International Journal of Innovation, Management and Technology, Vol. 1, No. 5, December 2010
ISSN: 2010-0248

Analyzing the Passenger Service Quality of the Indian Railways using Railqual: Examining the Applicability of Fuzzy Logic

Devi Prasad Maruvada, Dr Raja Shekhar Bellamkonda

Abstract—**This study identifies the attributes to evaluate the quality of Railway Passenger Services and develops a comprehensive instrument "RAILQUAL" on the basis of SERVQUAL and Rail Transport quality. Fuzzy set Theory has been applied to evaluate the service quality of the Indian Railways. This paper develops an analysis architecture, which consists of fuzzy measurement of S-I (Satisfaction - Importance) degree. The measurement of S-I gap with fuzzy approach is to reduce subjectivity and ambiguity of passengers' judgment of service quality. Fuzzy logic helps in representing the vagueness of evaluators' judgment. Using SERVQAUL methodology, the optimal fuzzy interval of gap scores is determined for each item. Fuzzy approach is a more realistic way to use linguistic assessments instead of numerical values. An empirical study is conducted using the proposed approach.**

Keywords–**Indian Railways, Fuzzy logic, Railqual, Service Quality.**

I. Introduction

In this era of Total Quality Assurance, every organization must define and manage service quality. As markets mature, service becomes a powerful competitive weapon, and indeed in some cases, the only form of differentiation. The challenge of any service operation is to bring together various facets of the business. Although in reality the content of a service may be largely invisible to the customer, his perception of service delivery is influenced disproportionately by the manner of his treatment at the point of contact. It is widely believed that service is difficult to manage because it is intangible. But many a service activity contains a considerable proportion of very tangible activities which are therefore capable of specification and measurement [1].

The Indian Railways (IR), more than 150 years old, is among one of the largest and oldest systems in the world, fondly called by people as the 'Lifeline of the Nation'. With an extensive network spread across the country, Indian Railways plays a key role in the social and economic development of India[2]. IR is a principal mode of transportation for long haul freight movement in bulk, long distance passenger traffic, and mass rapid transit in suburban area. It occupies a unique position in the socio-economic map of the country and is considered as a vehicle and barometer of growth [3]. Indian Railways lost its market share in Freight and Passenger segment due to lack of customer responsiveness and poor public perception [4].

Normally SERVQUAL studies of passenger service quality are performed by calculating the mean averages of the passengers' gap scores [5]. As a SERVQUAL questionnaire is built using Likert scaling, the categories are ranked in ordinal scales, which indicate that the calculation of mean scores is not an efficient method of evaluation. For a ranking scale, frequencies or percentages are offered to obtain reliable conclusions. Nevertheless, if the evaluation is performed by mean averages or standard deviations, the passengers' raw scores should be transformed into quantitative interval scores. For this reason, this study offers fuzzy numbers in the measurement of service quality. Recent research methodologies employ fuzzy set theory for solving decision making problems. How ever its application in the field of service quality management is still rare [6].

Additionally, fuzzy logic enables analysis using ill-defined sampling or where there is missing data [7]. In survey analysis, including SERVQUAL, it is hard to achieve an optimal sample that includes equally distributed gender, nationality, marital status, educational level and so forth. Therefore, generalizing the findings of a survey is quite risky, as the applicants in the sample cannot sufficiently reflect the quality evaluations of all passengers. Further more, a questionnaire itself is a subjective tool and daily variables can affect the results. The passengers' perceptions can change depending on their mood during the response time - or the purpose of the travel can also affect responses while filling in the questionnaire form. Passengers leaving for a holiday would be more optimistic than those traveling for business purposes [8]. The purpose of this study is to propose a fuzzy analysis architecture, which consists of fuzzy measurement of S–I gap based on SERVQUAL instrument, modified S–I analysis for attributes and ranking order determination for subjects, to address service quality management more effectively by including the vagueness of evaluators' judgment and identifying directions and targets for improvement [9]. An empirical study is conducted by using the proposed analysis architecture. The rest of this paper is organized as follows. Section 2 describes the modification/adaptation of SERVQUAL to Railqual, In Section 3 Fuzzy logic and arithmetic along with the proposed evaluation of service

Manuscript received October 19, 2010.
Devi Prasad Maruvada is Research Scholar in School of Management Studies,University of Hyderabad,India (Phone 91-40-2712585; e-mail: : mdprasad1967@gmail.com).
Dr Raja Shekhar Bellamkonda is Professor at School of Management Studies,University of Hyderaba,India (Phone: 91-40-2301363;email: b_rajashekhar@yahoo.com)

quality using fuzzy logic is presented. Section 4 gives conclusion and managerial implications.

II. Modification And Adaptation Of SERVQUAL As RAILQUAL

The SERVQUAL approach is the most common method for measuring service quality. The credit for heralding the service quality research goes to Parasuraman et al., [10]. They formulated a measure of service quality derived from data on a number of services, instead of counting on earlier dimensions of goods quality in the manufacturing sector. The entire approach was formulated on the tenet that customers entertain expectations of performances on the service dimensions, observe performance and later performance perceptions transform into satisfaction degree. SERVQUAL is much more humanistic, or customer-related, while most of the measures used in public transport industry are much more mechanistic, or have technical focus, or use more objective measures

It has been suggested that for some services the SERVQUAL instrument needs considerable adaptation [13] and that items used to measure service quality should reflect the specific service setting under investigation, and that it is necessary in this regard to modify some of the items and add or delete items as required [14]. In summary, in order to measure the quality of service thoroughly, the attributes used in SERVQUAL, the public transport industry and the railway service sector should be grouped together to form a pool of items for measurement. Hence, we have modified the attributes in the SERVQUAL model and created RAILQUAL (as shown in Table I) for measurement of Railway passenger Services.

This study used the RAILQUAL scale to measure the perceived service quality of rail transport users. The study followed the steps adopted by parasuraman, Zeithamal and Berry [11] and recommended by Churchill [14] in conducting the research. The research process starts by refining the service quality measurement scale as proposed in Parasuraman et.al, [12]. Focus group discussion is used for this refinement. The focus group discussion lasted approximately for three hours. Ten officers of South Central Railway (SCR) participated in this discussion. The contact author acted as moderator for the focus group discussion and took extensive notes of the proceedings. As a result of focus group discussion and review of transport quality literature a service quality measurement scale RAILQUAL with 5 dimensions and 22 items emerged. The items were segregated on the basis of logical reasoning and clubbed to form dimensions for which the reliability tests were done and the Cronbach Alpha values were ranging from 0.7 to 0.8 across five dimensions. The next step in the computation was the calculation of the RAILQUAL score for each of the 22 pairs of satisfaction / importance degrees.

The questionnaire utilized to gather the data comprised four main sections. Section 1 consists of 22 items to measure customers' satisfaction degree of railway services in general while Section 2 consists of a corresponding 22-item scale to measure the customers' importance degree of the services offered by SCR. The scores for each item ranged from "1" for "very poor" to "5" for "excellent" on a five-point Likert scale for *satisfaction degree* and "1" for "very unimportant" to "5" for very important for *importance degree*, according to the recommended procedures for scale development [14].

Respondents were selected from the staff of various government departments and institutions in Secunderabad city of India who are customers of the railway services. 300 sets of questionnaires were handed over to representatives (senior officers) of twenty government departments/institutions to be distributed to their staff who had used railway services before. Each department was allocated about five to ten questionnaires to be distributed, depending on its size. A total of 234 completed questionnaires were subsequently collected from the government representatives.

TABLE I

RAILQUAL Dimensions	RAILQUAL Attributes	Abre
TANGIBLES	1.Railway has modern looking equipment & infrastructure at stations and trains	RQ 1
	2.Railways Physical Facilities like Lighting, seating and Toilets are OK	RQ 2
	3.Staff of Railways are neat in Appearance	RQ 3
	4.Time Tables, Display Boards etc are visually appealing	RQ 4
REALIABILITY	5.Railways are accurate in Record Keeping	RQ 5
	6.Railways are accurate in timing of Trains	RQ 6
	7.Railways performs Service Correctly	RQ 7
	8.When you have problems Railways shows sincere interest in solving it	RQ 8
	9.Railways adheres to punctuality of Trains	RQ 9
RESPONSIVENES S	10.Railway staff are always willing to help	RQ 10
	11.Railway staff tell exactly when services will be performed	RQ 11
	12.Railway employees are not always willing to help	RQ 12
	13.Emplyess of Railways are too busy to respond	RQ 13
ASSURANCE	14. The Railways are trustworthy	RQ 14
	15. You feel safe in your travel	RQ 15
	16.Ralway Employees are courteous way	RQ 16
	17. Employees are Knowledgeable	RQ 17
EMPATHY	18. Railways give individual attention	RQ 18
	19. Railway operations are convenient to all passengers	RQ 19
	20.Railway employees give personnel attention	RQ20
	21. Railway has your best interest at heart	RQ 21
	22. It is easy to plan a railway journey	RQ 22

III. Fuzzy Arthmetic & Evaluation of Service Quality Using Fuzzy Logic

If the universe of discourse X be the subset of real numbers R, X= { $x_1,x_2,x_3,\ldots x_n$}. A fuzzy set $\widetilde{A}$ = {(x, $_{A(X)}$|) μ_{X}} in X is a set of ordered pairs where $\mu_{A(x)}$ is called a membership function and $\mu_{A(x)}$ X : X $\rightarrow$ [0,1].

Equation 1: Let $\widetilde{A}$ = { x, μ_A(X)) | x $\in$ X }

and Let $\widetilde{A}$ = { x, $\in_B$(X)) | x $\in$ X } [15]

$\mu_{A \cap B}$(X) = min (μ_A(X); μ_B(X)) x $\in$ X

$\mu_{A \cap B}$(X) = max (μ_A(X); μ_B(X)) x $\in$ X

Equation 2 :

The α - cut set $\widetilde{A}\,\alpha$ of fuzzy set $\widetilde{A}$ is defined as

$\widetilde{A}\,\alpha$ = { x, μ_A(X)) > α , x $\in$ X} , 0 $\leq$ α $\leq$ 1 , α $\in$ R [16]

Equation 3:

The Hamming distance d(μ_A(X); μ_B(X)) = $\int x$ | μ_A(X)- μ_B(X) | dx [15]

Where μ_A(X) and μ_B(X) denote the membership functions of triangular fuzzy numbers $\widetilde{A}$ and $\widetilde{B}$ individually.

A triangular fuzzy number $\widetilde{A}$ is represented by triplet (a1,a2,a3). The membership function μ_A(x) of $\widetilde{A}$ is defined as following.

$$Y_a^L(x) = \frac{x-a_1}{a_2-a_1}, a_1 \leq x \leq a_2$$

$$\mu_A(x) = Y_a^L(x) = \frac{x-a_3}{a_2-a_3}, a_2 \leq x \leq a_3$$

0, otherwise.

Linguistic terms, satisfaction degree and importance degree, are often vague. To provide more objective information, we fuzzify satisfaction degree and importance degree as triangular fuzzy numbers individually by equation 1 and apply equation 2 to aggregate group opinions.

A_{ave} denotes the average fuzzy number of n triangular numbers $\widetilde{A}$ =($a_1^{(i)}$, $a_2^{(i)}$, $a_3^{(i)}$) where i=1,2,3,…..,n. without loss of generality, $\widetilde{A}$ replaces A_{ave} . To justify whether an attribute is weak or strong [18], we compare V_A between two triangular fuzzy numbers as follows.

$$\widetilde{A} = A_{ave} = \frac{A_1 + A_2 + \ldots + A_n}{n} = \frac{(\sum_{i=1}^{n} a_1^{(i)}, \sum_{i=1}^{n} a_2^{(i)} \ldots \sum_{i=1}^{n} a_3^{(i)})}{n} = (a_1 + a_2 + a_3)$$

V_A = (a_1+2a_2+a_3)/4 , for the triplet (a_1, a2, a_3) of a triangular fuzzy number $\widetilde{A}$.

Here we are proposing a new method of measuring service quality which is based on linguistic variables. The model is divided into following steps.

Step 1: Create a triangular fuzzy number for the ith customer's linguistic terms by equation I

Let (Ai)k be a triangular fuzzy number that is the ith customer's linguistic importance degree, and let B be one of ith customer's linguistic satisfaction where k denotes kth attribute, i=1,2,3,…,n, k=1,2,3,…,p, n is the sample size, and represents the number of attributes.

To simplify mathematical symbols, we replace $\widetilde{A}$ by Ai and $\widetilde{B}$ by Bi, which represent the ith customer's importance degree and satisfaction degree for an attribute individually. The triplets (0,0,2),(0,2,4),(2,4,6),(4,6,8) and (6,8,8) of A_i for i=1,2,3,,….n in linguistic terms, mean " very un important", " unimportant", "fair", " important" , " very important" respectively.

Similarly the triplets (0,0,2).(0,2,4),(2,4,6),(4,6,8) and (6,8,8) of B_i for i=1,2,3,…n represent "very poor", " poor", " fair", "good", " excellent".

Step2: Creating an average triangular fuzzy number from n triangular fuzzy numbers as shown in Table II.

Suppose A_1 = ($a_1^{(1)}$, $a_2^{(1)}$, $a_3^{(1)}$) and B= ($b_1^{(1)}$ $b_2^{(1)}$, $b_3^{(1)}$) where i=1,2,3,…,n. We combine n customers' options and define A and B in as the average triangular fuzzy numbers of A_i and B_i respectively, where i = 1, 2, 3, n.

$$\widetilde{A} = A_{ave} = \frac{A_1 + A_2 + \ldots + A_n}{n} = \frac{(\sum_{i=1}^{n} a_1^{(i)}, \sum_{i=1}^{n} a_2^{(i)} \ldots \sum_{i=1}^{n} a_3^{(i)})}{n} = (a_1 + a_2 + a_3)$$

$$\widetilde{B} = B_{ave} = \frac{B_1 + B_2 + \ldots + B_n}{n} = \frac{(\sum_{i=1}^{n} b_1^{(i)}, \sum_{i=1}^{n} b_2^{(i)} \ldots \sum_{i=1}^{n} b_3^{(i)})}{n} = (b_1 + b_2 + b_3)$$

Step3: Creating the weak or strong attributes (shown in Table II)

If customers' satisfaction degree is greater than importance degree for an attribute, then we consider the attribute is strong or otherwise it is weak. To clarify which attribute is weak or strong objectively, it is important to differentiate whether the discrepancy between satisfaction degree and importance degree is positive or negative. Instead of average difference scores, we apply the following procedure to justify which attribute is preferable.

Let A = (a_1,a_2,a_3) be the average triangular fuzzy number of importance degree, and B = (b_1,b_2,b_3) be the one of satisfaction degree.

$V_{A=}$ = (a_1+2a_2+a_3)/4 and V_B = (b_1+2b2+b_3)/4

And V = V_B-V_A

If V < 0 indicates that the attribute is weak because passengers' satisfaction degree is less than importance degree. Therefore the attribute is under an inferior condition.

If V > 0 indicates that the attribute is strong because customer's satisfaction degree is more than importance degree. In other words, the attribute is under an advantageous condition.

If V = 0, that implies that the attribute resource is used sufficiently because customers' satisfaction degree exactly equals importance degree, how ever this case is rare.

Step 4: Defuzzification (shown in Table III)

The procedure of defuzzification is to locate the best nonfuzzy performance (BNP) value. There are several methods that serve this purpose. Mean of the maximum, Centre of area, and ∝ -cut method are the most common approaches [17]. This study utilizes the centre of area method due its simplicity and no requirements for the researchers'

personal judgment.

$$BNP = ((a_3-a_1) + (a_2-a_1))/3 + a_1$$

TABLE II

RAILQUAL	Average TFN of importance degree	Average TFN of Satisfaction Degree	BNP Value For Importance degree	BNP Value For Satisfaction degree	V=Vb-Va
RQ1	(4.33,6.27,7.30)	(2.73,4.68,6.58)	5.97	5.51	-0.46
RQ2	(4.35,6.27.7.30)	(3.69,5.66,7.18)	6.03	5.35	-0.68
RQ3	(3.17,5.05,6.57)	(3.49,5.45,7.10)	4.93	4.73	-0.20
RQ4	(4.06,6.00,7,29)	(2.82,4.77,6.61)	5.78	4.89	-0.89
RQ5	(3.76,5.68,7.05)	(2.60,4.54,6.42)	5.84	5.52	-0.32
RQ6	(4.38,6.33.7.40)	(2.98,4.77,6.61)	6.04	4.52	-1.52
RQ7		(3.31,5.29,7.04)	5.57	5.03	-0.54
RQ8	(3.85,5.77,7.09)	(3.14,5.09,6.85)	5.95	4.87	-1.08
RQ9	(4.27,6.21,7,37)	(2.94,4.89,6.78)	5.86	4.83	-1.03
RQ10	(4.17,6.10,7.31)	(2.90,4.87,6.72)	6.13	4.85	-1.28
RQ11	(4.49,6.43,7.46)	(2.94,4.89,6.78)	5.38	5.33	-0.05
RQ12	(3.62,5.54,6,98)	(2.90,4.87,6.72)	5.50	5.45	-0.05
RQ13	(3.77,5.67.,7.05	(3.60,5.59,7.17)	6.25	5.30	-0.95
RQ14	)	(3.21,5.15,6.86)	6.37	5.07	-1.30
RQ15	(4.68,6.62,7.46)	(2.78,4.76,6.61)	5.64	4.72	-0.92
RQ16	(4.75,6.74,7.63)	(3.49,5.46,7.06)	5.31	4.69	-0..62
RQ17	(3.93,5.87,7.11)	(2.61,4.57,6.38)	5.88	5.34	-0.54
RQ18	(4.22,6.15,7,26)	(2.75,4.70,6.57)	5.55	.	-1.20
RQ19	(4.00,5.97,7.20)	(2.81,4.73,6.53)	5.89	4.52	-1.06
RQ20	(4.03,5.97,7.18)	(3.07,5.04,6.89)	5.97	4.67	-0.94
RQ21	(3.59,5.49,6.86)	(3.01,4.94,6.78)	6.03	4.91	-0.98
RQ22	(4.16,6.10,7.29)	(2.63,4.57,6.50)	5.89	4.57	-1.23
	(3.82,5.75,7.08)			4.66	
	(4.18,6.14,7.34)				

The V - value is to evaluate the perceived service quality, which is the discrepancy between satisfaction degree and importance degree. As shown in Table III above, the V- value of each dimension is less than zero, which indicates that all the dimensions of RAILQUAL are in poor condition. It also means that a lot of work needs to be done by the Railway administration to achieve passenger satisfaction by improving service quality. Among all the dimensions, the "Empathy" dimension has the least V-value (-0.56) and "Reliability" dimension has the largest V-value (-1.08). This means that in Indian Railway passenger services, "Reliability" is the weakest dimension. If we can pay more attention to this Un dimension and make improvements on it, the degree of passenger satisfaction will be increased significantly.

TABLE III

DIMENTIONS	Average TFN of importance degree	Average TFN of Satisfaction Degree	BNP Value For Importance degree	BNP Value For Satisfaction degree	V=Vb-Va
TANGIBILITIES RQ1, RQ2, RQ3 RQ4)	(4.46,6.32,7.63)	(3.92,5.87,6.64)	6.14	5.48	-0.66
REALIABILITY RQ5,RQ6, RQ7, RQ8, RQ9	(4.96,6.34,7.63)	(3.64,5.29,6.77)	6.31	5.23	-1.08
RESPONSIVENESS RQ10 RQ11RQ12 RQ13	(3..27,5.24,7.15)	(3.09,4.97,5.75)	5.22	4.60	-0.62
ASSURANCE RQ14 RQ15 RQ16 RQ17	(4.55,6.24,7.33)	(3.94,4.89,6.92)	6.04	5.25	-0.79
EMPATHAY RQ18 RQ19 RQ20 RQ21 RQ22	(5.16,6.32,7.63)	(4.12,6.17,7.14)	6.37	5..81	-0.56

From Table III we can also find that the most important dimension is "Reliability" (which has the largest BNP value of 6.31) and the least important dimension is "Responsiveness" (5.22). More over, the most satisfying dimension is " Tangibles" with BNP of 5.48 and " Responsiveness" (4.60) is the worst. A more detailed analysis is presented in Table II. For each items V- value , the largest three V-values are RQ6,R14,RQ10 which are "Railways are accurate in timing of trains" (-1.52), "The Railway Services are trustworthy"(-1.30) , and "Railway staff are always willing to help"(-1.28). This indicates that the above attributes are in inferior condition.

In terms of BNP value for *importance degree* for each attribute, Table II shows that RQ14,RQ13,RQ10, which means that "The Railways are trustworthy" (6.37), "Employees are always busy to respond" (6.25) , "Railway staff are always willing to help" (6.13).

The least three values for the importance degree are RQ3, RQ16 and RQ11, which means that "Railway staff are neat in appearance" (4.93), "Railway employees are courteous" (5.31), "Railway staff will tell exactly when services will be performed" (5.38).

In terms of BNP values for *satisfaction degree* for each attribute, Table II shows that the largest three values are RQ5,RQ1 and RQ12. i.e., "Railways are accurate in record keeping" (5.52), "Railways has modern looking equipments and infrastructure at stations and trains" (5.51), "Railway employees are not always wiling to help" (5.45). The least three values are RQ6, RQ18 and RQ21. This means that "Railways are accurate in timing of trains" (4.52), "Railways give good individual attention" (4.52) and "Railways has your best interest at heart" (4.57).

IV. CONCLUSION

In this work, we developed a valid and reliable scale RAILQUAL for measuring service quality in Railway Passenger Services. The use of Fuzzy Set Theory has taken care of fuzziness of subjective human judgment and vagueness of evaluators. By using fuzzy approach, we have achieved more expressive results with linguistic data and also covered loss of data. Compared to the traditional statistical approach, Fuzzy logic offers a better means to avoid misleading results and their wrong interpretation. The

proposed fuzzy architecture with RAILQUAL can be used by Indian Railways to effectively investigate and track the trends periodically to improve service quality.

REFERENCES

[1] Gronroos, C., "A Service Quality Model and its Marketing Implications", European Journal of Marketing, No 4, pp 36-44, 1984.
[2] Raghuram and Rachna Gangwar, "Indian Railways in the Past Twenty Years Issues, Performance and Challenges", W.P. No. 2008-07-05, 2008.
[3] Asian Development Bank Report on Indian Railways, RRP: IND 36317
[4] White Paper on Indian Railways, Railway Board Publication, December 2009.
[5] Devi Prasad M and Raja Shekhar B, "Measuring Service quality of Indian Railway Passenger services using RAILQUAL model", IEEE ICMIT10, pp 292-296, 2010
[6] Hung-Tso lin.," Fuzzy application in service quality analysis" , Expert systems with applications 37(2010)517-526
[7] Sheng-Hshiung.,Tsaur,Te-Yi Chang, Chang-Hua Yen , "The evaluation of airline service quality by fuzzy MCDM", Tourism Management 23(2002) 107-115
[8] Ozlem Aydin and Fatma Pakdil., " Fuzzy Servqual Analysis in Airline Services" , Organizacia,vol 41,number3,May-June 2008
[9] George Bojadziev .,Maria Bojadziev.," Fuzzy Logic for Business,Finance,and Management, Advances in Fuzzy Systems-Vol 23 2n edition
[10] Parasuraman, A., Zeithaml, V.A. and Berr y, L.L., "Reassessment of Expectations as a Comparison Standard in Measuring Service Quality: Implications for Further Research", 1994.
[11] Parasuraman, A., Zeithaml, V.A. and Berry, L.L., "RAILQUAL: a Multiple-item Scale for Measuring Consumer Perceptions of Service Quality", Journal of Retailing, Vol . 64, Springer, pp. 12-40, 1988.
[12] Parasuraman, A., "A Conceptual Model of Service Quality and its Implications for Future Research", Journal of Marketing, Vol . 49, Fall, pp. 41-50, 1985.
[13] Dabholkar,P.A.,Thore,D.I, and Rentx, J.O. "A Measure of Service Quality for Retail Stores: Scale Development and Validation", Journal of Academy of Marketing Science, Vol . 24, Winter, pp. 3-16, 1996.
[14] Churchill, Gilbert AJr., "A Paradigm for developing Better Measures of Quality Constructs," Journal of Marketing Research, Vol . 16, February, 1979.
[15] Klier,G.J and Yuan,B., " Fuzzy Sets and Fuzzy Logic Theory and Applications", Englewood Cliffs,NJ: Prentice-hall (1995)
[16] Zimmermann,H.J.," Fuzzy set Theory and its applications, 3rd Ed., Boston: Kluwer Academic Publishers , (1996)
[17] Zhou, L.,Zhang,y., Xu,J., " A Critical Assement of SERVQUAL's Applicability in the Banking Context of China,Asis Pacific Advances in Consumer Research,Association for Consumer Reseach,GA,Vol.5 pp 14-21
[18] Chien,C.J and Tsai,H.H., " Using fuzzy numbers to evaluate perceived service quality", Fuzzy set and systems,116(2),pp.289-300

Devi Prasad Maruvada is a Research Scholar in School of Management Studies,University of Hyderabad,India . He is a Post Graduate in Management and also Post Graduate in Computer Applications. He has published papers in the area of Railway Service quality in IEEE conferences and in a few Management Journals.

Dr Raja Shekhar Bellamkonda is a Professor at School of Management Studies,University of Hyderabad . He did his PhD from Kakatiya Univesity,India.His area of specialisation is Supply chain Management,Service quality management and Total Quality management.He has published many papers in national and international journals and conferences. He has authored 3 books