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Behavioral Characteristics of Car Parking Demand: A Case Study of Kolkata

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Abstract

Managing car parking demand has acquired a dominant position in transport infrastructure planning, especially for metropolitan cities. In most cases, generalized parking generation rates are assumed to estimate parking demand at various locations with little or no consideration for other control parameters. This paper attempts to look into the behavioural characteristics of parking demand for various kinds of trips at various locations with varied urban order/hierarchy. It has not only tried to find out the parameters which significantly influence parking demand, but also to find the relative influence of each parameter on parking demand.

1. INTRODUCTION

India is one of the fastest growing and resilient economies of the world having a booming automobile market. Relaxation in foreign trade policies and a developing indigenous automobile manufacturing sector has added to the ever proliferating automobile fleet in urban India. The small city cars are affordable, attractive and have enticed the urban middle class who park free or at a nominal parking fee for majority of their trips. Parking is highly subsidized and parking fee is never a consideration in the mode choice of the motorists. All new developments provide ample free off-street parking space or at nominal cost, which encourages automobile ownership and usage without considering the limited road network capacity. Older parts of the cities, mainly the Central Business Districts, fail to provide adequate off-street parking supply to meet huge demand. On-street parking is the obvious solution, where motorists again park with nominal fee without considering the associated social costs. The negative impact of parking activities on the traffic and transportation scenario in most of the metropolitan cities of India is reaching an alarming stage. While it is quite normal for a country like India, passing through such a phase of economic development to have high aspirations and desires, the onus lies on the policy makers to guide and positively influence peoples' parking preferences and behaviors.

Problem of increasing automobile dependency and associated parking woes can not be solved without a detailed understanding of the motorists' behavior, psychology, parking characteristics and other factors governing mode choices.

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It would not be wise to blindly emulate the west and formulate plans based on their experiences. Complexities of the transportation scenario in the country should be studied indigenously as well as rigorously in order to develop plans that would create an environment whereby people can take appropriate decisions for their own good and benefit of the future generations.

This study is primarily aimed at analyzing the behavioral characteristics of automobile parking demand by identifying different parameters influencing parking demand, analyzing and measuring the influence of each parameter on parking demand and finally deriving demand functions based on these analyses. Parallel studies have also been conducted in order to derive mode choice functions, an attempt to ascertain the various parameters influencing the mode choice of motorists. Different functions would help planners and policy makers to make appropriate interventions in order to influence parking demand as well as mode choices. It is expected that controlling parameter values through policies and strategies would help in reducing and managing parking demand in certain cases and consequently may result in the reduction of automobile use with modal shift to public transit facilities.

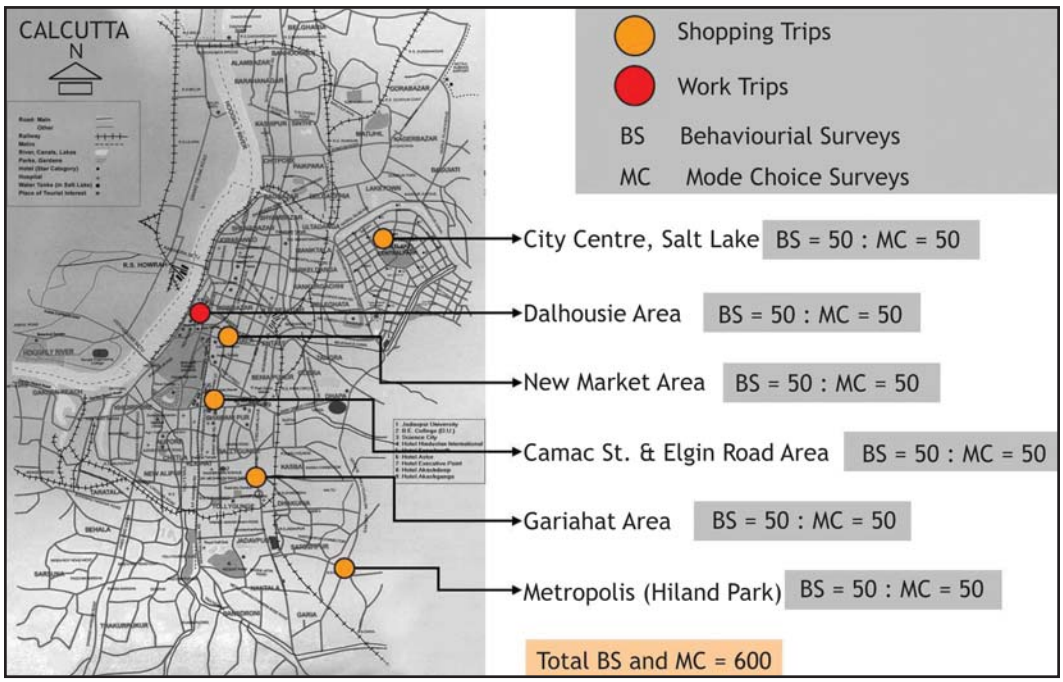
2. STUDY AREA AND SURVEY DESIGN

This study is confined to the city of Kolkata. In order to understand the parking behavior and mode choice of motorists with respect to shopping as well as work trips in the city of Kolkata, surveys have been conducted at six strategic locations. These locations are typical 'First' and 'Second' order commercial and business destinations in the city, namely the Camac Street Area, New Market Area, City Centre (Salt Lake), Gariahat Area, Metropolis (Hiland Park) and Dalhousie Area.

Primary surveys were suitably designed to correctly reveal the motorists' parking characteristics, the parameters influencing parking demand at the selected destinations and their relative influence on mode choice of the motorists. Based on these data, disaggregate demand functions, aggregate demand functions as well as mode choice functions have been derived for certain types of trips at certain destinations.

Primary surveys were carried out including the 'Parkers' Behavioral Survey' and 'Mode Choice Survey'. Both surveys were 'Revealed Preference Questionnaire Surveys' conducted at the identified 'First' and 'Second' order destinations within the city of Kolkata. A survey was done for 'work trips' in Dalhousie Area whereas in remaining areas survey was conducted for 'shopping trips'. Surveys were conducted for both 'Peak' as well as 'Lean' hours. On an average, around 50 persons were surveyed for 'Parkers' Behavioral Survey' and 50 for 'Mode Choice Survey' were conducted at each of the six study areas. The survey locations and sample sizes for surveys at each location is given in Fig. 1.

Figure 1: Survey Locations and Sample Size



3. DERIVATION OF DISAGGREGATE DEMAND FUNCTIONS

The 'Revealed Preference Survey' of over 50 respondents from each of the 5 study areas excluding Dalhousie Area for shopping trips have been used to formulate the disaggregate demand functions. These demand functions help in identification of the factors influencing parking demand in the study areas, highlighting the fact that parking demand analysis should be done in a case specific manner.

Parking demand has been expressed in terms of:

- Duration of parking (parking space usage per visit) in minutes;
- Number of visits per month (number of times a parking space is used per month); and
- Total parking space usage per month (duration x number of visits) in minutes.

The Parameters (Independent Variables) considered for analysis include:

- Age (a) in years
- Income (i) household income (dummy variable: 1=<Rs.5L, 2 = Rs.5-10L, 3 = > Rs.10L)
- Family Size (f)
- Distance Traveled (d) in km
- Travel Time (t) in minutes

- Time Index (tx) = (Time in alternate transit) / (Time in car)
- Cost Index (cx) = (Cost in alternate transit) / (Cost in car)
- Search Time (S) in minutes
- Walk Time (W) in minutes

Steps followed in the Multiple Regression Analysis using SPSS Software Package are:

- Inclusion of the dependent variable;
- Inclusion of the entire set of independent variables (parameters) or predictors;
- Variables having least partial correlation with the dependent variable removed sequentially (step-wise) so that all the variables that contribute least to the model (statistically insignificant) are eliminated; and
- Determining the final functional form containing only those parameters or predictors which have significant impact on the dependent variable (here parking demand).

Significance Level (Sig.) determines whether the particular parameter is a significant predictor of the dependent variable.

Durbin-Watson (lies between 0 and 4) tests for 'Independence of Residuals (Autocorrelation)' and a value close to 2 indicate that no strong evidence of autocorrelation problem exists.

Significance Level of the Full Model_is a measure of the overall 'Goodness of Fit'.

For example, the Parking Demand (Duration of Parking) Function of Hiland Park (Metropolis Area) is of the form:

$$D = 71.087(tx) - 12.314(S) + 28.828(W) + 38.382$$

t-value	(4.180)	(-2.282)	(1.698)	(0.922)
Sig.	(0.000)	(0.027)	(0.096)	(0.361)

n = number of observations = 50

Significance Level of the Full Model = 0.000

Durbin-Watson = 1.713

- Time Index, Search Time and Walk Time are the only statistically significant predictors of parking demand expressed in terms of 'Duration of Parking' at this location.
- This function not only explains the relationship of the independents with the dependent variable, but also the interrelation among the independents.
- The value of Durbin-Watson signifies that the predictors do not suffer from autocorrelation.

Again, the Parking Demand (Visits) Function of City-Centre (Salt Lake) is of the form:

$$V = 5.466(tx) - 1.639(cx) - 4.558$$

t-value (3.377) (2.656) (-1.579)
Sig. (0.001) (0.011) (0.121)
n = number of observations = 50
Significance Level of the Full Model = 0.001
Durbin-Watson = 2.073

Table 1: Demand (Duration of Parking) Functions of the Study Areas

Inependent Variable (Parameter)	Value	Camac Street	New Market	City Centre	Gariahat	Hiland Park
Age	B	0.957	1.466			
	t	2.315	2.199			
	Sig.	0.023	0.033			
Income	B		-21.362			
	t		-1.911			
	Sig.		0.062			
Distance Traveled	B	2.253	2.859	4.919		
	t	2.323	1.753	4.344		
	Sig.	0.022	0.086	0.000		
Time Index	B					71.087
	t					4.180
	Sig.					0.000
Search Time	B					-12.314
	t					-2.282
	Sig.					0.027
Walk Time	B				2.713	28.828
	t				1.470	1.698
	Sig.				0.148	0.096
Constant	B	36.638	45.138	63.988	74.892	38.382
	t	1.941	1.367	4.440	6.765	0.922
	Sig.	0.055	0.178	0.000	0.000	0.361
n		50	50	50	50	50
Sig. Level of Full Model		0.003	0.004	0.000	0.148	0.000
Durbin-Watson		1.938	2.009	1.713	2.243	1.713

Travel Time and Cost Index are found to be insignificant in the regression models of all the study Areas
Dependent Variable = Duration of Parking
B = Coefficient of the Parameter

- Time Index and Cost Index are the only statistically significant predictors of parking demand expressed in terms of 'Visits per Month' at this location.
- It is also observed that Time Index has a greater influence on parking demand than Cost Index when the two are compared.
- The value of Durbin-Watson signifies that the predictors do not suffer from autocorrelation.

Similarly, the Parking Demand (Total Parking Space Usage per Month) Function of New Market Area is of the form:

$$T = -12.315(a) + 166.208(i) + 81.447(S) + 595.154$$

t-value	(-2.535)	(1.906)	(2.193)	(2.022)
Sig.	(0.015)	(0.063)	(0.033)	(0.049)

n = number of observations = 50

Significance Level of the Full Model = 0.009

Durbin-Watson = 1.872

- Age, Income and Search Time are the only statistically significant predictors of demand expressed in terms of 'Total Parking Space Usage per Month' at this location.
- The parking demand increasing with decreasing age of the user group is a common trend observed and is crucial for parking demand assessment of particular zones.
- The value of Durbin-Watson signifies that the predictors do not suffer from autocorrelation.

The derived demand functions for all the 5 study areas have been summarized in the Table 1.

4. DERIVATION OF AGGREGATE LOG-LINEAR DEMAND FUNCTIONS

After derivation of disaggregate level parking demand functions, attempt was made to derive the aggregate demand functions (Table 2 and 3) at specific locations. 'Aggregate Demand Functions' have been formulated from the specifically designed 'Willingness-to-Pay', 'Willingness-to-Search' and 'Willingness-to-Walk' surveys, which were are a part of the 'Parkers' Behavioral Survey' questionnaire. These demand functions provide an insight into the parameters and their relative influence on parking demand. In this case, parking demand at a particular location has been expressed in the form:

$$\ln(n) = \alpha + \beta \ln (X)$$

Where n = parking demand expressed in number of spaces and X = parameter influencing parking demand.

Table 2: Demand (Visits per Month) Functions of the Study Areas

Inependent Variable (Parameter)	Value	Camac Street	New Market	City Centre	Gariahat	Hiland Park
Age	B		-0.141			
	t		-1.879			
	Sig.		0.067			
Income	B	2.404	3.838			
	t	2.857	3.060			
	Sig.	0.005	0.004			
Distance Traveled	B	-0.339	-0.390		-0.317	
	t	-3.055	-2.012		-2.352	
	Sig.	0.003	0.050		0.023	
Time Index	B		-3.295	5.466		5.075
	t		-1.720	3.377		4.734
	Sig.		0.092	0.001		0.000
Cost Index	B			1.639	-1.335	
	t			2.656	-2.474	
	Sig.			0.011	0.017	
Search Time	B					-0.623
	t					-1.810
	Sig.					0.076
Constant	B	6.129	45.138	-4.558	12.508	-0.521
	t	3.905	1.367	-1.579	6.728	-0.256
	Sig.	0.000	0.178	0.121	0.000	0.799
n		50	50	50	50	50
Sig. Level of Full Model		0.000	0.004	0.001	0.010	0.000
Durbin-Watson		1.735	2.009	2.073	1.390	1.643

Travel Time and Walk Time are found to be insignificant in the regression models of all the study Areas
Dependent Variable = Visits per month
B = Coefficient of the Parameter

In this case, â is termed as the elasticity of 'X' and measures the percentage change in 'n' per unit percentage change in 'X'. The parameters considered for the analysis include Parking Fee (F), Search Time in parking lot (S) and Walk Time from parking lot to destination (W).

For this particular analysis, data from all the 6 study areas was considered. The log-linear functions thus developed served as important tool for assessing and analyzing the impact of 'Parking Fee', 'Search Time in parking lot' and 'Walking Time from parking lot to destination' for the study areas under consideration.

Table 3: Demand (Total Parking Space Usage per Month) Functions of the Study Areas

Inependent Variable (Parameter)	Value	Camac Street	New Market	City Centre	Gariahat	Hiland Park
Age	B t Sig.		-12.315 -2.535 0.015			
Income	B t Sig.		166.208 1.906 0.063			
Distance Traveled	B t Sig.	-25.540 -2.754 0.007			-28.343 -2.041 0.047	
Time Index	B t Sig.			429.826 2.229 0.031		2953.794 6.834 0.000
Cost Index	B t Sig.			140.256 1.907 0.063	-99.165 -1.784 0.081	
Search Time	B t Sig.		81.447 2.193 0.033			
Constant	B t Sig.	763.640 9.288 0.000	595.154 0.049	-251.921 0.468	1022.961 0.000	-3108.635 0.000
n Sig. Level of Full Model Durbin-Watson		50 0.007 2.115	50 0.009 1.872	50 0.038 2.293	50 0.048 2.272	50 0.000 1.727

Travel Time and Walk Time are found to be insignificant in the regression models of all the study Areas
Dependent Variable = Total Parking Space Usage per month
B = Coefficient of the Parameter

For example, the log-linear functions of parking demand at Camac Street had been derived as:

$$\ln(n)=10.126-2.1229\ln(F)\rightarrow R^2=0.75$$

$$\ln(n)=5.5074-1.147\ln(S)\rightarrow R^2=0.86$$

$$\ln(n)=6.5553-1.5973\ln(W)\rightarrow R^2=0.76$$

It is observed that the price elasticity of parking demand is -2.1229, which implies that the parking demand at Camac Street would decrease by around 2.1229 percent for 1 percent increase in the parking fee. Similarly, the other parameter elasticities are respectively -1.147 and -1.573.

The sets of such demand functions for the different study areas have been summarized in Table 4. The sample size taken for generating the functions at

Table 4: Log-linear Parking Demand Functions of the Study Areas

Funtinoal Form	Independent Variable	Coefficient of Independent Variable at (Study Area)					
		Camac Street	New Market	City Centre	Gariahat	Hiland Park	Dalhousie
$\ln(n) = f[\ln(F)]$	ln (F)	-2.1229	-2.4486	-1.8036	-1.3852	-2.7448	-3.0994
	Constant	10.126	10.004	8.8044	6.6602	10.896	25.385
	(R Square)	0.75	0.93	0.86	0.91	0.88	0.92
$\ln(n) = f[\ln(S)]$	ln(S)	-1.147	-0.8586	-1.0573	-0.9093	-1.4822	-1.7512
	Constant	5.5074	4.6874	5.2406	4.9667	5.7792	5.2426
	(R Square)	0.86	0.88	0.83	0.85	0.85	0.76
$\ln(n) = f[\ln(W)]$	ln(W)	-1.5973	-1.4478	-1.4781	-1.2696	-1.1338	-0.7952
	Constant	6.5553	5.6088	5.6122	5.652	5.3173	4.756
	(R Square)	0.76	0.74	0.77	0.85	0.85	0.78

Dependent Variable = IN (n) ....where n = total number of parked vehicles

F = Parking Free; S = Search Time; W = Walk Time (Parking Space to Destination)

each study area was 50. It is expected that an increase in each of the identified parameters would result in a decrease in parking demand for all the locations. The observations corroborate the expectations.

These log-linear functions help in determining the different parameter-elasticities of parking demand at a particular location. The results would help policy makers to assess the impact of an intervention, such as change in parking fee on the parking demand or accumulation at a particular location. In the case study locations, the observed elasticities for parking price is much higher in all six locations compared to search time and walking distance from parking location. This means that increase in parking fee will be much more effective tool to curb parking demand at these locations compared to any intervention which will increase the search time or walking distance.

5. DERIVATION OF MODE CHOICE FUNCTIONS

It is often asked whether controlling parking at activity destinations will have enough leverage on automobile dependency through control of mode choice. This section tries to look into the relative impact of parking availability and other identified parameters on the mode choice of motorists. The choice function of the particular mode 'private car' has been generated for the 6 different study areas. Data from the 'Mode Choice Survey' conducted at the selected locations has been used for the analyses. The general form of the choice function is as follows:

$$U_C = \ln \left[\frac{P_C}{1 - P_C}\right] \quad B_0 + B_1X_1 + B_2X_2 + ... + B_nX_n$$

Where PC = probability that a randomly selected individual chooses C (here private car)
X1, X2,....., Xn = Parameters influencing the choice of C

Table 5: Mode Choice Functions of the Study Areas

Independent Variable	Value	Mode Choice FUnction for (Study Area)					
		Camac Street	New Market	City Centre	Gariahat	Hiland Park	Dalhousie
Conform In Public Transit	B	-1.651	-3.727		-1.338		
	S.E.	0.714	1.492		0.544		
	Sig	0.021	0.012		0.014		
Parking Availability at Destination	B	2.483	3.514	3.907	1.258	0.684	4.484
	S.E.	0.795	1.484	2.512	0.442	0.428	2.415
	Sig	0.002	0.018	0.120	0.004	0.110	0.063
Public Transit Availability	B	-1.995				-1.437	
	S.E.	0.715				0.789	
	Sig	0.005				0.789	
Safety in Public Transit	B					-1.05	-2.415
	S.E.					0.661	1.383
	Sig					0.112	0.081
Level of Congestion	B		-1.009				7.948
	S.E.		0.787				4.230
	Sig		0.200				0.060
Income	B	1.502					
	S.E.	0.988					
	Sig	0.128					
Duration of Parking	B	0.023					
	S.E.	0.011					
	Sig	0.037					
Distance Traveled	B			0.507			-0.344
	S.E.			0.286			0.48
	Sig			0.076			0.166
Constant	B	0.553	4.434	-21.358	-1.982	3.958	-24.688
	S.E.	3.472	4.664	13.569	1.601	2.069	14.804
	Sig	0.873	0.342	0.115	0.216	0.056	0.095
	n	50	50	50	50	50	50
	% Correctly Predicted	95.0	90.0	95.0	87.5	86.7	96.0
	Nagelkerke R Square	0.895	0.825	0.832	0.651	0.523	0.924

Dependent Variable = $\ln \left[\frac{P_C}{1 - P_C}\right]$

B0, B1, ….. , Bn = Coefficients estimated by the Binary Logistic Regression Model

The Dependent Variable in this case is: $\left[\frac{P_C}{1-P_C}\right]$

The Parameters (Independent Variables) considered for analysis include:

- Age (A) – in years
- Income (i) – household income (dummy variable: 1=< Rs. 5L, 2= Rs. 5-10L, 3=> Rs. 10L)
- Comfort level of Public Transit (CP) – dummy variable (1=Low; 5=High)
- Parking Availability at the Destination (PA) – dummy variable (1=Low; 5=High)
- Public Transit Availability (TA) – dummy variable (1=Low; 5=High)
- Safety Level of Public Transit (SP) – dummy variable (1=Low; 5=High)
- Level of Congestion (LC) – dummy variable (1=Low; 5=High)
- Duration of Parking (DP) – in minutes
- Distance Traveled (DT) – in km

These parameters are anticipated to affect the mode choice of car users at a particular location. It is to be noted that by Conditional Backward Elimination Method of Binary Logistic Regression Analysis using SPSS Software Package, the parameters (independent variables) which are significant predictors of the dependent variable at a particular location are identified and included in the mode choice function of that location in study area.

The sets of such mode choice functions for the different study areas have been summarized in Table 5. It can be clearly seen that parking availability at destination enters the mode choice function at all six locations. Relative influence of parking availability is also quite high.

6. CONCLUSIONS

This study highlights the parameters which influence the parking demand of an automobile owning household. It has been observed that each parameter has varied level of influence on parking demand for various locations. While looking at the aggregate level parking demand functions, similar location specific elasticities have been observed. This clearly points to the fact that varied policy tools need to be adopted for parking demand management at various locations. The mode choice functions derived in this study reveal that parking supply characteristics can play a significant role in reducing automobile dependency. However, the relative influence of parking parameters does depend on the trip purpose as well as location, order and hierarchy of the destinations. It must be taken into consideration that the equations derived in this study are based on relatively small sample sizes. Therefore, they are only useful in exploring the causal relationships and will not be rigorous enough to be used for prediction purposes.