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A Case Study on On-Street Parking Demand Estimation for 4-Wheelers in Urban CBD

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Abstract—*Lack of parking policy has become one of the most important aspects of transportation. The parking issue is trending all around the world especially in central business district (CBD). Metropolitan cities are affected mainly by this problem. Kolkata is one of the largest and oldest metropolitan cities in India which is also affected by the parking problems. Insufficient off-street parking facilities and tendency to park the vehicles near to the destination lead to high parking demand. The vehicle ownership and the poor quality of transit system are also the reasons for increase in demand. These factors result in reduction of the main carriageway width, decrease in flow speed and creates unnecessary congestion to traffic flow which creates cruising of parking. Proper parking management policy should be implemented to control the demand. In this study, two CBDs- Gariahat (one of the largest shopping area) and Dalhousie (one of the largest office area) have been selected as the case study area. In this study a parking demand model is developed to estimate the parking demand. Parameters like age, vehicle ownership, parking duration, annual family income, distance between origin and destination are incorporated to generate the demand model. Some field surveys like in-out survey and questionnaire survey were conducted to obtain the data for above mentioned parameter. The parking demand model is generated by linear regression analysis in SPSS. Further the estimated demand is compared with the existing supply.*

Keywords*: CBD area, accumulation profile, parking supply, parking fees, parking duration, parking demand, SPSS.*

1. INTRODUCTION

Over the last decade, a noticeable change has been found in the growth of urbanization in India. As the population growth is increased day to day, the use of transportation system is also increasing. But the urban transport problems degrading due to lack of organized urban road network, inefficient transit system. The economic and commercial growths are mainly observed in the core of the urban area i.e., CBD. A good transportation system must be implied to obtain the mobility in traffic movement. The on-street parking is one of the main reasons for cruising of parking in CBDs which creates congestion and resists the traffic flow. Due to the convenience of the people (in terms of availability of all needs), they prefer to visit CBDs to fulfill their requirements. The parking issue is prominent mainly in metropolitan cities. So, a metropolitan city, Kolkata is chosen as the case study area for this study.

Kolkata is one of the largest and oldest metropolitan cities in India. Due to dense population and dense industrialization, Kolkata CBD areas are also facing the same transport problems. The land use pattern of Kolkata is mainly concentrated in CBDs. Due to the less scattered land use pattern in other part of the city the maximum parking demand is generated in CBD. The growth of Kolkata will staged if we fail to manage the traffic movement of CBDs. As the parking issue is the main reason for resisting the traffic movement, the study is focused to manage the parking demand.

2. OBJECTIVE

The objectives of this study:

a. To generate the parking demand model and
b. To compute the parking demand and compare it with the present supply.

Many research works have been done earlier. A number of research papers are studied to fulfill the objectives. The findings of some of the related papers are briefly described in section 3.

3. LITERATURE SURVEY

Many research works on parking have already been done in past few decades. A number of papers have been studied to get the knowledge about the topic of parking demand analysis. The brief knowledge of the studied papers is discussed in the next few paragraphs.

In the year 2000, simple parking demand models were developed in Hong Kong by S. C. Wong, C. O. Tong, Wilkie C. H. Lam and Rayson Y. C. Fung [1] to calculate the future parking demand of the study area. The model was developed assuming linear and additive relation of off-street parking with land use variables.In 2001, role of parking price and supply in parking demand was investigated in Sydney CBD area by David A. Hensher, Jenny King[2]. They developed nested logit

model to represent the parking demand. They have considered two other important factors, viz. parking price and supply of parking space. The analysis concluded that parking price holds an important position over parking space supply in influencing a vehicle owner to park at a particular parking lot. Parking availability and cost of parking was also found out to be the vital parameter in parking demand of an area in a survey conducted in Hong Kong in 2004[3]. The accumulation profile of the vehicles in the parking lot was determined using snap shot method of survey which required less time and also was cost effective. In 2005, Xiuyuan Zhang, Yaming Shao, Youmei Wu And Xiufang Li[4] studied parking behavior of a vehicle on the basis of number of parking space, attractive property of the destination, parking scale and management measure relation. Here they have added the building attractive property along with the number of parking space and price to analyze the parking demand. In 2010, Huanmei Qin, Qing Xiao, Hongzhi Guan and Xiaosong Pan[5] studied the effect of public transport accessibility on parking demand of commercial buildings in Beijing. It was observed that up-to certain level, the parking demand decreased significantly when transit accessibility index increased. But the decrease in parking demand was not significant when the accessibility index increased beyond that level. Sandip Chakrabarti and Taraknath Mazumder[6] in 2010, have considered almost all the important factors that influence parking demand while formulating the relation. The parameters they considered were, age, income, family size, distance traveled, travel time, search time, ease time and cost. The level of influence of each parameter on parking was also described in this paper. "The Model of Parking Demand Forecast for the Urban CCD" by Cheng Tiexina, Tai Miaomiaoa and Ma Zeb[7] in 2012 included factors like average turnover rate, parking occupancy, service level, parking fees, growth rate of automobiles in their demand model. They used these factors to modify the basic parking generation rate model. This model is also reliable as the important factors are considered here. In the same year, in Salem city of Tamil Nadu, India, T.Subramani[8] suggested that on-street parking should be removed and off-street parking facilities should be introduced to reduce the congestions in the carriageway, especially in CBD area. They also suggested that high parking fees is an effective method of controlling parking problems.

J. Aderamo and K. A. Salau[9] in 2013 examined the problems faced by the transportation system and their causes. They found that the on-street parking is one of most important causes for the delay and congestions caused in traffic flow. They developed a demand model using linear regression analysis in SPSS tool. They included factors like ward population within 5 km radius from the selected street, average number of vehicles parked per hour, average vehicle ownership per household within the ward etc. in their demand model. The demand model is as follows:

$$Y = \beta_0 + \beta_1 \times x_1 + \beta_2 \times x_2 + \beta_3 \times x_3 + e \quad (1)$$

where:

y = Parking demand

x1 = Ward population within which a selected street is located (within 5 km radius from the selected street)

x2 = Average number of vehicles parked per hour

x3 = Average vehicle ownership per household within the ward (catchment area)

β_1, β_2, β_3 = Regression coefficient

β_0 = The intercept

e = error term

Similar regression equation like Eq 1 is developed in this study as well but with different parameters. The methodology for developing the parking demand model (Eq. 2) has been discussed in section 4.

4. METHODOLOGY

Parking demand is the number of parking space needed in a given area at some time interval. When the demand is more than the parking supply, the problem becomes more critical for the transportation system. The parking demand model is obtained by analyzing the data collected from various types of surveys. Parameters like average number of 4-wheelers owned, average duration of parking (in hours) and probability of preferring car over transit as the mode of transport were incorporated in this study. A general form of the regression equation (by incorporating the above mentioned parameters) is shown below.

$$Y = a_0 + a_1 \times x_1 + a_2 \times x_2 + a_3 \times x_3 \quad (2)$$

Where,

Y = Parking demand

x_1 = Average number of 4-wheelers owned

x_2 = Average duration of parking (in hours)

x_3 = Mode choice, i.e., Probability of preferring car over transit as the mode of transport = $1- \left[\frac{e^{U_t}}{1+e^{U_t}}\right]$ (3)

where,

U_t is the utility function of preference of transit which depends on parameters like age (A) of the user, annual family income (AI_f) and distance(D) of destination from origin.

Two types of surveys have been carried out to develop parking demand model. In-out survey is conducted to get the peak parking accumulation and the peak parking period. Questionnaire survey was carried out to get the value of desired parameters. Finally, a demand model is developed by using these data. The detailed of these surveys in discussed in section 6.

5. SURVEY LOCATION:

Areas within the Kolkata Metropolitan Area (KMA) are selected as the case study area. Two CBDs- Gariahat and Dalhousie are selected as case study area. The detailed description of the locations along with the location figures (Fig 1, Fig 2) are shown below.

Source: Wikimapia

Fig. 1: Map of Gariahat showing the survey street

Gariahat is an important junction (Fig.1) that has good connectivity with all other parts of Kolkata, especially south Kolkata. It is one of the largest shopping centers of the city which satisfies all the needs of people. Though a good accessibility of transit is available, still people like to visit this place by their own car. In spite of having two off-street parking lot people prefer to choose on-street parking to reduce ease time. The on-street parking creates a large parking demand, which creates cruise of parking.

Source: Wikimapia

Fig. 2: Map of Fairlie Place showing the survey street

Dalhousie square is one of the largest and oldest office areas in Kolkata which attracts work trips from within the city and also from the adjacent districts. The attractive characteristics of this location create a huge demand for on-street parking. This place does not have any off-street parking facilities thus forcing the people to park on street. Fairlie place is the street which has the maximum parking demand was selected by visual survey and is shown in Fig 2.

6. SURVEY AND DATA COLLECTION

In-out survey is done to observe the accumulation profile and compute occupancy of parking lot. The peak parking accumulation and the peak hours are obtained from this survey. In in-out survey, the initial occupancy of parking lot is taken. Then the number of vehicles that enter the parking lot for a particular time interval is counted. The number of vehicles that leave the parking lot is also taken. At the end of the survey the final occupancy is noted down.

The in-out survey was conducted at Gariahat from 12 noon to 9pm on a weekend and at Dalhousie it was conducted in a weekday from 9am to 7pm to determine the peak parking accumulation. The counting was done manually to complete the survey.

Questionnaire survey was also conducted at both the survey locations. A minimum number of questions were set to get maximum information. The survey was done over 100 respondents for each location. The extracted data is used to develop the parking demand equation (Eq. 2) of the two locations using linear regression analysis in SPSS. The results are shown in next section.

7. RESULT AND DISCUSSION:

Data collected from various types of surveys have been analyzed and presented in the following paragraph.

7.1 Parking accumulation:

Parking accumulation is the number of vehicles parked at a given instant of time is termed as parking accumulation. The unit of parking accumulation is “number of vehicles”.

Gariahat is primarily a shopping area. The peak parking period varies from day to day due to climatic condition, festivals, traffic jam etc. The peak parking on the day of conducting the survey lied between 6p.m. and 7.30p.m. The peak parking accumulation value is 89. The existing parking supply in that area was 60.

Dalhousie is an office area comprising of various offices and headquarters. The peak parking period here remains more or less same on every weekday due to the fixed office hours. The parking accumulation starts from 9a.m. and gradually increases to reach the peak at around 12noon. The peak period continues up to 4pm. The peak parking value obtained here is 169. The existing parking supply in that area was 107.

The Parking Demand Model and the estimated parking demand using the demand model is shown in next section.

7.2 Parking Demand Model:

The demand model is of the form of Eq. 2 as shown in section 4. The data obtained from the questionnaire survey was used. Linear Regression Analysis was carried out in SPSS and the regression equation was obtained for the two locations.

Gariahat. The table 1 below shows the correlation coefficients among the dependent and the independent variables. Table 2 shows the independent variables, their corresponding regression coefficients and the significance level of each variable. The variables are same as explained in section 4.

Table 1: Pearson correlation coefficients for Gariahat.

	Y	X1	X2	X3
Y	1			
X1	0.78	1		
X2	0.01	0.12	1	
X3	-0.26	-0.2	0.1	1

According to table 1, the parking demand has a high correlation of 0.78 with the number of 4-wheelers owned by a household and a low correlation with the duration of parking. It is also observed that the demand has a negative correlation with the mode choice.

Table 2: Result of regression analysis by SPSS

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	68.876	9.927		6.938	.000
	No. of 4-wheelers owned	15.412	1.774	.765	8.690	.000
	Parking Duration(hr)	-.746	.862	-.075	-.866	.391
	Mode choice	16.536	14.066	.103	1.176	.245
Dependent Variable: Parking Demand						

Table 2 also shows that the number of 4-wheelers owned by a family is a significant factor on which the parking demand is depended. Mode choice is also significant enough to affect the parking demand.

The R^2 value of the equation is 0.62. This means that these independent variables can explain 62% of the variation in parking demand. The remaining 38% depends on other independent variables which was not included in this equation. The final form of the demand model for Gariahat is as follows:

$$Y = 68.88 + 15.41 \times x_1 - 0.75 \times x_2 + 16.54 \times x_3 \qquad (4)$$

Dalhousie. The output obtained from the correlation and regression analysis in SPSS is shown below in Table 3 and Table 4. The variables are same as explained in section 4.

Table 3: Pearson correlation coefficients for Dalhousie.

	Y	X1	X2	X3
Y	1			
X1	0.83	1		
X2	-0.1	-0.13	1	
X3	0.76	0.71	-0.02	1

According to table 3, the parking demand has a high correlation of 0.83 and 0.76 with the number of 4-wheelers owned by a household and the mode choice respectively. A negative correlation of the parking demand exists with the duration of parking.

Table 4: Result of regression analysis by SPSS

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	99.081	10.951		9.048	.000
	No. of 4-wheelers	8.125	1.452	.594	5.597	.000
	Parking duration	.119	.771	.012	.155	.878
	Mode choice	57.446	17.694	.341	3.247	.002
Dependent Variable: Parking demand						

Table 4 also shows that the number of 4-wheelers owned by a family and the mode choice are significant factors on which the parking demand is depended. Parking duration has a significance of 0.87. Here the R^2 value is 0.75 which means that 75% of variations in the parking demand are dependent on the independent variables. The final form of the demand equation for Dalhousie is given as:

$$Y = 99.1 + 8.12 \times x_1 + 0.12 \times x_2 + 57.45 \times x_3 \qquad (5)$$

7.3 Parking demand estimation using the demand model

Finally, the parking demand is estimated based on Eq. 4 and Eq. 5. The estimated parking demand is presented in Table 5.

Table 5: Estimated parking demand using the demand model

Locations	Parking Supply (base year)	Parking demand (base year)		
		Minimuma	Averageb	Maximumc
Gariahat	60	69	72	90
Dalhousie	107	128	144	169

a: Estimated by using the minimum values of the independent variables

b: Estimated by using the average values of the independent variables

c: Estimated by using the maximum values of the independent variables

It is clearly observed that even the minimum parking demand is higher than the existing parking supply in both the locations. The maximum or the peak demand is quite high as compared

to the supply. This high demand is leading to the illegal second lane parking on the street which is decreasing the carriageway width and affecting the traffic flow. This parking demand should be reduced or controlled to avoid the cruise of parking.

8. CONCLUSION

A parking demand model is generated by the use of SPSS in this study for the two locations, viz. Gariahat (Eq. 4) and Dalhousie (Eq. 5). Using this demand model the parking demand is estimated and is compared with the existing parking supply. The present supply and estimated existing parking demand is shown in Table 5. The Pearson correlation coefficients among the dependent and independent variables are shown in Table 1 and Table 3 respectively for Gariahat and Dalhousie. It is observed that the even the minimum parking demand is less than the present supply. The situation will become worse for 'maximum' case. The demand will be much higher in future years if proper policy is not adopted to control the parking demand. The controlling factors for parking demand need to be found out to control the demand. The methodology used in this study can also be used for assessing parking demand for other similar type of CBDs.

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