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

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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 SERVQUAL 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 quality.
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 adhere to punctuality of Trains | RQ 9 |
| **RESPONSIVENESS** | 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. Employess 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. Railway 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 | RQ 20 |
| | 21. Railway has your best interest at heart | RQ 21 |
| | 22. It is easy to plan a railway journey | RQ 22 |
III. FUZZY ARITHMETIC & EVALUATION OF SERVICE QUALITY USING FUZZY LOGIC

If the universe of discourse X be the subset of real numbers R, X= {x₁, x₂, x₃, ..., xₙ}. A fuzzy set \( \tilde{A} = \{(x, \mu_A(x)) | x \in X \} \) in X is a set of ordered pairs where \( \mu_A(x) \) is called a membership function and \( \mu_A(X) : X \rightarrow [0, 1] \).

Equation 1: Let \( \tilde{A} = \{ x, \mu_A(x) | x \in X \} \) and Let \( \tilde{A} = \{ x, \mu_A(x) | x \in X \} \) and \( \mu_A(x) = \mu_A(x(x)) = \min(\mu_A(x);\mu_B(X)) \) x \in X

\( \mu_A(x) = \max(\mu_A(x);\mu_B(x)) \) x \in X

Equation 2:

The \( \alpha \)-cut set \( A_{\alpha} \) of fuzzy set \( \tilde{A} \) is defined as

\( A_{\alpha} = \{ x, \mu_A(x) | x \in X \} \), 0 \( \leq \alpha \leq 1 \), \( \alpha \in R \)

Equation 3:

The Hamming distance \( d(\mu_A(X);\mu_B(X)) = \int x | \mu_A(X) - \mu_B(X) | \ dx \) \[ 15 \]

Where \( \mu_A(X) \) and \( \mu_B(X) \) denote the membership functions of triangular fuzzy numbers \( \tilde{A} \) and \( \tilde{B} \) individually.

A triangular fuzzy number \( \tilde{A} \) is represented by triplet \((a_1, a_2, a_3)\). The membership function \( \mu_A(x) \) of \( \tilde{A} \) is defined as follows:

\[ Y_a(x) = \frac{x-a_1}{a_2-a_1}, a_1 \leq x \leq a_2 \]

\[ \mu_A(x) = Y_a(x) = \frac{x-a_3}{a_2-a_3}, a_2 \leq x \leq a_3 \]

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 \( \tilde{A} = (a_{11}, a_{21}, a_{31}), (a_{12}, a_{22}, a_{32}), ..., (a_{1n}, a_{2n}, a_{3n}) \) where \( i=1,2,3,....n \).

without loss of generality, \( \tilde{A} \) replaces \( A_{ave} \). To justify whether an attribute is weak or strong [18], we compare \( V_{\alpha} \) between two triangular fuzzy numbers as follows.

\[ \tilde{A} = A_{ave} = \frac{A_1 + A_2 + ... + A_n}{n} \]

\[ V_{\alpha} = \frac{(a_{11} + 2a_{21} + a_{31})}{4} \text{, for the triplet (a₁, a₂, a₃) of a triangular fuzzy number } \tilde{A} \]

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 i\(^{th}\) customer’s linguistic terms by equation I

Let \((A_i)_{k}\) be a triangular fuzzy number that is the i\(^{th}\) customer’s linguistic importance degree, and let \( B \) be one of i\(^{th}\) customer’s linguistic satisfaction degree where \( k \) denotes k\(^{th}\) 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 \( \tilde{A} \) by \( A_i \) and \( \tilde{B} \) by \( B_i \), which represent the i\(^{th}\) 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 unimportant”, “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 \( A_i = (a_{1i}, a_{2i}, a_{3i}) \) and \( B_i = (b_{1i}, b_{2i}, b_{3i}) \) 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 \( i = 1, 2, 3, n \).

\[ \tilde{A} = A_{ave} = \frac{A_1 + A_2 + ... + A_n}{n} = \frac{\sum a_{1i} + \sum a_{2i} + \sum a_{3i}}{n} = (a_1 + a_2 + a_3) \]

\[ \tilde{B} = B_{ave} = \frac{B_1 + B_2 + ... + B_n}{n} = \frac{\sum b_{1i} + \sum b_{2i} + \sum b_{3i}}{n} = (b_1 + b_2 + b_3) \]

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.

\[ V_{\alpha} = (a_1 + 2a_2 + a_3)/4 \text{ and } V_{\beta} = (b_1 + 2b_2 + b_3)/4 \]

And \( V = V_{\beta} - V_{\alpha} \)

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 \( \infty \)-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’
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.

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 item V-value, the three largest V-values are RQ6, RQ14, 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 willing 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


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