - const 13	$14X_{10}$ >= 3017 - - - - - - - - -const 13
$14X_{11}$ >= 2196 - - - - - - - - - const 14	$14X_{11}$ >= 3360 - - - - - - - const 14
$14X_{12}$ >= 3525 - - - - - - - - -const 15	$14X_{12}$ >= 4676 - - - - - - - - -const 15
$14X_{13}$ >= 2712 - - - - - - - - const 16	$14X_{13}$ >= 4508 - - - - - - - const 16
$14X_{14}$ >= 2061 - - - - - - - - const 17	$14X_{14}$ >= 2137 - - - - - - - - -const 17
$14X_{15}$ >= 2934 - - - - - - - - const 18	$14X_{15}$ >= 4998 - - - - - - - const 18
$14X_{16}$ >= 1980 - - - - - - - - const 19	$14X_{16}$ >= 4921 - - - - - - - - -const 19
$14X_{17}$ >= 2412 - - - - - - - - -const 20	$14X_{17}$ >= 2877 - - - - - - - const 20
$14X_{18}$ >= 3585 - - - - - - - - const 21	$14X_{18}$ >= 4053 - - - - - - - - -const 21
$14X_{19}$ >= 4284 - - - - - - - - -const 22	$14X_{19}$ >= 6461 - - - - - - - const 22
$14X_{20}$ >= 3522- - - - - - - - -const 23	$14X_{20}$ >= 5320 - - - - - - - - -const 23
$14X_{21}$ >= 3585 - - - - - - - - const 24	$14X_{21}$ >= 3325 - - - - - - - const 24
$14X_{22}$ >= 3564 - - - - - - - const 25	$14X_{22}$>= 2961 - - - - - - - - - -const 25
$14X_{23}$ >= 2625 - - - - - - - const 26	$14X_{23}$ >= 2533 - - - - - - - - -const 26
$14X_{24}$ >= 6936 - - - - - - - const 27	$14X_{24}$ >= 7759 -- - - - - - - - -const 27
$14X_{25}$ >= 4992 - - - - - - - const 28	$14X_{25}$ >= 5229 - -- - - - - - const 28
$14X_{26}$>= 2515 - - - - - - - const 29	$14X_{26}$ >= 3381 - - - - - - - - const 29
$14X_{27}$ >= 2814 - - - - - - - - const 30	$14X_{27}$ >= 4116 - - - - - - - -- - const 30

$14X_{28} >= 3300$ - - - - - - - -const 31
$14X_{29} >= 624$ - - - - - - - -const 32
$14X_{30} >= 3192$ - - - - - - - const 33
$14X_{31} >= 2928$ - - - - - - - const 34
$14X_{32} >= 1371$ - - - - - - - const 35
$14X_{33} >= 2748$ - - - - - - - const 36
$14X_{34} >= 3378$ - - - - - - - const 37
$14X_{35} >= 3432$ - - - - - - - - const 38
$14X_{36} >= 3744$ - - - - - - - -const 39
$14X_{37} >= 2784$ - - - - - - - -const 40
$14X_{38} >= 1296$ - - - - - - - -const 41

$14X_{28} >= 2989$ - -- - - - - - - const 31
$14X_{29} >= 2758$ - - - - - - - - -const 32
$14X_{30} >= 5432$ - - - - - - - - const 33
$14X_{31} >= 4655$ - - - - - - - - - const 34
$14X_{32} >= 1976$ - - - - - - - - const 35
$14X_{33} >= 3563$ - - - - - - - - - const 36
$14X_{34} >= 4544$ - - - - - - - - - const 37
$14X_{35} >= 4865$ - - - - - - - - - const 38
$14X_{36} >= 5159$ - - - - - - - - -const 39
$14X_{37} >= 3612$ - - - - - - - - -const 40
$14X_{38} >= 2142$ - - - - - - - - - - const 41

After formulating all the equation and the constraints it was fed to QM for windows V5 a linear programming solver tool so analyze the outputs , which is indicated below. As the constraints are different for normal working hour and peak operating hour depending on the flow of the passengers, those different data will be fed linear programming solver tool separately and the individual result will be discussed after ward

Linear equation has been fed for QM for windows V5 2015 in linear optimization mode

Normal hour

NORMAL HOUR

model input	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	X29	X30	X31	X32	X33	X34	X35	X36	X37	X38	d1-	d1+	d2-	d2+	d3-	d3+	RHS
minimize G																																							1		1		1		
Constraint 1	0.19	0.17	0.16	0.20	0.20	0.22	0.19	0.21	0.20	0.19	0.18	0.19	0.21	0.24	0.20	0.21	0.23	0.19	0.20	0.19	0.21	0.18	0.21	0.19	0.20	0.16	0.17	0.16	0.14	0.19	0.20	0.14	0.17	0.20	0.16	0.19	0.20	0.15	1	-1					1665
Constraint 2	6.2	4.6	4.4	6	6.8	10	6.4	7.3	8	6.8	6.1	6.7	11.2	19.6	7.4	12.2	17.8	6.7	6.3	8.8	10.1	7.3	11	7.9	8.2	5.1	6	5.1	2.8	6.8	6.4	2.8	5.1	6.4	4.1	6.6	7.2	3.2			1	-1			74092.5
Constraint 3	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14					1	-1	104300
Constraint 4	14																																												1308
Constraint 5		14																																											624
Constraint 6			14																																										2274
Constraint 7				14																																									792
Constraint 8					14																																								2826
Constraint 9						14																																							2568
Constraint 10							14																																						3888
Constraint 11								14																																					2004
Constraint 12									14																																				1776
Constraint 13										14																																			1122
Constraint 14											14																																		2196
Constraint 15												14																																	3525
Constraint 16													14																																2712
Constraint 17														14																															2061
Constraint 18															14																														2934
Constraint 19																14																													1980
Constraint 20																	14																												2412
Constraint 21																		14																											3585
Constraint 22																			14																										4284
Constraint 23																				14																									3522
Constraint 24																					14																								3585
Constraint 25																						14																							3564
Constraint 26																							14																						2625
Constraint 27																								14																					6936
Constraint 28																									14																				4992
Constraint 29																										14																			2515
Constraint 30																											14																		2814
Constraint 31																												14																	3300
Constraint 32																													14																624
Constraint 33																														14															3192
Constraint 34																															14														2928
Constraint 35																																14													1371
Constraint 36																																	14												2748
Constraint 37																																		14											3378
Constraint 38																																			14										3432
Constraint 39																																				14									3744
Constraint 40																																					14								2784
Constraint 41																																						14							1296

Figure 20 equation prepared for QM for windows V5 2015 in linear optimization mode(NH)

INSTRUCTION: Enter the value for constraint 4 for rhs. Any non-negative value is permissible.

Objective
- ○ Maximize
- ◉ Minimize

edited final 1

X27	X28	X29	X30	X31	X32	X33	X34	X35	X36	X37	X38	d1	d1-	d2	d2-	d3	d3-		RHS	Equation form
0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0			Min d1 + d2 + d3
.17	.16	.14	.19	.2	.14	.17	.2	.16	.19	.2	.15	-1	1	0	0	0	0	>=	2779	.19X1 + .17X2 ...
6	5.1	2.8	6.8	6.4	2.8	5.1	6.4	4.1	6.6	7.2	3.2	0	0	-1	1	0	0	>=	74092.5	6.2X1 + 4.6X2 ...
14	14	14	14	14	14	14	14	14	14	14	14	0	0	0	0	-1	1	>=	104300	14X1 + 14X2 + ...
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	1308	14X1 >= 1308
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	624	14X2 >= 624
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	2274	14X3 >= 2274
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	792	14X4 >= 792
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	2826	14X5 >= 2826
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	2568	14X6 >= 2568
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	3888	14X7 >= 3888
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	2004	14X8 >= 2004
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	1776	14X9 >= 1776
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	1122	14X10 >= 1122
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	2196	14X11 >= 2196
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	3525	14X12 >= 3525
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	2712	14X13 >= 2712

Linear Programming | Data Screen | Taylor's Introduction to Management Science Textbook | Developed by Howard J. Weiss

Figure 21 model input for QM for windows V5 2015 in linear optimization mode(normal hour)

The result obtained after solving the above input equation is seen in below figure 22 Linear programming result

INSTRUCTION: There are more results available in additional windows. These may be opened by using the SOLUTIONS menu in the Main Menu.

Objective
- ○ Maximize
- ◉ Minimize

Note
Multiple optimal solutions exist

Constraint 28	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 29	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 30	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 31	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 32	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 33	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 34	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 35	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 36	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 37	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 38	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 39	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 40	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 41	0	0	0	0	0	0	0	0	0	0	0	0	0
Solution	93.6	66.2	153.1	57.4	201.4	170.7	277	139.4	122.3	96.8	140.2	251.7	193.8

Figure 22 LP result from QM for windows V5 2015 in linear optimization mode (normal hour

From the result from QM windows V5 2015 a computed solution is summarized in table along with the actual current allocation and the demand figure for comparison purpose.

Route	demand	solution	Allocation
A	93	93.6	115
B	45	66.2	109
C	162	153.1	226
D	62	57.4	134
E	202	201.4	256
F	183	170.7	240
G	278	277	273
H	143	139.4	181
I	127	122.3	295
J	80	96.8	142
K	157	140.2	226
L	252	251.7	269
M	194	193.8	359
N	147	224.2	112
O	210	232.5	343
P	141	138.9	165
Q	172	173.1	179
R	256	249.6	248
S	306	323.2	328
T	252	225.9	406
U	256	255.7	231
V	255	241.4	365
W	188	203	181
X	495	490.8	480
Y	357	357	424
Z	180	174.8	273
AA	201	200.5	293
AB	236	204.4	222
AC	45	37.6	62
AD	228	246.3	300
AE	209	210	228
AF	98	92.1	146
AG	196	199.3	209
AH	241	236.5	328
AI	245	245.4	275
AJ	267	233	203
AK	199	191.7	119
AL	93	111.7	141

Table 20 LP result summary from QM for windows V5 2015 in linear optimization mode(normal hour)

Result on graph (normal hours only)

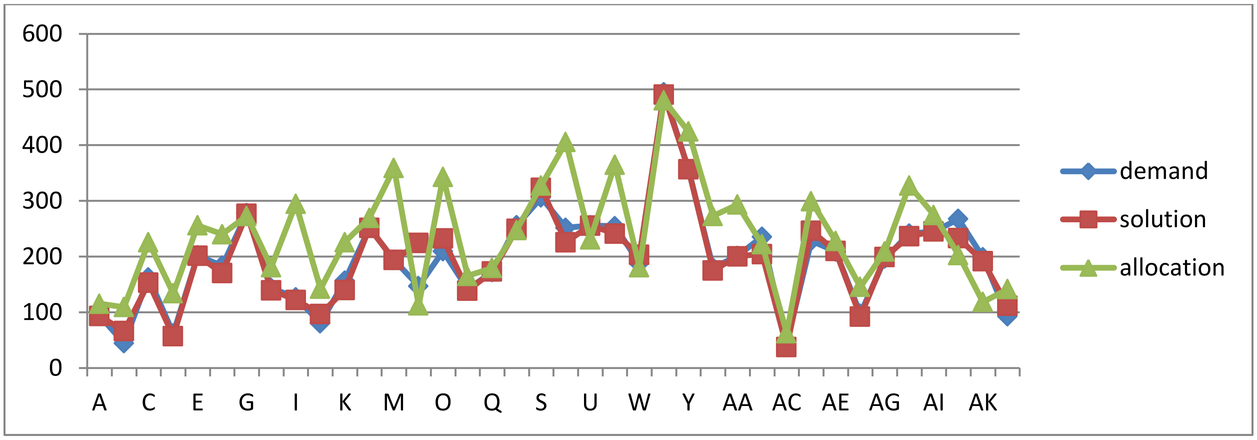


Figure 23 comparison of trip allocation for demand, actual allocation and lp solution

As it can be seen from the result summary and the graphical representation above the LP solution has brought a significant figure change from the actual unbalanced allocation that will nearly suit the forecasted demand. The degree of correction from the LP result varies from routes to routes yet in most of the routes the resulting solution is closer to the forecasted demand variation. Seeing some of the routes to be specific for example route A was allocated to have 115 trips by transport bureau while the forecasted demand was around 93 required trips. After consideration the constraints mentioned above and the formulated equation has brought up a solution of around 94 trips which is almost same of the forecasted demand which in turns shows 21 extra trips allocation which can be sent to another deficient route. In similar way observing route D will also show similar result of an excess of 73 trips while the demand forecast indicate around 62 required trips while the allocation was 134 trips yet the optimized allocation result from Lp solver dictate about 58 trips are enough to satisfy the demand on that specific route. another route like route N and route U has the opposite scenario in which a deficient allocation has been made when compared to the forecasted demand whereas the LGP result recommend to correct the allocation to 225 trips which shows a need in increase in trips yet the increment is seen to be excess in the lp solutions though compared to the demand.

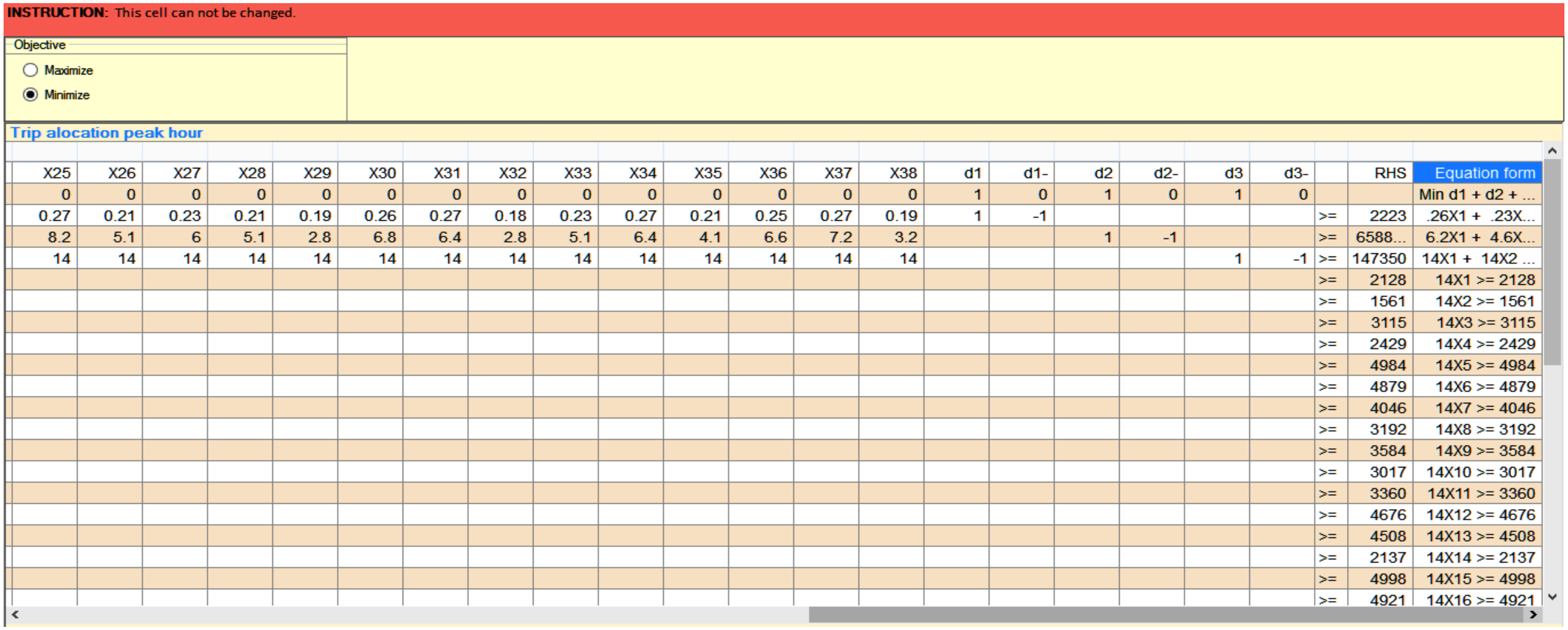
Peak hour

The above result works for only the specified normal hour since the constraints and the respective equation of the peak hour is different. Here under the Lp equation and the respective constraint for peak hour are formulated and fed to QM windows V5 2015.

PEAK HOUR

model input	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	X29	X30	X31	X32	X33	X34	X35	X36	X37	X38	d1-	d1+	d2-	d2+	d3-	d3+	RHS
minimize G																																						1		1		1		
Constraint 1	0.26	0.23	0.21	0.27	0.28	0.30	0.26	0.28	0.28	0.26	0.24	0.25	0.29	0.33	0.28	0.29	0.32	0.26	0.28	0.26	0.28	0.24	0.27	0.25	0.27	0.21	0.23	0.21	0.19	0.26	0.27	0.18	0.23	0.27	0.21	0.25	0.27	0.19	1	-1					2223
Constraint 2	6.2	4.6	4.4	6	6.8	10	6.4	7.3	8	6.8	6.1	6.7	11.2	19.6	7.4	12.2	17.8	6.7	6.3	8.8	10.1	7.3	11	7.9	8.2	5.1	6	5.1	2.8	6.8	6.4	2.8	5.1	6.4	4.1	6.6	7.2	3.2			1	-1			65889.8
Constraint 3	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14					1	-1	147350
Constraint 4	14																																											2128
Constraint 5		14																																										1561
Constraint 6			14																																									3115
Constraint 7				14																																								2429
Constraint 8					14																																							4984
Constraint 9						14																																						4879
Constraint 10							14																																					4046
Constraint 11								14																																				3192
Constraint 12									14																																			3584
Constraint 13										14																																		3017
Constraint 14											14																																	3360
Constraint 15												14																																4676
Constraint 16													14																															4508
Constraint 17														14																														2137
Constraint 18															14																													4998
Constraint 19																14																												4921
Constraint 20																	14																											2877
Constraint 21																		14																										4053
Constraint 22																			14																									6461
Constraint 23																				14																								5320
Constraint 24																					14																							3325
Constraint 25																						14																						2961
Constraint 26																							14																					2533
Constraint 27																								14																				7759
Constraint 28																									14																			5229
Constraint 29																										14																		3381
Constraint 30																											14																	4116
Constraint 31																												14																2989
Constraint 32																													14															2758
Constraint 33																														14														5432
Constraint 34																															14													4655
Constraint 35																																14												1976
Constraint 36																																	14											3563
Constraint 37																																		14										4544
Constraint 38																																			14									4865
Constraint 39																																				14								5159
Constraint 40																																					14							3612
Constraint 41																																						14						2142

Figure 24 equation prepared for QM for windows V5 2015 in linear optimization mode(PH)



INSTRUCTION: This cell can not be changed.

Objective

Maximize

Minimize

Trip alocation peak hour

X25	X26	X27	X28	X29	X30	X31	X32	X33	X34	X35	X36	X37	X38	d1	d1-	d2	d2-	d3	d3-		RHS	Equation form
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0			Min d1 + d2 + ...
0.27	0.21	0.23	0.21	0.19	0.26	0.27	0.18	0.23	0.27	0.21	0.25	0.27	0.19	1	-1					>=	2223	.26X1 + .23X...
8.2	5.1	6	5.1	2.8	6.8	6.4	2.8	5.1	6.4	4.1	6.6	7.2	3.2			1	-1			>=	6588...	6.2X1 + 4.6X...
14	14	14	14	14	14	14	14	14	14	14	14	14	14					1	-1	>=	147350	14X1 + 14X2 ...
																				>=	2128	14X1 >= 2128
																				>=	1561	14X2 >= 1561
																				>=	3115	14X3 >= 3115
																				>=	2429	14X4 >= 2429
																				>=	4984	14X5 >= 4984
																				>=	4879	14X6 >= 4879
																				>=	4046	14X7 >= 4046
																				>=	3192	14X8 >= 3192
																				>=	3584	14X9 >= 3584
																				>=	3017	14X10 >= 3017
																				>=	3360	14X11 >= 3360
																				>=	4676	14X12 >= 4676
																				>=	4508	14X13 >= 4508
																				>=	2137	14X14 >= 2137
																				>=	4998	14X15 >= 4998
																				>=	4921	14X16 >= 4921

Figure 25 model input for QM for windows V5 2015 in linear optimization mode(peak hour)

After the above data has been fed to Qm for windows V5 2015 in a linear programming solving mode the following result has been obtained.

INSTRUCTION: There are more results available in additional windows. These may be opened by using the SOLUTIONS menu in the Main Menu.

Objective
- ○ Maximize
- ◉ Minimize

Note
Multiple optimal solutions exist

Constraint 19	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 20	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 21	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 22	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 23	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 24	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 25	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 26	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 27	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 28	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 29	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 30	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 31	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 32	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 33	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 34	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 35	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 36	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 37	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 38	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 39	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 40	0	0	0	0	0	0	0	0	0	0	0	0	0
Constraint 41	0	0	0	0	0	0	0	0	0	0	0	0	0
Solution	152	111.5	222.5	173.5	356	348.5	289	228	256	215.5	240	334	322

Figure 26 LP result from QM for windows V5 2015 in linear optimization mode (peak hour)

Route	demand	allocation	LP result	deviation
A	152	107	152	45
B	112	101	111.5	11
C	223	208	222.5	14
D	174	124	173.5	50
E	356	236	356	120
F	349	222	348.5	127
G	289	252	289	37
H	228	167	228	61
I	256	272	256	-16
J	216	131	215.5	84
K	240	208	240	32
L	334	249	334	85
M	322	331	322	-9
N	148	104	152.6	49
O	357	317	357	40
P	352	153	351.5	199
Q	206	166	213	47
R	290	228	289.5	61
S	462	302	461.5	159
T	380	374	380	6
U	238	213	237.5	24
V	212	337	211.5	-125
W	178	167	180.9	14
X	549	444	554.2	111
Y	374	392	373.5	-18
Z	242	252	241.5	-11
AA	294	271	294	23
AB	214	205	213.5	9
AC	197	58	197	139
AD	388	276	306	30
AE	333	210	332.5	122
AF	137	134	141.1	7
AG	255	193	254.5	62
AH	335	302	324.6	22
AI	348	253	347.5	94
AJ	369	187	368.5	181
AK	258	109	258	149
AL	153	131	153	22

Table 21 LP result summary from QM for windows V5 2015 in linear optimization mode(peak hour)

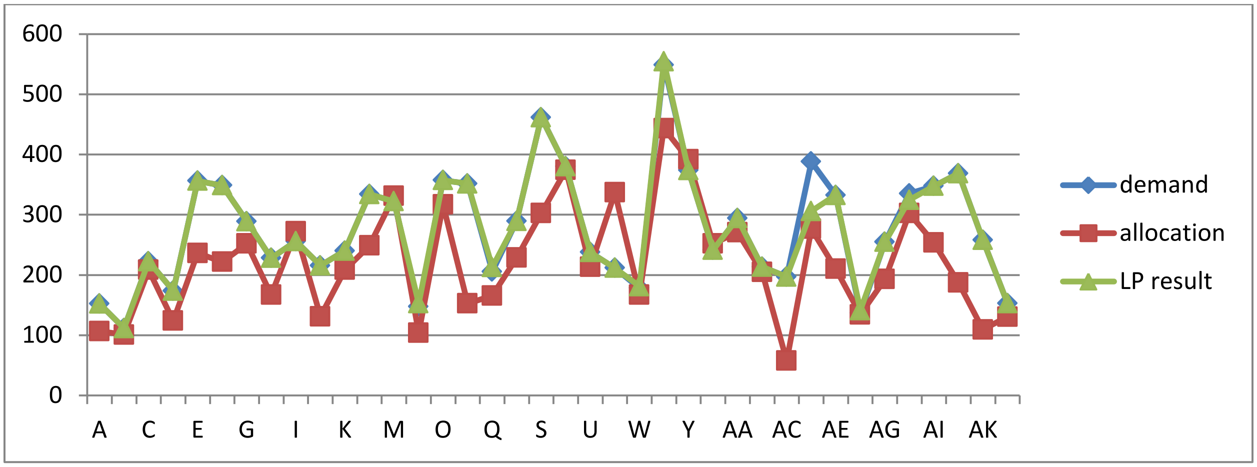


Figure 27 Graphical representation of demand, actual allocation and optimized solution

As it can clearly depicted from the summary table and the graph above the optimized linear programming solution tried to minimize the deviation between the actual current allocation of trips with the required trips or demand in simple word. The trip allocation correction from LP solution suggest a range from adding about 199 trips to reducing to 125 trips a day from a route considering some outliers. For example considering route B and C the lp solution is 11 and 14 trips a day greater from the actually used allocation. In other word for those routes an addition of 11 and 14 trips a day each is required to fulfill the demand at these specific routes. Where as in the routes like I and M the Lp solution has been found to be about 256 and 323 respectively which has a reduction of 11 and 8 allocated trips each. Some few also shows extreme deviation and are taken as extreme outliers and are considered an optimal solution In general we can summarize that the LP formulation and the respective result or solution will affect the actual current allocation in a way that is drawn near to the forecasted demand in each depots and a trip route in general.

Finally in order to clearly see the change brought by the linear programming allocation to the previously used actual allocation a comparison between the previous allocation with the new lp result and the demand and the new lp allocation is shown in graph below

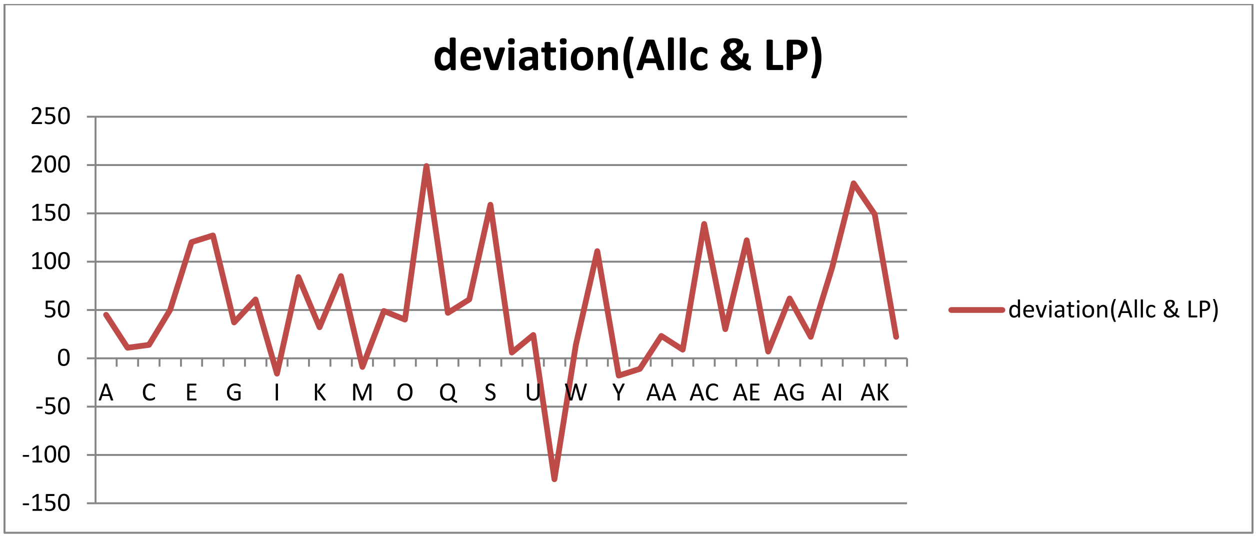


Figure 28 Observed difference between previous trip allocation and the new LP allocation

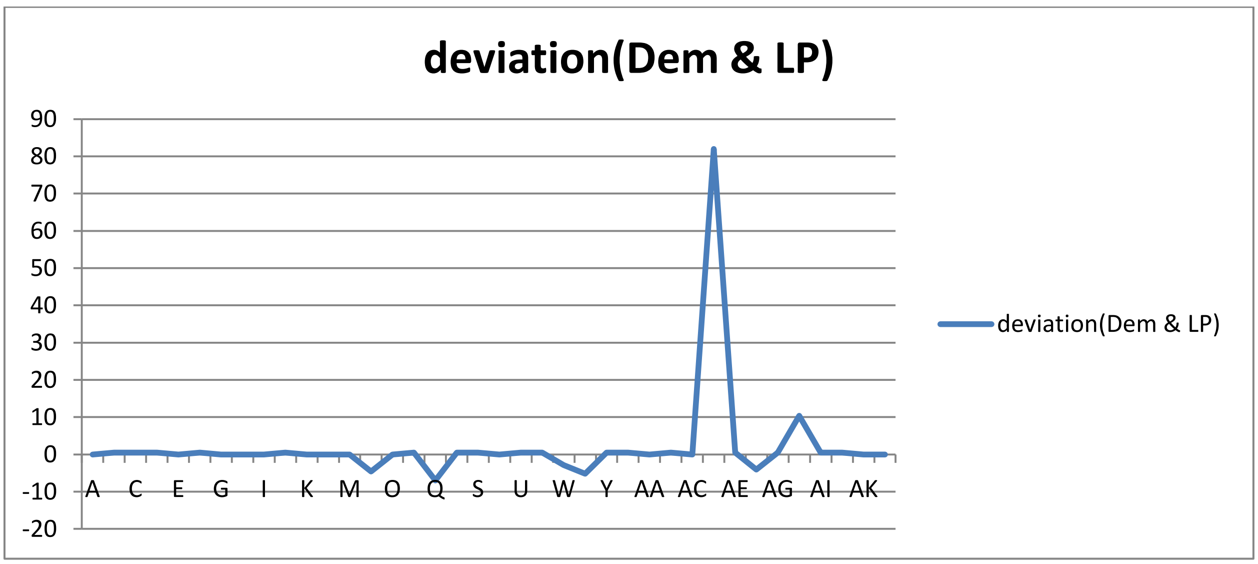


Figure 29 Observed difference between the route demand and the new LP allocation

From the above two graphs we can observe that the previously used allocation (shown on the first graph) significantly varies from the demand on that specific route some show a deficient number of trips where us the rest shows excess resource allocated in a place where the demand is lower. After using the Lp model for allocation of trips on those similar routes a significant change has been found that the allocated trips are near to the demand showing less deviation between demand and resource allocation or in other words has reduced excess and deficient allocation of trips significantly. Here it's important to note that some significant outliers are found on the lp optimal solution or result. For eg result for route AD has been found to be above 80 trips in excess which will be considered as non-optimal solution. In general Less deviation between the demand trip number on that route and LP allocated can be considered as an optimal solution.

Indicators improved

The task of formulating the case condition in mathematical formulation has provided some advancement and improvements in some if the indicators discussed in chapter four. In each of the indicators categories(practical financial and quantitative) some parameters has seen a noticeable upgrade in one or many features. To address some of them for instance to start with average minibus fleet operating in a day from the qualitative indicators categories a noticeable effect has been observed in later assessments.

In order to understand improvement of some of the qualitative indicator specifically average minibus fleet operating in a day it should be seen according to the result obtained in each of the 38 routes rather than understanding as total fleet since in the consideration taken while formulating the mathematical problem the total population of vehicle was considered as constant parameter and can only be improved in introduction additional resources to the system which wasn't considered in this study. Therefore considering individual route average fleets operating in a day there was more of balancing solution in routes showing significantly slack and surplus fleet allocations. Taking some sample routes for overview for instance route A had an average fleet per day around 115 trips for normal hour time frame and 107 trips for peak hour time frame which equals a total of 222 trips consuming around 37 minibuses each making 6 trips a day. After obtaining the solution from the mathematical modeling the outcome suggest a daily total trips in both time frames to be around 245 with about 40 minibuses each making 6 daily trips. Here the daily average fleet has increased from 37 to 40 showing around 8% upgrade. Considering another route like route D had an average daily fleet of 43 minibuses currently for about 258 total trips and after mathematical modeling result it would be assumed to be 39 daily minibuses by average which assumes 10% downgrade. In general most of the routes assumes a change and improvement of daily minibuses on the fleet schedule from their existing scenario.

Another change in the listed indicators was seen in average annual mileage per vehicle category. Similarly as the resulting mathematical; solution was providing a balanced allocation trips for each route excess allocation was reduced to a demand level allocation where as a scarce allocation were upgraded to full fill the minimum demand considering list of constraints. Thus a change has been noticed in aspect of annual mileage of vehicle since it is directly related with the fleet of the vehicles. The annual MPV was initially 54.6km/day excluding daily 20km movement of home to station and back to home voyages thus totally was around 74.6km/day by average but after the new allocation the new MPV is estimated to grow by 10% at least since in most routes there was observed an increment of double trips per day due to balancing of allocation. Considering the average route distance 5.1 km for a single trip most routes will experience 10.2km daily average increment which is above 10% increment on the current 74.6km/day MPV.

The other indicator which showed improvement is customer service satisfaction rate. Before the optimization was made the customer service satisfaction percentage was around 55.2% considering many factors. The newly adjusted and optimized allocation is excepted to upgrade this value since it brought change in the following three factors . the first one is the addressability of the service sector, the solution is applied by introducing some extra trips in some deficient routes thus there will be definitely improved addressability. The other factor in this indicator is the overall service rate.

The final result was obtained by optimizing the current allocation to a more balanced and addressable allocation thus in some specific routes specially those showing deficient in their allocation like routes E,J,P,S and AC has showed a significance of increment of service rate due to introduction of extra trip numbers. The third factor is the waiting factor since the allocation was not based on the demand or the customers' arrival rate in the past times the waiting time for getting serviced was 12 - 20 minutes by average yet after the new optimized result and increased number of trips in individual routes the newly obtained would reduce this waiting time up to 5 minutes by average considering improved service rate of 27,34,22 28 respectively in the routes E,F AC,AF and others.

In other aspects like overall vehicle revenue and other types of financial indicator it has been also seen an advancement by the performed optimization. As trip revenue is directly related with the numbers of trips a vehicle make, the optimized result suggest an increment of trips in those deficient routes which intern improves the revenue of those vehicle obtaining additional trips due to the optimization. Considering some of the route for instance route P and AK, before optimization the vehicles in those routes used to make average of 4 and 6 trips per day respectively yet due to the resulted optimized trip allocation they are supposed to make 7 and 12 trips a day respectively which shows an average increment of vehicle overall revenue of 30-40% approximately.

CHAPTER SIX
6. CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

As far as this study was concerned out of many fleet zones residing in the capital AA the megenagna zone has been selected for a study on overall performance of the fleet. Several reasons were considered to select this site as study location some of the factors include higher mobility rates higher vehicle population severe customer complaints relatively poor service rate and others related dominant factors. Then after the current performance status of this specific fleet network was measured and found to be relatively below average in most measuring criteria's when compared to some international standards. The practical indicators measured indicate service performance and quality was average (55.2% satisfaction level on service quality around 70% fare affordability) the performance measurement also showed average financial indicators and below average quantitative indicators.

When observing the financial indictors it was seen a conclusive result showing an annual net revenue 65000 – 90000 ETB which corresponds nearly more than 5 years of rate of return on investment considering current investment requirement of the sector. Here it is important to note there are other contributing factors for the financial wellbeing of the service sector for example most of the vehicles used for this industries are aged estimated to be 15-30 years old thus their maintenance and other related cost are higher which intern affects the profitability and ROR on investment.

Considering quantitative indicators also leave us in the below average zone, significantly lower PVPT value (26.56) compared to Lagos (60), cape town (172) Algiers (311) and international cities like Brussels and Rome(511&646) respectively, low TTD 1.64km (Asia is 400-500mtr) and lower PLF (89) leaving about 11% customers waiting for service and left unserviced support the argument that the service rate is relatively below average. In addition very low MPV(carrying only) around 54.6km/day/vehicle excluding no carrying MPV (Nairobi & cape town 90-130cmpv) (Trans africa - African Association of Public Transport (UATP), 2008) and very long waiting time for vehicle while there are vacant vehicle in nearby depots are overwhelming to indicate the current performance level.

Many reason can be given for the poor performance of the service sector in that specific fleet zone (stochastic nature of customer arrival, resource availability, allocation related and others) and for this study the trip allocation has been tried to be optimized using Linear goal programming approaches. The constraints consider was loading capacity route distance and trip frequencies. After a model has been formulated it was validated using a data collected from the fleet zone and an heuristic solving was made using QM for windows V5 2015 in linear optimization mode and a promising result has been attained.

Out of the allocation for the total 38 routes for only 2667 vehicles 89% of the earlier trip allocation was modified showing 16% need of increment and 73% decrement the remaining 11% route has never showed need of neither increment or decrement of allocated trips.

Using of the new optimized allocation will show improvement on some indicators like the MPV of vehicles because the time they spent on waiting line will be reduced which intern improve the financial gain or the investment return, In addition service quality of the sector will be improved by reducing the waiting time to get serviced in addition it also reduces a queue build up since the available resource will be shared and distributed according to the demand.

Finally It also indirectly reduces vehicle congestion on high ways in away the allocation won't allow one way traffic yet it distributes the resources on demand basis and intern there will be relatively even flow vehicles (direction wise).

6.2 RECOMMENDATION

The following suggestions points are sourced from the study are recommended to be considered by respective organ so that so possible advancement in the sector would be obtained.

It is indicated in the study that measurement of the public transport sector is made once in a three to five years bases even not considering the important and significant factors thus it is recommended to do the measurement and analysis frequently (once or twice a year) as much as possible since the scenario in the ground changes with in short period of time.

As indicated in the above statement while doing the performance analysis the city transport bureau with related concerned organs they basically focus on addressability factor only but in order to determine an accurate set of data and to take required adjustment decisions, the measurement and analysis should base on different contributing factors as indicated in this study.

In the specified dispatch zone as noted in the discussion part the allocation of vehicle was solely made by only considering choice of drivers and owners excluding the significant factors like arrival rate (customer demand) and traffic congestion and route capacity in general. Thus future trip allocation should be made by a scientific approach like the one showed in the research which is able to consider different contributing factors so that an optimized and balanced trip allocation would be experienced.

Other recommendation a modern and reliable data management system should be incorporated as the current overall system is a reliable one in addition improving the current data base system would also contribute its part in welcoming different academicians and researchers since it guarantees improved ease of access of relevant data.

The other point worth mentioning in the recommendation is the city transport bureau should be able to develop a system for efficiently monitor and control the cities dispatch system and overall route conditions. Some Asia and European cities transport administration module can be consider as role model sister cities where efficient and scientific public Transport administration systems is currently being widely experienced.

6.3 FUTURE WORK

The sample fleet zone selected for this study is only probably representative of the capital, in order to find a better optimal result the sample site should be a wider and representative which can accommodate the stochastic nature of the simultaneous pick up and dropping natures of public transport which also demands an inclusion of ignored constraint in future study.

Therefore it is planned for the future to incorporate wider sampling area which can inclusively represent the differentiated nature of customer arrival nature.in addition rather than consider a single Goal as an objective in this study future studies find a way to deal with simultaneous list of goals that would be optimized for better acceptability of the results.

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APPENDIX

A. INTERVIEW & QUESTIONEER

Addis Ababa University
Addis Ababa institute of technology
School of mechanical and industrial engineering

Greetings All! With the approval of the Addis Ababa Institute of Technology, I am conducting a thesis work for a fulfilment of my MSc degree program in Industrial Engineering entitled " **Performance measurement and analysis of Addis Ababa city taxi fleet network. Case site: megenagna fleet zone**".

The purpose of this research is to measure and analyse the current status of the public transportation sector and further develop a model which can indicate areas of improvement.

Therefore, I would like to request you to participate in this research because I believe that your experience in the sector would help us much.

I would request you to answer the questions freely and **every information provided here under will be treated in the strictest confidence**. The interview will take about 15-30 minutes to complete. Your genuine responses are essential to build an accurate picture of the issues that will be the very essential part of the this research work.

For any enquiry, please contact:

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Thank you in advance for your time and genuine response.

Interview questions

Target group : Taxi Drivers

Time : max 15 mins

Respondent number : up to 10

1. What is the name of your association you are in? When have you joined this association?
2. How many of your vehicles are registered under this Association?
3. What is the type of your vehicle, its model, fuel type, carrying capacity and other?
4. Where is you operating route, how many full trips u make per day?
5. What opportunities can be obtained from being registered under an association and what else benefits you acquired other than route dispatching?
6. Why have you chosen this route if it is by choice and what benefits you think you have obtained working in this specific route?
7. What are the common complaints raised from your customers?
8. What are the areas you expect the officials of transport bureau to improve so as to upgrade the serviceability?

Target group : Taxi associations

Time: max 15 mins

Respondent number : up to 5

1. What is the name of your association?
2. When was it established? How many vehicle you had when it was established?
3. How many vehicles you have under you now? How much of them are active and functioning?
4. What are the main services you provide for member vehicle owners and drivers?
5. What is the basis for allocating vehicles in specific route at your association?
6. What are the feed backs from drivers and vehicles owners on their route allocation?
7. How do you manage and control fleet and route coverage by your member vehicles?
8. What are the areas of improvement you point regarding route and trip allocation?
9. How do you evaluate the overall service sector quality in terms of addressability availability and others?
10. What are the main problems you are facing as a vehicle dispatching association?
11. What are the main benefits for members being organized under association?

Questioner

Target group : Taxi customer

Instruction : Read the following questions and circle your response

1. **How often you use public transportation to travel from place to place?**
   A. Once a week C. Thrice a week
   B. Twice a week D. More than 3 times a week
2. **What mode of transportation you prefer frequently when you travel in town?**
   A. Buses D. hailing taxis
   B. Train E. combined modes
   C. Medibuses F. other modes
   D. minibuses
3. **What is the main reason for choosing that specific mode of transportation in question number 2?**
   A. Comfort C. Fare affordability E. Other reason
   B. Accessibility D. The only available one
4. **How much do you have to wait to gain access to the desired mode of transport?**
   A. Less than 5 min C. 10-20 min E. Above 30 min
   B. 5 -10 min D. 20 -30 min
5. **Which part of the day you often travel?**
   A. Morning C. Afternoon E. cant specify
   B. Midday D. night
6. **How do u evaluate the overall service in terms of addressability and route coverage?**

A. Poor C. Good
B. Average D. excellent

7. **How do you evaluate the Fare given to the mode of transportation you often use?**
   A. Poor C. Good
   B. Average D. excellent
8. **Do you think the quality of the road and vehicles using it affect the overall quality aspect of** the sector?
   A. Yes B. No C. I have no opinion

9. **If you answer is Yes in question number 9, what do you think should be done to improve it?**
10. **In what aspect you expect the service sector official's action for immediate improvement?**

Target group : Addis Ababa Transport and management office

Instruction : Read the following questions and circle your response

1. What is the main task as office regarding public transport sector?
2. How wide is your operating area and how much routes and vehicles you have for dispatch?
3. What is the basis for dispatching vehicles on different routes?
4. How do you manage and control route coverage by coverage and fleet efficiency?
5. How often do you perform performance analysis and service evaluation of the sector?
6. What criteria and indicators you often use to measure the on-going performance of the service sector?
7. How do you make route and trip allocation given the scarce resource available
8. How do you collect feedback s from taxi association customers and drivers on the service quality?
9. What are the main feedbacks from your previous service evaluation?
10. How do you respond to open new route inquiries from customers and communities from unaddressed areas?
11. How do you manage the difference in interest between owner's choice of route and your allocation?
12. Do you have a means to integrate systematically and scientific approaches that will improve the current quality of the sector?

B. SUMMARY OF REVIEWED LITERATURES

NO	Title of article	Author &year	Objectives	Thematic area	approaches	Time window	result
1	The single dial a ride problem	Desrosiers et al. (1986)	Minimize route duration.	DARP-Single vehicle static	Exact dynamic programing	One pick up or drop off	Route duration hasbeen minmizaed for size no n</=40
2	An effective and fast herustics for the dial ride problem	Wolfler Calvo and Colorni (2007)	Maximize number of users that can be served, and minimize user inconvenience.	DARP-Multi-vehicle, static.	Clusters constructed by assignment heuristic,	On pick-up and drop-off.	No of users has been maximizaed from26321 to above 35000
3	Technical efficiency of canadian urban transit	Boame 2004	Performance analysis of canadian transit system		Data envelopment analysis		Operational Efficinciency of Canada bus transit system is about 78%
4	A tabu search herustics for static multi vehicle dial a ride problem	Cordeau and Laporte (2002)	To minimize route length of a dispatch vehicle	Multi vehicle dynamic	Vertex insertion heuristics	On pick-up and drop-off	Route length covered in a cycle has been reduced from 16.2 to14.6 km
5	Performance optimization of public transport using integrated AHP-GP	Anila Cyril,raviraj H. mulangi, Varghese jeorge	Performance optimization of kerala state road transport corporation(KSRTC)		Analytical hierarchy process and goal programming		Reduction of controllable cost by reducing staff per vehicle would increase bus service to 49.15% and accesibilty to 44.76%
6	Evaluation of Public Transportation Operation Based on Data Envelopment Analysis	Jiabin Lia , Xumei Chenb,c , Xin Lib,c , Xiucheng Guoa	Performance evaluation of transport operation		revised DEA method and sensitivity analysis of indexes.		the operation for each route/direction in its off-peak period is better than that in its peak period
7	Schedule Optimization of Public Transportation System By Using Linear Goal Programming Method	Sezgin Tekin, Sevil Kofteci, Metin Mutlu Aydın	Minimization of dispatch number of vehicles	Fleet allocation	Goal programming		Vehicle schedule has been modified in and there was increase in 78 to 84 % of meeting passenger demand.
8	Measuring and improving the efficiency and effectiveness of bus	Georgiadis, Georgios, Politis, Ioannis, Papaioannou,	Effectiveness improvement of public transport sector		Data Envelopment Analysis (DEA)		efficiency of local bus lines is slightly better than operational effectiveness without indicating

	public transport systems	Panagiotis					a clear positive or negative relationship between the two performance components
9	Determining the best performing benchmarks for transit routes with a multi-objective model: the implementation and a critique of the two-model approach	Samet Güner and Erman Coşkun	measurement of efficiency the service level based performance dimensions of transit systems		the two-model approach introduced by Shimshak and Lenard allonf with DEA		demonstrates the applicability of the two-model approach in the transportation industry and points out that despite the usefulness of the two-model approach to determine the best benchmarks in a multi-objective model
10	A mixed frontier model for urban bus performance evaluation	Kaisheng zhang, ya xu , Daniel(jian) sun	to evaluate the efficiency of an urban bus operation at different periods using a mixed frontier model and to explore a better operating strategy which is adaptive to bus demand fluctuation	Shanghai, China	A mixed data envelopment analysis–stochastic frontier analysis (DEA–SFA) model is used		The results indicate that the model effectively describes the characteristics of the bus line efficiency with time period changes, which provides an innovative perspective to solve the operational problem of the urban transit system.
11	Performance evaluation of bus routes: A provider and passenger perspective,	C. Sheth, K. Triantis, D. Teodorovic, (2007)	To measure Efficiency of services	USA	Network DEA model and Goal programming DEA		A 60 bus route has been analyzed and the route performance has been determined with the approach selected

C. VEHICLE ROUTES BY THEIR ASSOCIATION

Vehicle allocation of code 1 taxis with their respective Association

No	Route covered - ADDIS HIWOT	Dsitance (km)	Vehicles allocated Code 1
1	4killo - 6killo – ferensay - biretdildey	6.2	21
2	Minilik school - 6killo – bella	4.4	11
3	Altad mikael – urael – stadium	6.8	32
4	Gursholla – Balderas – biherawi - shebelle	10.2	18
5	bella- janmeda - 6killo – raguel	6.4	26
6	ferensay - giorgis – raguel	7.3	19
7	kazanchis total- 4killo - piassa - autobis tera	6.1	19
8	kazanchis - 4killo – shiromeda	6.7	24
9	lamberet- kebena - 4killo – piassa - autobis tera	11.2	17
10	Lamberet - bole Michael - saris – kalitymeharia	19.6	4
11	Megenagna – cmc - semit RA	7.4	18
12	megenagna – bole – saris - kality meneharia	17.8	26
13	Megenagna - shola - lamberet - kotebe – kara	6.3	26
14	megenagna mizan - gurd shola – mer i- hayat	8.8	29
15	Megenagna - mizan - stadium – tegbared	10.1	17
16	megenagna terminal - kebena - silase college - goirgis	7.3	29
17	megenagna – kebena - 4killo - piassa – mesalemia	7.9	23
18	Megenagna – adwa – aware - banko de roma - tana gebeya	8.2	21
19	minilik hospital - giorgis raguel	5.1	18
20	Shiromeda - silase – kuskuam	2.8	6
21	Shiromeda - 4killo – estifanos - stadium	6.8	27
22	Shiromeda - giorgis - autobis tera	5.1	18
23	Shiromeda - tabot maderia - kidanemihret	2.8	14
24	Shoal – kebena – piassa -19kutr mazoria	6.4	29
25	Shoal - kebena - 6killo-piassa	4.1	6
26	Shiromeda - 4 killo – filwuha - mexico	7.2	3

	TSEHAY	Distance(km)	C-1Vehicles allocated
1	4 killo - 6killo - 41eyesus	4.6	2
2	Minilikschool - 6killo – bella	4.4	4
3	altad mikael – urael - stadium	6.8	11
4	bella-janmeda - 6killo - raguel	6.4	21
5	ferensay - giorgis – raguel	7.3	25
6	hayat RA - abakiros RA – tafo - mishen	8	43
7	kazanchis - 4killo-shiromeda	6.7	22
8	Lamberet – kebena - 4killo – piassa - autobis tera	11.2	41
9	Lamberet - bole Michael - saris - kalitymeharia	19.6	6
10	Megenagna - cmc - semit RA	7.4	48
11	Megenagna – wesen – kara - yekabado condominium	12.2	17
12	megenagna mizan - kazanchis total - 4killo - piassa	6.7	18
13	Megenagna – shoal – lamberet – kotebe - kara	6.3	16
14	megenagna mizan - gurd shola - meri-hayat	8.8	18
15	megenagna terminal - kebena - silase college - goirgis	7.3	31
16	megenagna – kebena - 4killo - piassa - mesalemia	7.9	78
17	Megenagna – adwa – aware - banko de roma - tana gebeya	8.2	55
18	diaspora- adwa -aware-arbengnoch building	5.1	39
19	minilik hospital - giorgis - autobistera	6	24
20	Shiromeda - 4killo – estifanos - stadium	6.8	22
21	Shiromeda – giorgis - autobis tera	6.4	19
22	Shiromeda - tabot maderia - kidanemihret	2.8	4
23	Shiromeda - giorgis - raguel	5.1	24
24	Shoal – kebena - 6killo - piassa	4.1	16
25	megenagna signal – kazanchis - mexico	6.6	7

	ZEBRA	Distance(km)	C-1 vehicles allocated
1	4 killo - 6killo – 41 eyesus	4.6	9
2	Minilikschool - 6killo – bella	4.4	25
3	abakiros RA-nibu Michael - bole arabsa	6	7
4	Gursholla – Balderas - biiherawi - shebelle	10.2	12
5	hayat RA - abakiros RA – tafo - mishen	8	6
6	kazanchis hanan – filwuha - t/haymanot - atobis tera	6.8	4
7	kazanchis total - 4killo-piassa - autobis tera	6.1	4
8	Lamberet – kebena - 4killo – piassa - autobis tera	11.2	23
9	megenagna - bole-saris kality meneharia	17.8	14
10	megenagna mizan- kazanchis total- 4killo- piassa	6.7	17
11	Megenagna – shoal – lamberet – kotebe - kara	6.3	26
12	megenagna mizan - gurd shoal - meri - hayat	8.8	35
13	Megenagna – mizan – stadium - tegbared	10.1	12
14	megenagna terminal - kebena - silase college - goirgis	7.3	24
15	Megenagna - gurd shoal - hayat - abakiros RA	11	15
16	megenagna – kebena - 4killo – piassa - mesalemia	7.9	16
17	Megenagna - adwa - aware - banko de roma - tana gebeya	8.2	22
18	Diaspora - adwa – aware - arbengnoch bulding	5.1	11
19	minilik hospital - giorgis - autobistera	6	49
20	minilik hospital - giorgis raguel	5.1	15
21	Shiromeda - giorgis – raguel	5.1	19
22	Shoal – kebena – piassa -19kutr mazoria	6.4	38
23	megenagna signal - kazanchis-mexico	6.6	11
24	4killo – tourist – filwuha - ambassador	3.2	10