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E-SERVICE QUALITY OF INTERNET BASED BANKING USING COMBINED FUZZY AHP AND FUZZY TOPSIS

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Original scientific paper
Many researchers have used service quality scales for measuring service quality of banking sector including e-banking. Technology and technological tools are rapidly changed and every household has computers, pads and smartphones. They also get used to make banking operations with computers, pads or smartphones. In this study, we employed a fuzzy based prioritization using AHP and TOPSIS methods to the e-banking service quality indicators. The survey was carried out with the banking specialists and managers in both public and private banks inTurkey. The results provide helpful information for both web designers and internet users for developing and using the e-banking.

Keywords: *fuzzy AHP; fuzzy TOPSIS; internet based banking; service quality*

Kvaliteta e-usluge bankarstva temeljenog na Internetu kombiniranjem fuzzy AHP i fuzzy TOPSIS

Izvorni znanstveni rad
Mnogi su istraživači koristili mjerila za određivanje kvalitete usluga u bankarstvu uključujući e-bankarstvo. Tehnologija i tehnološki alati se brzo mijenjaju i svako kućanstvo ima računala, podloge i pametne telefone. Ljudi se navikavaju na obavljanje bankarskih poslova računalom ili pametnim telefonom. U ovom smo radu istraživali fuzzy AHP i TOPSIS metode u određivanju pokazatelja kvalitete u uslugama e-bankarstva. Istraživanje se provelo sa stručnjacima i menadžerima u bankarstvu u državnim i privatnim bankama u Turskoj. Rezultati su korisni i za web-dizajnere i korisnike interneta u razvoju i primjeni e-bankarstva.

Ključne riječi: *bankarstvo temeljeno na Internetu; fuzzy AHP; fuzzy TOPSIS; kvaliteta usluge*

1 Introduction

Services are located in all areas of our lives. For instance, we use communication and transportation service almost every day. Also we go to the bank for financial operation or go to the supermarket to meet daily needs and so on. All of these services and others are widely used depending on developments in information technology; the importance of services in our lives is increasing every day. On the other hand, in the service industry, the performance indicators are very important such as productivity, quality, efficiency, customer satisfaction. However, measurement of performance in service businesses because of the characteristics of services is not very easy.

For competitive survival, companies are focusing on areas in their operations that might give them an edge over their competitors. A key area has been the delivery of high levels of service quality [12]. During the past few decades service quality has become a major area of attention to practitioners, managers and researchers owing to its strong impact on business performance, lower costs, customer satisfaction, customer loyalty and profitability [6, 8, 13÷17]. Many researchers have defined the service quality and they identified the construct of it. In the literature the subject on how consumers perceive the service a company provides has been studied extensively, as evidenced by the research literature [11]. From an academic perspective McKenzie [11] cited in the literature from Cronin et al. (1994) and Zeithaml (2000) that has explored the theoretical framework and conceptualization of the construct, and from a practitioner standpoint, the linkages between providing high quality service and attaining superior firm performance. In this study, the service quality models are listed and explained. In the following sections, the employed methodology as the Fuzzy AHP and TOPSIS and the hierarchical model are explained with the numerical example and then the results are discussed in the final section.

2 Service quality models

Measuring service quality has so many difficulties for service providers. The reason for these difficulties is the unique characteristics of service such as inseparability, intangibility, perishability and heterogeneity. Many of researchers have developed the scales for measuring the quality of retail service. Seth et al. [14] discuss these scales in their study. These scales are listed in Tab. 1.

3 Methodology used

Many of the researchers measure the service quality by using these scales; especially SERVQUAL has been used in a number of studies [1, 9, 10, 18]. In this paper, a systematic and practical methodology is developed and presented for the assessment of internet banking among many alternatives based on fuzzy models using linguistic variables.

The sample study of the methodology has been carried out with internet bank specialists. First of all a literature review is done on the criteria for the evaluation of internet banking. Hierarchical E-Servqual model has been used for evaluation.

Moreover, the list of banks is gathered and a question form is prepared asking the pair wise comparison and evaluation of each criterion for each bank based on fuzzy AHP and fuzzy TOPSIS, respectively.

The first phase of the methodology consists of weighting the hierarchical criteria set via fuzzy-AHP method so that the weights are calculated in a pair wise comparison manner which is the advantage of AHP method. In the second phase, the alternative banks are evaluated by considering each criterion in the bottom level of the criteria set. The evaluation process is carried out according to TOPSIS methodology which depends on linguistic variables and fuzzy logic.

TOPSIS methodology concerns the distances of each alternative evaluation from negative ideal solution and positive ideal solution. Thus, the results of the solution show the closeness of each alternative that represents the importance among others. There exist two reasons to use TOPSIS model in the evaluation phase instead of any AHP method; when there are so many alternatives to be compared, then AHP method may generate inconsistency problem which is approved by so many studies in literature. The second reason is the complexity of comparison process; because alternatives should be evaluated more often than criteria set, the higher the number of alternatives, the higher the complexity. Instead of that, it would be more practical to use TOPSIS which includes linguistic evaluations based on fuzzy logic.

Table 1 Service Quality Models [14]

Author	Scale Name	Description
Grönross, 1984	Technical and functional quality model	The quality of service is measured by three components: Technical quality, functional quality and image.
Parasuraman et. al., 1985	GAP model	They identified five gaps and developed the scales based on these gaps. According to this model the service quality depends on differences between perceptions and expectations.
Haywood-Farmer, 1988	Attribute service quality model	According to this model, quality of service is very high when it meets customer preferences and expectations.
Brogowicz et. al., 1990	Synthesized model of service quality	The purpose of this model is to identify the dimensions associated with service quality in a traditional managerial framework of planning, implementation and control.
Cronin and Taylor, 1992	Performance only model	The authors investigated the conceptualization and measurement of service quality and its relationship with consumer satisfaction and purchase intentions.
Mattson, 1992	Ideal value model of service quality	This model identified that the expectation is treated as belief about having desired attributes as the standard for evaluation.
Teas, 1993	Evaluated performance and normed quality model	The author proposed two frameworks for service quality. One of them is evaluated performance and other is normed quality model.
Berkley and Gupta, 1994	IT alignment model	This model links the service and the information strategies of the organization. According to the model, relationship between service quality and information system is very important so that strategies for both must be tightly coordinated and aligned.
Dabholkar, 1996	Attribute and overall affect model	Both attribute model and overall affect model expected service quality would influence intentions to use technology-based self-service option.
Spreng and Mackoy, 1996	Model of perceived service quality and satisfaction	The model highlights the effect of expectations, perceived performance desires, desired congruency and expectation disconfirmation on overall service quality and customer satisfaction.
Philip and Hazlett, 1997	PCP attribute model	According to the model, every service consist of PCP (pivotal, core, peripheral) attributes where the vast majority of dimensions and concepts which have thus far been used to define service quality.
Sweney et. al., 1997	Retail service quality and perceived value model	Model 1 highlights that in addition to product quality and price perceptions, functional service quality and technical service quality perceptions both directly influence value perceptions. Model 2 highlights that in addition functional service quality perceptions directly influence consumers' willingness to buy.
Oh, 1999	Service quality, customer value and customer satisfaction model	The model provides evidence that customer value has a significant role in customer's post-purchase decision-making process. It is an immediate antecedent to customer satisfaction and repurchases intentions.
Dabholkar et. al., 2000	Antecedents and mediator model	A comprehensive model of service quality includes an examination of its antecedents, consequences, and mediators to provide a deeper understanding of conceptual issues related to service quality.
Frost and Kumar, 2000	Internal service quality model	The authors have developed an internal service quality model based on the concept of GAP model (Parasuraman et al., 1985). The model evaluated the dimensions, and their relationships, that determine service quality among internal customers and internal suppliers within a large service organization.
Soteriou and Stavrinides, 2000	Internal service quality DEA model	The authors presented a service quality model that can be used to provide directions to a bank branch for optimal utilization of its resources. The model does not aim to develop the service quality measures, it rather guides how such measures can be incorporated for service quality improvements.
Broderick and Vachirapornpuk, 2002	Internet banking model	This study proposes and tests a service quality model of internet banking.
Zhu et. al., 2002	IT-based model	This model highlights the importance of information technology (IT)-based service options. The model attempts to investigate the relationship between IT-based services and customers' perceptions of service quality.
Santos, 2003	Model of service quality	This study proposes a conceptual model of e-service quality with its determinants.

The mathematical formulations for phase 1 and phase 2 are:

Phase 1: Criteria Importance Weighting: Fuzzy-AHP Methodology

To apply the process depending on the hierarchy, according to the method of Chang's (1992) extent analysis, each criterion is taken and extent analysis for each criterion, g_i; is performed. Therefore, *m extent* analysis values for each criterion can be obtained by using the following notation [7]:

$$M_{g_i}^1, M_{g_i}^2, M_{g_i}^3, M_{g_i}^4, M_{g_i}^5, ..., M_{g_i}^m,$$

where g_i is the goal set (i = 1, 2, 3, 4, 5,..., n) and all the $M_{g_i}^{j}$ (j = 1, 2, 3, 4, 5,..., m) are Triangular Fuzzy Numbers (*TFNs*). The steps of Chang's analysis can be given as in the following:

Step 1: The fuzzy synthetic extent value (S_i) with respect to the i^{th} criterion is defined as the following Eq. (1).

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1}. \tag{1}$$

To obtain Eq. (2):

$$\sum_{j=i}^{m} M_{g_i}^{j} \tag{2}$$

perform the "fuzzy addition operation" of m extent analysis values for a particular matrix given in Eq. (3) below, at the end step of calculation, new (l, m, u) set is obtained and used for the next:

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right), \tag{3}$$

where l is the lower limit value, m is the most promising value and u is the upper limit value.

To obtain the following Eq. (4):

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1}, \tag{4}$$

perform the "fuzzy addition operation" of $M_{g_i}^{j}$ (j = 1, 2, 3, 4, 5, ..., m) values given as Eq. (5):

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \tag{5}$$

and then compute the inverse of the vector in the Eq. (6) such that

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right). \tag{6}$$

Step 2: The degree of possibility of

$M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ *is* defined as Eq. (7)

$$V(M_2 \geq M_1) = \sup_{y \geq x} [\min(\mu_{M_1}(x), \mu_{M_2}(y))] \tag{7}$$

and x and y are the values on the axis of membership function of each criterion. This expression can be equivalently written as given in Eq. (8) below:

$$V(M_2 \geq M_1) = \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{otherwise,} \end{cases} \tag{8}$$

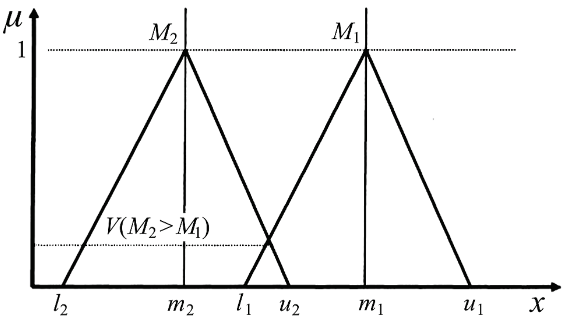

Figure 1 The intersection between M_1 and M_2 [19]

where d is the highest intersection point μ_{M_1} and μ_{M_2} (see Fig. 1) [19].

To compare M_1 and M_2 we need both the values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$:

Step 3. The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i (i = 1, 2, 3, 4, 5, ..., k) can be defined by Eq. (9):

$V(M \geq M_1, M_2, M_3, M_4, M_5, M_6, ..., M_k) = V[(M \geq M_1)$ and $(M \geq M_2)$ and $(M \geq M_3)$ and $(M \geq M_4)$ and ... and $(M \geq M_k)] = \min V(M \geq M_i)$, i = 1, 2, 3, 4, 5, ..., k. (9)

Assume the expression in Eq. (10) is:

$$d'(A_i) = \min V(S_i \geq S_k) \tag{10}$$

For k = 1, 2, 3, 4, 5, ..., n; $k \neq i$. Then the weight vector is given by Eq. (11):

$$W' = (d'(A_1), d'(A_2), d'(A_3), d'(A_4), d'(A_5), ..., d'(A_n))^T \tag{11}$$

where A_i (i = 1, 2, 3, 4, 5, 6, …, n) are n elements.

Step 4. Via normalization, the normalized weight vectors are given in Eq. (12) below:

$$W = (d(A_1), d(A_2), d(A_3), d(A_4), d(A_5), ..., d(A_n))^T, \tag{12}$$

where W is non-fuzzy numbers.

To evaluate the questions, people only select the related linguistic variable, then for calculations they are converted to the following scale including triangular fuzzy numbers developed by [4] and generalized for such analysis as given in Tab. 2.

Table 2 TFN Values [20]

Statement	TFN
Absolute	(7/2, 4, 9/2)
Very strong	(5/2, 3, 7/2)
Fairly strong	(3/2, 2, 5/2)
Weak	(2/3, 1, 3/2)
Equal	(1, 1, 1)

By using these linguistic statements and given in Tab. 2, criteria set are evaluated with the equations given in phase 1 (Eqs. (1)÷(12)) weight of each criterion is obtained and so that the weights can be used in TOPSIS methodology, they are converted to trapezoidal fuzzy number such as (a,a,a,a).

Phase 2: TOPSIS and Linguistic Variables for Ratings

By considering this main concept of TOPSIS model is implemented according to the following steps:

1) Normalize the evaluation matrix: x_{ij} is the evaluation matrix ***R*** of alternative *i* under the evaluation criterion *j*. After normalization, the elements of matrix *R* are converted into r_{ij}. Normalization is carried out by one of the methods which convert them into the numerical value, i.e. between 0÷1, according to the characteristics of the problem [2].

2) Construct the weighted normalization matrix according to the values determined for each criterion. These weights (w_{ij}) can be obtained by any method such as eigenvector, AHP, fuzzy numbers, linear programming models, etc., then these weight vector is multiplied by normalized matrix *R* to obtain the weighted normalized matrix v_{ij}.

3) Determine the negative and positive ideal solutions.

4) Calculate the separation measure. This measure is selected among the measures for calculating the distances. This can be an Euclidean distance [3] or vertex distance [2].

5) Calculate the negative closeness to the ideal solution. The relative closeness of the i^{th} alternative with respect to the ideal solution is calculated by negative distance over total distance.

6) Rank the priority: a set of alternatives is sorted according to descending order of relative closeness.

Fuzzy triangular and trapezoidal numbers are used to evaluate each bank alternative. The linguistic variable for evaluation lies between "very poor" and "very good", the membership function set is given in Fig. 2, and as an example, the linguistic variable "Very Good (VG) " can be represented as (8, 9, 9, 10), the membership function of which is given in Eq. (13):

$$\mu_{\text{Very Good}}(x) = \begin{cases} 0, & x < 8 \\ \dfrac{x-8}{9-8}, & 8 \le x \le 9 \\ 1, & 9 \le x \le 10 \end{cases} . \tag{13}$$

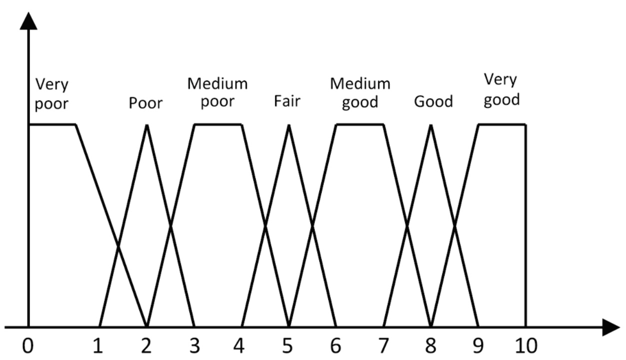

Figure 2 Linguistic variables for ratings [2]

In fact, evaluation of internet banking is a multiple-criteria decision-making problem, which may be described by means of the following sets [2]:

(1) a set of *K* users called $E = \{D_1; D_2; ...; D_K\}$

(2) a set of *m* possible bank alternatives called $A = \{A_1; A_2; ...; A_m\}$

(3) a set of *n* criteria, $C = \{C_1; C_2; ...; C_n\}$ with which internet banking performances are measured;

(4) a set of performance ratings of A_i ($i = 1; 2; ...; m$) with respect to criteria C_j ($j = 1; 2; ...; n$), called $X = \{x_{ij}; i = 1; 2; ...; m; j = 1; 2; ...; n\}$

Assume that a decision group has *K* decision makers, and the fuzzy rating of each decision-maker D_k ($k = 1; 2; ..., K$) can be represented as a positive trapezoidal fuzzy number $\widetilde{R}_k$ ($k = 1; 2; ...; K$) with membership function $\mu_{\widetilde{R}_k}(x)$. A good aggregation method should consider the range of fuzzy rating of each decision-maker. It means that the range of aggregated fuzzy rating must include the ranges of all decision-makers' fuzzy ratings. Let the fuzzy ratings of all decision makers be trapezoidal fuzzy numbers $\widetilde{R}_k = (a_k; b_k; c_k; d_k)$, $k = 1; 2; ...; K$. Then the aggregated fuzzy rating can be defined as $\widetilde{R} = (a; b; c; d)$, $k = 1; 2; ...; K$. Eqs. (14) to (17) shows the detailed computations:

where

$$a = \min_k \{a_k\} \quad (14), \qquad b = \frac{1}{K}\sum_{k=1}^{K} b_k \quad (15),$$

$$c = \frac{1}{K}\sum_{k=1}^{K} c_k \quad (16), \qquad d = \max_k \{d_k\} \quad (17).$$

After the ratings are aggregated into one matrix normalized weighted matrix is constructed by calculating Eq. (18):

$$V_{ij} = w_{ij} \times r_{ij}. \tag{18}$$

As mentioned before, weight of each criterion is calculated using Fuzzy-AHP method which produces crisp weights through fuzzy numbers. Thus, in order to aggregate weights with ratings, weights are assumed as trapezoidal fuzzy numbers which have equal values ($a = b = c = d$). Then rating matrix is multiplied by weight matrix and finally weighted normalized matrix is obtained.

According to the weighted normalized fuzzy-decision matrix, normalized positive trapezoidal fuzzy numbers can also approximate the elements $\widetilde{v}_{ij}, \forall i, j$. Then, the fuzzy positive-ideal solution (FPIS, A^*) and fuzzy negative-ideal solution (FNIS, A^-) can be defined as $A^* = (\widetilde{v}_1^*, \widetilde{v}_2^*, ..., \widetilde{v}_n^*)$, $A^- = (\widetilde{v}_1^-, \widetilde{v}_2^-, ..., \widetilde{v}_n^-)$, where the values can be calculated by Eqs. (19) and (20):

$$\widetilde{v}_j^* = \max_i \{v_{ij4}\} \tag{19}$$

and

$$\widetilde{v}_j^- = \min_i \{v_{ij1}\}, \tag{20}$$

$i = 1; 2; ... ; m$, $j = 1; 2; ... ; n$.

The distance of each alternative (internet banking) from A^* and A^- can be currently calculated with Eqs. (21)÷(22):

$$d_i^* = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^*), \quad i = 1, 2, ..., m \quad (21)$$

$$d_i^- = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^-), \quad i = 1, 2, ..., m \quad (22)$$

where d_v (.,.) is the vertex distance measurement between two trapezoidal fuzzy numbers that is calculated by Eq. (23):

$$d_v(\tilde{m}, \tilde{n}) = \sqrt{\frac{(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2 + (m_4 - n_4)^2}{4}}. \quad (23)$$

A closeness coefficient is defined to determine the ranking order of all possible s once d_i^* and d_i^- of each banks A_i (i = 1; 2; ...; m) has been calculated. The closeness coefficient represents the distances to the fuzzy positive-ideal solution (A^*) and the fuzzy negative-ideal solution (A^-) simultaneously by taking the relative closeness to the fuzzy positive-ideal solution. The closeness coefficient (CC_i) of each alternative (banks) is calculated in Eq. (24):

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \quad i = 1, 2, ..., m. \quad (24)$$

It is clear that CC_i = 1 if $A_i = A^*$ and CC_i = 0 if $A_i = A^-$. In other words, bank A_i is closer to the FPIS (A^*) and farther from FNIS (A^-) as CC_i approaches to 1. According to the descending order of CC_i, the ranking order of all banks is determined and the best one among a set of feasible banks is selected. For evaluation process, approval status for each alternative is defined in Tab. 3 which can also be used for further evaluation when a decision is required for any bank.

Table 3 Approval status [2]

Closeness coefficient (CC_i)	Evaluation status
$CC_i \in [0;0,2)$	Do not recommend
$CC_i \in [0,2;0,4)$	Recommend with high risk
$CC_i \in [0,4;0,6)$	Recommend with low risk
$CC_i \in [0,6;0,8)$	Approved
$CC_i \in [0,8;1,0)$	Approved and preferred

4 Model explanation

First step of our model is to determine the web site evaluation criteria of e-banking. In e-sq measurement of e-banking web sites, the objective is to determine the best e-banking service delivery performance among the most preferable public and private banks of Turkey. Figure 3 depicts the hierarchy of the e-banking website service quality model.

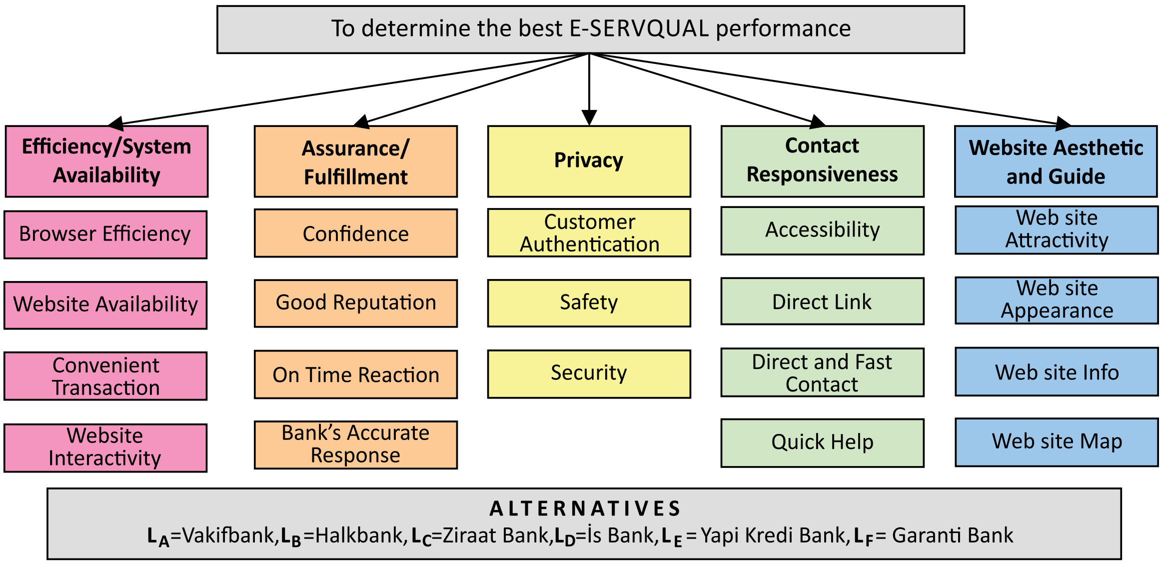

Figure 3 Hierarchical E-Servqual model

According to the hierarchical model of our study, we have determined the web site prioritization weights of banks. Therefore, the pair-wise comparisons with linguistic and fuzzy terms are performed from the experts' judgments. At the end of the F-AHP process, the prioritization results of the e-service quality of internet based banking are obtained.

The following step after the prioritization of e-SERVQUAL criteria is to classify the web sites of the alternative internet based banking. The fuzzy scale is used the same as for the AHP and the decision matrix with alternatives and criteria is carried out. In this study there are 6 internet based banking web sites in which 3 public banks and 3 private banks alternatives which belong to L_A = Vakifbank (www.vakifbank.com.tr), L_B = Halkbank (www.halkbank.com.tr), L_C = Ziraat Bank (www.ziraat.com.tr), L_D = İs Bank (www.isbank.com.tr), L_E = Yapi Kredi Bank (www.yapikredi.com.tr), L_F = Garanti Bank (www.garanti.com.tr). In the finalization of the methodology, the ranking of the web sites is determined.

4.1 Computational results

According to the criteria set, hierarchy structure pair wise comparisons within Fuzzy-AHP local and global importance weights are obtained as given in Tab. 4.

It is seen from Tab. 4 that the most important main criterion is "privacy" with the weight 0,437929 whereas the second criterion is "contact responsiveness" (0,280214). When the bottom level of the hierarchy is examined in terms of global importance, the first three sub criteria can be sequenced as "Direct and Fast Contact (0,096974)", "Confidence (0,092457)", and "Convenient Transaction/WPW (0,086191)". An interesting result is obtained showing that "Website Aesthetic and Guide" main criterion has no importance or any effect on selection and/or evaluation of internet banking, even if this criterion is in the E-Servqual model for evaluation. Therefore, the subcriteria of "Website Aesthetic and Guide" main criterion cannot affect further steps. In the TOPSIS methodology, after the criterion weights are obtained, these weights are distributed to the evaluation matrix consisting of alternative ratings in terms of each criterion. For this purpose simple matrix multiplication is applied as given in the Eq. (18) to obtain $[V_{ij}]$ matrix. The next step in this methodology is to define the FPIS and FNIS from V_{ij} so that the distances from these solutions can be calculated. Tab. 4 represents the FPIS and FNIS values for each criterion with trapezoidal fuzzy numbers (a, b, c, d), elements of which are placed in each cell.

Table 4 Fuzzy – AHP results for each criterion

	Criterion Name	**Importance level**	
Main criterion 1	**Efficiency/System Availability**	0,123357	
Main criterion 2	**Assurance/Fullfilment**	0,158143	
Main criterion 3	**Privacy**	0,437929	
Main criterion 4	**Contact Responsiveness**	0,280214	
Main criterion 5	**Website Aesthetic and Guide**	0,000000	
Efficiency/System Availability	**Sub criteria name**	**Local importance level**	**Global importance level**
Sub criterion 11	Browser Efficiency	0,080357	0,009913
Sub criterion 12	Website Availability	0,147000	0,018134
Sub criterion 13	Convenient Transaction/WPW	0,698714	0,086191
Sub criterion 14	Website Interactivity	0,073929	0,009120
Assurance/Fullfilment			
Sub criterion 21	Confidence	0,584643	0,092457
Sub criterion 22	Good Reputation	0,020857	0,003298
Sub criterion 23	On Time Reaction	0,130929	0,020705
Sub criterion 24	Bank's Accurate Response	0,263643	0,041693
Privacy			
Sub criterion 31	Customer Authentication	0,590929	0,258785
Sub criterion 32	Safety	0,142714	0,062499
Sub criterion 33	Security	0,265929	0,116458
Contact Responsiveness			
Sub criterion 41	Accesibility	0,212286	0,059485
Sub criterion 42	Direct Link	0,261857	0,073376
Sub criterion 43	Direct and Fast Contact	0,346071	0,096974
Sub criterion 44	Quick Help	0,179857	0,050399
Website Aesthetic and Guide			
Sub criterion 51	Website Attractivity	0,067214	0,000000
Sub criterion 52	Website Appearance	0,116286	0,000000
Sub criterion 53	Website Info	0,684571	0,000000
Sub criterion 54	Website Map	0,131929	0,000000

Table 5 FPIS & FNIS Values for Each Criterion

Criterion	**FPIS**				**FNIS**			
Browser Efficiency	0,008921	0,008921	0,008921	0,008921	0,000000	0,000000	0,000000	0,000000
Website Availability	0,018134	0,018134	0,018134	0,018134	0,000000	0,000000	0,000000	0,000000
Convenient Transaction/WPW	0,086191	0,086191	0,086191	0,086191	0,000000	0,000000	0,000000	0,000000
Website Interactivity	0,009120	0,009120	0,009120	0,009120	0,000000	0,000000	0,000000	0,000000
Confidence	0,092457	0,092457	0,092457	0,092457	0,000000	0,000000	0,000000	0,000000
Good Repuatiton	0,003298	0,003298	0,003298	0,003298	0,000000	0,000000	0,000000	0,000000
On Time Reaction	0,020705	0,020705	0,020705	0,020705	0,000000	0,000000	0,000000	0,000000
Bank's Accurate Response	0,041693	0,041693	0,041693	0,041693	0,000000	0,000000	0,000000	0,000000
Customer Authentication	0,258785	0,258785	0,258785	0,258785	0,051757	0,051757	0,051757	0,051757
Safety	0,062499	0,062499	0,062499	0,062499	0,000000	0,000000	0,000000	0,000000
Security	0,116458	0,116458	0,116458	0,116458	0,000000	0,000000	0,000000	0,000000
Accesibility	0,059485	0,059485	0,059485	0,059485	0,000000	0,000000	0,000000	0,000000
Direct Link	0,073376	0,073376	0,073376	0,073376	0,000000	0,000000	0,000000	0,000000
Direct and Fast Contact	0,096974	0,096974	0,096974	0,096974	0,000000	0,000000	0,000000	0,000000
Quick Help	0,045359	0,045359	0,045359	0,045359	0,000000	0,000000	0,000000	0,000000
Website Attractivity	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000
Website Appearance	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000
Website Info	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000
Website Map	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000

For each value of $[V_{ij}]$, both distances from FNIS and FPIS are calculated by using vertex distance (equation 23). The distance values are given in Tab. 6 and Tab. 7 for FPIS and FNIS, respectively. When this stem has been finished the trapezoidal fuzzy numbers are defuzzificated to single values. For the next step, all distance values through each row are summed to reach the overall distance of alternatives representing evaluations in terms of all criteria for both FPIS and FNIS. Then CC_i ratio is calculated to see the evaluation result of each alternative bank (see equation 24) and the results are given in Tab. 8.

According to the approval status scale given in Tab. 2 and the CC_i results in Tab. 7, none of the alternatives are in "approved and preferred status". However, none of them also are in either "Do not recommend" or "Recommend with high risk". All of them are in "Recommend with low risk". The performance values are very close to each other for the alternative L_F, L_D, L_E and L_A.

Table 6 Distances between banks and FPIS with respect to each criterion

Positive Distance	**Browser Efficiency**	**Website Availability**	**Convenient Transaction/WPW**	**Website Interactivity**	**Confidence**	**Good Repuatiton**	**On Time Reaction**
$D(L_A,A^*)$	0,004314	0,009539	0,043630	0,004594	0,043548	0,001464	0,013069
$D(L_B,A^*)$	0,004541	0,009824	0,044108	0,004781	0,056421	0,001568	0,013712
$D(L_C,A^*)$	0,005764	0,011701	0,056538	0,006091	0,056862	0,001919	0,013836
$D(L_D,A^*)$	0,003762	0,008685	0,042032	0,004618	0,049311	0,001438	0,012727
$D(L_E,A^*)$	0,003930	0,008658	0,040794	0,004760	0,045656	0,001453	0,012023
$D(L_F,A^*)$	0,003853	0,008043	0,037973	0,004546	0,054847	0,001442	0,011164
Positive Distance	**Bank's Accurate Response**	**Customer Authentication**	**Safety**	**Security**	**Accesibility**	**Direct Link**	**Direct and Fast Contact**
$D(L_A,A^*)$	0,019631	0,127961	0,030168	0,056853	0,030191	0,037710	0,051151
$D(L_B,A^*)$	0,023958	0,127961	0,036758	0,061456	0,032766	0,046164	0,064648
$D(L_C,A^*)$	0,027534	0,129631	0,041274	0,077731	0,037698	0,051973	0,070063
$D(L_D,A^*)$	0,019223	0,120718	0,029154	0,054279	0,027158	0,036576	0,049471
$D(L_E,A^*)$	0,019861	0,123466	0,029905	0,055513	0,028381	0,036342	0,050706
$D(L_F,A^*)$	0,018799	0,115350	0,028336	0,054803	0,026515	0,033588	0,051131
Positive Distance	**Quick Help**	**Website Attractivity**	**Website Appearance**	**Website Info**	**Website Map**		
$d(L_A,A^*)$	0,025250	0,000000	0,000000	0,000000	0,000000		
$d(L_B,A^*)$	0,025250	0,000000	0,000000	0,000000	0,000000		
$d(L_C,A^*)$	0,031281	0,000000	0,000000	0,000000	0,000000		
$d(L_D,A^*)$	0,022103	0,000000	0,000000	0,000000	0,000000		
$d(L_E,A^*)$	0,022365	0,000000	0,000000	0,000000	0,000000		
$d(L_F,A^*)$	0,021637	0,000000	0,000000	0,000000	0,000000		

Table 7 Distances between Banks and FNIS with Respect To Each Criterion

Negative distance	**Browser Efficiency**	**Website Availability**	**Convenient Transaction/WPW**	**Website Interactivity**	**Confidence**	**Good Repuatiton**	**On Time Reaction**
$D(L_A,A^-)$	0,005911	0,010725	0,052741	0,005924	0,063510	0,002396	0,010128
$D(L_B,A^-)$	0,005333	0,010448	0,052174	0,005412	0,053428	0,002248	0,010208
$D(L_C,A^-)$	0,004797	0,009223	0,042964	0,004440	0,052971	0,002136	0,010089
$D(L_D,A^-)$	0,006669	0,012271	0,057494	0,005902	0,060690	0,002440	0,011855
$D(L_E,A^-)$	0,006400	0,011702	0,056124	0,005765	0,061060	0,002416	0,011777
$D(L_F,A^-)$	0,006511	0,013170	0,063126	0,005975	0,055146	0,002435	0,013443
Negative distance	**Bank's Accurate Response**	**Customer Authentication**	**Safety**	**Security**	**Accesibility**	**Direct Link**	**Direct and Fast Contact**
$D(L_A,A^-)$	0,028635	0,125850	0,042065	0,077541	0,038441	0,046933	0,060810
$D(L_B,A^-)$	0,023958	0,125850	0,035127	0,068624	0,033828	0,036009	0,038720
$D(L_C,A^-)$	0,022106	0,124358	0,033138	0,061126	0,032939	0,028579	0,036543
$D(L_D,A^-)$	0,029181	0,134097	0,043356	0,080757	0,042035	0,048132	0,062456
$D(L_E,A^-)$	0,028337	0,130840	0,042398	0,079176	0,040460	0,048412	0,057649
$D(L_F,A^-)$	0,029871	0,141430	0,044438	0,079962	0,043047	0,051730	0,054470
Negative distance	**Quick Help**	**Website Attractivity**	**Website Appearance**	**Website Info**	**Website Map**		
$D(L_A,A^-)$	0,022369	0,000000	0,000000	0,000000	0,000000		
$D(L_B,A^-)$	0,022369	0,000000	0,000000	0,000000	0,000000		
$D(L_C,A^-)$	0,019305	0,000000	0,000000	0,000000	0,000000		
$D(L_D,A^-)$	0,029896	0,000000	0,000000	0,000000	0,000000		
$D(L_E,A^-)$	0,029621	0,000000	0,000000	0,000000	0,000000		
$D(L_F,A^-)$	0,030419	0,000000	0,000000	0,000000	0,000000		

Table 8 Computations of d_i^*, d_i^- and CC_i

Alternative	**Total d***	**Total d^-**	**$d^* + d^-$**	**CC_i**
L_A	0,499073	0,593979	1,093052	0,543413
L_B	0,553916	0,523738	1,077654	0,485998
L_C	0,619897	0,484715	1,104612	0,438810
L_D	0,481254	0,627232	1,108486	0,565846
L_E	0,483812	0,612136	1,095948	0,558545
L_F	0,472025	0,635175	1,107199	0,573677

5 Results

The objective of this research was to present a hybrid approach based on SERVQUAL and fuzzy TOPSIS for evaluating e-service quality of internet based banking alternatives in order to obtain to best qualified alternative that satisfies the needs and the expectations of e-users. The detailed literature and SERVQUAL scales are mentioned and then e-SERVQUAL framework was proposed for the internet based banking web sites. We develop a questionnaire for collecting data for evaluating the quality of internet based banking. After these steps, the questionnaire responses are aggregated to generate an overall performance score for measuring service quality using Fuzzy AHP and for ranking the alternatives using Fuzzy TOPSIS method. We perform AHP and TOPSIS methods in fuzzy environment for reducing the uncertainty of human decisions in assigning the evaluation of criteria. There are also many other multi criteria decision making techniques for selection of the best alternative as Analytic Network Process, DEMATEL, Electre etc. For further research, the application of techniques combined with these can be used for the service quality models and the selection of the best among the alternatives. The model proposed in this study also could be carried out to investigate the customer expectations and determine the web based service quality.

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