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Evaluation of On-Street Night Parking Demand: A Case Study of Roorkee City

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Abstract

Nowadays, parking is a challenging issue all around the world, especially in the Central Business District (CBD) during the day and in residential areas during the night. Parking demand in CBD is increasing day by day due to insufficient off-street parking facilities and the tendency to park near the destination. The on-street night parking demand is increasing in residential areas due to the non-availability of sufficient off-street parking facilities on the premises. In this study, one residential area in Roorkee has been selected as the case study area. Socio-economic, demographic and parking characteristics were used as parameters to generate the parking demand model. The selected parameters were collected from the field using the in-out survey and questionnaire survey. Two parking demand models were developed by logistic regression analysis. The first model was developed without the parking fees, while the second model considers parking fees as a parameter. Also, the sensitivity analysis was done on both models to examine the changes in the existing parking demand.

Keywords: On-street parking, Parking demand, Parking statistics, Sensitivity analysis, Parking policy.

1. Introduction

The gradual increase in vehicular ownership and non-availability of parking spaces in buildings and apartments is increasing the on-street night car parking demand in residential areas and is bringing the parking system to a critical stage (Guo, Z. 2013; Chen, Q et al.2017). It has been observed that in metro cities like Delhi, Kolkata and Chennai, car owners park their vehicles on-street during the nighttime (Das, Pritikana et al. 2021; Das, D. and Ahmed, M.A. 2018). Roorkee is one of the cities that is going through similar parking problems in residential areas. Night parking users are using the road space without paying a single penny. If the on-street night car parking demand is not controlled with immediate effect, it might reach an irreversible position. Hence, a systematic study of parking characteristics, parking demand, and controlling measures is very important for a town planner (Parmar, J et al. 2020; Wang, H et al. 2020; Yan, X. et al. 2019).

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Wilson (1992) examined the influence of parking prices on commuter mode choices in the city of Los Angeles using multinomial logit models. According to the study, the number of road users driving to work might be reduced by 25% to 34% if parking fee is instilled. Hensher and King (2001) evaluated the effect of parking quantity and cost by time of day using an expressed preference survey in the central business district (CBD) area. It was suggested that imposing restrictions at certain sites under present traffic might result in the displacement of parking spaces. Albert and Mahalel (2006) investigated the impact on travel behaviour by comparing driver perceptions regarding congestion and parking tolls. The results demonstrated that drivers always prefer to adjust their travel patterns to avoid parking fees. Kelly and Clinch (2006) did a case study in Dublin, Ireland, using 1,007 on-street parking customers to study the difference in pricing between business and non-business journeys. Becker and Carmi (2019) discovered that the additional parking cost compelled the vehicle users to leave their cars at home and changed their sentiments regarding the environment and comfort level. It was concluded that the parking fee policy could impact travel behaviours in many scenarios, including the selection of mode, parking space and driving route. Many researchers have investigated the effects of parking fee policies on parking demand. Kelly and Clinch (2009) analyzed the revealed-preference parking trend data using the pre- and post-price adjustments to the cost of on-street parking in Dublin, Ireland. Using this data, they determined the price elasticity of demand for on-street parking there using automated transaction data. Ottosson et al. (2013) studied the influence of parking charges on on-street parking in Seattle. According to the results, the pricing elasticity of the parking occupancy was inelastic. Also, it was identified that the variation of the occupancy depended on the time of day and neighbourhood factors. Milosavljevi'c and Simi'cevi'c (2014) studied and measured the influence of on-street parking charges on parking demand and garage operation in central Belgrade, Serbia, using the revealed preference data. They discovered that increasing the parking fees reduces parking volume, parking duration and garage occupancy. Pu et al. (2017) utilized information gathered from 2011 to 2014 in downtown San Francisco to analyze the sensitivity of parking occupancy due to the price change. The results showed an inverse relationship between parking demand and price. Wang et al. (2020) investigated the influence of parking regulation changes on parking turnover and duration using the parking metre data. However, the study was done from the data collected during four selected weeks on twelve roads and had a limitation of not revealing a long-term policy adoption.

After reviewing the papers, it is found that most of the work on parking has been conducted during the daytime and only a few studies were dedicated during night-time. With the increasing income of urbanites, car ownership and parking demand are also increasing. Urbanites do not have sufficient parking space at their possession and they are parking their vehicle on the street side during the night time.

Hence, the objectives of the study are to access the present parking condition in the residential area and to find the important factor that affects the on-street night car parking demand in the study area. This paper also aims to develop the parking demand model and investigate the effects of the selected factors on the existing parking demand using sensitivity analysis.

2. Study area

In this study, Ramnagar has been selected as the study area. Ramnagar is located in Roorkee tehsil of Haridwar district in Uttarakhand, India and shown in Figure 1. It is situated 20km from sub-district headquarters Roorkee and 49 km from district headquarters Haridwar, with approximately 45% of its residents residing in urban areas. Based on the census data, the population of Roorkee city was recorded at 345,000 individuals, covering an area of 8.11 square kilometers. Also, according to the most recent data available from the Ministry of Road Transport and Highways, the motorization rate for Uttarakhand, the state where Roorkee city is located, was 144 vehicles per 1,000 inhabitants as of march 2021 as compared with the rest of the country. Ramnagar is a residential area of Roorkee city. In this residential area, most people have their own cars and park their vehicles near buildings or apartments during nighttime on the street, as shown in Figure 2. Due to on-street night parking, sometimes people face many problems like congestion, accident, delay, etc. during the night. (Pierce, G. and Shoup, D. 2013; Zou, W. et al. 2016; Anas, A. and Lindsey, R. 2020). In this study total 38.5 ha area at Rammagar, Roorkee is used for calculate the actual parking demand at night. It is home to a total of 58 families. According to the population census, Ramnagar has a population of 419 individuals, consisting of 217 males and 202 females.

Also, in our field survey we have found that the parking accumulation in night time at Ramnagar, Roorkee is very high as compared to the other location in the city. This is the main reason for choosing this area as a case study area. More detailed about filed survey discuss in section 4.

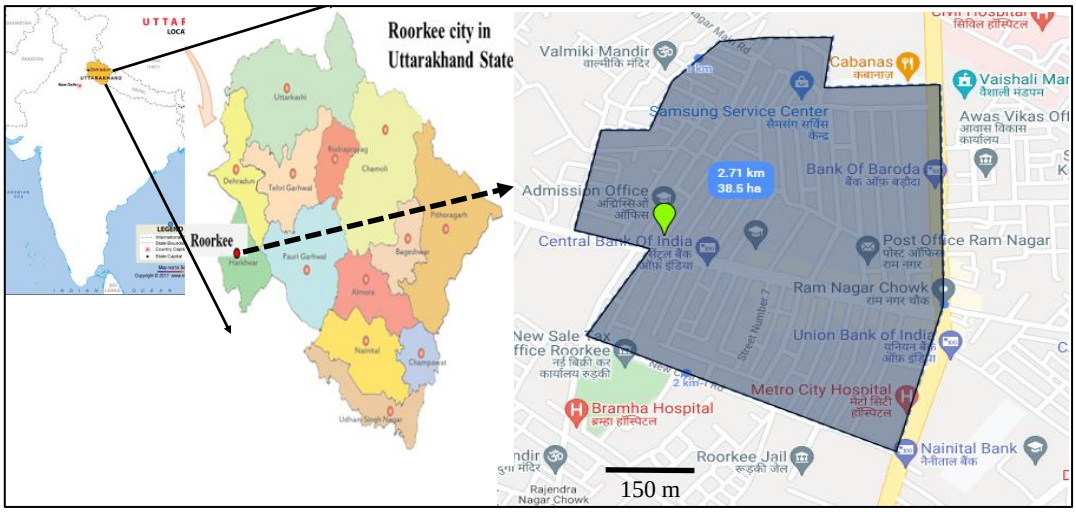

Figure 1: Illustration of study area, Ramnagar(Roorkee) Uttarakhand.
Source: Rahul A. et al. 2020.

Figure 2: On street car parking at night time Ramnagar, Roorkee.

3. Methodology

This study developed a methodology to estimate the effect of residential parking on parking demand. Initially, in-out surveys and license plates were carried out to find the overview of the parking location and parking demand (Das, D., Ahmed, M.A. and Deb, S. 2019). The socio-economic, demographic and parking-related data were obtained from households using the questionnaire survey (Ibem, E.O. and Amole, D. 2013). Further, the development of the parking demand equation using regression analysis and the formulation of the parking demand model was carried out using SPSS statistical software (Chakrabarti, S. and Mazumder, T. 2010; Al-Sahili, K. and Hamadneh, J. 2016). The sensitivity analysis was done to analyse the effect of each sensitive parameter on the parking demand (Muñoz-Medina, B. 2021; Gragera, A. 2021). The overall methodology of the study is shown in Figure.3.

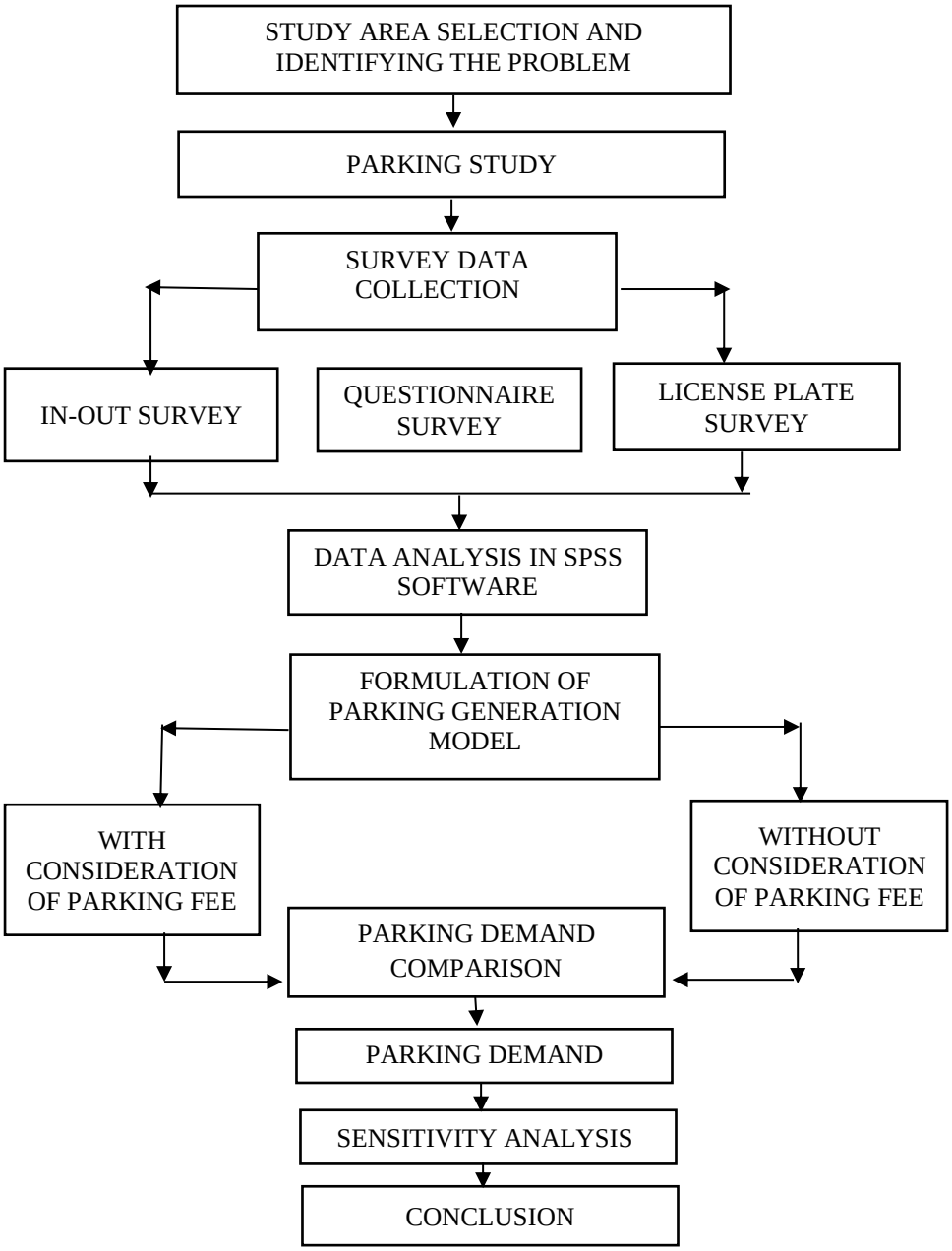

Figure 3: Methodology flow chart

The accumulation survey was done during peak hours to obtain information on the overall parking accumulated inside the survey area. The parking demand model has been developed by analysing the data collected from the questionnaire survey. Initially, sixteen parameters were considered to develop the model. The parameters considered for the study were age, family size, family income, presence of any backyard garage, the purpose of the trip, trip duration, frequency of your visit, parking lots have been allotted, origin to destination, parking duration, parking fee are willing to pay, choosing the parking location, search time, walking time, safety level of the parking and parking demand. A logistic regression analysis was carried out and the variables having less significant value were eliminated. Age, family size, family income, presence of any backyard garage, the purpose of the trip, trip duration origin to destination, parking duration, parking fee are willing to pay, choosing the parking location, search time and walking time were found to be significant. A general form of the logistic regression equation is shown below.

$$Logit\ (Y) = \ln\left(\frac{P_i}{1-P_i}\right) = a_0 + a_1X_1 + a_2X_2 + \cdots$$

Where, P_i is the probability of choosing a particular mode i, Y is the dependent variable, a_0 and a_1 are the regression coefficients and X_1 and X_2 are the independent variables.

4. Survey Techniques and Data Collection

In this study, critical field surveys for night parking such as license plate surveys and in-out surveys have been carried out to obtain the parking accumulation, parking volume, parking turnover, average parking duration, parking efficiency, etc. The overview of the different survey performed during the data collection is shown in Table 1.

Table 1: Overview of the surveys conducted.

Survey	*Survey timing*	*Time interval*	*Determinants*	*Survey duration*
In- out	10 pm to 9 am	1 hour	Parking occupancy, parking accumulation	7 days
License plate	10 pm to 9 am	1 hour	Parking duration, parking turnover	7 days
Questionnaire survey	11 am to 3 pm	4 hour	Personal details, trip and parking characteristics, Total no. of sample collected (300)	7 days

4.1 In-out Survey

The in-out survey has been conducted to observe the accumulation profile for the Ramnagar area. With the help of this survey, the peak hour and the peak parking accumulation are obtained. During the in-out survey, the number of vehicles entering the parking area and the number of vehicles leaving the parking area for a particular time interval was manually counted. At the end of the survey, the final accumulation was noted. The in-out survey was conducted from Monday to Sunday from 10 PM to 9 AM to determine the peak parking accumulation. The data accumulated is shown in Figure 4. In the figure, it could be observed that on all the weekdays, the higher number of vehicles

parked was from 2 PM to 4 PM and the peak parking hour of the week was observed on Wednesday from 2 PM to 3 PM.

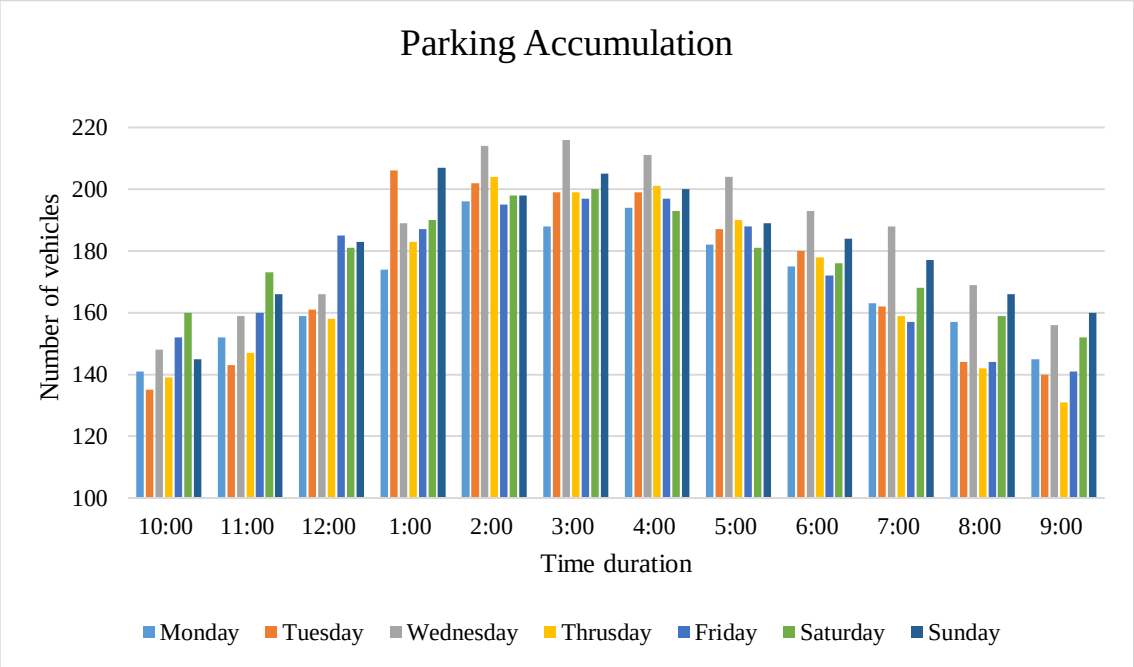

Figure 4: Parking accumulation profile for all day

4.2 License Plate Survey

The license plate survey was done each day from 10:00 PM to 09:00 AM. The survey was performed by observing the license plate numbers of each vehicle entering and leaving the parking areas in Ramnagar, Roorkee. The time interval between each manual observation was 1 hour. The accuracy of the data obtained from this survey is generally considered high as it focuses on monitoring each vehicle regularly. Parking duration, average occupancy, parking volume and turnover are determined from this survey and the statistics of the collected data are shown in Table 2.

Table 2: Parking statistic from in-out ad licence plate survey

Parking statistics	*Ramnagar, Roorkee*
Peak Hour	1 AM-3 AM
Peak Parking Accumulation	216 (No. of vehicles parked)
Parking turn over	18 veh/hr/bay
Average parking occupancy	77.1%
Average Parking Duration	10 hrs 24 mins

4.3 Questionnaire Survey

The questionnaire survey was conducted at the survey locations. A total of 300 samples were collected for this study. A qualitative and quantitative analysis was carried out to understand the current parking demand scenario. The adopted questionnaire was divided into three sections: personal information, trip characteristics, and parking characteristics. The data are tabulated in Excel and the analysis was done using SPSS. The extracted data was utilised to develop the parking demand equation using linear regression analysis. The response of the respondent was recorded and presented in Table 3.

Table 3: Questionnaire survey data

Variables	*Characteristics of survey respondents*
Gender	Male (95%), female (5%)
Family Size	≤ 3 (5.3%), 4 (15%),5 (25%), ≥ 5 (54%)
Family income (in Rs/ annum)	≤ 3L (11.4%), 3L- 5L (57.5%), 5L-7L (31.1%)
Presence backyard garage	Yes (20.3%), no (79.7%)
Number of cars parked at night time.	0 (2%), 1 (91%), ≥ 2 (7%)
Purpose of your trip	Working (75%), educational (9%), business (12.3%), shopping (1.3%), others (2.3%)
Trip duration (Origin to destination (in kms)	≤ 2 (1.3%), 2-4 (5%), 4-6 (14.1%), 6-8 (52.3%),≥ 8 (27.2%)
Frequency of your visit	Daily (95.3%), twice in a week (3.4%), thrice in a week (1.3%)
Average parking duration at night time (in hours)	≤ 2 (1.4%), 2-4 (0.4%), 4-6 (0.7%), 6-8 (16.8%), ≥ 8 (80.7%)
Any parking lots have been allotted	Yes (1.3%), No (98.7%)
Maximum parking fee are willing to pay? (in Rs\monthly)	0 (10.7%), 100-500 (85%), 500-1000 (4.3%)
Main reason for choosing the parking location	Near to the destination (65.2%), safety of the vehicle (28.4%), provides the free parking (0.3%), easy space availability (6.1%)
Maximum search time to find an empty parking space.? (in mins.)	≤ 5 (58.9%), 5-10 (40.8%), ≥ 10 (0.3%)
Average time to walk from parking space to destination? (in mins.)	0-5 (54.6%), 5-10 (45%), ≥ 10 (0.4%)
Safety level of the Parking Place.	Poor (17%), average (78.3%), good (4.7%)

5. Result and Discussions

5.1 Parking Demand Model

For the develpoment of parking demand model, the data collected from the questionnaire was used. Logistics Regression Analysis was carried out in SPSS and the regression equation was obtained for the Ramnagar, Roorkee (Mo, B. et al.2021; Wiers, H. et al.2022).

5.2 Logistics Regression Model

Table 4 shows the accuracy of the developed logistic regression model. If a higher value is obtained from the -2 Log-likelihood test, it indicates that the model is not desirable and not able to explain the variability of the dependent variable. The -2 log-likelihood method shows a lesser value indicating the model is good at predicting the dependent variable. It also shows that the difference between the actual and observed values is less while using this model.

Table 4: Model accuracy for Ramnagar, Roorkee

Model summary	*-2 Log-likelihood*	*Cox & Snell R Square*	*Nagelkerke R Square*
Without parking fee	27.768	0.305	0.698
With parking fee	27.767	0.306	0.697

Two models were developed to study the parking demand during the night time. Model 1 was developed without considering the parking fee. Model 2 was developed by considering parking fees as one of the independent variables. The significance and coefficient of each independent variable in developing the models are shown in table 5 and table 6. Table 5 shows the significance of the variables while not considering the parking fee and table 6 corresponds to the model with a parking fee. The coefficient for each variable is shown as B and the significance of each variable is shown as sig. In total, ten variables were found to be significant in model 1 as the sig. value was less than 0.05. Model 2 also has ten significant variables.

Table 5: Variables in the Equation

Variables	*B*	*S.E.*	*Wald*	*Sig.*	*Exp(B)*
Age	0.287	0.115	6.167	0.013	1.332
Family size	-3.650	1.739	4.404	0.036	0.026
Family income	5.381	2.058	6.837	0.009	217.168
Presence any backyard garage	-11.012	4.290	6.588	0.010	0.000
Purpose of your trip	2.023	.800	6.404	0.011	7.564
Trip duration origin to destination	2.899	1.240	5.465	0.019	18.158
Average parking duration at night time in hours	2.347	0.991	5.607	0.018	10.458

Reason for choosing the parking location	-5.571	2.612	4.548	0.033	0.004
Maximum search time to find an empty parking space.	-4.729	2.116	4.996	0.025	0.009
Average time to walk from parking space to destination	5.066	2.026	6.249	0.012	158.477
Constant	-18.309	7.500	5.959	0.015	0.000

In model 1, age, family size, family income, presence of any backyard garage, purpose of the trip, trip duration from origin to destination, reason for choosing the parking location, average parking duration at night, maximum search time to find an empty parking space and the average time for the users to walk from the parking space to destination were the variables found to be significant in modelling the parking demand. In this model, the maximum parking fee which the users are willing to pay was not considered. The R square value of the model 1 is 0.698. This means that these independent variables can explain 69% of the variation in parking demand. The final form of the demand model for Ramanagar, Roorkee is as follows,

$$Y = -18.309 + 0.287X_1 - 3.650X_2 + 5.381X_3 - 11.012X_4 + 2.023X_5 + 2.899X_6 + 2.347X_7 - 5.571X_8 - 4.729X_9 + 5.066X_{10} \quad \text{..... Eq. 1}$$

Where Y is the number of cars parked at night time, X_1 is age, X_2 is the family size, X_3 is the family income, X_4 is the presence of a backyard garage, X_5 is the purpose of the trip, X_6 is the trip duration from origin to destination, X_7 is the average parking duration at night, X_8 is the reason for choosing the parking location, X_9 is the maximum search time to find an empty parking space and X_{10} is the average time to walk from parking space to destination.

Table 6: Variables in the Equation

Variables	*B*	*S.E.*	*Wald*	*Sig.*	*Exp(B)*
Age	0.287	0.116	6.163	0.013	1.332
Family size	-3.650	1.740	4.402	0.036	0.026
Family income	5.380	2.058	6.831	0.009	217.008
Presence any backyard garage	-11.010	4.292	6.582	0.010	0.000
Purpose of trip	2.023	.800	6.399	0.011	7.562
Trip duration origin to destination	2.899	1.241	5.460	0.019	18.150
Average parking duration at night time	2.347	0.991	5.604	0.018	10.456
Maximum parking fee are willing to pay	5.065	2.027	6.245	0.012	158.380
Reason for choosing the parking location	-5.570	2.613	4.542	0.033	0.004
Maximum search time to find an empty parking space	-4.728	2.116	4.992	0.025	0.009
Constant	-18.307	7.501	5.957	0.015	0.000

In model 2, age, family size, family income, presence of any backyard garage, purpose of the trip, trip duration from origin to destination, reason for choosing the parking location, average parking duration at night, maximum search time to find an empty parking space, maximum parking fee which the users are willing to pay were the variables found to be significant in modelling the parking demand. The significant variables were almost similar for both models, but the average time for the users to walk from the parking space to destination was not found significant in model 2. The R square value of model 2 is 0.697. This shows that the independent variables could explain 69% of the variance in the parking demand. The parking demand model for Ramanagar, Roorkee is

$$Y = -18.307 + 0.287X_1 - 3.650X_2 + 5.380X_3 - 11.101X_4 + 2.023X_5 + 2.899X_6 + 2.347X_7 + 5.065X_8 - 5.570X_9 - 4.728X_{10} \quad \text{….. Eq. 2}$$

Where Y is the number of cars parked at night time, X_1 is age, X_2 is the family size, X_3 is the family income, X_4 is the presence of a backyard garage, X_5 is the purpose of the trip, X_6 is the trip duration from origin to destination, X_7 is the average parking duration at night, X_8 is the maximum parking fee which the users are willing to pay, X_9 is the reason for choosing the parking location and X_{10} is the maximum search time to find an empty parking space.

6. Sensitivity Analysis

Sensitivity analysis was done using One Factor at a Time (OFAT) analysis to examine the influence of the dependent variable over the independent variable by changing each dependent variable. Each of the significant variables was increased by 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40%, keeping the other significant variables unchanged. The sensitive analysis of the parking demand was done for model 1 and model 2. Figure 6 and Figure 7 show the result of sensitive analysis done on the model with the parking fee and without the parking fee, respectively. It was observed that increasing the age, family income and parking duration at night time have a positive effect on parking demand in both cases. People with higher age and family income prefer on-street parking, which further increases while considering parking fees as a factor. Factors like fee willingness to pay and availability of backyard garages negatively influence the parking demand. The change in family size does not affect the parking demand significantly. This is because most houses have one or two vehicles, irrespective of their family size.

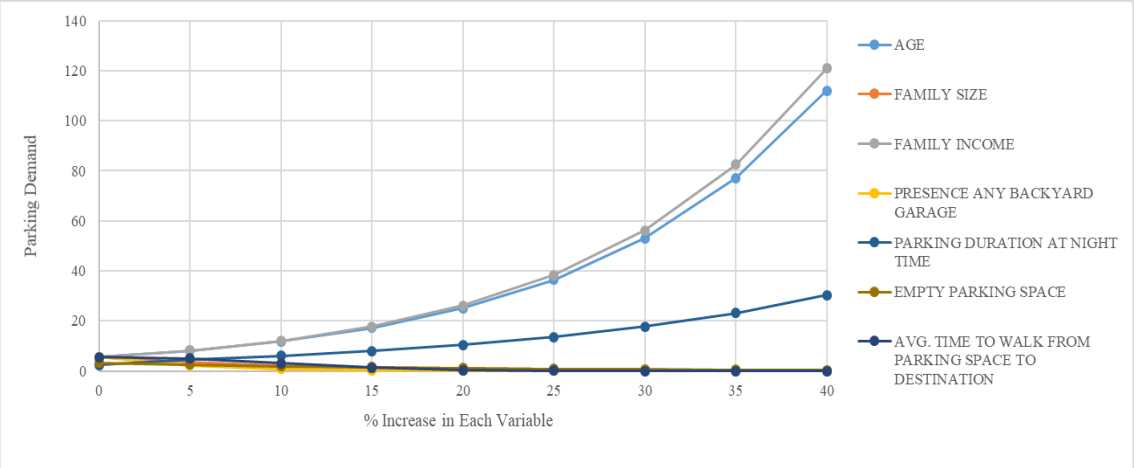

Figure 6: Sensitive analysis of the model 1

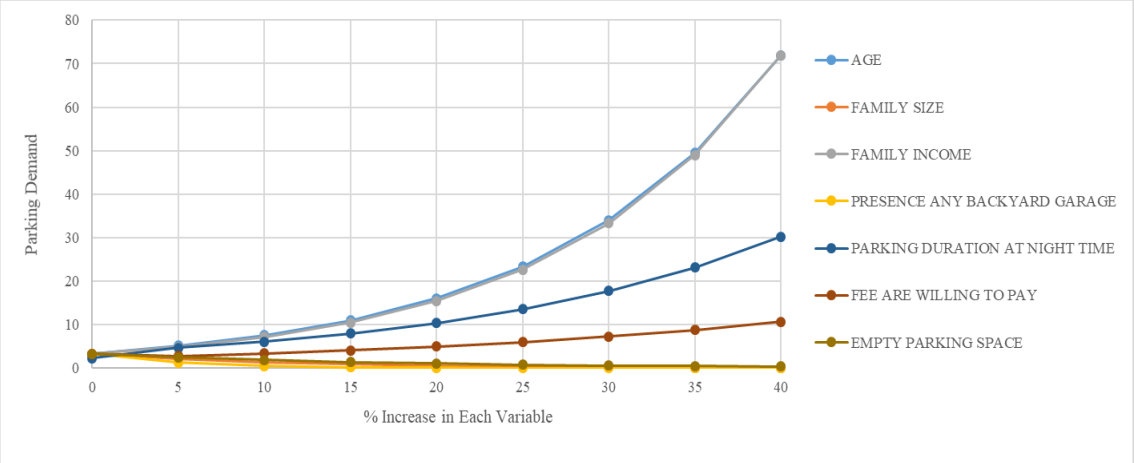

Figure 7: Sensitive analysis of the model 2

7. Conclusion

Car parking demand has been evaluated using a logistic regression model and was used to find out the parking demand during the nighttime. Three types of surveys have been conducted at Ramnagar, Roorkee, to collect data from the field. The result shows that the maximum number of parked vehicles was found to be 216 vehicles from 01:00 AM to 03:00 AM on Wednesday. The socio-economic data, demographic data and several parking statistics were used to generate the parking demand model and some of those parameters are found to be significant. Model 1 does not consider the parking fee as an independent variable and the parking fee was included in the development of model 2. While considering the parking fee in model 2, the average time to walk from parking space to destination was not found to be significant. This is due to the fact that people were not giving any attention to the distance between the parking space and the destination if the parking fee is implimented. In the field survey, it was found that 76% of the parking spaces were occupied with 24% free spaces indicating a higher demand. Further, in the sensitivity analysis, while increasing the variables in model 1, the parking demand increased up to 120%. But when model 2 was used, the parking demand did not go more than 75 %. This shows that including parking fees in the residential area decreases the parking demand significantly. Sensitivity analysis also shows that factors like the maximum parking fee willing to pay and the availability of backyard garages

negatively influence the parking demand. The sensitive analysis also revealed that people with higher age and family income have a tendency to increase the parking demand at night. If the parking fee policy is implemented in the future on a daily or monthly basis, it will play a significant role in reducing the on-street parking demand at night and parking problems in residential areas (Chu, C.P. and Tsai, M.T. 2011; Jansson, J.O. 2010). Through a well-formulated parking fee policy, revenue also could be generated, which may directly improve the economy (Timilsina, G.R. and Dulal, H.B. 2011; Minh, C.C. and Tu, T.T. 2022). Also, the impact of public promotion actions aimed at encouraging residents to adopt more sustainable modes of transportation on the results of analyzing the demand for on-street night car parking fees could be significant. By promoting alternative forms of mobility, such as walking, cycling, or using public transportation, or providing incentives for carpooling. The demand and congestion for car parking during nighttime may decrease. This could lead to a reduction in the revenue generated from parking fees. Therefore, analyzing the effects of public promotion actions on the demand for on-street night car parking fees is crucial to understand how sustainable mobility initiatives can influence parking behavior and potentially contribute to a more environmentally friendly transportation system.More over, the optimal management of night parking of vehicles requires a multifaceted approach that involves increasing the availability of parking spaces, implementing a permit system, implement time-limited parking, increasing public transportation, promoting carpooling, using technology, implementing reservation systems, and collaborating with private parking providers. By adopting these solutions, the parking system can be expanded and improved to meet the needs of vehicle owners and decrease the night parking demand in residential areas.

Due to the lack of manpower and the post-COVID scenario, the field survey could not be conducted in other areas, which is the limitation of the study. However, more case study areas will be considered for analysis in our future studies. Further, explanatory variables like congestion, delay and carpooling, etc. may be incorporated in the model to improve its performance in future.

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