

# Development of Accessibility Index for Newly Expanded City Areas in Fuzzy Framework: A Case Study

Leena Garg and B. K. Katti

**Abstract**—Urbanization has been observed at rapid rate particularly in metropolitan cities in India as they act as powerful magnets to pull rural population in search of jobs and better urban facilities, to result in expansion of cities. Pace of settlement in newly expanded areas at the periphery of the cities rests on the attraction potential they possess. The transportation amenities are one of the most important components of attraction for the area. This paper provides a basis through the present Area Accessibility Index developed employing Fuzzy Synthesis Approach in view of uncertainty in the subjective qualitative rating by the expert group for the transportation attributes. The analysis is for the newly expanded areas of Surat City in the state of Gujarat in India. The Area Accessibility Index for the expansion area provides the guidelines for planning and development of the area in a phase wise manner. AAI also plays role of attraction potential for the settlement in new expansion urban areas.

**Index Terms**—Attributes, EAAI, Expansion Areas, Fuzzy Synthesis Modeling, Urbanization

## I. INTRODUCTION

Ever increasing urbanization is a defining characteristic of the 21st century. Worldwide Urban areas are gaining an estimated 67 million people per year—about 1.3 million every week. By 2030 about 5 billion people are expected to live in urban areas—60% of the projected global population of 8.3 billion. So also is the pace of urbanization situation in India. The rapid growth of cities has also brought about the spatial spread of urban areas. Urban sprawl is quite significant in all metropolitan cities in India and acts as a catalyst in residential development in new areas. The city folk migrate in search of better earning opportunities to these newly developed areas. As the inner city areas get denser, the quality of infrastructure suffers. Heavy congestion on roads, ageing housing stock, a heavily burdened service supplies, all combine together in sending the population to the outskirts in search of better environment and less dense settlements. The settlement behaviour in these expansion areas is based on the attraction potential in terms of land cost, transportation infrastructure, environmental quality etc. Transportation facility plays a key role in determining the attraction potential of a given area.

In the present paper certain key attributes of the transportation infrastructure like connectivity with key areas, availability of mass transit and multiple modes of transit, the congestion situation of the area, and finally the vicinity of the city transportation centers like railway station and central bus stand have been taken in order to assess the Area Accessibility Index for the expanded areas for Surat City. The data is based on the subjective rating by different experts of the planning and transportation field.

For the uncertainty involved in the qualitative assessment Fuzzy Synthesis approach has been adopted to quantify and process the data in order to arrive at comprehensive Indices for the expansion areas of the city. Such Indices values can help in deciding the inadequacies in the transportation infrastructure which can further provide guidelines for planning and development of the city with reference to the urban sprawl.

## II. STUDY OBJECTIVES

- Study is on understanding of demographic and physiographic features of the expanded Areas.
- Qualitative assessment of transportation related attributes by the experts
- Formulation of Fuzzy Synthesis Model

## III. PROFILE OF EXPANDED AREAS

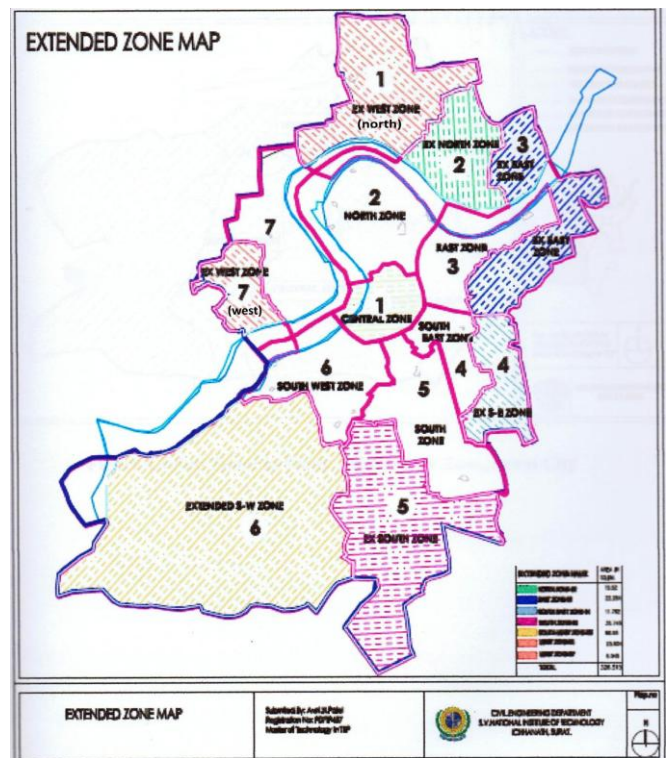


Fig. 1. Surat City Expanded areas (2006)

Seven expanded areas are shaded as EA-1 to EA-7. Here EA-1 and EA-7 areas are across the river Tapi on the right bank. The size, population and number of villages covered by the expanded areas are shown in Table I. The newly expanded areas provide scope of residential shift for spill over population of fast developing city.

TABLE I: DEMOGRAPHICAL FEATURES OF NEWLY EXPANDED AREAS

City Expansion Areas	Code Numbers	Area Sq. Km	Population (2001)	Density PPHa
West zone expansion (north side)	EA-1	25.604	25499	9.96
North zone expansion	EA-2	15.820	82110	51.90
East zone expansion	EA-3	22.284	130381	58.51
South east zone expansion	EA-4	11.782	62696	53.21
South zone expansion	EA-5	35.745	87893	24.59
South west zone expansion	EA-6	96.961	42789	4.41
West zone expansion (west side)	EA-7	6.045	11165	18.47
Total		214.241	442533	20.66 (average)

TABLE II: SELECTED TRANSPORTATION ATTRIBUTES OF THE EXPANDED ZONES

Reference No	Attributes	Associated Factors
A-I	Connectivity with CBD	CBD vicinity, accessible links
A-II	Modes and transport Cost	Various modes for the trips, frequency of supply, mobility, transport cost
A-III	Traffic Impedance	Traffic congestion, bottle necks, and travel time.
A-IV	Vicinity of main transport centres	Nearness to city bus service terminal, railway station, central bus stand for outstation trips.

TABLE IV: EXPERT'S RATING ON TRANSPORTATION ATTRIBUTES FOR WEST ZONE EXPANSION AREA (EA-7)

Attr.	Number of Experts (Rating out of 10)											Mean Rating	NMW
	1	2	3	4	5	6	7	8	9	10	11		
A-I	6	6	9	6	5	6	6	2	4	4	6	5.455	0.246
A-II	6	2	9	9	6	6	4	9	6	4	6	6.091	0.275
A-III	4	8	6	8	5	7	8	5	8	4	9	6.545	0.295
A-IV	4	2	9	1	3	4	4	2	6	2	8	4.091	0.184
												22.182	1.000

#### IV. QUALITATIVE ASSESSMENT OF EXPANSION AREAS

##### A. Transport System Attributes

The present status of transportation system prevailing for the newly expanded area is carried by Saaty's rating technique in 0-10 scale, expressed by the experts acquainted with the study areas through personal interviews with reference to design questionnaire format. The main transportation system attributes and their associate factors are briefed in Table II.

TABLE III: QUALITATIVE RATING OF ATTRIBUTES ON SAATY'S SCALE

Sr. no	Linguistic Variables	Saaty's Rating
1	Very poor	2
2	Poor	4
3	Good	6
4	Very Good	8
5	Excellent	10
6	Intermediate Values	1,3,5,7,9

##### B. Qualitative Ratings

Normally qualitative values are expressed in linguistic form which is more effective as it is in natural form.

A typical rating sheet by 11 experts for the four Transport System Attributes for the west zone expansion area is as shown in Table IV. End columns provide mean ratings and normalized mean weights (NMW).

The 0 and 10 ratings express the extreme both end conditions i.e. very poor to excellent. Normal ratings are computed for concerned attributes with reference to 11 experts, and further normalized mean weightage are determined to provide the relative weightage amongst the attributes as shown in the last column.

#### V. FORMULATION OF FUZZY SYNTHESIS MODEL FOR EAAI

Various steps involved in the development of Fuzzy Synthesis Model are

- Squeezing of qualitative rating to the scale of Likert
- Fuzzification of Likert scale values
- Synthesis of Fuzzy membership values
- Defuzzification of synthesis values
- Determination of Expansion Area Accessibility Index values.

TABLE V: FUZZY NUMBERS ON LIKERT SCALE

Attr.	1 0----2	2 2----4	3 4----6	4 6----8	5 8----10
A-I	1	2	7	0	1
A-II	1	2	5	0	3
A-III	0	2	3	5	1
A-IV	4	4	1	1	1

TABLE VI: FUZZY SETS FOR WEST ZONE EXPANSION AREAS

Attributes	1	2	3	4	5
A-I	(1, 0.091)	(2, 0.182)	(7, 0.636)	(0, 0.000)	(1, 0.091)
A-II	(1, 0.091)	(2, 0.182)	(5, 0.455)	(0, 0.000)	(3, 0.273)
A-III	(0, 0.000)	(2, 0.182)	(3, 0.273)	(5, 0.455)	(1, 0.091)
A-IV	(4, 0.364)	(4, 0.364)	(1, 0.091)	(1, 0.091)	(1, 0.091)

TABLE VII: MODIFIED FUZZY MEMBERSHIP NUMBERS ON RELATIVE WEIGHTAGE BASIS.

Attributes	1	2	3	4	5	Total	Percentage
A-I	0.022	0.045	0.156	0.000	0.022	.690	23.18
A-II	0.025	0.050	0.125	0.000	0.075	.875	29.28
A-III	0.000	0.054	0.080	0.134	0.027	1.019	34.09
A-IV	0.067	0.067	0.017	0.017	0.017	0.404	13.55
	<b>0.114</b>	<b>0.215</b>	<b>0.379</b>	<b>0.151</b>	<b>0.141</b>	<b>2.988</b>	<b>100</b>

TABLE VIII: EAAI VALUES FOR THE EXPANDED AREAS.

S. No	Expanded Zones	EAAI	Ranks
EA-1	1. West zone expansion (north side)	3.051	3
EA-2	2. North zone expansion	3.489	1
EA-3	3. East zone expansion	3.326	2
EA-4	4. South east zone expansion	3.032	4
EA-5	5. South zone expansion	3.005	6
EA-6	6. South west zone expansion	3.018	5
EA-7	7. West zone expansion	2.988	7

Critical qualitative rating on 0-10 scale is converted to Likert scale of 1-5 to get comprehensive fuzzy sets. Table VI indicates the Fuzzy set values for all the four attributes.

The fuzzy membership values in the range 0-1, shown in the above table are further modified by applying NMW of the attributes as determined and shown in the last column of Table IV, and they are presented in Table VII.

These numbers are synthesized on relative weight basis and the same are shown in the last row of the Table VII.

The last step in the Fuzzy Synthesis Modeling is Defuzzification of membership values to arrive at crisp values to get the Expansion Area Accessibility Index (EAAI) composed of 4 attributes impact values. In the present case of West Zone, EAAI value is worked out as:

$$\text{EAAI} = (0.114 \times 1) + (0.215 \times 2) + (0.379 \times 3) + (0.151 \times 4) + (0.141 \times 5) = 2.988$$

Here the modified membership values are multiplied with the Likert scale values, 1 to 5 successively. Thus 2.988 EAAI value would be Access Index for the West Zone. Similarly EAAI values for other zones are computed as outcome of Fuzzy Synthesis Model as under: (Table VIII)

## VI. OBSERVATIONS AND CONCLUSION

It can be concluded that North Zone expansion area (EA-2) has the highest EAAI value whereas the West Zone Expansion zone (EA-7) has the lowest EAAI value. This provides base for the ranking of the expansion areas with reference to transportation infrastructure and amenities in all the newly expanded areas. The attribute composition split expressed as percentage in the last column of Table VII indicates the share of particular attribute in overall

accessibility index. As far as West zone is concerned the contribution of accessibility with reference to main transportation centre (A-4) for outstation trips is quite poor (13.55%). However the positive point is that the traffic impedance is rather on the lower side with higher value of ease of access (A-3) because of external traffic corridors in form of ring roads that are available. Thus the model not only highlights the status of transport accessibility and mobility of the newly joined areas but also provides a base to understand and mark the shortfalls in accessibility components so that a planner can plan the project on a priority basis and take up the development programs to enhance the accessibility index.

The fast growing metropolitan cities are bound to expand with reference to the rapid urbanization process taking place. The newly expanded areas trigger off urban growth. The dimensions of urban growth of these new expansion areas and their growth rates depend upon number of zonal attributes. Land values, accessibilities, provision of infrastructure are some of the important attributes that provide pace for the growth. However Transportation system accessibility and mobility level attributes play a vital role in new area growth and development activities but very limited data in this regard

makes the analysis a tough task. Under such uncertain environment Fuzzy set theory application becomes an effective tool. In view of this Fuzzy Synthesis evaluation technique has been applied and found useful in developing the expansion area accessibility index for all the expansion areas for the cities. As per the present study North Expansion Zone of Surat city area stands first rank, and East Expansion area on the right bank of river Tapi finds second rank. The least preferred is New West zone because of poor accessibility and amenities.

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