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A Fuzzy logic approach to analyze the effect of metro corridor on middle income housing in Mumbai

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Abstract

In this paper, the authors analyze the effect of the metro corridor on the real estate undercurrents in Mumbai city, India. The study pertains to the dynamism of the residential property prices within a kilometer buffer area around the existing metro corridor in Mumbai. The paper applies Fuzzy Logic to comprehend the behavioral pattern of the residential property prices. Based on the data available from the popular property websites and expert surveys, the residential properties have been classified into three subtypes A, B and C. For each subtype, separate models are generated using a fuzzy inference system and the respective housing prices (per square feet) are predicted. Results highlight that (i) the functions determined pricing as a whole, and (ii) effects of other parameters on house prices differed significantly with the user group.

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Keywords: Housing pricing; metro-rail corridor; Middle Income Group; fuzzy logic;

1. Introduction

In a city, public transport nodes like railway station, bus stations and highway intersections attract large scale residential and commercial clustering around them. These nodes have manifold effects on the activity patterns of the individuals as well as the land use, which are mirrored in the pricing pattern of the surrounding properties (both residential and commercial). These effects can be positive as well as negative. The important positive effects include increased accessibility, better connectivity and mixed land use. On the other hand, the negative effects include noise and air pollution, disturbed surrounding and increased rates of criminality/anti-social activities (Bowes et al., 2001).

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The growth of housing near to these nodes pertains to these influencing factors and the pricing pattern behaves in accordance to these influencing factors.

In India, the suburban railways are the primary transport choice of a large section of the population, whereas the large-scale traffic congestion and the resulting delays have made the private transportation less favorable. The railway services are primarily availed by the lower and middle-income section of the population as it is a cheaper and faster mode of transportation (Cropper et al., 2012). However, the exponential growth of population in the metro cities has made the suburban railway system overburdened with passenger loads (Sehgal et al., 2011). The metro-rail services started in the major cities of the country, like Kolkata, Delhi, Mumbai and Chennai.

The introduction of this new service in the cities has stirred on the development process. With more impetus being given on the transport-oriented development (TODs), the impact of these newer transportation nodes on the economic development process of the cities is significant. The real estate sector, which is a major contributor to the city's economic growth, seeks advantage of the increased connectivity and accessibility provided by these additional transportation services. In general, it has been reported that housing prices are determined by demand and supply in the market for an emerging economy (Mahalik et al., 2011). A large number of factors can affect the housing demand, which includes city demographics, income growth, employment growth, interest rate, and location characteristics such as accessibility, crime rate, distance from the Central Business District (CBD) (Venkatesh, 2013). While on the supply side, construction cost and type of building appear to be some of the major parameters. This paper attempts to analyze the effects of addition of a new transport service (here the metro line) and the resulting connectivity and accessibility, on the surrounding residential property prices in Mumbai city using fuzzy logic.

The first section of the paper deals with the background of the study. It is followed by the review of related literature in the second section. The third section discusses the study area, data and methodology. It is followed by results and discussion in the fourth section and conclusion in the final section.

2. Literature Review

As discussed above several factors explain the variation in the pricing pattern of properties, both residential and commercial, in a city. As pointed out by Beyazit (2015), investment on public transport services like railways has "Wider Economic Impacts". These factors are classified into four broad categories namely, structural, household, locational and environmental (Tomkins et al., 1998; Wilhelmsson, 2000). Locational attributes include accessibility parameters, parameters concerning proximity to different amenities and local land-use regulations. Accessibility is one of the most important requirements in improving upon cities like Mumbai. Many studies have addressed the effects of road, rail and air access on property values. In most applications, accessibility is generally measured in terms of proximity to CBD. Investment in the different modes of transportation reduces the demand around CBD by drawing households to settle around access points like railway stations or airports (Fejarang, 1993). Proximity to railway station helps reduce the travel time and the cost of transportation of goods and people and therefore one can expect that the prices should decrease as we move away from the station. As pointed out by Goldberg (1981), investment in railway supports more compact urban structure. But in reality, no consistent trends have been recorded between proximity to a railway station and housing prices, as pointed out by Debrezion et al. (2007). Different studies show different types of impact of existing railway station on property prices. Debrezion et al. (2007) further pointed out that the type and magnitude of effect of proximity to railway station depend on the type of railway (light rail, heavy rail/metro, commuter rail), and the type of property (residential or commercial) on which the effect is being studied and socio-economic factors (income). Mohammad et al. (2013) have pointed out that commuter rail has higher impacts on the property values than light railways. They also pointed out that "*land and property value changes tend to be higher at distances from 500 to 805 m of a railway station, compared to distances half a mile away*". On the other hand, Gibbons et al. (2005) chose 2 km threshold around the station for property price variation analysis based on the maximum feasible walking time to a station (20- 30 minutes). According to Debrezion et al. (2011), the impact of railway stations on property prices varies for three main reasons: firstly in terms of the level of services they provide; secondly, the type of property, either residential or commercial; and thirdly, the demographic segmentation of the neighbourhood. Similarly, proximity to a highway or arterial road and proximity to an airport also have an impact on property value. Though proximity to a highway increases accessibility and has a considerable effect on property values (Kim et al.,

2007), it also results in greater exposure to traffic noise, which can have a substantial adverse effect on housing prices (Wilhelmsson, 2000). In the same way, proximity to airport is also associated with negative externalities in the form of noise costs as well as congestion and pollution costs arising from the additional road traffic (Tomkins et al., 1998). This value of this proximity also differs with the difference in the economic section of the society. Nearness to a railway station is of greater significance to the lower and middle-income sections of the society than to the higher income groups, due to the formers' greater dependence on the cheaper public transport modes. In addition, "this group depends mostly on slow modes (walking and bicycle) to access railway stations, it would be expected that locations adjacent to a railway station would be occupied by poor segments of the community" (Debrezion et al., 2011).

Dewees (1976) found that the site rent increases perpendicular to the facility within one third mile distance (Approximately half a kilometer) to the existing subway station. There are other studies, which also confirm similar findings (Bajic, 1983; Damm et al., 1980; Grass, 1992; Guiliano, 2004). Geoghegan (2002) investigated the value of open space in residential prices and concluded that permanent open spaces have a significant positive impact on the prices. This is true for the sea facing areas of Mumbai. In addition, being geographically restricted, Mumbai is cramped for space and thus open spaces and parks are becoming rarer/vague and therefore more valuable.

The other factors include structural and household attributes (for example: age, building type (residential/commercial), number of rooms, date of sale, number of toilets, garage space (parking space), etc) (Tomkins et al., 1998). The empirical analysis by Blanco et al. (2011) also showed that the size of the property measured in floor area and the number of rooms are the major determinants of price. Tiwari et al. (1999) showed that the size of the household is the main factor that determines the rent of a dwelling unit. Their findings also suggest that in Mumbai the impact of attributes like availability of basic services like water, sanitation and power, on property prices is comparatively less. Blanco et al. (2011) have shown that the composition of a household (e.g. number of children – dependent or non-dependent, single parents or married cohabiting parents, etc.) influences the pricing pattern. However, the results indicated that the impact was not significant. Noise and air pollution are the major environmental attributes that affect property prices (Blanco et al., 2011; Kim et al., 2007). However, including too many correlated variables can lead to a lot of false results and interpretations (Chau et al., 2003).

As pointed out by Pagourtzi et al. (2003), the methods of house price estimation can be classified into traditional methods, like comparable method, investment/income method, profit method, multiple regression method and stepwise regression method, and advanced methods like hedonic pricing method, spatial analysis and fuzzy logic. Hedonic pricing is the most widely used methods for estimating the relation between price and external variables. This methodology uses multiple regression techniques and "is used for market valuation of goods for their utility-bearing characteristics" (Liu et al., 2006; Selim, 2009). However, the real estate market has a huge uncertainty and vagueness in itself and as pointed out by Kuşan et al. (2010) "these techniques can lead problems if the process of pricing is extended to contain the points of view as outliers, non-linearity, spatial and other kinds of relations between observations, discontinuity and fuzziness". Selim (2009) points out that such methods are suitable for straightforward estimation of relationship between price and other determining characteristics, but become problematic when the agenda of aspects is widened. Thus, to quantify the human decision behavior, a better method is required which gives the precise information and does not need strict mathematical modelling of data and at the same time examine the human decision making by using fuzzy linguistics rule. Various studies have pointed out the applicability of fuzzy logic and fuzzy inference system (FIS) in dealing with the risks and uncertainties of the real estate market (Bagnoli et al., 1998; Byrne, 1995; Lee et al., 2004). Dilmore (1993) is considered to be the first to apply fuzzy logic to real estate studies. However, the major challenge in using the FIS is the determination of the sets and rules in fuzzy logic that demands deep domain knowledge and expertise. Combining the fuzzy system with the Artificial Neural Networks (ANN) can provide a viable solution to this problem through adaptive neuro fuzzy inference system (ANFIS). ANFIS uses a Takagi Sugeno fuzzy inference system (Vieira et al., 2004) and is widely used in various fields like engineering especially, civil (Dong et al., 2011), power (Mellit et al., 2011) and geomatics (Yilmaz, 2010) as well as in biological and biomedical sciences (Buyukbingol et al., 2007; Chang et al., 2010). . In the existing literature, a very few studies considered real estate appraisal using ANFIS model. Guan et al. (2008) reported that results coming from ANFIS are comparable to traditional regression method and it can be used in the application of real estate studies. They also highlight that "ANFIS allows the creation and refinement of fuzzy rules through neural networks and has received considerable attention in numerous studies in various fields". Hence, in this study ANFIS method is applied to calculate the real estate market prices using different attributes.

3. Study Area - Mumbai

Mumbai city, also referred to as Greater Mumbai region, has a huge population base of 12.44 million (Census of India, 2011). The city has been divided into three zones namely the island city, the western suburbs and the eastern suburbs. The decadal population growth of the city, as shown in Figure 1, highlights that the population increase is primarily concentrated in the suburban areas. This indicates towards phenomenon of daily commutation in Mumbai, from the suburban residential areas to the job centres, which are mostly located in the inner city. Therefore, the public transportation services, primarily suburban railways, buses and metro services play a significant role in the daily commutation activities in the city. In this study, we are focusing on the role of metro services in the real estate of the city.

Metro railway services in Mumbai came up much later (in 2014), as compared to the other cities like Kolkata (in 1984) and Delhi (in 2002). The Master Plan for Mumbai metro was approved in 2004 and it covers nine corridors with a total length of 172 km. The entire plan is divided into three phases with an expected completion by 2021. Presently, the only line, where the service is operative, runs on Versova -Andheri- Ghatkopar corridor, running from west to the east through the central portion of the city covering a distance of 11.4 km (see Figure 2). This corridor directly connects the eastern and western suburbs of the city and is directly connected to the suburban railway system at common nodes at Andheri and Ghatkopar facilitating modal interchange. The metro corridor runs through a high population density area, including important commercial centers like Maharashtra Industrial Development Corporation (MIDC) and Santa Cruz Export Processing Zone (SEEPZ). In order to capture the proximity effect, in this study, a buffer of one-kilometer is drawn around the corridor, following the Unified Traffic and Transportation Infrastructure (UTTIPEC) guidelines (MCGM, 2014). This buffer offers the minimum time taken for commutation to the stations using cycles or other para-transit services. Beyond this, the impact of nearness to the station is likely to be overshadowed by the connectivity through different paratransit modes like auto rickshaws and taxis, which is a characteristic feature of the city. The selected area covers a densely populated zone with higher residential, commercial and industrial land use. Existing studies showed that a metro-corridor has equal influence within a one-kilometer buffer zone. Hence, to analyze the effects, authors selected units on sale within the one-kilometer buffer of the metro corridor, referred to as the “equi-influence” zone.

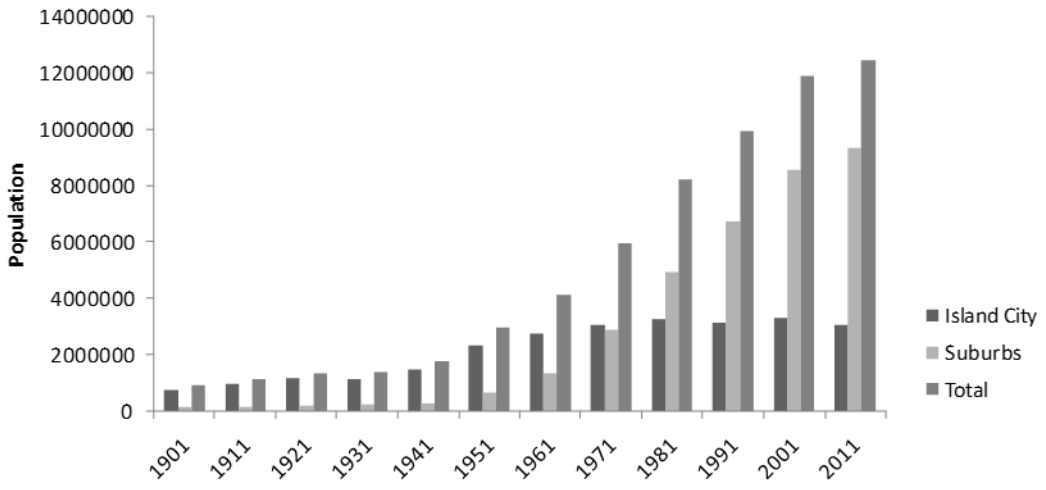

Fig. 1. Decadal Change of Population of Mumbai

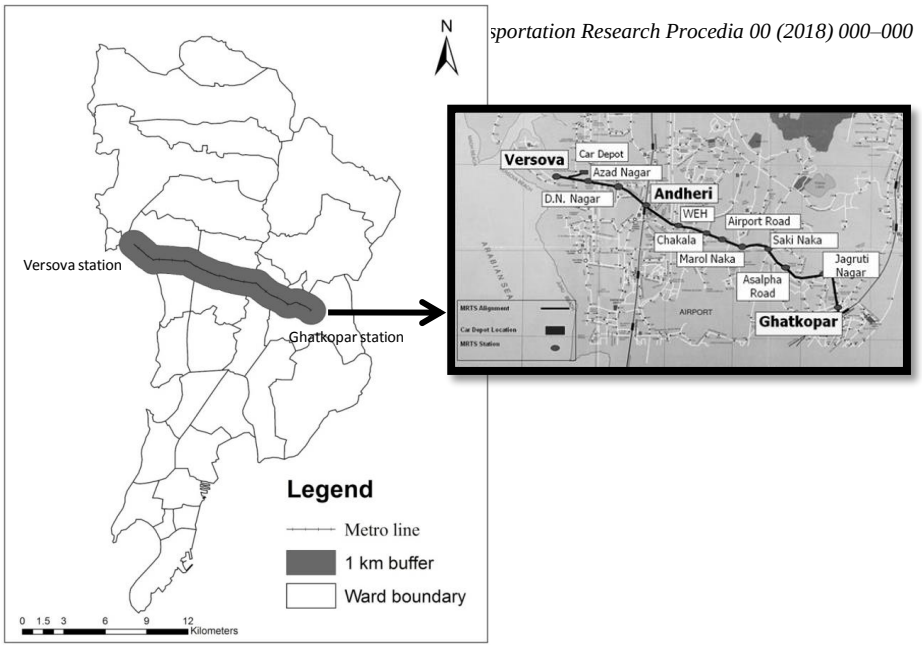

Fig. 2. Study area- Versova -Andheri- Ghatkopar corridor

4. Data and Methodology

The variables considered in this study are broadly classified under three heads: (1) property characteristics, (2) connectivity and accessibility, and (3) amenities. Property characteristics include features like the built-up area (BUA), age of the property, building orientation, number of stories as well as availability of facilities like parking, lift, gas pipeline, gymnasium and swimming pool. The factors falling under-connectivity and accessibility are the distance to airport, the nearest metro stations, the nearest suburban railway station and the nearest bus stop/station. Finally, the third factor of amenities include the respective distances to banks (including ATM services), hospitals, schools, parks, theatres, departmental stores and shopping malls. The detailed methodology followed in the study is illustrated in Fig 3.

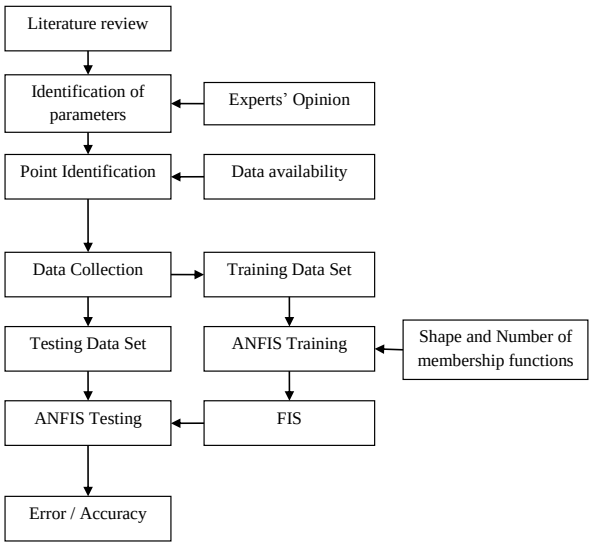

Fig. 3. Detailed Methodology

The model preparation is preceded by an expert based on face-to-face surveys carried out with five experts in this field. Four of the experts have a strong background in housing and real estate sector belonging to both private and public sectors, while one belongs to the academics arena. The objective of the survey was to understand the specific parameters that affect the property prices in Mumbai (in and around in metro corridor). Based on the opinion collected through the survey conducted, the following parameters are selected for the model (see Table 1). It is to be noted here that this study does not undertake the rented properties. The requirements and preferences of people for each of these types of properties vary considerably. Although home loans play a significant role, yet the loan amount would be dependent on job profile and income status. Further, one can say that availability of public transport or distance to any amenity will be of little significance to these families due to their choice of self-sufficient gated communities exemplifying the urban splintering effect in cities like Mumbai (Buzar et al., 2007). The properties are further divided into three groups (Type A, Type B and Type C) to create a separate model for each.

Nomenclature

Type A one RK (Room and Kitchen) and one BHK (Bedroom, Hall and Kitchen)
Type B two BHK
Type C three and more than three BHK

Table 1. Selected Parameters for the study.

Sr. No.	Type A	Type B	Type C
1	Age of the property	Age of the property	Age of the property
2	Distance to Metro	Distance to Domestic airport	Distance to Domestic Airport
3	Distance to Schools	Distance to Metro	Shopping Malls
4	Distance to Parks	Shopping Malls	
5	Distance to Shopping Malls		

Here RK and BHK refer to different apartment types. In RK the kitchen area is included within the room area, while BHK refers to bedroom, hall and kitchen areas built separately. When there is only one room, it is called one BHK and with increasing number of rooms they are referred to as two and three BHKs respectively. Based on extensive search from different real estate web portals and local real estate agents, 213 on-sale properties were identified, within the study area. The data of their asking price (the minimum price that a seller is willing to receive for a commodity) and all 21 parameters affecting them was collected, using stratified random sampling technique, from secondary sources and through extensive field survey. It is to be pointed out here that this study is based on the asking prices of the properties due to the difficulty of obtaining the exact transaction prices. The nature of transaction of the Indian housing market keeps many of the transition records shadowed. As such, the true transaction prices are either not recorded or are not freely available. As compared to that, the asking prices are easily available through online real estate web portals and hence are preferred in this study over the transaction prices. As the study area is near to the domestic airport, the distance to the domestic airport is considered for Type B and Type C properties. Because, people looking for these properties have the maximum probability of using the airport.

4.1. Model Formation

Based on the objectives of the paper, the ANFIS model is found to be appropriate to study the effect of the parameters on housing prices in and around the metro corridor in Mumbai. The model was built using the ANFIS editor in Fuzzy Toolbox in MATLAB. In a typical ANFIS model, data sets are generally divided into three parts (training, testing and checking), but dividing a small data set into 3 parts may cause loss of information (Guan et al., 2008). Hence, after collecting data of Type A, Type B and Type C properties separately from secondary sources (like online housing websites), it is divided into two parts: the first part containing properties present to the North of the metro line while the second part containing properties to the South of the metro line. The data set (213) is divided into training data set of 126 and testing data of 87. The above method ensures that the data selected for training is not a

biased data. The training and testing data sets for all types of houses are summarized in Table 2. It is to be noted here that the training data set and the testing data set are independent of each other.

Table 2: Training and testing data sets

Type of House	**Training data set**		**Testing data set**	
	Number of data	Position with respect to metro line	Number of data	Position with respect to metro line
A	52	North	46	South
B	44	South	23	North
C	30	North	18	South

For each model, authors have used a grid partition ANFIS model rather than sub-clustering ANFIS model, to predict housing price accurately. A grid partition ANFIS model should be used for less number of parameters (less than six). In the ANFIS model, Gaussian and Bell membership functions were used because of their smoothness and since non-linearity minimizes the total error produced in a model. The output membership function was taken as constant. The housing prices were determined using hybrid neuro fuzzy algorithm; that uses a learning algorithm based on gradients or inspired by the neural networks theory (heuristical learning strategies) to determine its parameters (fuzzy sets and fuzzy rules) through the patterns processing (input and output)" (Vieira et al., 2004). It uses backpropagation and least square for input and output membership functions respectively. The modelling part has been explained in fig. 4.

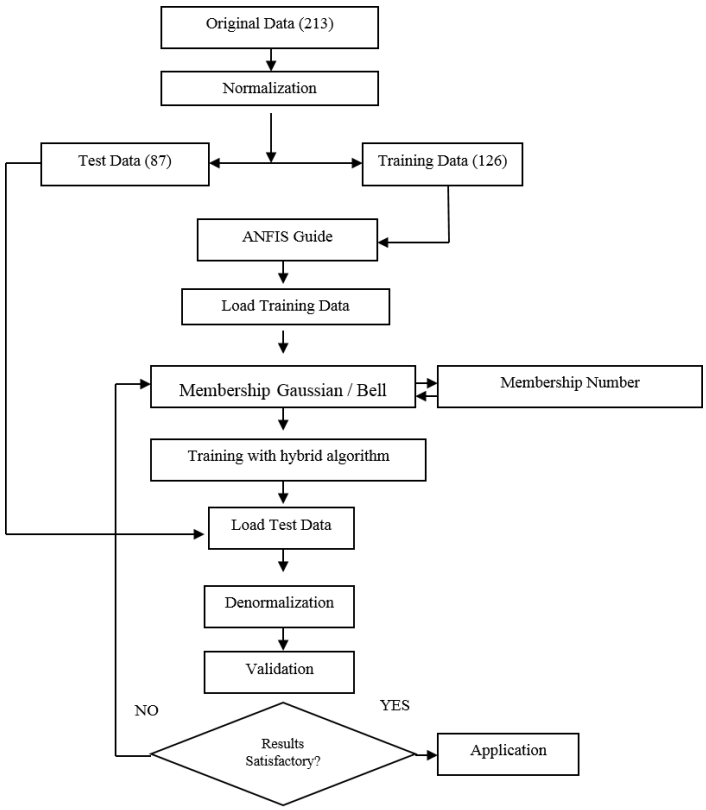

Fig. 4. Flowchart showing the computation of the ANFIS model (adopted from Erdirencelebi et al. (2011))

Table 3: Inputs required for the ANFIS model

Type of house	A	B	C
Number of membership functions	Built up area: 3	Built up area: 4	Built up area: 5
	Age of the property: 3	Age of the Property: 3	Age of the Property: 3
	Distance to Metro: 2	Distance to Domestic airport: 2	Distance to Domestic airport: 3
	Distance to School: 3	Distance to Metro:2	Distance to shopping mall: 3
	Distance to Park: 3	Distance to shopping mall: 3	
	Distance to Shopping Mall: 2		
Number of Epochs	9	146	8
Membership function type	Gauss	Bell	Bell

Finally, to train the data of each model using ANFIS, the number of epochs, number of membership functions and type of membership functions were selected such that the error obtained in each model was minimized. Table 3 summarizes the inputs given for each model. On training the data, the Fuzzy Inference System formed for each model is then used to check the testing data set and to extract the relationships between property value and each of the parameters. Mean Absolute Percentage Error (MAPE) is used as a measure of the prediction accuracy of these models.

5. Results

The graphical plots of housing prices (INR/sq ft.) with each of the parameters were extracted from the resulting adaptive neuro-fuzzy inference system and have been illustrated below in Fig 5, Fig 6, Fig 7 for Type A, Type B and Type C properties respectively. The results are elaborated in the following sections. The model accuracy obtained was more than 60% for all three typologies. Table 4 gives the prediction accuracy of the models.

Table 4: Prediction Accuracy of model

Type of housing	Model Accuracy
One RK and one BHK	69.24%
Two BHK	63.17%
Three and more than three BHK	65.14%

5.1. Model limitations

There are several limitations associated with this study, some of them are as follows:

- The prices considered in this study are the asking prices of the properties, which may be different from the actual transacted prices. It is to be noted that, data of the transacted prices is difficult to obtain owing to confidentiality and sensitivity of personal financial details.
- Even though slums can be found in every part of Mumbai, the effect of such slum areas on the neighboring properties has not been considered.
- The quality of amenities like schools, parks and shopping malls has not been taken into account. Instead, just the distance to such amenities has been considered.
- The parameters finally considered in the model for each type of property, may not be exhaustive. Only a few parameters were taken since the ANFIS model cannot efficiently handle a large number of parameters and due to lack of availability of data for parameters.

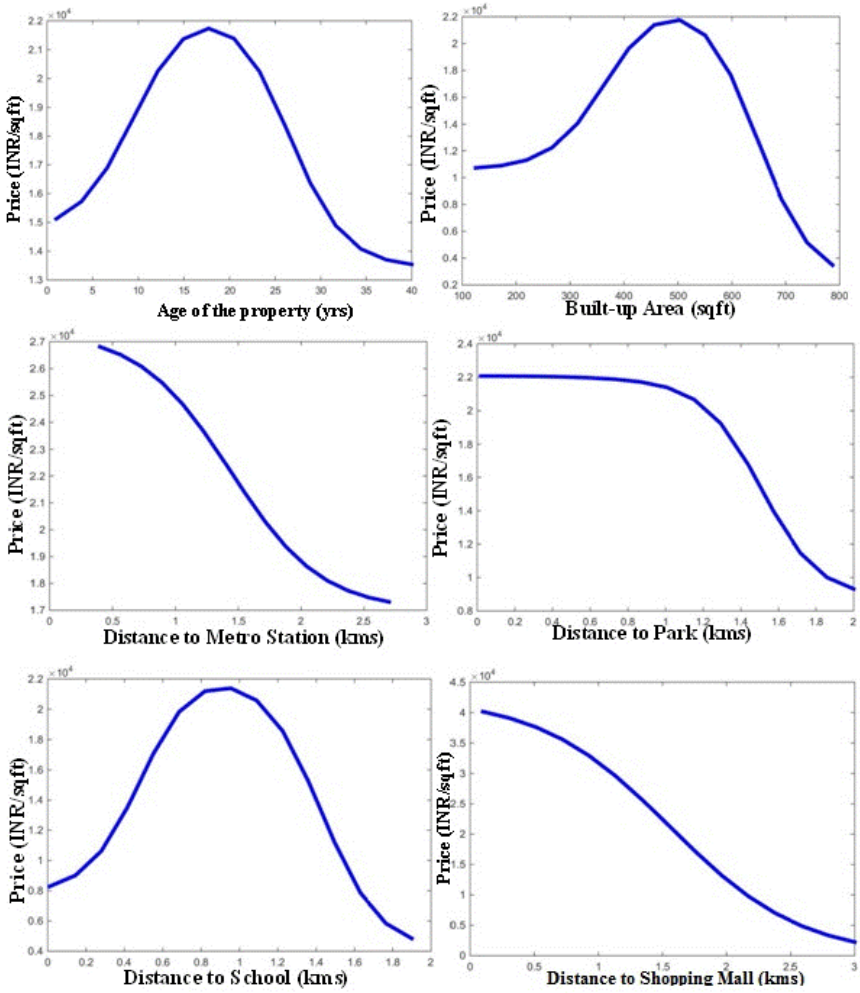

Fig. 5. Effect of various parameters on Type A (1RK & 1BHK) properties

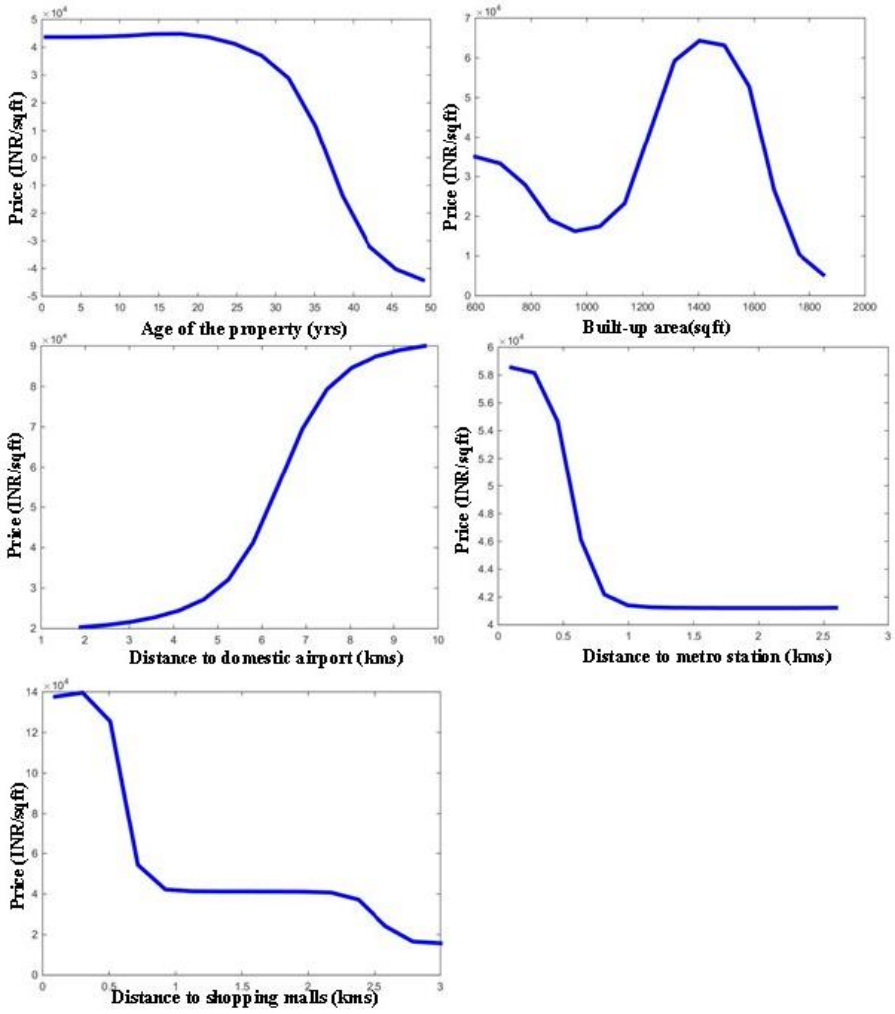

Fig. 6. Effect of various parameters on Type B (2BHK) properties

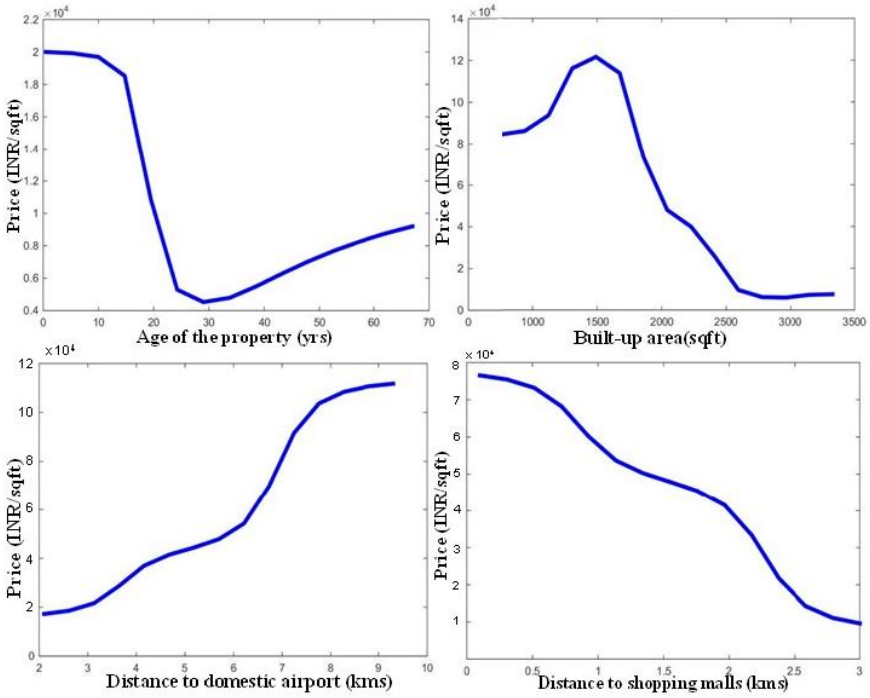

Fig. 7. Effect of various parameters on Type C (>= 3BHK) properties

5.2. Effect of property characteristics

In the case of Type A properties, housing prices are found to increase with the age of the property, until an age of around 15 to 20 years. Thereafter, as the property becomes very old, prices start declining. On the other hand, in the case of Type B and Type C properties, price shows an overall decreasing trend with age, though the effect is negligible during the first 15 to 20 years. It is also observed that the price/sq. ft. increases with built-up area, reaches a maximum and then decreases for all the types of houses. This means that for very large areas of a particular type of property, the total price might very well exceed the budget of people looking for that type. Hence, the price/sq. ft. for very large areas is reduced to keep the total price within limits. The range of built-up area for which the maximum prices of Type A, Type B and Type C properties are found to be 400-600 sq. ft., 1200-1400 sq. ft. and 1400-1800 sq. ft. respectively.

5.3. Effect of connectivity or accessibility:

Type A and Type B properties show a decrease in value with increasing distance from the metro station. However, the decrease in value of Type A properties is gradual but the impact of a metro railway station is seen to extend over a larger distance as compared to Type B properties. The distance to the domestic airport is observed to have a negative impact on the value irrespective of the type of residential property.

5.4. Effect of Amenities:

The relationship of price with distance from the park is positive, i.e., as the distance from the nearest park increases, price decreases. This is because even though open spaces or parks play a very important role in the development of children and the health of elders as well, they are becoming a rarity in a city as congested as Mumbai. Prices are found to increase with increasing distance from school, up to a certain threshold, and beyond that, prices begin to fall. This suggests that though the greater commuting distance to school has a negative impact on the value of a property, people

prefer not to stay very close to a school. Shopping malls can be seen to have a positive impact on a property irrespective of its type, i.e., property prices increase with nearness to the shopping mall. Although, the impact of distance of shopping malls on Type C properties is not significant.

6. Discussion

As evident from the results, it is found that the effect of property characteristics on the pricing pattern within the study area given a varied picture. The effect of age is more pronounced on the properties with greater carpet areas than the smaller ones. This can be because the developers are investing more on the construction of double or triple bedroom flats over smaller flats. In other words, new properties with one RK (Type A) and one BHK flats have become rare and the resale component of such properties can be the reason behind the increase in price with age. After a certain age when the depreciation takes its toll, the property starts losing its value. The other factor is the built-up area that can be explained as for very large areas the total price may well exceed the individual budget. Hence, the price per unit area is normalized/ reduced to keep the total prices within limits.

Nearness to the metro station is a deciding factor for property values of one RK and one BHK and two BHK flats than three BHK flats. In case of single bedroom properties, the effect of nearness to the stations extended over larger distance than the two BHK and others. This might be due to the socio economic status of the owners (who could afford one RK or one BHK) and might not own vehicles. Therefore, the owners might have more dependence on the metro railways (or other public transportation) for daily commutation. Properties located near to the airport are negatively affected by the noise generated as well as the associated the road congestion encountered due to the proximity to the airport. The impact of school is felt up to one km, beyond which the prices continue to fall. People have the tendency to stay closer to the schools, but they may not opt to stay in the immediate surroundings in order to avoid the noise and the congestion especially during the drop- off and pick- up times. Finally, the nearness to the shopping centers positively influences the property prices. Distance to a shopping mall is a primary deciding factor in case of double bedroom properties where the zone is within less than a kilometer, as the respective owners may prefer to walk for their daily shopping needs, while the impact on the triple bedroom properties is not very significant. This can be attributed to the fact that increased reliance on private modes regulates the impact of distance in the latter case.

The real estate companies, state government and developers mainly control the real estate market in Mumbai (Nijman, 2000). Generally, the value of a house is the total value of the structure – built up area (BUA) - and land (Bourassa et al., 2001). With limited land supply and dominance of local players, there is a third component, location cost, which plays a significant role in deciding the housing prices. This location cost (premium) depends on the numerous factors such as surroundings built environment, accessibility, city's demography etc. Therefore, in a closed-ended metropolitan city like Mumbai, the rise in the housing prices is expected to be expanded due to the limited land supply, higher per capita financial capability and increased investment opportunity.

7. Conclusion

The new draft development plan of Mumbai (2034) suggested developing the metro stations as TODs; it is necessary to understand the behaviour of the real estate forces around these transportation nodes. The paper applies the fuzzy logic to comprehend the behavioural pattern of the residential property prices around the metro stations. This is a primary effort as such a method is still not evident in the real estate study in Indian cities. Though there is a scarcity of appropriate data to conduct such studies in India, the present paper prepares the model based on real data available from the online property websites and real estate agents. The metro services in Mumbai are a comparatively newer addition to the transport profile of the city. Though it covers a short route, its scope for providing an alternative transportation mode for the daily commuters is highly appreciated. It is due to the higher levels of road congestions and the overburdened condition of the suburban railways. The nearness to the transportation service is expected to emerge as a pull factor and its impact on the newer properties emerging in its influence zone as well as the already existing property can be taken to the very positive. Therefore, it is the future scope of the paper to analyze and compare the effects of the locational factors and the other factors in determining the pricing pattern of the properties.

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