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Assessment of On-Street Parking for Congested Area of Vadodara City

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***Abstract*— Major cities of India are facing on-street parking problem especially in CBD area. Insufficient data for on-street parking demand and absence of concrete parking policy leads to business as usual condition on major streets of CBD area. Therefore, a 12 hour parking inventory using license plate method was carried out for the two busy urban streets of the CBD area of Vadodara. Survey witnessed demand spilling over the supply with poor turnover for major duration of the inventory. This study was an attempt to model the response of the vehicle parkers using on-street parking for a policy measure framed under guideline of National urban transport policy (NUTP 2014). The survey data was analysed using fuzzy technique revealed that house hold income, frequency of trip and duration of parking influenced the parking choice behaviour of driver.**

Keywords*— *On-street parking, fuzzy logic, NUTP, Commercial Business District (CBD)

I. INTRODUCTION

The speedy economic development and much comfortable and faster vehicles of India have led to dramatic increase in the number of private vehicles particularly motorised two wheelers and passenger cars. Statistics revealed by the Centre for science and environment (2009) states that country reached first millions of personalized vehicle in 1971, after that another 20 years passed to add 2 more million. But in last decade just only in 4 years (2001 to 2004) 16 Million vehicles were added. This growth of vehicles directly results in increase of parking demand spaces. Addition of a single vehicle leads to likely demand for parking space at 3 places, at the residence, work place and shopping areas. The problem of parking demand becomes more acute in high commercial city centres where limited public parking plots fails to meet ever increasing parking demand. The second order metropolitan cities of India are facing daily problems of parking particularly in CBD area. Free on-street parking policy and insufficient management measures on major urban street of CBD areas of this cities leads to chaotic parking behavior, double lane parking, congestion during peak hours and high level of air pollution. Global practices followed in developed countries for efficient management of on-street parking space have proved effective tool in handling the parking demand. The present paper showcases response of vehicle parkers to paid policy measure for on-street and off street parking by adopting differential graded parking fees as per parking duration.

II. PARKING POLICY –AN EFFECTIVE MANAGEMENT TOOL

According to "Choc-A-Block parking measures to address mobility crisis (2009)" to optimize the use of road spaces and to reduce the numbers of personalized vehicles various steps such as congestion and road pricing, parking levers, tax measures to promote public transport have been introduced globally. While in some instances, traffic congestion reduced significantly as a result of parking price. Studies by Miller and Everett (1982) and Pickrell and Shoop (1980) have considered the impact of parking charges on the decision to drive to work. These charges have often more significant impact on the travel demand compared to other management measures. Thus, in present paper, an attempt has been made to know the effectiveness of the time restraint parking policy if implemented as management tool and further fuzzy logic based approach of soft computing technique has been adopted to model the same. The paper is organised in six sections wherein first two section discusses the parking problem and its mitigating measures, section three and four covers study area and data collection –analysis and finally the last two section involves fuzzy rule based model for parking policy-(FRB-PP), discussions and conclusions.

III. STUDY AREA

Vadodara is the cultural capital of Gujarat where all traditional festivals are celebrated in a unique way. Vadodara is the 20th largest populous city in India. Vadodara is the third largest city of Gujarat tailing behind Ahmadabad and Surat, with an area of 159.95 sq. km and population of 18.22 lakh (2014). The vehicles registration of the Vadodara city in last five years is remarkable as shown in figure: I.

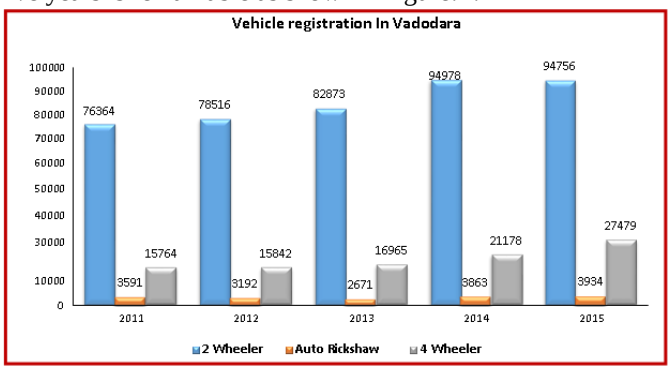

Figure 1: Vehicle registration in Vadodara Source: RTO Vadodara

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It can be observed that average 85000 of 2 Wheelers are added every year since five years on the roads of Vadodara city which amounts to addition of approximately 230 two wheelers per day. While 4 Wheeler are increasing every year at an average number of 19500 which indicates daily addition of 53 cars on the roads of Vadodara city. Considering the parking bay size of 2 wheeler as 2.5*0.85 and for four wheelers as 2.5*5 as per the IRC standards, the demand of parking space estimates to be 488 m2 for 2 wheelers and 662 m2 for 4 wheelers per day assuming parking at residence only. For the present study the vehicle registration data collected from the RTO was analysed and the vehicle growth for the CBD having 3-4% of total urban area was exclusively segregated to know the vehicle population growth in the CBD area which is as shown in figure: II.

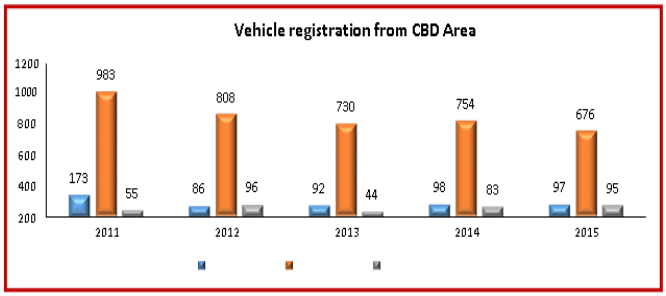

Figure II: Vehicle registrations from CBD area Source: RTO Vadodara

Figure: II reveals that growth of 2 wheelers and four wheelers are consistent in the CBD area of Vadodara city. This addition of vehicles generates high demand of parking space in congested CBD area. Due to compact and mixed land use of CBD area it also adds pressure to on-street parking demand. Figure: II reflects the fact that residents of CBD area are not concerned about the availability of parking space. With reference to this cumulative parking space requirement for the Vadodara city is increasing exponentially as shown in figure: III. It is observed hat year by year cumulative demand for parking space of 2wheeler and 4 wheeler has increased to 2050000(1200+850) m2 i.e. 2.05sq.km within five years and which needs to be addressed to prevent pressure on urban infrastructure.

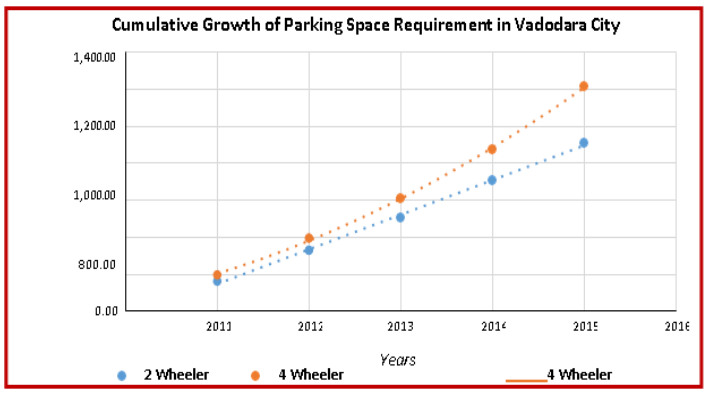

Figure III: Cumulative growth of parking space requirement in Vadodara City

With reference to this high demand of parking, for the present study, two busy streets of CBD zone of old city were selected as the study area. The characteristics of these roads are as follows:

M. G. Road: This road is heavy traffic volume road of Vadodara city .It involves increased commercial activities like jewellery shop, readymade garment, and cosmetics shops in the vicinity of each other which has high potential for trip attraction. It allows the on-street parking on either side of carriage way with odd- even date parking scheme. The sectional view of this roads is as shown in figure: IV and V

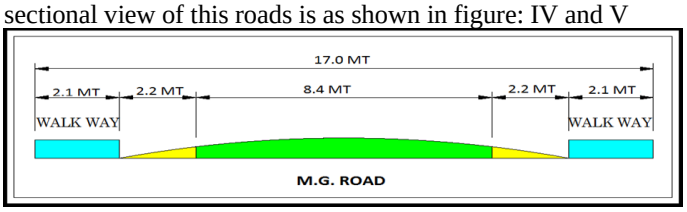

Figure: IV Sectional view of M.G Road

Jubelibaug to Kothi: This Street is one of the popular road of the city area in Vadodara having high commercial activities like footwear shop, readymade garments shop, cinema threatre, Banks as well as few religious places which automatically attract the visitors and thereby generates high demand of parking

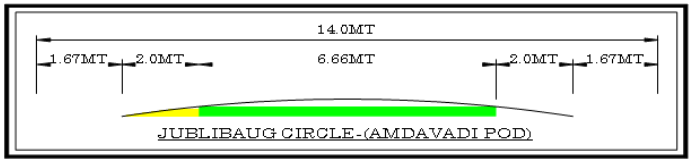

Figure: V Sectional view of Jubelibaugh to kothi road

On both streets it was observed that no demarcations of parking bays were made for the vehicles. Due to heavy flow of traffic on both the roads it was practically difficult to implement enforcement for illegal parking which resulted in double parking and occupancy of para-transit as well as car commonly featured on both the sides of road. Such chaotic parking reduced the carriage way width which created conflict and delay to through traffic, apart from congestion problems. Encroachment by the street hawkers as well as illegal parking of vehicles restricted the available stretch of carriage way for through traffic

IV. DATA COLLECTION AND ANALYSIS

Parking surveys were conducted to collect the parking statistics like parking accumulation, parking volume, parking index and parking turnover. The “license plate method” was adopted to conduct the survey. The Registered number plates of on-street parked vehicles were noted manually at one hour interval. Full day 12 hours survey was conducted from 9.00 a.m. to 8.00 p.m. The twelve hours survey facilitated segregation of long term and short term parkers. It also provided base for deciding the parking charges and revenue generation. Right angle parking of 2 wheelers was permitted on both the streets for width of 2 meters as shown in figure V. For the analysis of parking data the vehicles parked on the opposite side of the subject date (Odd or Even) were considered as illegally parked vehicle as they can be penalised.

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The geometrics of the road is as shown in Table: I.

Name of Road	Jubeli baugh to kothi Road	M.G. Road
Type of carriageway	Undivided	Undivided
Total Length of the street selected	920 meters.	350 meters
Effective length of the stretch for parking	722.5 meters.	323 meters.
No. of parking bays in terms of two wheelers (As per IRC 2.5m*0.85m)	850	380

Table I: Geometric of selected streets

Parking inventory was conducted on normal working day with the help of six enumerators with four patrolling on the legal side parking and remaining recording illegal parking. In the survey, double parking on legal side was included as legal demand for the observation. The survey observed legal parking volume 637 (530-2 wheeler, 75-Cycle, 32- other) at 7:00 pm on M.G Road and 889(707-2 wheeler, 18-4 wheeler, 143-cycle, 15-auto rickshaw, 5-other) at 5:00 pm on Jubelibaugh to kothi road and.

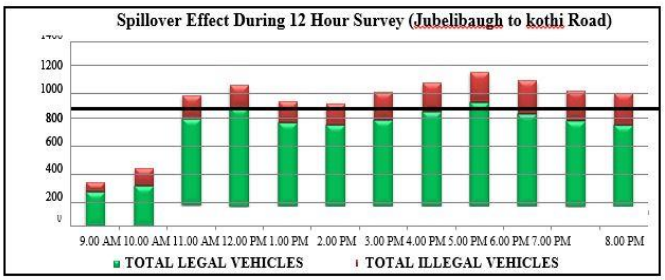

Figure VI: Spill over effect during 12 hour survey on Jubelibaugh to kothi Road

Figure: VII shows that total parking demand spilled over the parking supply for most period of the day except 9:00 am and 10:00 am. The survey observed that though legal parking spaces were available still people parked illegally. This reflects the tendency of people to walk less and to park their vehicles near their destination. It is also evident from the above figure that commuter visiting longer street has more tendency to park illegally to minimize the walking distance upto destination. The local authority of the city offers free on-street parking to the private vehicle users. At present the dominant private mode of travel in CBD area is motorised 2 wheeler followed by 4 wheeler. The result of on street parking survey of the two street suggested that effective parking policy is inevitable to manage high parking demand. The NUTP has already recommended to charge on-street parking facility such that land cost is reflected. With this policy recommendation, in present study stated preference survey for paid on-street parking policy with reference to time restraint measures was offered to the parkers arriving in the CBD area and their response was collected. Field survey of 410 respondents was carried out during normal working hours for weekdays and weekends using structured questionnaire survey. The response was collected for three basic parameters i.e. socio-economic status, travel attributes and parking policy response to model their behaviour. The questionnaire format consisted of 11 variables, 3 of which were mode abstract (not affecting trip making decision) like Gender, origin and destination and 8 were mode specific (affecting trip making decision) such as house-hold income, travel time, trip length, purpose of trip, frequency of visiting CBD area, parking duration of the vehicle, searching time for the parking space and walking time from the parking to the destination in the CBD. The response to the time restraint policy was collected for the proposed parking charge reflecting the land cost as shown in the following table: II. The respondent were offered graded parking charge for on-street as per the parking duration and fixed parking charge for off-street parking.

Duration	On-street Parking charge		Duration	Off street parking charge (Fixed charges applied)	
	2-wheeler	4-wheeler		2-wheeler	4-wheeler
0 – 1 hr	₹05	₹20	0 – 1 hr	5 ₹	20 ₹
1 – 2 hr	₹10	₹40	0 – 2 hr	5 ₹	20 ₹
2 – 4 hr	10 ₹/ hr	25 ₹ / hr	2 – 4 hr	10 ₹	20 ₹
>4 hr	15 ₹ / hr	30 ₹ / hr	> 4 hr	10 ₹	30 ₹

The above parking charge were proposed by considering as per the "Land cost" published by the land revenue department of government of Gujarat. The graded parking charge proposed according to parking duration were based on the key principle suggested by NUTP 2014.The descriptive analysis of the collected response for the respondent is tabulated below.

The choices against the proposed time restraint policy offered to the respondent were:

1. Continue to arrive by private mode and ready to pay prescribed parking charge
2. Shift to off street parking with less parking charge
3. Shift to another mode of transport
4. Change the destination where free parking is available

Socio Economic Attributes				
Gender	Male: 83%			Female: 17%
House hold Income (HHI)	<20,000 (LIG)	20,000- 40,000 (MIG)		>40,000 (HIG)
	32%	37%		31%
Purpose of Trip	Work: 54%		Education: 05%	
	Shopping: 33%		Others: 08%	
Frequency of trip (FREQ)	Daily(D): 46%		Monthly(M): 09%	
	Weekly(W): 29%		Occasionally(O): 16%	
Travel and parking attributes				
Trip Length	<3 km:	3-7km:	7-11km:	>11 km:
	25%	53%	15%	7%
Parking Duration (PARKDUR)	<1/2 hour:	1/2- 1 hour	1-2 hour	>2 hour
	31%	17%	21%	31%
Searching time	Immediately	0-2 minute	2-5 minute	> 5 minute
	29%	24%	24%	23%
Walking time	2-5 minute	5-10 minute	>10 minute	
	60%	24%	10%	
Response to time restraint policy	Ready to pay: 53%		Change to off-street: 27%	
	Change mode: 9%		Change destination: 11%	

Table III: Descriptive analysis of Survey data

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The variable house hold income was classified into three groups LIG(Low income group),MIG(Middle income group) and HIG(High income group).

V. DEVELOPMENT OF FUZZY RULE BASED MODEL

The attraction potential of CBD area for shopping is very high in most of the Indian cities and visitors prefer to use private vehicles for their trips in these areas. These leads to high parking demand which is difficult to manage under free on-street parking regime adopted by local authorities. The time restraint policy measures can prove to be an effective tool to manage the existing parking space. The response to such policy measures by visitors of different socio-economic class can be easily captured by fuzzy approach. Thus, the development of fuzzy interference system based model to capture the choice behaviour were carried out using the fuzzy logic tool box in MATLAB (version- 8.1).

A. Fuzzy Inputs and Outputs

Fuzzy rule based model for parking policy (FRB-PP) is being developed here with the input variables monthly household income, frequency of trip and duration of parking of the vehicles. From the descriptive statistics it is very much clear that there has been a greater variation in the response to the paid parking policy with reference to the above mentioned variables. The stated preference surveyed observed that response of people was affected by different income group of people and also influenced by the variables like frequency of visit and parking duration. Hence, these variables were considered as an input for the development of FRB-PP. The four options in output were continue to arrive by private mode and ready to pay prescribed parking charge, Shift to off street parking with less parking charge, Shift to another mode of transport, Change the destination where free parking is available.

B. Fuzzy Model structure

The fuzzy model operates in three steps as mentioned below and the respective fuzzy logic structure is depicted in Figure: VIII.

- Fuzzifications of crisp input variables through Membership Functions (MFs).
- Rule-based inference.
- Defuzzification

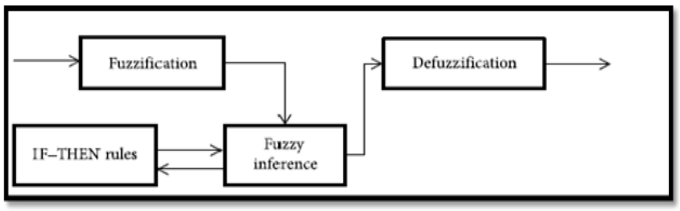

Figure VIII: Fuzzy logic methodology

C. Setting up of membership function

The data collected during road side interview surveys pertaining to household income, frequency and Parking duration are rather in crisp forms which need further fuzzifications through appropriate membership functions. The triangular and trapezoidal functions around a crisp value better reflects the flexible boundary conditions for the inputs. The inputs are further categorized into reasonable number of fuzzy sets to reflect on their likely impacts. With this background, the model inputs – HHI – was labelled from 'LOW' to 'HIGH' and the inputs like FREQ and PARKDUR was labelled from 'LOW' to 'VERY HIGH' as shown in Fig XI. The model output which was in form of policy responses (PRs) were four in number and were formed using the trapezoidal Membership Function. Later, either the left and/or right spread as well as overlapping of the trapezoidal MFs are set to meet the trend in the empirical data. The final ranges of the input and output fuzzy sets are as shown in Table: V

Sr. no	Attribute	Membership function	Type of waveform	Range
Input variable				
1	Household income	Low (<20,000 Rs)	Trapezoidal	[0 0 0.8 1]
		Medium (20,000-30,000)	Trapezoidal	[0.8 1.3 2 2]
		High (>40,000)	Trapezoidal	[1.7 2.5 3 3]
2	Parking duration	Low (<0.5 hr)	Trapezoidal	[0 0 0.8 1]
		Medium (0.5-1)	Trapezoidal	[0.7 1 1.7 2]
		High (1-2)	Trapezoidal	[1.7 2 2.7 3]
		Very High (>2)	Trapezoidal	[2.7 3 4 4]
3	Frequency	Low (Daily)	Trapezoidal	[0 0 0.5 1]
		Medium (Weekly)	Trapezoidal	[0.7 1.3 1.8 2]
		High (Monthly)	Trapezoidal	[1.8 2.2 2.7 3]
		Very High (Occasionally)	Trapezoidal	[2.7 3 4 4]
Output variable				
1	Response to paid parking policy	Ready to pay	Trapezoidal	[0 0 0.7 1]
		Shift to off street parking	Trapezoidal	[0.7 1 1.7 2]
		Change the mode	Trapezoidal	[1.7 2 2.7 3]
		Change the destination	Trapezoidal	[2.7 3 4 4]

Table V: Development of Membership Functions

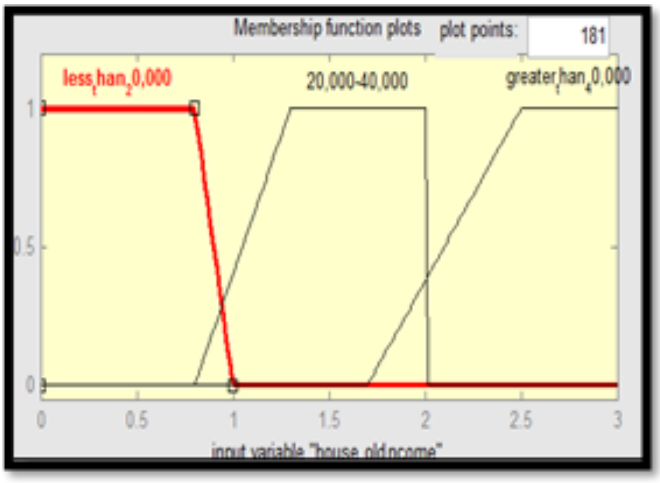

Figure IX: Membership function of Fuzzy variables

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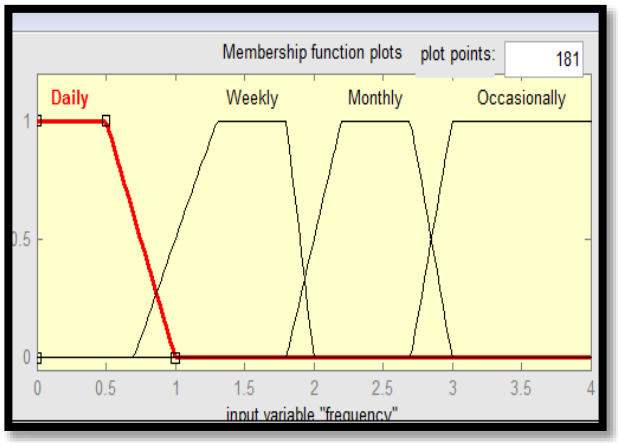

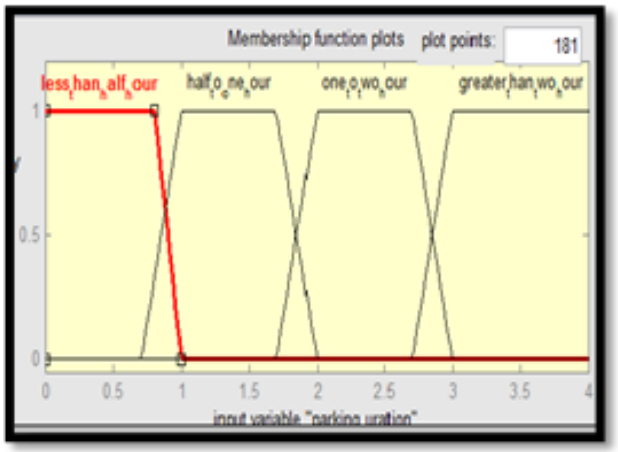

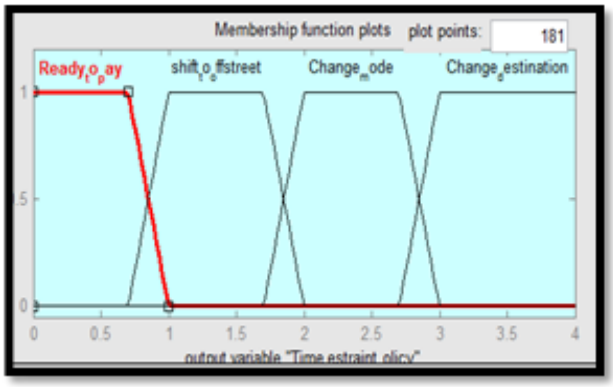

D. Fuzzy rule formation

Fuzzy rule base for FRB-PP was developed for three income groups, each having 16 numbers of rules with four levels of parking duration and four levels of frequency for each income category. The rule base was constituted by 48 numbers of IF–THEN rules for three income categories. A typical rule is IF Household income is 'Low' AND Parking duration is 'Low' AND Frequency is 'Low', THEN response to time restraint policy will be 'Change to Off-street'. Numbers of such rules were framed on appropriate reasoning and likely response of the parking policy.

E. Defuzzification process

As the output generated by fuzzy inference system cannot be used directly, it is necessary to defuzzify the fuzzy quantities into crisp terms for the application purpose. Many Defuzzification techniques have been proposed by researchers. The most commonly used method is Centroid method in Mamdani inference mechanism. The method calculates weighted average of the elements in the support set and analyses the combined shape of membership function, which gives us comparatively good results. The output membership areas are determined by the height of the membership function on the Y-axis as dictated by the rule strength value obtained by Max Min function approach. The centroids of the areas marked are computed for each of the competing output membership functions. Subsequently, centre of gravity is computed using the weighted average values which is depicted in MatLab rule viewer window.

VI. COMPARISON OF OBSERVED AND FUZZY RESPONSE

The comparison of observed policy response and the one predicted by the developed fuzzy rule-based model is shown in Figure: X. The model can predict the response to the parking policy at accuracy level of 67%. The response 'change to off-street' and 'change mode' was modelled at less than 2% error in the fuzzy logic. The absolute mean error of the model was found to be 4% while the root mean square error was 5% which is statistically acceptable.

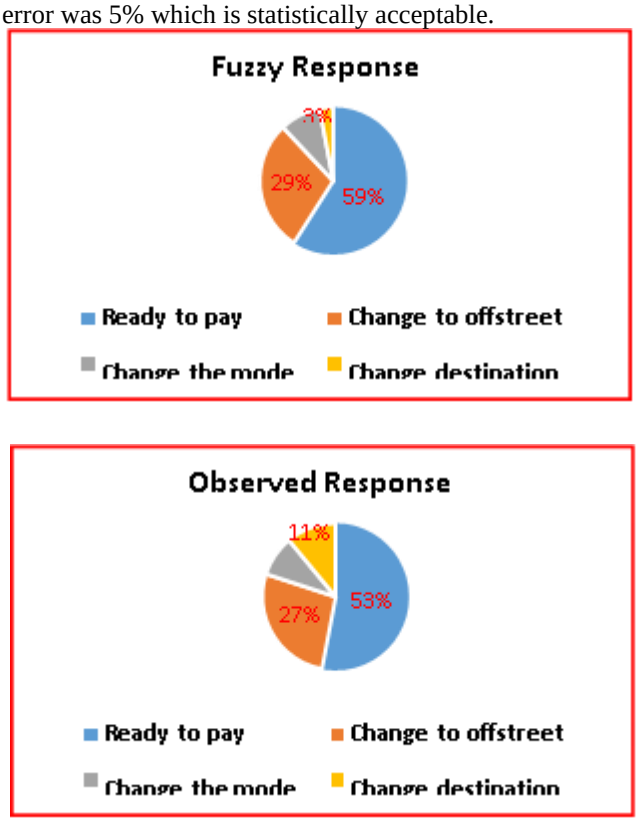

Figure X: Comparision of FUZZY response with observed respons

The cross classification table for the observed and predicted response for the paid on-street parking policy is shown in table: VI. It was observed that fuzzy model over estimated "Ready to pay" choice and under estimated change the destination choice of policy response as the behavior of respondent were subjective and difficult to model.

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	Predicted (Number of response)					
		Ready to pay	Shift to off street	Change mode	Change destination	Total
Observed (No. of Response)	Ready to pay	183	22	12	0	217
	Shift to off-street	31	69	11	0	111
	Change mode	9	18	10	0	37
	Change destination	19	10	4	12	45
	Total	242	119	37	12	410

Table VI: Cross classification Table

It is observed from the table that "ready to pay" choice is over estimated by the fuzzy model and the "change the destination" is under estimated which may be due to fact that respondent with identical socio economic, travel and parking attributes behaves subjectively to paid parking policy.

VII. RESULT AND DISCUSSION

- Lack of demarcation of individual parking bay on the study street results in chaotic and in disciple parking behavior and demand assessment survey reflected mass disobedience behavior of people in form of illegal parking. Also, the high amount of illegal parking observed during the survey reflects poor enforcement measures in the study area.
- On-street parking demand management has become one of the burning problem of urban transportation planning. One of the effective tool to manage this problem is paid parking policy with reference to time restraint measures. The descriptive statistics and the fuzzy model reveals that behavior of people to the proposed on-street parking policy is associated with household monthly income, frequency of trip and parking duration.
- Impact of parking fees to travel choices varies significantly. A combination of parking charges and restricting parking availability is likely to be more effective in encouraging behavioral change.
- Segmentation of the available on-street parking space as per the duration of the stay of parkers may prove effective in managing on-street parking demand.
- The Logit regression technique is a popular conventional approach based on crisp inputs for the response modelling. In reality, it depends on the judgement by the traveler perception and in linguistic expressions, wherein the boundaries are not fixed and uncertainty prevails. Hence, fuzzy rule-based model is considered as the better option to address the shortcomings in crisp based modelling. The developed model (FRB-PP) finds applications in assessment of effectiveness of policies. Hence, modelling through soft computing techniques can give more reliable results representing the actual psychology of the individual.
- Statistical test like absolute mean error and root mean square error, Chi square endorses the prediction accuracy of the model and from cross classification table, it could be concluded that overall accuracy of model is 66% and the fuzzy model was found to be fairly accurate for "change to off street" and "change mode" choices.

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