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Quality Assessment of Public Transport by Fuzzy Sets Approach: A Case Study

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Abstract: ***The Daily needs and mobility patterns are increasing day by day in urban areas. This leads to the increase in number of trips from Origin to Destination. For those increasing needs a mass transit like Public Transport (PT) is very much helpful if its quality is being verified. The quality of Urban Transport is well accomplished by considering Public Transport Facility, as it plays a major role in the urban areas. This paper concentrates on enhancing the quality of PT by Fuzzy Sets approach. The main idea is to select some Parameters which are related to the quality of PT and by analysing them using the Fuzzy sets concept to calculate the non-fuzzy outputs and to obtain a Composite index called Level of public transport service (LOPTS), which is obtained as 0.52 and it is said to be in Poor condition according to fuzzy sets concept, by increasing the frequency of service for PT it will impact all the remaining selected attributes such that the LOPTS for the study area can be improved. For the current case study Vizianagaram (Urban area), Andhra Pradesh, India is considered.***
Keywords: Public Transport Facility, Fuzzy Sets, Urban Areas, Composite Index, LOPTS.

I. INTRODUCTION

All the government organisations and various agencies are constantly working on the improvement of Mass transit systems and various public facilities. The quality of any system can be effectively increased when it is monitored in certain aspects which are related to it.

A. Need of Quality in Public Transportation System

Any public transport facility will try to give the maximum Level of Service for the users. To increase the demand for the Public transport it should satisfy all the user needs otherwise passengers may choose other mode of transport as their daily mode of commute. So the quality of the public transport has to be carefully enhanced so that all the commuters will prefer for the mass transit like public transport. Some indicators has to be selected in view of commuters and they can be examined in terms of user perception so that the relative output will be efficient.

II. CASE STUDY

For this study Vizianagaram (urban) area has been selected for the quality assessment of Public transport facility.

A. Introduction

Vizianagaram is a town and the district headquarters of Vizianagaram district in the Indian state of Andhra Pradesh. It is a municipality and also the mandal headquarters of Vizianagaram mandal.It is located 18 km inland from the Bay of Bengal and 42 km to the northeast of Visakhapatnam. As of 2011 census, it was most populous town of Vizianagaram district andwith a population of 2,44,598.[2]

B. Vizianagaram Town Profile

Vizianagaram district was formed on 1 June 1979, with some parts carved from the neighboring districts of Srikakulam and Visakhapatnam. It is the least populous district in Andhra Pradesh.[2]

C. Location and Geography

Vizianagaram is located at 18.12°N 83.42°E. It has an average elevation of 74 metres (242 feet). The district is bounded on the east by Srikakulam District, on the west and south by Visakhapatnam district, on the southeast by the Bay of Bengal, and on the northwest by Odisha state. The principal rivers flowing in the district are Nagavali, Vegavathi, Gomukhi, Suvarnamukhi, Champavathi and Gostani. The Nagavali is the main river, which flows in about 112 km in Vizianagaram district. The River Gosthani has its origin in Ananthagiri forest area and flows through Srungavarapukota (S.Kota) and Jami mandals.[2]

D. Area and Population

The Vizianagaram Municipal Corporation represents the urban agglomeration area of the town with a population of 2,44,598 as per the 2011 census.

Source: Municipal Corporation, Vizianagaram Town Development Plan (CDP)

E. Demographics

As of 2011 Census of India, the town had a population of 227,533. The total population constitute, 111,596 males and 115,937 females -a sex ratio of 1039 females per 1000 males, higher than the national average of 940 per 1000. 20,487 children are in the age group of 0–6 years, of which 10,495 are boys and 9,992 are girls. The average literacy rate stands at 81.85% with 169,461 literates, significantly higher than the national average of 73.00%.

Source: Vizianagaram Town Development Plan (CDP)

F. Vehicle Population

The No of vehicles registered up to 2016 for Vizianagaram District is shown in TableI

TABLEI:NO OF VEHICLES REGISTERED UP TO 2016 FOR VIZIANAGARAM DISTRICT

Vehicle type	2011	2012	2013	2014	2015	2016
2 wheeler	132113	149585	166081	186317	207787	221662
Autos	10306	12051	14277	16604	19014	21535
Four wheeler	12610	14500	16132	17763	20046	22300
Commercial	11525	12312	13371	14727	16243	18535
Total	166554	188448	209861	235411	263090	284032

Source: Vizianagaram Regional Transport Authority (RTO)

It is clearly observed that the two wheeler growth is more compared to other modes, especially auto rickshaws, as shown in Fig. 2.1 below.

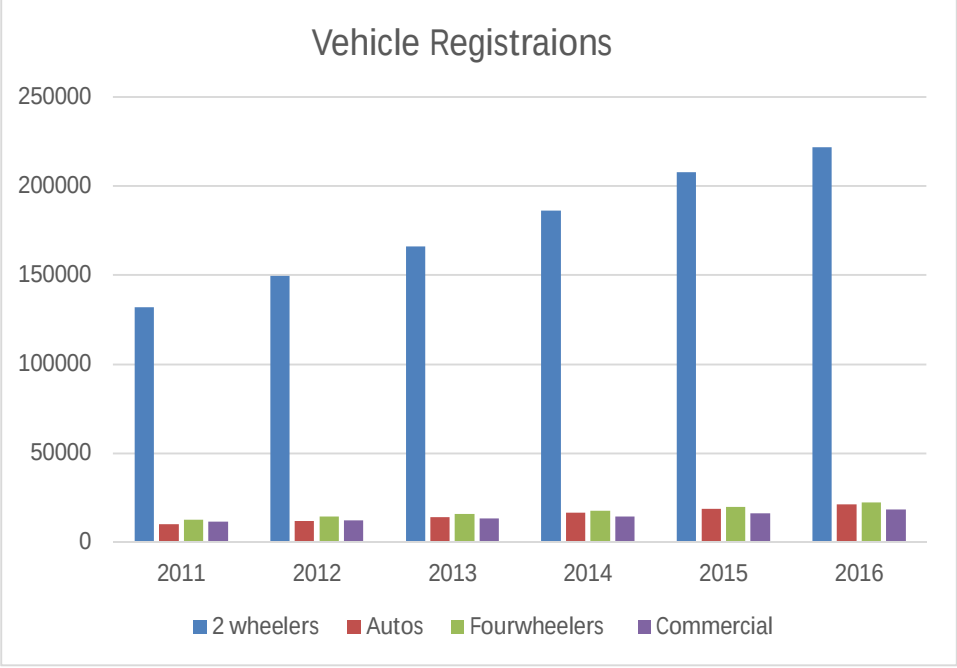

Fig.1 No of Vehicles registered up to 2016 for Vizianagaram District

G. Road Network

Vizianagaram is one of the major towns on the east coast of India connected by a major highway NH-26 and a part of the of Indian highways connecting Raipur and Natavalasa Road. Vizianagaram district has a total of 123.33Kms of National highway passing through it.[2]

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Fig2: Image of vizianagaram (Urban) (Study Area)

III. STUDY METHODOLOGY

The Study Methodology involves various steps and procedure followed for the case study area to obtain a composite index called LOPTS (Level of Public Transport Service). The various attributes selected for the study are Frequency of Service (F), reliability (Re), Availability of Seats(A),Comfort levels of seats (C),Cleanliness of Vehicles (Cl), Fare collected(Fr),Disturbance level (D), Jerk/Impact (Je), Safety(Sa), ease of obtaining transfers(Tr). All these attributes are examined by considering the user perception of various commuters.

A. Data Collection

For the collection of data for fuzzy sets approach various questionnaires are prepared and the commuters are requested to answer those questions. Based on their perception the rating of users for "Average Service Quality" has been classified in to various classes as Class A (Extremely important), Class B (Very Important), Class C (Important), Class D (Moderately important), Class E (Less Important). Similarly for "Average Weightages" it is classified as Class A (Very Good), Class B (Good), Class C (Ok), Class D (Poor), Class E (Very Poor).

IV. FUZZY SETS APPROACH

A. Public Transport Quality Analysis using Fuzzy Sets Approach

In this approach for Average Service quality and Average weightages for a particular attributes are assessed and taken as letter grades. The collected information can be effectively processed by using the following equation [1]

$$R = \sum_{i=1}^{N} (R_i * W_i) / \sum W_i$$

Where,

R= Overall rating of service level of a Category of service.

Ri = the rating of the i^{th} service quality of the category of bus service for the existing condition

Wi = the weight of that service attribute i

N =Number of attributes that define the overall service level

Each term in the right-hand side of (1) is represented with A,B,C,D or E. A rational approach to evaluate eqn. (1) is represented by letter grades using fuzzy sets approach, instead of using single number to represent letter grades as in the case of Numerical rating approach [6]. A fuzzy set is a set of paired numbers that describes the degree of support to each service quality. In describing the service quality, the attributes for which higher values represent higher level of satisfaction (e.g., comfort level of seats), have been represented as very high (highly satisfactory) = A, high = B, moderate = C, low = D and very low = E. The attributes for which lower values represent higher level of satisfaction (e.g., noise) have been represented as very low (highly satisfactory) = A, low= B, moderate = C, high = D, very high = E[1]

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Thus, fuzzy sets can account for uncertainty associated with quantification of the letter grade. In other words, these letter grades, when they are used along with the fuzzy sets in a qualitative evaluation, can form a comprehensive rating scale. The fuzzy sets that represent the letter grades adopted in this study are characterized by their membership functions as shown in Table II and in FigIV. In this study a linear (triangular) membership function is assumed for simplicity in illustrating the presented methodology,[1][3][4][5]

When each term in the right-hand side of (1) is substituted by a fuzzy set, the evaluation of the equation involves operations such as fuzzy-set addition, fuzzy-set multiplication and fuzzy-set division. Definitions of these fuzzy operations, as one might expect, are different from their counterparts in the conventional mathematics [7]. Rather than directly implementing these operations as it is tedious, the following process is used in this study,[3]. The general concept for processing fuzzy information using a model such as (1) is illustrated in Fig III. The main idea is to "defuzzify" each fuzzy set into a group of real intervals before entering into eqn. (1). Once this is accomplished, the conventional mathematics takes over, which results in a group of nonfuzzy intervals as the output. The final fuzzy set is reconstructed from this group of nonfuzzy intervals. A computer program Best Alternative Selection System (BASS) is also available to implement the computational process [8][9]. The final result of the computation is a fuzzy set that represents the overall service level. An example showing the entire computation process is given in Appendix-1.[1]

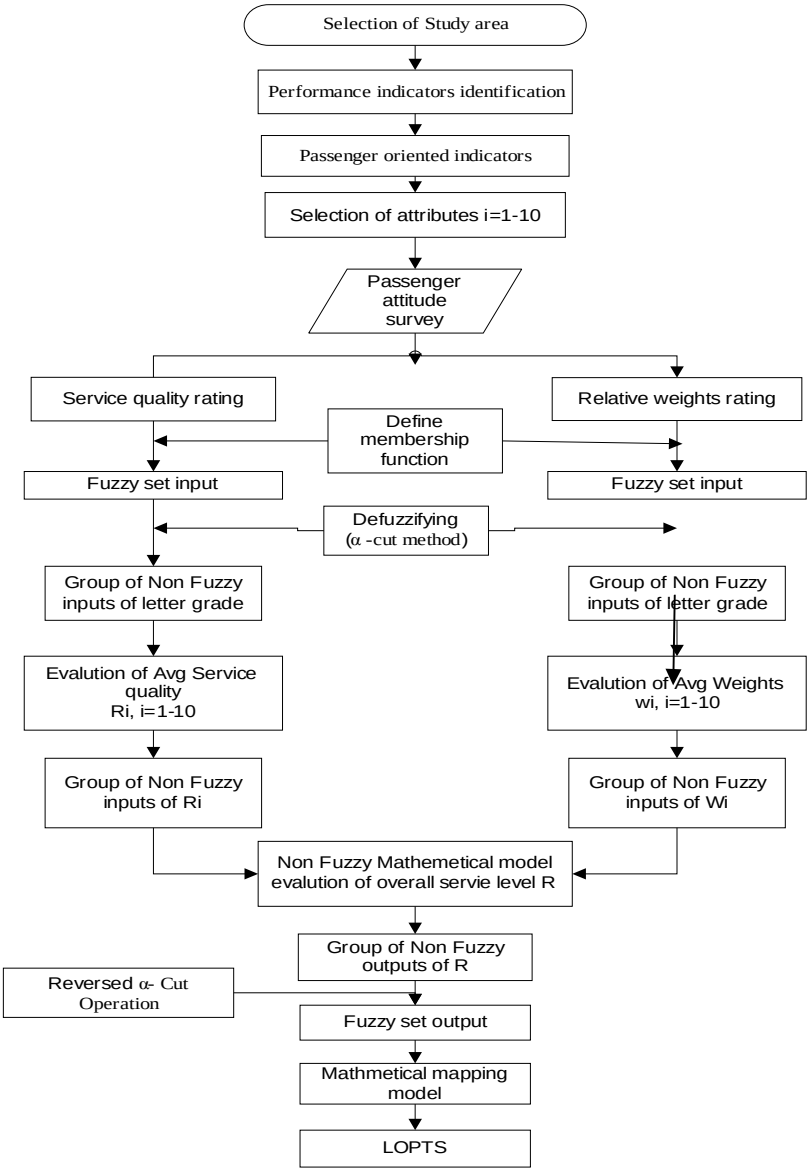

Fig3: Study Methodology adopted for the case study

Table Ii: Membership Functions Of Fuzzy Sets That Represent Letter Grades For Ratings And Weights [1]

Description for weight	Letter Grade (Fuzzy Set) (1)	Membership Function, f(y) (defined over a real interval, (0,1))
Extremely important	A	f(y) = 5(y-0.8), $0.8 \leq y \leq 1.0$
Very important	B	f(y) = 10(y-0.5)/3, $0.5 \leq y \leq 0.8$ f(y) = 5 (1.0-y), $0.8 \leq y \leq 1.0$
Important	C	f(y) = 10(y-0.3)/3, $0.3 \leq y \leq 0.6$ f(y) = 5(0.8-y), $0.6 \leq y \leq 0.8$
Moderately important	D	f(y) = 10(y-0.1)3, $0.1 \leq y \leq 0.4$ f(y) = 5(0.6-y), $0.4 \leq y \leq 0.6$
Less important	E	f(y) = 5(y), $0.0 \leq y \leq 0.2$ f(y) = 5(0.4-y), $0.2 \leq y \leq 0.4$

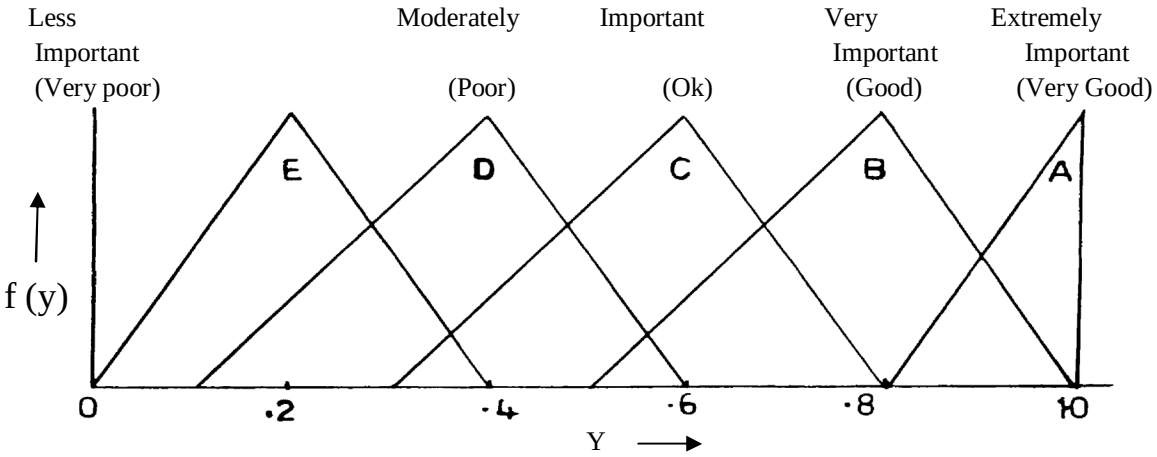

Fig4: Membership Functions (Linear) of Fuzzy Sets that Represent Letter Grades for Ratings and Weights.

$$LOPTS = (A_l - A_r + 1)/2 \quad \text{..... (2)}$$

where A_l = area enclosed to the left of the membership function that depicts the final fuzzy set, which varies with overall rating of service level, i.e. more the overall rating more the Al value is; and A_r = area enclosed to the right of the membership function that depicts the final fuzzy set. The defined LOPTS value ranges from 0.0 to 1.0, with 1.0 indicating the perfect service level and 0.0 indicating the worst service level. The more the value of A_l and lesser the value of A_1, the better the service; the lesser the value of A_l and more the value of A_r, the poorer the service.[1]

Table iii. Relative weights of various attributes for public transport [1]

Attributes	Number of passengers putting weights on				
	A	B	C	D	E
Frequency of Service(F)	80	273	126	11	3
Reliability(Re)	63	262	160	6	2
Availability of Seats(A)	34	230	210	18	1
Comfort levels of seats(C)	40	175	248	24	6
Cleanliness of vehicle(Cl)	69	249	147	28	2
Fare Collected(Fr)	30	181	240	32	10
Disturbance levels (D)	80	228	150	20	15
Jerk/ Impact(Je)	75	212	160	40	6
Safety(Sa)	324	115	40	10	4

Ease of obtaining Transfers(Tr)	50	180	218	40	5

A=Extremely important ; B= Very Important ; C= Important ; D= Moderately ; E= less Important

Table iv. Service quality of various attributes for public transport [1]

Attributes	Number of passengers putting weights on				
	A	B	C	D	E
Frequency of Service(F)	70	262	140	15	6
Reliability(Re)	65	271	143	10	4
Availability of Seats(A)	60	170	250	11	2
Comfort levels of seats(C)	30	210	237	10	6
Cleanliness of vehicle(Cl)	55	273	160	5	0
Fare Collected(Fr)	22	199	255	12	5
Disturbance levels (D)	25	110	205	110	43
Jerk/ Impact(Je)	23	160	213	72	25
Safety(Sa)	80	174	223	9	7
Ease of obtaining Transfers(Tr)	94	176	203	11	9

A=Very Good; B=Good; C= Ok; D= Poor; E= Very Poor

Table v. Group of non-fuzzy inputs for average weights and service quality rating [1]

Attributes	Public transport service					
	Average Weights			Average Service quality rating		
	α=1	α=0.5	α=0	α=1	α=0.5	α=0
Frequency of service(F)	(0.77,0.77)	(0.63,0.85)	(0.49,0.94)	(0.75,0.75)	(0.61,0.84)	(0.47,0.92)
Reliability(Re)	(0.75,0.75)	(0.61,0.84)	(0.47,0.93)	(0.76,0.76)	(0.61,0.84)	(0.47,0.93)
Availability of seats(A)	(0.71,0.71)	(0.57,0.81)	(0.42,0.90)	(0.71,0.71)	(0.57,0.80)	(0.42,0.89)
Comfort levels of seats(C)	(0.69,0.69)	(0.54,0.78)	(0.40,0.87)	(0.70,0.70)	(0.55,0.79)	(0.41,0.89)
Cleanliness of vehicles(Cl)	(0.74,0.74)	(0.60,0.83)	(0.46,0.92)	(0.75,0.75)	(0.61,0.84)	(0.46,0.93)
Fare collected(Fr)	(0.68,0.68)	(0.53,0.77)	(0.38,0.86)	(0.69,0.69)	(0.54,0.79)	(0.40,0.88)
Disturbance level(D)	(0.74,0.74)	(0.60,0.82)	(0.46,0.90)	(0.59,0.59)	(0.44,0.68)	(0.30,0.78)
Jerk/ Impact (Je)	(0.73,0.73)	(0.58,0.81)	(0.44,0.90)	(0.63,0.63)	(0.49,0.73)	(0.34,0.82)
Safety(Sa)	(0.90,0.90)	(0.79,0.94)	(0.67,0.97)	(0.73,0.73)	(0.58,0.81)	(0.44,0.89)
Ease of transfers(Tr)	(0.69,0.69)	(0.55,0.78)	(0.40,0.87)	(0.74,0.74)	(0.60,0.82)	(0.46,0.90)

Table vi. Group of non-fuzzy outputs for overall rating and composite index [1].

Type of service	Overall rating	α cut intervals	Non fuzzy outputs	Composite index (LOPTS)

Public Transport	$\sum_{i=1}^{N}(R_i * W_i) / \sum W_i$	α = 1 α = 0.5 α = 0	(0.71,0.71) (0.56,0.79) (0.42,0.88)	**0.52**

V.CONCLUSIONS

A. By using the concept of fuzzy sets the quality of Public transport service for the vizianagaram urban area has been calculated as 0.52.

B. Considering the concept of fuzzy sets the value obtained for LOPTS is nearer to 0.5 and it is considered to be poor for the selected study area and it has be improved for better connectivity.

C. Frequency of service can be increased for the Public transport service so that it reflects all the remaining attributes in direct and indirect manner, which leads to the improvement of LOPTS of Public transport service for Vizianagaram Urban area.

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APPENDIX I

Examples Illustrating Fuzzy Computations in This Paper

This appendix details the fuzzy computations defined in (1) and the LOPTS defined in (2). The computation process is described in the following step-by-step procedure,[3].

For defuzzifying a fuzzy set select a group of α - cut values which are appropriate. In this example, only three values - 0.0, 0.5 and 1 .00are used.[1]

For α = 0.0, obtain the α- cut interval for each of the input fuzzy sets. According to the membership function defined in Table-1 and Fig. 1, the following α-cut intervals can be obtained for the given input fuzzy sets.[1]

TABLEVII A GROUP OF NON-FUZZY INPUT FOR VARIOUS LETTER GRADES AT DIFFERENT α -CUT INTERVALS[1]

Letter grade	For α =0	For α =0.5	For α =1
A	(0.8,1)	(0.9,1)	(1,1)
B	(0.5,1)	(0.65,0.9)	(0.8,0.8)
C	(0.3,0.8)	(0.45,0.7)	(0.6,0.6)
D	(0.1,0.6)	(0.25,0.5)	(0.4,0.4)
E	(0,0.4)	(0.1,0.3)	(0.2,0.2)

The average weightage for the attribute 1, i.e., access for Public transport service is calculated as:

For α= 1.0

$$= \frac{(80(1,1) + 273(0.8,0.8) + 126(0.6,0.6) + 11(0.4,0.4) + 3(0.2,0.2))}{(80 + 273 + 126 + 11 + 3)}$$

$$= \frac{((80,80) + (218.4,218.4) + (75.6,75.6) + (4.4,4.4) + (0.6,0.6))}{493}$$

$$= \frac{(379,379)}{493} = (0.77,0.77) \text{ (Refer Table -2)}$$

In similar way the average weightages and average ratings for all the attributes, for Public transport service for α - cut intervals of 0, 0.5 and 1.0 are calculated and presented in Table 4.
Calculate R using (1) with the preceding α- cut intervals. This step is essentially to perform an interval computation (Moore, 1966; Dong & Wong, 1987). Using α = 0 as an example, for Public transport service.

$$R_{\alpha=0} = \frac{((0.49,0.94) * (0.47,0.92) + (0.47,0.93) * (0.47,0.93) + \ldots\ldots\ldots\ldots + (0.40,0.87) * (0.46,0.90))}{((0.49,0.94) + \ldots\ldots\ldots\ldots + (0.40,0.87))}$$

$$= (0.42,0.88)$$

Repeat step 5 for α = 0.5 and 1.0. This step results in $R_{\alpha=0.5}$= (0.56, 0.79) and $R_{\alpha=1}$ = (0.71, 0.71) for city service. For district service, repeat step 5 for α = 0, 0.5 and 1.0. The results are shown in Table 5.
The selected a values and the calculated intervals as a whole represent the resulting fuzzy set for city service and this is shown in Fig.5. The LOPTS value is calculated using (2), in a way similar to the example presented in the text.

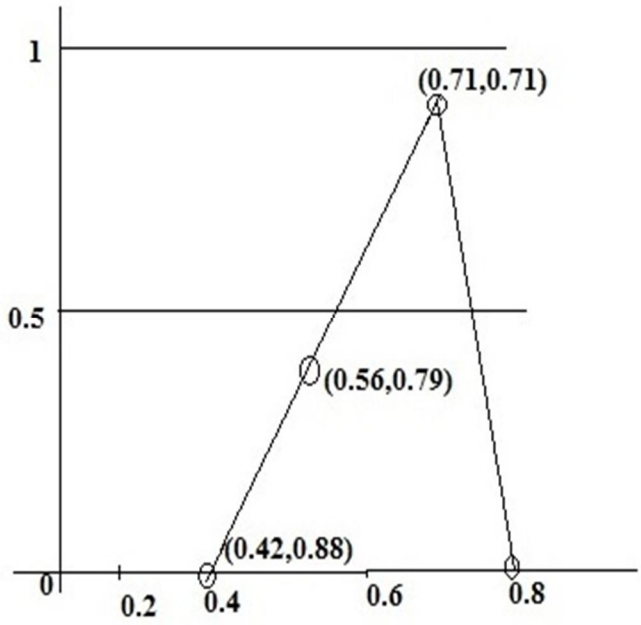

Fig 5: Resulting Fuzzy set Obtained for example in appendix-1

$$A_l = (0.42 + 0.71)/2 = 0.56$$

$$A_r = (0.28 + 0.40)/2 = 0.54$$

$$LOPTS = (0.56 - 0.54 + 1)/2 = 1.02/2 = 0.52$$

APPENDIX II

TABLEVIII GUIDELINES FOR RATING DIFFERENT SERVICE QUALITIES [1]

Rating grade	Maximum Frequency (min)	Reliability	Space/ Seat availability	Disturbance level	Ease of Transfers	Comfort & Cleanliness of vehicle	Safety
A	≤5	0	≤50	<60	≤5	Bus Shelter with seats in good condition	Two doors at 1/4th and 3/4th length and step height ≤15cm
B	6-10	0.1-1.5	51-70	60-69	6-10	Bus shelter in good condition	Two doors at the front and 3/4th length and step height ≤15cm
C	11-15	1.6-3	71-85	70-79	11-15	Bus shelter in moderate condition	Two doors and the step height 16-20cm
D	16-20	3.1-4.5	86-100	80-89	16-20	Bus shelter with poor maintenance	Two doors and the step height >20cm
E	>20	>4.5	>100	≥90	>20	No bus shelter	Single door and the step height >20cm