

# ITS USING FUZZY LOGIC FOR REAL-TIME DEMAND-RESPONSIVE TRANSPORT SYSTEM

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## ABSTRACT

Persuading people to shift from personal vehicles to public transport is amongst the most important elements of any strategy to meet the growing urban travel demand in a sustainable manner. Demand responsive system to passengers is an advanced public transport system as well as for an integrated transport system such as parking, public transport, etc. Human decisions are complex in nature and to a certain degree are uncertain and random in nature. So, fuzzy logic is applied, which is a better tool to deal with these uncertainties; and randomness. This paper presents a real time demand responsive system for the quick response to the passenger demand. The framework include two main functionality: 1. Passenger demand forecasting for time series, and 2. opting the best service strategies using fuzzy logic in passenger demand attributes. The proposed demand responsive system works primarily according to the predicted up-to-date attribute of passenger demand. Proposed system also integrates with fuzzy logic system to capture the real time OD pattern with the smart card swiping system. In order to estimate the real time demand the model works on two platform namely, Fuzzy inference system and also with the help of GIS. Paper mainly focus on two areas of demand responsive system namely, public transport and parking. Bangalore and Gandhinagar are the urban centres taken as case study considering the availability of data.

## KEYWORDS

Intelligent transport system, Demand Responsive system, Mode choice, Parking Demand, Pricing

## 1 INTRODUCTION

Indian roads are flooded with vehicles which creates road-traffic problems such as, congestion, delays and road accidents, which becomes a serious threat to the many cities. Thus road traffic conditions in India are becoming worse. The total registered vehicles in the country grew at a Compound Annual Growth Rate (CAGR) of 10.5% between 2002 and 2012 (Highways, 2013). 2001-2011 data revealed that growth rate of registered motor vehicles becomes almost three times the growth rate of road network and among registered vehicles, cars and taxis recorded an increase of about 200%. Transportation costs are increasing and the city centre road corridors are flooded with vehicles. So public transport is an important mode to alleviate these problems. (O.P, (2006))states, persuading people to shift from personal vehicles to public transport is amongst the most important elements of any strategy to meet the growing urban travel demand in a sustainable manner. But the selection of mode choice is always governed by the people's perception on a particular mode of travel, which is dependent on certain factors that are uncertain in nature. So in order to deal with these uncertainties which are very difficult to be quantified and meanwhile to increase the public transport ridership, an attempt has been made to develop a model for improving the ridership of public transport based on fuzzy logic technique.

Commuters generally shift to personalised modes of travel adding congestion to the urban corridors with increase in generalised cost of travel due to lack of public transport and its reliability for travel. The study aims to develop a model for improving the ridership of public transport system with specific reference to generalised cost in Gandhinagar city, a typical Indian city with a population of over 2,43,362 as per census 2011 which shows a decreasing trend in public transport share.

The study will attempt to demonstrate how people's perception on certain modes of travel can be used as a tool to improve the ridership of public transport. Parameters like, reliability, travel cost, in-vehicle time, discomfort, waiting time and journey speed have been generally used in the analysis. Human decisions are complex in nature and to a certain degree are uncertain and random in nature. So, fuzzy logic is applied, which is a better tool to deal with these uncertainties; and randomness. In order to develop a fuzzy logic model, Gandhinagar city is considered for the study, which shows a declining trend. Lack of better system of mass transport is experienced in Gandhinagar city which compels the road users to choose their personal means of transport as their primary choice adding to congestion.

The aim of the study is to develop a demand responsive model for real time passenger needs based on the selected attributes in determining the mode choice of the commuters as well as the parking demand choice. The objective of the study is to develop fuzzy membership functions with appropriate ranges and rules to create a human perception on mode choice and also to model generalised cost by identifying the parameters influencing the choice of the commuters. Here considering the availability of data, different study areas are chosen for showing the analysis pattern. Gandhinagar city is taken for public transport modelling, whereas, Indiranagar area in Bangalore is taken for parking study.

The entire study is divided into following sections: Section 1 briefly presents the background for the research and introduced the technique; Section 2 details out the study area characteristics; Section 3 broadly explains the methodology followed for the study with flow diagram; Section 4 presents the literature review on various studies carried out using fuzzy logic technique; Section 5 summarizes the inference of existing situation of public transport system. Section 6 deals with the modelling part of generalised cost and application of fuzzy logic in developing the model; Section 7 gives the conclusion of the study.

## 2 LITERATURE REVIEW

Fuzzy logic comprises of key elements namely *Input variables*, *Output variables*, *Linguistic variables*, *membership functions* and *rules*. Creating fuzzy rules from the numeric data was proposed further by researchers are used for mode choice modelling and trip distribution (Vythoukcas, 2003). Choice behaviour model using fuzzy logic proved to be a reliable soft computing technique which can deal with the uncertainty, ambiguity, subjectivity and imprecision (Pradipsarkar, 2013). (Amrita Sarkar, 2012) shown the procedures for creating fuzzy rules using linguistic variables to develop the fuzzy logic based four stage model. There are other ways to generate fuzzy rules are through ANFIS (Adaptive Neuro Fuzzy Inference System) method through clustering technique (Tharwat O. S. Hanafy, 2014). Intelligent transport system enabled with technologies has been elaborated by (Ortiz & Amin, 1995). (Swain, 2006) done study on the application of fuzzy logic in intelligent transportation system. (Mohan) explains the benefits of the ITS in transportation planning.

### 3 NEED FOR THE STUDY

In order to have smarter mobility for smarter cities, key challenge is to capture the uncertain human perception on mode choice. Mobility can be smart enough if the mobility promises the aspects that people want. Human perception on mobility is one of the unexplored path, which have the capability to take mobility to next level of being SMART. These commuters choose a particular mode for a travel based on different parameters of generalized cost namely, comfort level, in-vehicle time, waiting time, safety, pollution, fare etc. These parameters of generalised cost of travel also have an impact on city's economic growth. Till now none of the development plan tries to incorporate the people's perception on mode choice. Thus, there is a need for a model to reduce the generalised cost of travel for road users through which ridership of public transit can be improved and meanwhile promises a sustainable mobility within a city.

### 4 DATA SOURCE

*For public transport study:*

Public transport survey has been carried out to capture the human perception attributes such as Waiting time, Journey speed, Travel cost, In-vehicle time.

*For Parking Study:*

Parking Generation rate per 100sq.m., Parking turnover, Parking Occupancy, existing supply and peak parking demand.

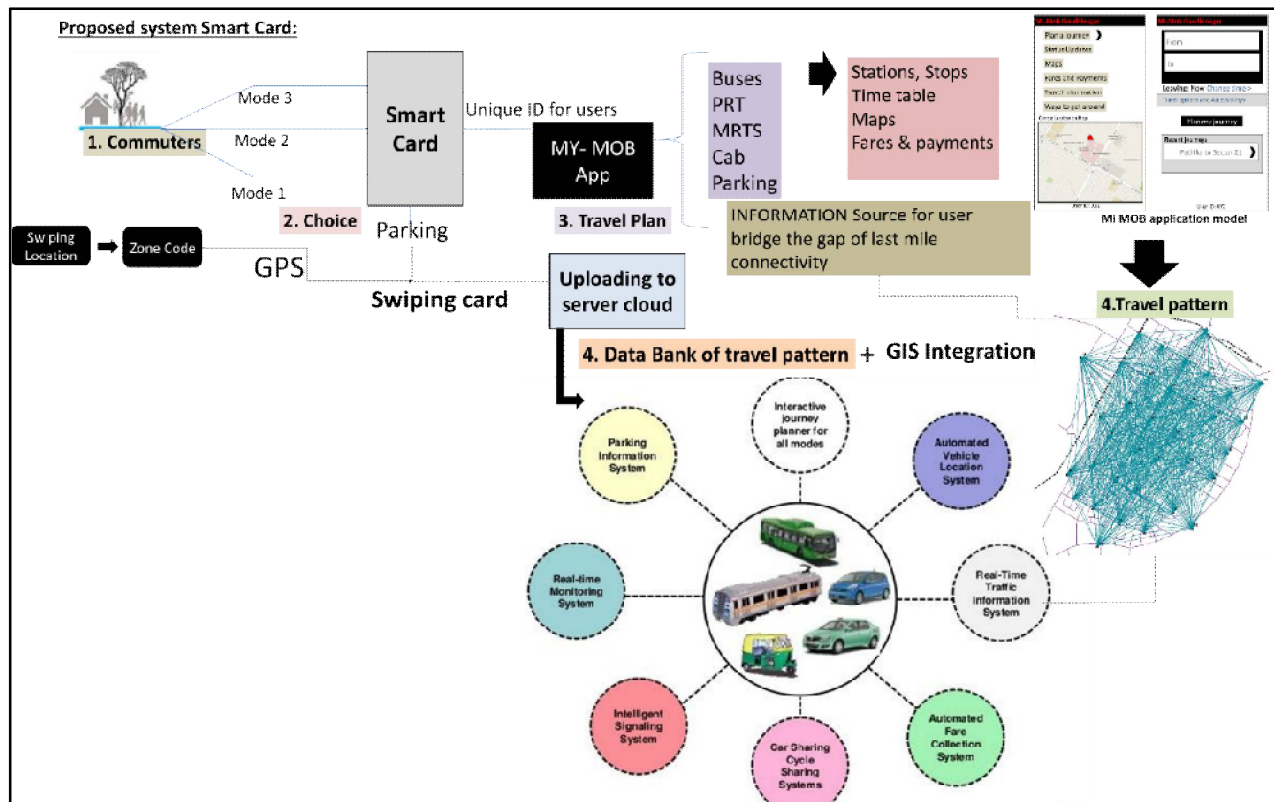


FIGURE 1 Architecture of demand responsive system

## 5 ARCHITECTURE

### Study Area Characteristic

#### *For Public transport Study:*

Gandhinagar city, the capital of state of Gujrat located in the western tip of India, with urban population 206,167 as per census 2011. The city of Gandhinagar has 30 sectors and is spread across an area of 177 sq.km. Total public transport route length within the study area is 151km. Average trip length is observed to be 4.1km. Total passengers carried is 35698.

#### *For parking Study:*

Indiranagar area which is a medium sized neighbourhood located on the eastern side of Bangalore with population of 40,356. It spreads over an area of 3.6 sq.km. 16 roads are taken for demand survey. Map showing the study area chosen: Gandhinagar (on left) and Indiranagar (on right)

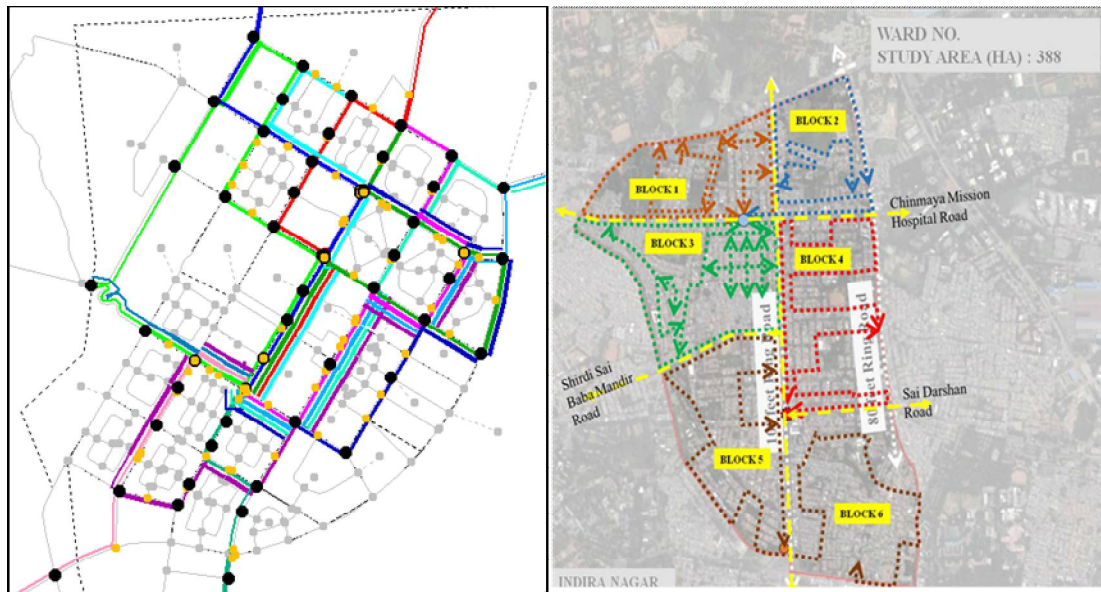


FIGURE 2 Showing the study area chosen

## 6 HOW THE MODEL WORKS?

In order to estimate the real time demand the model works on two platform namely, Fuzzy inference system and also with the help of GIS. Demand estimation through fuzzy logic estimation has been presented below with the help of sample study chosen.

### 6.1 For Public transport study:

Proposed model works in 2 stage process:

- 1) Influence of each attributes of generalised cost on both private vehicle users and public transport users are analysed by the model.
- 2) Proposed model works on the basis of the set of “IF Then Else” conditions applied on the selected attributes of generalized cost of travel.

### Stage 1: *How the generalised cost of travel is calculated?*

In order to calculate the generalised cost of travel, Random utility Theory is used.

Now, let us consider a generalized form of utility equation as follows:

$$U = a (\text{In-vehicle Travel Time}) + \beta (\text{Travel cost}) + \gamma (\text{Discomfort Level}) + \text{constant} \dots (1)$$

Where:

In-vehicle travel time, travel cost, and discomfort level are the attributes of travel

$a$ ,  $\beta$ , and  $\gamma$  are the coefficients associated with these attributes.

$$C(i,j) = a_1 t_{ij} + a_2 d_{ij} + F_{ij} + d \dots \dots \dots (2)$$

Where,

$t_{ij}$  is the in-vehicle travel time between origin  $i$  and destination  $j$

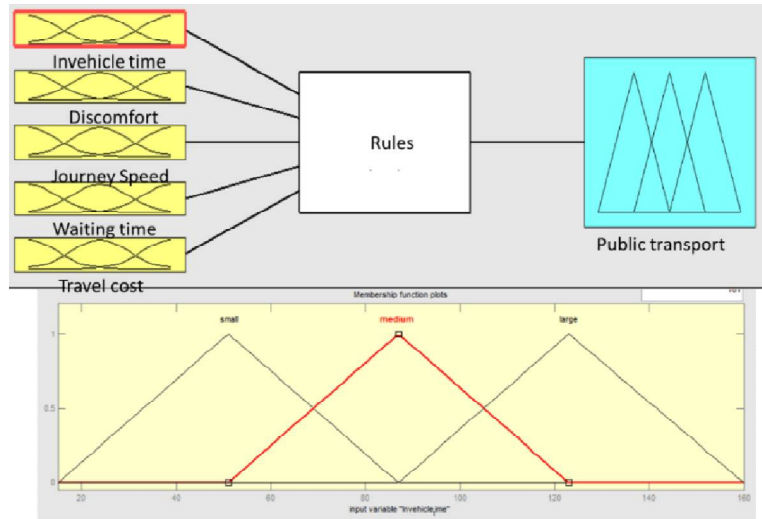
$d_{ij}$  represents the discomfort level experienced

$F_{ij}$  is the direct cost of travel from  $i$  to  $j$

$D$  is the modal penalty representing all attributes not included in generalized cost (e.g., safety, convenience, reliability etc.)

- The developed model allows the decision makers to upload data for each attributes there by allows model to calculate the generalised cost of travel for both private vehicle users and public transport users. The model converts all the attributes into unit of cost.
- Generalised cost for personalised vehicles are analysed to compare with existing generalised cost of public transport and for making different scenario.

**Stage 2 :** Psychology of commuters can't be captured by using discrete models like Multinomial logit, Binary logit etc. Fuzzy logic mechanism deals with rules as it captures the psychology of travellers on different variables. Since attributes are uncertain and dynamic, proposed model uses the mechanism of Fuzzy logic which converts the crisp data into linguistic variables in range of  $[0,1]$ . Simple, plain-language IF X AND Y THEN Z rules are used to describe the desired system response in terms of linguistic variables rather than mathematical formulas. The number of these is dependent on the number of inputs, outputs, and the designer's control response goals. Thus Fuzzy logic mechanism are more good in capturing the human psychology and most of the conventional methods use crisp data which can't show the exact output stating peoples decision.



**FIGURE 1**Shows the test carried for membership functions created in fuzzy inference system of Matlab 2011

IF Travel cost in mode 'X' is Very Big AND Comfort level in mode 'X' is Very Low THEN Utility of mode 'X' is Very small. Different combination of rules are programmed as default in the model that reflects the human behaviour of mode choice based on the identified attributes. Illustration of Scenario developed for Trivandrum city is shown below in **Table 1**.

**TABLE 1** Test carried for Scenario building in Matlab

| Attributes                         | Existing      | Scenario 1    | Scenario 2    | Scenario 3    | Scenario 4    |
|------------------------------------|---------------|---------------|---------------|---------------|---------------|
| Invehicle travel time (min per km) | 5             | 5             | 3             | 4             | 3             |
| Discomfort level                   | 2             | 3             | 2             | 1             | 1             |
| Waiting time (min)                 | 8.16          | 4             | 8             | 4             | 8             |
| Journey Speed (kmph)               | 19            | 20            | 18            | 25            | 30            |
| Travel cost (paise per km)         | 58            | 58            | 80            | 100           | 125           |
| Generalised cost                   | <b>301.87</b> | <b>325.88</b> | <b>312.28</b> | <b>376.06</b> | <b>452.71</b> |

## 6.2 For Parking Study:

An important aspect of parking demand model is parking selection and the factors related to it. For, example, walking distance from parking plot to destination, land use, parking supply available etc. Parking demand varies due to influence of each location advantages as well as its characteristics. So it is necessary to divide the study area into subzones based on its parking characteristics as well as the current parking demand. The following parameters were used to formulate a model in order to predict the future demand for on-street parking in the study area:

- Parking supply (in ECS)- The observed parking length converted to ECS/ the design supply in ECS
- Parking Generation rate- Parking(in ECS) generated per 100sqm of built up area in a zone



**FIGURE 6 Division of subzones to model parking demand**

Parking generation rate method is used to calculate the parking demand generated from land use in unit area. The parking demand in certain subzones is equal to total parking demand generated by certain areas. Generation rate is calculated by dividing observed ECS in respective areas by total floor area in terms of 100 sq. meter.

- Parking turnover
- Parking index

**Table 2** shows the selected indicators as well as the existing parking demand observed in respective subzones Figure 6 shows the division of subzones based on its parking characteristics as well as homogeneity of land use for better accuracy demand prediction.

**TABLE 2 Selected indicators for model building**

| Zone         | Supply (ECS) | Parking generation rate/100sq.m | Turnover | Occupancy | Existing parking demand (ECS) |
|--------------|--------------|---------------------------------|----------|-----------|-------------------------------|
| 1            | 33.2         | 0.9                             | 10       | 1.5       | 71.7                          |
| 2            | 26.7         | 0.6                             | 10       | 1.5       | 32.7                          |
| 3            | 24.5         | 0.7                             | 10       | 1.5       | 37.4                          |
| 4            | 3.3          | 0.1                             | 9.5      | 1.5       | 7.3                           |
| 5            | 11.7         | 0.2                             | 12       | 1.8       | 17.5                          |
| 6            | 39.3         | 0.3                             | 13       | 2.2       | 25.9                          |
| 7            | 42.7         | 0.5                             | 18       | 2.2       | 32.8                          |
| 8            | 13.7         | 0.2                             | 18       | 2.2       | 18.8                          |
| 9            | 23.3         | 0.6                             | 9        | 0.8       | 44.9                          |
| 10           | 26           | 0.5                             | 9        | 0.8       | 46.9                          |
| <b>Total</b> |              |                                 |          |           | <b>336.1</b>                  |

### 6.2.1 Parking Demand model selection:

Parking behaviour and its variation from time to time is uncertain in nature, which cannot be predicted with conventional methods such as multinomial logit model, binary logit model etc. So in this context soft computing approach can provide a better outcome in terms of accuracy as well as to learn the parking behaviour of its certain locations. Neural network based algorithm is used along with fuzzy logic to exploit the advantage of the self-adaptability and learning the existing behaviour of areas through training. This hybrid system is called “Adaptive network based fuzzy inference system”. Matlab software is used to formulate parking demand forecasting model.

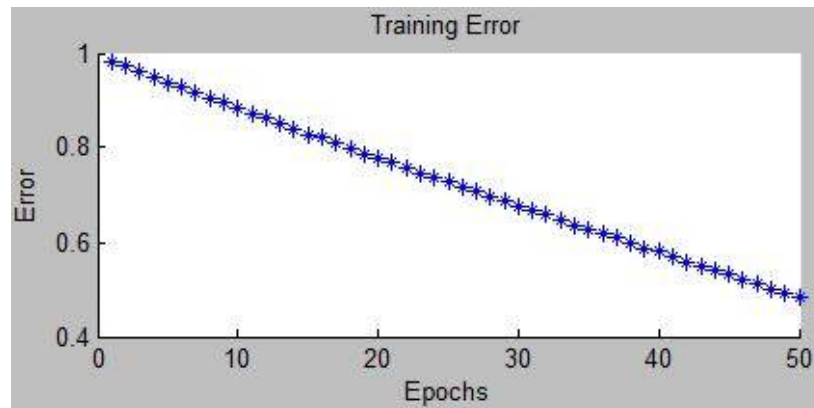
### 6.2.2 Training the existing data

Parking demand Modeling is carried out mainly in two stages. In brief, 1st stage mainly deals with the training data using ANFIS, whereas, 2nd stage deals with the generating fuzzy rules and fuzzy membership functions.

Stage1: Crisp values given as input data has been trained with minimal error through n number of iterations using MATLAB software.

Stage 2: After training, fuzzy membership functions and rules have been created thereby, captures the parking behavior for better output.

The **Figure 7** shows the training of data to minimal error through 50 Epochs using ANFIS tool in Matlab.



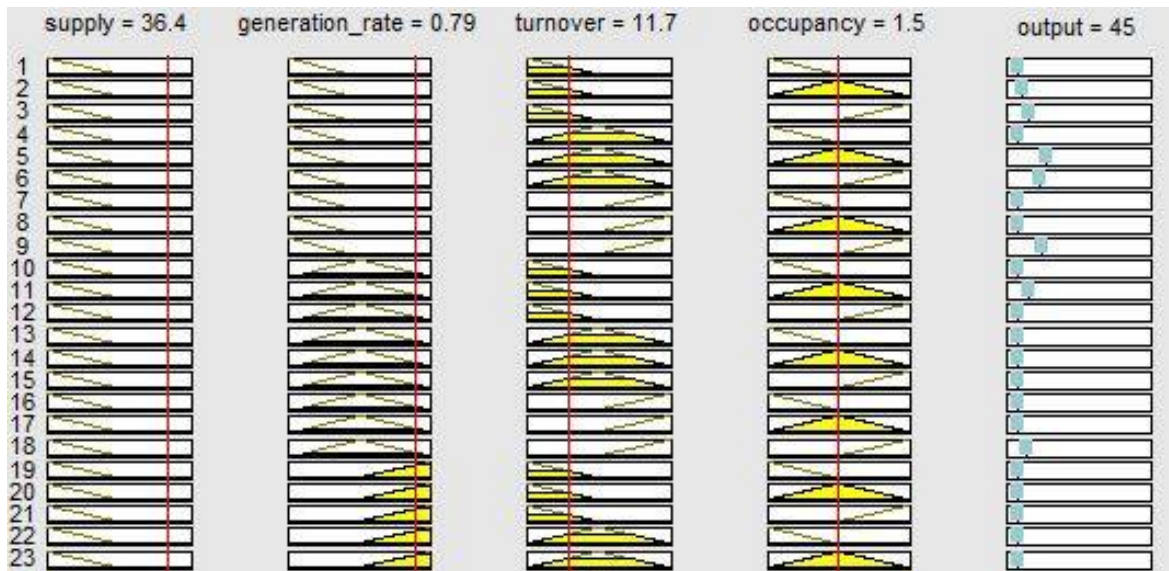
**FIGURE 7 Training of dataset**

Through Training data Fuzzy inference system has been generated with respective membership functions for the selected variables. The system creates a network structure by creating membership functions for the input variables by assigning network weights. Then the system is trained for training data set and rules are generated corresponding to each data pair set. These final extracted rules are then tested using MATLAB Fuzzy Tool Box for a set of testing data; the results have shown that the algorithm gives a very good performance in terms error calculated as:

$$\text{Error} = (\text{Actual Output} - \text{Computed Output})$$

81 Rules generated by the system from training data are listed below

Predicted output from the model with change in values of selected indicators are shown in the **Figure 9**.



**FIGURE 9 predicted demand with variation in variables**

### 6.2.3 Demand forecasting for the Horizon period

In order to do demand forecasting, two scenarios have been considered. In First scenario, based on considering only the design impact on parking demand and no enforcement/regulative measures. Whereas, second scenario deals with impact of pricing as well as design considerations for parking demand modelling. Horizon period is taken as 10 years from base year i.e. 2026. Demand forecasting for 2026 is considered to be base scenario taking into account of time span of implementation process of proposed design. During the modelling process, parking indicators such as parking turnover and parking duration are kept as it is in existing data to reflect the parking behaviour on predicted demand.

**TABLE 3 Scenario formulated for Demand Prediction for 2026 and 2036**

| Base scenario (2026)                        | Scenario 2036                  |
|---------------------------------------------|--------------------------------|
| 1. Considering no enforcement/regulation    | Considering strong enforcement |
| 2. Basis of design consideration            | design consideration           |
| 3. With parking fee and without parking fee | Increase in FAR as 4           |
| 4. NO increase in FAR                       |                                |

### 6.2.4 Base scenario 2026

*Design consideration alone:* Predicted peak demand for base scenario 2026 on the basis of design consideration is 227.35 ECS, whereas, existing demand is 336.1 ECS. Thus peak hour demand is thereby reduced by 32%.

**TABLE 4 Shows the predicted demand for 2026**

| Zone | Supply (ECS) | Parking generation rate/100sq.m | Turnover | Occupancy | Existing parking demand (ECS) | Predicted peak parking demand for 2026 (ECS) |
|------|--------------|---------------------------------|----------|-----------|-------------------------------|----------------------------------------------|
| 1    | 33.2         | 0.9                             | 10       | 1.5       | 71.7                          | 57                                           |
| 2    | 26.7         | 0.6                             | 10       | 1.5       | 32.7                          | 6.6                                          |

| Zone  | Supply (ECS) | Parking generation rate/100sq.m | Turnover | Occupancy | Existing parking demand (ECS) | Predicted peak parking demand for 2026 (ECS) |
|-------|--------------|---------------------------------|----------|-----------|-------------------------------|----------------------------------------------|
| 3     | 24.5         | 0.7                             | 10       | 1.5       | 37.4                          | 19.7                                         |
| 4     | 3.3          | 0.1                             | 9.5      | 1.5       | 7.3                           | 7.25                                         |
| 5     | 11.7         | 0.2                             | 12       | 1.8       | 17.5                          | 13.6                                         |
| 6     | 39.3         | 0.3                             | 13       | 2.2       | 25.9                          | 9                                            |
| 7     | 42.7         | 0.5                             | 18       | 2.2       | 32.8                          | 28                                           |
| 8     | 13.7         | 0.2                             | 18       | 2.2       | 18.8                          | 17.2                                         |
| 9     | 23.3         | 0.6                             | 9        | 0.8       | 44.9                          | 14                                           |
| 10    | 26           | 0.5                             | 9        | 0.8       | 46.9                          | 55                                           |
| Total |              |                                 |          |           | 336.1                         | 227.35                                       |

### *Pricing Impact:*

Since willingness to pay survey has not been carried out as a part of study, which is one of the limitation. Therefore, Predicted peak parking demand for 2026 considering design impact as well as pricing impact is formulated with the help of creating another data set for the existing situation. The pricing impact on the existing situation is generated with the help of values of willingness to pay borrowed from *Parking Action Plan Report for Zone A* (DULT, 2015). Parking action plan report for Zone A says 68% of the people are willing to pay parking fee. Predicted peak parking demand from the model for 2026, just by introducing pricing is 213 ECS. The predicted demand for 2026 without considering the impact of pricing is 227.35 ECS, whereas, in 2016 peak parking demand is 336.1 ECS. Thus, demand observed to decrease by 36% in 2026. **Table 5** shows the predicted peak parking demand of 2026 by introducing pricing.

**TABLE 5** Shows the predicted demand just after pricing for 2026

| Existing peak parking demand (ECS) |       | Predicted parking demand 2026 (ECS) |      |
|------------------------------------|-------|-------------------------------------|------|
| Two wheeler                        | Car   | Two wheeler                         | Car  |
| 43                                 | 28.7  | 47.5                                | 19.8 |
| 19.6                               | 13.1  | 4.5                                 | 0.9  |
| 22.5                               | 15    | 10                                  | 4.6  |
| 4.4                                | 2.9   | 4.4                                 | 3    |
| 8.8                                | 8.8   | 6.4                                 | 7.8  |
| 15.6                               | 10.4  | 6.6                                 | 6.2  |
| 19.7                               | 13.1  | 11                                  | 7.8  |
| 11.3                               | 7.5   | 12.9                                | 8.1  |
| 22.5                               | 22.5  | 14                                  | 3    |
| 23.5                               | 23.5  | 22.2                                | 12.7 |
| 190.7                              | 145.4 | 139.5                               | 73.9 |

Predicted demand for variation in pricing is modelled by taking 5Rs change for two wheelers and 10 Rs change for Car users. Peak hour parking demand by introducing pricing is predicted to be 93% of peak hour predicted demand without pricing. **Table 6** shows the variation in peak demand with change in price. In case of two wheelers, for 10Rs demand observed to reduce by 29%. By increasing the price to Rs 40, demand expected to decrease by 67%. For Car users, introducing 20 Rs as base price, the peak parking demand reduced by 32%. When the parking price is Rs60, peak hour parking demand of car users is reduced by 83%. To encourage public transport as well as to utilize the proposed number of bays, pricing that are suitable to match demand and supply can be chosen to avoid chaotic parking situations and thereby ensure safe and comfortable parking system for the users.

**TABLE 6 Shows the predicted parking demand variation for change in price for two Wheelers and car users**

| 2026          |                         |                     |          |               |                                                | 2wheelers    |      |      |      |      |      |      |      | Car           |      |      |      |      |      |     |  |
|---------------|-------------------------|---------------------|----------|---------------|------------------------------------------------|--------------|------|------|------|------|------|------|------|---------------|------|------|------|------|------|-----|--|
| Base scenario |                         |                     |          |               |                                                | Pricing      |      |      |      |      |      |      |      |               |      |      |      |      |      |     |  |
|               | Design<br>Supply<br>ECS | Generati<br>on rate | Turnover | occupanc<br>y | Predicted<br>parking<br>demand                 | Zw<br>demand | 10   | 15   | 20   | 25   | 30   | 35   | >40  | car<br>demand | 20   | 30   | 40   | 50   | 60   | >60 |  |
| 0             | 27.7                    | 0.9                 | 10.0     | 1.5           | 57.0                                           | 47.5         | 30.0 | 27.2 | 21.0 | 10.1 | 16.0 | 14.6 | 12.5 | 19.8          | 13.5 | 11.0 | 9.9  | 5.8  | 3.4  | 1.4 |  |
| 1             | 4.0                     | 0.6                 | 10.0     | 1.5           | 6.6                                            | 4.5          | 2.9  | 2.5  | 1.9  | 0.6  | 0.6  | 0.5  | 0.5  | 0.9           | 0.6  | 0.5  | 0.5  |      |      |     |  |
| 2             | 13.3                    | 0.7                 | 10.0     | 1.5           | 19.7                                           | 10.0         | 7.9  | 6.9  | 6.2  | 5.8  | 5.1  | 4.7  | 4.0  | 4.6           | 3.1  | 2.6  | 2.3  | 1.3  | 0.8  | 0.3 |  |
| 3             | 3.3                     | 0.1                 | 9.5      | 1.5           | 7.3                                            | 4.4          | 3.5  | 2.8  | 2.5  | 2.3  | 2.0  | 1.8  | 1.5  | 3.0           | 2.0  | 1.6  | 1.4  | 0.9  | 0.5  | 0.2 |  |
| 4             | 26.7                    | 0.2                 | 12.0     | 1.8           | 13.6                                           | 6.4          | 5.5  | 5.0  | 4.6  | 4.1  | 3.7  | 3.3  | 2.8  | 7.8           | 5.3  | 4.4  | 4.0  | 2.3  | 1.3  | 0.5 |  |
| 5             | 15.0                    | 0.3                 | 13.0     | 2.2           | 9.0                                            | 6.6          | 5.0  | 4.6  | 3.5  | 3.2  | 2.9  | 2.6  | 2.3  | 6.2           | 4.2  | 3.4  | 3.1  | 1.8  | 1.1  | 0.4 |  |
| 6             | 33.0                    | 0.5                 | 18.0     | 2.2           | 28.0                                           | 11.0         | 9.4  | 8.6  | 7.8  | 7.1  | 6.4  | 5.7  | 5.1  | 7.8           | 5.4  | 4.4  | 4.0  | 2.3  | 1.4  | 0.5 |  |
| 7             | 21.0                    | 0.2                 | 18.0     | 2.2           | 17.2                                           | 12.9         | 9.6  | 7.5  | 6.8  | 6.6  | 5.5  | 4.9  | 4.4  | 8.1           | 5.5  | 4.5  | 4.1  | 2.3  | 1.4  | 0.5 |  |
| 8             | 9.3                     | 0.6                 | 9.0      | 0.8           | 14.0                                           | 14.0         | 6.6  | 4.4  | 4.0  | 3.6  | 3.3  | 2.9  | 2.6  | 3.0           | 2.3  | 2.0  | 1.7  | 1.0  | 0.6  | 0.5 |  |
| 9             | 23.5                    | 0.5                 | 9.0      | 0.8           | 55.0                                           | 22.2         | 18.9 | 16.9 | 15.8 | 14.0 | 13.0 | 11.2 | 10.2 | 12.7          | 8.6  | 7.0  | 6.3  | 3.7  | 2.2  | 0.8 |  |
|               | 176.8                   |                     |          |               | 227.4                                          | 139.5        | 99.2 | 86.3 | 74.1 | 57.5 | 58.4 | 52.3 | 46.0 | 73.9          | 50.5 | 41.3 | 37.2 | 21.4 | 12.7 | 5.1 |  |
|               |                         |                     |          |               | change in demand with<br>Increase in price (%) |              | 29   | 38   | 47   | 59   | 58   | 63   | 67   |               | 32   | 44   | 50   | 71   | 83   | 93  |  |

## 7 CONCLUSION

In this study, a Neuro-fuzzy model was developed considering the people's perception and response, in order to capture the demand responsive demand for public transport and parking. It enables the estimation of the public transport ridership scenario as well as the parking demand estimation in a dynamic way. In case of parking the parking pricing can also be estimated considering the variation in the real time demand variation. The output from the fuzzy logic model may be further integrated with GIS, thereby opening the possibility of visualising the spatial aspects which may aid in policy decisions due to increased comprehensive capability and ease of visualising. The other benefits of the model is based on the systems capability to automatically keep a running total of the various aspects concerned with the commuters journey. This includes the zones through which the journey was made, time taken for each journey, the type of mode used and the corresponding fares etc. This would in turn help in providing a smart and connected transport system, in accordance to the real time demand. This in turn reduces the supply-demand gap. In addition, it would prove helpful in fixing the price. The effect of pricing is but crucial for parking, and this can be aided with the knowledge of response to price variations and the real time estimation of parking demand. Thus, this research may prove beneficial for administrators and policy makers, aiding them in their decision making process.

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