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The Study and Optimization of Parking Facilities in Central Business District: A Case Study of Saddar Peshawar, Pakistan

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Abstract—*Importance of transportation in development of a region is multidimensional. Parking is an integral part of a well-planned transportation system which is often ignored or ill planned in metropolitan cities. This force drivers to park haphazardly, consequently rising parking demand and congestion on the adjacent links.*

The parking problem in Peshawar is a big issue since long time but the Central Business District of Peshawar, Saddar region has affected at large. High parking demand and Traffic jam has become a daily nuisance, wasting time of the drivers, creating psychological distress, air and noise pollution which are detrimental to the environment. Also, it has a negative effect on the businesses in the region.

Parking problems are caused by high trip generation rate in the peak hours due to the presence of major shopping malls and recreational centers. Another big factor is the population growth rate which has risen at highest rate in the last decade and this has led increased number of personal motorized vehicle ownership.

Huge number of vehicles rush to Saddar in peak hours but there is no proper parking management system to cater the demand. Existing parking policies encourage drivers to utilize On-street parking due to deficiency of Off-street parking. Although there are no parking provisions on some roads, but vehicles are still parked there due to weak enforcement and the unwillingness of drivers to park in Off-street parking that are at a distance from On-street parking.

The CBD has shopping centers at small distances from each other with many of shopping centers and offices have no private parking. Also, construction of new shopping centers is on the rise which is further increasing the already high parking demand. Until now there has no policies developed to cope with the increasing parking demand and traffic congestion.

in this research, firstly in and out survey was conducted throughout the week to find the peak days and hours of parking demand. In the second stage detailed number plate survey was conducted in the peak parking demand period for two hours and detailed data was collected for all the parking including accumulation, occupancy, average parking turnover and average parking duration. On-street parking showed high parking index as compared to off street. High parking demand was recorded from Monday to Wednesday. Although demand was low on Saturday as compared to Monday, Tuesday and Wednesday but the peak hour shifted to later hours of the day. The overall parking demand for on-street parking was much higher than off-street due to the tendency of parkers to park near their destination and they are 38 in number while off-street are only 6. After analysis it was clear that new off-street parking facilities need to be built to discourage on-street parking so that it can equalize the on-street and off-street parking demand and relieve congestion in peak hours.

Keywords- *Central business district, parking demand, peak hour, parking mismanagement, private parking*

I. INTRODUCTION

There is no doubt that transportation is the most critical and important sector for a country's economy. Transportation has impact on environment, as well as on mobility, and these are two of the important factors considered in urban economy and quality of life. A region's economic status depends upon how well the it is served by different modes of Transportation. Metropolitan cities face severe problems due to rapid and uncontrolled development by an unacceptable level of difference in traffic and parking supply/demand which results in environmental degradation, traffic congestion and accidents[1].

Saddar is the Central business District of Peshawar. It has highest land values, vehicular and pedestrian flow. Shortage of parking supply has been observed due to the lack of private parking facilities by major shopping centers, offices and institutions[2].

The total area consists of 2,99,450 square meters (3,223,252 square feet), in which there are 38 on-street and 6 off-street parking. This huge amount of parking provision in the area with a large amount of commercial activity caused a lot of problems for drivers and pedestrians. This also encourages parkers from nearby regions to park in On-street parking, which is an extra load over the already congested parking and creates more difficulties especially in peak hours.

On the other hand, the traffic and parking management techniques did not evolve with time due to which the lanes are completely clogged in the peak hours and traffic move at a snail's pace from dawn till dusk.

Although some experts favor On-street parking as it provides convenience, acts as safety buffer for pedestrians, occupies less space than Off-street parking and encourages shared use of space, but there are researchers who oppose parking on the roads because it causes traffic congestion, traffic crashes, and environmental pollution[3]. Cars spend around 95% of the time parked and only 5% of the time moving, this depicts the importance of a well-organized parking system[4]. According to another survey, out of 8760 hours in year the car runs for an average for only 400 hours leaving 8360 hours when it is parked[5].

To accommodate the huge vehicle volume, cities must have to develop their road and parking systems or else these problems are more likely to get severe, like it happens in CBDs. Solution for this is a systemic survey and parking management system, to decongest roads and solve parking and traffic problems[6].

A systematic study will present a viable solution for the parking problem and all the other problems created due to parking mismanagement. This research focuses on studying the existing conditions of on-street and off-street parking in Saddar and finding measures to relieve parking demand and traffic congestion in the peak hours by suggesting alternative solutions.

II. OBJECTIVES

- To study parking demand of existing on-street and off-street parking facilities.
- To study existing parking supply and demand relationship and present solutions to normalize it.
- To find the peak hours of parking demand and examine the locations where parking demand is high.
- To find measures to relieve high parking demand sites and minimize its negative impacts on traffic.

III. SCOPE OF THE STUDY

Existing parking condition is at worse in Saddar. Parkers wander for hours in search of vacant spaces; this creates difficulties for through traffic and hinder the flow. For the whole CBD there are a total of 38 on-street and 6 off-street parking. This large number On-street parking encourages drivers to park on roadside. Mostly vehicles are parked on road alongside the on-street parking lots in second and third rows, which is another major cause of congestion in Saddar. There is a dire need to conduct a comprehensive parking survey to examine the existing problems, suggest countermeasures and present a parking management plan that can bring the demand and supply disparity to a minimum.

IV. METHODOLOGY

Methodology consists of the following steps:

- Selection of study area location.
- Inventory of on-street and off-street parking facilities located in the study area.
- Conducting parking surveys.
- Finding the peak hours of parking demand.
- Collection of data in the peak hours of parking demand.
- Analysis of the collected data.
- Conclusions and recommendations for the best use of the parking facilities and to relieve peak parking demand in the study area.

V. LOCATION OF THE STUDY AREA

Peshawar, the provincial capital of Khyber Pakhtunkhwa is the first in Khyber Pakhtunkhwa province and sixth most populous city in Pakistan with a population of 1,970,042 and its population growth rate almost doubled within the last 20 years[7]. The high population growth rate results in more personal vehicles, which consequently rises the parking demand and traffic volume. The same trend is observed in Peshawar which has brought its traffic to a complete halt especially in Saddar CBD. The total area of Saddar is 2,99,450 square meters (3,223,252 square feet), in which there are 38 on-street and 6 off-street parking. This has made the region so congested that the lanes are clogged most of the time which is problematic for both parkers and through traffic.

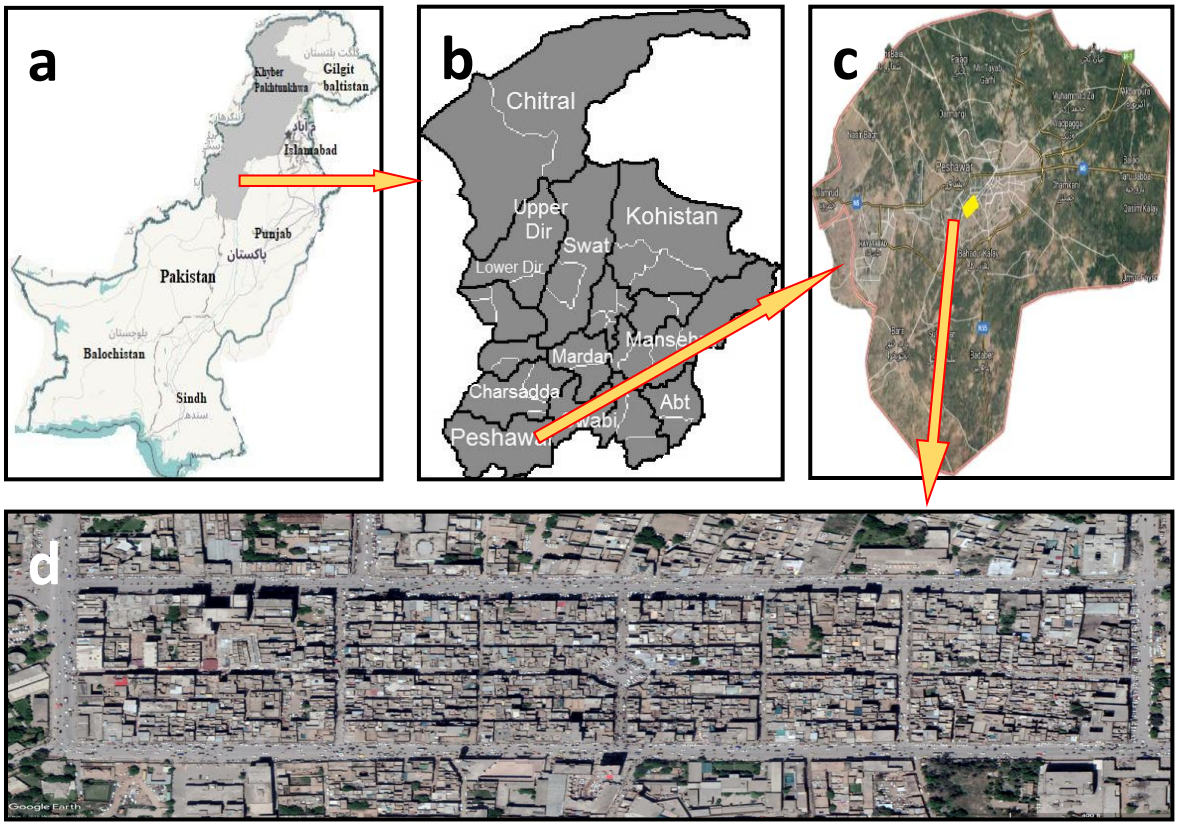


Figure 1- (a) Pakistan map, (b) Khyber Pakhtunkhwa Province, (c) Peshawar map, (d) Saddar, study area map

VI. DATA COLLECTION

6.1. Inventory of on-street and off-street parking:

Inventory of on-street and off-street parking was made as shown in figure 2 below. Total on-street and off-street parking were 38 and 6 respectively, with P1 to P38 denoting on-street parking and P A to P F off-street parking.

All 38 on-street parking are located on 4 major and 4 minor arterials. The major arterials are Saddar road, Sunehri masjid road, Fakhr-e-alam road and Stadium road. Minor arterials are Tipu sultan road, Lala Ayub road, Qazi road and Faiz Ullah khan road. Parking 1 to 8 are located on Saddar road, 9 to 12 on Fakhr-e-alam road, 13 to 20 on Sunehri masjid road, parking 21 is located on Stadium road, parking 22, 27, 28, 31, 32, 37 and 38 are located on Tipu sultan road, 23 to 26 are on Faiz Ullah khan road, 29 and 30 on Qazi road, and 33 to 36 are on Lala ayub road.

Parking 2 and 3 are bike only parking and rest are car parking and the rest are car parking. Parking 2, 4, 9, 10, 11 and 29 are perpendicular parking, parking 12 is 75-degree parking, the rest are parallel parking.

In off-street parking PA and PC are mixed parking with separate bike and car sections, the rest are car parking.

Second and even third rows of illegal parking were also observed in most of the parking throughout the parking surveys. Although the accumulation profiles were low, but still it is a big hurdle for through traffic and for parkers as well.

Abrupt parking is another problem both in On-street and Off-street parking which wastes a lot of capacity and due to no strict enforcement rules this trend is on the rise. The whole data collection process took 2 months and 15 days.

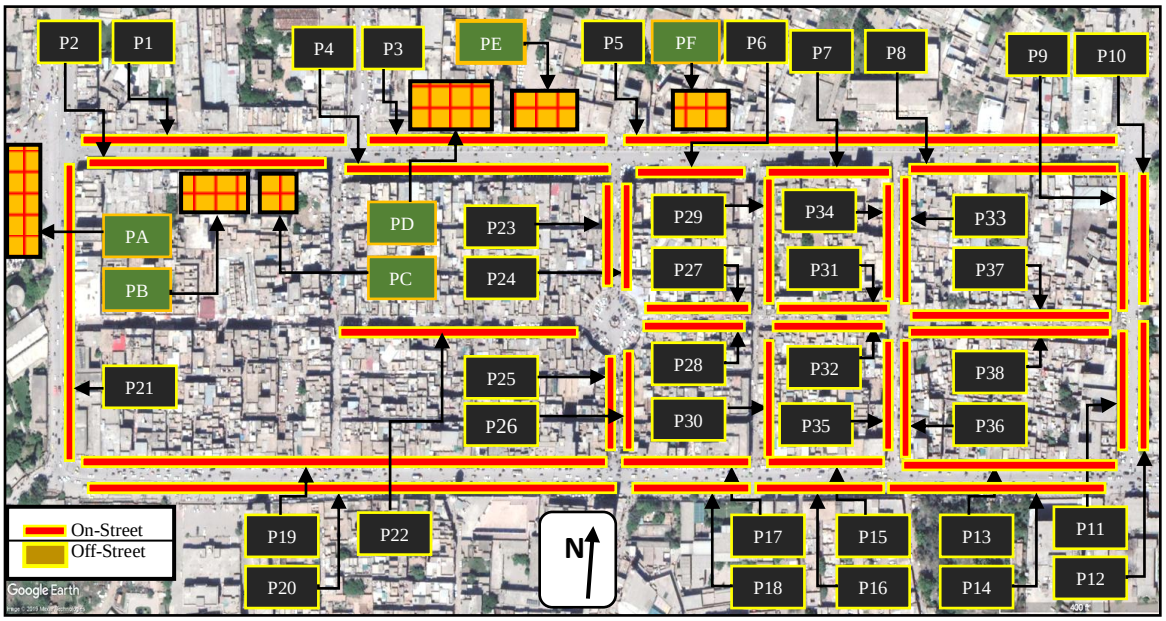


Figure 2- Locations and names of on-street and off-street parking illustrated in black and green respectively in Saddar CBD Peshawar

6.2. Parking Surveys

In the first stage of this research in and out survey was conducted for On-street and off-street parking from Monday to Saturday, 7:00 am to 10:00 pm at one-hour duration to get a general idea of the parking demand observe the peak parking demand hours.

After spotting the peak hours of parking demand in the in and out survey, detailed parking survey (number plate survey) were conducted only on days that showed a constant increase in parking demand in the peak hours. Number plate survey was from 1:00 pm to 3:00 pm.

VII. PARKING MEASUREMENTS

Accumulation and occupancy data were collected in the initially conducted in and out survey from Monday to Saturday, between 7:00 am and 10:00 pm at one-hour interval. After finding the peak hours and days of the week that presented high parking accumulation and occupancy, number plate survey was conducted from 1:00 pm to 3:00 pm at an interval of 15 minutes and the following data were collected.

7.1. Parking Accumulation

Parking accumulation is the number of vehicles (cars, bikes etc.) parked at a specified survey location at a given time[8].

7.2. Parking Occupancy

Parking occupancy, Parking index or parking efficiency is the ratio of the number of parking spaces occupied to the total spaces available in an on-street or off-street parking expressed in percent[8].

Occupancy (%) = (Number of parking spaces occupied/Number of parking spaces available) *100

7.3. Turnover

Number of vehicles utilizing a parking lot during a specified parking survey period[8].

7.4. Average Parking Duration

it is the average parking time a vehicle spend in a parking during the specific survey period[8].

Average Duration = Total Vehicle Hours/Total vehicles parked during the survey period

I. ANALYSIS OF PARKING DATA

8.1. On-street parking occupancy

In the first stage of the research in and out survey was conducted in which on-street and off-street parking data were collected from Monday to Saturday from 7 am to 10 pm at an interval of one hour.

Accumulation and occupancy were calculated for the mentioned parking in the in and out survey. Variations in the Occupancy from Monday to Saturday for the on-street and off-street parking are illustrated in the figures below.
As can be seen in figure 3 on Monday the parking index is high between 1 and 3 pm with the highest percentage recorded at 2 pm. Although some minor increase in demand is recorded after 3 pm in few of the parking on Tuesday and Wednesday but majority of parking displayed higher occupancy between 1 and 3 pm as illustrated in figure 4 and 5.

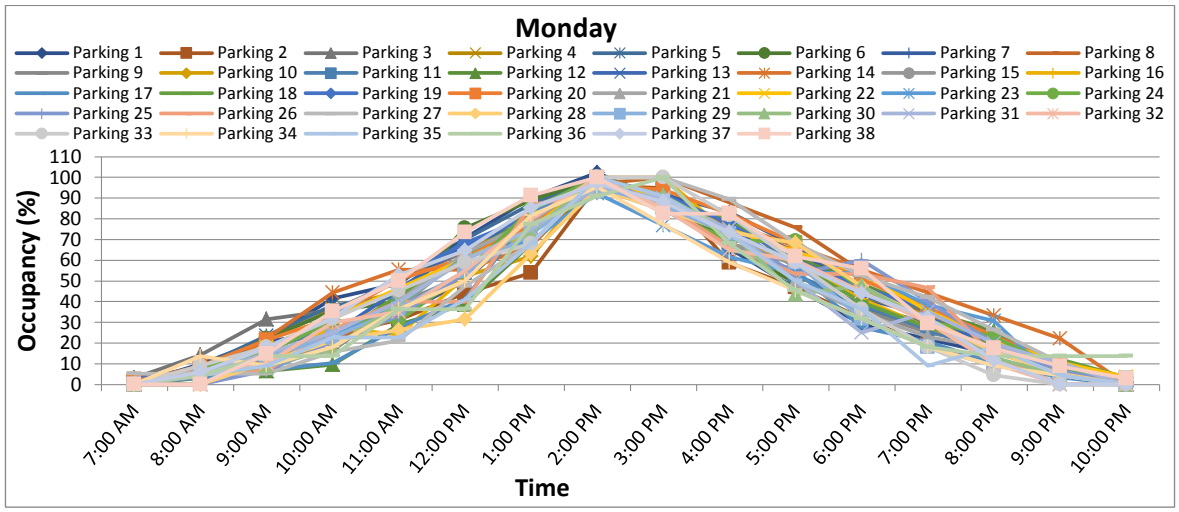


Figure 3- Monday On-street parking occupancy in percent illustrated for parking 1 to 38 from 7 am to 10 pm

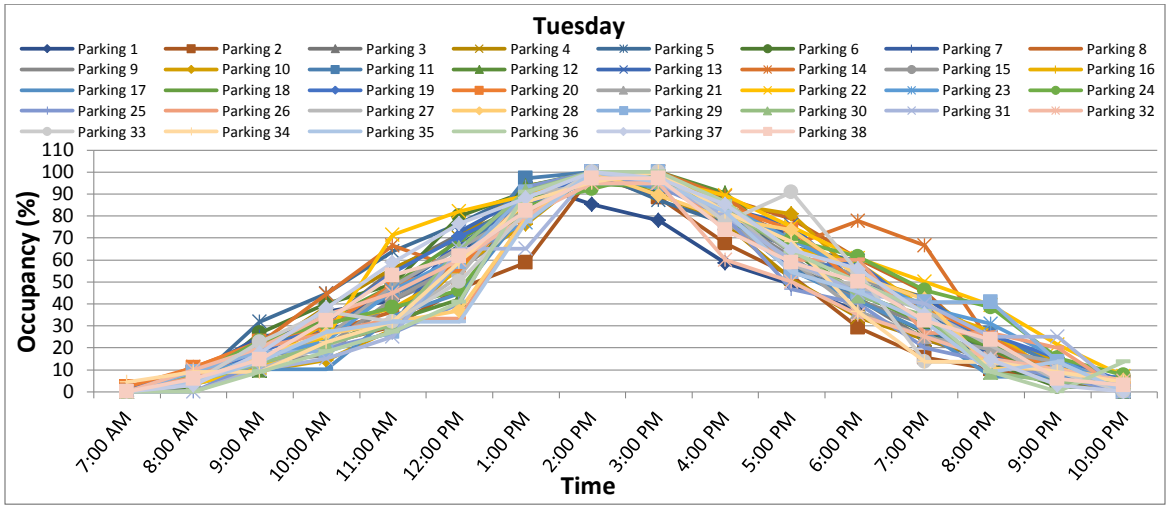


Figure 4- Tuesday On-street parking occupancy in percent illustrated for parking 1 to 38 from 7 am to 10 pm

On Thursday the parking index started increasing from 11 pm reaching almost 90 percent at 1 pm. On Thursday comparatively demand was lower than Monday, Tuesday and Wednesday as can be seen in figure 6.
Occupancy on Friday started rising at 12 pm with highest percentage recorded at 1 and 2 pm after which the demand declined at a steady phase until 4 pm and at a higher phase afterwards. Figure 7 shows that the highest peak hour occupancy on Friday was 60 percent which was lowest among the occupancy values recorded throughout the week.

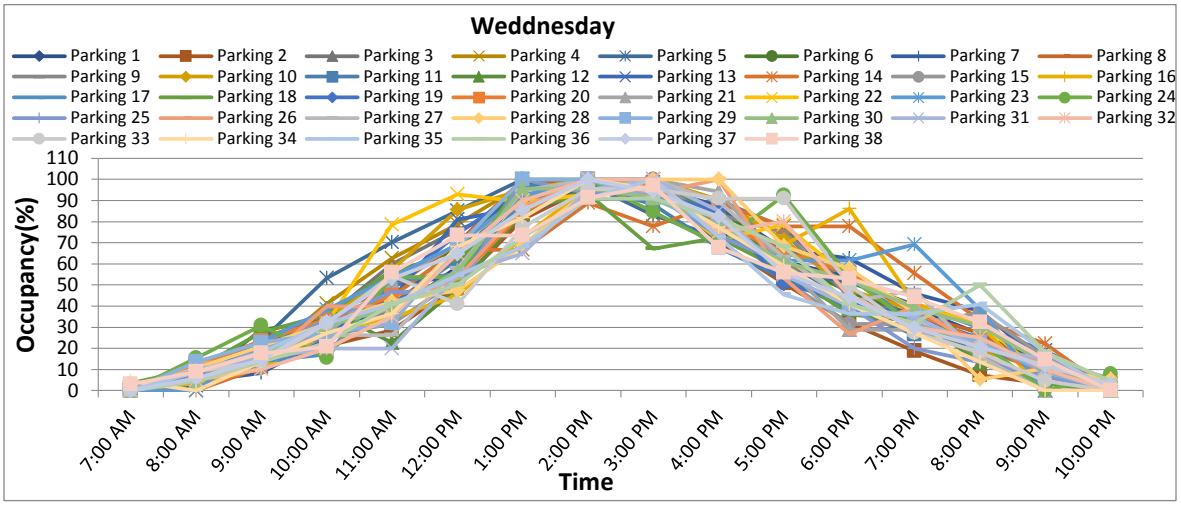


Figure 5- Wednesday On-street parking occupancy in percent illustrated for parking 1 to 38 from 7 am to 10 pm

On Saturday the highest occupancy recorded was 80 percent which was lower than Monday, Tuesday, Wednesday and Thursday but the peak hour shifted between 6 to 8 pm as is clear from figure 8. The reason for this shift is the presence of major shopping and recreational centers in this CBD region. A large amount of public rushes to Saddar at Saturday evening hours for shopping and recreational purposes which rises the parking demand.

Most of them prefer to park in on-street parking so they can easily unpark while going back home which causes a lot of trouble for through traffic, consequently blocking the roads. This blockage of through traffic also makes it difficult for additional parkers to park and unpark their vehicles. This cycle continues for hours and causes unnecessary delay for parkers as well as for through traffic and pedestrians.

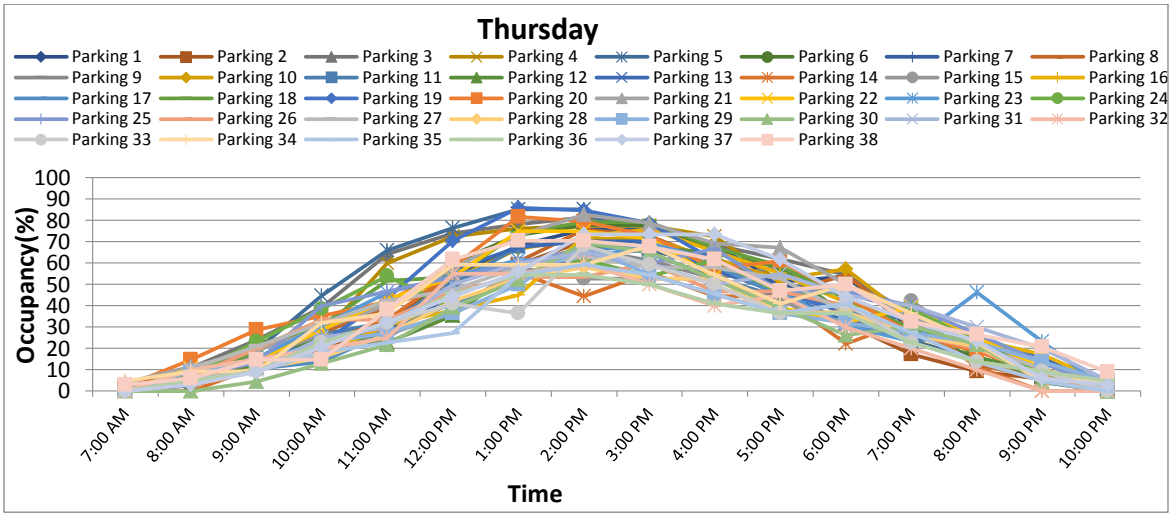


Figure 6- Thursday On-street parking occupancy in percent illustrated for parking 1 to 38 from 7 am to 10 pm

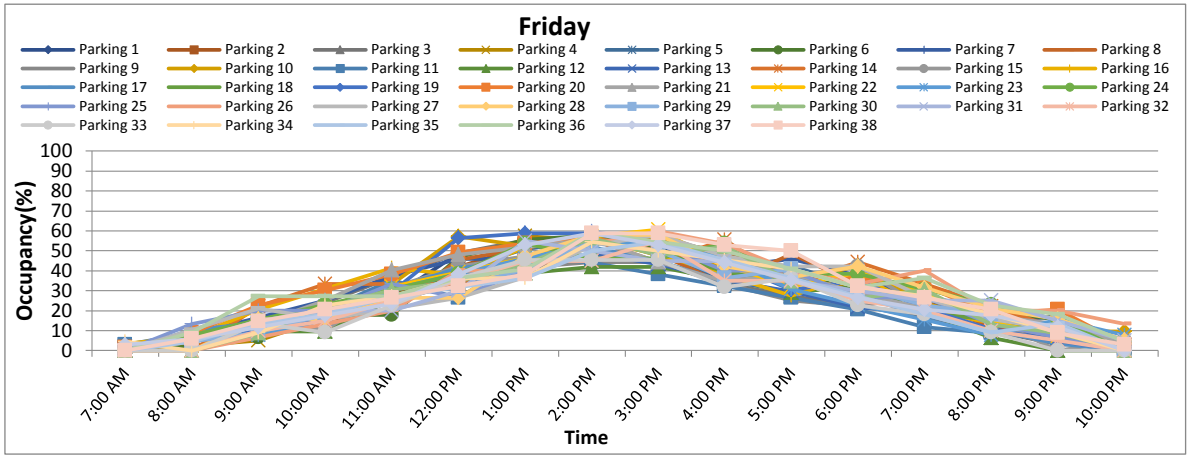


Figure 7- Friday On-street parking occupancy in percent illustrated for parking 1 to 38 from 7 am to 10 pm

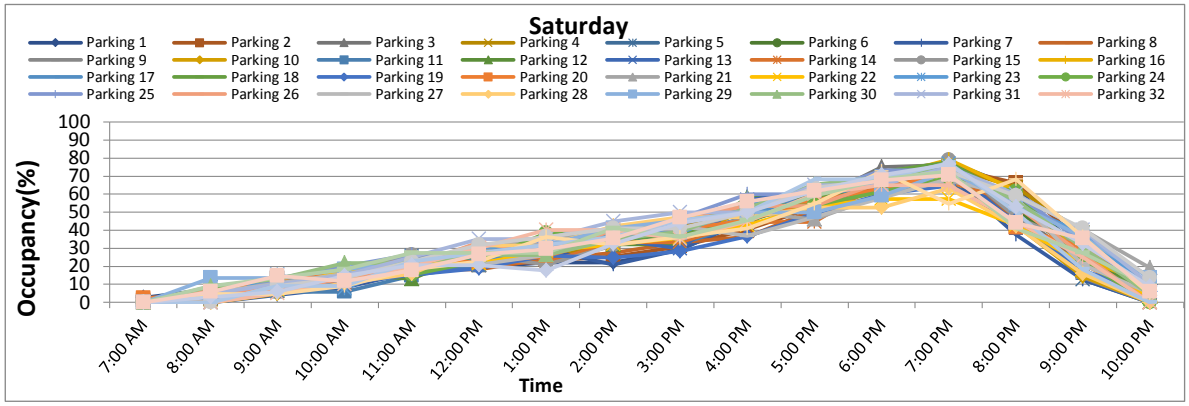


Figure 8- Saturday On-street parking occupancy in percent illustrated for parking 1 to 38 from 7 am to 10 pm

The reason the occupancy rises and then decline at almost a constant rate is because all the parking are very close to each other as shown in figure 2, and if one parking is slightly or fully occupied the parkers prefer to park at the adjacent one to avoid conflict with other parkers.

8.2. Off-street parking occupancy

There are a total of 6 off-street parking in Saddar. Parking A is situated near stadium road and the rest are in the vicinity of Saddar road. Parking PD, PE, PF are car parking and PB is bike only parking, while PA and PC are mixed (cars and bikes) parking in which 4a and 6a are car parking and 4b and 6b are bike parking portions. Data collection for cars and bikes portions were carried out seperately in parking PA and PC.

Off-street parking are situated near each other at one side of the cbd, due to which the drivers in the other side of cbd are compelled to park on road which creates additional problems for through traffic and also for parkers themselves.

For off-street parking the peak occupancy for Monday, Tuesday and Wednesday was 70, 80 and 75 percent shown below in figuer 9, 10 and 11 respectively with Highest demand observed between 1 and 3 pm resembling on-street parking demand where also the peak parking demand was observed between 1 and 3 pm.

On Thursday highest occupancy was between 12 and 4 pm with the highest value reached up to 70 percent at 2 pm. On Friday the Highest occupancy was 50 percent between 1 and 3 pm, which is pretty much low as compared to occupancy values from Monday to Thursday.

On Saturday the occupancy rose to 50 percent at 2 pm and afterwards to almost 70 percent at 6 pm due to shopping trips on Saturday evening. Although the peak hour of parking demand shifted to 6 pm but the highest demand was still less than Tuesday for Off-street parking.

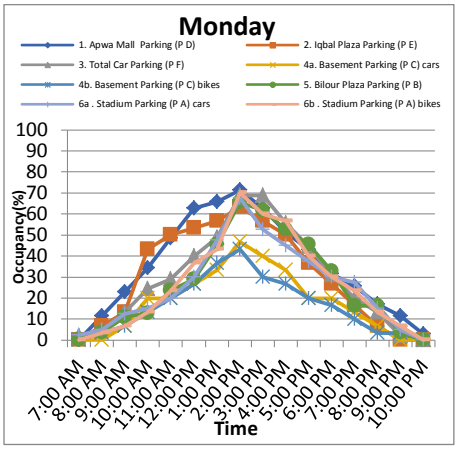


Figure 9

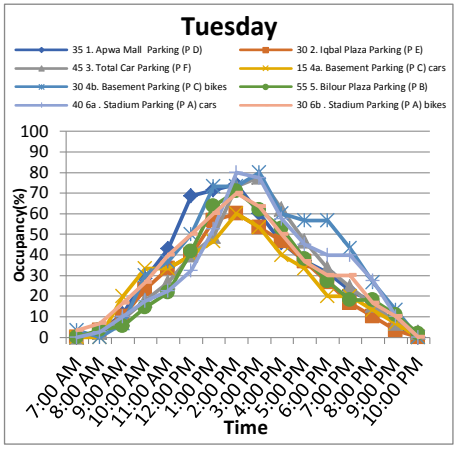


Figure 10

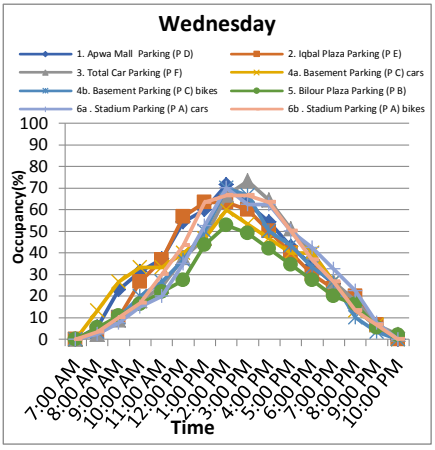


Figure-11

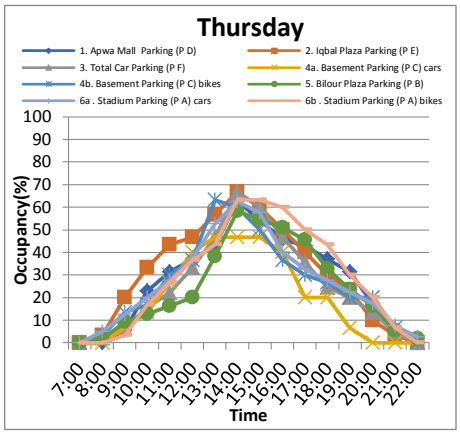
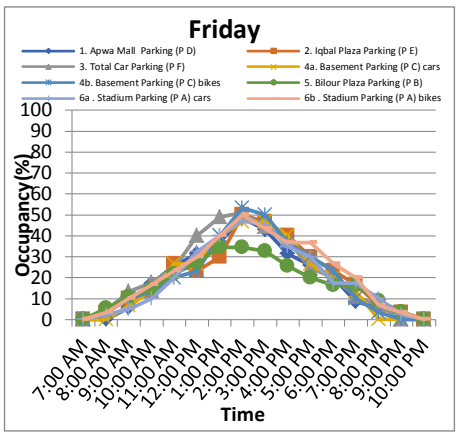


Figure-12



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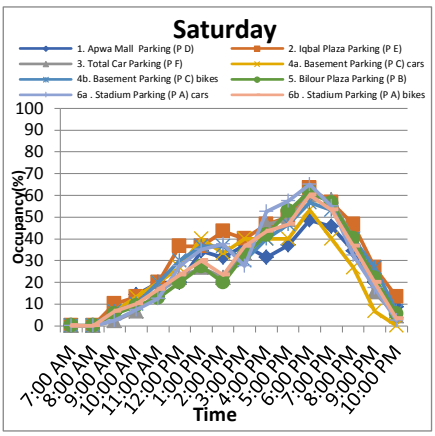

Figure-14

8.3. On-street and Off-street parking occupancy from 1 to 3 pm

More detailed data for on-street and off-street parking was collected in number plate survey on Monday, Tuesday and Wednesday between 1 and 3 pm because demand was consistently high on all of the three days between 1 and 3 pm as was observed in the initial in and out survey conducted from Monday to Saturday.

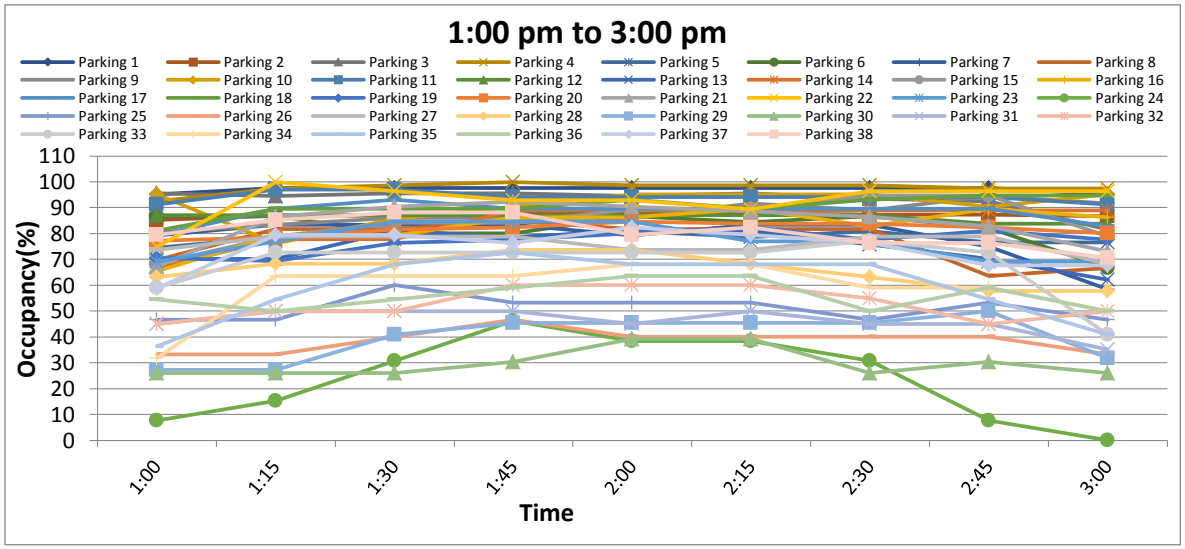

Figure 15- On-street parking occupancy in percent illustrated for parking 1 to 38 from 1 to 3 pm

Data was collected at an interval of 15 minutes for a period of two hours as shown in figure 15 and 16.
For On-street parking most of the parking showed full occupancy between 1 and 3 pm. However, the highest occupancy of 100 percent was observed between 1:30 and 2:30 for majority of parking.
For off-street parking, there were no major fluctuations in occupancy from 1 to 3 pm. The highest occupancy observed was 79 percent.

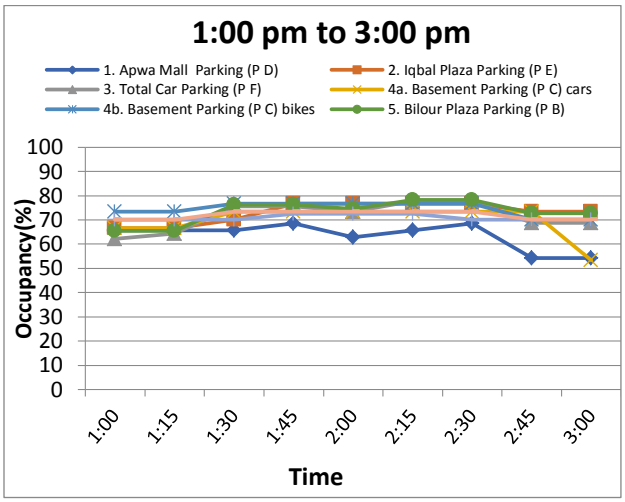

Figure 16- Off-street parking occupancy in percent illustrated for parking 1 to 6 from 1 to 3 pm

8.4. Average turnover

For on-street parking, average turnover ranges from 0.54 for parking 29 to 1.86 for parking 6 as shown in table 1 and figure 17. Furthermore, high average turnovers were observed for parking located on major arterials.
On the other hand, average turnover for off-street parking ranges from 0.77 for parking D to 1.03 for parking A (bikes section), clearly illustrated in table 2 and figure 18. For off-street parking the overall turnover for bike parking was high as compared to car parking. Overall turnover rates are lower for both on-street and off-street parking as is clear from data.

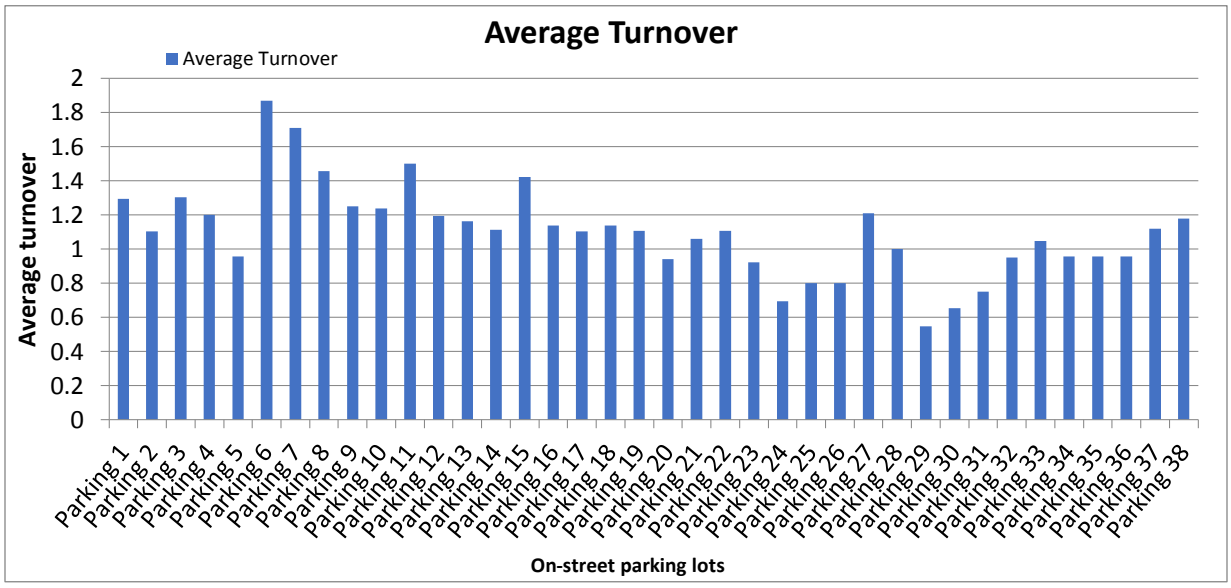

Figure 17- On-street parking turnover illustrated from 1 to 3 pm

Table 1- Average parking turnover and average parking duration of on-street parking

S.No	Names	Average Turnover	Average parking duration(minutes)
1	Parking 1	1.29	101.32
2	Parking 2	1.10	106.72
3	Parking 3	1.30	96.5
4	Parking 4	1.2	110
5	Parking 5	0.95	110.66
6	Parking 6	1.86	59.46
7	Parking 7	1.70	62.19
8	Parking 8	1.45	71.56
9	Parking 9	1.25	94.66
10	Parking 10	1.23	99.23
11	Parking 11	1.5	84.70
12	Parking 12	1.19	97.70
13	Parking 13	1.16	86.51
14	Parking 14	1.11	102
15	Parking 15	1.42	80.55
16	Parking 16	1.13	98.18
17	Parking 17	1.10	107.81
18	Parking 18	1.13	107.5
19	Parking 19	1.10	93.98
20	Parking 20	0.94	117.07
21	Parking 21	1.05	107.45
22	Parking 22	1.10	113.22
23	Parking 23	0.92	112.5
24	Parking 24	0.69	46.66
25	Parking 25	0.8	86.25
26	Parking 26	0.8	65
27	Parking 27	1.21	84.78
28	Parking 28	1	89.21
29	Parking 29	0.54	98.75
30	Parking 30	0.65	62
31	Parking 31	0.75	83
32	Parking 32	0.95	75
33	Parking 33	1.04	88.04
34	Parking 34	0.95	82.85
35	Parking 35	0.95	83.57
36	Parking 36	0.95	79.28
37	Parking 37	1.11	89.60
38	Parking 38	1.17	92.62

8.5. Average parking duration:

In On-street parking only 2 (5.26%) parking have average parking duration less than 60 minutes, 25(65.79%) parking have average parking duration between 60 and 100 minutes and 11 (28.95%) parking have average parking duration more than 100 minutes, as shown in table 1 and figure 19.

Average parking duration for Off-street parking ranges between 93.87 and 118.2 minutes. No parking in Off-street parking have average parking duration less than 90 minutes with only 3(37.5%) parking having average duration between 90 and 100 minutes and 5 (62.5%) parking having average duration more than 100 minutes as illustrated in table 2 and figure 20.

Parking A (bikes section) has the lowest parking duration of almost 94 minutes among other off-street parking, while in On-street parking lowest is 46.66 minutes for parking 24. 28.95 % of On-street parking and 62.5% of Off-street parking have average parking duration above 100 minutes. This depicts a higher average parking duration for off-street parking.

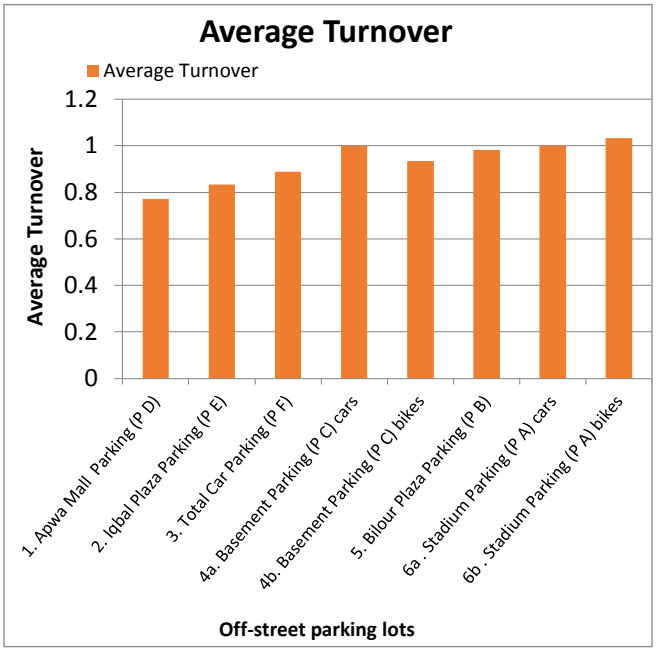

Figure 18- Off-street parking turnover illustrated from 1 to 3 pm

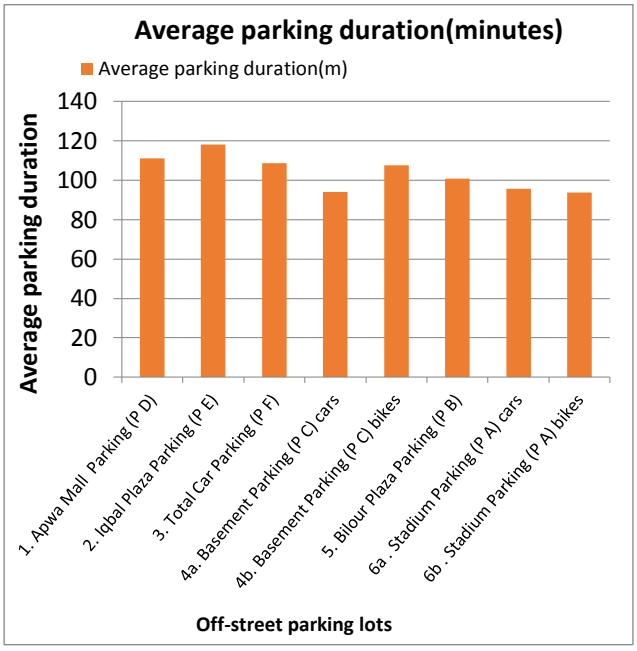

Figure 20- Average parking duration of Off-street parking illustrated from 1 to 3 pm

Table 2- Average parking turnover and average parking duration of off-street parking

S. No	Names	Average Turnover	Average parking duration(minutes)
1.	Apwa Mall Parking (P D)	0.77	111.11
2.	Iqbal Plaza Parking (P E)	0.83	118.2
3.	Total Car Parking (P F)	0.88	108.75
4a.	Basement Parking (P C) cars	1	94
4b.	Basement Parking (P C) bikes	0.93	107.67
5.	Bilour Plaza Parking (P B)	0.98	100.83
6a.	Stadium Parking (P A) cars	1	95.62
6b.	Stadium Parking (P A) bikes	1.03	93.87

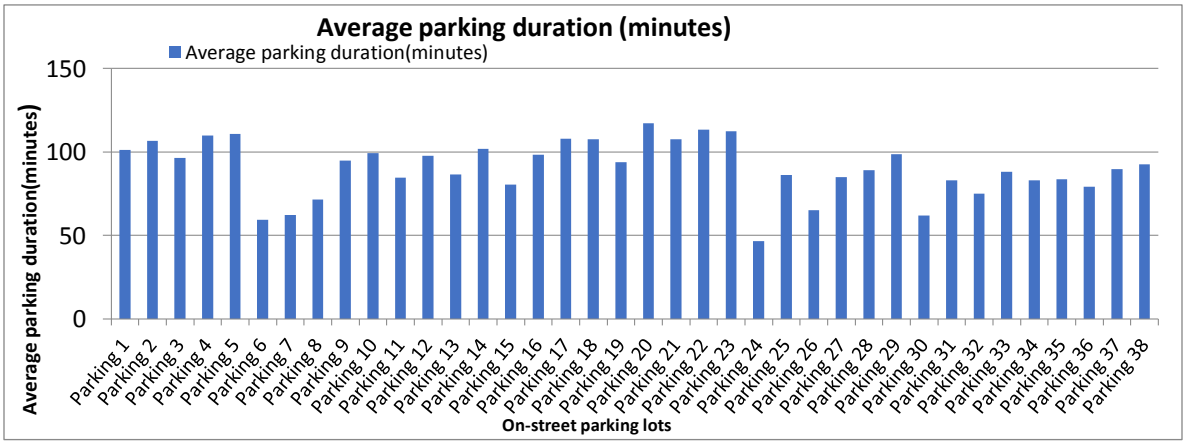

Figure 19- Average parking duration of On-street parking illustrated from 1 to 3 pm

IX. MAJOR PROBLEMS FOUND

- Fixed parking fee is charged for both On-street and Off-street parking which encourage drivers to park for larger duration hence a lower turnover was observed, also this fixed fee generates less revenue as once the drivers pay, they can park for the whole day.
- Vehicles are parked irregularly in both On-street and Off-street parking which decrease the capacity and hence increases parking demand.
- Parking and unparking of vehicles in on-street parking hinders through traffic and causes accidents.
- No parking bays are reserved for disabled persons.
- Street vendors are everywhere and hinder the parking as well as through traffic vehicle movements.
- Shopping centers and offices that does not have their own private parking, also rely on On-street parking, resulting in high on-street parking demand as compared to off-street demand.
- Parkers do not consider the parking markings and park in every direction which decrease the parking capacity.
- Parkers do not follow rules and policies strictly and mixed parking of bikes, cars and other vehicles were observed throughout the parking survey period.
- Drivers having business in the other side of CBD are not willing to park in the Off-street parking due to the large walking distance, thus they prefer to park On-street, consequently increasing the On-street parking demand comparatively to Off-street parking in peak hours. Off-street parking are not distributed evenly throughout CBD.

Figure 21- (A) Despite of No parking sign parked vehicles can be seen, (B) Van parked in bike specific parking, loading/unloading and free movement of pedestrians on roads without zebra crossing, can be seen in the background, (C,E) Mixed parking with different angles in car specific parallel parking on Saddar road, (D) Bikes and rickshaws parked in irregular pattern in a car parking on Sunehri masjid road, (F) Mixed irregular parking in a bike specific parking on Saddar road with street vendors sitting in the parking lot.

X. RESULTS

- Occupancy was high for On-street and low for Off-street parking.
- On-street and off-street parking turnover difference was not considerable. On-street parking turnover was a bit higher than Off-street however the overall turnover was still low for both on-street and off-street parking. Turnover should be higher for On-street parking in CBDs to encourage short term parkers.
- Off-street parking depicts higher average parking duration than on-street parking.
- Mostly higher demand was observed on parking situated on major arterials.
- Off-street parking are situated at one side, while On-street are distributed throughout the CBD.

XI. CONCLUS IONS:

- On-street parkers should be encouraged to park in Off-street parking as occupancy was high for On-street and low for Off-street parking.
- The number and capacity of Off-street parking should be increased to cope with the high peak parking demand, this will also relieve On-street parking demand.
- Off-street parking should be rearranged and distributed evenly throughout Saddar as all of them are located at one side of the CBD, i.e. Saddar and Stadium road.
- The parking fee should be variable for different hours of the day, and it should be increased for On-street parking in peak hours to regulate the high demand.
- Irregular and mixed parking should be avoided to increase capacity.
- Enforcement policies should be made stricter, and illegal parkers should be fined.
- Traffic jams were found mostly in the vicinity of angled parking as they acquire a large portion of road width thus all the perpendicular and other angled parking should be converted to parallel parking to increase road capacity for through traffic and prevent traffic jams in peak hours.
- Provision of two Off-street multistory parking plazas at both ends of the CBD will be a viable solution to relieve the high On-street parking demand. This will also equalize the demand for On-street as well as Off-street parking.

XII. RECOMMENDATIONS

- Variable parking fee should be charged for different hours of the day to regulate high parking demand in peak hours.
- High parking fee should be charged in peak parking demand hours for On-street parking and low for Off-street parking to discourage On-street and encourage Off-street parking. It will also decrease cruising for parking on streets and hence will decrease congestion and traffic jams in peak hours.
- Street vendors should be removed from the vicinity of On-street parking so that there are no hurdles for drivers while parking and unparking.
- Strict actions should be taken by law enforcement agencies to avoid illegal parking in the second and third rows in on-street parking.

XIII. REFERENCES

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