ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

CHARACTERISTICS AND EFFECTS OF ON-STREET PARKING IN ADDIS-ABABA A CASE STUDY ON MARKED BOX PARKING FACILITIES IN NIFAS SILK LAFTO SUB-CITY

By
Wengel Yilma Wake

A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of

The Requirements for the Degree of

Master of Science

In

Civil Engineering (Road and Transport Engineering)

Advisor: Bikila Teklu Wodajo (Ph.D.)

June 2023

Addis Ababa, Ethiopia

ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF GRADUATE STUDIES

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

CHARACTERISTICS AND EFFECTS OF ON-STREET PARKING IN ADDIS-ABABA A CASE STUDY ON MARKED BOX PARKING FACILITIES IN NIFAS SILK LAFTO SUB-CITY

By

Wengel Yilma Wake

A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of The Requirements for the Degree of Master of Science In Civil Engineering (Road and Transport Engineering)

Submitted by;
Wengel Yilma ---------- signature ---------- 27-06-2023 Date

Approved By Board of Examiners;

Dr. Bikala Teklu
Advisor ---------- Signature ---------- 18/07/23 Date

Dr. Yonas Minalu
Examiner ---------- Signature ---------- 22-06-223 Date

Dr.Getu Segni
Examiner ---------- Signature ---------- 04-07-2023 Date

Abrham Gebre (Dr.)
Dean, School of Civil & Environmental Engineering

Chairperson ---------- Signature ---------- Date

UNDERTAKING

I certify that research work titled *"CHARACTERISTRICS AND EFFECTS OF ON-STREET PARKING IN ADDIS-ABABA A CASE STUDY ON MARKED BOX PARKING FACILITIES IN NIFAS SILK LAFTO SUB-CITY"* is my original work performed under the supervision of my research advisor **Dr. Bikila Teklu.** The work has not been presented elsewhere for assessment and a degree in any other university. Where material has been used from other sources has been properlyacknowledged.

Signature _____

Undertaker's Full Name: Wengel Yilma Wake

Place of Undertaking: Addis Ababa, Ethiopia.

Date: June 2023

Place and date of submission: - School of Graduate Studies, Addis Ababa University

June 2023

Contact Address: wengelyw02@gmail.com

ACKNOWLEDGEMENT

To begin with, I thank God for giving me the capacities, mettle and drive to complete this proposal work. Secondly, I would like to thank my advisor, Dr. Bikila Teklu , for his support and direction all through the proposal work beginning from the very beginning.

My deep hearted gratitude to Addis Ababa institute of technology by giving me the opportunity to avail the scholarship program in pursuing my master's degree in Road and Transport Engineering . Also, I would like to say thanks a lot to all my friends who shared their unselfish help and kind support in the research.

Finally, my special thanks go to my family who are always been there on times of difficulties and giving me moral support to complete this research work.

ABSTRACT

As of now in Addis Ababa there are so numerous issues which are basically concerned with deficiency of stopping space such as congestion of streets due to imbalance between on-street parking capacity and demand of parking space by vehicle and Regarding this problem Addis Ababa city traffic management agency has been implementing different types of parking facilities one of which is marking of Box on Street parking areas on the outer lane of the existing roads. However; the effects of these areas on existing traffic and efficiencies of these parking facilities on service condition are not assessed adequately. Therefore this study asses accordingly the effects and efficiencies of legal on street parking in Addis Ababa a case study on Nifas silk lafto Sub-City From Bisrate gebriel square to Karl square. methods used for data collection were field survey to conduct a comprehensive parking occupancy survey ultimately to find the characteristics and efficiency of the parking space, to find vehicle maneuvering time which are used to estimate the reduction of the adjacent lane capacity because of disruptions of traffic flow while maneuvering of vehicles from parking lane. In the instance of secondary data collection, relevant information was retrieved from relevant materials, such as published literature and internet-based sources.

The results of the study indicate that on-street parking facilities in Bisrate Gebriel square to Karl square road segment are inadequate mainly on mid-day period leading to illegal parking. Another result of the study shows that reduction in lane width of traffic lanes and vehicle maneuvering of parking vehicles on adjacent lane impacts road capacity. The average speed of vehicles by 6.25 %.Which was found to reduce a speed of 0.0382 km/hr. for each percentage increment of parking occupancy when on-street parking is considered removed from the kerb side of the road this reduction on road capacity due to both allocations of traffic lanes for on-street parking and Disruption of Traffic flow of adjacent lane.

Table of Contents

ACRONYMS

AACRA: Addis Ababa City Roads Authority

AASHO: American Association of State Highway Officials

HCM: Highway Capacity Manual

IP: Parking Index

POS: Parking Occupancy Survey

TPC: Theoretical parking capacity

VAP: vehicle accumulation profile

List of Tables

List of Figures

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Every time, In order to travel from place to place of the major facilities and public services, like the market area, the schools, the religious centers, offices and the like, are concentrated in the city center. This demand has driven to the development of transportation but adversely affect the effective uses of road due to lack of parking space in Addis Ababa (Shiferaw, 2014)

For drivers, on-street parking in city centers is a convenient option. However, the availability of such parking spaces may affect highway capacity and be a contributing factor in the high number of road traffic accidents, as well as have other direct or indirect consequences on public transportation use, business, the environment, and property values. (Chick, C. [1996]. On-Street Parking: A Guide to Practice. Landor Publishing, London.) According to studies, the design of on-street parking can have a significant impact on road capacity if parking places are not carefully selected and controlled. Not properly managed parking can create significant delays, particularly on busy highways, resulting in a stop-and-go traffic flow.

There are about more than 1,200,000 vehicles found in Ethiopia and among them, around 630,440 of registered vehicles are found in Addis Ababa (Ministry of Transport, 2020). Due to the increments of those sectors in the city, Parking facilities is going to become the basic issue, So getting parking facilities simply is the highest problem and difficult which leads the drivers spend more time for searching the vacant parking spots as it is shown in reality situation (Chaniotakis, 2014).

Hence, the study aims to assess the effects and efficiencies understanding the extent of a dearth of parking places resulting in street congestion and recommending appropriate remedies for present parking challenges.

1.2 Statement of the problem

Following an enormous Increase of number of population and expanding of urban centers in Addis Ababa, the number and concentration of vehicles is large. Despite large number of cars in the city, adequate parking areas are not provided for the vehicles. This in turn results massive parking problems. According to the Federal Transport Authority and the Addis Ababa Transport Authority, Addis Ababa is home to more than 70% of Ethiopia's total vehicles. As a result, one of the main goals for improving Addis Ababa's transportation operations should be to provide enough parking spaces. However, current parking facilities, including street parking and shuttle operations, are insufficient and troubled by structural issues. It is obvious that supplying car parking spots is a basic requirement for Addis Ababa's growth and development; otherwise, parking issues would harm drivers, pedestrians, and the business community. The required parking facilities are not sufficient in the city. Regarding this problem Addis Ababa city traffic management agency has been implementing different types of parking facilities one of which is marking of Box on Street parking areas on the outer lane of the existing roads. However; the effects of these areas on existing traffic and its road environment and Characteristics of these parking facilities on service condition are not assessed adequately.

1.3 Research Question

The following are questions which are expected to be countered by this research:

(i) What are the parking demand and supply assessment of the study area?
(ii) What are the Characteristics of existing parking facility in relation to parking demand based on Parking index measurement?
(iii) What are the effects of on-street parking facility on traffic congestion?

1.4 Objectives of the Study

1.4.1 General objectives

The primary purpose of this study is to evaluate the characteristics and effects of legal marked box on- street parking in Addis Ababa a case study on Bisrate-Gebriel square to karl square which is found in Nifas silk Lafto Sub-City

1.4.2 Specific objectives

The Specific objectives of the study are:

1.4.2.1 Parking demand and supply assessment of the case study area

1.4.2.2 Measuring and Identifying parking characteristics of legal on- street parking facility

1.4.2.3 To measure the effects of marked box on street facilities on Road Capacity

1.5 Scope and Limitation

This research will be limited by Assessing the effects and efficiencies of only

- marked(box) legal on-street parking
- On case-study area (Bisrate-Gebriel square to karl square which is found on Nifas Silk Lafto Sub-city).

This study will not consider other legal on-street parking facilities and illegal on-street parkng.

1.6 Significance of the study

The outcome of this thesis work is predicted to result in some major gains that can be realized as a result of the research. The findings of this study will aid in determining the efficiencies and effects of the marked box on street facilities that are provided in various

parts and sub-cities of Addis Ababa. Accordingly, this study will make contribution considerable details on the following topics.

- The findings might be utilized to provide standards and references for parking management in Addis Ababa, particularly in terms of planning, organizing, and controlling for future purposes.
- The investigation can also detect and rectify flaws in the administration of on-street parking imparting higher opportunity approaches and guidelines.
- Contribute to the body of knowledge in marked street parking facilities and to identify literature gaps to be considered in future research works.

1.7 Organization and Structure of the research

This study is organized in five chapters. **Chapter One** covers the study's general background, problem statement, research question, general and specific study objectives, the research's scope and limitations. **Chapter Two** deals with literature review including Literatures on On-street parking Characteristics, Types of parking, factors Affecting parking and Effects of parking. **Chapter Three** provides the design set up for data collection, the details of the study area, and the analysis of the data. **Chapter Four** deals with a complete data analysis as well as a discussion of the results. Conclusion and recommendations are the study's **fifth and final chapter**, and it presents the study's primary findings and recommendations for further research.

CHAPTER TWO

LITERATURE REVIEW

In this chapter, all-inclusive literature review is presented. This chapter contains of review of pervious works related to On-Street parking particularly about efficiencies and effects of On-Street parking. Literatures on On-street parking Characteristics, Types of parking, factors Affecting parking and Effects of parking are presented. Reviewing of related articles and their method of data collection and analysis are also Included In this Chapter.

2.1. Introduction

Examination of the literature shows several perspectives on parking facilities exist. According to the Addis Ababa City Roads Authority who is in charge of the city roads in Addis Ababa (AACRA), While parallel kerbside parking is normally operated in the direction of traffic flow, it poses the least obstruction to the orderly and regular flow of traffic along a road under properly managed conditions." While angle parking reduces the amount of space available in a given length of road, it has the advantage of reducing the frequency of accidents that occur during parking and departure procedures. Where street parking is required, parallel parking is the ideal strategy to utilize; street capacity must be kept to a minimum since parallel parking demands a narrower lane for parking and moving. To maintain a safe and orderly parking situation (Addis Ababa City Roads Authority, 2003).

Addis Ababa City Roads Authority also notes that angle parking can accommodate large number of cars when compared to parallel parking. Angle kerb side parking, on the other hand, necessitates more roadway Parallel parking is narrower and provides a greater risk to pedestrians. According to research, when angle parking is converted to parallel kerb side parking, the accident rate is cut in half and traffic capacity for that stretch of road is significantly increased.

Types of Parking

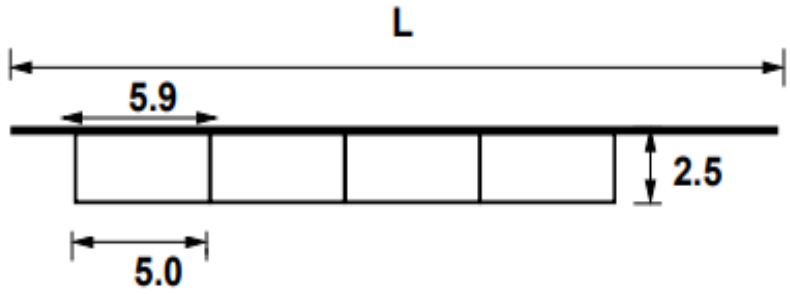
On-street parking: refers to automobiles parked along the sides of the road. In addition, on-street parking as its name suggests, a parking space on the public road although this may become somewhere parked on the road, or the side of the road, is only semi-public. On-street parking often takes place, either legally or not, on space at the side of the road that is nominally reserved for pedestrians.

In On-street parking service is a common feature in most of the developed cities around the world. On-street parking assists to improve economic viability of commercial developments along transport corridors by providing easy and convenient access for customers, delivery vehicles and employees of such developments. However, the provision of on-street parking along transport corridors could adversely impact the capacity as well as the achievable driving speeds of the adjacent road. Road safety is another key factor which needs to be considered when considering the provision of on-street parking along a transport corridor. The debate regarding the merits and drawbacks of on-street parking stem from a lack of research surrounding the subject over the last two to three decades. The utilization of on-street parking is considered to be a more efficient use of land as it limits the need for off-street parking and access points to properties adjacent to major arterial roads. This aspect of on-street parking also reduces costs for the businesses, maximizes land utilization and creates a pedestrian friendly environment for the community by delineating vehicles and land use. Extending from this concept it is believed to improve pedestrian safety by providing a barrier between the flowing traffic and the footpath as well as reducing the speed of vehicles travelling on the roadway. Although there are a number of benefits in providing on-street parking, there are some adverse impacts, particularly on traffic flow. On-street parking can impact the road capacity in two ways. The reduction of the available lanes of a road to accommodate on-street parking is the primary factor that reduces road capacity. Additionally, on-street parking maneuvers can cause extensive delays, especially on heavily trafficked roads. This creates stop-start traffic flow behavior for the lanes adjacent to the parking lane, thus affecting the capacity of the road section (Wijayaratna, 2015).

Parallel parking: The vehicles are parked along the length of the road. There is no backward movement involved while parking or un-parking the vehicle and it is the most 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. Parallel parking of cars is shown in figure below. The length available to park N number of vehicles,

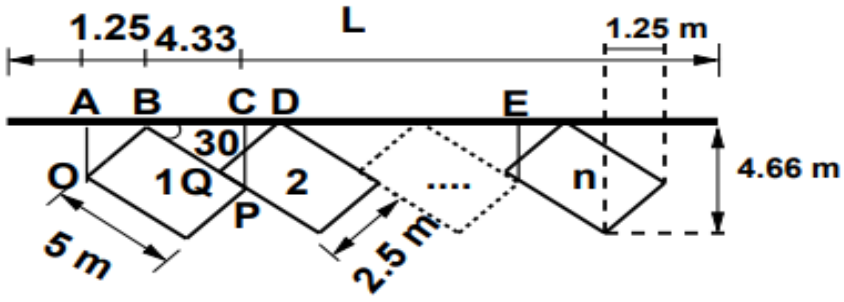
L=N/5.9

Figure 2.1: parallel parking type adapted (Tom V. Mathew et al, 2014).



30^0 parking: In thirty degree parking, the vehicles are parked at 30^0 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 low in this type of parking. An example is shown in following figure.

Figure 2:2 30^0 parking type (Tom V. Mathew et al, 2014)



From the Figure,

AB = OBsin30^0 = 1.25,

BC = OPcos30^0= 4.33,

BD = DQcos 60^0= 5,

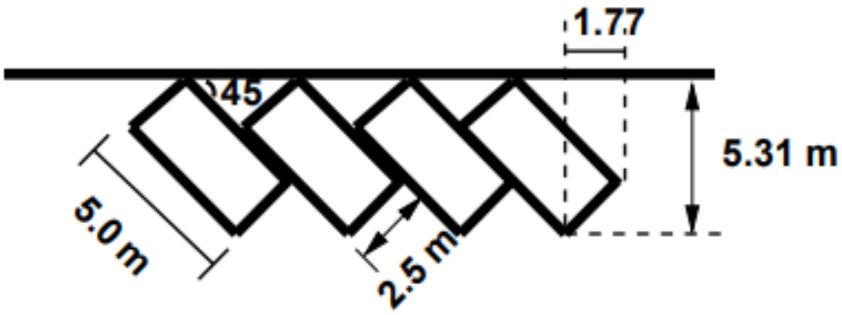
CD = BD-BC=5-4.33= 0.67,

AB+BC = 1.25+4.33= 5.58

For N vehicles, L=AC+ (N-1) CE =5.58+(N-1)5=0.58+5N

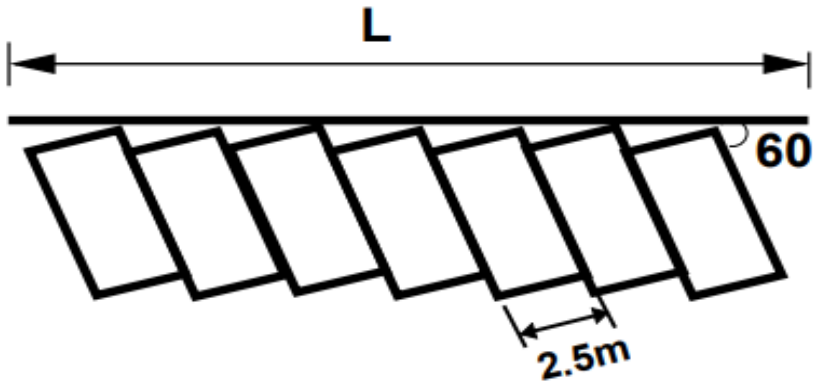
45◦ parking: As the angle of parking increases, more number of vehicles can be parked. Hence compared to parallel parking and thirty degree parking, more number of vehicles can be accommodated in this type of parking. From figure below, length of parking space available for parking N number of vehicles in a given kerb is L = 3.54 N+1.77

Figure 2.3:45° parking type (Tom V. Mathew et al, 2014)



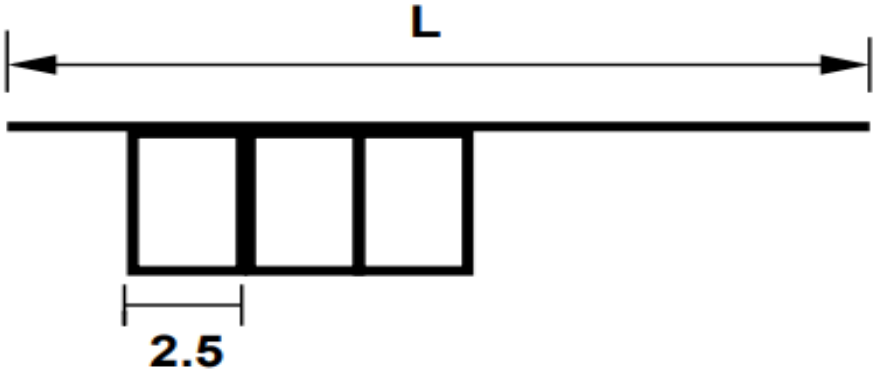
60^0 Parking: The vehicles are parked at 60◦ to the direction of road. More number of vehicles can be accommodated in this parking type. From the figure below, length available for parking N vehicles =2.89N+2.16.

Figure 2.4:60° parking type (Tom V. Mathew et al, 2014)



Right angle parking: In right angle parking or 90◦ parking, the vehicles are parked perpendicular to the direction of the road. Although it consumes maximum width kerb length required is very little. In this type of parking, the vehicles need complex maneuvering and this may cause severe accidents. This arrangement causes obstruction to the road traffic particularly if the road width is less. However, it can accommodate maximum number of vehicles for a given kerb length. An example is shown in figure below. Length available for parking N number of vehicles is L = 2.5N.

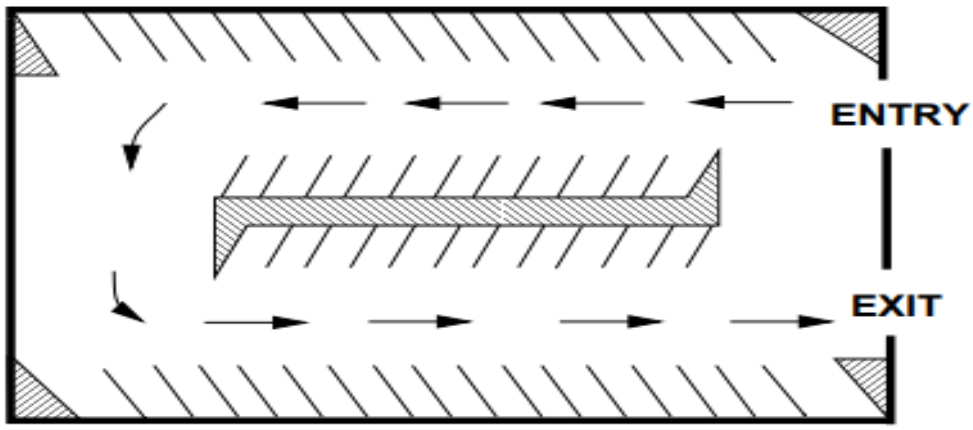
Figure 2.5:90° parking type (Tom V. Mathew et al, 2014)



Off street parking

In many urban centers, some areas are exclusively allotted for parking which will be at some distance away from the main stream of traffic. Such a parking is referred to as off-street parking. They may be operated by either public agencies or private firms. A typical layout of an off-street parking is shown in figure below:

Figure 2.6: off street parking (Tom V. Mathew et al, 2014)



2.2 Effects of on street parking

There are several advantages to offering on-street parking. there are also some adverse impacts, particularly on traffic flow.

2.2.1. Positive Effects

On-street parking helps business projects along transportation corridors increase their economic viability by offering simple and accessible access for consumers, delivery trucks, and staff. Marshall, Garric, and Hansen (2008). It is taken into account how much on-street parking is used. Because it eliminates the requirement for off-street parking and access

sites for homes near major arterials, it is a more efficient use of property (Litman 2013, Sculle & Jakle, 2004). By separating automobiles and land use, On-street parking lowers company costs, boosts site utilization, and creates a neighborhood that is more pedestrian-friendly. Extending this principle, it is thought that placing a barrier between flowing traffic and the sidewalk, as well as limiting the speed of cars traveling on the street, will increase pedestrian safety. 2006 (Byrd and Sisiopiku). On-street parking is an important part of marketing companies in urban areas. On-street parking is a type of shared parking. It is effective approach for permitting many customers to make use of the same area at different times to attain more than one destination. On-street parking gives clean get right of entry Businesses that are located on town streets require significantly less land per square foot than those that are located off-street. (Allison L. C., 2002).

On-street parking can be beneficial in the following ways, according to (Norman and Wesley, 2008):

- **Improved efficiency:** Users prefer on-street parking spots over off-street surface lots and garage parking in the town center, resulting in increased efficiency. On-street parking spaces experience high turnover and more users.
- **Better land use:** Using the side of a street for parking minimizes large amounts of land compared to off-street parking. As stated by Norman and Wesley (2008), by providing street parking, town centers which are Medium-sized businesses may preserve more than one hectare of land on average. On-street parking's efficiency allows for far higher-density commercial development than would be possible if the center relied only on off-street surface lots.

  Availability of on-street parking is a major component of spot accessibility. It opens up the chances for street vendors to interact with commuters and also makes road side retail shops more reachable. It is unfeasible to have parking lots for every small business along the street. Conversely, restriction of parking can harm the local merchants as it reduces their number of customers and so their profits. Supply of parking spaces near the commercial area is also a vital aspect in

this regard. Lesser supply compared to the parking demand frustrates shoppers in finding an empty parking space; consumer utility thence drops down and alternative destinations might be prioritized. On-street parking is also more convenient to the street shoppers rather park their vehicles off-street far from their destinations. Because on an average, people are reluctant to walk more than a radius of 200 m from their parking locations (Baker RG V, Wood S , 2010).

Economy of a commercial area is dependent on the number of consumers which is roughly associated with the number of trips. All the factors therefore, involved in destination choice criteria, have influence in economy of commercial area. However, most of the earlier researches postulating different destination choice mod- els for shopping trips, did not include 'on-street parking' in those factors. Instead, the factors were lim- ited only to quality and price of the products, size of the shopping area and distance to the destination. After the Second World War, scenario was changing gradually as rapid growth in automobile industry had encouraged the car ownership resulting in an increased parking demand near shopping areas. Thus, parking became one of the key factors for the shoppers' destination choice. Recker and Kostyniuk (Recker, 1978) conducted a household questionnaire survey in New York and identified 'on-street parking' as a major influencing element to the shoppers' destination choice. In a similar study (McCarthy PS, 1980), trip makers were asked to identify and also to rate the attributes which they thought playing role in their destination choice. 'Ease to park at shopping area' came out as a significant quality among all 19 identified attributes contributing towards destina- tion choosing decision. However, the independency of 'parking' as an attribute is arguable since it may carry a high positive correlation with the size of shopping area (Shobeirinejad M, Smart JCR, Sipe N, Burke M, 2013).

Researchers have further observed that this influence of 'on-street parking' may vary depending upon the type of goods to be shopped. A study (Timmermans et

al., 1982) conducted in Nether- land included similar questionnaire survey with only addi- tion that the respondents had to assign weightage values (maximum weight 100) to different attributes for shopping of daily and non-daily goods separately. Therefore, it was observed that on-street parking is more important for shop- ping of non-daily goods since overall weightage of parking for non-daily goods was found 80.6 against 62.8 for daily goods. This may be because of the fact that shopping of non-daily goods involves longer time compared to the daily goods and hence, availability of parking space is more crucial in that case. Shobeirinejad et al., 2013)) also verified this 'goods wise variation' as it was noticed that for cloth shopping, commuters prefer the market area having a larger parking opportunity. However for grocery shopping, commuters may accept the minimal parking scope.

- **Improved safety:** when amenities such as on-street parking are included. Drivers often go at a much slower pace. Slower vehicle speeds offer pedestrians, cyclists, and drivers more time to react, and the likelihood of a life-threatening collision is greatly reduced. In summary, on-street halting can help to create a more secure environment by reducing automobile traffic and making lanes safer for bikes and pedestrians. According to Christopher (2006), on-street parking is used as chicanes in many European towns to make the street appear smaller and control activity in private ranges. Slower vehicle speeds offer pedestrians, cyclists, and drivers more time to react, and the likelihood of a life-threatening collision is greatly reduced.

2.2.2 Negative Effects

on street parking includes some main problems on the traffic flow such as congestion of roads, environmental pollution, accidents in the road sides and obstruction to firefighting operations process in the city (Marshall, Garrick & Hansen 2008).

On-street parking in city centers is an attractive facility for drivers. However, the

availability of such parking facilities may affect the capacity of the highway and be a contributory cause in the high number of road traffic accidents as well as having other direct or indirect effects on other issues such as the use of public transport, business, environment and property values. Studies have shown that the design of on-street parking often influence the road capacity if parking locations are not selected and controlled in a careful manner. Inappropriate parking can cause severe delays especially on busy roads resulting in a stop-start situation to the traffic flow. London is one of many cities that has these problems which can be alleviated by the implementation of what is called "Red Route" which mainly aims at controlling parking in those busy roads.

Most previous studies have taken into account the reduction in road width to accommodate for on- street parking and its effect on reduction in road capacity. Hobbs reported the influence of the physical use of road space, parking maneuvers and opening of car doors on increasing delay. Studies in Nebraska, USA indicated that on-street angle parking is more hazardous than that of parallel parking. The main reason is the lack of adequate visibility for the driver during reversing maneuvers. However, all of these studies have not explicitly considered the effect of parking maneuvers as a cause of congestion.

2.2.2.1 on Road Capacity

On-street parking has two effects on road capacity. The biggest factor that lowers road capacity is the reduction of available lanes to allow on-street parking. On-street parking maneuvers can also create significant delays, particularly on congested highways. This causes the lanes adjacent to the parking lane to have a stop-start traffic flow pattern, reducing the capacity of the road section. (Sahan Wijayaratna 2015).

According to the American Association of State Highway and Transportation Officials (AASHTO 2011), reducing kerb side on-street parking may boost the road capacity of four lane arterial highways by 50 percent and 80 percent increase in the capacity of six-lane

arterial roadways Weant and Levinson (1990) found that eliminating on-street parking from a four-lane road doubles capacity, while removing on-street parking from a six-lane road boosts capacity by 67%. This result demonstrates the direct influence of on-street parking on traffic lanes when on-street parking is permitted. Based on analysis on a road performance of Gajah Mada St., Rambipuji, Jember roads when on-street parking is allowed and not allowed; road performance of when on street parking is allowed on the side of a street, the capacity of the road has grown by 25%, the Degree of Saturation has lowered by 25%, the speed has improved by 11%, and the degree of road service has increased from road D to Level of service of road C when compared to road performance with on-street parking.

On the analysis, it is also concluded that The link between parking space utilization and road segment performance, parking space usage and road segment performance have a very strong relationship and impact on each other. (Sonya Sulistyono et al., 2015)

On-street parking in transportation corridors may have a negative impact on the capacity and achievable driving speeds of the nearby road. Marshall, Garrick, and Hansen (Marshall, Garrick, and Hansen, 2008). Portilla et al. (2009) utilized micro-simulation modeling to show that 30 parking moves per hour lowered the road capacity of the remaining lanes by up to 16 percent. Vehicle maneuvers entering and departing parking slots have become a potential source of congestion as the frequency of parking and traffic volumes have increased. The time it takes for a car to enter or exit a parking spot is measured in parking maneuver times. The maneuver patterns have a big influence on these periods. Other considerations could include the type of vehicle, capacity of the driver, and size of parking slots.

Yousif and Purnawan (1999) conducted a thorough investigation of the time it takes to access and exit on-street parking spots. The research looked into methods to enhance the design and supply of on-street parking facilities in order to shorten the time it takes to park. The study also looked at how long it took to park in parallel parking spots and angle

parking spaces on the street, as well as how long it took to depart them. According to the data, the reverse parallel parking method takes the longest time and is proportional to the vehicle's size. on the study Different parking maneuver patterns of parallel (legal), parallel (illegal) and angle parking (legal) have been observed. All parking actions that required reversing to park or un park took an average of more time to accomplish. In the case of parallel parking, reversing maneuvers may be required solely when entering a parking facility between two parked vehicles. When parking at an angle, though, you must always reverse. These moves could be a contributing factor in producing temporary traffic jams, which could lead to operational issues such as congestion, delays, and possibly accidents. The increase in the frequency of such maneuvers could exacerbate these operational problems especially when traffic flow levels are moderate to high. Therefore, such maneuvers should be avoided, wherever possible, by including any necessary changes to the design of on-street parking facilities. This may be done by avoiding angle parking and instead making advantage of the available road space by parallel parking.

Stalls for parallel parking should be created to allow enough maneuvering area for parking cars, with optional marking procedures to establish acceptable distances between stalls. This might reduce the requirement for reversing maneuvers or the time necessary for reversing maneuvers. (Yousif & Purnawan (1999))

Sahan Wijayaratna conducted a study on on-street parking. The study's findings clearly show that when an on-street parking zone's time limitation is short, The capacity reduction in the next lane to a parking lane is greater. When on-street parking is authorized, the research offers a number of road capacity decrease parameters to consider predictions. When traffic volumes are moderate to heavy, such as during peak hours, on-street parking may have an impact on moving traffic. Because there are just a few tiny openings in the flowing traffic stream to allow cars to progressively alter their speeds in a safe manner or to give way to others seeking to park, entering or exiting parking maneuvers might create temporary bottlenecks and cause congestion. Angle parking with reversing manoeuvres

requires not only longer manoeuvring times, but relatively more road space to complete the manoeuvre, causing more congestion. This results in a stop-start traffic flow pattern for the lanes adjacent to the parking lane, reducing the road section's capacity. Wijayaratna, 2015

Drivers mental workload and behavior in the presence of on-street parking contributes to, or fails to reduce, this increased crash risk. On-street parking tends to co-exist with visually complex streetscapes that may affect workload and crash risk in their own right. (Jessica Edquist et al., 2012), The present paper reports results from a driving simulator study examining the effects of on-street parking and road environment visual complexity on driver behavior and surrogate measures of crash risk. Twenty-nine participants drove a simulated urban commercial and arterial route. Compared to sections with no parking bays or empty parking bays, in the presence of occupied parking bays drivers lowered their speed and shifted their lateral position towards roadway center to compensate for the higher mental workload they reported experiencing. However, this compensation was not sufficient to reduce drivers' reaction time on a safety-relevant peripheral detection task or to an unexpected pedestrian hazard. Compared to the urban road environments, the less visually complex arterial road environment was associated with speeds that were closer to the posted limit, lower speed variability and lower workload ratings. These results support theoretical positions that proffer workload as a mediating variable of speed choice. However, drivers in this study did not modify their speed suf- ficiently to maintain safe hazard response times in complex environments with on-street parking. This inadequate speed compensation is likely to affect real world crash risk. (Jessica Edquist et al., 2012),

2.2.2.2 on Road Safety

According to O'Flaherty, the accident potential of angle parking, is much higher than parallel parking. As a result, as compared to parallel parking, angle parking may be deemed less advantageous, and caution should be used when doing it.

2.2.2.3 Road side Accidents

Due to parking in the on-street parking the vehicles created accidents by carelessness maneuvering, carelessness opening of the doors and in the time of entering and existing from parking facilities. Jessica Edquist, has done research into the impact of on-street parking and the visual complexity of the road environment on travel speed and reaction time. Theoretical viewpoints that propose workload as a mediator variable of speed choice are supported by these findings. In complicated areas with on-street parking, however, drivers in this research did not adjust their speed enough to maintain safe danger reaction times. This inadequate speed adjustment is likely to have an impact on collision risk in the actual world. Although on-street parking has numerous advantages, it might endanger the safety of road users if not handled correctly, according to Charles Peprah. Congestion, threat to pedestrian safety, and inconveniences are all caused by a variety of reasons, including behavioural attitudes. As a result, it's critical to concentrate In order to promote effective on-street parking and pedestrian safety, it is more important to focus on culture and attitude than it is to rely just on visible and factual information. To influence the culture and attitudes of road users, education, sensitization, and enforcement of on-street parking regulations are required.

2.2.2.4. Environmental pollution:

In the parking activities vehicles sending some toxic gas into environment when car moving to search parking lot and creates high noise in the city of entering and existing time from parking locations. This pollution gases affects the aesthetic beauty of building and city.

2.3. Parking Characteristics

Parking characteristic is a fundamental quality that may be used to analyze parking services and challenges in the research location. Parking accumulation, parking volume, parking turn over, parking index, parking duration, and parking capacity are all parking characteristics. To study operational circumstances and plan the growth of parking lots,

parking characteristics are required. (Sahan Wijayaratna(2015))

- The quantity of cars parked in a location at any particular moment is referred to as ***parking accumulation.***
- The number of cars parked in a specific location or parking space for a specific period of time is referred to as ***parking volume.*** In most cases, one day is used.
- ***Turnover parking*** is the rate of parking usage for a certain period of time. The parking turnoverr rate is obtained from the division between the total numbers of parked vehicles with the number of parking lots available during the observation time.
- ***Parking duration*** is the amount of time a car is parked on a parking lot is referred to as the ***parking duration.*** The parking duration is derived by subtracting the parking time out from the parking time in. The average length of time parking may be computed using the parking duration of each vehicle and each kind of parked vehicle.
- The number of cars that can be serviced by a parking lot during service time is referred to as ***parking capacity.*** The number of available plots divided by the average duration of parking time yields capacity.
- ***Parking index (IP)*** **is** calculated by dividing the number of parking vehicles with available parking lots. the available capacity, or when difficulties arise. If IP1 is true, then parking requirements are still within existing capacity or are not a concern.

At any given time, the proportion of parking spaces in a specific region or facility that are occupied. The number of automobiles that have gathered in a parking place over a period of time is referred to as ***parking occupancy.*** The average number of parked automobiles per legal parking spot is known as the occupancy rate. There are parking facility issues in the neighborhood if the occupancy rate is more than 85%. (FIG Congress, 2010).

The percentage of on-street parking that is fully occupied while remaining fairly available is referred to ***Parking Capacity.*** On-street parking occupancy rates of 100 percent or more are considered unwelcome. Parking experts, most notably Donald Shoup of UCLA (2005), have established an on-street parking occupancy of 85 percent as the reference point for the

practical capacity of on-street parking.

Availability (Vacancy): The percentage of parking spots in a facility or region that are not in use at any particular moment. Availability or vacancy is equal to 100% minus the percentage of occupancy; therefore it communicates the same notion as occupancy. Availability is a helpful term since it describes how a user (such as a vehicle looking for parking) perceives the current occupancy rate.

The amount of time a car is parked at a certain area is referred to as the ***duration of parking.***

The number of cars that occupy a parking place in a certain period of time is referred to as ***parking turnover.*** Vehicles per hour or another time period is commonly used to measure turnover. Turnover of parking is computed from calculating an average within a specific region and among spaces of the same type. Turnover is a measure of a parking space's productivity or efficiency (i.e., quantity of users served).

2.4. Parking Study

It is critical to have information on the availability of parking spaces, the amount of their use, and parking demand. It's also necessary to calculate parking fees. All of this information is supposed to be provided through parking surveys, this led to the improvement of parking surroundings.

Parking Capacity Estimation

For the same region, two methodologies employing two distinct data sources are used to assess parking capacity. The vehicles accumulation profile (VAP) and theoretical parking capacity will be determined by O-D survey data, whereas raw and actual parking capacity will be determined by field data collection and the use of geographic data: the difference between these two should be related to parking regulation. 2O12 (Diallo, A., Morency, C., and Saunier, N.).

The vehicle accumulation profile (VAP): Morency et al. devised a method for determining the vehicle accumulation profile (2006). This allows you to calculate the number of parked vehicles in a specific location during a certain time span. The concept of vehicle arrivals and departures governs the accumulation of cars in a given location

2.5. Parking Survey

To acquire the above-mentioned parking data, a survey is undertaken. In-out surveys, fixed period sampling, and license plate technique surveys are the most popular parking surveys (Mathew,T. and Kirshana, K., 2006)

2.5.1. In- out survey

The occupancy count in the specified parking lot is found at the start of this survey. The number of cars entering the parking lot within a certain time frame is then tallied. The number of cars leaving the parking lot is also counted. The parking lot's ultimate occupancy is also taken. The amount of labor necessary here is really low. However, parking duration and turnover data and data on the length of time that a certain car used that parking lot is not obtained by this survey method . It is not possible to gather data on parking duration and turnover. (T. Matthew and K. Kirshana, 2006)

2.5.2. License Plate Method of Survey

This is the most exact and realistic info available. Every parking slot is observed at a continuous period of fifteen minutes or Thirty minutes in this survey, and the license plate number is recorded. This will provide information on how long a certain car occupied a parking space. However, this procedure is quite time consuming. (T. Matthew and K. Kirshana, 2006).

2.5.3. Fixed Period Sampling Method of Survey

This is nearly identical to an in-out survey. At the start of the survey, all cars are tallied. The count is then collected again at a set time period, which can range from 15 minutes to an hour. There's a risk it will be overlooked the number of cars that were parked for a brief time. (T. Matthew and K. Kirshana, 2006)

2.6. Previous Studies

On-street parking is a common form of parking, known for its efficiency in terms of land use and convenience to motorists as it allows them to park their vehicles nearer to their destinations. On street parking has also many disadvantages related with it. On street parking hampers the carrying capacities of the roads which results in traffic jams and sometimes may also cause casualties. (Sahan Wijayaratha, 2015)

Previously Efficiencies and Effects of on street parking facilities are previously studied and analyzed by researchers using different methodology.

(Sahan Wajayaratna, 2015) carried out the study that uses field surveys to determine how long it takes to perform parking maneuvers and the ensuing delays on Sydney's metropolitan highways. These surveys were then statistically analyzed, and a connection was constructed to determine the impact of these disruptions on road capacity.

The study attempts to develop a mathematical model to quantify the potential Impacts on Road Capacity from on-street parking by formulation of road capacity adjustment factor and comparison of Estimation of road capacity when on-street parking is permitted and estimation of road capacity of a traffic lane incorporating the proposed on-street Adjustment factor are provided. Three different types of parking maneuvers were analyzed. Different sites based on Time restrictions are analyzed. On the study, it is concluded that short term parking has greater impact on road capacity than longer term parking's.

Yousif and Purnawan (1999) conducted a thorough investigation into the amount of time it takes to get into and out of on-street parking spots. The study looked into measures to enhance on-street parking facility design and availability in order to reduce the amount of time it takes to park. The study also looked at how long it took to park in parallel parking spots and angle parking spaces on the street, as well as how long it took to depart them. The reverse parallel parking method takes the most time and is the most difficult and is strongly connected with vehicle size, according to the research.

(H-S. Leuing & K.P. Wijayaratna) on study of "Implications of Parking Policy on Traffic flow with in Urban Environments" studied tries to comprehend the effects of on-street parking maneuvers on the environment traffic flow through an empirical analysis of field data. The study conducted parking surveys, collecting qualitative and quantitative data related to parking behaviour, on selected major arterial roads within Sydney, Australia. Analysis of survey data suggests that delays increase for parking zones with a greater level of parking turnover. Furthermore, the study completes a microsimulation modelling exercise to highlight the performance impacts of parking policies within Sydney. Finally, the study proposes alternative policies which could reduce the traffic flow implications of on-street parking. This study provides an understanding of the implications of on-street parking manoeuvres on traffic flow through an empirical analysis of field data collected in Sydney, Australia. The reverse parallel parking manoeuvre was found to result in the greatest impedance on traffic flow out of the identifiable parking manoeuvres. The magnitude of the disruption is dependent on the turnover rate of the parking zone, with a

greater turnover rate resulting in more manoeuvres and accordingly a greater impact on traffic flow. Thus, shorter time restrictions result in a greater deterioration of the traffic conditions. Based on these findings, a parking policy encouraging front-in parking manoeuvres is proposed. Furthermore, the study completes a microsimulation modelling exercise to highlight the performance impacts of various parking policies currently applied within Sydney again presenting a deterioration of the arterial road performance with the presence of on-street parking.

On a research Titled “On street parking and its impact on road performance” conducted by (Sonya et al. 2018) When comparing the performance of roadways when on street parking is permitted and when on street parking are not permitted on the side of the street, road performance is examined on both cases. road performance characteristics which were studied are Free flow rate, road capacity, degree of saturation, travel speed, and service quality. Based on the study result, road capacity has increased by twenty five percent, Degree of saturation has decreased by twenty five percent, and travel speed has increased by eleven percent. The performance of the road section examined using field data is the performance of the road with parking on the road body. The performance of roads without street parking is calculated by multiplying the effective lane width of the road body section used for parking by the number of parked cars.

Therefore, after looking at previous studies, which are studied on on-street parking facilities, this study was conducted on Characteristics/efficiencies and effects of on-street parking. Efficiency and Characteristics of on- street parking is studied based on parking index/parking occupancy rate. Effects of on street parking are analysis of field data more specifically the effects of existence of on-street parking on road capacity.

CHAPTER THREE

RESEARCH METHOD

3.1 Introduction

This Chapter presents the underlying principle of research design and methodology, the research location, the choice of relevant study data gathering procedures and data analysis methods in accordance with the research problem.

3.2 Research Location

According to the data obtained from transport management office the following places are among areas marked with box for parking purpose.

Table 3.1: Marked Box on-street parking areas in Addis Ababa

	Place of parking Box marked In Addis Ababa City	No.of parking Box
1	From megenagna-kasanchis	257
2	From urael to bole bras	284
3	From Sholagebeya – 24-jakros-Saelitemihret	368
4	From mexico-lideta court-abnet	238
5	From 4 killo to paisa	91
6	From Abune petros to winget roundabout	366
7	From Megenagna to CMC michael	153

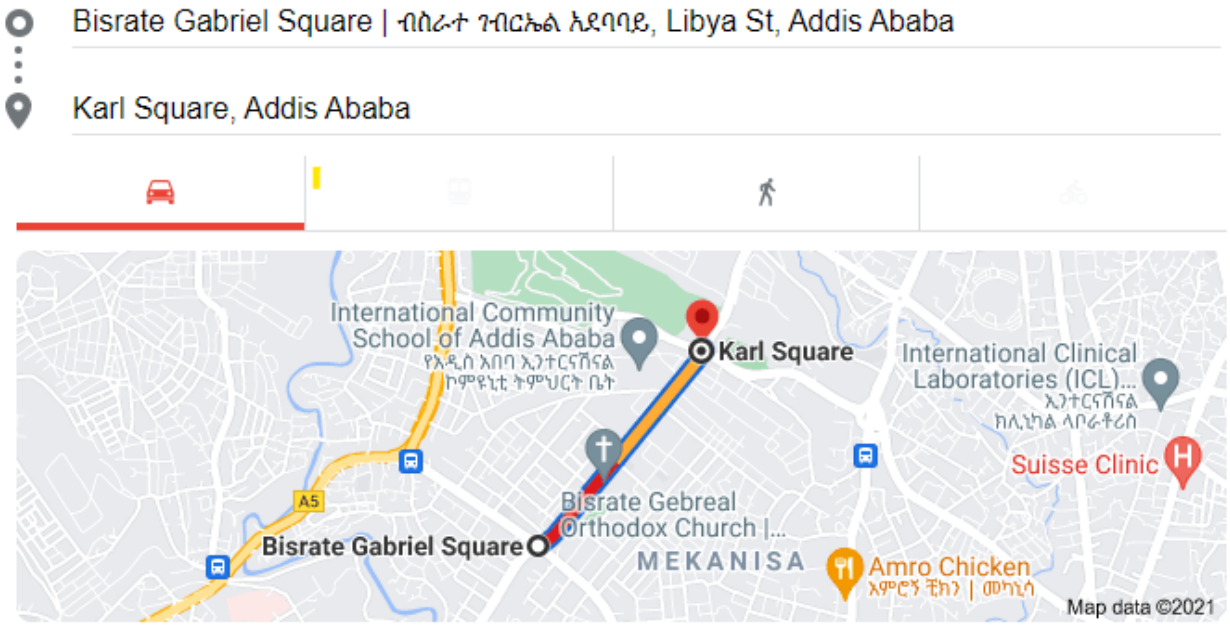
	Place of parking Box marked In Addis Ababa City	No.of parking Box
8	From Gofa roundabout to legehar cherkos	161
9	From Denbel to meskel flower	117
10	From getfam to begtera/Adisu stadium	145
11	22 weha limat ANB Building	19
12	Wede lancha Mesmer maseltegna	639
13	From gotera masalecha welosefer	115
14	From kebena to Arat killo	119
15	from bisrate gebriel to karl roundabout	106
16	Denbel-bamebis	73
17	Kasanchis-Bambis	
17	Denbel-Kidestemariam-4 killo	33
18	From kebena-minilik hospital	81
19	From 6 killo to shiro-meda	74

Source: Addis Ababa City transport management office

Since the project was motivated to study on marked box on-street facilities the researcher selected **from bisrate gebriel to karl roundabout road segment** on which the outer lane of the road is marked box for on-street parking, here in the city of Addis Ababa. The Study site is randomly selected from a list of areas which are marked with box for parking purpose. Some of the characteristics of the studied Area are area is covered by business

activities the availability of marked on street facility, existence of moderate to high traffic on the road segment, The visibility of the marked areas, The use of marked on street facilities properly with time restrictions during peak hours. The studied street has a length of 1.2km. It has two directional flows and each direction is separated by medians on the center of the road and there are three traffic lane and walk way in each direction.

Figure 3.1: Study Area



Source: Google Map

Major Land uses of the adjacent location are Many commercial centers, Schools, embassy residents, hotels were mostly occupy the adjacent locations. The owners and customers of these centers and people who run business on these centers and many others are expected to use this on-street parking facilities.

In the study area, there is parking restriction on direction of Bisrate gebriel square to Karl Square during morning traffic peak hour periods (from 06:00 am to 10:00 am) and on direction of Karl square to Bisrate-gebriel square during afternoon traffic peak hour periods(from 04:00pm to 07:00pm)

Figure 3.2: Marked Box On-street Parking Facilities of the Study Area

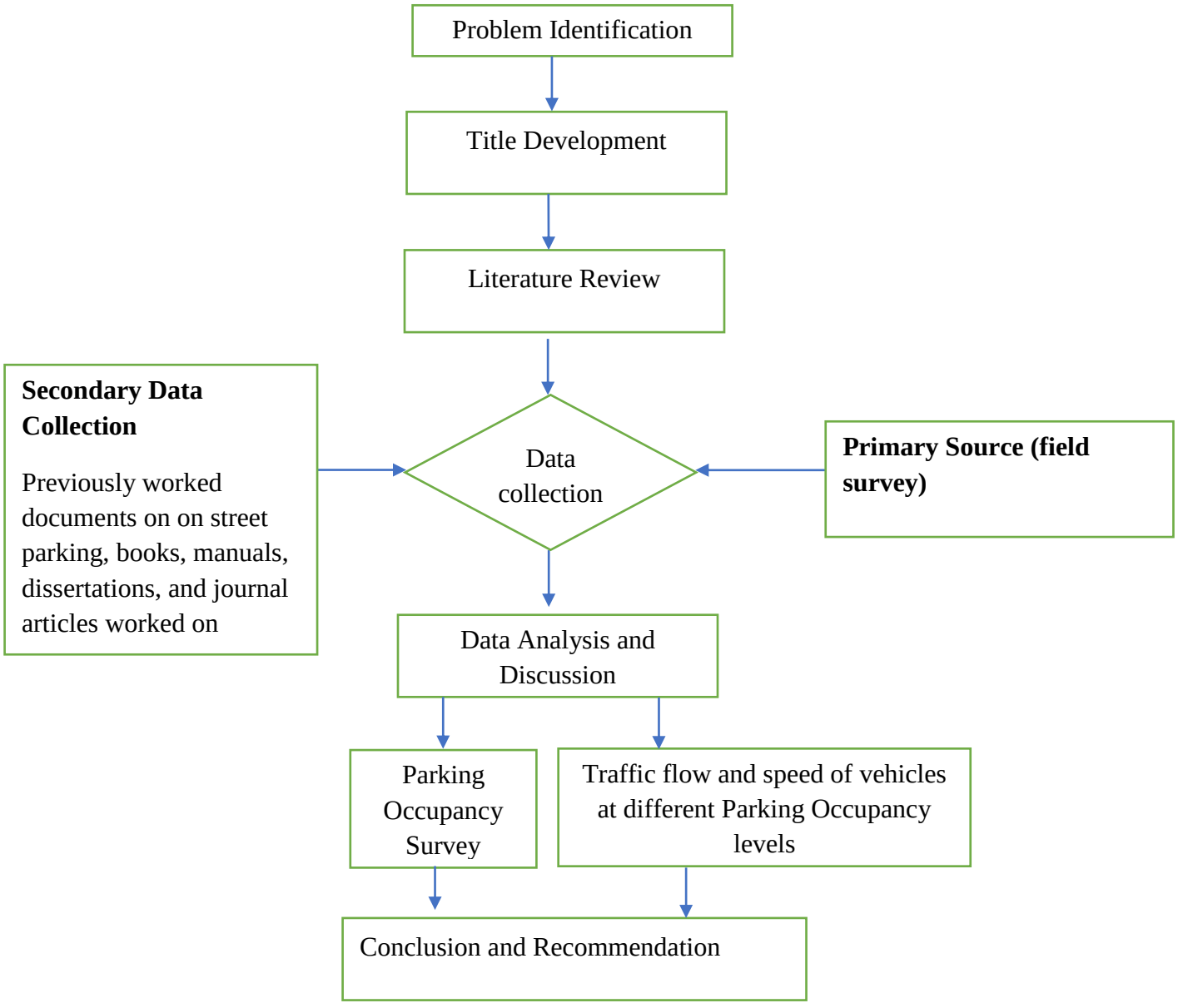
3.3. Research Design, Methods of Data Processing and Analysis

3.3.1. Research Design

In this study, a mathematical model and sensitivity analysis is developed to analyze the effects of parking on the side of the street on road capacity which arises from reduction of available lane of a road to accommodate on-street parking and entering and living on-street vehicle maneuvering on adjacent lane. Field surveys were conducted to obtain adequate data which enables to enumerate the impact of on-street parking on traffic flow. Traffic flow and speed of through vehicles at different parking occupancy levels were compared and analyzed to understand the impact of on-street parking facility on road capacity. Parking occupancy survey is also conducted to evaluate the efficiencies of marked on street

parking facilities and to study the characteristics of marked box on street parking facilities. This survey is conducted based on data obtained from field surveys. Parking occupancy rate and parking load of the studied street are determined in order to estimate the efficiency of these on-street parking facilities.

Figure 3.3: Research frame



3.3.2. Data Collection

In this study different methods of data collection were employed, which can be collected or gained by two methods of data collection systems, these are primary data collection methods &secondary data collection methods. Field survey which includes direct & indirect observation of the parking activities in the study area are the primary data collection methods, the literature reviewed connected with the study on parking activities are used under secondary data collection methods.

3.3.2.1 Primary Data Collection

- Pilot Survey

An observational pilot field survey was undertaken first to determine the most practicable, viable, and safe manner of conducting the field survey required to collect data. The pilot study was carried out by the researcher during the morning and Afternoon periods at a location in Karl Square to Bisrate - gebriel Square.

The observations and findings of the pilot survey which assisted in the development of the survey methodology are discussed in this section.

Existing traffic and parking situation of the study road was recorded on the pilot survey. It was recorded that The studied street consist of six(6) lanes on two directions i.e three (3) lanes each direction which are separated by a median. On each direction one(1) lane is subjected to on street parking and has marked on-street boxes.

During the Pilot Survey, the nature of the parking zone was documented. The turnover rate and, as a result, the number of moves into and out of parking zones were modified by time limits linked with each parking zone. As a result, the length of time a parking zone is restricted might be regarded a factor that influences traffic flow and road capacity. Thus, It is noted that there is parking restriction on direction of Bisrate gebriel square to Karl Square during morning traffic peak hour periods (from 06:00 am to 10:00 am) and on direction of Karl square to Bisrate-gebriel square during afternoon traffic peak hour periods(from 04:00pm to 07:00pm)

Major Land uses of the adjacent location are also observed during this pilot survey. Many commercial centers, Schools, embassy residents, hotels were mostly occupy the adjacent locations. The owners and customers of these centers and people who run business on these centers and many others are expected to use this on-street parking facilities.

The information gathered during the pilot survey was utilized to create the final survey technique, which is detailed in the following section.

Based on the Pilot Survey At the research site, the following information and data were gathered:

- Current parking and traffic conditions - parking limits, occupancy rates, lane widths, and the number of available traffic lanes;
- The time, date, and weather;
- Number of vehicles parked/hour (number of disruptions to traffic flow) – turnover rate;
- The start and finish timings of the traffic flow disturbance (in minutes) during each parking maneuver;

➢ Parking occupancy survey

For considering the efficiency of on street parking, extent of parking space usage and parking demand, parking surveys are used to provide all this information. To determined parking capacity,in the selected areas Field Survey is considered. Based on it Parking Occupancy Surveys (POSs) were conducted for one week from 10:00 a.m. to 4:00 p.m. in six interval of times 10:00 a.m. – 11:00 a.m., 11 a.m. - 12 a.m., 12:00 a.m. -1:00 p.m., 1:00 p. m. – 2:00 p.m., 2:00 p. m. – 3:00 p.m., 3:00 p. m. – 4:00 p.m.,; including all week days and weekends for 6 hours using 30 minute interval of time., in each interval The number of cars parked in a certain region for a given length of time was taken into account.

This technique was utilized to collect numerical data from the subject region, and the time of day when the areas were generally inhabited or unoccupied was taken into account. The following information was gathered on on-street parking spots: location, condition, type,

number of parking spaces, and the number of cars parked in the research area for a certain time period.

Data collected though Parking Occupancy survey are used to determine parking Accumulation, Parking occupancy rate, average occupancy, parking volume, parking load and parking efficiency. In order to obtain field data; an appropriate Data Collection Sheet is developed and used (see appendix)

- Parking survey on maneuvering of vehicles

One-hour evaluations were done to gather enough information to create a mathematical model to determine the link between on-street parking and road capacity. For one hour, video recording was utilized to capture the start and finish timings of traffic flow disturbance (time) for each parking move. During each parking maneuver, the disruption to traffic flow (time taken) was documented using a digital watch from video playback. To observe parking behavior and measure disturbances to traffic flow as a result of parking on the side of street maneuvers.

- Traffic Volume and Traffic flow

On-street parking reduces parking capacity and can impact the traffic flow due to using of the traffic lane for parking purpose and by creating stop start traffic flow caused by on-street parking maneuvers. Hence, in order to analyze the effects of on-street parking on traffic flow detailed traffic flow analysis was done on the studied street.

Two directional and traffic volume count and traffic flow data collection was done on both directions of the road segment on a direction of which goes from bisrate gebriel to karl round about and the other direction which goes from karl round about to bisrate gebriel. This was counted for one week day at 15 minutes interval staring from 10:00 am to 4:00 pm. A total of 6 hours traffic volume count was conducted.

All types of Vehicles that has been seen on the studied street were counted. All vehicle types were converted to Passenger Car Equivalent to determine the total peak hour flow in a unit of vehicle per hour. From the field volume count, directional traffic flow was determined for each

fifteen minute count and it was changed to hourly flow that is pointed out using the unit of (veh/hr).

The traffic flow data shown above was measured at time interval having lower, medium and higher parking demand hour. This was very helpful to capture the effect of the onstreet parking on the performance of the road like average speed and travel time.

- Average Travel speed of vehicles

Traffic flow is influenced by the speed of the traffic on existing roads. Speed is a function of several factors such as the geometric design features, traffic conditions like the presence of other vehicles, time and place, the environment, and the driver, and the traffic system in general.

To obtain Running speed of vehicles on the study area, travel speed was measured at the same time with recording of parking demand as well as recording time of traffic volume. The length of the stretch while video recording was measured in the field and by dividing the length of the stretch by the time for which the vehicle is in motion. It is determined from video playback as the length of the section in the video recording is measured at the site and the traffic speed is determined by dividing the length of the road segment by time a vehicle travels the segment of the road which is obtained from a video play back.

3.3.2.2 Secondary Data

Secondary data was gathered through reviewing related literatures, books, journals, and papers. To obtain information about methods to measure efficiencies of on street parking and the background for such survey lay mostly on related literatures, guidelines, manuals and other previously conducted researches and journals. possible effects of on street parkings on road capacity and road environment are also studied and presented on these research are based on related literatures.

3.3.3 Method of Data Processing and Analysis

To analyze Efficiency and effects of marked box on-street parking facilities, two different data sets were analyzed in two different data analysis methods. These methods of data processing and analysis are described hereunder;

3.3.3.1. To analyze the parking demand and supply data and parking Characteristics of on-street parking.

The results of the field survey were quantified by determining the study street's parking occupancy rate, average occupancy, parking volume, parking load, total parking load, and parking efficiency. The input data from the parking occupancy survey is used to create the parking demand analysis.

Parking capacity of on-street parking on the surveyed road is Estimated both from formula N=L/5.9 for on-street parking. data from transport management office is also considered for the actual number of marked on-street parking stalls.

Parking configuration of the study area is obtained from pilot survey.

To provide a clear presentation and better comprehension, the obtained data was presented in the form of a chart, graph, and tables.

The data was sorted into tables, figures, indexes, graphs, and maps, which were then evaluated and interpreted. The problem-solving methods explain the issues, and the analyses' findings aid in the formulation of policy suggestions.

Parking surveyed data will be analyzed and illustrated as discussed here under:

occupancy rate (Parking index): The sum of each interval over the total number of parking spots in the region.

Average Occupancy: Is the total number of intervals divided by the sum of the occupancy of each interval.

Parking Volume: Is the hourly parking turnover or the total number of automobiles parked.

Parking Load: The accumulation at each interval is multiplied by the time interval to get the result. The time interval is used to express it.

Total Parking Load is the total amount of parking load

Parking efficiency is the total number of parking spots divided by the total number of parking spaces

Occupancy rate, parking index and parking efficiency are used to indicate the efficiencies of the existed marked box on-street parking facilities.

If 85 percent of a parking lot' slots are filled, it's deemed full. When a parking supply is 85 percent to 90 percent full, it runs at maximum efficiency. There may be delays and difficulty in locating a place if occupancy reaches this level. Even if there are places available in the system, the parking supply may be seen as insufficient. (Litman (2013))

3.3.3.2. To analyze the effects of on-street parking on road performance

The main impact of on-street parking on through traffic flow on the adjacent lane is caused from automobiles maneuvered into and out of on-street parking places A one-hour field survey was done to gather enough data to create a mathematical model to determine the link between on-street parking and road capacity. Start & end times of disruption to the traffic flow (time) during each parking maneuver was recorded. During each parking maneuver, the amount of traffic flow disruption (time taken) was measured using a video camera and then digital watch was used to acquire the data through video play back. The influence of parking maneuvers on traffic flow is also noted. The complete parking maneuvers entering and leaving maneuvers were measured. Parking maneuver times are the length of time required by vehicles to enter or leave the parking stalls.

Vehicles maneuvering data obtained from field survey is analyzed by the formula provided in Highway Capacity Manual.

Highway Capacity Manual (HCM) Provides the following formula for Finding an adjustment

factor for adjacent lane

$$Fp = (N-0.1-18* Nm/3600)/N)$$

where,

fp = adjustment factor for vehicle maneuvering

N= number of lanes in lane group

Nm= number of parking maneuvers/h

18=assumed average time taken for parking maneuvers

In this study, a Sample mean of maneuvering times which is obtained in the above section is used instead of assumed average time for parking maneuvers i.e., 18 sec.

On-street parking reduces parking capacity and can impact the traffic flow due to using of the traffic lane for parking purpose and by creating stop start traffic flow for the adjacent lane caused by on-street parking maneuvers. Hence, in order to analyze the effects of on-street parking on traffic flow detailed traffic flow analysis was done on the studied street.

As the studied street is two directional and traffic volume count and traffic flow analysis was done on both directions i.e, the one which goes from bisrate gebriel to karl round about and the other which goes from karl round about to bisrate gebriel. This was counted for one week day at 15 minutes interval staring from 10:00 am to 4:00 pm.

While Conducting traffic different types of Vehicles were observed using the studied road, Car (Automobile cars) is the dominant vehicle types in the studied street. Other types of Vehicles that has been seen on the studied street are Bus and Heavy Vehicles. All vehicle types were converted to Passenger Car Equivalent to determine the total peak hour flow in a unit of vehicle per hour. From the field volume count, directional traffic flow was determined for each fifteen minute count and it was changed to hourly flow that is pointed out using the unit of (veh/hr).

Traffic flow data was arranged Based on different Parking Occupancy Percentage/Levels and as shown on the graph below it is indicated that traffic flow was lower at lower parking Occupancy hours, Medium Parking Occupancy hours, at Higher Parking Occupancy Hours.

The data's obtained from field surveys and video playbacks on Traffic flow and speed are studied in Conjugation with the parking demand data. Comparison of Traffic flow and Average Speeds on Different Parking Occupancy rates or on different classes was done and it was analyzed together with Parking demand data. Based on outputs from regression analysis of Average Speed, Traffic flow and on-street parking Occupancy percentages or rates Sensitivity Analysis or what if analysis was conducted.

As running speeds are useful to assess the traffic capacity of highways, Speed is a function of several factors such as the geometric design features, traffic conditions like the presence of other vehicles, time and place, the environment, and the driver, and the traffic system in general. When on street parking exists or is permitted on a road segment, Speed of a through Vehicle is also influenced by the existence of on street parking on adjacent lane.

Running speed of the study area is determined by dividing the length of the stretch by the time for which the vehicle is in motion. It is determined from video playback as the length of the section in the video recording is measured at the site and the vehicle speed is determined by dividing the length of the road segment by time a vehicle travels the segment of the road which is obtained from a video play back.

In order to determine the significance of the effect of traffic flow and parking occupancy on the average speed, sensitivity analysis was carried out. Two of the factors which influenced moving traffic speed and overall road capacity and level of service are traffic flow and parking occupancy. Hence, traffic flow and Parking Occupancy were considered as explanatory Variables and speed was considered as dependent variable.

The impact of on-street parking and flow on speed is performed for an aggregated data of both directions and using the average parking occupancy rate of week days. The average speed used which was recorded at the same time simultaneously of recording on-Street data and traffic flow was used in order to analyze the Effects of On-street parking on Speed on different Traffic flow conditions.

The impact of on-street parking on speed was assessed by developing a regression model when on-street parking is allowed on the road. To model the relationship between the Explanatory Variables i.e, traffic flow and on-street parking occupancy percentage with speed of vehicles, Multiple Linear regression model which include flow and on-street parking as explanatory variables to describe the variation of the dependent variable speed of vehicles is used.

In this approach, the average speed was compared during different intensities of parking occupancies. The parking occupancy was categorized into three classes as low, medium and high parking level.

In order to ensure a clear presentation and better understanding, the gathered information was presented in the form of chart, graph and tables.

Thus, the organized data in the form of tables, figures, indices, graphs and maps have been analyzed and interpreted. The analyzing processes clarify the Characteristics of On-Street Parking and the results of the analysis helps to determine the Effects of On-street parking on road capacity and also to give recommendations.

CHAPTER FOUR

DATA PRESENTATION AND ANALYS

This Chapter deals with analyzing and presenting the facts collected during field surveys regarding on-street parking problems at a selected street in the city of Addis Ababa. In addition to the primary data, secondary data were also analyzed and results produced. The analysis of the study was structured and conducted to answer the research questions by addressing the objective of the research. In this chapter; findings of the survey and analysis with detailed interpretations and discussions are explicitly presented.

4.0. Results of the survey

The information and data collected during the survey were divided into two categories for analysis. The findings of the parking occupancy survey are reported in the first part. The outcomes of the data gathered in part two are presented in field survey on reduction of road capacity.

4.1. Result of parking occupancy survey

The parking survey was done, as stated in chapter three for one week on 10:00 a.m. , 10:30 a.m. , 11:00 a.m., 11:30 a.m., 12:00 a.m., 12:30 a.m., 1:00 p.m., 1:30 p. m., 2:00 p.m., 2:30 p. m.,3:00 p.m.,3:30 p. m., 4:00 p.m. This survey aims to collect the data of parking accumulation, parking volume, parking load, average parking duration, parking capacity, and occupancy rate of on-street parking which are located between karl square to Bisrate Gebriel square. The Survey comprised of field survey on on-street parking. The field survey is conducted including all week days and weekends for 6 hours using **30 minute interval of time.** One week data was recorded and counted from field surveys on the date from March 20, 2021 to March 26, 2021

The following information was gathered during the field survey: parking spot location, capacity, and current state. The studied street is 1.2 km on one direction and 2.4 km on both directions.

.

4.1.1. Parking Demand Analysis

The parking demand analysis is carried out based on the input data, which are listed below.

a. The fixed period sampling approach was employed to perform the parking analysis survey.

b. It lasted six hours, with 30 minute intervals, and the results were analyzed.

4.1.1.1. Parking capacity of the studied Street

The amount of parking available is regulated by taking the number of marked box on-street parking from the data obtained from transport management office. According to the data obtained from transport management office, from bisrate gebriel to karl round about there are a total of 106 marked on street parking spaces.

The data obtained from transport management office is considered in this study.

4.1.1.2. Determination of parking load and parking occupancy rate of the Studied Street

If 85 percent of a parking lot' slots are filled, it's deemed full. When a parking supply is 85 percent to 90 percent full, it runs at maximum efficiency. There may be delays and difficulty in locating a place if occupancy reaches this level. Even if there are places available in the system, the parking supply may be seen as insufficient. Litman (2013)

Therefore, parking occupancy or parking Index is used as a measure of Efficiency of the marked box on street parking facilities based on the field parking occupancy survey data.

Parking surveyed data is analyzed and illustrated as discussed here under and in following

tables.

Parking accumulation: is the number of automobiles parked in a certain location at any given moment. For example the parking accumulation of Monday at 10:00 a.m. is 82 vehicles.

Parking capacity: is the maximum number of cars that a parking lot can service in a given amount of time. 106 marked box on-street parking areas are available. Therefore, 106 vehicles can be parked in a place at a time.

Occupancy rate (Parking index): Is the total number of parking spots in the locations when each interval is added together. It's computed by dividing the total number of parked cars by the total number of parking spaces available. For example the occupancy rate of Monday at 10:00 am is = (82/106)*100= 77.36% and a parking Index of 0.77.

Average Occupancy: Is the total of each recording time's occupancy divided by the number of intervals. During the surveying period on Monday, the average occupancy at the survey location was 96.44 percent.

Parking Volume: Is the hourly parking turnover or the total number of automobiles parked. During the Surveying Period on Monday, 1329 automobiles were parked in the investigated area for a total of six hours, or an average of one hour 1329/6 = 222 vehicles.

Parking Load : The accumulation at each interval is multiplied by the time interval to get the result. The time interval is used to express it. It is (82 x 30) = 2460 during the first 30 minutes on Monday.

Total Parking Load is the total number of cars in the parking space, for instance on Monday it is estimated by dividing number of cars which is 39,870 and for 6 hours. So it is calculated to be 39870/6 = 6,645 vehicles minutes and it is equivalent to 110.75 vehicle hour.

Efficiency of parking space is the total number of parking spaces divided by the total number of parking spaces. For average accumulation on Monday = (102 /106)*100 = 96.44 %

Detailed Parking occupancy survey results and their analysis of all weekdays and weekends of the week are presented in the following section.

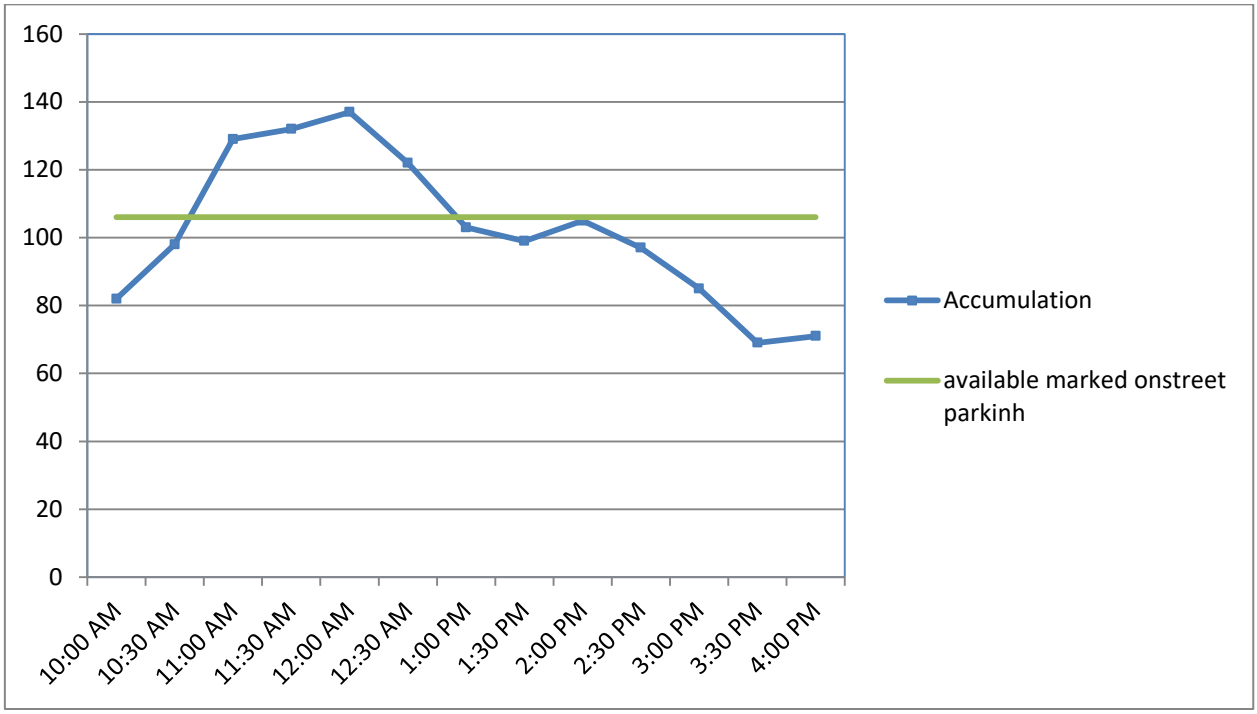
Parking occupancy survey results on the data collected **Monday** from 10:00 am to 4:00pm and parking accumulation curve in Monday is presented on table 4.1 and figure 4.1 respectively.

The below parking demand analysis and parking occupancy survey illustrates parking characteristics of the study area and detail parking characteristics of the studied street. The results shows after lifting of the morning parking restriction, parking demand is lower and it starts to rise as the time approaches to mid day and parking demand begin to decline once it reaches its peak demand level and becomes minimum after mid day peak hour parking demand towards afternoon peak hour parking restriction time. As the analysis is showing, at demand of parking is greater than that of the legally available parking space more at mid-day (11:00am to 2:00pm) of the day as the morning and afternoon peak hour periods, parking is not allowed and are not included in this study. The above table and figure shows that there is double parking and illegal parking during mid- day peak hour as the demand of parking exceeds the number of available lanes.

Table 4.1 Parking Occupancy Survey results Monday

Monday					
Data recording time	Accumulation	Parking Occupancy Rate	Parking Index	Parking Load (30 Minute Duration)	Capacity/ Available Bays
10:00 AM	82	77.36%	0.77	2460	106
10:30 AM	98	92.45%	0.92	2940	106
11:00 AM	129	121.70%	1.22	3870	106
11:30 AM	132	124.53%	1.24	3960	106
12:00 PM	137	129.25%	1.29	4110	106
12:30 PM	122	115.09%	1.15	3660	106
1:00 PM	103	97.17%	0.97	3090	106
1:30 PM	99	93.40%	0.93	2970	106
2:00 PM	105	99.06%	0.99	3150	106
2:30 PM	97	91.51%	0.92	2910	106
3:00 PM	85	80.19%	0.80	2550	106
3:30 PM	69	65.09%	0.65	2070	106
4:00 PM	71	66.98%	0.67	2130	106
Average Occupancy/Index	102	96.44%	0.96		
Total Parking Load				39,870.00	
Parking Volume	1329				

Figure 4.1. Parking Accumulation curve on Monday



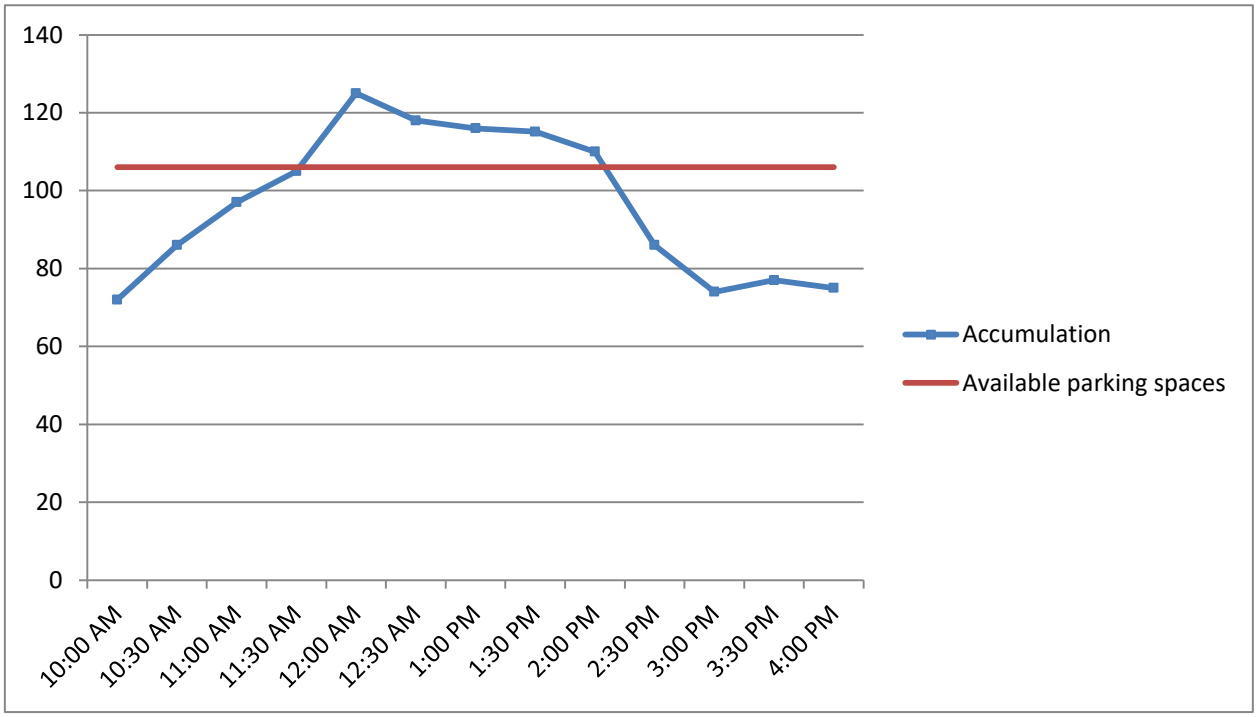
Parking occupancy survey results on the data collected **Tuesday** from 10:00 am to 4:00pm and parking accumulation curve in Tuesday is presented on table 4.2 and figure 4.2 respectively.

The below parking demand analysis and parking occupancy survey illustrates parking characteristics of the study area and detail parking characteristics of the studied street. The results shows after lifting of the morning parking restriction, parking demand is lower and it starts to rise as the time approaches to mid day and parking demand begin to decline once it reaches its peak demand level and becomes minimum after mid day peak hour parking demand towards afternoon peak hour parking restriction time. As the analysis is showing, at demand of parking is greater than that of the legally available parking space more at mid-day (5:30am to 2:00pm) of the day as the morning and afternoon peak hour periods, parking is not allowed and are not included in this study. The above table and figure shows that there is double parking and illegal parking during mid- day peak hour as the demand of parking exceeds the number of available lanes.

Table 4.2. Parking Occupancy Survey results Tuesday

Tuesday				
Data recording time	Accumulation	Parking Occupancy Rate	Parking Load (30 minute duration)	Available Bays
10:00 AM	72	68%	2160	106
10:30 AM	86	81%	2580	106
11:00 AM	97	92%	2910	106
11:30 AM	105	99%	3150	106
12:00 PM	125	118%	3750	106
12:30 PM	118	111%	3540	106
1:00 PM	116	109%	3480	106
1:30 PM	115	109%	3454	106
2:00 PM	110	104%	3300	106
2:30 PM	86	81%	2580	106
3:00 PM	74	70%	2220	106
3:30 PM	77	73%	2310	106
4:00 PM	75	71%	2250	106
Average Occupancy		91.16%		106
Total Parking Load			37,684	
Parking Volume	1256.14			

Figure4.2: Parking Accumulation curve on Tuesday



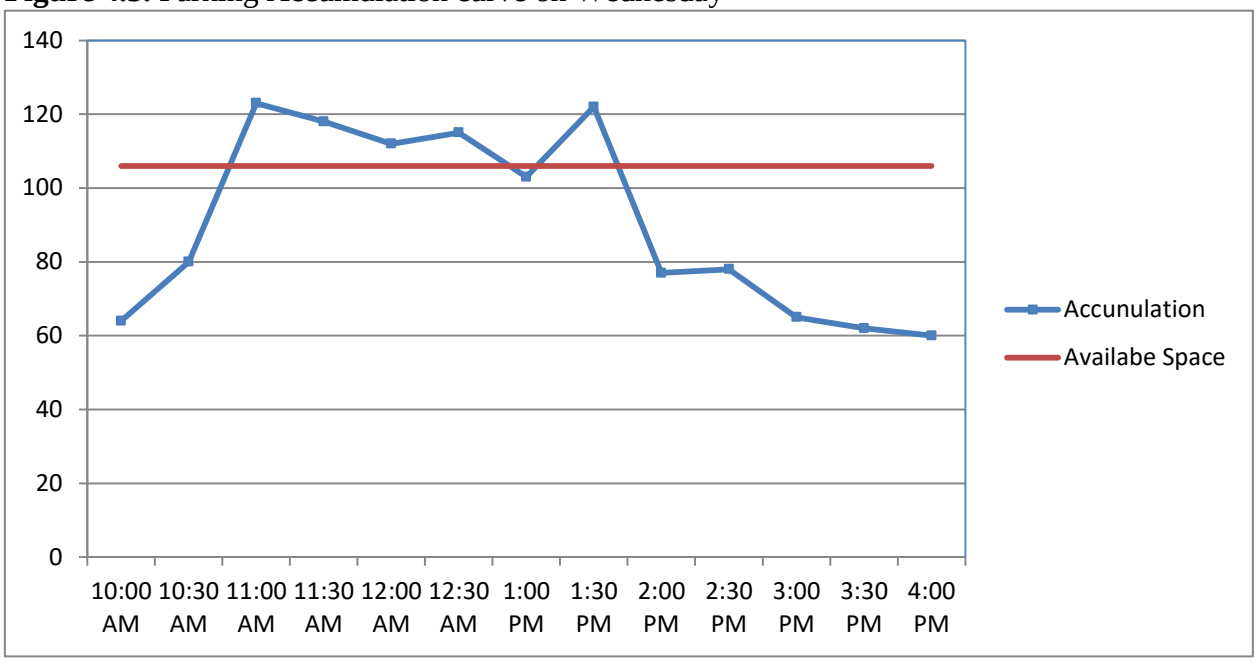
Parking occupancy survey results on the data collected **Wednesday** from 10:00 am to 4:00pm and parking accumulation curve in Wednesday is presented on table 4.3 and figure 4.3 respectively.

The below parking demand analysis and parking occupancy survey illustrates parking characteristics of the study area and detail parking characteristics of the studied street. The results shows after lifting of the morning parking restriction, parking demand is lower and it starts to rise as the time approaches to mid day and parking demand begin to decline once it reaches its peak demand level and becomes minimum after mid day peak hour parking demand towards afternoon peak hour parking restriction time. As the analysis is showing, at demand of parking is greater than that of the legally available parking space more at mid-day (11:00am to1:30pm) of the day as the morning and afternoon peak hour periods, parking is not allowed and are not included in this study. The above table and figure shows that there is double parking and illegal parking during mid- day peak hour as the demand of parking exceeds the number of available lanes.

Table 4.3. Parking Occupancy Survey results on Wednesday

Wednesday				
Data recording time	**Accumulation**	**Parking Occupancy Rate**	**Parking Load (30 MINUTE DURATION)**	**Available Bays**
10:00 AM	64	60%	1920	106
10:30 AM	80	75%	2400	106
11:00 AM	123	116%	3690	106
11:30 AM	118	111%	3540	106
12:00 PM	112	106%	3360	106
12:30 PM	115	108%	3450	106
1:00 PM	103	97%	3090	106
1:30 PM	122	115%	3660	106
2:00 PM	77	73%	2310	106
2:30 PM	78	74%	2340	106
3:00 PM	65	61%	1950	106
3:30 PM	62	58%	1860	106
4:00 PM	60	57%	1800	106
Average Occupancy		86%		106
Total Parking Load			37,684.27	
Parking Volume	**1256.142378**			

Figure 4.3. Parking Accumulation curve on Wednesday



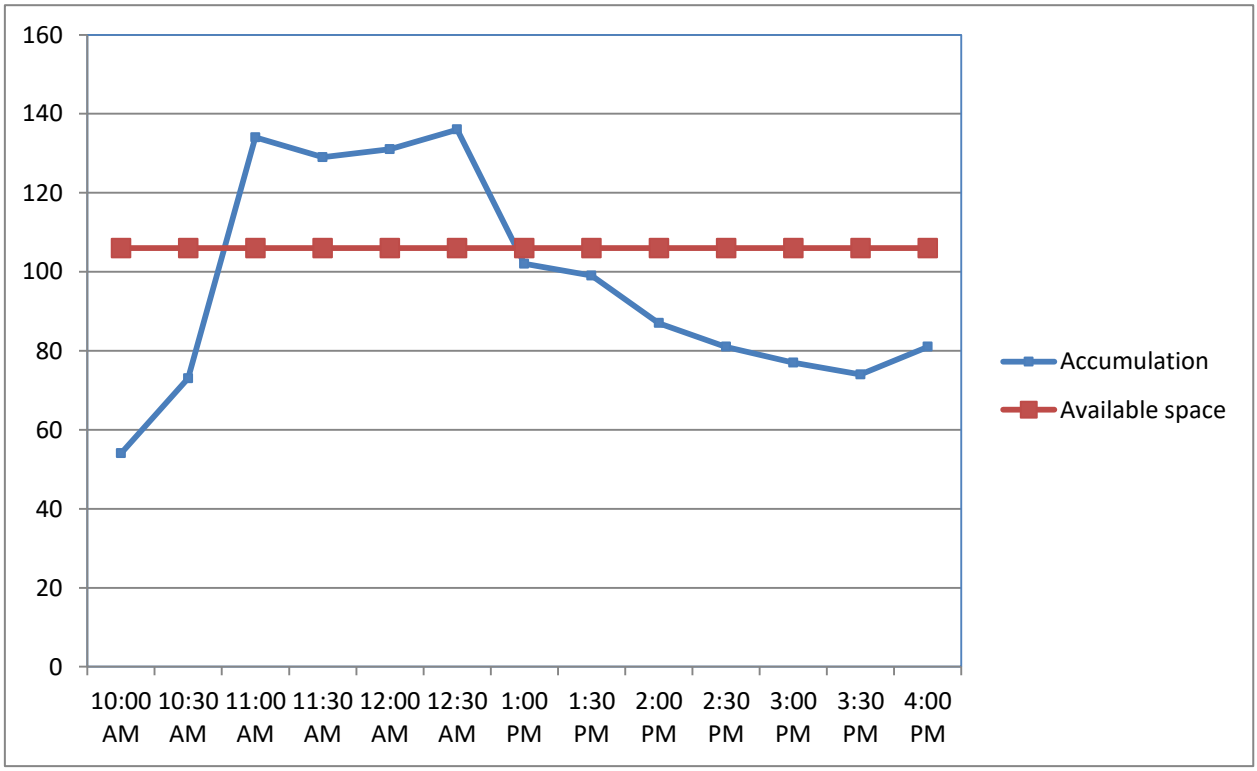
Parking occupancy survey results on the data collected **Thursday** from 10:00 am to 4:00pm and parking accumulation curve in Thursday is presented on table 4.4 and figure 4.4 respectively.

The below parking demand analysis and parking occupancy survey illustrates parking characteristics of the study area and detail parking characteristics of the studied street. The results shows after lifting of the morning parking restriction, parking demand is lower and it starts to rise as the time approaches to mid day and parking demand begin to decline once it reaches its peak demand level and becomes minimum after mid day peak hour parking demand towards afternoon peak hour parking restriction time. As the analysis is showing, at demand of parking is greater than that of the legally available parking space more at mid-day (11:00am to6:30pm) of the day as the morning and afternoon peak hour periods, parking is not allowed and are not included in this study. The above table and figure shows that there is double parking and illegal parking during mid- day peak hour as the demand of parking exceeds the number of available lanes.

Table 4.4: Parking Occupancy Survey results Thursday

Thursday				
Data recording time	Accumulation	Parking Occupancy Rate	Parking Load (30 minute duration)	Available Bays
10:00 AM	54	51%	1620	106
10:30 AM	73	69%	2190	106
11:00 AM	134	126%	4020	106
11:30 AM	129	122%	3870	106
12:00 PM	131	124%	3930	106
12:30 PM	136	128%	4080	106
1:00 PM	102	96%	3060	106
1:30 PM	99	93%	2970	106
2:00 PM	87	82%	2610	106
2:30 PM	81	76%	2430	106
3:00 PM	77	73%	2310	106
3:30 PM	74	70%	2220	106
4:00 PM	81	76%	2430	106
Average Occupancy		91%		
Total Parking Load			37,740.00	
Parking Volume	1258			

Figure 4.4: Parking Accumulation curve on Thursday



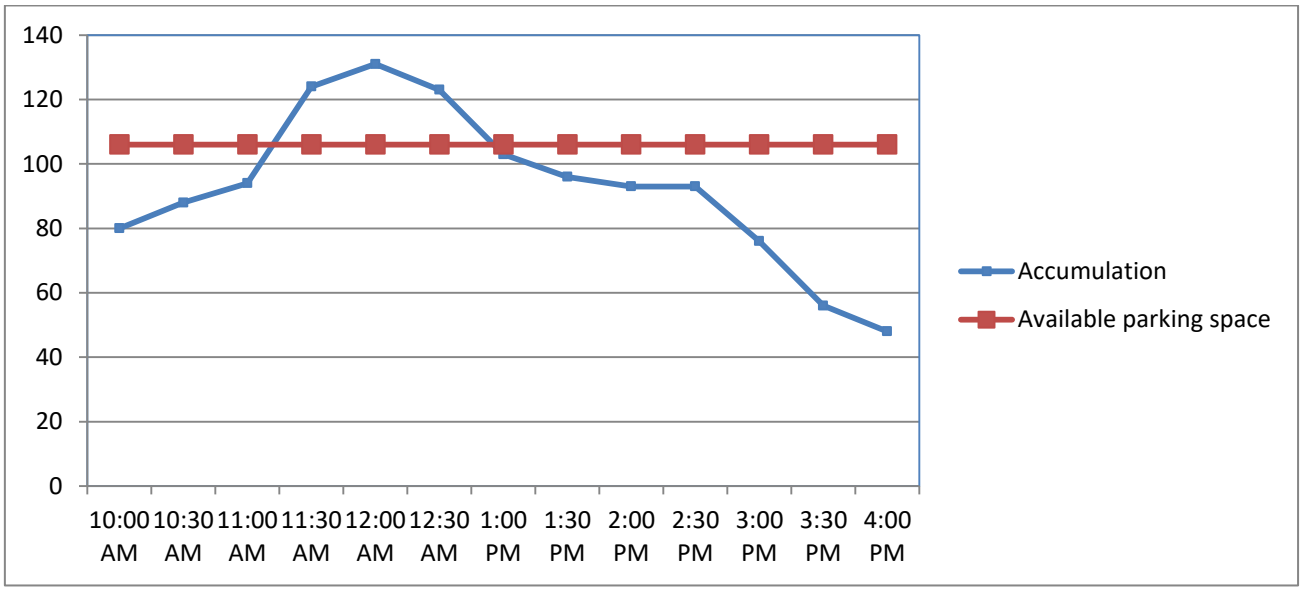
Parking occupancy survey results on the data collected **Friday** from 10:00 am to 4:00pm and parking accumulation curve in Friday is presented on table 4.5 and figure 4.5 respectively.

The below parking demand analysis and parking occupancy survey illustrates parking characteristics of the study area and detail parking characteristics of the studied street. The results shows after lifting of the morning parking restriction, parking demand is lower and it starts to rise as the time approaches to mid day and parking demand begin to decline once it reaches its peak demand level and becomes minimum after mid day peak hour parking demand towards afternoon peak hour parking restriction time. As the analysis is showing, at demand of parking is greater than that of the legally available parking space more at mid-day (11:30am to12:30pm) of the day as the morning and afternoon peak hour periods, parking is not allowed and are not included in this study. The above table and figure shows that there is double parking and illegal parking during mid- day peak hour as the demand of parking exceeds the number of available lanes.

Table 4.5.: Parking Occupancy Survey results Friday

Friday				
Data recording time	**Accumulation**	**Parking Occupancy Rate**	**Parking Load (30 minute duration)**	**Available Bays**
10:00 AM	80	75%	2400	106
10:30 AM	88	83%	2640	106
11:00 AM	94	89%	2820	106
11:30 AM	124	117%	3720	106
12:00 PM	131	124%	3930	106
12:30 PM	123	116%	3690	106
1:00 PM	103	97%	3090	106
1:30 PM	96	91%	2880	106
2:00 PM	93	88%	2790	106
2:30 PM	93	88%	2790	106
3:00 PM	76	72%	2280	106
3:30 PM	56	53%	1680	106
4:00 PM	48	45%	1440	106
Average Occupancy		**91%**		
Total Parking Load			**37,740.00**	
Parking Volume	**1258**			

Figure 4.5: Parking Accumulation curve on Friday



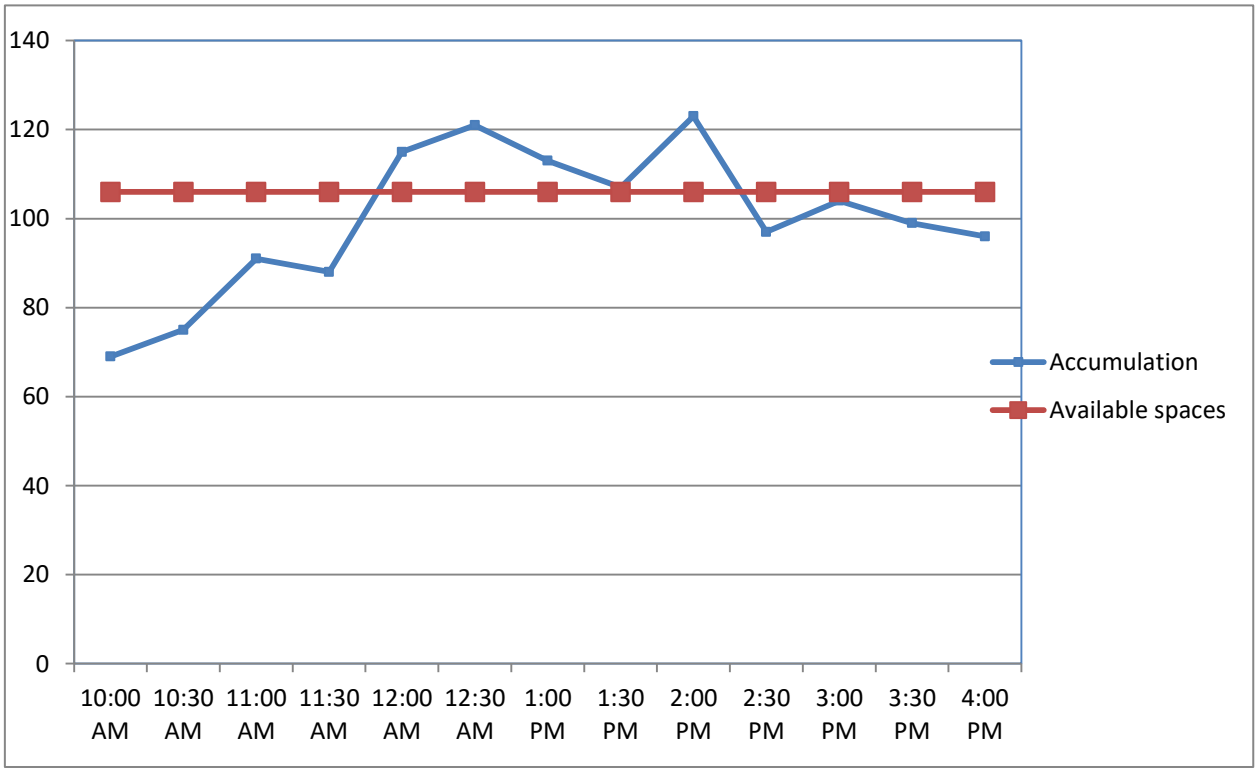
Parking occupancy survey results on the data collected **Saturday** from 10:00 am to 4:00pm and parking accumulation curve in Saturday is presented on table 4.6 and figure 4.6 respectively.

Table 4.6: Parking Occupancy Survey results Saturday

The below parking demand analysis and parking occupancy survey illustrates the parking characteristics of the road segments in the study region in detail. According to the findings, at mid-day (12:00am to 2:00pm) of the day demand of parking is greater than that of the capacity of parking space. as the morning and afternoon peak hour periods, parking is not allowed and are not included in this study.

Saturday				
Data recording time	Accumulation	Parking Occupancy Rate	Parking Load (30 MINUTE DURATION)	Available Bays
10:00 AM	69	65%	2070	106
10:30 AM	75	71%	2250	106
11:00 AM	91	86%	2730	106
11:30 AM	88	83%	2640	106
12:00 PM	115	108%	3450	106
12:30 PM	121	114%	3630	106
1:00 PM	113	107%	3390	106
1:30 PM	107	101%	3210	106
2:00 PM	123	116%	3690	106
2:30 PM	97	92%	2910	106
3:00 PM	104	98%	3120	106
3:30 PM	99	93%	2970	106
4:00 PM	96	91%	2880	106
Average Occupancy		94%		
Total Parking Load			38,940.00	
Parking Volume	1298			
Parking efficiency				

Figure 4.6: Parking Accumulation curve on Saturday

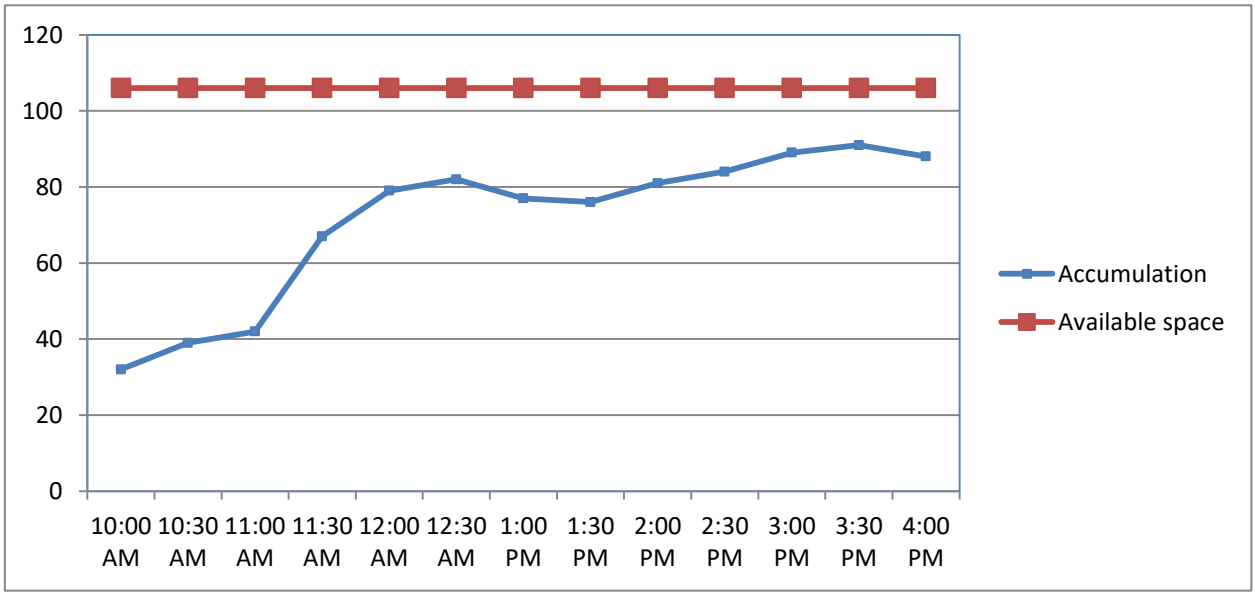


Parking occupancy survey results on the data collected **Sunday** from 10:00 am to 4:00pm and parking accumulation curve in Sunday is presented on table 4.5 and figure 4.5 respectively.

Table4.7: Parking Occupancy Survey results Sunday

Sunday				
Data recording time	Accumulation	Parking Occupancy Rate	Parking Load (30 Minute Duration)	Available Bays
10:00 AM	32	30.19%	960	106
10:30 AM	39	36.79%	1170	106
11:00 AM	42	39.62%	1260	106
11:30 AM	67	63.21%	2640	106
12:00 PM	79	74.53%	3450	106
12:30 PM	82	77.36%	3630	106
1:00 PM	77	72.64%	3390	106
1:30 PM	76	71.70%	3210	106
2:00 PM	81	76.42%	3690	106
2:30 PM	84	79.25%	2910	106
3:00 PM	89	83.96%	3120	106
3:30 PM	91	85.85%	2970	106
4:00 PM	88	83.02%	2880	106
Average Occupancy		67.27%		
Total Parking Load			27,810.00	
Parking Volume	927			

Figure 4.7: Parking Accumulation curve on Sunday



The above parking demand analysis and parking occupancy survey illustrates the parking characteristics of the road segments in the study region in detail. According to the findings, parking demand is lower than other weekdays and Saturday. It is also noted that Parking Accumulation is less than parking capacity or available space.

Parking Occupancy Rate on week days

The detailed parking characteristics of the road segments of the examined region are shown in the above parking demand analysis and parking occupancy survey. The research reveals that parking demand is considerable for the time period observed, and there are parking issues, particularly during mid-day (11:00am to 2:00pm) of the day as the morning and afternoon peak hour periods, parking is not allowed and are not included in this study.

Based on parking demand analysis the below presented figures and tables shows parking occupancy rates on weekdays based on field data. Figure 4.8 shows the percentage of occupancies of parking spaces during survey period. First, the study area's congestion rate was discovered to be relatively lower during the first hours of parking from restriction time is over (from 10:00a.m to 11:00am) with occupancy rate 66%-80%. then peak parking occupancy rate is recorded from 11:00am to 1:30Pm with occupancy rate of 109% to 120% . This is probably because parking restriction times are ended and business- purpose car users use the parking space during this time and both business- purpose and private purpose car users use this parking space during lunch time as many hotels and business areas are available during these periods. From 2:00 p. m- 4:00 p. m parking occupancy rate lowers to 63% to 71% as the parking restriction time is about to start and for other reasons. This implies vehicles are parked outside the marked box on-street areas whch may impact the traffic flow and traffic management activities.

Table 4.8.: Average Occupancy Rate on Weekdays

Time of Recording	Parking occupancy rate (percent)					Average Parking Occupancy Rate
	Monday	Tuesday	Wednesday	Thursday	Friday	
10:00 am	77%	68%	60%	51%	75%	66%
10:30 am	92%	81%	75%	69%	83%	80%
11:00 am	122%	92%	116%	126%	89%	109%
11:30 am	125%	99%	111%	122%	117%	115%
12:00 am	129%	118%	106%	124%	124%	120%
12:30 am	115%	111%	108%	128%	116%	116%
1:00 pm	97%	109%	97%	96%	97%	99%
1:30 pm	93%	109%	115%	93%	91%	100%
2:00 pm	99%	104%	73%	82%	88%	89%
2:30 pm	92%	81%	74%	76%	88%	82%
3:00 pm	80%	70%	61%	73%	72%	71%
3:30 pm	65%	73%	58%	70%	53%	64%
4:00 pm	67%	71%	57%	76%	45%	63%
				91.29%		

Figure 4.8: Parking occupancy rate on weekdays

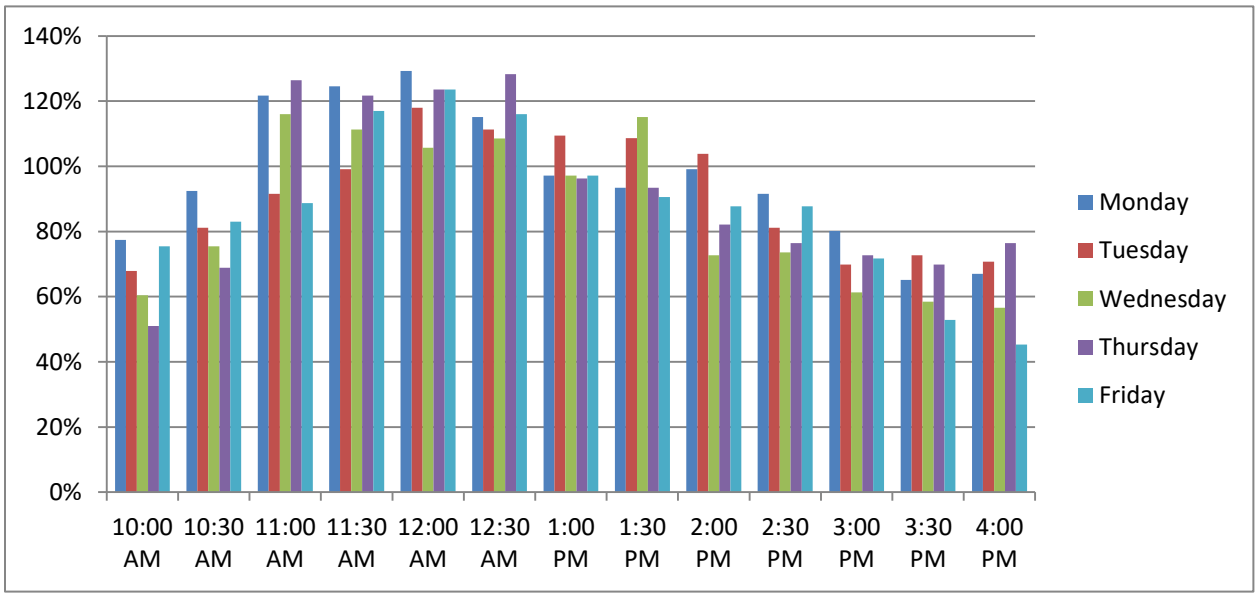
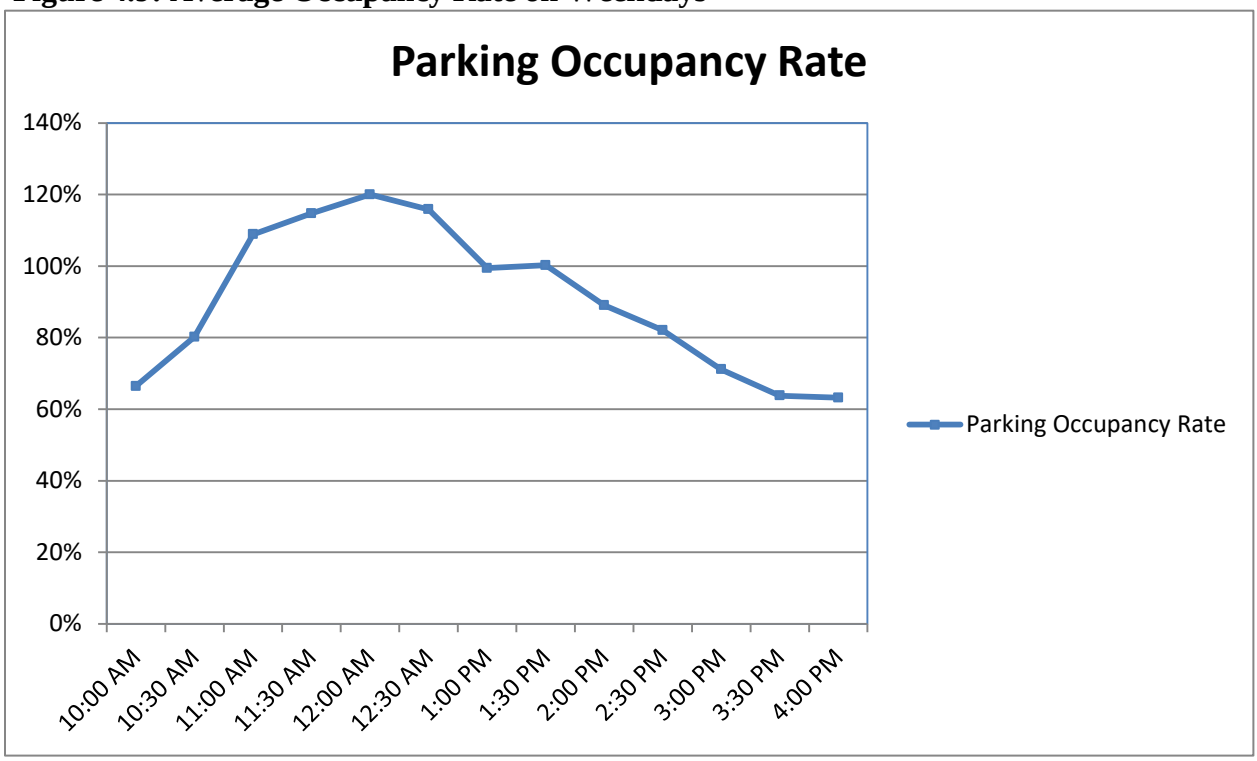
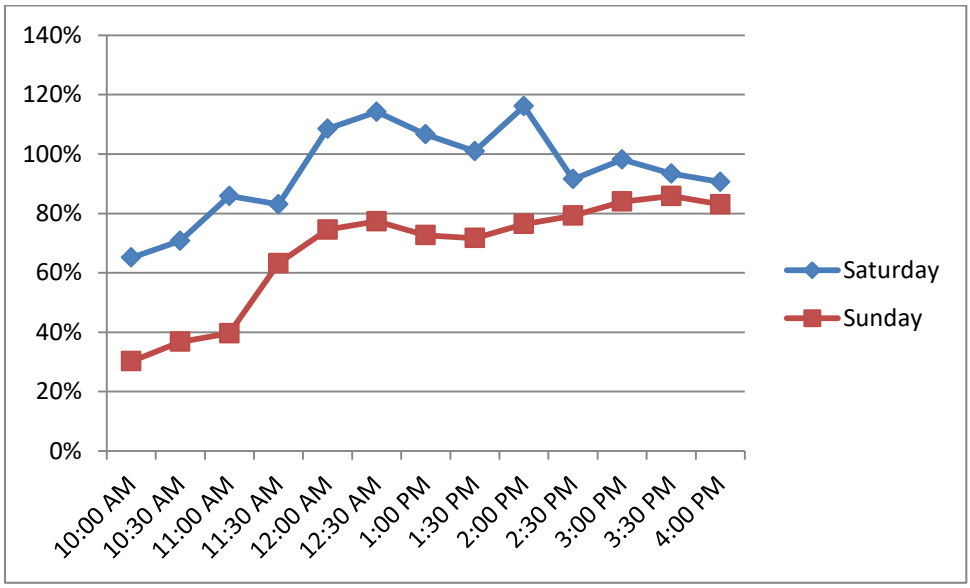


Figure 4.9: Average Occupancy Rate on Weekdays



Source-Field Survey, 2022 (January)

Figure 4.10: Parking Occupancy Rate on weekends



It was noted that during recording of parking demand data, there were many closed business centers as the season of data recording was on major feasting season of Ethiopian Orthodox Church and also it was noted that the data recorded is in the Summer Season of the year. Hence, Parking Occupancy Percentages and other Parking Demand Characteristics May Vary Seasonally. And the parking Occupancy and Parking Accumulation will increase on Other Seasons of the year.

4.2. Impact Analysis of On-Street Parking

4.2.1. Determination of Adjustment factor for on-street parking on adjacent lane

The main impact of on-street parking on through traffic flow on the adjacent lane is the result of automobiles moving into and out of on-street parking spots. Field survey was done for one hour in order to collect enough data to create a statistical model to determine the link between on-street parking and road capacity. During each parking maneuver, the start and end timings of traffic flow disturbance (time) were recorded. Disruption to traffic flow (time taken) during each parking maneuver was recorded using a video camera and then digital watch was used to acquire the data through video play back. The influence of parking maneuvers on traffic flow is also noted. The complete parking maneuvers entering and leaving maneuvers were measured. Parking maneuver times are the length of time required by vehicles to enter or leave the parking stalls.

Vehicles maneuvering data obtained from field survey is analyzed by the formula provided in Highway Capacity Manual.

Highway Capacity Manual (HCM) provides the following formula for Finding an adjustment factor for adjacent lane road capacity.

$$Fp = (N-0.1-18* Nm/3600)/N)$$

where,

fp = adjustment factor for vehicle maneuvering

N= number of lanes in lane group

Nm= number of parking maneuvers/h

18=assumed average time taken for parking maneuvers

Table 4.9 –Results of the Vehicle Maneuvering data

Maximum Value	14.01
Minimum Value	9.08
Sample mean	11.4622
Standard deviation	1.1871

Hence, taking in to consideration of the above findings the sample mean of 11.46 seconds is used as Parking maneuver times which is the length of time required by vehicles to enter or leave the parking stalls.

Table 4.10. – Average turnover of parking spaces at survey site

Total Number of vehicles parked during one (1) hour survey	number of available parking spaces surveyed for determination of maneuver	Nm (number of parking maneuvers)
60	16	3.75

Accordingly, N_m The average turnover of cars per parking spot per hour was selected as the value for the expression generated for road capacity adjustment factor, fp for on-street parking, which is 3.75.

In this study, we have a Sample mean of 11.46sec which is obtained in the above section is used instead of assumed average time for parking maneuvers i.e., 18 sec.

The parking adjustment factor, fp, accounts for the frictional effect of a parking lane on flow in an adjacent lane group as well as for the occasional blocking of an adjacent lane by vehicles moving into and out of parking spaces.

Fp = (N-0.1-11.46*Nm/3600)/N

Fp = (1-0.1-11.46* 3.75/3600)/1

Fp = 0.888……. Adjustment factor for on-street parking on adjacent lane

Therefore, providing on-street parking on the curb side of the road may result a reduction on a capacity of an adjacent lane by 22.2 percent and a reduction of two lane capacity by allocating the parking lanes for parking.

4.2.2. Traffic Flow

On-street parking reduces parking capacity and can impact the traffic flow due to using of the traffic lane for parking purpose and by creating stop start traffic flow for the adjacent lane caused by on-street parking maneuvers. Hence, in order to analyze the effects of on-street parking on traffic flow detailed traffic flow analysis was done on the studied street.

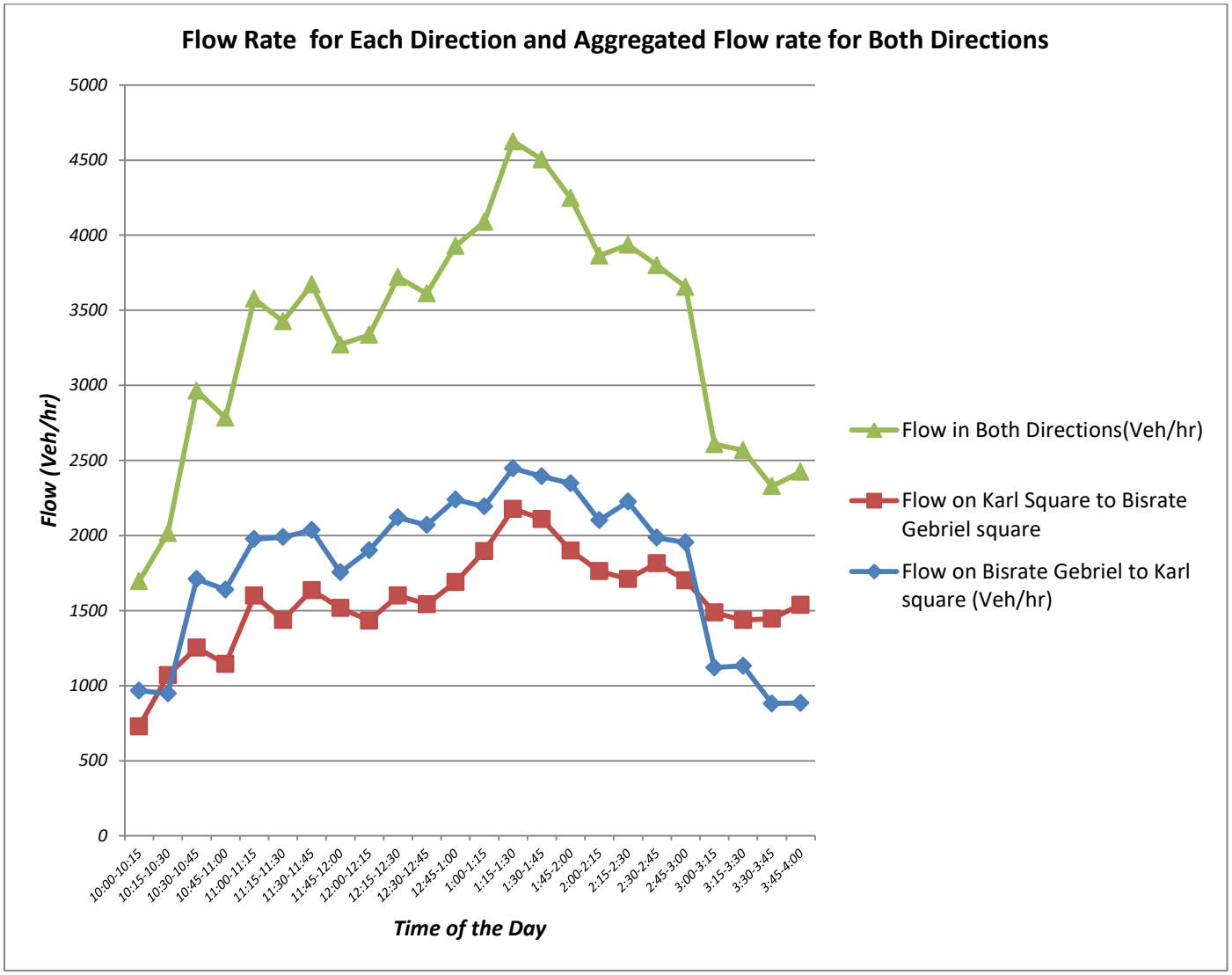
As the studied street is two directional and traffic volume count and traffic flow analysis was done on both directions i.e, the one which goes from bisrate gebriel to karl round about and the other which goes from karl round about to bisrate gebriel. This was counted for one week day at 15 minutes interval staring from 10:00 am to 4:00 pm.

While Conducting traffic different types of Vehicles were observed using the studied road, Car (Automobile cars) is the dominant vehicle types in the studied street. Other types of Vehicles that has been seen on the studied street are Bus and Heavy Vehicles. All vehicle types were converted to Passenger Car Equivalent to determine the total peak hour flow in a unit of vehicle

per hour. From the field volume count, directional traffic flow was determined for each fifteen minute count and it was changed to hourly flow that is pointed out using the unit of (veh/hr).

On the studied street, It is Observed that the traffic flow is lower at the start of the morning traffic count which is the time when parking restriction is lifted then the traffic flow starts to raise to peak hour volume of 1987 Veh/hr on a direction of Karl Square to Bisrate Gebriel Square (from 1:15pm to 2:15pm) and 2380 veh/hr peak hour volume on a direction of Bisrate Gebriel to karl square both at mid-day (from 1:00pm to 2:00pm) with a total of 4624 vehicles/hour on both directions (from 12:30pm to1:00pm) then it starts to decline after mid-day to the afternoon peak hour on both directions but on karl square to Bisrate gebriel direction, the traffic flow starts to raise as it approaches to the afternoon peak hour. The hourly traffic flow distribution for the studied site is summarized in the graph below:

Figure 4.11: Traffic Flow Rate During Times of the Day



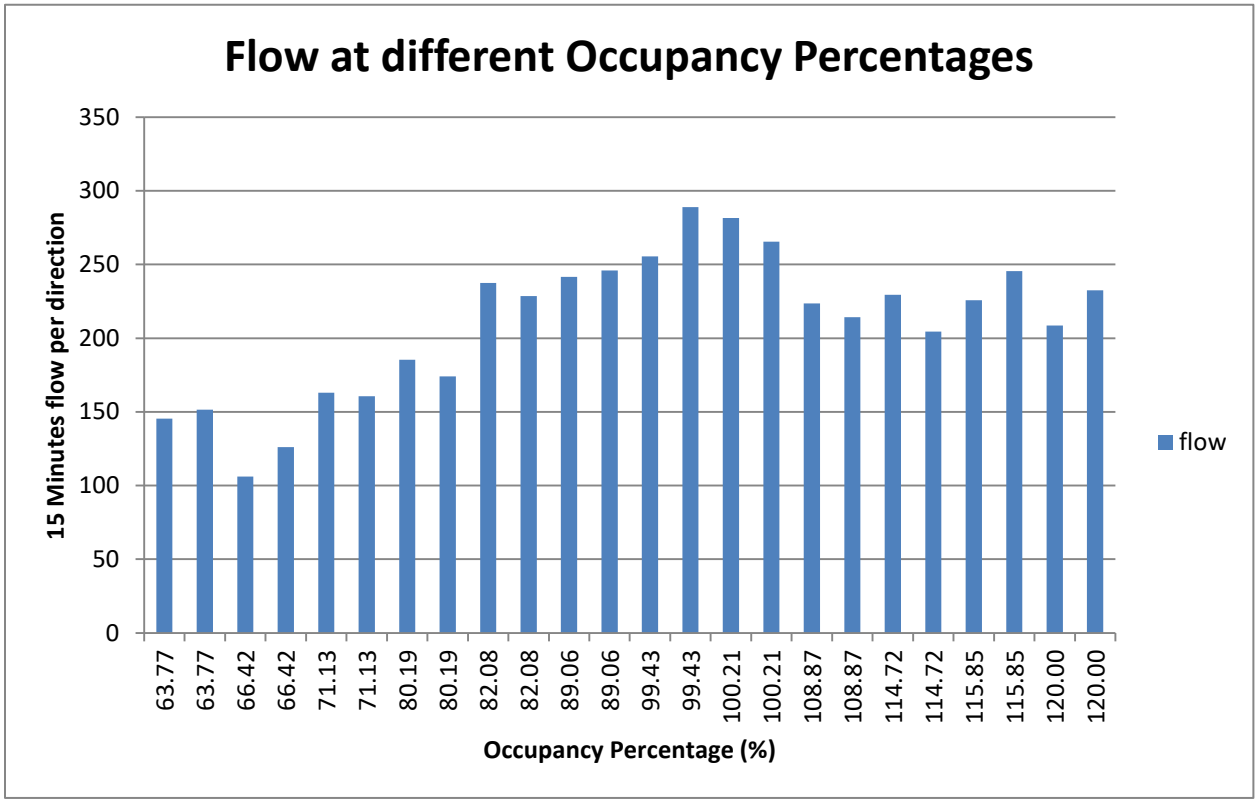
It was observed that Traffic Composition was Traffic flow is interrupted by various factors including existence of on street parking, Pedestrian Crossing, Turning and entering and leaving of vehicles.

On-Street parking has a high impact on traffic congestion. An effect of on-street parking on a traffic flow is lower when the level of traffic flow is lower and it becomes moderate to high as

the traffic flow increases. When proportion of parking maneuvers increases or when parking occupancy increases, the more traffic volume and traffic flow is influenced.

Traffic flow data was arranged Based on different Parking Occupancy Percentage/Levels and as shown on the graph below it is indicated that traffic flow was lower at lower parking Occupancy hours at the time of 10:00 am to 10:30 am and from 3:00pm to 4:00 pm and the traffic flow was Maximum at Medium Parking Occupancy hours at the time of 10:30am to 11:30am and 1:00pm to 3:00 pm and at Higher Parking Occupancy Hours Medium traffic flow was recorded, the traffic flow was reduced to some extent from Medium Parking Occupancy Hours and higher than lower parking occupancy Hours.

Figure 4.12: Traffic Flow Rate at Different Occupancy Percentages



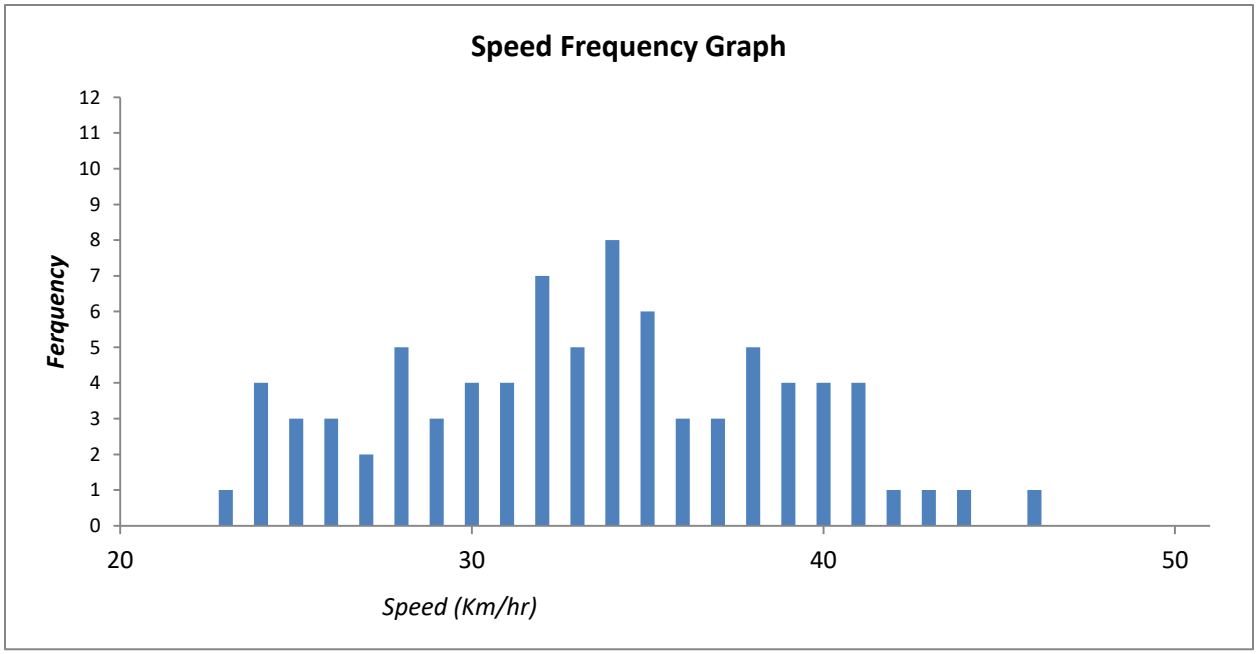
This was very helpful to capture the effect of the on-street parking on the performance of the road like average speed and travel time. The peak 15 minutes traffic on the site is shown above.

4.2.3. Average Speed

As running speeds are useful to assess the traffic capacity of highways, Speed is a function of several factors such as the geometric design features, traffic conditions like the presence of other vehicles, time and place, the environment, and the driver, and the traffic system in general. When on street parking exists or is permitted on a road segment, Speed of a through Vehicle is also influenced by the existence of on street parking on adjacent lane.

Running speed of the study area is determined by dividing the length of the stretch by the time for which the vehicle is in motion. It is determined from video playback as the length of the section in the video recording is measured at the site and the vehicle speed is determined by dividing the length of the road segment by time a vehicle travels the segment of the road which is obtained from a video play back. The speed variation and distribution on the study segment is shown on the following graph

Figure 4.13: Speed Frequency Graph



As indicated on the above graph, on the data of running speed recorded on the time of the day when on street parking is permitted. The average speed of vehicles using the road segment is found to be mainly from 25 km/hr to 40 km/hr.

As speed is one of the parameters which determines the capacity and Level of Service of a road, Average speed of vehicles at different occupancy levels and at different flow rates are analyzed in order to capture the effect of on-street parking on road capacity.

The impact of on-street parking on Speed was assessed by Conducting Sensitivity/What if Analysis and developing a regression model.

4.2.4. Sensitivity/What-If Analysis

In order to determine the significance of the effect of traffic flow and parking occupancy on the average speed, sensitivity analysis was carried out. Two of the factors which influenced moving traffic speed and overall road capacity and level of service are traffic flow and parking occupancy. Hence, traffic flow and Parking Occupancy were considered as explanatory Variables and speed was considered as dependent variable.

The impact of on-street parking and flow on speed is performed for an aggregated data of both directions and using the average parking occupancy rate of week days. The average speed used which was recorded at the same time simultaneously of recording on-Street data and traffic flow was used in order to analyze the Effects of On-street parking on Speed on different Traffic flow conditions.

Multiple Linear Regressions

The impact of on-street parking on speed was assessed by developing a regression model when on-street parking is allowed on the road. To model the relationship between the Explanatory Variables i.e, traffic flow and on-street parking occupancy percentage with speed of vehicles, Multiple Linear regression model which include flow and on-street parking as explanatory variables to describe the variation of the dependent variable speed of vehicles is used.

R^2 - value of 0.730 was obtained by considering flow and on-street parking as explanatory variables and speed (v) as dependent variable. If all possible explanatory variables are included, the coefficient of determination (R-Squared value) approaches 1. This Implies that there are other predictors which may influence speed there are several factors in the traffic environment, which cannot all possibly be studied together and not included in this study. In this study thus, flow and on-street parking were studied. The output from a multiple regression is displayed horizontally in the following equation. Results of Regression model using flow and on-street parking as an explanatory variable gives the following equation/model:

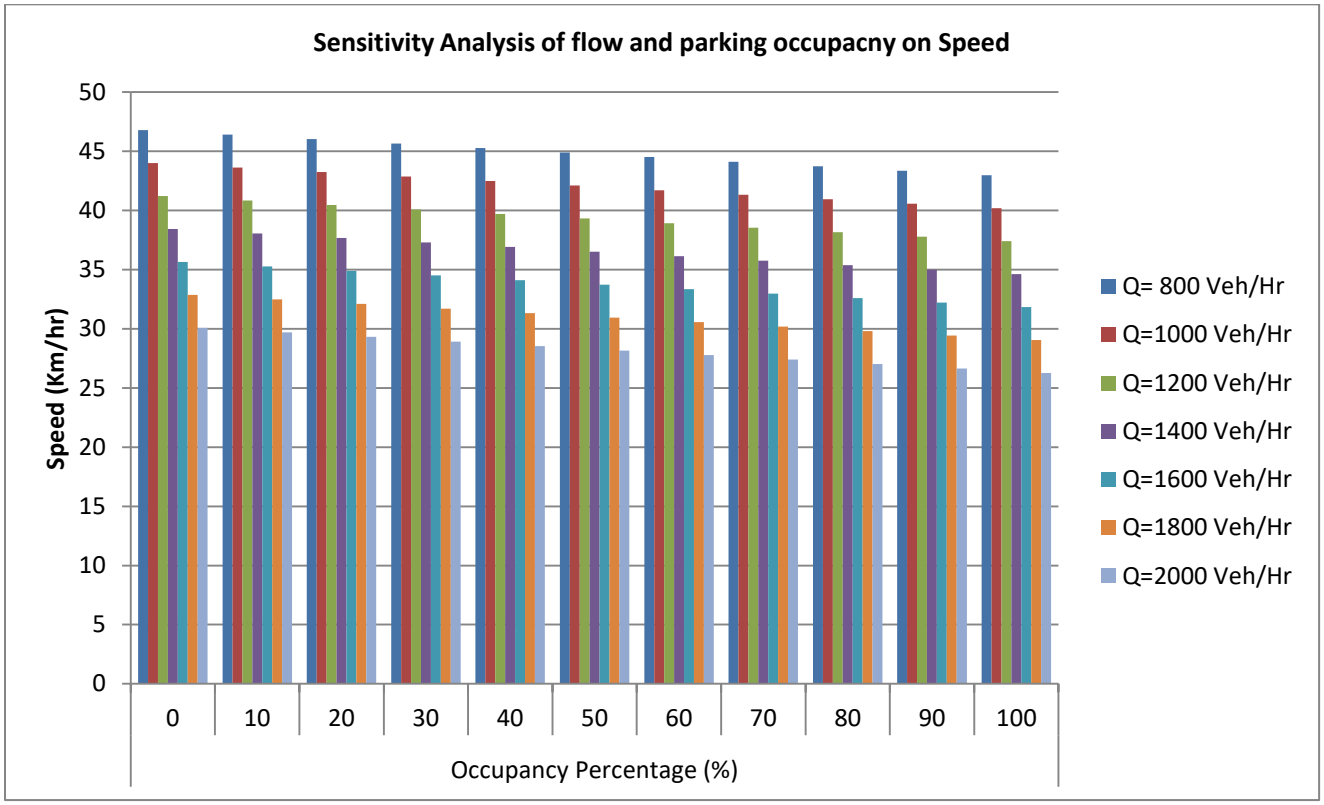
*V= 57.95035-0.106*Flow -0.0382*Parking Occupancy, with value of* R^2 *= 0.73022*

As it is shown on the above Equation, the Coefficient value for Flow is - 0.1069 which indicated speed of a vehicle is mainly influenced by traffic flow level of the road and also it is shown that speed of a through vehicle is also influenced by Parking Occupancy percentage on the sides of the street having Coefficient of - 0.0382.

Both signs Coefficients of Explanatory variables are negatives; It Implies that an increase in traffic flow and parking occupancy percentage on existence of on-street parking decreases the speed of a through vehicle.

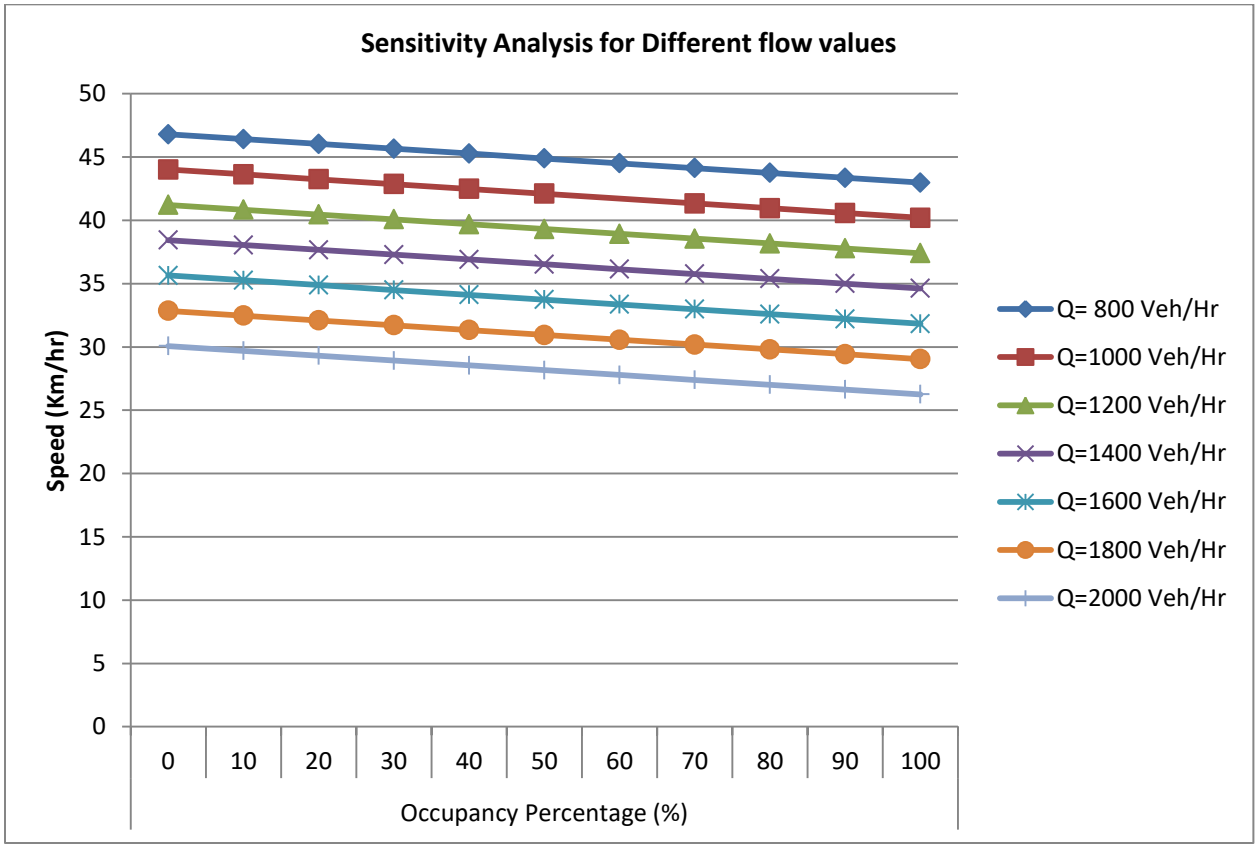
To analyze how different values of traffic flow and parking occupancy levels affect speed of vehicles, What If Analysis or Sensitivity Analysis is used. The value of the flow and parking occupancy was changed at constant rate. The level selected for each parameter was based on the range of possible outcomes for the variable. The flow was changed at 200 veh/hr rate with a minimum value of 800 Veh/hr and a maximum value of 2,000veh/hr. the parking occupancy was changed at 10% rate with a minimum value of 0% and a maximum value of 100% for legal parking. The result of the sensitivity analysis is shown in the graph below:

Figure 4.14: Sensitivity Analysis of Flow and Parking Occupancy



The result of Sensitivity of Speed on parking occupancy rate and traffic flow is shown above. It is indicated that, average speed of vehicles decreases as the traffic flow and parking occupancy increases. Maximum speed was obtained when Occupancy percentage is zero or if the parking occupancy percentage is absent the average Speeds becomes maximum. Average speed ranging from 46.798 Km/hr for the lower traffic volume of 800 Veh/hr to 30.072 Km/hr for 2000Veh/hr. average speed was decreased by 3.818 Km/hr from the situation where occupancy percentage is non- Existence to the case where the sides of the street is fully occupied by on-street parking. As the result of the analysis, Both Traffic Flow or traffic volume were found to be significant factors for reduction of speed. Traffic volume was found to be very significant factor for reduction of speed. However, the parking occupancy was also slowing down 0.3812 Km/hr reduction of speed for each increment of parking occupancy by 10%.

Figure 4.15: Sensitivity Analysis for Different flow Values



The results provide two of the determinants of the distribution of average speed of the running vehicle under the influence of on-street parking. The results indicate that the influence of on-street parking results from various related factors. Such influence can be reflected by the distribution of average speed of the running vehicle. Change of levels of parking occupancy and traffic flow could change the average speed of running vehicle. The levels of Parking Occupancy and number of parking maneuvers are considered as the most significant influencing factors of on-street parking on road capacity and speed of vehicles. The presence of an on-street parking along a street as well as the maneuvering of a vehicle both in and out of the parking stall really does hinder the flow of traffic and reduces the average speed of a moving vehicle.

4.2.5. Comparison of Average Speeds on Different Parking Classes

In this approach, the average speed was compared during different intensities of parking occupancies. The parking occupancy was categorized into three classes as low, medium and high parking level.

The observed parking occupancy data along with their corresponding speed and flow data were rearranged in ascending order and divided into three equal percentiles to represent the low, medium and high parking occupancy level.

Table.4.18 Comparison of Average Speeds on Different Parking Classes

speed (km/hr)	15 minutes flow/direction/lane	Parking Occupancy (%)	Occupancy Level
40.47	146	63.77	Lower
40.05	152	63.77	
42.00	106	66.42	
41.00	126	66.42	
40.24	163	71.13	
40.27	161	71.13	
32.92	185	80.19	Medium
32.99	174	80.19	
32.89	238	82.08	
32.93	229	82.08	
32.27	242	89.06	
32.27	246	89.06	
22.63	256	99.43	
22.38	289	99.43	
22.48	282	100.21	
22.51	266	100.21	
33.08	224	108.87	

23.42	214	108.87	
32.96	230	114.72	Higher
32.99	205	114.72	
32.44	226	115.85	
22.64	246	115.85	
32.96	209	120.00	
32.45	233	120.00	

In addition to parking occupancy, the reduction in speed was occurred due to other factors like traffic flow increase, a higher level of pedestrian activities and others. Moreover, the comparison of average speeds on different parking classes was performed. The 40.47 km/hr speed when parking was lower was found to be significantly different from 27.64 km/hr of average speed when the parking occupancy was higher.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

Addis Ababa city traffic management agency has been implementing different types of parking facilities one of which is marking of Box on Street parking areas on the outer lane of the existing roads. However; the effects of these areas on existing traffic and its road environment and efficiencies of these parking facilities on service condition are not assessed adequately.

This study has focused on assessing the efficiencies of on-street parking facilities and investigating and quantifying the impacts of on-street parking both on direct impacts on road capacity of on-street parking by reduction of traffic lane width due to allocation of such spaces for parking and on indirect impacts of on-street parking on road performance and capacity by outcome of entering and leaving of vehicles on adjacent lane caused by parking is allowed on the adjacent lane. To collect useful data Field survey and review of literatures were used. Parking occupancy survey and development of mathematical models was used to access the collected data.

Based on parking demand analysis the below presented figures and tables shows parking occupancy rates on weekdays based on field data. The study shows the percentage of occupancies of parking spaces during survey period. Percentage of occupancies indicates the congestion rate of the parking spaces at a specific time in a studied road. During the first hours of the study, the congestion rate of parking spaces at studied road was recorded to be relatively lower during the first hours of parking from restriction time is over (from 10:00a.m to 11:00am) with occupancy rate 66%-80%. then peak parking occupancy rate is recorded from 11:00am to 1:30Pm with occupancy rate of 109% to 120% . This is probably because

Parking restriction times are ended and business- purpose car users use the parking space during this time and both business- purpose and private purpose car users use this parking space during lunch time as many hotels and business areas are available during these periods. From 2:00 p. m- 4:00 p. m parking occupancy rate lowers to 63% to 71% as the parking restriction time is about to start and for other reasons. This implies vehicles are parked outside the marked box on-street areas which may impact the traffic flow and traffic management activities.

The reductions of total lane width because using of two lanes each 3.5 and a total of 7m for parking. The parking occupancy was also found to reduce the average speed of vehicles by 6.25 %.Which was found to reduce a speed of 0.0382 km/hr. for each percentage increment of parking occupancy. Additionally, the result indicates on-street parking markedly impact the capacity of roads, o.88 adjustment factor was considered for reduction on Adjacent lane due to vehicle maneuvering Effects as compared to through lane and from Comparison of road capacity with and with-out on-street parking.

5.2 Recommendation

Based on the analysis made on efficiency and effects of on street parking the following solution are proposed to maximize the efficiency and for minimizing effects of these on street parking facilities.

- On-street parking should be considered at early stages of designing of roads and shall be incorporated on the design and construction of roads. This may reduce the impacts of these on-street parking facilities on the existing traffic.
- Parking demand shall be studied before applying marked box on-street facilities.
- Other parking facilities shall support on-street parking facilities in order to accommodate the parking demand over the capacity of these parking facilities.
- Increasing the number of sites which have on-street parking and choosing sites that have a greater number of different parking demand levels would be helpful in obtaining more accurate and/or more conclusive results.

REFERENCE

AACRA, Addis Ababa City Road Authority Manual, Section 19, Addis Ababa,2003

Alisar Aoun. Et.al. (2013), "Reducing parking demand and traffic congestion at the American University of Beirut", USA

Abas Bedru (2019), "Modeling the Ipact of On-Street Parking on Traffic Flow Characteristics In Major Roads of Bahirdar City, Ethiopia."

American Association of State Highway and Transportation Officials (AASHTO) (2011) A Policy on Geometric Design of Highways and Streets, 6th ed., AASHTO, Washington DC.

Gila Alberta, David Mahalel (2006), "Congestion tolls and parking fees: A comparison of the potential effect on travel behavior", Israel

Hai Yang, Wei Liu.et.al. (2013), "On the morning commute problem with bottleneck congestion and parking space constraints", China

Jin Cao and Monica Menendez (2015), "Generalized Effects of On-Street Parking Maneuvers on the Performance of Nearby Signalized Intersections", Transportation Research Record: Journal of the Transportation Research Board, No. 2483, Transportation Research Board, Washington, D.C.

Jessica Edquist. et.al. (2012), "The effects of on-street parking and road environment visual complexity on travel speed and reaction time", Human Factors group, Monash University Accident Research Centre, Australia

Mathew,T. and Kirshanna, K., 2006. Introduction to transport engineering . Chapter 38, Parking.

Natinal Research Council, Highway Capacity Manual (2000)

Mayank A. Gaodi, Prathmesh Thakre. et.al. (2018), "a Review on: Effects of on street parking on different factors", Maharashtra, India

O'Flaherty, C A (1986) Highways: Traffic Planning and Engineering, 3rd edition, Edward

Arnold Publishers, London.

Portilla, A I, Orena, B A, Berodia, J L M and Diaz, F J R (2009) 'Using M/M/infinite queuing model in on-street parking manoeuvres', Journal of Transportation Engineering, vol. 135, no. 8, p.p. 527-535.

Richard Arnott, Eren Inci (2006), "An integrated model of downtown parking and traffic congestion", Boston College, Department of Economics, Chestnut Hill, MA 02467-3806, USA

Sahan Wijayaratna (2015), "Impacts of On-street Parking on Road Capacity", Sydney, Australia

Samaher Yousif & Purnawan (1999), "On-street parking: Effects on traffic congestion", University of Sharjah and Universitas Andalas

Sonya Sulistyono, Harnen Sulistio, et.al. (2017), "On street parking and its impact on road performance", Jember, East Java, Indonesia

Subhadip Biswas, (2017), "Effects of On-Street Parking in Urban Context: A Critical Review", Uttarakhand, India

Tom V. Mathew and K V Krishna Rao (2007), "Introduction to Transportation Engineering"

Wesely E.et.al. (2008), "Reassessing On-Street Parking" Transportation Research Board of the National Acadamies, Washington, D.C.

APPENDIX

APPENDIX (1)

Parking Occupancy Survey (POSs)

Parking Occupancy Survey (POS_s)

Study Date
Street : Bisrate-Gebriel Square to karl square
Direction of parking Both Directions
Direction of Travel: Both Directions

Date: Monday	
dutation	Number of vehicles parked
10:00am	82
10:30am	98
11:00am	147
11:30am	113
12:00am	108
12:30am	119
1:00 pm	103
1:30 pm	99
2:00 pm	105
2:30 pm	113
3:00 pm	85
3:30pm	69
4:00pm	85

Parking Occupancy Survey (POS_s)

Study Date
Street : Bisrate-Gebriel Square to karl square
Direction of parking Both Directions
Direction of Travel: Both Directions

Date: Tuesday	
dutation	Number of vehicles parked
10:00am	**64**
10:30am	**86**
11:00am	**97**
11:30am	**105**
12:00am	**118**
12:30am	**140**
1:00 pm	**125**
1:30 pm	**115**
2:00 pm	**148**
2:30 pm	**69**
3:00 pm	**56**
3:30pm	**68**
4:00pm	**55**

Parking Occupancy Survey (POS_s)

Study Date
Street : Bisrate-Gebriel Square to karl square
Direction of parking Both Directions
Direction of Travel: Both Directions

Date: Wednesday	
dutation	Number of vehicles parked
10:00am	**64**
10:30am	**80**
11:00am	**136**
11:30am	**128**
12:00pm	**112**
12:30am	**117**
1:00 pm	**101**
1:30 pm	**133**
2:00 pm	**77**
2:30 pm	**48**
3:00 pm	**86**
3:30pm	**91**
4:00pm	**94**

Parking Occupancy Survey (POS_s)

Study Date
Street : Bisrate-Gebriel Square to karl square
Direction of parking Both Directions
Direction of Travel: Both Directions

Date: Thursday	
dutation	Number of vehicles parked
10:00am	**54**
10:30am	**73**
11:00am	**184**
11:30am	**165**
12:00pm	**156**
12:30am	**141**
1:00 pm	**99**
1:30 pm	**102**
2:00 pm	**69**
2:30 pm	**61**
3:00 pm	**72**
3:30pm	**67**
4:00pm	**81**

Parking Occupancy Survey (POS_s)

Study Date
Street : Bisrate-Gebriel Square to karl square
Direction of parking Both Directions
Direction of Travel: Both Directions

Date: Friday	
dutation	Number of vehicles parked
10:00am	**80**
10:30am	**88**
11:00am	**94**
11:30am	**132**
12:00pm	**152**
12:30am	**127**
1:00 pm	**103**
1:30 pm	**123**
2:00 pm	**93**
2:30 pm	**93**
3:00 pm	**76**
3:30pm	**56**
4:00pm	**48**

Parking Occupancy Survey (POS_s)

Study Date
Street : Bisrate-Gebriel Square to karl square
Direction of parking Both Directions
Direction of Travel: Both Directions

Date: Saturday	
dutation	Number of vehicles parked
10:00am	79
10:30am	85
11:00am	101
11:30am	98
12:00pm	125
12:30am	131
1:00 pm	117
1:30 pm	112
2:00 pm	96
2:30 pm	107
3:00 pm	78
3:30pm	86
4:00pm	82

Parking Occupancy Survey (POS_s)

Study Date
Street : Bisrate-Gebriel Square to karl square
Direction of parking Both Directions
Direction of Travel: Both Directions

Date: Sunday	
dutation	Number of vehicles parked
10:00am	32
10:30am	39
11:00am	42
11:30am	67
12:00pm	79
12:30am	82
1:00 pm	77
1:30 pm	76
2:00 pm	81
2:30 pm	84
3:00 pm	89
3:30pm	91
4:00pm	97

APPENDIX- 2

VEHICLE MANUEVERING SURVEY DATA

Data on Vehicle Maneuvering Time

It.NO	Recorded Maneuvering Time	It.NO	Recorded Maneuvering Time	It.NO	Recorded Maneuvering Time	
	13.72	21	13.48	41	10.49	
2	11.59	22	10.52	42	11.44	
3	11.71	23	11.78	43	10.34	Maximum
4	11.18	24	9.34	44	9.29	14.01
5	12.17	25	13.71	45	10.43	Minimum
6	10.57	26	11.48	46	9.85	9.08
7	11.16	27	10.76	47	12.87	Standard Deviation
8	11.8	28	11.99	48	11.21	1.1871
9	10.4	29	11.17	49	11.35	Average (mean)
10	12.45	30	9.66	50	10.24	**11.46**
11	11.52	31	11.94	51	12.77	
12	12.38	32	13.47	52	12.64	
13	11.11	33	9.08	53	11.56	
14	9.98	34	9.45	54	11.9	
15	9.68	35	9.85	55	12.3	
16	11.85	36	10.83	56	11.44	
17	14.01	37	11.59	57	12.81	
18	12.22	38	11.11	58	12.99	
19	11.53	39	11.97	59	12.11	
20	10.59	40	13	60	11.9	

Appendix III

Photographs of the Area


TOYOTA


ከጠዋ-ት
12:00-4:00


ናርዲ ሚኒ ማርኬት