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Evaluation of Parking Problems for Transportation System in Addis Ababa-A Case Study

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Abstract: ***Parking is the act of stopping and disengaging a vehicle and leaving it unoccupied. These days, parking is a major challenge in different sub cities of Addis Ababa. Among Addis Ababa sub-cities, Addis ketema sub-city where, public circulation is one of the most obvious problems, and parking seems to be an overlooked element of transportation development. Sites of activities such as market centers, shops, churches, mosques, offices, schools, and similar places often generate huge parking demands, and increase the parking problems in the sub-city.***

The study used the License plate method of parking survey for both on street and off-street parking surveys. These have been done for two days, one from the weekday Friday and one from the weekend Saturday from 9:00AM-5:00PM. The existing parking conditions were analyzed using Ms-excel. The relationships of utilized parking spaces to the available parking capacity were developed by SPSS software. The effects of on-street parking on travel time have been also analyzed using vissim simulation modeling software in two different situations one by considering roadside parking and the other by removing roadside parking. Based on the findings the average parking occupancy of off-street and on-street parking was 90% and 80% respectively. However, off-street parking turnover is lower than on-street parking. This means the average parking duration of off-street parking were about 4hr per vehicle while the average parking duration of on-street parking were 2hr per vehicle. Using linear regression analysis, the relationship developed between utilized parking spaces and the available parking capacity of off-street and on-street parking show that parking spaces have been nearly full utilization of available capacity. The total average segment delay of total duration along the road segment due to roadside parking P4, P5 and P6 were 7.29, 12.01 and 25.95 seconds per vehicle respectively.

Keywords: Off-street parking, on-street parking, parking efficiency, parking utilization, travel time

I. INTRODUCTION

A. Background

Globally, the rate of urbanization is increasing at an alarming rate with 50% of the world population expected to live in urban areas by 2025 and more transformation are expected in developing countries (World Bank, 2003). Despite some economic benefits, the rapid urban growth in these developing countries is outstripping the capacity of most cities to provide adequate services for their citizens (Cohen, B 2004). A high urbanization rate in combination with the intensity of desire for car ownership in developing countries causes a rapid growth of motorization (Gakenheimer, R 199).

The urban transport problems today manifest in the form of poorly maintained urban road network and road complementary facilities; inefficient public transport system and poor land-use-transport planning (Aderamo et al., 2013). But, cities and their transport systems are fully complementary. Cities are locations with a high level of accumulation and concentration of economic activities, which form complex spatial structures that are supported by transport systems (Rodrigue et al., 2006). The transportation systems according to Berry and Horton (1970) are the veins and arteries of urban areas linking together social and functional zones. Urban productivity is highly dependent on the efficiency of its transport systems to move people and goods between multiple origins and destinations. Thus, the most important transport problems are often related to urban areas when transport systems, for a variety of reasons cannot satisfy the requirements of urban mobility (Rodrigue et al., 2006).

Addis Ababa, capital of Ethiopia, is commercial and political center and exemplary of the rapid urban growth of Ethiopia. According to Central Statistical Agency, Ethiopia (2007) the population of Addis Ababa has nearly doubled every decade since the 1980s. The 2013 population size of the city is estimated at 3.1 million and is estimated to reach 12 million in 2024. It is also home to two continentally important institutions: the AU Commission and UN Economic Commission for Africa. It also accommodates many international Aid and Development organization and more than 100 embassies. Addis Ababa plays a critical role in sustaining the country's double-digit economic growth and delivering the potential benefits of urbanization.

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According to Federal Road Transport Authority report,2011 in Addis Ababa, as elsewhere, where cars are one of the dominant modes of transportation, public circulation is one of the most obvious problems, and parking seems to be an overlooked element of transportation development. Parking is defined as Wikipedia definition; it is the act of stopping and disengaging a vehicle and leaving it unoccupied. Parking on one or both sides of a road is often permitted, though sometimes with restrictions. Some buildings have parking facilities for the use of the buildings' users. Countries and local governments have rules for design and use of parking spaces. Now, this research paper specifically evaluates the effect of parking efficiency and parking problems on transportation system in Addis Ababa, specifically in Addis ketema sub-city. The existing parking service is inadequate and suffers from operational problems, mainly street parking. Consequently, it has contributed to inefficient utilization of the road network, safety and congestion problems. Thus, parking remains one of the critical issues that need to be addressed through the transport planning of the city. This document is a template. For questions on paper guidelines, please contact us via e-mail.

B. Statement of the Problem

People in business and customers regard on-street parking as an essential service because on-street parking occupies less land per space than off-street parking and provides convenient access to destinations. But, according to (Hongwei Guo et.al. 2012), on-street parking should be prohibited. Their reasons are that on-street parking occupies the resources of roadways; including car lanes, bike lanes, and sidewalks and that the parking maneuver (entering parking stalls) and un parking maneuver (departing from parking stalls) increase the delay of through traffic and reduce the capacity of the adjacent travel lane. Also, on-street parking has been found to increase traffic accidents. Transport Policy of Addis Ababa; August, 2011, report identified parking as one of the key "infrastructural" challenges in Addis Ababa sub- city. Illegal parking is a major problem in different location of the city. Roadside parking is a common phenomenon, which reduces the traffic corridors meant for the efficient movement of automobiles and taxies. The resultant effect of such illegal parking is traffic congestion which also leads to delay in travel time and increases the cost of travel time. Unfortunately, off – street parking facilities are absent in most parts of the city. Especially, in Addis Ketema sub-city around Merkato, which is the largest center of market place in Africa, on-street parking has been dominating and off street parking under story building has been converted to other purposes such as shops and stores. Places of activities such as market centers, shops, churches, mosques, offices and similar places often generate enormous parking demands, and create parking problems in the sub-city. Thus, parking today has become a major obstruction to smooth flow of traffic in the entire sub-cities of the capital.

This study, therefore, intends to fill the identified gap, by reviewing the practices of parking in the sub-city so as to find out the challenges and prospects faced by the concerned bureau in its efforts to reduce road traffic congestion, to increase parking efficiency and to evaluate the constraints encountered in implementing and execution of the parking management practice.

C. Objectives

The key objective of the study was to evaluate the effect of parking and problems on transportation system in Addis Ketema sub-city.

Some of the Specific Objectives are as follows

1) To study the characteristics and nature of the existing parking condition of Addis Ketema sub-city.
2) To develop the relationship of utilized parking spaces and available parking capacity of on-street and off-street parking of selected locations.
3) To evaluate the influence of on-street parking on travel time (moving traffic) at selected road sections.
4) To develop an implementation plan or scheme that overcomes the problems associated with parking.

D. Significance of the Study

Success in parking management policy directly influences the efficiency of the transportation system, the economic competitiveness of a city, and the quality of life for the communities. Hence, the goal of this research would be provided an updated and comprehensive scan of current practices in on-street parking operations for congestion and concerned with off-street parking management and municipal authorities. Furthermore, the findings obtained from the study is helpful to gain information and knowledge about the parking and the corresponding impact in the city, which in turn, could help to develop countermeasures that could reduce the related transportation problem in the city. Also, this information initiates the investors to invest towards the parking generating. In addition, the result of the study is expected to generate important findings that can help as useful input for further research to refine the conceptual and methodology of the present study.

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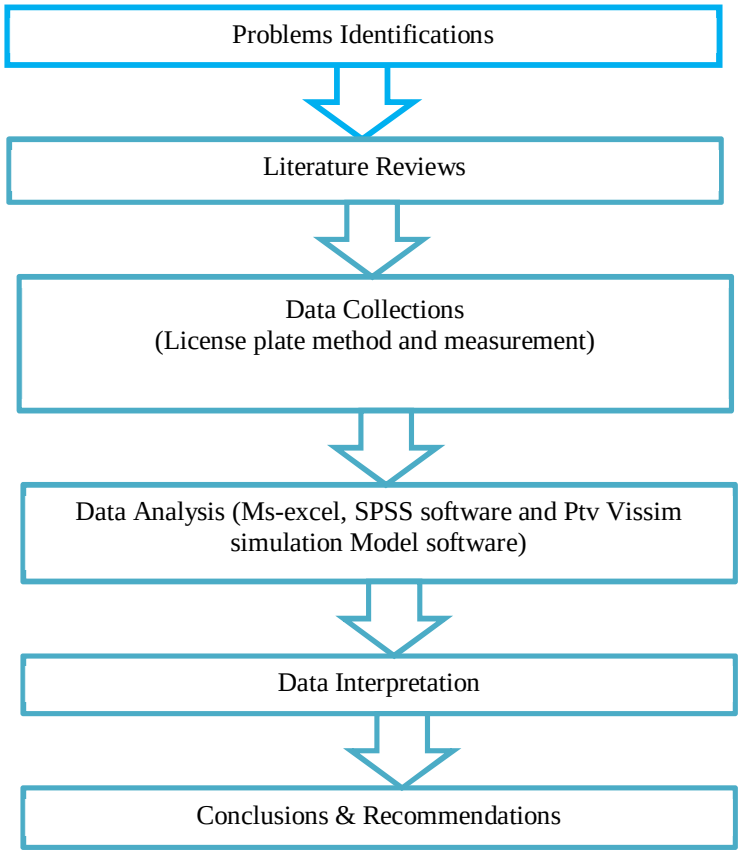
II. RESEARCH METHODOLOGY

A. Study Area

According to Addis Ababa City Government, 2010 report the current administration of Addis Ababa constitutes ten sub-cities, 'Kefle Ketemas'and 116 Woredas. Among these sub-cities the researcher intended to study the parking condition of Addis ketema sub-city due to the high volume of vehicles. This is because Addis Ketema sub-city possesses different public centers; the largest market center "Merkato," the city bus station, main cross country bus station of the city and, the Grand Anwar Mosque and the St. Raquel Orthodox church also found in this sub-cities.

1) *Study Design:* Both quantitative and qualitative types of data were used during the study period. Quantitative data was used to explore numerical information on the existing parking condition whereas qualitative type of data was used to describe the effect of on-street parking on travel time. Parking data were surveyed using license plate method of survey and volume traffic flows were counted using video camera. Characteristics of road geometry like gradient, lane width and segment length were also measured directly from the study area. These were the methods of parking data collections. The methodologies of analyses used in this research paper were Microsoft-Excel, linear regression analysis and Vissim simulation model software analysis, which were collected from the study area. To achieve the objectives of the research, the researcher performed the following activities. After thoroughly, organizing literature review of different previous published researches, indicate the gap and develop parking occupancy and parking space utilization by analyses of on street and off street parking occupancy. The step by step is as shown in the chart below;



2) *Data Collection Process:* A simple method was adopted to study the condition of both off-street and on-street parking. This simple method includes three important parts like preparation, survey and output. In the preparation part, papers related to the parking were collected and examined the general character of the area. In survey part some of the primary surveys were conducted, primary surveys like; parking volume count, parking capacity, accumulation and parking duration. In the third part, the outcome of the survey was analyzed to see the requirement to implement the new parking policy. The figures at the spot are as follows

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Steps has been followed to analyse input data for vissim software

a) Step1. Drawing the geometric features of the road segments on the Network object

b) Step2. Defining parking routes

A vehicle to use a parking lot, define a vehicle route of the type Parking lot that leads to the desired parking lot. To define a parking route, insert a routing decision on a link and on a destination section located on the parking lot of choice. For a routing decision, also define multiple destination sections located on different parking lots. Routing decision may lie on a connector. The destination section may also lie on a connector, if the parking lot is located on a connector.

c) Step3. Then select Parking lot and insert the size of parking lot. The initial parking occupancy also inserted.

d) Step4. Select the travel time measurement and specify the test section along the road segment.

III.DATA ANALYSIS

A. The Characteristics and Nature of the Existing Parking Condition

The characteristics and nature of the existing parking condition were shown with parking accumulation curve of a total number of vehicles with time interval in which the vehicles parked for some period.

In the following part, the parking locations (P1-P6) were analyzed individually. The parking locations were shown in diagram with respective locations. All parking parameters (parking statistics) results were presented in tabular form. Accumulation curve also provided for the two days. A total number of vehicles parked in an area at each fifteen minutes interval. It expressed in a number of vehicle parked. The data collected were useful in quantifying variation in demand over the course of the day. It also helped in identifying the peak period. Graph was plotted time vs number of vehicles. The variation was because of the land use, purpose, etc.

TABLE 1

Evaluation Result For Parking Location P1- Yirga Haile Underground Parking

Analysis	Unit	Date	
		Friday	Saturday
Study Period	Hour	8	8
Total number of bays	Bays	60	60
Parking volume	Vehicles	89	84
	vehicle/hour	11.1	10.5
Parking load	vehicle-hour	435.5	457.5
Ave. Parking duration	Minutes	298.99	334.64
Ave. Parking turnover	veh/bay/hour	0.19	0.18
Ave. Parking occupancy/ efficiency	Percent	91%	95%
Parking capacity	vehicle-hour	480	480

Results from table 1 shows about 11veh/hr were parked in both days. Long term parking vehicles were predominant at P1. Vehicles were parked for an average of five hours in both days. The efficiency of parking P1 was 91% on Friday and 95% on Saturday. That is parking spaces were utilized more on Saturday.

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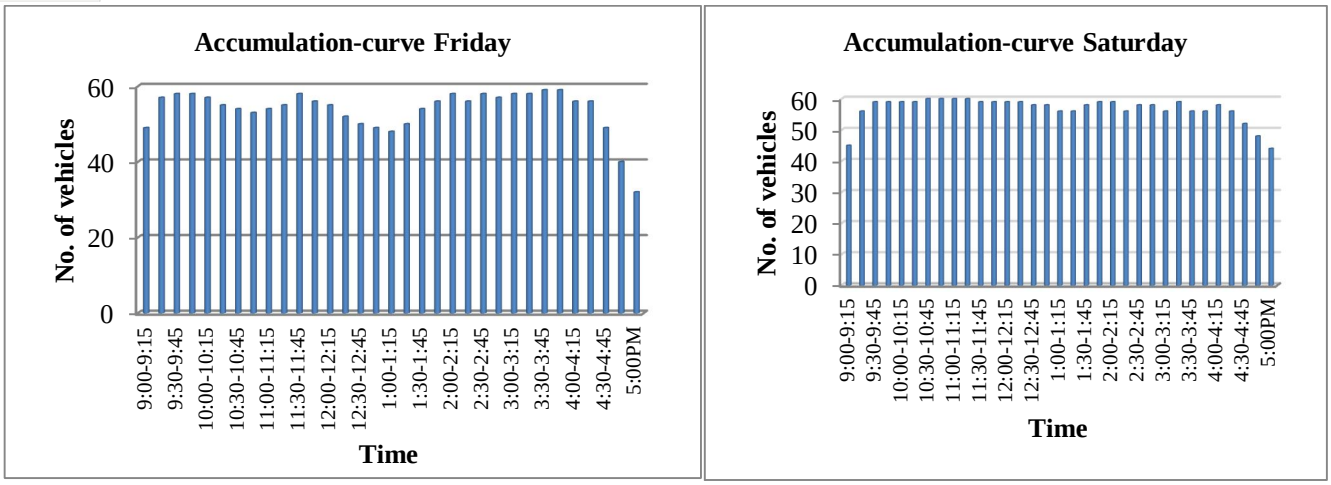

Figure 1: Vehicle accumulation graph of P1 on Friday and Saturday

TABLE 2
Evaluation Result For Parking Location Of P2-Tana Parking

Analysis	Unit	Date	
		Friday	Saturday
Study Period	Hour	8	8
Total number of bays	Bays	185	185
Parking volume	Vehicles	728	826
	vehicle/hour	91.0	103
Parking load	vehicle-hour	1269.5	1307.75
Ave.Parking duration	Minutes	104.11	97.2276
Ave.Parking turnover	veh/bay/hour	0.49	0.56
Ave.Parking occupancy/ efficiency	Percent	86%	88%
Parking capacity	vehicle-hour	1480	1480

Results from table 2 shows about 91 veh/hr were parked on Friday and 103 veh/hr on Saturday. Long term parking vehicles were not predominant at P2. Vehicles were parked for an average of 100 minutes in both days. The efficiency of parking P2 was 86% on Friday and 88% on Saturday. That is parking spaces were utilized more on Saturday.

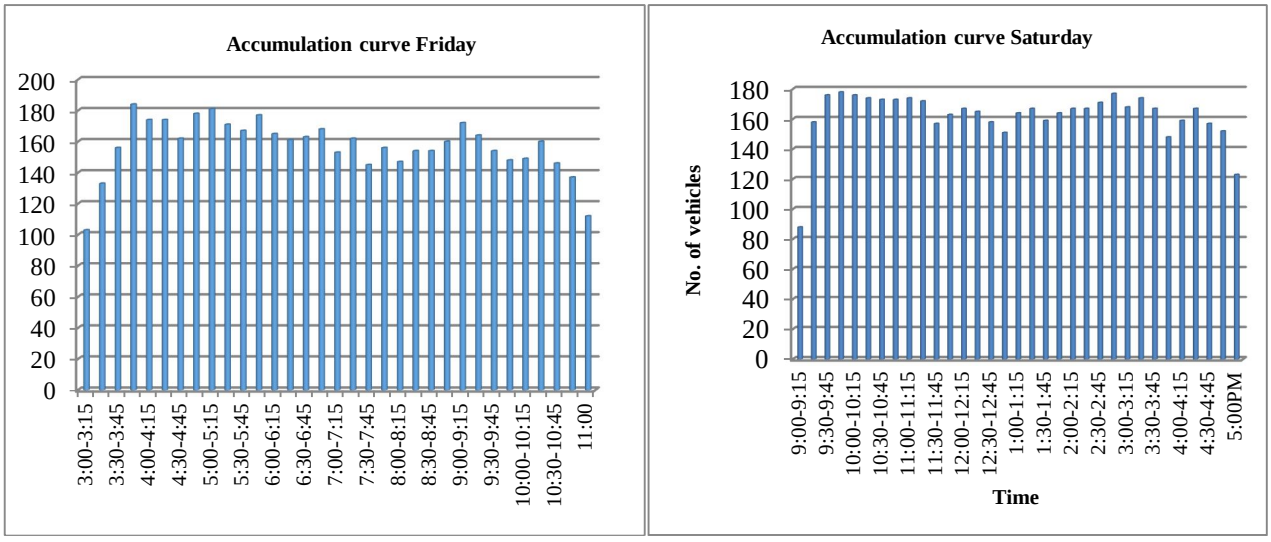

Figure 3: Vehicle accumulation graph of P2 on Friday and Saturday

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TABLE 3
Evaluation Result For Parking Location Of P3- Surface Parking

Analysis	Unit	Date	
		Friday	Saturday
Study Period	Hour	8	8
Total number of bays	Bays	50	50
Parking volume	vehicles	68	78
	vehicle/hour	9	10
Parking load	vehicle-hour	363.0	368.3
Ave. Parking duration	minutes	325.1	288.85
Ave. Parking turnover	veh/bay/hour	0.17	0.20
Ave. Parking occupancy/ efficiency	percent	91%	92%
Parking capacity	vehicle-hour	400	400

Results from the above table 3 shows about 9 veh/hr were parked on Friday and 10 veh/hr on Saturday. Long term parking vehicles were predominant at P3. Vehicles were parked for an average of six hours in both days. The efficiency of parking P3 was 91% on Friday and 92% on Saturday. That is parking spaces were utilized more on Saturday.

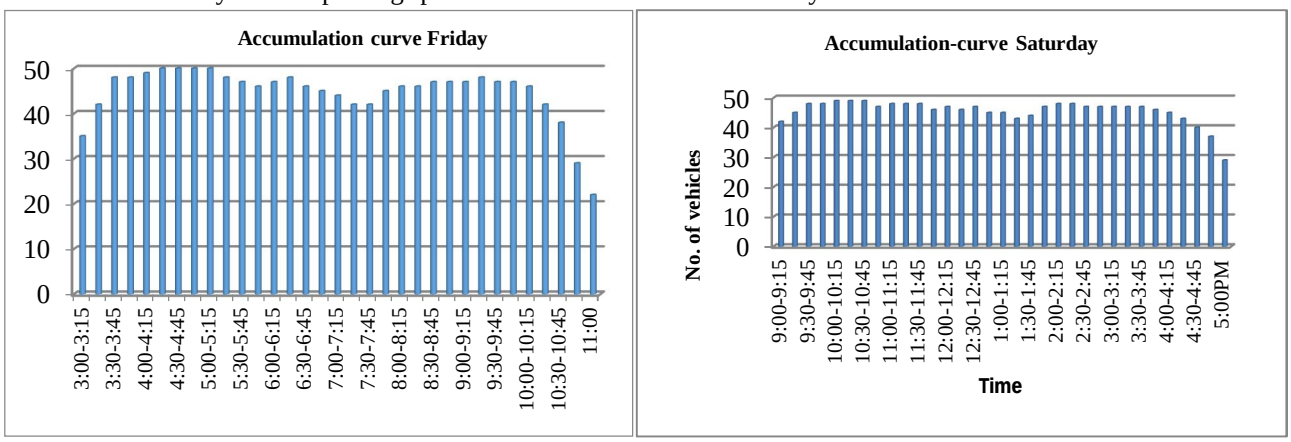

Figure 4: Vehicle accumulation graph of P3 on Friday and Saturday

TABLE 4
Evaluation Result For Parking Location Of P4 On Street Parking

Analysis	Unit	Date	
		Friday	Saturday
Study Period	Hour	8	8
Total number of bays	Bays	61	61
Parking volume	Vehicles	299	309
	vehicle/hour	37	39
Parking load	vehicle-hour	406.0	413.25
Ave. Parking duration	Minutes	83.13	81.84
Ave. Parking turnover	veh/hour/bays	0.61	0.63
Ave. Parking occupancy/ efficiency	Percent	81%	82%
Parking capacity	vehicle-hour	504	504

Results from table 4 shows about 37veh/hr were parked on Friday and 39veh/hr on Saturday. Long term parking vehicles were not predominant at P4. Vehicles were parked for an average of 80 minutes in both days. The efficiency of parking P4 was 81% on Friday and 82% on Saturday. That is parking spaces were utilized more on Saturday. The graphs has been plotted and are as shown in the figure below

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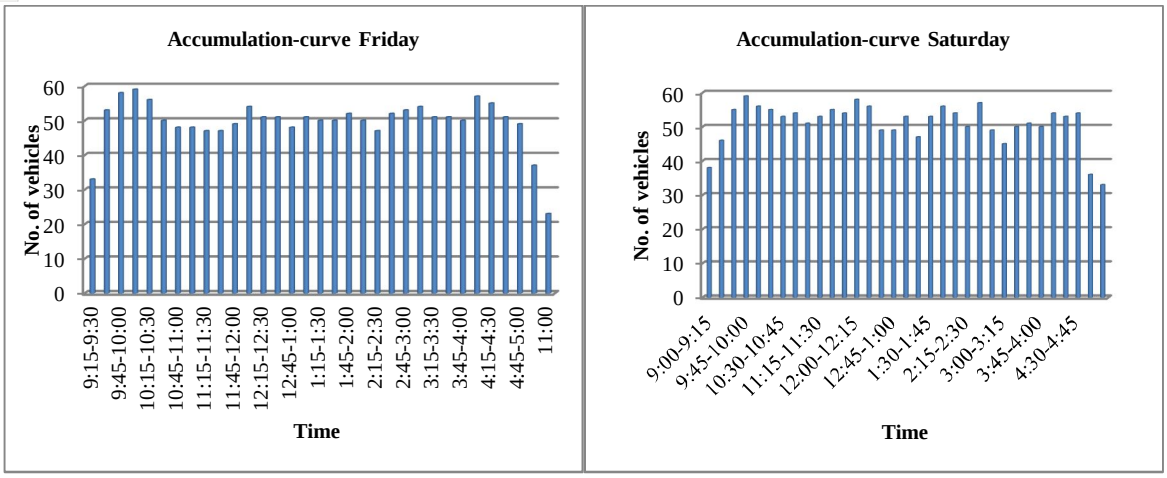

Figure 5: Vehicle accumulation graph of P4 on Saturday

TABLE 5
Evaluation Result For Parking Location Of P5 On Street Parking

Analysis	Unit	Date	
		Friday	Saturday
Study Period	Hour	8	8
Total number of bays	Bays	56	56
Parking volume	Vehicles	120	143
	vehicle/hour	15.0	18
Parking load	vehicle-hour	355.0	365.3
Ave. Parking duration	Minutes	180	155
Ave. Parking turnover	veh/bay/hour	0.27	0.32
Ave. Parking occupancy/ efficiency	Percent	79%	82%
Parking capacity	vehicle-hour	448	448

Results from table 5 shows about 15veh/hr were parked on Friday and 18veh/hr on Saturday. Long term parking vehicles were not predominant at P5. Vehicles were parked for an average of 170 minutes in both days. The efficiency of parking P5 was 79% on Friday and 82% on Saturday. That is parking spaces were utilized more on Saturday. The graphs has been plotted and are as shown in the figure below.

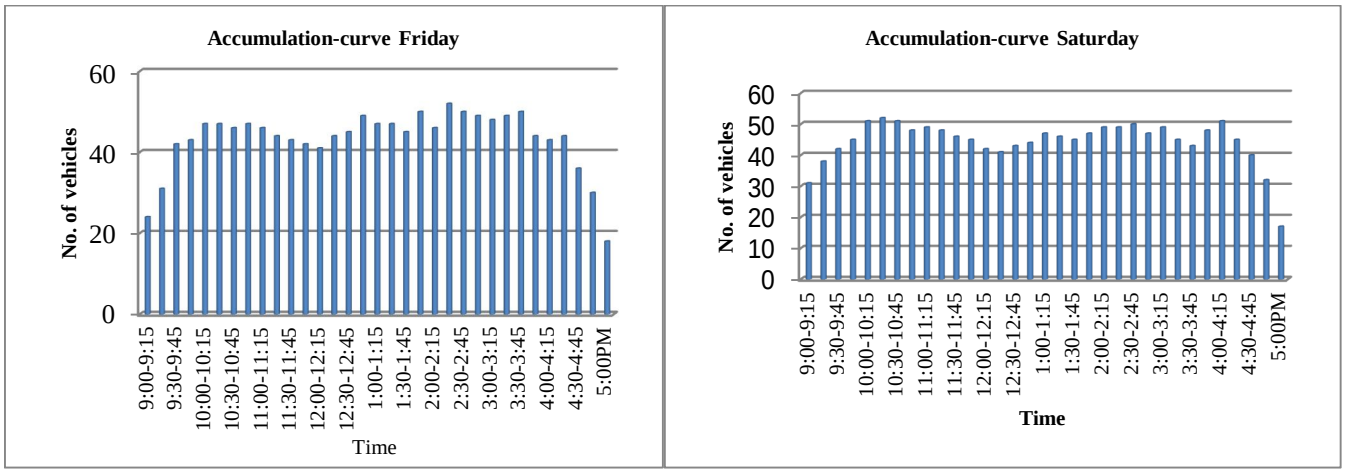

Figure 6 Vehicle accumulation graph of P5 on Friday and Saturday

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TABLE 5 Evaluation Result For Parking Location P6 On Street Parking

Analysis	Unit	Date	
		Friday	Saturday
Study Period	Hour	8	8
Total number of bays	Bays	64	64
Parking volume	Vehicles	267	294
	vehicle/hour	33	37
Parking load	vehicle-hour	424.8	424.75
Ave. Parking duration	Minutes	97.13	83.01
Ave. Parking turnover	veh/bay/hour	0.52	0.57
Ave. Parking occupancy/ efficiency	Percent	83%	83%
Parking capacity	vehicle-hour	512	512

Results from table 5 shows about 33veh/hr were parked on Friday and 37veh/hr on Saturday. Long term parking vehicles were not predominant at P6. Vehicles were parked for an average of 90 minutes in both days. The efficiency of parking P6 was 83% on Friday and 83% on Saturday. That is parking spaces were utilized equally in both days. The graphs has been plotted and are as shown in the figure below.

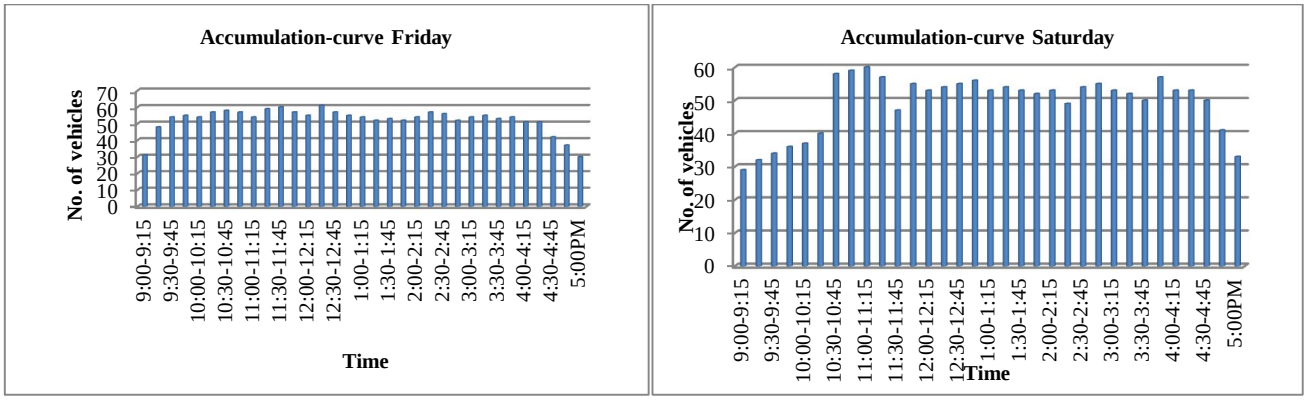

Figure 7: Vehicle accumulation graph of P6 on Friday and Saturday

B. Aggregated Data Analysis

The following table shows the result of aggregated data analysis of all parking locations.

TABLE 6 Aggregated Data Analysis

Analysis	Unit	Date	
		Friday 4/08/2017	Saturday 5/08/2017
Study Period	Hour	8	8
Total number of bays	Bays	476	476
Parking volume	vehicles	1571	1734
	vehicle/hour	199	219
Parking load	vehicle-hour	3253.8	3336.85
Ave. parking duration	minutes	182	174
Ave. parking turnover	veh/bay/hour	0.38	0.41
Ave. parking occupancy/ efficiency	percent	85%	87.6%
Parking capacity	vehicle-hour	3808	3808

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To conclude based on the above data, there are about 300 legal off-street parking and about 180 on-street parking spaces in study area. The parking spaces are serving the demand with on street and off-street facility.

From 10:00AM -4:00PM, the utilized spaces for off-street parking of P1 and P2 were almost constant. The parking accumulation was almost uniform between 9:00AM – 5:00PM. Here, parking space utilization of off-street parking less when compared to on - street parking as had shown from figure 1 and 2. These show that, on-street parking was preferred to park by vehicle owners. Because, the park/un park time is short. The parking capacity is good. It can serve additional 14% of the vehicle-hour in weekday and up to 571 vehicle-hours on Saturday.

The parking spaces utilized on Saturday is higher than that of the weekdays. Based on this, the parking users expected to be significantly associated with commercial trips than work trips.

The hourly parking volume for study area is about 219 veh/hr on Saturday and 199veh/h for weekdays. In other words, in every one-hour a minimum of 199 different vehicles have parked.

Average parking duration is 182 minutes for weekday and 174 minutes for weekend. The average parking turnover is 0.38veh/bay/hour for weekday and 0.41veh/bay/hour on Saturday. This result shows a poor value of parking turnover because vehicles have parked for a long time about 3 hours.

The average weighted efficiency is from 85% to 87%. More than 14% of the parking capacity have not utilized for different reasons. For example, the easiness to find a vacant parking space

C. The Relationship of Utilized Parking Spaces and Parking Capacity of On-Street and off- Street Parking

The relationship of parking utilized spaces and the available parking capacity of off-street and on-street parking were analyzed using linear regression model of analysis. Regression function involves a set of unknown parameters Bi and constant value B. If a regression function is linear in the parameters, it termed as a linear regression model. In this case, there were one dependent variable (utilized parking space) and one independent variable (parking capacity).

Parking occupancy is one of the utilized parking space determinations. Therefore, the utilized parking space is the percentage of parking occupancy of the actual number of available parking capacity. The on-street and off-street utilization of parking was recorded in six study areas within the sub-city. The graphs below (Figure 8) summarize the occupancy results of the combined study areas of off-street and on-street parking.

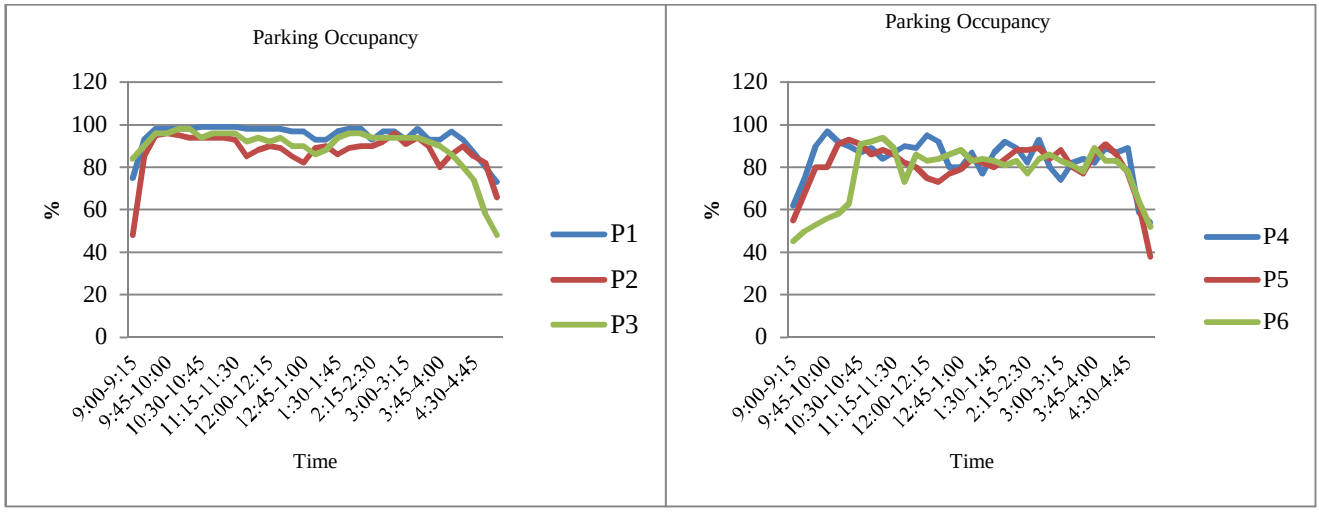

Fig 8 Parking occupancy of off street and on-street parking

The above graph results shows based on the 61 on-street spaces evaluated, the peak occupancy occurred during 9:30AM-10:30AM (about 97%) was observed on Saturday at P4. For location P5 the peak occupancy occurred during 10:15AM-11:15AM about 93% while location P6 the peak occupancy occurred during 10:30AM-11:30AM about 94% Since, the study area was found within business areas the parking occupancy is higher in the morning and higher than others day. Overall, the occupancy rates for the on-street parking spaces were relatively low compared with off-street parking. In general, the maximum utilized parking spaces are the maximum parking occupancy of the actual parking capacity. Parking occupancy is the ratio of space utilized to capacity during peak-hour. The Regression Analysis with various input and output parameters is as follows for the different types of parking.

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TABLE 7
Regression Input Table Of Off-Street Parking

Location	No. of bays (C)	Peak-occupancy (%) ($\lambda = \frac{S}{C}$)	Max. Utilized parking space (S)
P1	60	99	59
P2	185	96	178
P3	50	98	49

TABLE 8
Regression Input Table Of On-Street Parking

Location	No. of bays (C)	Peak-occupancy (%) ($\lambda = \frac{S}{C}$)	Max. Utilized parking space (S)
P4	61	97	59
P5	56	93	52
P6	64	94	60

TABLE 9
Regression Output Table Of On Street And Off-Street Parking

Regression statistics	ON street parking	OFF Street Parking
R	0.965	1
R Square	0.931	1
Adjusted R square	0.863	0.999
Standard Error	0.283	0.024
F	13.547	1636.81
Significance F	0.169	0.016
Constant (B)	-5.796	-0.993
Co efficient of X (Beta)	1.041	0.966

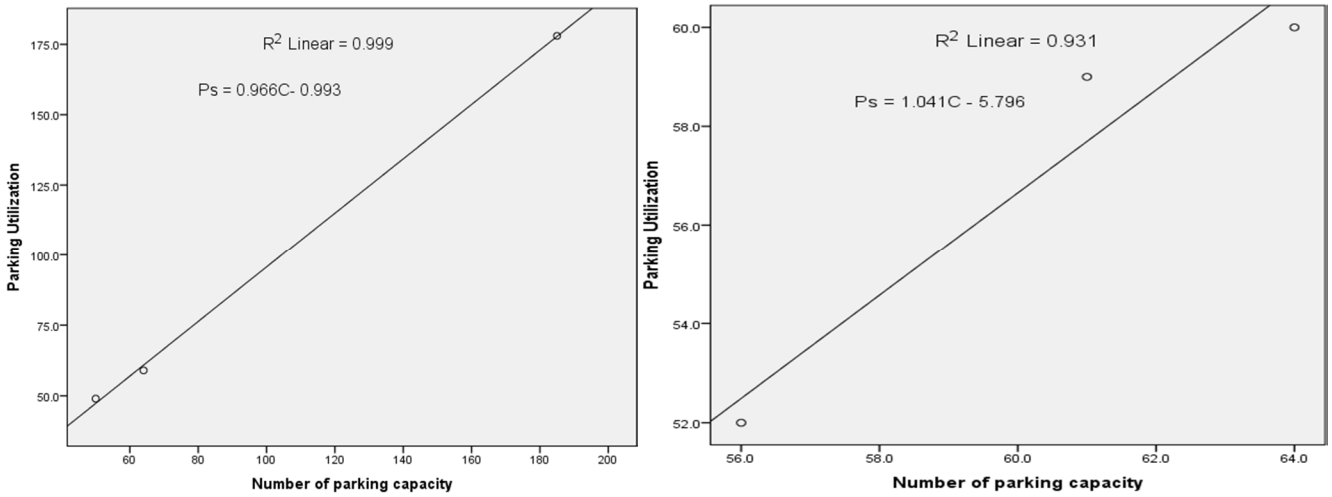

Figure 9 Parking utilized vs. parking capacity graph of off Street and on-street parking

Generally, from the above figures the utilized parking spaces is linearly correlated with available parking capacity. As the number of available parking capacity increases the utilized parking spaces by a vehicles also increases. That is the larger parking capacity available there are more vehicles utilized it. The relationship is shown by developed equations.

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D. The Influence of On Street-Parking on Travel Time (Moving Traffic)

Travel-Time Study Considering On-Street Parking

Travel time is the actually observed time for a vehicle to traverse the test section over a specified route under existing traffic conditions. The travel-time study measures the total elapsed time of travel, including stops and delay due to on-street parking.

The travel time analysis has done only on the selected roadside parking location along road segment. These were

1) P4 roadside parking along Tesema Aba Kemaw St. from right side (Teklehymanot square to Urago market center)

2) P5 roadside parking along Tesema Aba Kemaw St. from left side (Teklehymanot square to Urago market center)

3) P6 roadside parking in front of Grand Anwar mosque (Urago market center to Fitawurari Gebeyehu St.)

From the parking survey data, the observed peak parking counts at each parking area through the period of survey have been taken as the peak parking accumulation for the respective parking areas. The researcher took peak hour reading for the purpose of travel time analysis to indicate the influence of on street parking on travel time throughout the day reading. From the figure 7 and 8 and table 8 shows that the parking accumulation on Saturday was relatively uniform and higher than Friday. Therefore, the researcher select Saturday for travel time analysis to indicate the effect of roadside parking on travel time.

TABLE 10
Characteristics Of Test Sections

Test section	Section1, P4	Section2, P5	Section3, P6
No. of Parking bays	61	56	64
Ave. Parking load(veh-hour)	53	46	51
Ave. Number of parking vol.(veh/h)	39	18	37
Occupancy (%)	87	80	77
Section length(m)	230	215	245
No. of lane	3	3	2
Lane width	3m	3m	3.5m
Gradient (%)	3.5	-3.5	0.9

Therefore, the influences of on-street parking on travel time measured by average travel time. The average travel time determined first, by considering on-street parking along the road segment, and then, by removing on-street parking. The difference of these values can determined the effect of on-street parking on travel time

E. Input Data for Travel Time Analysis Using Vissim Software

The various inputs for different parking sections P4, P5 and P6 such as type of vehicle, number of vehicle, relative flow, average parking rate, average speed, mean and standard deviation values were given to analyse the behaviour for vissim software and then the out generated is as shown in the tables and figure below.

1) *Travel Time:* Average travel time at 15min interval was determined for the selected road segments. These were done by considering two scenarios: by considering roadside parking and by removing roadside parking along the road segment. The results were shown in the table below.

The speed of traffic flow at a scenario of roadside parking is determined from the actual travel time that recorded the traffic flow of each vehicle between the test sections.

So, speed = distance between test section/ actual travel time

Distance between the test section= 230m

Actual travel time= 21seconds

Speed= 230/21= 10.95m/sec which is equal to 40Km/hr.According to Vissim 9.0 Manual, the time distribution is allocated in the parking routing decisions. A vehicle, which assigned a parking space via a parking routing decision, carries out on an automatically generated route and parks for as long as the time distribution specifies. After the time expires, the vehicle leaves the parking bays and begins on an automatically generated route

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Table 11
Peak Hour Input Data For Travel Time Analysis Along (P4)

Vehicle type	Total No. of Vehicles	Relative flow	Ave. parking rate (%)	Ave. Speed (km/hr)	Time Distribution(sec)	
					Mean	St dev.
Cars	621	0.553	87	40	4931	19
Mini-buses	349	0.331				
Buses	7	0.006				
Trucks	93	0.083				
Motor cycles	52	0.046				
Total	1122	1.000				

Table 12
Peak Hour Input Data For Travel Time Analysis Along (P5)

Vehicle type	Total No. of vehicles	Relative flow	Ave. parking rate (%)	Ave. Speed (km/hr)	Time Distribution	
					Mean	St dev.
Cars	670	0.594	80	40	9360	40
Mini-buses	317	0.281				
Buses	12	0.011				
Trucks	98	0.087				
Motor cycles	31	0.027				
Total	1128	1.000				

Table 13
Peak Hour Input Data For Travel Time Analysis Along (P6)

Vehicle type	Total No. of Vehicles	Relative flow	Ave. parking rate (%)	Ave. Speed (km/hr)	Time Distribution(sec)	
					Mean	St dev.
Cars	491	0.505	77	40	4980	27
Mini-buses	359	0.369				
Buses	7	0.007				
Trucks	78	0.080				
Motor cycles	38	0.039				
Total	973	1.000				

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TABLE 14
Travel Time Output By Considering The Two Scenarios

Time int.	Travel time with roadside parking (sec)			Travel time without roadside parking (sec)		
	P4=230m	P5=215m	P6=245m	P4=230m	P5=215m	P6=245m
9:00-9:15AM	29.53	28.01	88.31	19.55	18.73	28.04
9:15-9:30AM	26.25	28.01	107.04	19.53	18.76	28.03
9:30-9:45AM	56.66	87.7	139.52	19.55	18.77	28.09
9:45-10:00AM	81.61	76.53	126.61	19.61	18.7	28.1
10:00-10:15AM	105.48	126.98	148.77	19.62	18.74	28.08
10:15-10:30AM	96.19	108.71	131.85	19.59	18.74	28.18
10:30-10:45AM	91.88	107.11	141.24	19.54	18.78	27.98
10:45-11:00AM	91	103.27	127.54	19.52	18.74	27.97
11:00-11:15AM	39.1	56.04	157.88	19.55	18.77	28.03
` 11:15-11:30AM	39.08	56.05	143.45	19.51	18.84	27.99
11:30-11:45AM	39.1	56.11	94.95	19.56	18.78	28.01
11:45-12:00AM	39.16	56.08	37.46	19.55	18.78	28.01
12:00-12:15AM	39.16	56.11	37.47	19.54	18.77	27.94
12:15-12:30AM	39.23	56.31	37.48	19.55	18.77	28.1
12:30-12:45AM	39.07	56.06	37.53	19.51	18.7	27.97
12:45-1:00AM	39.03	55.97	37.55	19.62	18.84	28.18
1:00-1:15PM	39.09	56.02	37.56	19.6	18.7	28.08
1:15-1:30PM	39.03	56.03	37.63	19.61	18.73	28.11
1:30-1:45PM	39.06	56.02	37.56	19.63	18.72	28.18
1:45-2:00PM	19.58	28.05	27.96	19.53	18.8	18.7
2:00-2:15PM	19.56	27.98	27.97	19.51	18.74	18.8
2:15-2:30PM	19.55	28.06	28.09	19.49	18.78	18.78
2:30-2:45PM	19.56	27.99	28.01	19.5	18.73	18.76
2:45-3:00PM	19.59	27.96	27.96	19.53	18.76	18.74
3:00-3:15PM	89.63	114.82	101.05	19.55	18.73	28.05
3:15-3:30PM	97.16	117.51	133.14	19.52	18.76	27.98
3:30-3:45PM	89.85	142.82	111.96	19.55	18.78	27.98
3:45-4:00PM	92.2	139.98	112.04	19.6	18.7	28.08
4:00-4:15PM	19.57	28.03	28.11	19.53	18.7	18.79
4:15-4:30PM	19.55	27.98	27.95	19.5	18.82	18.8
4:30-4:45PM	19.55	27.99	28.01	19.51	18.78	18.76
4:45-5:00PM	19.74	28.05	27.94	19.57	18.77	18.82

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The table above shows the travel time by considering on-street parking was greater than the travel time without considering on-street parking. The average travel time along roadside parking of P4, P5 and P6 were 48, 64.1 and 75.55 seconds respectively. Also, the results were shown using graphs to interpret each roadside parking along the road segment. According to the result shown in the figure 4.27 below, it shows the morning and afternoon peak periods recorded the highest travel time and the lowest travel time recorded during mid-day for all road segments along P4, P5 and P6 roadside parking. This is because the road connects the residential area of the city to the largest market center, Merkato, and the area is surrounded with commercial shops, in which the parking demand is high between peak hour 10:00 AM and 11:00 AM as shown from parking statistics. Road segment along P5 has a higher travel time during afternoon peak period. This is because of the workday ending around 4:00 PM, before this time the employee go to commercial areas before they are leaving to their homes so that parking is high.

Similarly, these segments have the highest travel time during the morning period than afternoon time. However, for the road segment along P4, it has relatively less travel time even though it has slightly higher in the morning and afternoon peak. When they compared to each other, the three-road segment on the different segment length, the road segment along P6 has the highest travel time from the other. On the other hand, road segment along P6 has low travel time during mid-day. Also the same has been plotted in the graphs and shown in the figure below.

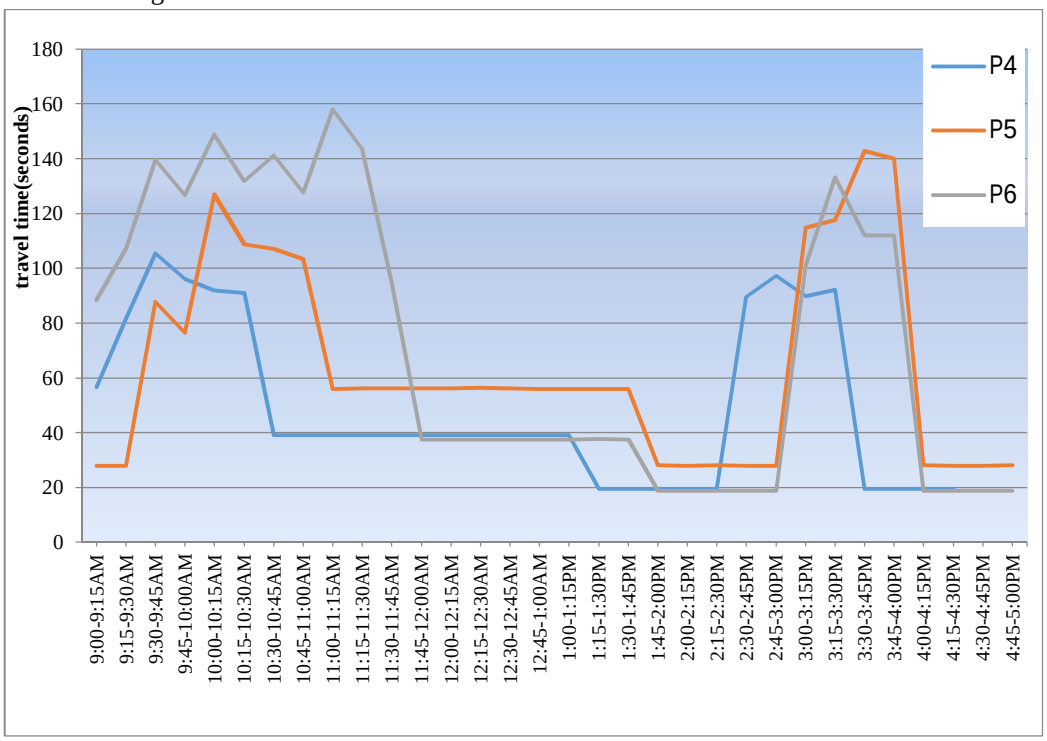

Figure 10 Travel time for roadside parking along the road segment

F. Total Segment Delay

Delay is the additional time experienced by a road user in association to the theoretical (ideal) travel or the actual travel time. The delay of vehicles in leaving travel time measurement is obtained by subtracting the theoretical (ideal) travel time from the actual travel time. The theoretical (ideal) travel time is the travel time that achieved if there were no other vehicles and/or no signal control or other reason for stops by removing on-street parking. The actual travel time is the travel time that achieved by considering on-street parking.

Total segment delay was the summation of average stopped delay in seconds per vehicle without at public transport stops and in parking bays and the average vehicle delay (additional delay) in seconds per vehicle determined above. The average delay of each 15 minutes interval was considered to determine the total segment delay as shown from table 14.

Additional delay= Actual travel time – theoretical (ideal) travel time

Total segment delay= Σ (Ave. sopped delay + Additional delay) sec/veh

The table 14 below shows the total segment delay which is the summation of average stopped delay per vehicles in seconds and the average vehicle delay (additional delay) per vehicles in seconds. The total average segment delay along P4, P5 and P6 were 7.29, 12.01 and 25.95 seconds per vehicle respectively.

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TABLE 14
Total Segment Delay Of On-Street Parking Along The Road Segment

Time int.	Average stopped delay (sec/veh)			Average additional delay (sec/veh)		
	P4	P5	P6	P4	P5	P6
9:00-9:15AM	5	10.35	15.41	9.98	9.28	60.27
9:15-9:30AM	5.55	20.32	30.92	6.72	9.25	79.01
9:30-9:45AM	7.12	14.3	21.33	37.11	68.93	111.43
9:45-10:00AM	7.6	4.02	14.82	62	57.83	98.51
10:00-10:15AM	8.02	6.96	8.95	85.86	108.24	120.69
10:15-10:30AM	5.86	5.68	35.57	76.6	89.97	103.67
10:30-10:45AM	6.91	14.12	26.77	72.34	88.33	113.26
10:45-11:00AM	13.24	25.29	23.82	71.48	84.53	99.57
11:00-11:15AM	10.69	2.43	10.69	19.55	37.27	129.85
11:15-11:30AM	10.87	11.01	24.91	19.57	37.21	115.46
11:30-11:45AM	7.98	12.51	31.07	19.54	37.33	66.94
11:45-12:00AM	8.21	24.32	21.67	19.61	37.3	9.45
12:00-12:15AM	6.19	24.59	29.72	19.62	37.34	9.53
12:15-12:30AM	7.68	32.27	25.19	19.68	37.54	9.38
12:30-12:45AM	3.21	23.45	34.66	19.56	37.36	9.56
12:45-1:00AM	5.5	6	38.96	19.41	37.13	9.37
1:00-1:15PM	8	5.68	33.95	19.49	37.32	9.48
1:15-1:30PM	3.33	13.9	43.61	19.42	37.3	9.52
1:30-1:45PM	12.1	8.2	37.47	19.43	37.3	9.38
1:45-2:00PM	10.64	11.2	38.03	0.05	9.25	9.26
2:00-2:15PM	11.9	9	7.9	0.05	9.24	9.17
2:15-2:30PM	5.3	9.3	7.88	0.06	9.28	9.31
2:30-2:45PM	1.18	4.9	4.43	0.06	9.26	9.25
2:45-3:00PM	2.59	9.54	10.13	0.06	9.2	9.22
3:00-3:15PM	6.54	5.39	15.43	70.08	96.09	73
3:15-3:30PM	6.56	11.44	22.78	77.64	98.75	105.16
3:30-3:45PM	8.95	9.97	33.84	70.3	124.04	83.98
3:45-4:00PM	12.59	8.32	42.61	72.6	121.28	83.96
4:00-4:15PM	5	18	37.59	0.04	9.33	9.32
4:15-4:30PM	8	10	37.47	0.05	9.16	9.15
4:30-4:45PM	6	4.4	38.03	0.04	9.21	9.25
4:45-5:00PM	5.3	8.1	7.7	0.17	9.28	9.12

Figure 11 shows the total segment delay in seconds per vehicles for the selected road segment length by considering the length of the given segment. The result in the figure should not be compared each other because these segments are not equal in length, therefore, it should be read for a single road segment only at once.

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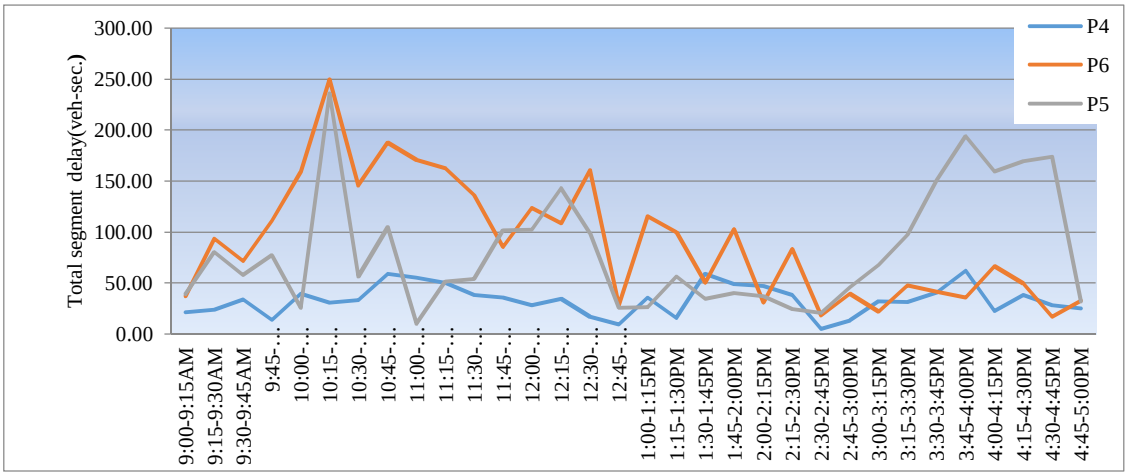

Figure 11 Total segment delay of the road segment of roadside parking

The total segment delay of road segment along P6 has maximum during morning peak hour because the parking volume has increase during this hour and the travel time of vehicle in a given segment also increase as a result the total segment delay of road segment along P6 is maximum. In the same case, total segment delay of road segment along P5 during afternoon peak-hour time became the highest because of parking volume and travel time increase simultaneously. For the case of road segment along P4 has similar appearances with a little variation throughout the day.

IV. CONCLUSION AND RECOMMENDATION

A. Conclusion

1) There are about 300 legal off-street parking and about 180 on-street parking spaces were evaluated in the study area. The hourly parking volume for study areas were about 219veh/h on Saturday and 199veh/h for weekdays. In other words, in every one hour a minimum of 199 different vehicles park.

2) The average parking occupancy/efficiency of off-street parking and on-street parking were around 90% and 82% respectively. But, the average parking duration of off-street parking were about 4 hours and 2 hours at on-street parking.

3) The average parking turnovers of off-street and on-street parking were 0.30veh/h/bay and 0.50veh/hour/ bay respectively. This result shows vehicles are parked at off-street parking for a long time than on-street parking.

4) The aggregate weighted efficiency is from 85% to 86%. More than 14% of the parking capacity is not utilized for different reasons. For example, the easiness to find a vacant parking space.

5) The relationships have been developed for estimating on-street and off-street utilized parking spaces of selected streets and off-street parking facilities in the study area. Therefore, the utilized parking spaces show nearly full utilization of the available parking capacity; in turn this create further parking investment in the study area.

6) The average travel time along roadside parking of P4, P5 and P6 were 48, 64.1 and 75.55 seconds respectively.

7) According to the segment delay analysis results the total average segment delays of parking P4, P5 and P6 along road segments were 7.29, 12.01 and 25.95 seconds per vehicle respectively.

B. Recommendation

1) According to the findings of the study the vehicles parked for the average parking duration of 180 minutes. In location P1 and P3; one car was observed parked for at least six hours and five hours respectively. Additionally, based on the turnover rate 0.19; these parking are very un-utilized. Therefore, there should be parking time-restriction and intervention through parking fare rate at these parking locations. These interventions will improve the parking turnover. This also shift on-street parking to off-street parking since improving parking turnover will increase parking capacity.

2) The weighted parking efficiency is 85% to 86%. For example, the easiness to find a vacant parking space can be increased by implementing ITS tools. In return, this will increase the efficiency of utilizing available parking space. The average occupancy rate were above 80 percent in all parking types, the reason for high parking demand were not only related to short of parking supply, but also related to high parking duration and poor parking managements. So, there should give attention to parking policies and management.

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3) The analysis result shows that the road segments are serving more for roadside parking than moving traffic. Therefore, the city administration should consider this issue and formulate parking control enforcement. Parking control can be used to limit parking duration, control types of vehicles or users allowed to access the space, provide a clearway allowing the parking lane to be used as a through lane where peak hour traffic volumes exceed the available lane capacity.

4) Transport related office especially Addis Ababa City Transport Program Management Office (TPMO) should work further on parking problems.

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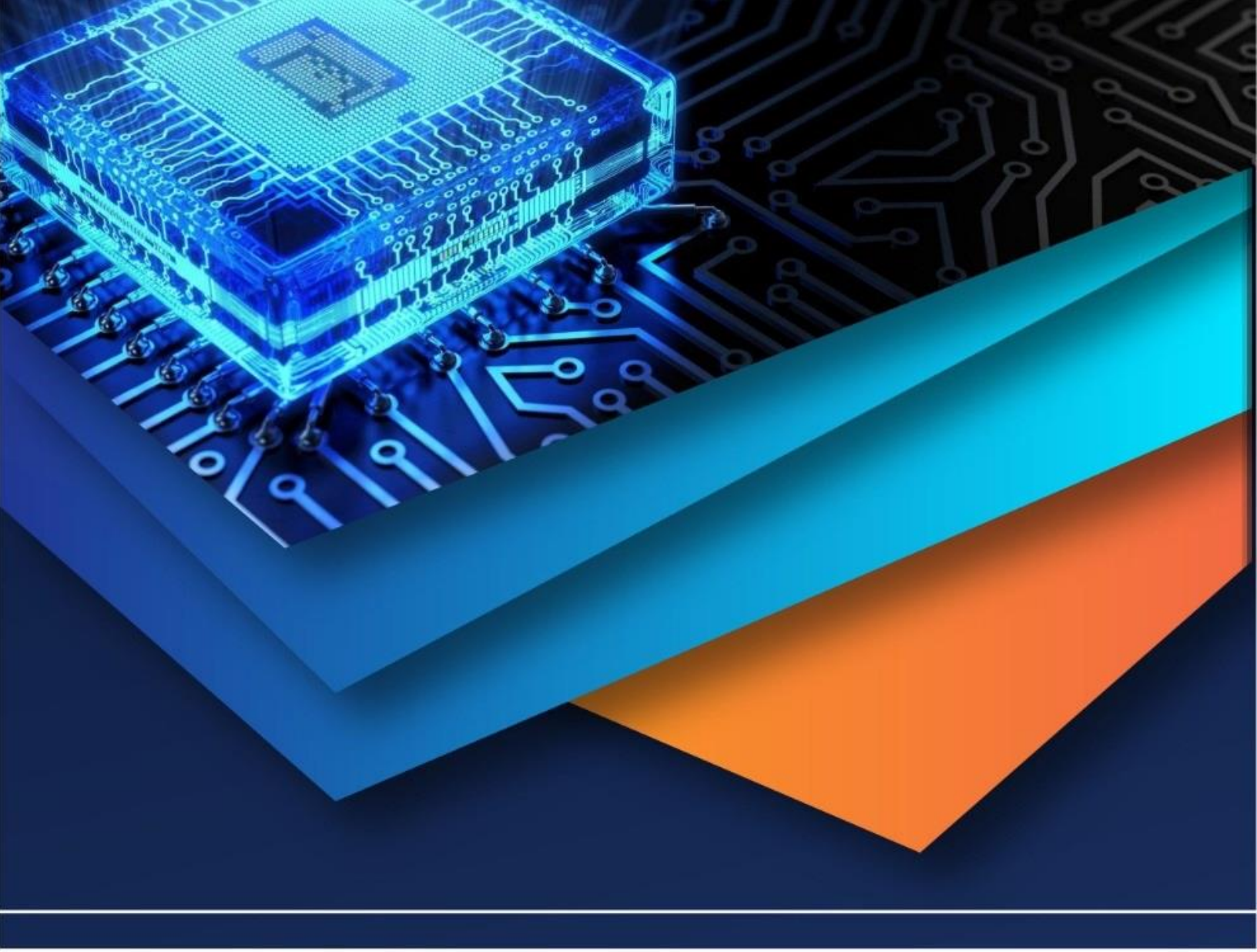

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