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Evaluation of Parking Characteristics: A case study of Delhi

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Abstract

In major cities, as the development goes on, the parking generation rate increases rapidly which leads to major parking problems. A study has been carried out in Delhi to study the parking characteristics and to measure the adherence to parking guidelines. Parking surveys have been carried out at nine sections, typically at commercial and shopping areas in Delhi. On-street and off-street parking characteristics were analyzed considering the parking statistics which includes parking accumulation, parking occupancy, parking load, average parking duration, parking index/parking efficiency. Some areas, even having sufficient parking capacity suffered from congestion due to improper management and lack of availability of required signs, marking of bays and other smart techniques. As a result of analysis, the peak parking saturation values at P1 and P3 parking at Nehru place came 0.97 and 0.98 respectively which shows optimal utilization of parking. According to total volume study at Nehru place, the peak parking saturation is 3.25 and 6.21 for car and bike respectively which shows high spill over condition. Also at Bhikaji cama place back side parking and Atta market bike parking shows spill over condition as per study. At Kamla nagar market, parking space is well utilized. Observing the study outcomes, some guidelines has been suggested for optimal utilization of available space. Study outcomes will be helpful for engineers, planners and policy makers.

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Keywords: Parking characteristics; Parking statistics; Demand-Capacity ratio; Accumulation; Policy guidelines

1. Introduction

With rapid growth of the metro cities all over the world, the parking generation rate goes on increasing very rapidly which creates major problems of parking in most of the urban areas. In the recent years, with the rapid development of economy and rapid increase in the vehicles, parking problems in urban areas of metro cities have become increasingly prominent. Delhi is one of those cities located in India. It has a population of about 1.67 crore (census

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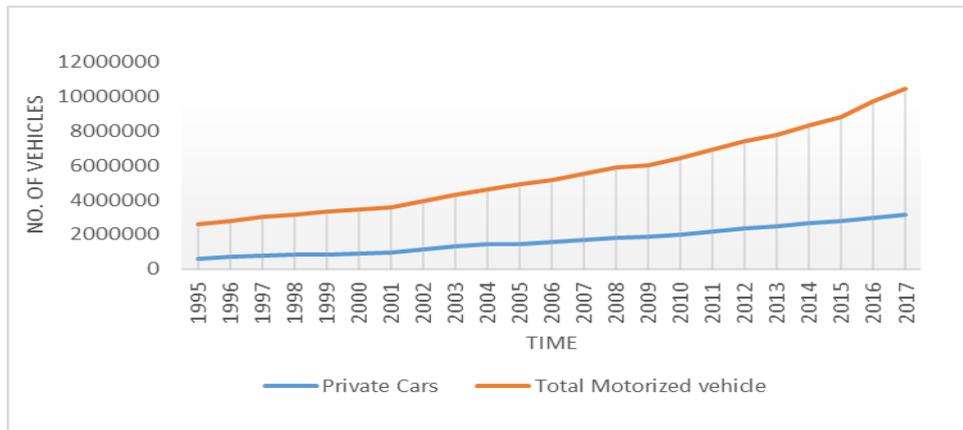


Figure 1 Vehicular growth in Delhi Region

(Source: Delhi Statistical Handbook)

India, 2011) and has more than one crore registered vehicle (Transport dept., NCT of Delhi, 2017), which is more than double a ten years back. The city is located in northern region of India having an area of 1,484 sq.km and is the largest commercial center in northern India. The ingress of traffic from the nearby NCR towns also adds significant traffic congestion to Delhi. Interestingly, the population growth in Delhi is 1.4% but the vehicular growth is around 7%. The growth of vehicular population from past years is shown in the figure 1. It has been observed that in many areas of the Delhi that due to improper parking system and facilities, the demand cannot be fulfilled by the available supply of space for parking. This will create a spill over condition at some locations. Also, there is common problem of illegal parking on the curb itself due to lack of parking space and improper management, which reduces the effective carriageway width of the road and affect the speed of the through traffic. It is also a common problem in Indian cities that most of the parking lots are not marked properly, i.e. there is no available parking bays for vehicle, which leads to haphazard parking and ultimately the efficiency of the parking space reduces considerably. In India, very limited studies have been done regarding parking characteristics and measures adherence to parking policy.

In this study, the problematic parking locations have been selected in Delhi-NCR to provide solutions which will help to reduce problems. Different field surveys and parking inventory has been conducted to study various parking statistics and also the demand and supply of parking areas have been considered.

2. Literature Review

Car parking is an issue of significance both at local and at strategic level planning (William, Russell & Michael, 2013). In order to make a firm parking policy, it is desirable to study the parking behaviour and characteristics properly. Number of studies has been done on parking in the past, such as estimation of parking accumulation profiles from the survey data by the cluster analysis technique (Tong, Wong & Leung, 2004) which states that parking supply is an effective means to restrain the car ownership and usage, however acute shortage of parking might drive away commercial and other activities. Shoup (2006) shown that even a small time for searching a curb space for parking will create considerable amount of traffic. Also, the search time increases approximately 20 percent in the commuting time (van Ommeren, Wentink, Dekkers, 2011). High number of on-street parking spaces along the major road in the urban area affects local traffic operations, especially when traffic is large (Zhenshan, Zhirong, Yi, 2014). They proposed a solution of “Division, Construction, Adjust & Share” for parking management to the Wujiang district’s urban parking problem. Paul C. Box (2004) studied the hazard and congestion due to on-street parking, specially the angular parking, which is useful for the local officials and planners to improve the safety and operation of the traffic. Since, the old areas are pre-planned, there is limited parking spaces available which creates spill over. Shuang Li, Ru-Hua Zhang, and Yue-Chun Ge (2017) have carried out the comprehensive survey and analysis of parking facilities in old community in Jinan, China and used the parking supply model based on livable environment to determine the

suitable scale of parking supply. A study based on stated preference survey was undertaken by David and Jenny in 1999 to investigate the role of parking pricing and supply as well as the location of parking lot on the demand of the parking in the particular area of the Sydney central business district.

In many urban areas, the illegal parking is also the common problem which is hazardous to traffic safety. Also, haphazard parking due to lack of parking space marks leads to inefficient utilization of the parking lot area. In Greece, the analysis had been carried out (Christina and Constantinos, 2012) regarding the illegal parking behaviour in six different cities for which the data has been collected in the year of 2010. In that, three cities are taken in Athens and other three are smaller Greek cities. It is seen that illegal parking is more in big urban cities due to saturation of parking spaces and also the tendency to park as near as possible to the destination. One of the major solution to reduce the demand for parking is to reduce or stable the private car ownership and mode shift from private car to public transportation. Parking fee is one of most influencing factor for the mode shift. The study of willingness of people to shift from private car to public transport has been done by Kian Ahmadi Azari et al. (2013) in CBD area of Mshhad (Malaysia). They found the elasticity for search time (0.182) greater than that for egress time (0.083) that means demand is more sensitive to the search time.

Recently, Qun Chen et al. (2015) have studied the characteristics of parking in Central Shanghai of Shanghai city, china. The authors have classified the whole survey area based on the land use and analysed parking facilities for the same. Authors also suggested the parking policy for different areas and to use the modern techniques in parking to balance the parking facilities types and to provide choice to parking users.

3. Methodology

The parking demand is directly related to the land use of a particular area. It is common that commercial area having large number of offices will require large space for the parking because the people coming in the offices by private vehicle park their vehicle throughout the day and also the extra space for visitors. The area having market place having fluctuating demand throughout the day depending upon the requirement of the visitors. The demand for parking at weekend will be higher compare to week days. The different types of areas having different land use have been selected as study area in Delhi region such as commercial and business-oriented area, market area. The location of this areas has been shown in the figure 2. These are the areas having problems of spill over, haphazard parking, violation of enforcement rules and illegal parking, parking on carriageway which are mainly arises due to improper parking management, insufficient parking space at some locations, absence of required signs for parking, tendency of the drivers to park the vehicle as near as possible to the final destination, indecorous utilization of the available parking space. So that these locations have been selected to as a study area to



Legend: 1. Bhikaji Cama Place; 2. Nehru Place; 3. Kamla Nagar market; 4. Atta market, Noida.

Figure 2 Location of study areas in Delhi

analyse and evaluate the parking characteristics and also to suggest the parking guidelines for the same. The procedure followed regarding the data collection is described in the further section of this paper. Different type of field survey required for parking like In-Out survey, license plate survey and parking inventory survey have been carried out to

collect the data. 12 hours data was collected at weekdays to study the typical characteristics. A detailed analysis have been done to evaluate different parking characteristics. Finally, the parking guidelines have been suggested based on the observation and analysis.

3.1. Study area

For this study, the parking locations in different areas of the Delhi have been selected which are having different land use like shopping, business-offices and market areas. The map of Delhi as well as the location of study areas in Delhi metropolitan city is shown in figure 2. The study areas were selected based on its importance and type of activities. Bhikaji Cama place is mainly the business area having private and public sector offices. Many buildings in this area having appertaining parking at the ground floor level itself and servers the parking needs of the people working in those buildings. Other off-street parking lots are available for visitors having short term parking requirements and for office employee as well. The Nehru place area is big commercial market of electronics items as well as having large number of offices, so the parking demand in this area is high throughout the day. Also the multi-storey parking is available over here which is managed by the private authority. Both of this areas having paid parking, for which parking price vary according to duration. Kamla nagar market is a live market place where parking demand occurs mainly due to the shoppers and some steady parking for shop-holders for which vehicle remains at same parking space throughout the day. At this place, only on-street parking is available for mixed traffic without bifurcation of different category of vehicle. Since it is market place, the demand fluctuation is more and most vehicles are parked for short time duration. Fourth study area is Atta market, which is also a large market place situated in Noida. Here also the parking is available on road itself. Here bifurcated parking for two-wheelers and cars is provided. Parking demand for two-wheelers remains very high at this place.

3.2. Data collection

The data required for the study were collected by the field surveys like In-Out survey, license plate survey, etc. The data were collected on the normal week days of November, 2017 to analyse the typical situation. For each area, the data were collected for from 08:00 am at morning to 07:30 pm at night. A general survey form has been designed to record the time and license plate number of the vehicle. In the In-Out survey, the data have been recorded as entry and exit time of each vehicle with license number plate. Also, the number of vehicles that enter a parking lot and exits from a parking lot has been recorded at each half an hour interval. Two persons, one at entry gate and one at exit gate are required for this survey. In the license plate survey, the parking lot was monitored at half an hour interval by recording the registered license plate number of each vehicle that occupy a particular space. This data helped in calculating the duration for which the parking space is utilized. Also the parking inventories has been carried out to find out the total supply/capacity of the parking lot.

4. Parking Characteristics Analysis

Before describing the analysis, some important definitions regarding the parking statistics illustrated as follows should be considered (Dr. Tom V. Mathew, 2014; Qun Chen, 2015):

1. **Parking accumulation:** Parking accumulation is the number of vehicle parked at any given instantaneous time. Normally it is conveyed through accumulation curve. Accumulation curve is the graph obtained by plotting the number of vehicles parked with respect to time.
2. **Peak parking saturation:** It is the ratio of the number of vehicles parked at peak time to the capacity of parking space in terms of number of bays.
3. **Parking volume:** Parking volume gives the value of total number of vehicles parked for a given time duration or survey period. The repetition of same vehicle is allowed, i.e. each unique vehicle is counted. The actual volume of vehicles entered in the parking lot is recorded.
4. **Parking load:** Parking load is the total area under the accumulation curve. It is also obtained by multiplying total number of vehicles that occupies the parking space at each time interval with that interval. It is stated as vehicle-hours.

5. **Peak parking ratio:** It is the ratio of numbers of vehicles parked at peak time to the average numbers of vehicles at each time.
6. **Average parking duration:** It is the ratio obtained by dividing the parking load (vehicle-hours) by the total parking volume throughout the survey period.
7. **Parking turnover:** It is a measure of occupancy of particular bay in a parking lot, which is obtained by dividing the number of parked vehicles for a given duration by total number of available parking bays. It can be designated as number of vehicles per bay per time duration.
8. **Parking index:** Parking index is a measure of efficiency of parking space. It is defined as the ratio of total number of vehicles parked in a time duration to the total space available that is capacity. It gives as aggregate measure of how effectively the parking space is utilized.

The parking characteristics of different areas have been tabulated in following description. Also, the plots for parking accumulation curves and parking Demand to Capacity ratio (D/C) for the same are shown.

It can be observed from the table 1 that the peak parking accumulation is lower than the actual capacity of that parking lot. The values of parking index shows the efficiency of parking lot, which are lower than 1 for all three parking lots, which indicates that sufficient parking space is available. Even though, due to improper management and absence of proper designed parking, there is scarcity of parking at this accumulation, mainly in case of two wheeler parking. The accumulation curve for the parking lot P1 shows the peak time at evening. Average duration for parking vehicle at all three lots lesser than even 4 hours, so it is possible to say that most of the vehicles are of short term visitors only. The accumulation curves for parking lots P1 and P2 demonstrates that there is more fluctuation for a given duration of time of the day, which is mainly due to the visitors because the vehicles of the employee working in the offices will not be removed during working time. There is no substantial fluctuation in the profile for parking lot P3. The profile curve represents the value of Demand as a percentage of total Capacity of a particular parking lot. Obviously, the accumulation profile will vary according to the fluctuation in the demand at that parking lot. Parking index values are well low below 85% which shows low efficiency of parking.

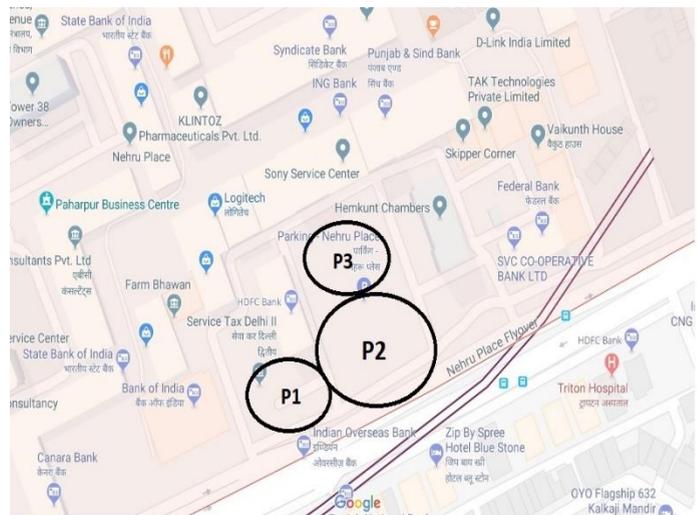


Figure 3 Parking location at Nehru Place

Table 1. Parking Characteristics at different parking lots of Nehru Place

Parking Statistics	P1(car)	P2(car)	P3(bike)
Peak Time	16:00-16:30	13:00-13:30	15:00-15:30
Peak Parking Accumulation	95	97	320
Peak parking saturation	0.97	0.45	0.98
Average Parking Accumulation	52.63	55.92	218.12
Peak parking ratio	1.80	1.73	1.47
Average Parking Duration(min)	115	190	139
Parking Index (%)	53.71	26.37	67.11

Table 2 describes the parking statistics for the total gate volume study, which has been collected through In-Out

survey conducted at Nehru Place street parking lot having the only entry and exit gates. It can be seen from the accumulation curve that number of parked vehicles increases at the starting of the day gradually, reaches a peak (15:15 for car & 16:45 for 2-wheeler) and decreases after that. Here, the problem arises for the peak saturation which is far more than the unity that creates spill over condition due to insufficient parking space. Even the average parking accumulation is too high than the capacity of the parking area. Here also the average parking duration is between 2-3 hrs which indicates the predominance of short term parkers. Parking index is greater than 100% because of accumulation of vehicles is too high than the capacity.

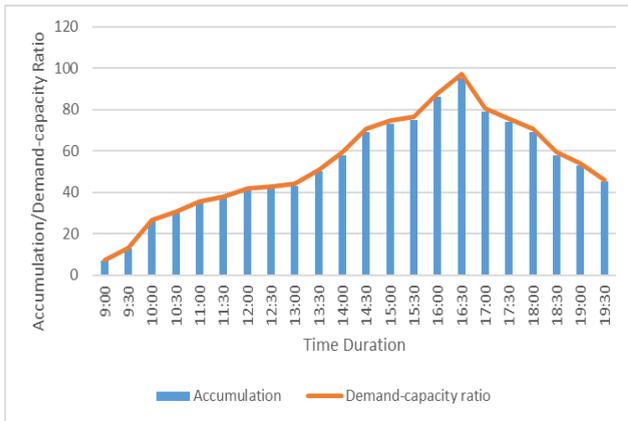


Figure 4 Parking accumulation and D/C ratio curve for P1

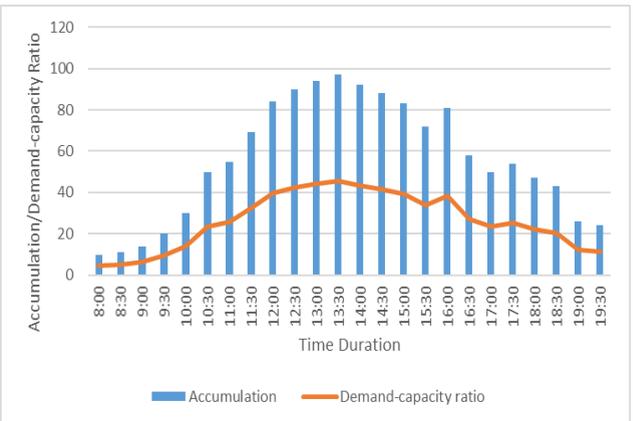


Figure 5 Parking accumulation and D/C ratio curve for P2

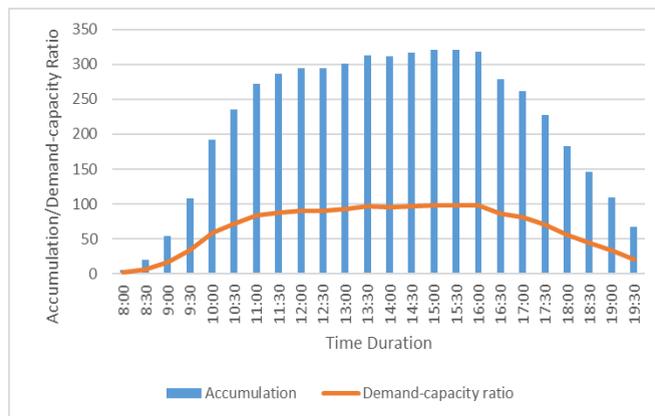


Figure 6 Parking accumulation and D/C ratio curve for P3

Table 2. Parking Characteristics for total volume of Nehru Place

Parking Statistics	Car/Jeep	Two Wheeler
Peak Time	15:15-15:30	16:45-17:00
Peak Parking Accumulation	1009	2017
Peak parking saturation	3.25	6.21
Average Parking Accumulation	674.66	1376
Peak parking ratio	1.49	1.46
Average Parking Duration(min)	176	153
Parking Index (%)	217.63	423.38

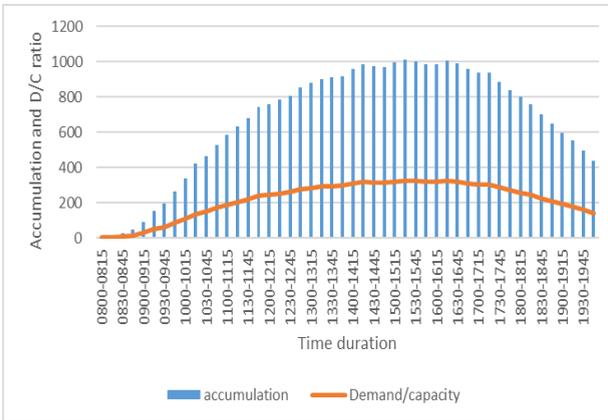


Figure 7 Parking accumulation and D/C ratio curve for Cars/Jeep

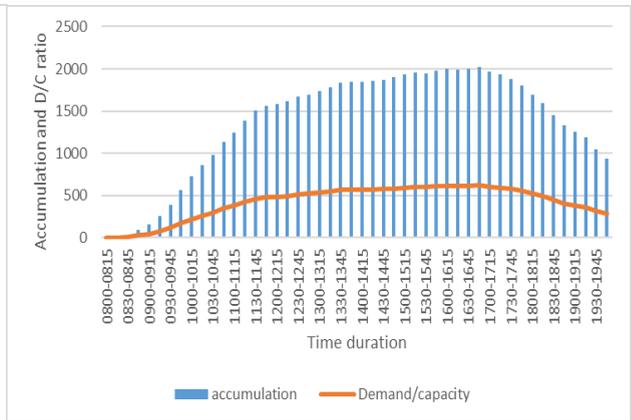


Figure 8 Parking accumulation and D/C ratio curve for two wheeler

Table 3 below describes different parking characteristics for the data collected at Bhikaji Cama Place for on-street parking. . It can be seen from the table that peak parking saturation at back side of the location is more than 1 (1.12), which is clear indication of the insufficient parking space. For other two lots, the peak saturation value is less than unity, i.e. sufficient parking space is available. The average parking duration values shows around 2 hours, which shows that on-street parking facilities at this area is mainly occupied by the visitors that are short duration parkers arriving for the small business works. Figure 13 indicates that most number of cars are parked for half or less than half hour duration. Parking index value for back side is 77% which shows that parking space is well utilized. For other two, values are lower than 85%, which shows parking space not efficient.

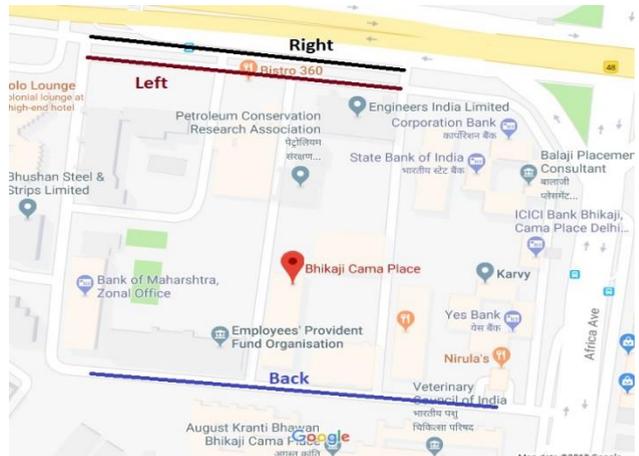


Figure 9 On-street parking at Bhikaji Cama Place

Table 3. Parking Characteristics at different parking lots of Bhikaji Cama Place (On-street)

Parking Statistics	Back	Right	Left
Peak Time	13:00-13:30	16:00-16:30	13:00-13:30
Peak Parking Accumulation	149	64	75
Peak parking saturation	1.12	0.63	0.83
Average Parking Accumulation	101.7	38.04	52.75
Peak parking ratio	1.46	1.68	1.42
Average Parking Duration(min)	113	93	98
Parking Index (%)	77.05	42.26	58.61

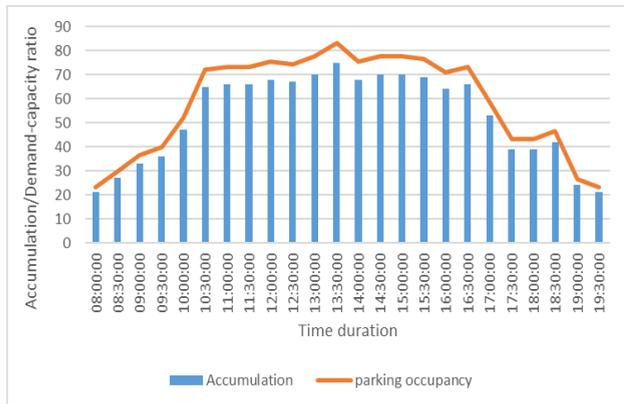


Figure 10 Parking accumulation and D/C ratio curve for back side parking

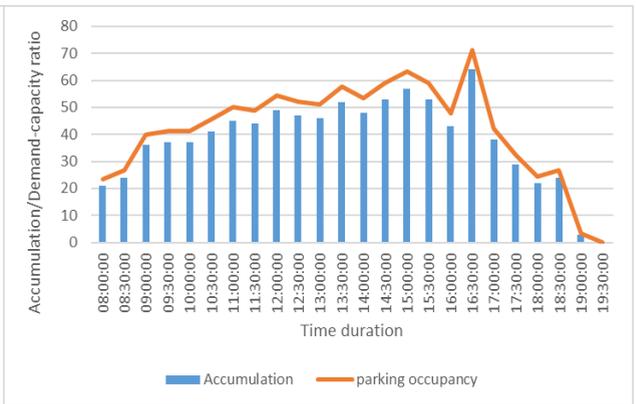


Figure 11 Parking accumulation and D/C ratio curve for right side parking

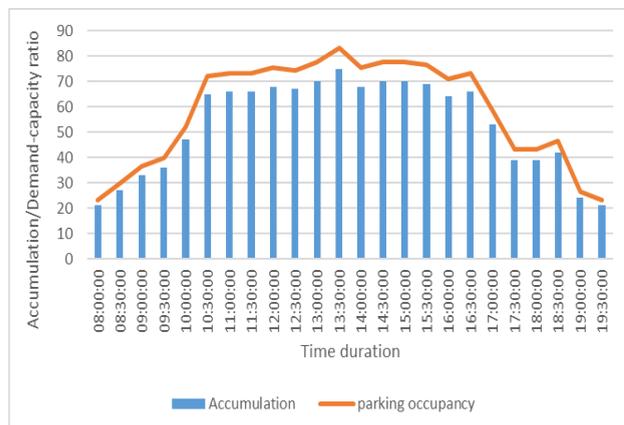


Figure 12 Parking accumulation and D/C ratio curve for left side parking

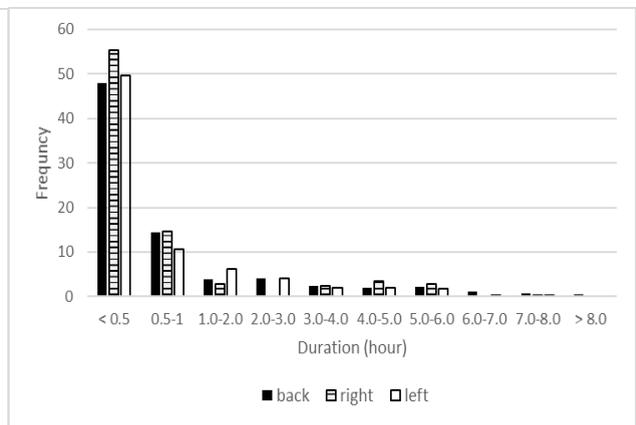


Figure 13 Parking Duration distribution for all three parking lots

Table 4 shows the parking characteristics of the Atta market which is mainly the shopping area. Only on-street parking is available at this place. It is seen that sufficient amount of parking space is available over here for cars but as shown in the table 4, the peak parking saturation for two-wheelers parking far more than 1 that creates spill over

condition.

Table 4. Parking Characteristics for on-street parking at Atta Market

Parking Statistics	Car	Two wheeler
Peak Time	16:30-17:00	15:00-15:30
Peak Parking Accumulation	97	303
Peak parking saturation	0.87	3.22
Average Parking Accumulation	59.96	181
Peak parking ratio	1.62	1.67
Average Parking Duration(min)	79	82
Parking Index (%)	54.02	192.64

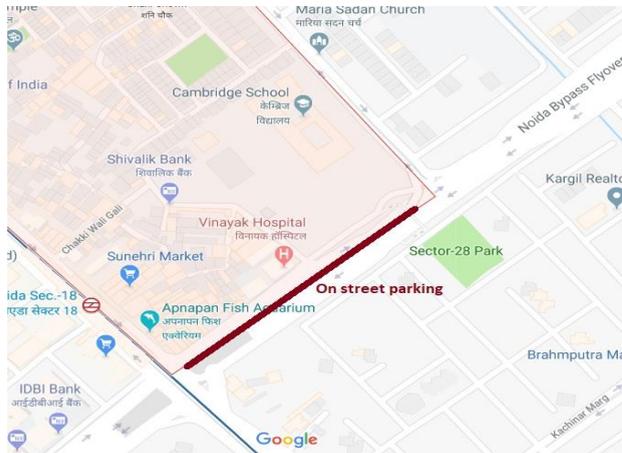


Figure 14 On-street parking location at Atta market

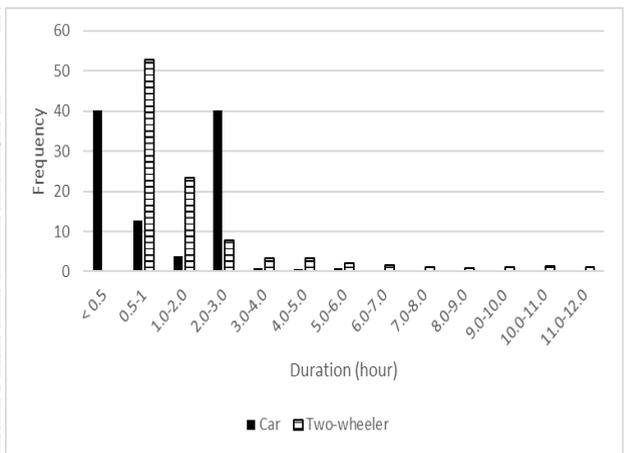


Figure 15 Parking duration distribution for car and two wheeler

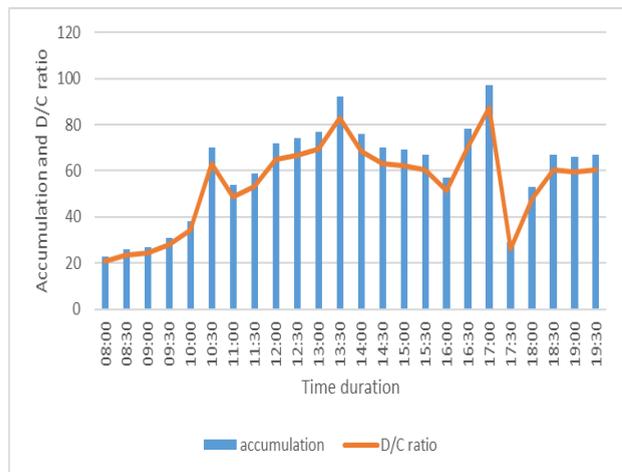


Figure 16 Parking accumulation and D/C ratio curve for cars

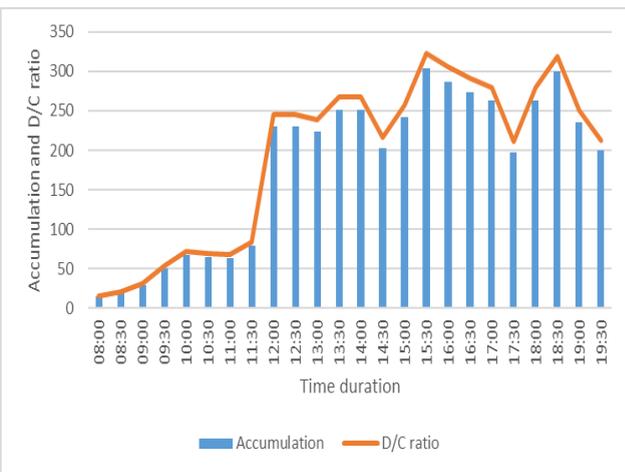


Figure 17 Parking accumulation and D/C ratio curve for two-wheeler

From the figure 15, it is clear that more than 50% of the two wheelers are parked for the duration of 0.5-2.0 hours that are the people come for shopping in this area. It shows that there is less demand in the morning (08:30-10:00), but after that it goes on increasing and reach the peak between afternoon and evening and again decreases. It can be seen from the accumulation profile for two-wheelers parking that there is drastic increase in the demand at afternoon at 12:00 (figure 17). As an effect of spill over, the illegal haphazard parking occurs on the road, which reduces the speed and also the safety for the through traffic. The speed and delay study over here shows that there is delay of 31 sec, 39 sec and 49 sec at the time of 10:00, 14:00 and 19:00 respectively.

Another on-street parking study has been done at Kamla nagar, between Kamla nagar market gate to Spark mall and estimated parking characteristics is described in table 5. Here, Equivalent Car Space index is used to convert the space required for the two wheeler parking into equivalent car space (IRC: SP: 12-2015). Then the accumulation profile and curve for demand to capacity ratio is plotted (Figure 20 & 21). The land use at Kamla Nagar is for market and shopping area. So, it is common to see that the duration for parking will be less, which is clearly justifiable from the figure 19 that shows that about 80% of the total vehicles occupies a particular parking space for maximum of 1 hour duration.

Table 5. Parking Characteristics for on-street parking at Kamla nagar

Parking Statistics	Left side	Right side
Peak Time	19:00-19:30	18:00-17:00
Peak Parking Accumulation	34.75	38.5
Peak parking saturation	0.77	0.85
Average Parking Accumulation	22.67	20.24
Peak parking ratio	1.53	1.90
Average Parking Duration(min)	39	26
Parking Index (%)	50.37	44.98

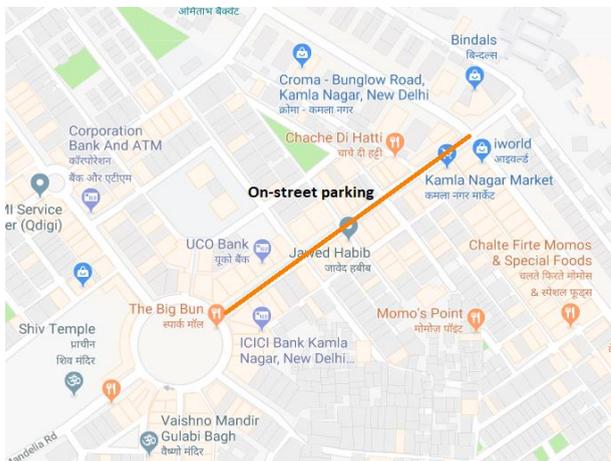


Figure 18 Parking location at Kamla Nagar market

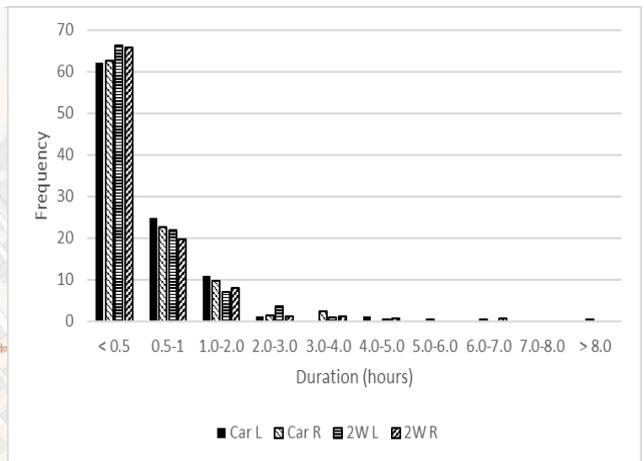


Figure 19 Duration distribution for different parking

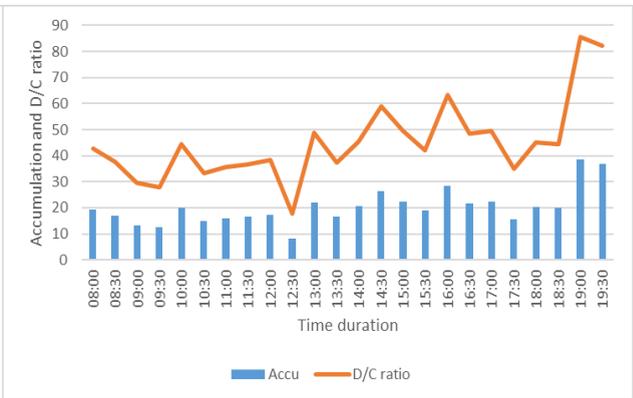
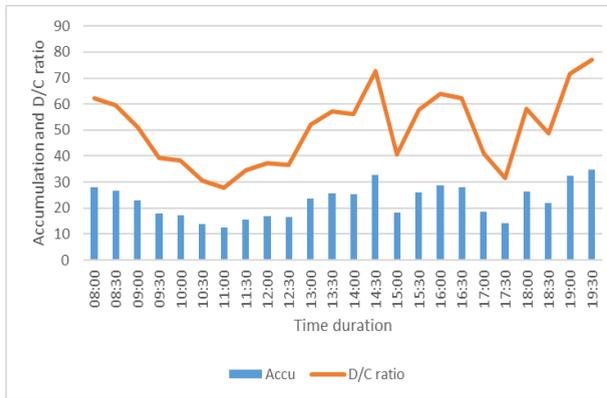


Figure 20 Accumulation and D/C ratio for left side parking

Figure 21 Accumulation and D/C ratio for right side parking

5. Results and Discussion

A detailed analysis of parking characteristics of different area and having different type of facilities have been carried out, which shown in the foregoing section. It is observed that at Bhikaji Cama place as well as Nehru place commercial parking, the space is just sufficient to assimilate the demand except back side on-street parking at Bhikaji Cama place, where spill over occurs at afternoon time. There is required to provide more space for parking. Also at Nehru place, peak parking saturation for P1 and P3 is about one (0.97 and 0.98 respectively), that means there will be requirement of more parking space in future due to increasing growth of private vehicles day by day. Analysis has also been carried out for total volume of vehicles using parking space at Nehru place, which has very high spill over throughout the daytime. But the authority has managed to accumulate as many vehicles as possible into the available parking space at the cost of rules and regulations of the existing parking policy. Same situation occurs at Atta market on-street parking for two-wheeler for which peak parking saturation is 3.22. It encourages the illegal parking, which has negative impact of the safe traffic operation. While the on-street parking for cars are well utilized over here which has saturation of 0.87. On-street parking at Kamla nagar market has saturation of 0.77 and 0.85, which also shows the well utilization of available parking facilities and supply is sufficient to fulfil the existing demand.

From the above study and inventory, it is clear that improvement in the existing condition is require for optimal utilization of available space. At Nehru place, it is require to increase the capacity of the surface parking lot. The provision of multi-storey parking is require to increase the supply to avoid the new land acquisition for the parking. It is always seen that the driver first prefer to use the on-street parking to park the vehicle as near as possible to the destination. Less walking time, difference in parking price, less time for park (on-street parking is easily accessible than off-street one), less duration for parking are the main factors in the mind of drivers which leads them to use on-street parking. The balance between on-street and off-street parking should be maintained. Parking price differentiation and proper guiding and information system are the two main aspects which the planner and policy makers should keep in mind. Currently the parking price in the studied area for both type of parking facilities are same. It is suggested to keep higher parking fees for on-street parking in compare to the off-street parking lot. Also there should be cumulative increase in the fees with respect to the duration of time of parking. That will encourage the long-term parker to use off-street parking lot rather than go for on-street. Also the parking price should be kept in such a way that it has positive impacts on effective utilization of parking space. It is recommended to set the price to maintain 85-90% occupancy rate, which is called *performance-based or responsive pricing* (D. Shoup, 2005).

It has been observed many times that due to lack of knowledge and information regarding the off-street parking facilities, drivers are unable to find empty parking space in a lot. They see the situation from the gate itself and if not

found the space, they proceed further to search parking or park illegally or park at on-street parking if available. In the past studies, Arnott and Rowse (2009) have found out that the cars searching for parking contribute 14 percent of the traffic density and generate 50 percent increase in the congestion related time-loss. Shoup (2006) also estimated that 30 percent of the traffic on an average searching for the traffic after study of 11 US cities, with an average search time of 8.1 minutes. So, it is necessary to implement proper information system to reduce the search time as well as to encourage the use of off-street parking over curb parking. It is being suggested to establish digital or manual board at the entry of parking lot, which provides the information regarding the status of parking space and number of available empty parking space. Provision of parking meter is also a better way to regulate the parking area. Also the management authority is suggested to proportionate the figures of on-street and off-street parking demand and draw the drivers who require- long-term parking towards off-street parking lot and short-term parking towards on-street parking facilities.

In most of the Indian cities, there is no proper marks for parking, as we have observed in our study. It leads to indecorous and haphazard parking at both type of parking facilities which impacts ineffective utilization of available parking space. It encourages the drivers to park illegally in case of curb parking, which reduces the effective carriageway width and traffic flow speed. Indian road congress has published the latest IRC:SP:12-2015, in which, the parking design with proper marking and required signage. But it is not properly followed by most of the cities in India. The planners are suggested to follow the guidelines given by the IRC and policy makers should also keep in mind while making policy. Han et al. (2005) have shown in their study that illegal commercial vehicle parking causes approximately 47 million vehicle-hours of delay each year in the US, which is the third most influencing factors for delay behind construction and crashes. Same situation also prevailing in India. So, planners are suggested to design proper parking lots with require signs and markings and also policy makers are suggested to make a firm policy which includes the provisions regarding enforcement against illegal parking.

It is also suggested to make a policy which stable or reduces growth rate of vehicles and encourage the use of public transportation instead of private vehicles. It is suggested to make a parking fare accordingly so that there is reduction in the use of private vehicles in the city. In Hong Kong city, only 7 percent of the total commuters travel by the private car (Travel characteristics survey, 1993). This is because of the low rate of car ownership and high parking charges levied at the working place. Thus, this type of policy effective one to reduce the car ownership and their usage in the city. The price elasticity of trips generated by vehicles with respect to fees levied for parking is typically between -0.1 to -0.3, i.e. there will be 1-3% reduction in the vehicle trips when increasing 10% in the parking price, depending upon the conditions (Litman, 2009). The charges of park should be determined based on the land value at a particular area or the rent that is being charge for the same. Low usage of private car and promoting the use of public transport is also the better aspect from equitable transport point of view. Policy makers should note that “Role of Transportation is the movement of people and not the vehicles.”

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