International Journal of Advanced Science and Technology
Vol.80 (2015), pp.1-18
http://dx.doi.org/10.14257/ijast.2015.80.01

Technology Based Self Service Banking Service Quality Evaluation: a Graph Theoretic Approach

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Abstract

The technology based self service banking (TBSSB) refers to automated banking services that customer avail in self service mode using various electronic banking channels, without any interaction with bank employees. Researchers have used numerous methods to evaluate automated banking service quality. In this paper, a methodology to quantify the overall effect of key TBSSB service quality attributes is discussed. The TBSSB service quality index is calculated by using fuzzy along with graph theory and matrix methods. Broad attributes affecting TBSSB service quality are identified. The fuzzy numbers are used to convert intangible attributes to crisp scores and then graph theoretic approach has been applied to calculate the single numerical index. This study may help bank management to take various decisions pertaining to TBSSB service quality using TBSSB index. It will also assist academicians in better understanding of TBSSB services.

Keywords: *Technology based self service banking, Fuzzy Numbers, Graph Theoretic Approach, TBSSB index*

1. Introduction

Branch banking is progressively being replaced by the technology based self service banking (TBSSB) or self service automated banking. The TBSSB services are provided by banks with the help of automated channels like ATM, internet banking, mobile banking and tele banking. Across the world, the banks are using technology for providing services in the self service mode through the various electronic channels. This trend is prevalent in India also. The services through these channels offer numerous advantages both to the banks and their customers. For the banks, the benefits are reduction in transaction expenses and lesser load on branches. For the clients, self administration provides value to customers by anytime and anywhere banking. The acceptance of automated banking among people is growing day by day. This growth leads to growing interest of organizations and academicians in measuring automated banking service quality. Most of the studies on automated banking quality cover only one of the automated banking channels. As explained by Joshua [1], customers tend to use the services of the different automated banking channels in a complimentary manner. So, considering aspects pertaining to only one channel will not be able to present the comprehensive picture of automated banking service quality. Banks need to spend huge amount of money for providing TBSSB services. So there must be an evaluation method that can help banks to quantify TBSSB service quality in single numeric value. Therefore, in the present study we find broad attributes affecting automated selfservice banking service quality. On the basis of various attributes affecting TBSSB service quality, single numerical index value (TBSSB index) for automated banking using Fuzzy numbers and Graph Theoretic Approach (GTA) is calculated. Maximum and minimum value of TBSSB index is also calculated.

ISSN: 2005-4238 IJAST

2. Literature Review

In the past, studies were conducted to evaluate automated banking service quality by using numerous methods. Most of the evaluation methods emphasized on grouping of various attributes affecting automated banking service quality into dimensions (factors) using factor analysis. Some studies also used approaches like Analytical Hierarchy Process (AHP), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Elimination and Choice Expressing Reality (ELECTRE), Fuzzy TOPSIS etc for evaluating automated banking service quality.

Joseph *et al.*, [2] investigated the impact of the technology enabled service delivery on perceived service quality in Australian banking. The researchers identified the six dimensions of e-banking service quality as: convenience/accuracy; feedback/complaint management; efficiency; queue management; accessibility and customisation using the items generated from focus groups. Broderick & Vachirapornpuk [3] identified five key elements that are regarded as central influences on perceived service quality. The elements are customer expectations of the service, the image and reputation of the service organization, aspects of the service setting, the actual service encounter, and customer participation. Al-Hawari *et al.*, [4] proposed 22-item instrument to capture key characteristics of Banks' Automated Service Quality from the customers' perspective. The instrument was designed to measure five dimensions of service quality which included ATM quality, telephone banking quality, Internet banking quality, customer perception of core service and customer perception of price. Ibrahim *et al.*, [5] explored six key factors of the electronic service quality perceptions of UK banking customers. The factors include the provision of convenient/accurate electronic banking operations; the accessibility and reliability of service provision; good queue management; service personalisation; the provision of friendly and responsive customer service; and the provision of targeted customer service. Rasolinezhad [6] ranked five electronic banking methods comprising ATM banking, Phone banking, Internet banking, Mobile banking and SMS banking in Iran using Analytic Hierarchy Process (AHP). Amiri *et al.*, [7] investigated and explained effective factors for improving e-banking by using Fuzzy TOPSIS in Persian bank. Ganguli and Roy [8] conducted a research on undergraduate students of a University in the Massachusetts state of the USA. They identified four generic service quality dimensions in the technology-based banking services – customer service, technology security and information quality, technology convenience, and technology usage easiness and reliability. Kahraman & Kaya [9] proposed an e-banking website quality assessment methodology based on an integrated fuzzy AHP-ELECTRE approach to rank the alternatives. Fuzzy AHP was used to assign weight to criterion and fuzzy ELECTRE was used to assess the quality levels of the websites. Elbadrawy et al., [10] developed a hybrid model evaluation of e-banking services. By using PROMETHEE in conjunction with AHP, they proposed a structured model for evaluating the performance of the three electronic banking services; ATMs, Telephone Banking, and Internet Banking. AHP was used to determine the relative importance of service quality multi-criteria dimensions from bank customers' point of view, and PROMETHEE method was applied for ranking the performance of different electronic banking services.

From the literature survey, it is observed that there is hardly any literature on mathematical modelling of automated banking service quality using Fuzzy numbers and Graph Theoretic Approach resulting in single numerical index.

3. Measurement using Fuzzy Numbers

As per Kahraman *et al.*, [11], the opinion from humans is usually vague and subjective. Fuzzy set theory, introduced by Zadeh [12] may be used to manage the vagueness and subjectivity of human thoughts, particularly linguistic variables since it can represent vague expressions such as "usually," "fair" and "satisfied," which are regarded as the natural representation of respondents' preference and judgment. Bellman and Zadeh [13] were the first to relate fuzzy set theory to decision-making problems, as mentioned in Rao [14].

Rao [15] illustrated the conversion of the linguistic terms into triangular fuzzy numbers and then the fuzzy numbers into crisp scores using the method proposed by Chen and Hwang [16] on various scales such as 5 point, 7 point and 11 point scale. The reason of using triangular fuzzy numbers is its computational simplicity. In the present work, an 11-point scale is used for representation of the qualitative attributes. Figure 1 show the linguistic terms to fuzzy numbers conversion. The crisp score of a fuzzy number 'M' is obtained as follows:qs

$$\mu_{\max}(x) = \begin{cases} x, & 0 \le x \le 1 \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

$$\mu_{\min}(x) = \begin{cases} 1-x, & 0 \le x \le 1 \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

The fuzzy max and fuzzy min of fuzzy numbers are defined in a manner such that absolute locations of fuzzy numbers can be automatically incorporated in the comparison cases. The left score of each fuzzy number 'Mi' is defined as

$$\mu_L(M_i) = \operatorname{Sup}_X\left[\mu_{\min}(x)^{\wedge}\mu_{M_i}(x)\right] \tag{3}$$

The left score is a unique, crisp, real number in (0, 1). It is the maximum membership value of the intersection of fuzzy number Mi and the fuzzy min. The right score may be obtained in a similar manner:

$$\mu_R(M_i) = \operatorname{Sup}_X\left[\mu_{\max}(x)^{\wedge}\mu_{Mi}(x)\right] \tag{4}$$

Again, right score is a crisp number (0, 1). Given the left and right scores, the total score of a fuzzy number Mi is defined as:

$$\mu_T(M_i) = \left[\mu_R(M_i) + 1 - \mu_L(M_i)\right]/2 \tag{5}$$

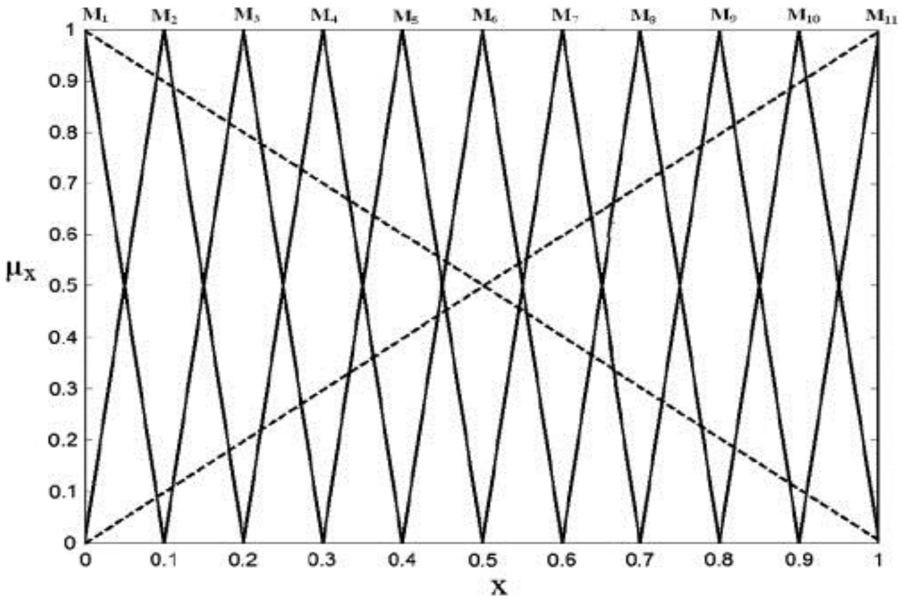

Figure 1. Linguistic Terms to Fuzzy Numbers Conversion (11-point scale) Source: Chen and Hwang [16]

By using the equations (1) to (5), the crisp score (total score) can be computed. Linguistic terms, Fuzzy Numbers and Crisp Scores for 11-point scale as calculated in Rao [15] are shown in Table 1.

Table 1. Conversion of Linguistic Terms into Crisp Scores (11-point scale)

S.No.	Linguistic term	Fuzzy number	Crisp score
1	Exceptionally low	M1(0,0,0.1)	0.0455
2	Extremely low	M2(0,0.1,0.2)	0.1364
3	Very low	M3(0.1,0.2,0..3)	0.2273
4	Low	M4(0.2,0.3,0.4)	0.3182
5	Below average	M5(0.3,0.4,0.5)	0.4091
6	Average	M6(0.4,0.5,0.6)	0.5000
7	Above average	M7(0.5,0.6,0.7)	0.5909
8	High	M8(0.6,0.7,0.8)	0.6818
9	Very high	M9(0.7,0.8,0.9)	0.7727
10	Extremely high	M10(0.8,0.9,1)	0.8636
11	Exceptionally high	M11(0.9,1,1)	0.9545

Source: Rao [15]

The relative importance among the attributes can also be described using the same 11-point scale as shown in Table 2.

Table 2. Conversion of Linguistic Terms into Fuzzy Scores (Relative Importance Value on an 11-point Scale)

Linguistic term	Fuzzy number	Crisp score
One attribute is exceptionally less important than the other	M1	0.0455
One attribute is extremely less important than the other	M2	0.1364
One attribute is very less important than the other	M3	0.2273
One attribute is less important than the other	M4	0.3182
One attribute is slightly less important than the other	M5	0.4091
Two attributes are equally important than the other	M6	0.5000
One attribute is slightly more important than the other	M7	0.5909
One attribute is more important than the other	M8	0.6818
One attribute is much more important than the other	M9	0.7727
One attribute is extremely more important than the other	M10	0.8636
One attribute is exceptionally more important than the other	M11	0.9545

Source: Rao [15]

4. Graph Theoretic Approach

As explained in Gandhi and Agrawal [17], Graph theoretic approach (GTA) is a multi-disciplinary systematic and logical approach to build and analyse systems. Graph theoretic and matrix model consists of digraph representation, matrix representation and permanent representation. GTA technique is used to calculate single numerical index for evaluation of critical attributes related to a problem. Some of the areas in which graph theory has been applied are mentioned in Table 3.

4.1. Digraph

A digraph (directed graph) is used for representing the attributes (variables) under consideration and their interdependency within the system. A system digraph represents the attributes through its nodes and interdependency of the attributes is represented by the edges between the nodes. A node V*i* represents the *i*th attribute and the edges represents the relative importance between the attributes. The number of nodes in the digraph represents the total number of attributes considered for evaluation. In the digraph method, if a node '*i*' exhibits relative importance over node '*j*' during the evaluation, then a directed edge is drawn from node '*i*' to node '*j*' (*i.e.*, V*ij*). But, If a node '*j*' exhibits relative importance over node '*i*' then a directed edge is drawn from node '*j*' to node '*i*' (*i.e.*, V*ji*). Figure 2 shows a digraph having 6 attributes (vertices) connected through edges.

Table 3. A Few Areas in which Graph Theory has been Employed

SNo	Paper Title	Author
1	'FMEA – a digraph and matrix approach'	Gandhi and Agrawal [18]
2	Selection of automobile vehicle by evaluation through graph theoretical methodology	Venkatasamy and Agrawal [19]
3	'A digraph approach to TQM evaluation of an industry'	Grover et al. [20]

4	Graph theory and matrix approach for performance evaluation of TQM in Indian industries	Kulkarni [21]
5	'Human resource performance index in TQM environment'	Grover et al. [22]
6	'A material selection model using graph theory and matrix approach'	Rao [23]
7	'Selection of power plants by evaluation and comparison using graph theoretical methodology'	Garg et al. [24]
8	Selection, identification and comparison of industrial robots using digraph and matrix methods	Rao and Padmanabhan [25]
9	'Quantification of risk mitigation environment of supply chains using graph theory and matrix methods'	Faisal et al. [26]
10	'Graph models and mathematical programming in biochemical network analysis and metabolic engineering design'	Lanzeni et al. [27]
11	Critical factors of website performance: a graph theoretic approach	Saha and Grover [28]
12	A fuzzy multi attribute decision making approach for evaluating effectiveness of advanced manufacturing technology – in Indian context	Goyal and Grover [29]

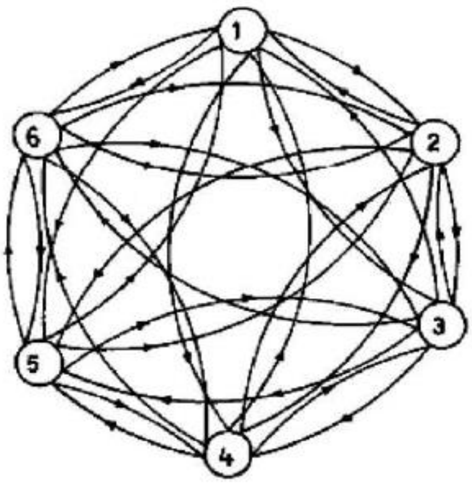

Figure 2. Digraph Representing Six Attributes (vertices) and their Interdependency (Edges)

For mathematical analysis, the digraph is represented in the matrix form. The matrix represents all the attributes and their interrelations. Matrix 1 is a 6 × 6 matrix and considers all the attributes (D*i*) and their relative importance (*i.e.*, a_{ij}) with respect to each other in the system.

Matrix 1. Matrix Representation of a Six Attributes Digraph

Attribute	1	2	3	4	5	6
1	D_1	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}
2	a_{21}	D_2	a_{23}	a_{24}	a_{25}	a_{26}
3	a_{31}	a_{32}	D_3	a_{34}	a_{35}	a_{36}
4	a_{41}	a_{42}	a_{43}	D_4	a_{45}	a_{46}
5	a_{51}	a_{52}	a_{53}	a_{54}	D_5	a_{56}
6	a_{61}	a_{62}	a_{63}	a_{64}	a_{65}	D_6

In the matrix, '*Di*' symbolizes the *i*th evaluation attribute representing the node '*Vi*'. a_{ij} represents the relative importance among the attributes and is represented by the edge drawn from '*i*' to '*j*' in the digraph. The permanent function of the attribute matrix is represented as 'Per A'. Equation (6) shows the sigma form of the permanent function for six attributes. If the attributes are more, then it can be extended further.

$$
\begin{aligned}
\text{per } A = & \prod_{i=1}^{6} D_i + \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{ji}) D_k D_l D_m D_n \\
& + \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \left(a_{ij} a_{jk} a_{ki} + a_{ik} a_{kj} a_{ji} \right) D_l D_m D_n \\
& + \left[\left(\sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \left(a_{ij} a_{ji} \right) \left(a_{kl} a_{lk} \right) D_m D_n \right. \right. \\
& \left. \left. + \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \left(a_{ij} a_{jk} a_{kl} a_{li} + a_{il} a_{lk} a_{kj} a_{ji} \right) D_m D_n \right) \right] \\
& + \left[\sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \left(a_{ij} a_{ji} \right) \left(a_{kl} a_{lm} a_{mk} + a_{km} a_{ml} a_{lk} \right) D_n \right. \\
& \left. + \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \left(a_{ij} a_{jk} a_{kl} a_{lm} a_{mi} + a_{im} a_{ml} a_{lk} a_{kj} a_{ji} \right) D_n \right] \\
& + \left[\sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \left(a_{ij} a_{ji} \right) \left(a_{kl} a_{lm} a_{mn} a_{nk} + a_{kn} a_{nm} a_{ml} a_{lk} \right) \right. \\
& + \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \left(a_{ij} a_{jk} a_{kl} \right) \left(a_{lm} a_{mn} a_{nl} \right) \\
& + \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \left(a_{ij} a_{ji} \right) \left(a_{kl} a_{lk} \right) \left(a_{mn} a_{nm} \right) \\
& \left. + \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \left(a_{ij} a_{jk} a_{lm} a_{mn} a_{ni} + a_{in} a_{nm} a_{ml} a_{lk} a_{kj} a_{ji} \right) \right]
\end{aligned} \quad (6)
$$

In equation (6), in total $(n + 1)$ *i.e.*, $(6 + 1)$ groups are made. These groups represent the measure of attributes and their relative importance. So, total seven groups are made, and their importance is discussed below.

The first group represents the measures of inheritance level of implementation factors. The second group is absent as there is no self-loop in the digraph. The third group contains interrelationships between the sub factors (*i.e.*, a_{ij} a_{ji}) and measures of four remaining factors. The fourth group represents a set of three factors relative importance loop and measure of three factors. The fifth group contains two sub groups. The terms of the first subgroup represent the relative importance among the two factors and the measure of two implementation factors. The second subgroup contains the relative importance among the four factors and the measure of the two implementation factors. The sixth group contains two sub groups. The first sub-group is a set of two factor's interdependence, *i.e.*, $a_{ij}a_{ji}$, a set of three factor interdependence, *i.e.*, $a_{kl}a_{lm}a_{mk}$ or its pair $a_{km}a_{ml}a_{lk}$ and measure of remaining implementation factor. The second sub-group is a set of five implementation factors interdependence, *i.e.*, $a_{ij}a_{jk}a_{kl}a_{lm}a_{mi}$ or its pair $a_{im}a_{ml}a_{lk}a_{kj}a_{ji}$ and measure of remaining implementation factor. Similarly, seventh group analyses sub-grouping in terms of a set of two and four behavioural factor interdependence, 2– three behavioural factor interdependence, 3 – two behavioural factor interdependence and six implementation factors interdependence.

5. Methodology with Illustration of Fuzzy Graph Theoretic Approach

Based on the study of Goyal and Grover [29], the methodology for computing TBSSB index using graph theory and fuzzy numbers can be summarised in the following steps

Step I: To identify and rank the various attributes (variables) that affect the service quality in TBSSB system.

Step II: To establish the relative importance of the attributes.

Step III: To develop a digraph of the attributes depending upon their interdependency.

Step IV: To develop a variable permanent function matrix on the basis of digraph.

Step V: To calculate the permanent function (index number) of the TBSSB system by using the values of the evaluation measures and their interdependency.

6. Illustration

The illustration of above methodology is given below

Step I: Identifying and ranking of the various attributes affecting the service quality in TBSSB system

The various attributes affecting TBSSB service quality are shown in Table 4. The attributes are identified and adapted through a comprehensive review of various studies on automated service quality comprising of Joseph *et al.*,[2], Joseph and stone [30], Ibrahaim *et al.*,[5], Doll and Torkzadeh [31], Van Riel *et al.*, [32], Yang *et al.*, [33], Ganguli and Roy [8], Al-Hawari [34], Sahadev and Purani [35], Meuter *et al.*, [36], Bauer *et al.*, [37], Ho and Lin [38], Narteh [39], Sureshchandar *et al.*, [40], Katono [41], Yen and Lu [42], Loonam and O'Loughlin [43], Coulter and Coulter [44], Bitner *et al.*, [45], Ribbink *et al.*, [46], Herington and Weaven [47], Kim and Lim [48], Chen and Hitt [49], Parasuraman *et al.*, [50], Dabholkar and Bagozzi [51], Kumbhar [52], Dilijonas *et al.*, [53] and Parasuraman [54].

A survey is conducted to find out the level of importance of TBSSB service quality attributes on 11-point scale ranging from exceptionally low to exceptionally high. The survey questionnaire constitutes many questions, but questions related only to the evaluation of attributes are used in this paper, and results have been shown.

Table 4. List of Attributes

Variable	Attribute
V1	Security that customer personal information will not be shared with third party
V2	Guiding customers to solve problem, in case it occurs
V3	Conducting error free transaction every time
V4	Security in doing financial transaction
V5	Providing precise and sufficient information as per customer need
V6	Providing consistent services
V7	24x7 service availability
V8	Giving prompt responses to customer request
V9	Ease of use
V10	Providing customer feedback services
V11	Giving directions to new users
V12	Having adequate menu options for everyday banking needs
V13	Acknowledging customer by name
V14	Having security features and customers awareness of the same
V15	Consuming less time as compared to branch banking
V16	Giving more freedom of mobility to customers
V17	Offering product according to customer preferences
V18	Having user friendly system

Data is collected using self-administered questionnaires from the customers of different banks in Delhi and NCR area in India using convenience sampling. The respondents who are above 18 years of age and use at least one mode of TBSSB services are only considered for the purpose of survey. Out of 600 distributed questionnaires, 440 are received back. Only 414 from 440 responses are usable, resulting in response rate of 69 percent. The value of Cronbach's alpha coefficient (α) is found to be 0.713, indicating the reliability of the instrument. Table 5 presents the demographic profile of the respondents.

Mean values and ranking of the attributes are shown in Table 6. On the basis of table 1, different attributes are assigned crisp score corresponding to their ranking. Attribute V4 has the highest mean value of 10.39, so highest rank 18 is assigned to V4. Therefore, highest crisp score of 0.9545 is assigned to V4, which represents exceptionally high attribute. Attribute V10 has the lowest mean value of 4.15, so lowest rank 1 is assigned to V10. Correspondingly, crisp score of 0.0455 is assigned to V10, which represents exceptionally low attribute. For other attributes in-between the highest and lowest rank, range is decided and attributes falling within a given range are assigned a particular crisp score as shown in Table 6.

Table 5. Profile of Respondents

		Percent
Gender	Male	57.00
	Female	43.00
Age	18- up to 25 yrs	21.50
	More than 25 -up to 35 yrs	38.40
	More than 35- up to 45 yrs	30.00
	More than 45 yrs	10.10
Highest Completed Education	12th or Below	2.20

	Graduate	66.40
	Post Graduate and above	31.40
Occupation	Student	12.60
	Salaried	58.90
	Self employed	22.50
	Others	6.00
Annual Income(in INR per annum)	upto 2 Lacs	21.00
	More than 2- up to 5 Lacs	39.60
	More than 5- up to 10 Lacs	30.20
	More than 10 Lacs	9.20
TBSSB usage per month	Up to 5 times	54.83
	More than 5 – up to 10 times	31.40
	More than 10 – up to 20 times	10.63
	More than 20 times	3.14

Table 6. Mean Values, Rank and Crisp Score of Various Attributes

Attribute	Mean Value	Rank	Crisp Score
V4	10.39	18	0.9545
V3	9.85	17	0.8636
V9	9.75	16	0.8636
V7	9.20	15	0.7727
V15	8.88	14	0.6818
V1	8.58	13	0.6818
V2	8.51	12	0.6818
V14	7.89	11	0.5909
V6	7.75	10	0.5909
V18	7.67	9	0.5909
V12	7.47	8	0.5000
V8	7.32	7	0.5000
V11	7.24	6	0.5000
V5	6.61	5	0.4091
V17	6.16	4	0.3182
V16	5.25	3	0.2273
V13	4.65	2	0.1364
V10	4.15	1	0.0455

Step II: Establishing the relative importance among the attributes

Relative importance of the attributes is established on the basis of their ranking Goyal and Grover [29]. To compare the two attributes, their corresponding mean values are subtracted. For example, to compare V1 with V2, their corresponding means (8.58, 8.51) are subtracted, which gives 0.07 (positive sign indicates that the first attribute is more important than the second one).

Table 7. Pair Wise Difference of Mean between Attributes

Var	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18
V1	0	0.07	-1.27	-1.81	1.97	0.83	-0.62	1.26	-1.17	4.43	1.34	1.11	3.93	0.69	-0.30	3.33	2.42	0.91
V2	-0.07	0	-1.34	-1.88	1.90	0.76	-0.69	1.19	-1.24	4.36	1.27	1.04	3.86	0.62	-0.37	3.26	2.35	0.84
V3	1.27	1.34	0	-0.54	3.24	2.10	0.65	2.53	0.10	5.70	2.61	2.38	5.20	1.96	0.97	4.60	3.69	2.18
V4	1.81	1.88	0.54	0	3.78	2.64	1.19	3.07	0.64	6.23	3.15	2.92	5.74	2.50	1.51	5.14	4.23	2.71
V5	-1.97	-1.90	-3.24	-3.78	0	-1.14	-2.59	-0.71	-3.14	2.46	-0.63	-0.86	1.96	-1.28	-2.27	1.36	0.45	-1.06
V6	-0.83	-0.76	-2.10	-2.64	1.14	0	-1.45	0.43	-2.00	3.60	0.51	0.28	3.10	-0.14	-1.13	2.50	1.59	0.08
V7	0.62	0.69	-0.65	-1.19	2.59	1.45	0	1.88	-0.55	5.05	1.96	1.73	4.55	1.31	0.32	3.95	3.04	1.53
V8	-1.26	-1.19	-2.53	-3.07	0.71	-0.43	-1.88	0	-2.43	3.17	0.08	-0.15	2.67	-0.57	-1.56	2.07	1.16	-0.35
V9	1.17	1.24	-0.10	-0.64	3.14	2.00	0.55	2.43	0	5.60	2.51	2.28	5.10	1.86	0.87	4.50	3.59	2.08
V10	-4.43	-4.36	-5.70	-6.23	-2.46	-3.60	-5.05	-3.17	-5.60	0	-3.09	-3.32	-0.50	-3.73	-4.73	-1.10	-2.01	-3.52
V11	-1.34	-1.27	-2.61	-3.15	0.63	-0.51	-1.96	-0.08	-2.51	3.09	0	-0.23	2.59	-0.65	-1.64	1.99	1.08	-0.43
V12	-1.11	-1.04	-2.38	-2.92	0.86	-0.28	-1.73	0.15	-2.28	3.32	0.23	0	2.82	-0.42	-1.41	2.22	1.31	-0.20
V13	-3.93	-3.86	-5.20	-5.74	-1.96	-3.10	-4.55	-2.67	-5.10	0.50	-2.59	-2.82	0	-3.24	-4.23	-0.60	-1.51	-3.02
V14	-0.69	-0.62	-1.96	-2.50	1.28	0.14	-1.31	0.57	-1.86	3.73	0.65	0.42	3.24	0	-0.99	2.64	1.73	0.21
V15	0.30	0.37	-0.97	-1.51	2.27	1.13	-0.32	1.56	-0.87	4.73	1.64	1.41	4.23	0.99	0	3.63	2.72	1.21
V16	-3.33	-3.26	-4.60	-5.14	-1.36	-2.50	-3.95	-2.07	-4.50	1.10	-1.99	-2.22	0.60	-2.64	-3.63	0	-0.91	-2.42
V17	-2.42	-2.35	-3.69	-4.23	-0.45	-1.59	-3.04	-1.16	-3.59	2.01	-1.08	-1.31	1.51	-1.73	-2.72	0.91	0	-1.51
V18	-0.91	-0.84	-2.18	-2.71	1.06	-0.08	-1.53	0.35	-2.08	3.52	0.43	0.20	3.02	-0.21	-1.21	2.42	1.51	0

Similarly, the difference of means is calculated for each pair as shown in Table 7. Difference of means gives the idea about, how much one attribute is important than the other. To assign the crisp score for each comparison, the mean differences are divided into 11 ranges on the 11-point scale and using the Table 2 crisp score is assigned to values falling in a particular range as shown in Table 8

Table 8. Mean Ranges on 11-point Scale (on the basis of Table 2)

Linguistic terms	Fuzzy Numbers	Mean Range	Crisp Score
One attribute is exceptionally less important than the other	M1	-5.83 to -7	0.0455
One attribute is extremely less important less than the other	M2	-4.67 to -5.83	0.1364
One attribute is very less important than the other	M3	-3.50 to -4.67	0.2273
One attribute is less important than the other	M4	-2.34 to -3.50	0.3182
One attribute is slightly less important than the other	M5	-1.17 to -2.34	0.4091
Two attribute are equally important than the other	M6	-1.17 to 1.17	0.5000
One attribute is slightly more important than the other	M7	1.17 to 2.34	0.5909
One attribute is more important than the other	M8	2.34 to 3.50	0.6818
One attribute is much more important than the other	M9	3.50 to 4.67	0.7727
One attribute is extremely more important than the other	M10	4.67 to 5.83	0.8636
One attribute is exceptionally more important than the other	M11	5.83 to 7	0.9545

Each Pair wise difference of mean between attributes of Table 7 is converted into crisp score using Table 8 and is shown in Table 9. For example, the difference of means between V1 and V2 in table 7 is 0.07, which is assigned crisp score 0.5000 as per Table 8. Similarly crisp values are assigned to other mean differences as per Table 8.

Table 9. Relative Importance among Attributes in Terms of Crisp Score

Var	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18
V1	0	0.5000	0.4091	0.4091	0.5909	0.5000	0.5000	0.5909	0.4091	0.7727	0.5909	0.5000	0.7727	0.5000	0.5000	0.6818	0.6818	0.5000
V2	0.5000	0	0.4091	0.4091	0.5909	0.5000	0.5000	0.5909	0.4091	0.7727	0.5909	0.5000	0.7727	0.5000	0.5000	0.6818	0.6818	0.5000
V3	0.5909	0.5909	0	0.5000	0.6818	0.5909	0.5000	0.6818	0.5000	0.8636	0.6818	0.6818	0.8636	0.5909	0.5000	0.7727	0.7727	0.5909
V4	0.5909	0.5909	0.5000	0	0.7727	0.6818	0.5909	0.6818	0.5000	0.9545	0.6818	0.6818	0.8636	0.6818	0.5909	0.8636	0.7727	0.6818
V5	0.4091	0.4091	0.3182	0.2273	0	0.5000	0.3182	0.5000	0.3182	0.6818	0.5000	0.5000	0.5909	0.4091	0.4091	0.5909	0.5000	0.5000
V6	0.5000	0.5000	0.4091	0.3182	0.5000	0	0.4091	0.5000	0.4091	0.7727	0.5000	0.5000	0.6818	0.5000	0.5000	0.6818	0.5909	0.5000
V7	0.5000	0.5000	0.5000	0.4091	0.6818	0.5909	0	0.5909	0.5000	0.8636	0.5909	0.5909	0.7727	0.5909	0.5000	0.7727	0.6818	0.5909
V8	0.4091	0.4091	0.3182	0.3182	0.5000	0.5000	0.4091	0	0.3182	0.6818	0.5000	0.5000	0.6818	0.5000	0.4091	0.5909	0.5909	0.5000
V9	0.5909	0.5909	0.5000	0.5000	0.6818	0.5909	0.5000	0.6818	0	0.8636	0.6818	0.5909	0.8636	0.5909	0.5000	0.7727	0.7727	0.5909
V10	0.2273	0.2273	0.1364	0.0455	0.3182	0.2273	0.1364	0.3182	0.1364	0	0.3182	0.3182	0.5000	0.2273	0.1364	0.5000	0.4091	0.2273
V11	0.4091	0.4091	0.3182	0.3182	0.5000	0.5000	0.4091	0.5000	0.3182	0.6818	0	0.5000	0.6818	0.5000	0.4091	0.5909	0.5000	0.5000
V12	0.5000	0.5000	0.3182	0.3182	0.5000	0.5000	0.4091	0.5000	0.4091	0.6818	0.5000	0	0.6818	0.5000	0.4091	0.5909	0.5909	0.5000
V13	0.2273	0.2273	0.1364	0.1364	0.4091	0.3182	0.2273	0.3182	0.1364	0.5000	0.3182	0.3182	0	0.3182	0.2273	0.5000	0.4091	0.3182
V14	0.5000	0.5000	0.4091	0.3182	0.5909	0.5000	0.4091	0.5000	0.4091	0.7727	0.5000	0.5000	0.6818	0	0.5000	0.6818	0.5909	0.5000
V15	0.5000	0.5000	0.5000	0.4091	0.5909	0.5000	0.5000	0.5909	0.5000	0.8636	0.5909	0.5909	0.7727	0.5000	0	0.7727	0.6818	0.5909
V16	0.3182	0.3182	0.2273	0.1364	0.4091	0.3182	0.2273	0.4091	0.2273	0.5000	0.4091	0.4091	0.5000	0.3182	0.2273	0	0.5000	0.3182
V17	0.3182	0.3182	0.2273	0.2273	0.5000	0.4091	0.3182	0.5000	0.2273	0.5909	0.5000	0.4091	0.5909	0.4091	0.3182	0.5000	0	0.4091
V18	0.5000	0.5000	0.4091	0.3182	0.5000	0.5000	0.4091	0.5000	0.4091	0.7727	0.5000	0.5000	0.6818	0.5000	0.4091	0.6818	0.5909	0

Step III: Developing a digraph of the attributes depending upon their interdependency

The Digraph for evaluation of attributes is presented in Figure 3. A TBSSB service quality digraph represents 18 attributes in the form of 18 nodes from V1 to V18. The edges between the nodes represent the interdependency of the attributes.

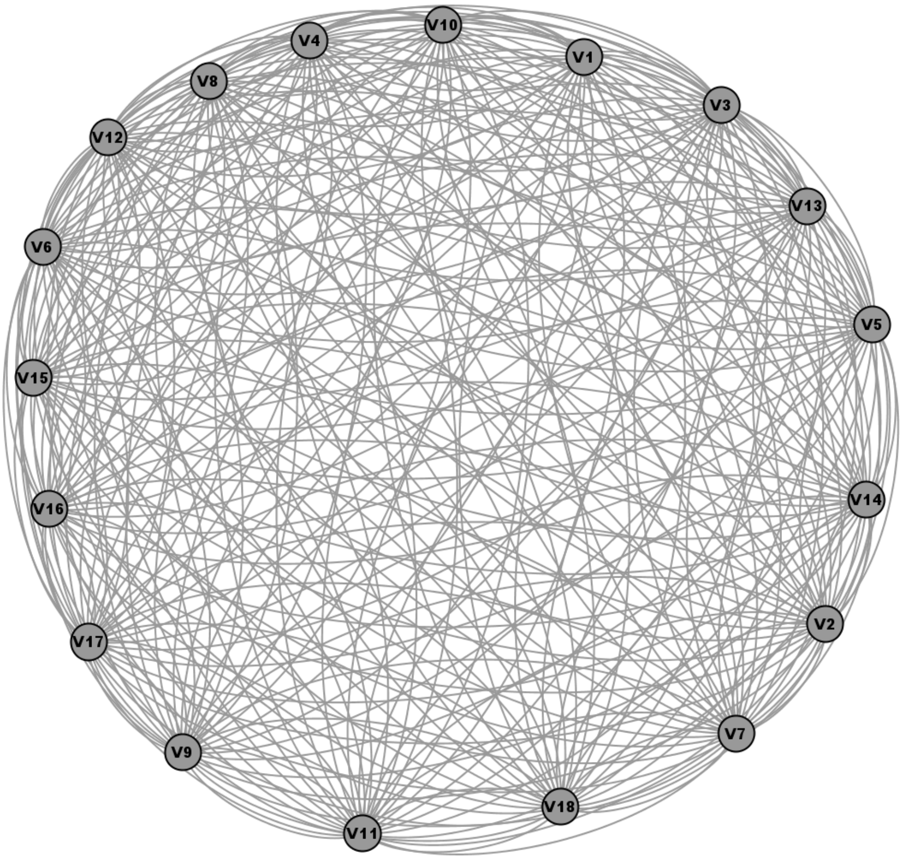

Figure 3. Digraph for Attributes Evaluation of TBSSB System

Step IV: Developing an attribute permanent function matrix on the basis of digraph.

An 18X18 matrix with diagonal elements representing the attributes and non-diagonal elements representing the relative importance among the attributes is prepared for calculating the permanent of a matrix. In the matrix, the off diagonal elements represent the relative importance values as shown in Table 9. The crisp scores of attributes (Table 6) are used as diagonal element values for the purpose of calculation of permanent function of the matrix. The resultant matrix is shown in matrix 2.

Matrix 2. Matrix for Computing Permanent Function of TBSSB

Var	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18
V1	0.6818	0.5000	0.4091	0.4091	0.5909	0.5000	0.5000	0.5909	0.4091	0.7727	0.5909	0.5000	0.7727	0.5000	0.5000	0.6818	0.6818	0.5000
V2	0.5000	0.6818	0.4091	0.4091	0.5909	0.5000	0.5000	0.5909	0.4091	0.7727	0.5909	0.5000	0.7727	0.5000	0.5000	0.6818	0.6818	0.5000
V3	0.5909	0.5909	0.8636	0.5000	0.6818	0.5909	0.5000	0.6818	0.5000	0.8636	0.6818	0.6818	0.8636	0.5909	0.5000	0.7727	0.7727	0.5909
V4	0.5909	0.5909	0.5000	0.9545	0.7727	0.6818	0.5909	0.6818	0.5000	0.9545	0.6818	0.6818	0.8636	0.6818	0.5909	0.8636	0.7727	0.6818
V5	0.4091	0.4091	0.3182	0.2273	0.4091	0.5000	0.3182	0.5000	0.3182	0.6818	0.5000	0.5000	0.5909	0.4091	0.4091	0.5909	0.5000	0.5000
V6	0.5000	0.5000	0.4091	0.3182	0.5000	0.5909	0.4091	0.5000	0.4091	0.7727	0.5000	0.5000	0.6818	0.5000	0.5000	0.6818	0.5909	0.5000
V7	0.5000	0.5000	0.5000	0.4091	0.6818	0.5909	0.7727	0.5909	0.5000	0.8636	0.5909	0.5909	0.7727	0.5909	0.5000	0.7727	0.6818	0.5909
V8	0.4091	0.4091	0.3182	0.3182	0.5000	0.5000	0.4091	0.5000	0.3182	0.6818	0.5000	0.5000	0.6818	0.5000	0.4091	0.5909	0.5909	0.5000
V9	0.5909	0.5909	0.5000	0.5000	0.6818	0.5909	0.5000	0.6818	0.8636	0.8636	0.6818	0.5909	0.8636	0.5909	0.5000	0.7727	0.7727	0.5909

V10	**0.2273**	**0.2273**	**0.1364**	**0.0455**	**0.3182**	**0.2273**	**0.1364**	**0.3182**	**0.1364**	**0.0455**	**0.3182**	**0.3182**	**0.5000**	**0.2273**	**0.1364**	**0.5000**	**0.4091**	**0.2273**
V11	**0.4091**	**0.4091**	**0.3182**	**0.3182**	**0.5000**	**0.5000**	**0.4091**	**0.5000**	**0.3182**	**0.6818**	**0.5000**	**0.5000**	**0.6818**	**0.5000**	**0.4091**	**0.5909**	**0.5000**	**0.5000**
V12	**0.5000**	**0.5000**	**0.3182**	**0.3182**	**0.5000**	**0.5000**	**0.4091**	**0.5000**	**0.4091**	**0.6818**	**0.5000**	**0.5000**	**0.6818**	**0.5000**	**0.4091**	**0.5909**	**0.5909**	**0.5000**
V13	**0.2273**	**0.2273**	**0.1364**	**0.1364**	**0.4091**	**0.3182**	**0.2273**	**0.3182**	**0.1364**	**0.5000**	**0.3182**	**0.3182**	**0.1364**	**0.3182**	**0.2273**	**0.5000**	**0.4091**	**0.3182**
V14	**0.5000**	**0.5000**	**0.4091**	**0.3182**	**0.5909**	**0.5000**	**0.4091**	**0.5000**	**0.4091**	**0.7727**	**0.5000**	**0.5000**	**0.6818**	**0.5909**	**0.5000**	**0.6818**	**0.5909**	**0.5000**
V15	**0.5000**	**0.5000**	**0.5000**	**0.4091**	**0.5909**	**0.5000**	**0.5000**	**0.5909**	**0.5000**	**0.8636**	**0.5909**	**0.5909**	**0.7727**	**0.5000**	**0.6818**	**0.7727**	**0.6818**	**0.5909**
V16	**0.3182**	**0.3182**	**0.2273**	**0.1364**	**0.4091**	**0.3182**	**0.2273**	**0.4091**	**0.2273**	**0.5000**	**0.4091**	**0.4091**	**0.5000**	**0.3182**	**0.2273**	**0.2273**	**0.5000**	**0.3182**
V17	**0.3182**	**0.3182**	**0.2273**	**0.2273**	**0.5000**	**0.4091**	**0.3182**	**0.5000**	**0.2273**	**0.5909**	**0.5000**	**0.4091**	**0.5909**	**0.4091**	**0.3182**	**0.5000**	**0.3182**	**0.4091**
V18	**0.5000**	**0.5000**	**0.4091**	**0.3182**	**0.5000**	**0.5000**	**0.4091**	**0.5000**	**0.4091**	**0.7727**	**0.5000**	**0.5000**	**0.6818**	**0.5000**	**0.4091**	**0.6818**	**0.5909**	**0.5909**

Step V: Calculation of permanent function

The TBSSB service quality permanent function is represented as:
TBSSB service quality permanent function = Per (*TBSSB*)
The expanded form of the above equation in terms of various groups and sub-groups can be made in the same manner as that of equation 6.
Per (TBSSB) or TBSSB index is calculated by considering the data from Matrix 2. Permanent function value is calculated with the help of computer program (wxMaxima version 13.04.2). The calculated value is

Per (TBSSB) =10181961183 (*i.e.*, 1.0181961183 X 10^{10})

TBSSB index is maximum when the performance effect of all the attributes is maximum. For obtaining Per ($TBSSB_{Max}$), the diagonal elements of the Matrix 2 are replaced by 0.9545 (highest crisp value) and off diagonal elements are kept same. The calculated value of maximum permanent function of TBSSB matrix is

Per ($TBSSB_{Max}$) = 24579293935 (*i.e.*, 2.4579293935 X 10^{10})

Similarly, Minimum TBSSB index is calculated by replacing diagonal elements of Matrix 2 with 0.0455 (lowest crisp value). The calculated value of minimum permanent function of TBSSB matrix is

Per ($TBSSB_{Min}$) = 3565249961 (*i.e.*, 3.565249961 X 10^9)

The maximum and minimum value of TBSSB index indicates the range with in which it may vary. Banks may conduct a survey and find TBSSB index for their organisation.

7. Conclusions and Implications

In this paper, attempt is made to quantify the overall effect of TBSSB service quality. In total 18 attributes affecting TBSSB service quality are considered for the purpose of evaluation. Fuzzy numbers and Graph Theoretic Approach (GTA) is used to compute single numerical index for the TBSSB service quality system using a five step sequential process. Firstly, various attributes affecting service quality of TBSSB system are identified and ranked by conducting a survey. Reliability of the questionnaire is tested using Cronbach's alpha test. After that the relative importance among the attributes is established. The survey data is converted into crisp score by using 11-point scale. Then a digraph is made on the basis of the interdependency between the attributes. Using the digraph, an attribute permanent function matrix is developed. Finally, using the values of the evaluation measures and their interdependency, index number for the TBSSB system is calculated. Calculations are also made for maximum and minimum value of TBSSB index.

The banking sector which keeps on experimenting with new technologies can adopt this methodology to evaluate their technology. Banks may conduct the survey and find TBSSB quality index for their respective organisations. Banks may assess themselves by comparing their automated service quality index with maximum and minimum computed value of TBSSB. At a particular period of time, similar banks may be compared and rated by computing TBSSB indices. Index value can be computed for different modes of automated banking and values may be used for the purpose of inter banking mode comparison. Index may also be calculated for branch banking service quality. By calculating this index, banks will be in a position to compare their automated banking quality with that of branch banking. By doing this, they may justify their investments in technology based services. In short, this will helps bank managers to make decisions related to various aspects of automated banking including future investments which ultimately will result in better quality, higher customer satisfaction, loyalty and profitability. The methodology used in this paper can be extended to any number of attributes. This study may act as a reference towards future research work. The same GTA approach using fuzzy numbers for computing index value may be replicated for other services like telecommunications, online retailing and insurance.

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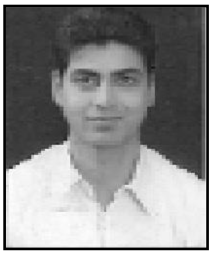

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