DEVELOPING PARKING MANAGEMENT STRATEGIES FOR HAWASSA CITY :

A CASE STUDY OF MENEHARYA SUB-CITY

M.Sc. THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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A THESIS SUBMITTED TO THE
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ADVISORS’ APPROVAL SHEET

This is to certify that the thesis entitled **"Developing parking management strategies for Hawassa City : a case Study of Meneharya sub-city"** submitted in partial fulfillment of the requirements for the **Degree of Master's** with specialization in **Road and Transport Engineering**, the Graduate Program of the **Department of Civil Engineering** and has been carried out by **Haile Hassen Bogale** Id.No **PGRo/017/09**, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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EXAMINERS' APPROVAL SHEET

We, the undersigned members of the board of examiners of the final open defence by **Haile Hassen Bogale** have read and evaluated his thesis entitled **"Developing parking management strategies for Hawassa city : A case Study of Meneharya sub-city "** and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/School Graduate Committee (DGC/SGC) of the candidate's department.

DECLARATION

I hereby declare that this MSc thesis entitled as **"Developing parking management strategies for Hawassa city"** is my original work and has not been presented for a degree in any other University, and all sources of material used for this thesis have been duly acknowledged.

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ACRONMYS

AACRA	Addis Ababa city road authority
CBD	Central business district
E	Earth
ERA	Ethiopian road authority
LP	Linear programing
N	North
Off-P	Off-street parking
On-P	On-street parking
PEL	Planning and environmental linkage
PI	Parking index
RHS	Right Hand Side
SNNPR	Southern nation nationalities and peoples region
Sq. m	Square meters

ABSTRACT

Parking is one of an essential component of the transportation system. Vehicles may park at every destination. Increase in number of vehicle in developing cities like Hawassa will made the cities more congested and increase delays. Parking studies are therefore used to determine the demand for and the supply of parking facilities in an study area, the projection of the demand and the views of various interest groups on how best to solve the Problem. This thesis basically focus on developing parking management strategies of the city by selecting typical sub-city by using percentile and Weighted Factor Rating method. For the study both primary and secondary data used as a data source. Primary data collected from firsthand information through field surveys /mainly by license plate method/ from paved corridors of the sub- city, municipality interview and questionnaires. Secondary data sources also be collected from Hawassa city municipal documents , reports and Addis Ababa city road authority /AACRA/ manual . Data collection by field survey will made for two types of parking, for on street and off-street parking. Mainly license plate method of survey, questionnaires and interviews are used to collect data for the study. The analysis of the data from the questioners is carried out by using percentages and frequency count. As from questionnaires vehicle users are purposed for business, work, leisure and restaurant users respectively. In addition, the data from the city municipality road traffic safety administration indicates present usage of parking facility in the study area. The result of parking statistics mainly parking occupancy and parking index shows that there is the space for vehicles to park but problem of management results with unpatterned parking and becomes the case for parking accidents By better management and model formulation for on -street parking utilization area minimized. For instance by 30^o parking, 1492m^2 area of parking will be saved. By 45^o parking 4102 m^2,by 60^o parking 5268 m^2 and by 90^o parking 6040 m^2 area of parking will be saved. Number of improved parking spot is 119 by 30^o parking. 328 , 421 and 483 number of parking spots improved by 45^o,60^o and 90^o angle parking respectively. But since the carriage way of roads in the city is not much wide parking at wider angle is not recommended. Model validation , sensitivity analysis and model result evaluation also indicated that the existing parking capacity can be improved by better management.

Key words: parking index, parking duration, parking turnover, linear programming, , off-street parking, on-street parking.

1. INTRODUCTION

1.1 Background of the study

Parking is an essential component of the transportation system. Vehicles may park at different destination. Parking facilities are a major cost to society, and parking conflicts are among the most common problems facing designers, operators, planners and other offices. Such problems can be often defined either in terms of supply (too few spaces are available, somebody must build more) or in terms of management (available facilities are used inefficiently and should be better managed). The provision of parking is an essential consequence of the movement of people and goods into and within urban areas. However, parking is also associated with traffic congestion due to too many vehicles seeking to gain access to particular locales at one time and the inability of the road and parking systems to provide for them (Robert , 2001).

Parking management refers to policies and programs that result in more efficient use of parking resources. When appropriately applied parking management can significantly reduce the number of parking spaces required in a particular situation, providing a variety of economic, social and environmental benefits. When all impacts are considered, improved management is often the best solution to parking problems (Litman, 2008).

Management solutions tend to be better than expanding supply because they support more strategic planning objectives: Reduced development costs and increased affordability, More compact, multi-modal community planning (smart growth), and reduce motor vehicle use (thereby reducing traffic congestion, accidents and pollution),Improved user options and quality of service, particularly for non-drivers, Improved design flexibility, creating more functional and attractive communities, Ability to accommodate new uses and respond to new demands, Reduced impervious surface and related environmental and aesthetic benefits(Litman, 2013).

Parking demand is mainly influenced by the type and function of land use and the quality of the public transport system- and hence the parking policy developed for any particular area depends very much on the local situation. In villages and the smaller towns and in the outer areas of larger towns parking policy is often based on providing enough parking spaces (supply) to meet the demand. In large towns and cities, however, the overall transport objectives of reducing accidents and safeguarding the accessibility of the central area by reducing traffic congestion on the radial roads and in the town Centre and the quality of life in and about the central area by reducing noise and environmental pollution usually become paramount, and parking policy may be aimed at controlling the parking supply so as to induce appropriate shifts in the modal split in favor of public transport to reduce the parking demand (Rao and Tom, 2007).

1.2 Statement of Problem

Hawassa is one of the fast growing city in the urbanization and transportation sectors .It is also business and political center for southern nation nationalities and peoples region. In addition, it accommodates many international Aid and Development organization. Due to fast growth, the city is exhibiting high social, economic, structural challenges. There are about more than 100,000 vehicles found in the city (including 2-wheeled motor vehicles) and among them, 35% of vehicles are unregistered/unlicensed (City Transport Administration, 2017).

As a report of WHO(2014), in world level traffic accident is the case for 1.3 million peoples death and is becoming case of death for about 1.9 million peoples per year and is becoming most fourth case for fatal death in 2020 if not managed properly. In Ethiopia, more than 8000 peoples are died, sever and light body injury and many property damage occurred due to traffic accident and it is more than 500 million birr when converted to money . Additionally in Ethiopia 14% of traffic density is created by searching for parking space and 50% of increase in congestion-related time loss on roads has been generated due to shortage of parking space.

Based on the observation, parking management system in the city is very poor and also there is gap to enforce different service suppliers to apply parking requirement as one of the criteria during delivering different service licenses for better service.

Investigation of parking management strategies for the city therefore necessitate to determine the demand for and the supply of parking facilities in an area and investigation on how best to solve the Problem.

1.3 Objectives

1.3.1 General objective

The General objective of this study is developing parking management strategies for Hawassa city specifically Menehareya sub city.

1.3.2 Specific objectives

The specific objectives of the study are:

- To examine the existing parking demand and supply of Hawassa city.
- To examine the existing parking trend in the city.
- To develop parking optimization model for better management of the parking facilities.

1.4 Scope and Limitation of study

1.4.1 Scope of study

The study mainly focused about developing parking management strategies for Hawassa city by examining the existing parking demand and supply of the city, by examining the existing parking trend in the city and by indicating the best suit parking management strategies for the city by using linear programing model.

1.4.2 Limitation of study

Due to time and budget limitation , the study limited to Menharya sub-city by percentile and Weighted Factor Rating selection criteria method . On-street survey data collected from paved corridors for model formulation for the city. The formulated model constraints consists of arrival rate, average parking accumulation , parking angles and average parking duration . Three vehicle types(trucks, passenger cars and motor vehicles) are considered and three wheeled vehicle is considered as passenger car.

1.5 Significance of the study

The significance of this study is

- To indicate the solutions for problems related to current parking trend by effective use of existing parking space.
- To identify whether the problem is associated with supply or management in order to indicate the effective parking management strategy.
- To indicate the direction for the city local authorities mainly road traffic safety management offices to apply parking management strategies in the city for better service.
- Also the study used to provide minimum, safe and feasible parking areas that earns different advantages for passengers as well as car users and additionally the paper has the significance for other researchers for further study.

2. LITERATURE REVIEW

2.1 Introduction

Parking is the stopping or standing of a vehicle, whether occupied or not for the purpose of and while actually engaged in loading or unloading property or passengers. It is an important component of transportation policy and management in any city. Parking facilities are a major cost to society, and parking conflicts are among the most common problems facing designers, operators, planners and other officials. Such problems can be often defined either in terms of supply (too few spaces are available, somebody must build more) or in terms of management (available facilities are used inefficiently and should be better managed) **(**Robert ,2001).

The need for parking spaces is usually great in areas where land uses include business, residential, or commercial activities. The growing use of the automobile as a personal feeder service to transit systems has also increased the demand for parking spaces. Providing adequate parking space to meet the demand for parking in the CBD necessitate the provision of parking bays along curbs, which reduces the capacity of the streets and may affect the level of service . The provision of parking facilities is an essential for the movement of people and goods into and within urban areas. However, parking is also associated with traffic congestion due to too many vehicles seeking to gain access to particular locales at one time and the inability of the road and parking management systems to accommodate the service (Roess ,2004).

2.1.1 Parking management

Parking management refers to policies and programs that result in more efficient use of parking resources. It includes several specific strategies. When appropriately applied parking management can significantly reduce the number of parking spaces required in a particular situation, providing a variety of economic, social and environmental benefits. When all impacts are considered, improved management is often the best solution to parking problems. (Trenton Downtown Parking Policy Report , 2008)

2.1.2 Parking Principles

Based on the information from Trenton Downtown Parking Policy(2008), ten general principles that can help and guide planning decision to support parking management:

Consumer choice: - People should have viable parking and travel options.

User information:-Motorists should have information on their parking and travel options. Sharing: - Parking facilities should serve multiple users and destinations.

Efficient utilization: - Parking facilities should be sized and managed so spaces are frequently occupied

Flexibility: - Parking plans should accommodate uncertainty and change.

Prioritization: - The most desirable spaces should be managed to favor higher-priority uses.

Pricing:-As much as possible, users should pay directly for the parking facilities they use.

Peak management:-Special efforts should be made to deal with peak-demand.

Quality vs. quantity: - Parking facility quality should be considered as important as quantity, including Aesthetics, security, accessibility, and user information.

Comprehensive analysis:-All significant costs and benefits should be considered in parking planning.

2.1.3 Parking Management Benefits

Parking management gives more flexible facility location and design. Parking management gives architects, designers and planners more ways to address parking requirements, reduces costs to governments, businesses, developers and consumers, improved quality of service. Many strategies improve user quality of service by providing better information, increasing consumer options, reducing congestion and creating more attractive facilities. Another benefits is some management strategies generate revenues that can fund parking facilities, transportation improvements, or other important projects. It can reduce land requirements and so helps to preserve green space and other valuable ecological, historic and cultural resources. Parking management is an important component of efforts to encourage more efficient transportation patterns, which helps to reduce problems such as traffic congestion, environmental and noise pollution, energy consumption and traffic accidents. Parking management helps create more accessible and efficient land use patterns, and support other land use planning objectives. It also can help to create more attractive and efficient urban environment by reducing total paved areas, allowing more flexible building design, increasing walkability and improving parking facility design (House of Common Transport Committee, 2013).

parking is an asset, which needs to be managed. It is a common misconception that providing as many parking spaces as possible is the best way to managing parking so as to maximize access. Rather, the key is to ensure that parking stock is managed so that spaces are made available for customers when and where is deemed appropriate for their needs. In this context, it is the number of parking acts that can be accommodated that is important not the absolute number of parking spaces provided. Proper management of parking will benefit your town in many ways, including contributing positively to economic performance and visual amenity. A parking 'free for all', with no restrictions or controls on parking and a lack of enforcement, represents a failure to manage the asset and a failure to provide good customer service. This may then adversely affect economic performance. Management of parking can have appositive impact on economic viability by enabling 'better' (more productive) use to be made of the spaces with in towns, providing that it is done sensitively and appropriately. Public space is often limited within market towns, and it is not uncommon for the most attractive parts of the town, such as historic market squares, to be hidden behind area of parked cars (Shiferaw, 2014).

2.1.4 Car parking standards

Local authorities now normally specify the number of parking spaces to be provided with a new development when granting planning permission. In some instances this will be the maximum number of parking spaces that is permitted, in other cases it will be the mini- mum number that must be provided. On the roads are normally congested that most people use public transport to access it .At the cores of the central areas of large cities maximum parking limits might be imposed. By contrast, the outer reaches of large towns and smaller towns with good access roads and poor public transport services would typically have strict requirements regarding the minimum number of spaces that must be provided with a new development (Mcshane, 2002).

2.1.5 Parking requirements

There are some minimum parking requirements for different types of services. For residential plot area less than 300 square meter one parking space required. For residential plot area from 500 to 1000 square meter, minimum one-fourth of the open area should be reserved for parking. Offices require at least one space for every 70 square meter as parking area. One parking space is enough for 10 seats in a restaurant where as theatres and cinema halls need to keep only 1 parking space for 20 seats (Tom and Rao, 2007).

2.2 Parking Surveys

Parking surveys collected to conduct parking statistics. As Tom and Rao (2007) in their research of residential car parking, the most common parking surveys are in-out survey, fixed period sampling and license plate method of survey:

2.2.1 In-out survey

In this survey, the occupancy count in the selected parking lot is taken at the beginning. Then the number of vehicles that enter the parking lot for a particular time interval is counted. The number of vehicles that leave the parking lot is also taken. The final occupancy in the parking lot is also taken. Here the labor required is very less. Only one person may be enough. But we won't get any data regarding the time duration for which a particular vehicle used that parking lot. Parking duration and turnover is not obtained. Hence we cannot estimate the parking fare from this survey.

2.2.2 Fixed period sampling

For quick survey purposes, a fixed period sampling can also be done. This is almost similar to in-out survey. All vehicles are counted at the beginning of the survey. Then after a fixed time interval that may vary between 15 minutes to 1 hour, the count is again taken. Here there are chances of missing the number of vehicles that were parked for a short duration.

2.2.3 License plate method of survey

This results is the most accurate and realistic data. In this case of survey, every parking stall is monitored at a continuous interval of 15 minutes or so and the license plate number is noted down. This will give the data regarding the duration for which a particular vehicle was using the parking bay. This will help in calculating the fare because fare is estimated based on the duration for which the vehicle was parked. If the time interval is shorter, then there are less chances of missing short-term parkers. But this method is very labor intensive.

2.3 Parking statistics

Before taking any measures for the better management conditions, data regarding availability of parking space, extent of its usage and parking demand is essential. Parking surveys are intended to provide all these information. Since the duration of parking varies with different vehicles, several statistics are used to access the parking need. The following parking statistics are normally important (Tom and Rao, 2007).

Average parking duration: It is the ratio of total vehicle hours to the number of vehicles parked.

$$\text{Parking duration} = \frac{\text{parking load}}{\text{parking volume}} \qquad 2.1$$

Where:- *Parking volume* is the total number of vehicles parked at a given duration of time. This does not account for repetition of vehicles. The actual volume of vehicles entered in the area is recorded.

Parking load gives the area under the accumulation curve. It can also be obtained by simply multiplying the number of vehicles occupying the parking area at each time interval with the time interval. It is expressed as vehicle hours.

Parking turnover: It is the ratio of number of vehicles parked in duration to the number of parking bays available.

$$\text{Parking turnover} = \frac{\text{parking volume} * 100}{\text{No: of bays available}} \qquad 2.2$$

Parking index: It is also called efficiency. It is defined as the ratio of number of bays occupied in time duration to the total space available. It gives an aggregate measure of how effectively the parking space is utilized.

$$\text{Parking index} = \frac{\text{parking load}}{\text{Parking capacity}} \qquad 2.3$$

Parking occupancy: are represented how many of the available spaces are occupied.

$$\text{Parking occupancy} = \frac{\text{vehicle parked}}{\text{Number of space}} \qquad 2.4$$

Parking accumulation: It is defined as the number of vehicles parked at a given instant of time. It is expressed by accumulation curve. Accumulation curve is the graph obtained by plotting the number of bays occupied with respect to time.

Number of parking spaces is measured by dividing the length of street where parking is allowed by the average length of a car with different available consideration .

Number of parking space $= \frac{L-[(b*5)+(e*3)+Tc*15)+(i*7)]}{a}$ ……...(2.5) (Abdoulaye Diallo et al., 2012)

Where:

L= average length of the stretch of road (m) b= number of terminal-fountain (5 meters)
e= number of driveways(3 meters) Tc = number of bus stops(5meters)
i= number of spaces where there is a strict prohibition of parking (7 meters.)
a = average space (linear) occupied by a parked car (m)

2.4 Parking facilities

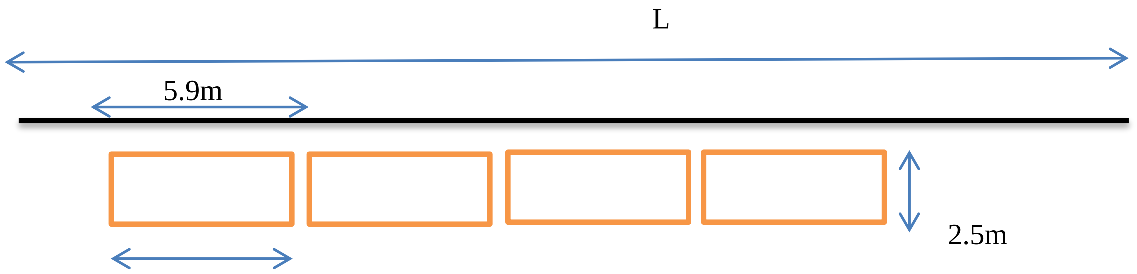
There are four following kinds of car parking facilities (Babatunda,2012):

Private car parking: a parking facility like parking in multi-story building and underground parking lot.

Public parking: which is includes like gateway and railway station parking

On-street parking (On-P): is the adequate space for vehicles at the side of the road. Bus stop is a parking space provided for motorists along the road way in the central business districts and also at designated place. On street parking means the vehicles are parked on the sides of the street itself. This will be usually controlled by government agencies itself. Common types of on-street parking are as listed below. This classification is based on the angle in which the vehicles are parked with respect to the road alignment (Tom and Mathew, 2014).

Parallel parking: The vehicles are parked along the length of the road. Here there is no backward movement involved while parking or unparking the vehicle. Hence, it is the safest parking from the accident perspective. However, it consumes the maximum curb length and therefore only a minimum number of vehicles can be parked for a given kerb length. This method of parking produces least obstruction to the on-going traffic on the road since least road width is used.



5m Figure 2.1 parallel parking

30◦ parking: In thirty degree parking, the vehicles are parked at 30◦ with respect to the road alignment. In this case, more vehicles can be parked compared to parallel parking. Also there is better maneuverability. Delay caused to the traffic is also minimum in this type of parking.

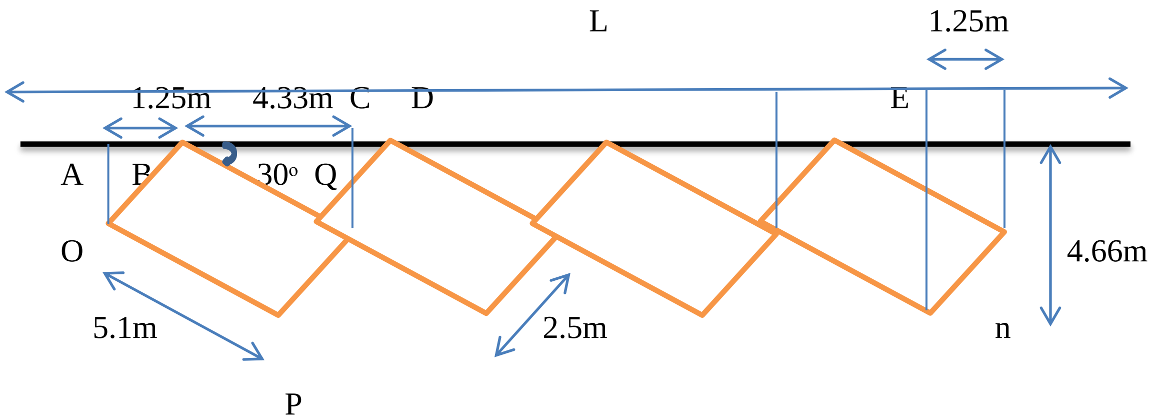


Figure 2.2 30° parking

The general formula formulated as the following

$$AB = OB\sin 30^\circ = 1.25$$

$$BC = OP\cos 30^\circ = 4.33$$

$$BD = DQ\cos 60^\circ = 5.1$$

$$CD = BD - BC = 5.1 - 4.33 = 0.67$$

$$AB + BC = 1.25 + 4.33 = 5.58$$

N=Number of vehicles $L = AC + (N-1)\,CE = 5.58 + (N-1)5 = 0.58+5N$

45°parking: As the angle of parking increases, more number of vehicles can be parked. Hence compared to parallel parking and thirty degree parking, more number of vehicles can be accommodated in this type of parking.

For L= Length of parking space, N=number of vehicles in a given area. L = 3.54 N+1.77

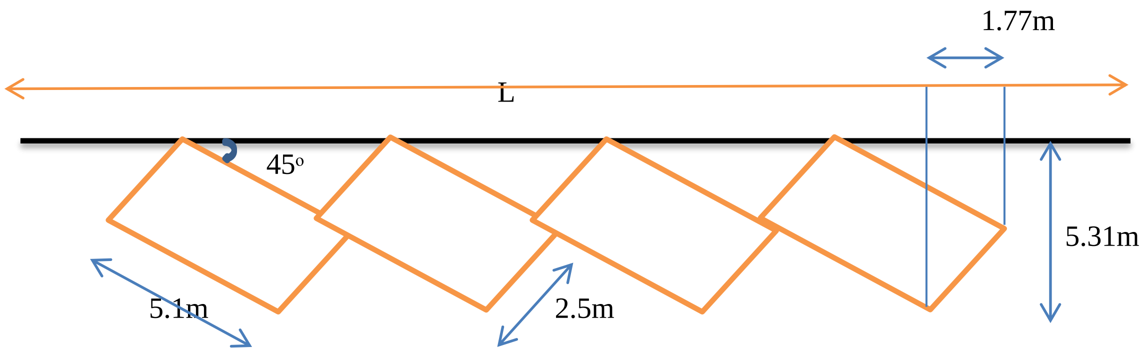


Figure 2.3 45° parking

60° parking

This type of parking area accommodated more than the above parking types and it's recommended to the angle parking in the on-street roads.

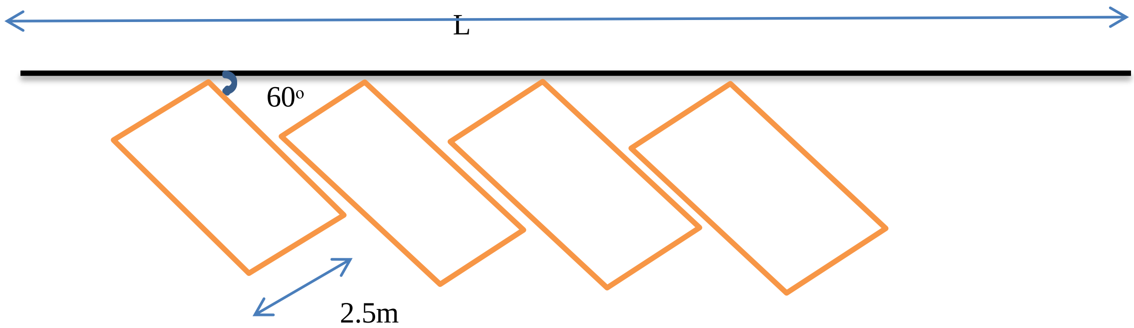


Figure 2.4 60° parking

Length available for parking N number of vehicles is L = 2.89N+2.16.

Right angle parking : The right angle parking, the vehicles are parked perpendicular to the direction of the road. This parking angle saved maximum road width and length that creates congestion on the roads by reducing road diameters. In this type of parking, the vehicles need complex maneuvering and this may create congestion and accidents. This arrangement causes obstruction to the road traffic particularly if the road width is less. The 90 degree angle parking is the most efficient in terms of layout and perception.

Length available for parking N number of vehicles is L = 2.5N

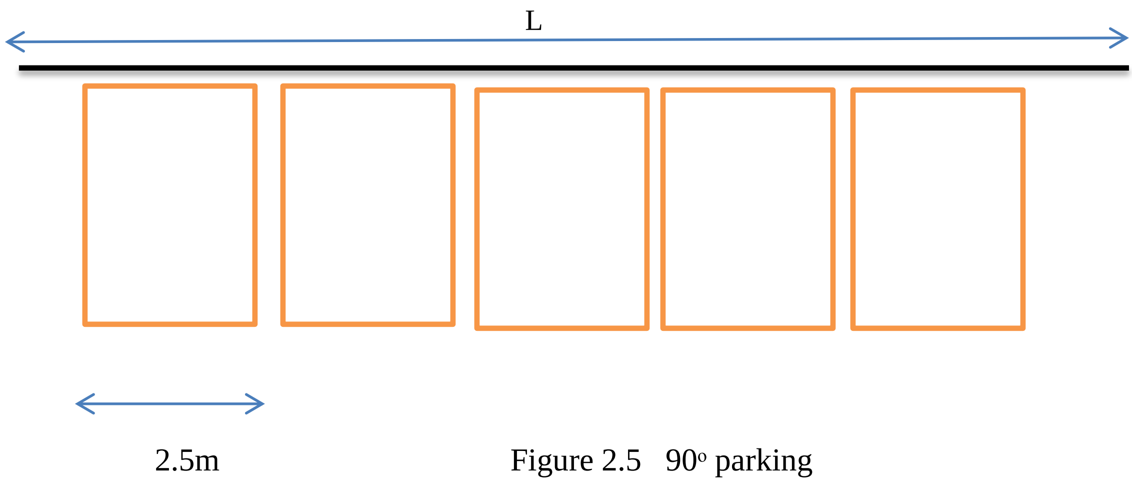


Figure 2.5 90° parking

Off-street parking (Off-P): is the place where near to their destination and outside from carriageway. Terminal is parking space whether at the earth or off-street in a lot, garage, shopping center or private driveway.

2.4.1 Parking control Unit

Parking Control Unit is the parking space used for a vehicle, which depend on vehicle dimension and additional space needed for a vehicle to maneuver whose value depending on the parking angle. PCU of each vehicle can be obtained in the following.

Table 2.1 Vehicle and parking dimensions for different vehicle types

No	Types of Vehicles	Width (M)	Parking width (M)	Length (M)	Parking length (M)
1	Motorcycle	0.8	1.3	1.9	2.4
2	Passenger car	1.5	2.5	4.0	5.0
3	Medium bus	2.1	3.1	6.0	7.0
4	Big bus	3.5	4.5	9.3	10.3
5	Truck	2.4	3.4	7.2	8.2
6	Small bus	1.6	2.6	4.1	5.1

Source:Said Munzir et al.,(2010).

2.5 Different Strategies and Policies Regarding Parking

In the world different strategies and policies are formulated to manage parking problems in the city (Sharma K.M. et al.,2017).

Table 2.2 parking strategies

No	Strategies and Policies	Descriptions
1	Centralized Parking strategy	In the centralized parking system large number of people gathered at once parking place which we call a center for the parking and then travel by the help of other modes of transportation. The centralized parking lot is good with respect to economic, environmental and urban design perspective but raise concerns for building occupants, such as lack of parking proximity.
2	Meters In Parking Lots	In metric parking system, using meters in parking it will help us to optimize turnover of parking space for priority customers. As we use parking meters its price deflects according to the market demand in which they raise charges of curb in peak hours in the parking lots.
3	Mixed Use Parking	In the mixed parking strategy when maximum demand arriving in the parking lot, the drivers requires shared parking in mixed use areas, these demand occurs at different times. Such as temples, churches, mosques etc. They should share their parking with the nearby residential parking lots and commercial establishments on the occasion of festival or religious functions. This strategy works effectively they provide a lot of parking space on the peak time to minimize congestion on the roads.
4	Shuttle Service	In the shuttle service promoted parking, the system introduces shuttle buses to reach final specific destination. In the system, customers use centralized parking to park their vehicles and then with the help of shuttle bus service commuters may reach their final destination.
5	Parking Freezes	In parking freezes system After certain time limit some parking areas in the neighborhood are not allowed to be used for the purpose of

		parking in the city especially in the residential streets. For instance, parking is not allowed in the residential streets close to city center after 5pm. The amount of parking required can be directly reduced through parking freezes that cap the total number of parking spaces in a particular district for the limited time.
6	Smart Parking	Smart parking a system that informs and navigates the driver about the free space available in the nearby parking area using smart sensors and Smartphone application, the resident may get a notification on his Smartphone about a free space that is at some distance from his home. Currently, many municipalities rely on old-fashioned parking standards that result in an abundance of parking at the cost of community's character and vitality. Smart parking approaches can address these issues through a variety of techniques by tailoring standards, managing demand and improving parking facility design.
7	Demand Reduction	The centralized and shared parking not only decrease the parking requirements but also provide ways to reduce excess parking supply. The Demand reduction strategy directly focusing on the reduction of parking demand by replacing parking spaces for bus stops or reserved parking spaces for carpooling, car sharing, etc. It is also possible to reduce the need for parking lot and the associated costs influencing the demand for parking. It can be achieved by increasing the price of parking or by promoting non-auto transport incentives.

Source : Sharma K.M, et al. ,(2017)

2.5.1. Parking management strategy alternatives

Shared Parking

Shared parking is defined as ,the use of a parking space to serve two or more individual land uses without conflict or encroachment .This practice is already commonly seen in larger downtowns, where parking (usually in garages)is not necessarily tied to a particular building and its uses, but can be used by anyone visiting any of the nearby buildings. Shared parking is most commonly found in downtowns and larger activity centers, but it can be a vital component in good mixed-use or transit-oriented developments, or anywhere that place-making is a focus. The pedestrian environment of a site often benefits greatly from shared parking (Smith, 2005).

Institutional Parking

Since the largest peak-period demand for parking comes from home-to-work trips, and a majority of commuters drive to work alone, employer parking management strategies can be very successful at reducing overall vehicle miles traveled (VMT). The goal of employer parking strategies is to reward people who take alternative modes of transportation and discourage or penalize single-occupant drivers, with the use of incentives and disincentives. The greatest reduction in single-occupant drivers is seen when employers eliminate parking subsidies while implementing other incentives. If employers offer incentives to use other modes and continue to subsidize parking, it is difficult or impossible to reduce the number of single occupant drivers. If employers continue to provide free parking, there will always be a high demand for it. This has an influence on the development of municipal zoning laws , which often require excessive parking spaces. There is a need to coordinate the efforts of reducing employer-subsidized parking and the changing of local zoning requirements (Wilson and Shoup, 1990).

Structured Parking

The choice between surface and structured parking is generally driven by land costs. Where land costs are higher– usually in denser, more urban environments . It becomes more economical to build up than to build out (Bier et al., 2006).

On-street Residential Neighborhood Parking

Some areas with high demand for parking and/or high parking fees may push demand for parking into nearby residential neighborhoods. This demand can be managed with parking permits for residents. Overly restrictive regulations in residential areas can, however, lead to increased public and private parking development costs, which can prevent transit-oriented and traditional neighborhood development. Local authorities should evaluate neighborhoods on a block-by-block basis, balancing the residential parking demand with employee and customer access (Shoup,2004).

Peripheral Parking Lots

Parking lots placed outside of the central business district, usually with shuttle service to major destinations, are called peripheral parking. When within 1 mile of the activity center, however, most users will actually walk to their final destination. The primary goal of peripheral lots is to divert traffic from the central business district (CBD) or major destinations where traffic bottlenecks might occur. Unlike other parking management strategies, the use of peripheral parking might change where people drive, but it is generally not an attempt to influence the mode choice or travel behavior of the driver (Kuzmyak et al., 2003).

Sub-station

It related with peripheral parking lot but substation is with in short radius from service area and is out of carriage way.

On-street Commercial Area Parking

On-street parking, as close to a business as possible, is the most convenient type of parking for potential customers, and keeping those spots available for short-term use should be a high priority. If on-street commercial parking is not managed or priced, commuters, employees and spillover parkers avoiding fees will use the parking spaces and the desired patrons will not have a place to park. Municipalities charge a price that will ensure that approximately 15% of the spaces are always vacant. This could be in the form of variable pricing that maintains a high enough price so that there will always be some vacancy, but not so high as to send business to other locations. Prices and restrictions would vary by block, time-of-day, and day-of-week (Shoup, 1990).

Managing parking in commercial areas typically involves ,setting peak hour, daytime, or 24-hour parking restrictions; establishing parking time limits, and installing parking meters . The most important factor influencing the behavior of single-occupant drivers is parking cost to user, not supply; there is also a less intense relationship for maximum time limits. It is important for communities to develop contingency plans so that they can provide the minimum spaces, and have strategies to provide more if necessary (Kuzmyak et al., 2003).

2.6 Concept of Optimization

Optimization is also known as mathematical programming, finding optimal solutions that give maximum performance, profit, output or satisfaction and minimum cost, waste or dissatisfactions. It solves the problem of deciding how to optimally allocate scarce resources such as people, materials, spaces, money and land. An optimization model attempts to optimize an objective function by searching for the best set of decision variables that fulfill the given constraints. It is common to use the word" optimize", which means to maximize or minimize, in any optimization problem. A mathematical function, also known as an objective function, to be optimized could be a function of only one variable, called single-objective problem, or a function of multiple variables, called multiobjective problem. Furthermore, an objective function could also be constrained or unconstrained (Charpin et al.,2015).

2.6.1 Optimization models

There are different optimization models to best utilize the available spaces. The optimization models are linear programming (LP) model , nonlinear programming (NLP) model and also Integer programming (IP) model. Integer programming (IP) required additional requirement that is the variable in the model have to be integer, Mixed integer linear programming required only some of the variable are required to be integer, Non-linear Programming(NLP) includes some process solving a programming problem subject to certain constraints, over a set of unknown real variables, but where some of the constraints or the objective function are non-linear (Pinedo, 2005) but linear programming is formulated as a linear programming problem because it can optimize the resources and the decision variables are real number and objective and constrain equations are linear (Munzir et al.,2010). Definition of terms used in the model, model formulation and input parameters for linear programing model presented as follows:

Definition of Terms Used in the Model

i = Types of vehicles considered in model formulation**.**

j = Number of parking spot at on-street parking lot,

$a_{i,j}$ = Parking area for each type of vehicles (i) at parking lot with parking spot(j).

$A_{i,j}$ = Total parking area capacity for each type of vehicles (i) at parking lot (j)

c_x, c_y, c_z = parking area utilization factors for different types of vehicles

$Td_{i,j}$ = Average parking duration of each type of vehicles (i) at parking spot(j) in on-street parking lot.

$Pa_{i,j}$ = Average parking accumulations of each type of vehicles (i) at parking spot (j) in on-street parking lot.

r_{ij} = Average Arrival rate of each types of vehicles (i) at parking spot (j) in on-street parking lot.

The objective of the model is to maximize the existing on-street parking capacity by considering different constraints such as road length and width, parking angles, average parking duration, average parking accumulation, arrival rate of vehicles, vehicles size and the following assumptions are considered.

1. The on-street parking locations parking capacity is known or is assumed.

2. The vehicles arrive at the on-street car parking zone with arrival rate of vehicles per 15 minutes and their average parking duration in 15 minutes interval is considered for all types of vehicles.

3. Size and area of different types of vehicles varies for respective vehicle types. For instance, the size of vehicle types of passenger cars and motorcycles are assumed to be smaller than a truck and the parking spots of truck are assumed to be greater than parking spots of both vehicles.

The process of Model Validation and Sensitivity analysis determines whether the results are appropriate or the need of modification as well as the choice of other the solution techniques as necessary.

Model Formulation

The objective of the model is to maximize the total parking area capacity for the vehicles. That is maximizing $\Sigma^{n}_{i=1} \Sigma^{m}_{j=1} (a_{1,j}+a_{2,j}+a_{3,j})$ by fulfilling different constraints. The first constraint is to set the overall combined parking area capacity for the types of vehicles (i) at parking spot (j)ensures that the sum of the parking area in each parking lot is less than or equal to the total parking area capacity ($A_{i,j}$). and is expressed as

$$\Sigma^{n}_{i=1} \Sigma^{m}_{j=1} a_{i,j} \leq A_{i,j} \text{ --2.6}$$

The other constraints of parking area capacity based on different situation in parking lot such as arrival rate of vehicles, average parking duration, and average parking area accumulations based on vehicles size and parking angle. In this regard, the following equations (2.7), (2.8) and (2.9) constraint show that the parking area required for each types vehicles a_{ij} and the proportion of vehicles (i) average arrival rate ($r_{i,j}$),average parking accumulation ($Pa_{i,j}$) , and average parking duration ($T_{d\ i,j}$) for every 15 minutes for each types of vehicles(i)in the parking lot. Which is expressed as:

$$\Sigma^{n}_{i=1} \Sigma^{m}_{j=1} a_{i,j} \frac{ri,j}{\Sigma\, n\ i=1\ \Sigma\, m\ j=1\ ri,j}) \leq a_{i,j} \text{ ------------------------------2.7}$$

In the model constraint, in Equation (2.7) ensure that the proportion of vehicles average arrival rate every 15 minutes for each types of vehicles computed from the average arrival rate divided by total average arrival rate for three types of vehicles (i) and the multiplied by parking space capacity is less than or equal to the total parking space.

$$\Sigma^{n}{}_{i=1} \Sigma^{m}{}_{j=1} a_{i,j} \frac{Tdi,j}{\Sigma\, n\, i=1\, \Sigma\, m\, j=1\, Tdi,j}) \leq a_{i,j} \text{ ---------------------2.8}$$

In the model constraint, in Equation (2.8) reflect that the proportion of vehicles average parking duration at every 15 minutes for each types of vehicles(i) computed from the average parking duration divided by total average parking duration for three types of vehicles (i) and then multiplied by parking space capacity is less than or equal to the total parking space for vehicle (i).

$$\Sigma^{n}{}_{i=1} \Sigma^{m}{}_{j=1} a_{i,j} \frac{Pai,j}{\Sigma\, n\, i=1\, \Sigma\, m\, j=1\, Pai,j}) \leq a_{i,j} \text{ ---------------------2.9}$$

In the model constraint, in Equation (2.9) ensure that the proportion of vehicles average parking accumulation every 15 minutes for each types of vehicles computed from the average parking accumulation divided by total average parking accumulation for three types of vehicles (i) and the multiplied by parking space capacity is less than or equal to the total parking space for vehicle(i).

The non-negativity in Equation (4.3e) keeps the variables equal to or greater than zero.

$$a_{i,j} * r_{i,j} * Td_{i,j} * Pa_{i,j} \geq 0 \text{ ---2.10}$$

The constraints equations (2.6), (2.8), (2.9), and (2.10) were formulated. But in this study model, added additional constraint which is Equation (2.7) for optimization of parking spaces in the on-street parking lot. Equation (2.7) is called the average arrival rate constraint of vehicles in the parking lot this equation (2.7) included additional three sub constraints for instance are constrain of Trucks (a_1), constrain of Passenger cars (a_2) and constraint of motorcycles (a_3). The general LP-model that determine the optimal parking space by reducing parking area and is formulated as follow:

Objective function: maximize $\Sigma^{n}{}_{i=1} \Sigma^{m}{}_{j=1}(a_{1,j}+a_{2,j}+a_{3,j})$

Subject to:

Constraint of total parking capacity

$$C_x a_{1,j}+C_y a_{2,j}+C_z a_{3,j}) \leq A_{i,j}$$

Constraint of arrival rate (ri,j)

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{r1,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (r1,j+r2,j+r3,j)}) \leq a1,j$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{r2,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (r1,j+r2,j+r3,j)}) \leq a2,j$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{r3,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (r1,j+r2,j+r3,j)}) \leq a3,j$$

Constraint of parking Duration (Tdij)

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Td1,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Td1,j+Td2,j+Td3,j)}) \leq a1,j$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Td2,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Td1,j+Td2,j+Td3,j)}) \leq a2,j$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Td3,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Td1,j+Td2,j+Td3,j)}) \leq a3,j$$

Constraint of parking accumulation(Pa ij)

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Pa1,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Pa1,j+Pa2,j+Pa3,j)}) \leq a1,j$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Pa2,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Pa1,j+Pa2,j+Pa3,j)}) \leq a2,j$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Pa3,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Pa1,j+Pa2,j+Pa3,j)}) \leq a3,j$$

3. MATERIALS AND METHODS

3.1. General

Before conducting the study, different literatures were reviewed and also preliminary observation performed in the city. The following figure shows general design flow of the research.

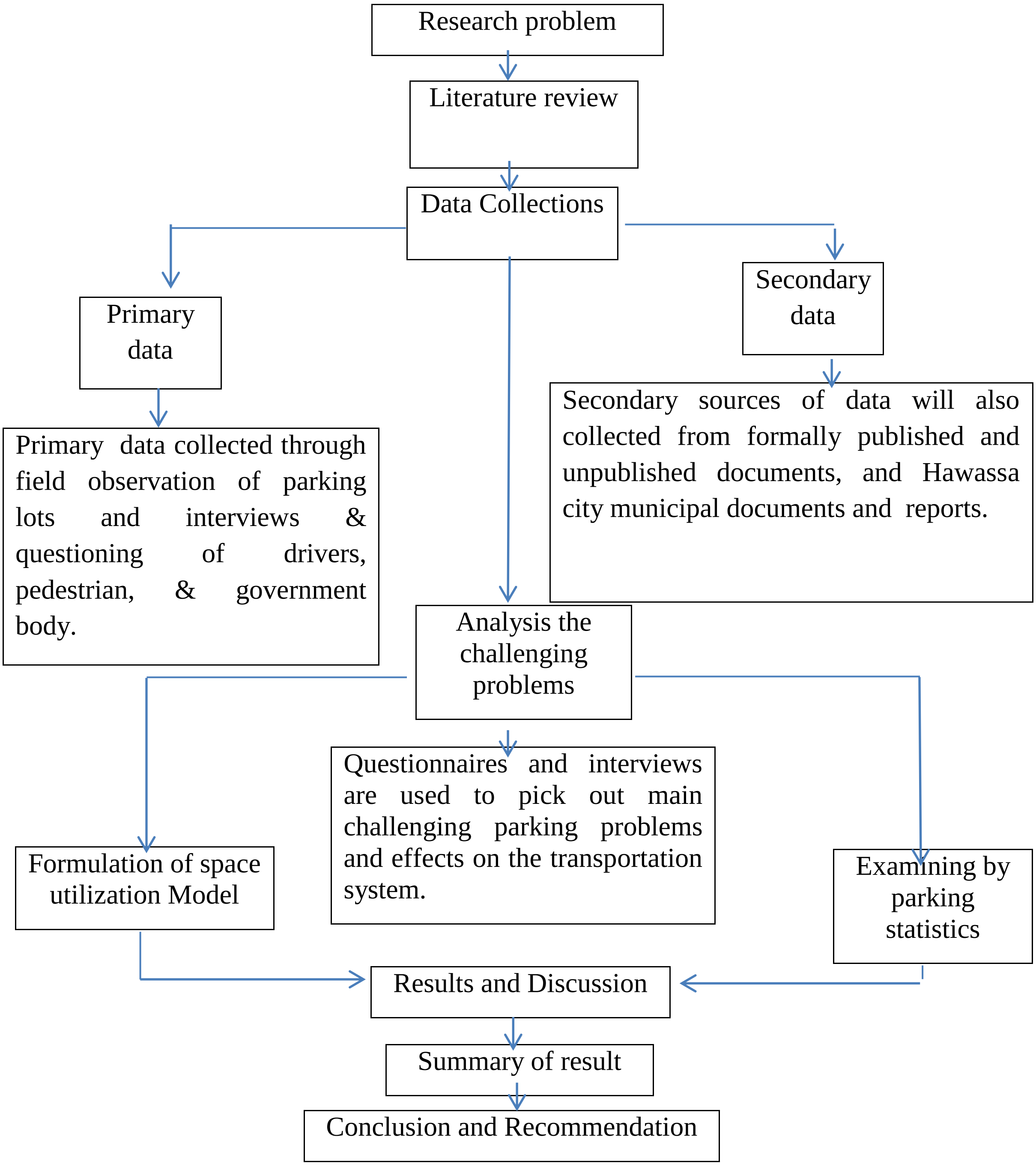


Figure 3.1 Schematics of the study

3.2 Description of study area

Hawassa is a city in southern Ethiopia, on the shores of Lake Hawassa in the Great Rift Valley. It is located 285 km south of Addis Ababa via Debrezeit. It lies on the Trans-African Highway 4 Cairo-Cape Town, and has latitude of 7°3′43″N, longitude of 38°28′34″E and an elevation of 1708 meters above sea level.

Figure 3.2 Location of Hawassa city: *source Google map,(2017) Scale 1: 5000*

Based on the Census conducted by the Central Statistical Agency of Ethiopia 2015, the city has a total population of 258,808, of whom 133,123 are men and 125,685 women. While 61% are living in the city of Hawassa, the rest of population of this zone is living at surrounding rural kebeles. Currently it is estimated that the population of Hawassa city is around a half million and more than 100,000 registered and unregistered vehicles are found in the city including two-wheeled motor vehicles.

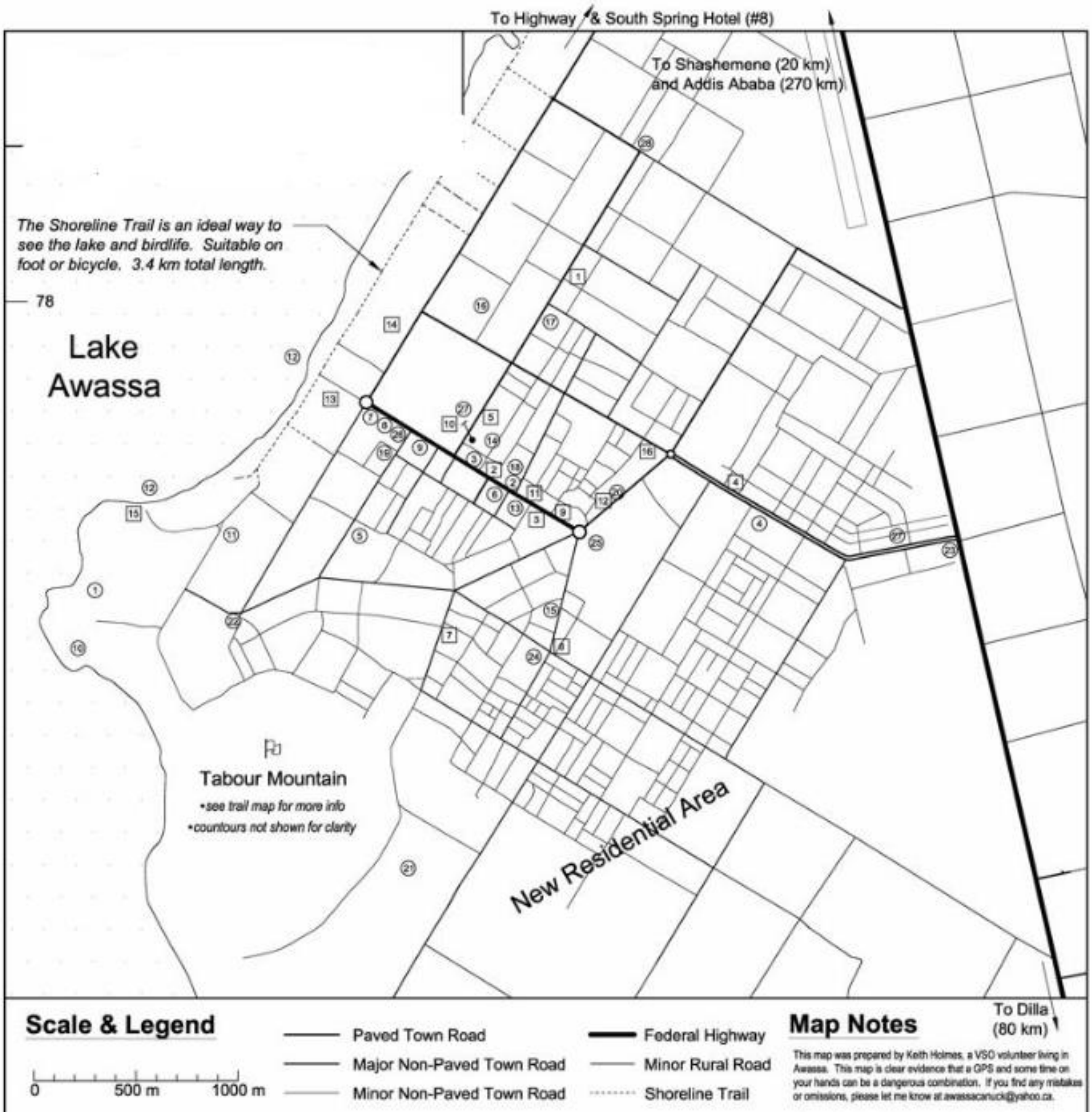


Figure 3.3 Hawassa city road network map : *Source Google map,(2017)*

3.2.1 Identification of study area

There are different methods to identify or select parking area selection criteria. Among them here we used:

a) percentile method and

b) Weighted Factor Rating Method .

a) Percentile method

By this method particular (focused) data among total annual data be checked. In the following table percentile of parking related accidents of each sub-city calculated.

Table 3.1 Damages caused by vehicle accident at Hawassa city

Year G.C.	**Number of accidents**	**Fatal /death accident**	**Serious body damage**	**Light body damage**	**Property damage**
2008	117	29	48	22	422,752
2009	195	16	33	61	42,954
2010	112	15	20	42	542,820.99
2011	158	19	26	44	565,376.71
2012	201	27	41	72	1,718,120
2013	140	22	60	48	650,550
2014	166	22	46	59	1,442,890
2015	106	28	47	32	843,700
2016	77	26	31	15	712,070
2017	106	20	32	24	1,698,000
2018	**218**	**30**	**31**	**83**	**1,780,500**

Source : Hawassa city road traffic safety dedication,(2018)

Table 3.2 Hawassa city distributed accidental data

Sub-city	Number of accidents	Accidents related to parking	Percentile(%)
Misrak sub-city	23	4	17.4
Mehal sub-city	20	5	25.0
Bahil adarash sub-city	25	6	24.0
Menharya sub-city	**33**	**9**	**27.3**
Tabor sub-city	19	4	21.0
Haik-dar sub-city	27	7	25.9
Adis ketema	22	4	18.2
Tulla sub-city	20	3	15.0

Source : Hawassa city road traffic safety dedication,(2018)

Since accidental percentile value of Menharya sub-city is relatively higher than the other sub-cities , it is more critical by percentile method.

b) Weighted Factor Rating Method.

In this method of rating, different factors are assigned based on relative importance for parking area selection criteria and weightage score assigned by professionals and experts for each site using parking area selection criteria. This method of rating merges and considers both qualitative and quantitative factors. The following table shows the parking area selection criteria and selected score values for Ethiopian cities. The ranking has been given based on professional skill, local consideration and standards .In terms of location, local planning authorities may wish to consider the effect on car ownership of the availability of local services that can be reached on foot and by bicycle and access to public transport. The availability of public car parking spaces should also be considered. Since the city center is an important destination for drivers, the location of the car parking close to potential customers' destinations also becomes an important factor (Anders , Gerrard et al., 2001).

Table 3.3 Factors influencing location choice

Factors	Percentage indicating factor as key Influence on parking location choice
Road links	16
Staff parking	15
Lease or rent costs	15
Proximity to market or client	12
Customer or visitor parking	11
Proximity to labor supply	11
Rail or **bus links**	6
Proximity to goods or services	5
Traffic noise	3
Proximity to competitors	3
Air quality	3

Source: Shiferaw A (2014)

The following table shows the parking area selection criteria and score values. Weights are ranked by the city municipal professionals who has detail information about parking area consideration factors. The ranking has been given based on professional skill, local consideration and standards. The scores are given according to proximity level that is (1= very low, 2=low, 3=moderate, 4=high, 5= very high).

Table 3.4 Weighting consideration for sub-cities

Parking area consideration Factors	**% of weight**	**Sub-cities**							
		Mehal	Menharya	Tabor	Misrak	Haik dar	Bahil Adarash	Adis ketema	tula
Road links	16	3	4	2	3	3	3	3	1
Staff parking	15	2	3	3	2	3	3	2	0
Parking Lease or rent costs	15	0	2	1	1	1	1	1	0
Proximity to market or client	12	2	2	2	4	2	2	2	2
Customer or visitor parking	11	4	5	4	1	4	4	4	4
Proximity to labor supply	11	5	3	4	2	3	4	4	4
Rail or **bus links**	6	1	2	2	3	2	2	2	1
Proximity to goods or services	5	3	4	2	3	2	3	2	1
Traffic noise	3	2	2	2	2	3	2	2	1
Proximity to competitors	3	2	3	2	2	2	2	2	2
Air quality	3	1	2	1.5	1	1	1	1	1
Total weighted score		237	**304**	242.5	222	219	262	242	151

Source: Shiferaw A (2014)

As from Weighted Factor Rating Method total weighted score of Menharya sub-city is higher than other sub cities. So, by both methods above, the study focuses on this sub-city.

3.3 Methods of data collection

3.3.1 Data Sources

The data for the variable of interest in the population investigate the availability and benefit of car parking. And also, it is required for the study to collect information from the target groups (derivers, transport and road safety officers and municipal officers) , the stakeholders of the industry. The study uses both primary and secondary sources.

Primary data source

Primary data collected from firsthand information through the driver interview, field survey (by license plate method) and questionnaires.

Field survey

A field survey consists in going in the field to conduct a comprehensive survey of data related to the calculation of parking statistics. Data collection by field survey made for two types of parking, for on-street and off-street parking.

In On-street parking mainly license plate method of survey, questionnaire's and interviews takes place as presented in appendix-3 and 2 respectively. However, for off-street parking, surveys and interviews are carried out.

Questionnaire for stakeholders of parking industry and community of Hawassa

In line with the objectives of the study, the purpose of the questionnaire will be to obtain information mainly about the view and opinion of the stake holders. It will concerning about the importance of car parking, and to what extent the problem of parking affect their daily activity. The ideas used in the questionnaire drawn mainly from current condition of the city, to address the objectives and the needs to be further development in the parking industry.

The questionnaire will have following parts. These are:

Part I: is intended to seek information about the current city parking service.

Part II: is intended to assess which problems discourage you from using the parking.

Part III: is consisted of questions about your preference to improved service.

Interview for government organizations

Interview will have three parts that will design to the government officials considering the stakeholders. The purposes of these interview questions were to triangulate or cross check what would the government officials say about the current parking access.

Part I. From the management strategies which strategy does Hawassa city following.

Part II. What opportunities and challenges exist in system and will be occurring and

part III is about Parking Industry, Strategy and Policy.

Secondary data sources

Secondary sources of data will also collected from formally published and unpublished documents, and Hawassa city municipal documents and reports.

3.3.2. Sampling techniques

Sampling technique is the process of taking small ratio of observation from large population in order to get information of this large population from observation (Blue Man, 1976). For the effectiveness of the study and derivers time pattern researcher uses simple random sampling technique to select representative sample from target population for questionnaire.

Sample size determination

One of the most common questions asked to survey methodology is sample size determination. As it well known and appropriate sample size is one of the mean of gaining higher precision. There are several approaches to determining the sample size. These include using a census for small populations, imitating a sample size of similar studies, using published tables, and applying formulas to calculate a sample size (PEOD6, sample size determining, reviewed April 2009).

The study is done by using the following formula to calculate sample size (Cochran,1963).

$$n_o = \frac{z^2 p\, q}{e^2} \quad \text{------------------------------------} \quad 3.1$$

The recommended value for degree of confidence 95%, α =0.05 Margin of error (the degree of precision 5% =0.05

Where:- n_O= sample size

Z^2= (1-confidence level (95%)) =1.96 (from statistical table)

e=precision<u>+5</u>%

p =population estimated attribution of interest do.

q = attribution of interest does not.

Table 3.5 Standard table to determine the sample size

Size of population	Sample size(n) ±%5	Precision level(e) ± %10
500	222	83
1000	286	91
2000	333	95
3000	353	97
100,000	**398**	**100**
>100,000	400	100

Source : Singh, Ajay S et al., (2014)

Since the population (number vehicles in the city) is around 100,000 , the representative sample size of the study is 398.

3.4 Method of data processing and analysis

3.4.1 Data processing

The main processing and analysis discussion that were done in this paper are analysis of the existing car parking trend and finding optimal parking space for the Meneharya sub-city. These are done to identify the real problems and to develop mathematical LP model to give the optimal solution for the problems found from surveys, observations, questionnaires and interviews from the drivers and responsible government bodies. Finally, compare the developed model output performance with the existing performance to see the possible improvements.

3.4.2 Data analysis

3.4.2.1 Method of analysis to examine existing parking demand and supply of the study area

Mainly license plate method of field survey is used to examine parking demand and supply of the study area. The results from this method describes quantitatively to obtain parking statistics. The data collected from selected corridors in the study area and then the maximum will be selected. The study requires 2 hours duration for each measurement of the days at an interval of 10 minute for calculating parking statistics in order to be more accurate. The survey takes place to obtain data to analyze the parking statistics like parking index to indicate the extent of effective usage of the available space , parking turnover and also parking occupancy which shows the extent of parking area usage .Also current parking trend of the study area is examined by using parking standards. The results of the data from the questionnaire's carried out by using frequency, counts and percentages and then findings are summarized.

3.4.2.2 method of analysis to indicate the best suit parking management strategies of the city

There is no available experienced parking management strategies in the city. Due to the reason drivers are using the spaces unmanageably. So that parking space optimization model used to minimize the parking space utilization by developing model for selected corridor /from St. Gabriel church to Hawassa University Agricultural Campus/ . Linear programing (LP) model used since to optimize the single output parameter (parking area) by considering different inputs like parking angles, average parking duration, average parking accumulation and arrival rate of vehicles. Model validation and sensitivity analysis conducted to relate the model with the ground problem.

4. RESULTS AND DISCUSSION

4.1 Analysis of existing parking demand and supply of the study area

4.1.1 Analysis of the Questionnaire and interview

The survey questionnaire are subjective and objective questions were prepared and used to assess the current parking behaviors and views and opinions about the current situation of car parking trend in Hawassa city. The purpose of the survey is to identify the main challenging problem of parking and to develop the solution to minimize the parking problems in the city. The data has been collected randomly from the drivers. The following are the discussion part of the collected questionnaires.

For the purpose of this study 398 respondents to be participated according to sample size determination (Cochran,1963). But by unwillingness of the respondents and time shortage for respondents to reply, 386 respondents participated.

Table 4.1 derivers parking purpose

Activity	Frequency	Percent (%)
Business	178	46
Shopping	93	24
To use restaurants	50	13
Leisure	42	11
Other	23	6
Total	386	100

According to the result of questionnaire from above table the most parking users are a business workers when compared with other activities indicates the land use of the study area is commercial area.

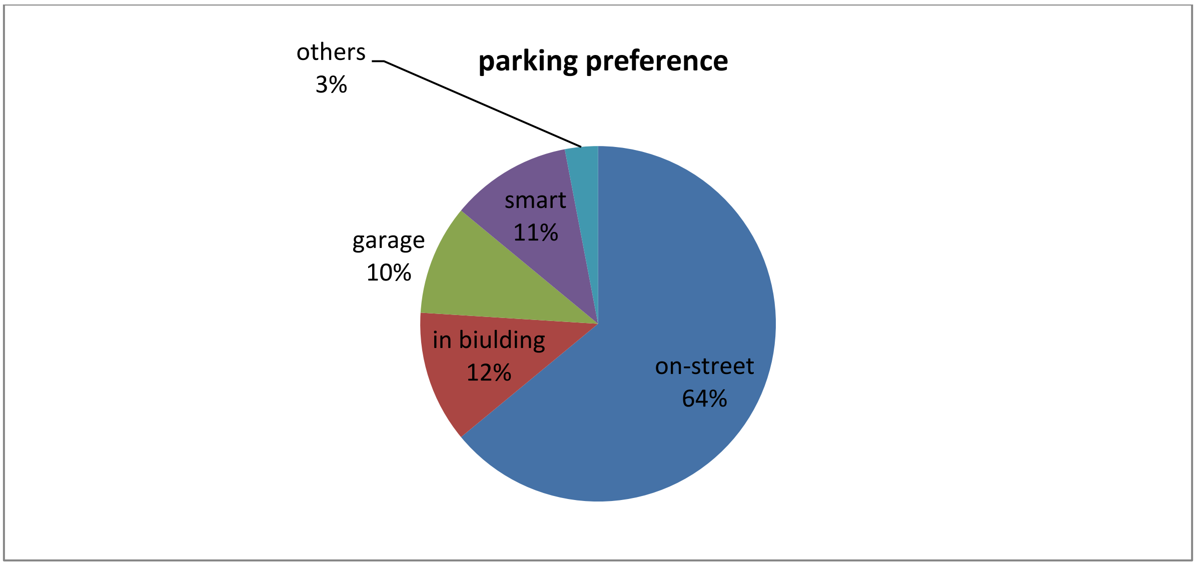


Figure 4.1 Parking preference

As the respondents for the questionnaire about the parking type preference to minimize the time from parking to their destination and for security purpose most of the car users prefer on-street parking.

Parking preference criteria

The questionnaire result for the question of what are the prioritized criteria for parking lot preference, 79% of drivers selecting free space availability and security and safety for their cars, and 13.5% for walking time and walking distance to final destination, and 5% for the area nearest to different activities. Therefore, the city concerning about the parking space for the cars to fulfill the demand of the drivers.

Table 4.2 Parking preference criteria

Preference criteria	Frequency of Response	Percentages (%)
Free space availability	160	41.5
Security safety	143	37
walking distance to final destination	29	7.5
walking distance to final destination	23	6
Nearest to roads and market	19	5
Others	12	3
Total	386	100

Analysis from interview

The interview discussion were made with Hawassa city transport and road traffic safety office and the city municipal officers. The response from the respondents about the interview questions and the result discussed as the following:

Table 4.3 Interview questions and responses from officials

No.	Questions	Response
1	Would you please tell us about the existing parking facilities in Hawassa city?	As the city road and transport officers Parking users merely search for free space and uses the available space for parking. This is due to lack of provided legalized and marked parking facility supply by service owners.
2	Are there any experienced parking management strategies applied in the city?	As from city transport officials Since lack of implementation of parking standard enforcements for different purposed building it's difficult to apply parking management. For example Hawassa view hotel is nothing parking consideration with more than 85 number of seats.
3	Are there any strategy for parking service improvement in the city?	As the road and traffic safety officials of the city, different parking problems are facing car users as well as pedestrians like ineffective use of available space, reduced carriage way of the road due to improper on-street parking. The officials agreed on the issue that the current parking trend of the city needs to be improved.

Generally the analysis result of interview shows that there is the gap to enforce different service suppliers to apply parking requirement as one of the criteria during delivering different service licenses.

4.1.2 Results from license plate survey

Before taking any measurement, data regarding availability of parking space, extent of its usage and parking demand is essential. Parking surveys are intended to provide these information. Since the duration of parking varies with different vehicle types, several statistics are used to access the parking need. From the collected data, the maximums are selected and by using this data parking statistics are calculated.

Corridors with high parking demand at weekend time

A major corridor with such characteristics is the corridor from St. Gebrel church to Hawassa University Agriculture campus.

For this corridor peak parking demand is at weekend late afternoon. This is because vehicle users who uses bar and restaurants and who visits church is more significant.

Table 4.4 Number of parked vehicles for a particular time(Sunday survey)

Time in minute (pm)	No of parked car
05:00 (afternoon)	17
05:10	18
05:20	20
05:30	25
05:40	32
05:50	24
06:00	20
06:10	19
06:20	18
06:30	19
06:40	18
06:50	17
07:00	15

Figure 4.2 Parking usage survey

$$Parking\ load\ = (17 + 18 + 20 + 25 + 32 + 24 + 20 + 19 + 18 + 19 + 18 + 17 + 15) * 10/60\ min$$

= 222vehicle*10/60 min

$= 37$ vehicle hour

$$\text{Parking index} = \frac{\text{parking load}}{\text{parking capacity}}$$

$$\text{Parking index} = \frac{\text{37 vehicle hour}}{\text{32 *2 vehicle hour}} * 100\%$$

$= \underline{57.8\ \%}$

Parking index value calculated above indicates around only 58% of the available spaces are used effectively which needs proper management for better service.

In this corridor there are four /4/ on-street commercial parking bays available at which vehicle drivers used it as parking even it is legally not provided for the purpose. Since the short width of carriage way the vehicles are parked at parallel arrangement to the road way.

Common types of on-street parking is based on the angle in which the vehicles are parked with respect to the road alignment. the standard dimensions of a car is taken as 5 × 2.5 meters and that for a truck is 3.75 × 7.5 meters (IRC, 2007).

$$\text{Parking turnover} = \frac{\text{parking volume} * 100}{\text{No: of spaces available}}$$

Number of parking space $= \frac{L-[(b*5)+(e*3)+Tc*15)+(i*7)]}{a}$……………(4.1) (Abdoulaye Diallo et al, 2012)

Where:

L= average length of the stretch of road (m)   b= number of terminal-fountain (5 meters)

e= number of driveways(3 meters)   Tc = number of bus stops(5meters)

i= number of spaces where there is a strict prohibition of parking (7 meters.)

a = average space (linear) occupied by a parked car (m)

Number of parking space= $\frac{2450-[(2*5)+(4*3)+1*15)+(0*7)]}{5.1}$ =395

Parking turnover= $\frac{\text{parking volume} *100}{\text{No: of spaces available}} = \frac{222*100}{395}$ = 51.27%

The above parking turnover value indicates only half of the available parking space used efficiently.

Parking occupancy = $\frac{\text{vehicle parked}}{\text{Number of bays}} = \frac{222}{4}$ = 55.50%

It shows how much available spaces occupied.

Corridor with high parking demand at work time

A major corridor with such characteristics is the corridor from Wanza roundabout to South Star International Hotel.

At this corridor the peak parking demand is at morning time .This is because home-work trip is more significant.

Table 4.5 Number of parked vehicles for a particular time (Monday)

Time in minute(am)	No of parked car
02:00	22
02:10	27
02:20	31
02:30	25
02:40	20
02:50	19

03:00	18
03:10	16
03:20	17
03:30	17
03:40	18
03:50	19
04:00	14

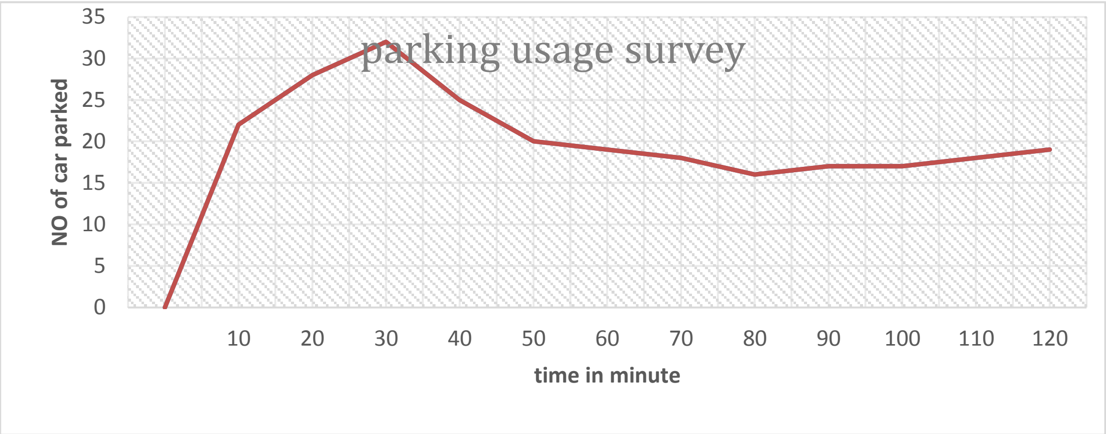


Figure 4.3 Parking usage survey

$$\text{Parking load} = (22 + 28 + 32 + 25 + 20 + 19 + 18 + 16 + 17 + 17 + 18 + 19 + 14) * 10/60 \text{ min}$$

= 254 vehicle*10/60 min

$$= 39 \text{ vehicle hour}$$

$$\text{Parking index} = \frac{\text{parking load}}{\text{parking capacity}}$$

$$\text{Parking index} = \frac{39 \text{ vehicle hour}}{32 * 2 \text{ vehicle hour}} * 100\%$$

=59.75 %

Parking index above indicates around 59% of the available space used effectively.

At this corridor vehicle users are using road side for parking usage even the space is not provided for the purpose. Also at this corridor there is the space which is for bidden for the parking which is up to 200m.

Since the short width of carriage way the vehicles are parked at parallel arrangement to the road way.

$$\text{Parking turnover} = \frac{\text{parking volume} * 100}{\text{No: of bays available}}$$

Length of curb for parking(right) = curb length – road crossings – pedestrian crossings – forbidden area- terminals .

$$\text{Number of parking spaces} = \frac{L-[(b*5)+(e*3)+Tc*15)+(i*7)]}{a}$$

Where:

L= average length of the stretch of road (m) b= number of terminal-fountain (5 meters)
e= number of driveways(3 meters) Tc = number of bus stops(5meters)
i= number of spaces where there is a strict prohibition of parking (7 meters.)
a = average space (linear) occupied by a parked car (m)

$$\text{Number of spaces in corridor} = \frac{2350-[(2*5)+(3*3)+(2*15)+(1*7)]}{5.1} = 453$$

$$\text{Parking turnover} = \frac{\text{parking volume} * 100}{\text{No: of spaces available}} = \frac{264*100}{453} = 58.4\%$$

parking turnover shows parking usage efficiency.

$$\text{Parking occupancy} = \frac{\text{vehicle parked}}{\text{Number of bays}} = \frac{264}{4} = 66\%$$

It shows how much available spaces occupied.

The corridor with high parking demand at lunch time

A major corridor with high parking demand at lunch time is the corridor from Atote Warka to Terufat traffic light. This is because more vehicle users are attracted to get alternative café and restaurant services around the area.

Table 4.6 Number of parked vehicles for a particular time

Time in minute (LT)	**No of parked car**
12:00	24
12:10	22
12:20	26
12:30	29
12:40	32
12:50	38
01:00	31
01:10	28
01:20	25
07:30	26
07:40	23
07:50	24
08:00	25

Figure 4.4 Parking usage survey

$$\text{Parking load} = (24+22+26+29+32+38+31+28+25+26+23+25) * 10/60 \text{ min}$$

= 329vehicle*$10/60$ min

$= 54$ vehicle hour

$$\text{Parking index} = \frac{\text{parking load}}{\text{parking capacity}}$$

$$\text{Parking index} = \frac{54 \text{ vehicle hour}}{38 * 2 \text{ vehicle hour}} * 100\%$$

=<u>62.1 %</u>

Parking index calculated above indicates how much the available spaces are used effectively.

In this corridor there are four 8 on-street commercial parking bays available at which vehicle drivers used it as parking even it is legally not marked or provided for the purpose. Since the short width of carriage way the vehicles are parked at parallel arrangement to the road way.

Parking turnover = $\frac{\text{parking volume} * 100}{\text{No: of bays available}}$

Number of parking spaces= $\frac{2100-[(2*5)+(4*3)+2*15)+(0*7)]}{5.1}$ =401

Parking turnover =$\frac{\text{parking volume} * 100}{\text{No: of spaces available}} = \frac{241}{401} =$ 59.87%

Parking turnover shows parking usage efficiency.

Parking occupancy = $\frac{\text{vehicle parked}}{\text{Number of bay}} = \frac{241}{6}$ = 40.25 %

Which means the efficiency of the parking space usage is around 40% which indicates poor parking space management in the city.

Parking statistics value calculated above indicates that the available spaces are not used effectively and needs proper management.

4.2 Current parking trend of the study area

As the city transport administration, there is no provided parking space and formulated policy and strategy in Hawassa city. But the demand for parking increases from time to time due to urbanization and commercialization. In the study area, there is no marked facilities for on-street parking and insufficient off-street parking but the vehicles are parked besides the road.

4.2.1 Current usage of parking facility in the study area.

Interview questions were set and forwarded to government officials, namely, Hawassa city road and traffic safety office the city municipality. The information from officials shows that there is no provided legalized and marked on-street parking facility in the city. However, there is some private owned off-street parking around some business center areas which is basically provided for their own customers. But it is not at an appropriate place and it is not much enough. It is either at pedestrian walkway or at an side of the road which is the main case for reduction of carriage capacity.

Figure 4.5 Inappropriate on-street parking in the city /at pedestrian walk way/

Current car parking practice is not giving appropriate service to the community and need to be improved. There is no parking management strategy for available parking spaces. Clear strategy and specific policy should be designed in the future. The procedure, principle and practice should be developed for both on-street and off-street parking in detail with the future development of master plan. The following table shows comparison between the actual provided quantity of parking and the space required for their respective service.

Figure 4.6 The city's present parking usage habit / on-street : parallel parking/

Table 4.7 Comparison between Current city parking provision and requirement

No	Name	Service	Provided	Required (Krishna rao,2009)	Remark
1	Bera (162 seats)	Hotel	80m^2	1 for every 10 seat (204 m^2)	Inadequate
2	Postal	Office	50m^2	1 for every 70 m^2	Inadequate
3	Pinna#1 (120seats)	Hotel	75m^2	1 for every 10 seat (150m^2)	Inadequate
4	Lewi /menhaya/ (96seats)	Hotel	156 m^2	1 for every 10 seat (137m^2)	Needs management
5	Dashen /menharya/	Bank	30m^2	1 parking space for 70 m^2	Inadequate

**single parking space for standard car is 5.1m by 2.5m which is 12.75m^2*

4.2.2 current off-street parking habit

Figure 4.7 Unmanaged off-street parking in the city

Figure 4.8 Private off-street parking/parking at pedestrian walk way rather than using provided space/

4.3 Parking management strategy for the study area

On-street Commercial Area Parking

On-street parking, as close to a business as possible, keeping the available spots for different term use is important. There is no available experienced parking management strategies in the city. Due to the reason drivers are using the spaces unmanageably. So that parking space optimization model used to minimize parking space problems by developing the model for on-street parking .

The objective of the model is to maximize the total parking area capacity for the vehicles and maximizing the existing on-street parking capacity by considering different constraints such as road length, parking angles, average parking duration(T_d), average parking accumulation(P_a), arrival rate of vehicles(r_{ij}), vehicles size and considering the following assumptions.

1. The on-street parking capacity for selected road corridor /from St.Gebrel church to Hawassa University Agriculture campus/ is 60, j = 1,2,3,….,60.
2. The vehicles arrive at the on-street car parking zone with arrival rate of vehicles per15 minutes and their average parking duration in 15 minutes interval is considered for all types of vehicles.

3. The size of vehicle type passenger car and motorcycle are assumed to be smaller than a truck and the parking spots of truck are assumed to be greater than parking spots of both vehicles additionally three wheeled vehicle is considered as passenger car.
4. Three types of vehicles : Trucks (a_{1j}), Passenger cars(a_{2j}), and motorcycle (a_{3j}) are considered : which means i = 1,2,3

In the following tables 4.8 and 4.9 parking areas of each vehicles calculated by considering parking dimension of the vehicles, angles of parking, existing parking capacity.

Table 4.8 Calculation of vehicles parking area based on parking lot capacity.

No	Parking angle of vehicles	Equations to calculate the length of parking corridors (Tom, Mathew et al, 2014)	Existing parking capacity for design vehicle(N)	Parking Lot Length
1	Parallel parking	L= 5.9N	60	354
2	30	L= 5.58 + (N-1)*5	60	300
3	45	L=3.54N+ 1.77	60	214
4	60	L= 2.89N + 2.17	60	175
5	90	2.5N	60	137

Table 4.9 Vehicles parking area based on parking lot capacity.

			Types of vehicles and their width			Parking area for each types of vehicles in (m. sq)		
No	Parking angle	Parking lot length	Truck parking width	cars parking width	motorcycle parking width	Truck parking area(a1j)	Cars parking area(a2j)	Motor cycle parking area(a3j)
1	Parallel parking	354	3.75	2.5	1.3	**1312.50**	**875**	**455.00**
2	30	300	3.75	2.5	1.3	1127.18	751.45	390.75
3	45	214	3.75	2.5	1.3	803.14	535.425	278.42
4	60	175	3.75	2.5	1.3	658.35	438.9	228.23
5	90	137	3.75	2.5	1.3	562.50	375	195.00

4.3.1 Parking area Factors Analysis

The following parking area factors /parking statistics/ analysis calculation based on the survey data.

Parking Lot Accumulation: Parking lot accumulation calculated based on the survey data for a 15 minute interval is the total of number of vehicles (i) in the place for that time interval in the parking lot (j) is sum vertical the same day arrival rate of vehicles in the parking lot. For instance in appendix-3 the Monday Accumulation for the time interval for 15 minutes a 44 vehicles.

Parking Duration: the Parking duration calculated by considering both sides parking lot accumulation capacity=120 parking spot available. It can be calculated as sum of the accumulation for each time interval * time interval divided by the parking volume.

$$\text{Parking duration} = \frac{\text{sum of the accumulation arrival rate of vehicle (i)} * \text{time interval}}{\text{total parking capacity(j)}}$$

Parking Load: The parking load is calculated by summing the each type of vehicles (i) arrived in the time interval of 15 minutes and multiplied by the time interval 15 minutes and divided by 60 minutes.

$$\text{Parking load} = \frac{\text{sum of arrival rate of vehicle (i) in time minute interval}}{\text{60 minutes}} * \text{time interval}$$

Average hourly Parking capacity = the parking capacity of vehicles (i) multiplied with number of hours in the parking lot.

Occupancy of Parking Lot: Occupancy allows determine whether or not we have enough parking spaces. Occupancies are the ideal demand shows the space being met without waste**.** Occupancy for that time interval is accumulation in that particular interval divided by total number of bays.

Average Parking Duration: Average parking duration determined by the average arrival rate of vehicles (i) per hour divided by total available number of bay.

$$\text{Average Parking Duration} = \frac{\text{average arrival rate of vehicle (i) per hour}}{\text{total number of bays}}$$

Parking Turnover: Parking turnover determined by the total arrival rate of vehicles (i) is divided by the maximum arrival numbers of vehicle

$$\text{Parking Turnover} = \frac{\text{total arrival rate of vehicle (i) per hour}}{\text{total number of vehicles (i)at parking lot (j)}}$$

Parking Index: Parking index determined by the total parking load divided by maximum arrival rate of vehicles (i) multiplied by total service time

$$\text{Parking Index} = \frac{\text{parking load}}{\text{maximum arrival rate of vehices (i)}*2hr}*100$$

Table 4.10 Summary of daily parking demand

No	Parking Days	Demand Per Day	Maximum daily arrival rate of vehicles (i)
1	Monday	389	64
2	Tuesday	403	80
3	Wednesday	413	77
4	Thursday	416	78
5	Friday	416	78
6	Saturday	449	90
7	Sunday	263	46
average daily demand		**393**	

Total parking demand per day which is average amount of cars parked in the place is 393 vehicles per day.

Table 4.11 Summary of the parking area factors from table and survey data in Appendix-3

No.	Maximum daily arrival of vehicles	average hourly parking capacity	Parking loads of vehicles per hours	average parking duration (minutes)	Arrival rate of vehicles per hour
1	64	60	16	16	32
2	80	60	20	20	40
3	77	60	19.25	19.25	39
4	78	60	19.5	19.5	39
5	78	60	19.5	19.5	39
6	**90**	**60**	**22.5**	**22.5**	**45**
7	46	60	11.5	11.5	23

The above average parking duration for each type vehicles such as trucks, passenger cars and motorcycles calculated based on the survey data from the appendix.

Table 4.12 Arrival rate of vehicles

arrival rates of vehicles (i) at the parking lot			proportion of arrival rate of ($r_{i,j}$) for each types of vehicles(i)			proportion parking accumulation(pa_{ij}) for each types of vehicles(i)		
Motor cycle	Passenger car	Truck	Motor cycle	Passenger car	Trucks	Passenger car	Motor cycle	Trucks
8	52	2	0.125	0.8	0.03	0.5	0.33	0.2
18	62	0	0.2	0.7	0	0.5	0.33	0.2
6	67	4	0.07	0.87	0.005	0.5	0.33	0.2
10	68	0	0.12	0.87	0	0.5	0.33	0.2
10	68	0	0.12	0.87	0	0.5	0.33	0.2
8	80	2	0.08	0.89	0.03	0.5	0.33	0.2
10	30	6	0.2	0.65	0.15	0.5	0.33	0.2

4.3.2 Input Parameters

To develop the linear proportion model the input parameters are need to be determined first.

Terms Used in the Model

i =1,2,3 : Three types of vehicles considered : truck(a_{1j}),passenger car(a_{2j}) and motor bicycles(a_{3j})

j =1,2,3,…,60 : Number of parking spots at on-street parking lot.

$a_{i,j}$ = Parking area for each type of vehicles (i) at parking lot with parking spot(j).

$A_{i,j}$ = Total parking area capacity for each type of vehicles (i) at parking lot (j)

c_x,c_y,c_z = parking area utilization factors for different types of vehicles

$Td_{i,j}$ = Average parking duration of each type of vehicles (i) at parking spot(j) in on-street parking lot.

$Pa_{i,j}$ = Average parking accumulations of each type of vehicles (i) at parking spot (j) in on-street parking lot.

r_{ij} = Average Arrival rate of each types of vehicles (i) at parking spot (j) in on-street parking lot.

The overall combined parking area capacity for the types of vehicles (i) at parking spot (j) ensures that the sum of the parking area in each parking lot is less than or equal to the total parking area capacity ($A_{i,j}$). and is expressed as:

$\Sigma^{n}_{i=1} \Sigma^{m}_{j=1} a_{i,j} \leq A_{i,j}$ --(4.2)

The constraints of parking area capacity based on different situation in parking lot : arrival rate of vehicles, average parking duration and average parking area accumulations based on vehicles size and parking angle. The following equations constraint shows that the parking area required for each types vehicles a_{ij} and the proportion of vehicles (i) average arrival rate ($r_{i,j}$),average parking accumulation ($Pa_{i,j}$) , and average parking duration ($T_{d\ i,j}$) for every 15 minutes for each types of vehicles(i)in the parking lot.

The objective function is to maximize parking area.

Written as : Maximize $\Sigma^{n}_{i=1} \Sigma^{m}_{j=1}(a_{1,j}+a_{2,j}+a_{3,j})$ and

The non-negativity equation keeps the variables equal to or greater than zero.

a_{ij} ,r_{ij}, Td_{ij} ,Pa_{ij} ≥ 0 -- 4.3

The proportion of vehicles average arrival rate at every 15 minutes for each types of vehicles computed from the average arrival rate (r_{ij}) divided by total average arrival rate for three types of vehicles (i) and the multiplied by parking space capacity is less than or equal to the total parking space of each vehicles.

Written as:

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{ri,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (r1,j+r2,j+r3,j)}) \leq a_{ij}$$

The parametric values of parking is taken from the survey data shown in appendix are presented in table, after substituting the value of input parameters and constraints into the model with parking areas for each vehicle types from table 4.8 in parking spot(j) : trucks(a_{1j}), passenger car(a_{2j}) and motor vehicles(a_{3j}) is 1312.5, 875 and 455 square meters respectively.

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{r1,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (r1,j+r2,j+r3,j)}) \leq 1312.5$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{r2,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (r1,j+r2,j+r3,j)}) \leq 875$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{r3,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (r1,j+r2,j+r3,j)}) \leq 455$$

The proportion of vehicles average parking duration at every 15 minutes for each types of vehicles (i) computed from the average parking duration divided by total average parking duration for three types of vehicles (i) and then multiplied by parking space capacity is less than or equal to the total parking space for vehicle (i).

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Tdi,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Td1,j+Td2,j+Td3,j)}) \leq a_{ij}$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Td1,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Td1,j+Td2,j+Td3,j)}) \leq 1312.5$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Td2,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Td1,j+Td2,j+Td3,j)}) \leq 875$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Td3,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Td1,j+Td2,j+Td3,j)}) \leq 455$$

Similarly, the proportion of vehicles average parking accumulation at every 15 minutes for each types of vehicles computed from the average parking accumulation divided by total average parking accumulation for three types of vehicles (i) and the multiplied by parking space capacity is less than or equal to the total parking space for vehicle(i).

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Pai,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Pa1,j+Pa2,j+Pa3,j)}) \leq a_{ij}$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Pa1,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Pa1,j+Pa2,j+Pa3,j)}) \leq 1312.5$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Pa2,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Pa1,j+Pa2,j+Pa3,j)}) \leq 875$$

$$(a_{1,j}+a_{2,j}+a_{3,j})*(\frac{Pa3,j}{\Sigma\ ni=1\ \Sigma\ m\ j=1)\ (Pa1,j+Pa2,j+Pa3,j)}) \leq 455$$

For vehicle types truck(a_1)passenger car(a_2) and motor bicycles (a_3) in parking spot (j) with the constraints arrival rate(r_{ij}), parking duration(T_{dij}), Angle of parking and parking accumulation(P_{aij}) with objective value of maximization of parking space which has expected output of increasing number of parking spots the model subjected to :

$$28.125\ a_1j + 12.5\ a_2j + 2.47a_3j \leq 2624.5$$

Which means summation of the product of coefficient of parking area utilization factors and the areas of each vehicle should be less than the grand total parking area of the vehicles. By using the parking dimensions of each vehicle from table 2.1, the model is justified as follows:

$$a_{1j}= \text{parking length *parking width} = 3.5m * 8.5m = 29.75m^2$$

$$a_{2j}= \text{parking length *parking width} = 2.5m * 5.0m = 12.50m^2$$

$$a_{3j}= \text{parking length *parking width} = 1.5m * 2.5m = 3.75m^2$$

$$28.125\ a_{1j} + 12.5\ a_{2j} + 2.47a_{3j} \leq 2624.5$$

$$28.75(3.5m*8.5m)+12.5(2.5m*5m)+2.47(1.5m*2.5m) \leq 2624.5\ m^2$$

$$1020.825\ m^2 \leq 2624.5\ m^2$$

4.3.3 Summary of the result

The model is formulated to save parking space available for effective utilization. As it indicated in the table 4.13 and figure 4.9 below, maximum parking area saved is 6040 meter squares from 90 degree parking angle compared with existing parking capacity from appendix-4. And parking areas 1492.48 from 30 degree parking, 4102.06 from 45 degree parking and 5268.08 meter square from 60 degree parking angle will be saved. 90 degree parking angle saves maximum parking area. In another direction, it highly reduced road width or diameters. For instance, 20meter width roads reduced to 15 meter width for passengers cars type and from 20meter road diameters reduced to 12.5meter for trucks type vehicles and which are not recommended for the roads .It creates congestion on the roads, reduces carriageway capacity of the road and it's difficult to move vehicles freely on the roads. So that it's not recommended to provide 90 degree on-street angle parking for such road width of the study area**.** Since 0^o, 30^o and 45^o angled parking be recommended for the study area. Therefore ,for the roads with width greater than 12m, 30 degree parking angle recommended and for the roads with width greater than 15m, 45 degree parking angle recommended for on-street parking for the study area because high parking area will be saved when compared to parallel parking /from Software output in appendix – 4/**.**

Table 4.13 Summary of saved parking area

				Saved parking area form Angle parking		
No	Parking Angles	Total Parking Area (meters. sq) or objective value	Saved Parking Area	Truck Parking Area($a1_{,j}$)	Cars Parking Area(a_2,j)	Motorcycle Parking Area(a3,j)
1	Parallel parking	10,570	0	0	0	0
2	30 ^{o} parking	9077.520	1492.98	53	119	4279
3	45^o parking	6467.94	4102.06	146	328	1667
4	60^o parking	5301.92	5268.08	187	421	2133
5	90 ^{o} parking	4530	6040	215	483	2445

*saved parking area for each parking angle is calculated by subtracting total area of each parking from the area at parallel parking. For instance,

Improved area by 30^o parking angle = area at parallel parking – area at 30^o parking.

=10570-9077 = 1493 square meter.

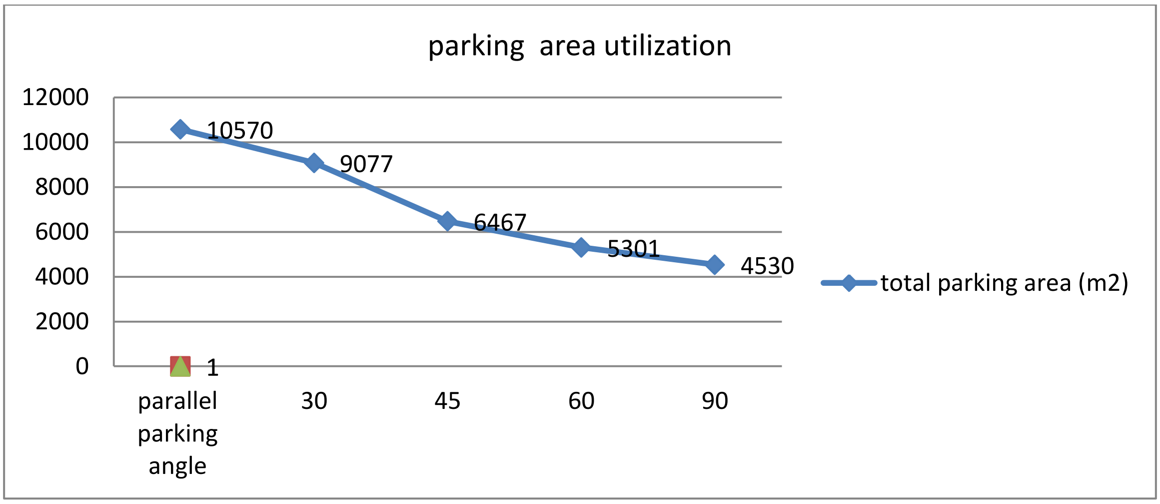


Figure 4.9 Parking area utilization

4.3.4 Model Result Evaluation

The software's objective value(parking area) final result without considering parking angle is 10,570 meter square (appendix-4) used to park the vehicles such as trucks, passengers cars and motorcycles. As explained the actual parking capacity determined by considering parking area for each type vehicle (i) in the parking spot (j) in the parking lots. The existing parking capacity is 60 vehicles in on the side of the paved road. The following table and figure shows the number of saved parking spot compared to the existing at different parking angles.

Parking area for each types of vehicles (i) in parking spot(j) $= \frac{\text{saved parking area(aij)}}{\text{parking area utilisation factor(cx)}}$

For instance, for 30° parking angle, number of improved parking

spot$= \frac{\text{saved parking area(aij)}}{\text{parking area utilisation factor(cx)}} = \frac{1492}{12.75} = 119$

For 45° parking angle, number of parking spot$=\frac{4102}{12.75} = 328$, similar way for 60° and 90°.

Table 4.14 Model result evaluation

No	Parking angle	Existing parking capacity	Improved Number of parking spot
1	Parallel parking	60	0
2	30degree parking	60	119
3	45 degree parking	60	328
4	60 degree parking	60	421
5	90 degree parking	60	483

Figure 4.10 Existing and Improved parking capacity

4.3.5 Model validation

The process of Model Validation and Sensitivity analysis determines whether the results are appropriate or the need of modification as well as the choice of other the solution techniques as necessary.

Parking space optimization model used to minimize parking problems by developing LP model. The objective of the model is to maximize the existing on-street parking capacity by considering different constraints like parking angles, average parking duration, average arrival rate of vehicles, vehicles size, average accumulation capacity and considering different assumptions.

Case-1:Considering average daily arrival rate and average parking duration of vehicles.

In this scenario considered average daily maximum arrival rate of vehicles in the parking lot, average parking duration, and without considering vehicles size effects on the parking lot capacity, and result delivered after solving with software. The value of average daily maximum arrival rate and average parking duration taken from statically parking calculation based on on-street parking survey from appendix and the result are based on scenario are **220** parking spot.

The result shows that the maximum needed parking spot are 220 but by the existing parking lot capacity is 60 vehicles only. So that 160 cars or 62.5 % are can't found parking space. As result, the drivers park illegally and the situation creates congestion on the roads and difficult to traffic flow. When considered average daily arrival rate of cars and average parking duration and based on the survey data average daily arrival rate and average parking duration are 20 vehicles per hour and 16 minutes respectively.

Case-2: Considering average daily maximum arrival rate and average parking duration of vehicles.

The scenario considered average daily maximum arrival rate of vehicles in the parking lot, average parking duration, and without considering vehicles size effects on the parking lot capacity, and result delivered after solving with software. The value of average arrival rate and average parking duration taken from appendix and the result are based on scenario are 1062 parking spot.

The result shows that the maximum needed parking spot are 1062 and the parking lot capacity is 60 vehicles only. So that 1002 passenger cars or 94.35 % are can't found parking space this creates the problem in the city due to unpatterned parking . As result, the drivers wait for long time or use parking illegally this situation creates congestion on the roads and difficult to traffic flow. When considered average daily arrival rate of cars and average parking duration and based on the survey data average daily arrival rate and average parking duration are 45 vehicles per hour and 24.5 minutes respectively.

Without considering parking angle

In this case considering vehicles parking lot parking capacity, by considering the same vehicle size in each constrain of the model, the same average arrival rate, the same average parking duration, different parking area respectively with vehicles size and without considering parking angle the result delivered after solving with software is 10,570m^2**.**

Considering parking angles

In this case by considering vehicles parking lot parking capacity, considering the same size vehicles in each constrain of the model, the same average arrival rate, the same average parking duration and considering parking angle with 30^0 in the parking lot and the result delivered after solving with software is 9077m^2.Similarliy, other solutions of parking areas are 6467, 5301 and 4530 meter squares from 45, 60 and 90 degree parking angles respectively.

4.3.6 Sensitivity Analysis

Developing the problem as linear programming and found solution by considering main parameters for the situation. The parameters are considered by changing coefficient of constraints, changing coefficient of objective function and the right-hand-side constraints value change in the LP model. If the optimal solution is relatively insensitive to reasonable change and it is confident to implementing the solutions. But, if the optimal solution is sensitive to change and it need precise estimation of those parameters.

Considering right hand side and the coefficients of constraints which are proportion of vehicles average arrival rate, average parking accumulation and average parking duration for each type of vehicles values increased by 1 and the new optimal solution obtained and described in below table.

Table 4.15 Comparison of Sensitivity Analysis result

No	Parking Angles	Optimal Solution	After sensitivity analysis	
			changing right hand side(meters. sq)	changing coefficients of constraints
1	parallel parking	10,570	10571.00	10,569.000
2	30 degree parking	9077.520	9077.530	9076.520
3	45 degree parking	6467.94	6468.940	6465.940
4	60 degree parking	5301.92	5302.920	5300.920
5	90 degree parking	4530	4531.000	4529.000

In sensitivity analysis, the result shows that there are some changes when considering right hand side and changing the value of constraints in the model. The changes indicate that when we increase the parking area directly increase parking capacity of the vehicles in the parking lot and increase of average arrival rate and parking duration decreases parking capacity of parking lot.

5. CONCLUSION AND RECOMENDATION

5.1 Conclusion

Parking statistics indicates that how much spaces occupied by parked vehicles and also its effectiveness. So that the statistics value indicates that the available space for parking needs management for effective use.

- Calculated parking index value for the corridors is around 59% which indicates the level of effective utilization of available space. Its effectiveness is not much enough. Parking occupancy value indicates how much of available space is occupied and for the study area it is up to 60%. The another parameter (parking turnover) which shows efficiency of parking usage is calculated as 51%. This all parking statistic values indicates that available parking space is not fully occupied by parked vehicles and also not effectively used for the purpose.
- Current car parking practice is not giving appropriate service to the community and need to be improved and also there is no experienced parking management strategies in the city. To be more effective, the city municipal and road traffic management should apply specific parking management strategy.
- Parking area consumption is highly dependent on the angle of parking. Consumption area at 90^o parking angle is much less than all others. But since carriageway of the city road is not much wider the higher angles to not be used . Rather 30^o and 45^o parking angles be used for on-street parking which saves required parking area than parallel parking.

5.2 Recommendation

Current car parking practice of the city is not giving appropriate service to the community and the following recommendations forwarded for the stakeholders.1

- The city municipality should enforce the building designers to consider the parking service in their design.
- Different private and public institutions should provide and manage their parking space for their customers as the requirement.
- Provision of off-street parking facilities like sub-stations, shared parking and Peripheral Parking Lots are important to have advanced current and future parking usage. But provided spaces should be out of carriage way in order to increase capacity of the road. also the station should be much more enough, economical and located at accessible area for future usage. Additionally the vehicle users (derivers) should use the space properly at recommended condition.
- Since there is no experienced on-street parking management in the city clear strategy and specific policy should be designed. The procedure, principle and practice should be developed for both on-street and off-street parking in detail with the future development of master plan of the city. To cope up the problems more, different parking management strategy alternatives should be checked.

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APPENDICES

Appendix -1 : Factors influencing location choice

Please ranking by using likert scale based on your professional skill. (1= very low, 2=low, 3=moderate, 4=high, 5= very high) the following parking area factors are based on our country criteria. (Shiferaw, 2014).

Parking area consideration Factors	**% of weight**	**Sub-cities**							
		Mehal	Menharya	Tabor	Misrak	Haikdar	Bahiladarash	Adis ketema	tula
Road links	16								
Staff parking	15								
Parking Lease or rent costs	15								
Proximity to market or client	12								
Customer or visitor parking	11								
Proximity to labor supply	11								
Rail or **bus links**	6								
Proximity to goods or services	5								
Traffic noise	3								
Proximity to competitors	3								
Air quality	3								
Total weighted score									

Appendix-2 : Questionnaire and Interview

A. Questionnaire

Hawassa University Institute of Technology

School of civil Engineering and built environment

(Postgraduate Program)

Dear respondent, first of all thank you for your cooperation.

This questionnaire is designed to gather data for research purpose for the fulfillment of a MSC in the title of "**Developing parking management strategies for Hawassa city"** for Hawassa car parking. Accordingly, your responses are extremely important for the purpose of this research and result is used for **research purpose only**. Hence, you are kindly requested to feel free and respond all the questions.

Questionnaire used for Hawassa city parking trend

The objective is to collect information of city parking service operation- and parking -deficiency and identify the problem area and make recommendations for future parking service improvements.

Instruction: Please fill in the questionnaire by putting 'x' on the blank space.

I. Personal Information

Gender: Female □ Male □

Age ………………

Employment status (indicate all applicable)

Driver □ passenger □ other ☐

Non driver □

For what purpose do you use parking? Rank according to frequency

Shopping □ business □ Leisure □

Family visits □ to eat restaurant □ work □

II Information about current city parking service:

Which parking do you use regularly? ___________(parking Number)

How many times do you use parking? _________________per day/week/month

How many times do you get the appropriate service area?

In every trip □ once in every ten trip □ once every five trip □

Once per two trips □ I don't get at all □

How long do you wait at the parking?

Less than 5min □ 5 to 10min □ 10 to 15 min □ more than 15 min □

How long do you walk to reach the service area from parking?

Less than 500m □ 500 to 1000m □ more than 1000m □

III Which problems discourage you from using the parking? (Give rank)

Robbery inside the parking area □ Price □

Robbery at the bus stop □ density □

Crowdedness □ lack of parking □

Risk of accident □ poor treatment by operators □

Status □ Delay□ others □

IV Questions about your preferences to improved service:

Please, rank the ill-effects of car parking on commercial area

Congestion □ accident □

Delay □ air pollution □ others □

Please, rank the factors that will decrease your comfort outside the parking.

Long waiting □ security □

Lack of parking shade □ others □

Lack of information about schedule □

Please, rank the factors below according to your priority of preference for better service.

Good quality bus □ less walking distance □

Safety □ high frequency service □

No congestion □ Affordable price □

Punctuality □ no delay □

What price will you be willing to pay for better and improved service per hour?....................

B. Interview question for government officials

1. Would you please tell us about the inventory or existing parking facilities in Hawassa city?
2. What opportunities and challenges exist in parking and will be occurring?
3. Are there any experienced parking management strategies applied in the city?
4. Are there any strategy for parking service improvement in the city?

Appendix – 3 : Survey Data from On-Street Parking

Table a : Survey Data from On-Street Parking

	Monday **Morning**				**afternoon**				hourly total	arrival	arrival	arrival
	0-15	15-30	**30-45**	45-60	**0-15**	15-30	**30-45**	45-60	vehicles	truck	cars	motorcycle
2hr-3hr	5	3	4	5	7	8	2	6	40	2	30	8
3hr-4hr	6	3	3	2	4	2	7	3	30	0	26	4
4hr-5hr	4	4	4	6	3	3	5	3	32	0	30	2
5hr-6hr	2	5	6	3	6	5	3	4	34	4	26	4
6hr-7hr	11	9	7	8	8	6	9	6	**64**	4	52	8
7hr-8hr	7	6	8	3	6	8	5	8	51	5	40	6
8hr-9hr	3	7	6	4	4	3	3	7	37	0	30	7
9hr-10hr	0	8	4	6	6	2	6	4	36	2	31	3
10hr-11hr	2	3	8	7	3	1	7	2	33	3	27	3
11hr-12hr	4	3	3	8	0	7	4	3	32	2	28	2
Daily total	44	51	53	52	47	45	51	46	389			

Table b : Survey Data from On-Street Parking

											l	
	Tuesday								Hourly total vehicles	truck	cars	motorcycle
	0-15	15-30	**30-45**	45-60	**0-15**	15-30	**30-45**	45-60				
	Morning				afternoon							
2hr-3hr	4	6	7	5	5	4	5	5	41	2	32	7
3hr-4hr	6	3	6	3	4	2	7	3	34	0	30	4
4hr-5hr	4	4	4	6	3	3	5	5	34	2	24	8
5hr-6hr	2	5	6	3	6	5	3	4	34	2	30	2
6hr-7hr	12	11	9	8	8	13	9	10	**80**	0	62	18
7hr-8hr	7	6	5	3	6	8	5	8	48	2	30	16
8hr-9hr	3	7	6	4	4	3	3	7	37	1	30	6
9hr-10hr	1	8	4	6	6	2	6	4	37	3	26	8
10hr-11hr	2	3	3	7	4	1	7	2	29	0	23	6
11hr-12hr	4	3	3	4	3	5	4	3	29	3	20	6
Daily total	45	56	53	49	49	46	54	51	403			

Table c : Survey Data from On-Street Parking

Morning		Wednesday			afternoon				Hourly total vehicles	truck	cars	motorcycle
	0-15	15-30	**30-45**	45-60	**0-15**	15-30	**30-45**	45-60				
2hr-3hr	4	6	7	5	5	4	5	5	41	2	32	7
3hr-4hr	6	3	6	3	4	2	7	3	34	0	30	4
4hr-5hr	4	4	4	6	3	3	5	5	34	2	24	8
5hr-6hr	2	5	6	3	6	5	3	4	34	2	30	2
6hr-7hr	12	11	9	8	8	13	9	10	**80**	0	62	18
7hr-8hr	7	6	5	3	6	8	5	8	48	0	30	8
8hr-9hr	3	7	6	4	4	3	3	7	37	1	30	6
9hr-10hr	1	8	4	6	6	2	6	4	37	3	26	8
10hr-11hr	2	3	3	7	4	1	7	2	29	0	23	6
11hr-12hr	4	3	3	4	3	5	4	3	29	3	20	6
Daily total	48	55	62	55	49	45	54	45	413			

Table d : Survey Data from On-Street Parking

Morning Thursday afternoon									Hourly total vehicles	truck	cars	motorcycle
	0-15	15-30	**30-45**	45-60	**0-15**	15-30	**30-45**	45-60				
2hr-3hr	7	6	4	5	4	6	4	6	42	2	32	8
3hr-4hr	6	3	4	2	4	2	7	4	32	1	28	3
4hr-5hr	4	4	4	6	6	3	5	3	35	2	25	8
5hr-6hr	2	5	6	3	6	5	3	4	34	0	32	2
6hr-7hr	10	12	12	9	9	8	10	8	**78**	0	68	10
7hr-8hr	7	6	8	3	6	8	5	8	51	2	41	8
8hr-9hr	3	7	6	4	4	3	3	7	37	0	30	7
9hr-10hr	4	8	4	6	6	2	6	4	40	2	34	4
10hr-11hr	2	3	8	7	3	1	7	2	33	0	33	0
11hr-12hr	4	2	4	8	3	6	4	3	34	0	29	6
Daily total	49	56	60	53	51	44	54	49	416			

Table e : Survey Data from On-Street Parking

Morning				Friday	afternoon			Hourly total vehicles	truck	cars	motor cycle
	0-15	15-30	**30-45**	45-60	**0-15**	15-30	**30-45**	45-60				
2hr-3hr	5	8	6	4	7	7	6	6	49	0	39	10
3hr-4hr	4	3	3	2	4	2	7	3	28	0	24	4
4hr-5hr	4	4	4	6	3	3	5	3	32	0	32	0
5hr-6hr	2	5	6	3	6	5	3	4	34	0	34	0
6hr-7hr	10	12	12	9	9	8	10	8	**78**	0	68	10
7hr-8hr	5	8	8	3	4	8	5	8	49	6	31	5
8hr-9hr	3	7	6	4	4	3	3	7	37	4	27	6
9hr-10hr	4	8	4	6	6	2	6	4	40	0	40	0
10hr-11hr	3	3	8	7	2	2	7	2	34	2	24	8
11hr-12hr	4	3	3	8	3	7	4	3	35	0	25	9
Daily total	44	61	60	52	48	47	56	48	416			

Table f : Survey Data from On-Street Parking

	Morning				Saturday afternoon				Hourly total vehicles	truck	cars	motorcycle
	0-15	15-30	**30-45**	45-60	**0-15**	15-30	**30-45**	45-60				
2hr-3hr	8	8	7	6	5	6	5	6	51	4	40	7
3hr-4hr	6	4	3	2	6	2	6	6	35	0	30	5
4hr-5hr	4	5	4	6	3	3	5	3	33	2	25	3
5hr-6hr	3	5	6	3	6	5	3	4	35	0	30	5
6hr-7hr	11	13	12	10	11	14	11	8	**90**	8	80	2
7hr-8hr	7	6	8	3	6	8	5	8	51	3	41	7
8hr-9hr	3	7	6	6	4	3	3	7	39	2	29	8
9hr-10hr	4	8	4	6	6	2	6	4	40	2	30	8
10hr-11hr	5	3	8	7	3	1	7	2	36	0	30	6
11hr-12hr	4	3	5	8	3	6	4	6	39	4	25	10
Daily total	55	62	63	57	53	50	55	54	449			

Table g : Survey Data from On-Street Parking

Morning				Sunday	afternoon				Hourly total vehicles	truck	cars	motorcycle
	0-15	15-30	**30-45**	45-60	**0-15**	15-30	**30-45**	45-60				
2hr-3hr	3	4	0	1	3	0	0	2	13	0	11	2
3hr-4hr	3	3	3	2	4	2	4	1	22	5	13	4
4hr-5hr	4	4	4	6	3	3	5	3	32	2	29	1
5hr-6hr	2	5	2	3	3	5	3	4	27	7	18	2
6hr-7hr	6	7	6	5	4	6	6	6	46	8	36	2
7hr-8hr	3	6	4	3	3	0	5	4	28	2	24	2
8hr-9hr	3	4	3	4	4	3	3	7	31	2	21	8
9hr-10hr	0	3	4	4	0	2	6	4	23	0	18	5
10hr-11hr	2	3	4	2	3	1	4	2	21	6	15	0
11hr-12hr	4	2	3	0	3	3	2	3	20	0	22	0
Daily total	30	41	33	30	30	25	38	36	263			

Appendix – 4 : Output of the objective value from model

Parking angle of 45^o

```
Global optimal solution found.
Objective value:                              6467.940
Infeasibilities:                              0.000000
Total solver iterations:                             0
Elapsed runtime seconds:                          0.08
Model Class:                                        LP
Total variables:             13
Nonlinear variables:          0
Integer variables:            0
Total constraints:           11
Nonlinear constraints:        0
Total nonzero:               53
Nonlinear nonzero:            0
                       Variable           Value        Reduced Cost
                             A1        0.000000            30.03000
                             A2        0.000000            15.98000
                             A3        0.000000            9.284000
                             S1        1616.985            0.000000
                             S2        803.1400            0.000000
                             S3        535.4250            0.000000
                             S4        278.4200            0.000000
                             S5        803.1400            0.000000
                             S6        535.4250            0.000000
                             S7        278.4200            0.000000
                             S8        803.1400            0.000000
S9                           S9        535.4250            0.000000

                             S10       278.4200             0.00000


                            Row    Slack or Surplus      Dual Price
                              1        6467.940            1.000000
                              2        0.000000            1.000000
                              3        0.000000            1.000000
                              4        0.000000            1.000000
                              5        0.000000            1.000000
                              6        0.000000            1.000000
                              7        0.000000            1.000000
                              8        0.000000            1.000000
                              9        0.000000            1.000000
                             10        0.000000            1.000000
                             11        0.000000            1.000000
```

Parking angle with 60^o

```
Global optimal solution found.
Objective value:                              5301.920
Infeasibilities:                              0.000000
Total solver iterations:                             0
Elapsed runtime seconds:                          0.09
Model Class:                                        LP
Total variables:            13
Nonlinear variables       :  0
Integer variables:           0
Total constraints:          11
Nonlinear constraints:       0
```

```
Total nonzero:                53
Nonlinear nonzero:                0
                          Variable           Value        Reduced Cost
                                A1        0.000000            30.15500
                                A2        0.000000            14.53000
                                A3        0.000000            4.500000
                                S1        1325.480            0.000000
                                S2        658.3500            0.000000
                                S3        438.9000            0.000000
                                S4        228.2300            0.000000
                                S5        658.3500            0.000000
                                S6        438.9000            0.000000
                                S7        228.2300            0.000000
                                S8        658.3500            0.000000
                                S9        438.9000            0.000000
                               S10        228.2300            0.000000

                               Row    Slack or Surplus      Dual Price
                                 1        5301.920            1.000000
                                 2        0.000000            1.000000
                                 3        0.000000            1.000000
                                 4        0.000000            1.000000
                                 5        0.000000            1.000000

                                 6        0.000000            1.000000
                                 7        0.000000            1.000000
                                 8        0.000000            1.000000
                                 9        0.000000            1.000000
                                10        0.000000            1.000000
                                11        0.000000            1.000000
```

Parking angle with 90°

```
Global optimal solution found.
Objective value:                              4530.000
Infeasibilities:                              0.000000
Total solver iterations:                             0
Elapsed runtime seconds:                          0.09
Model Class:                                        LP
Total variables:                   13
Nonlinear variables:                0
Integer variables:                  0
Total constraints:                 11
Nonlinear constraints:              0
Total nonzero:                     53
Nonlinear nonzero:                  0
                            Variable           Value        Reduced Cost
                                  A1        0.000000            30.15500
                                  A2        0.000000            15.98000
                                  A3        0.000000            9.284000
                                  S1        1132.500            0.000000
                                  S2        562.5000            0.000000
                                  S3        375.0000            0.000000
                                  S4        195.0000            0.000000
                                  S5        562.5000            0.000000
                                  S6        375.0000            0.000000
                                  S7        195.0000            0.000000
                                  S8        562.5000            0.000000
                                  S9        375.0000            0.000000
                                 S10        195.0000            0.000000
```

Row	Slack or Surplus	Dual Price
1	4530.000	1.000000
2	0.000000	1.000000
3	0.000000	1.000000
4	0.000000	1.000000
5	0.000000	1.000000
6	0.000000	1.000000
7	0.000000	1.000000
8	0.000000	1.0000000