Evaluation of E-commerce Website Quality Using Fuzzy Multi-criteria Decision Making Approach

Serhat AYDIN, Cengiz KAHRAMAN

***Abstract*— Achieving an accomplished e-commerce depends on high quality websites which are preferred by prospective customers. Assessing e-commerce website quality can be considered as a multi-criteria decision making problem because of its complex structure including qualitative and quantitative factors. In this study, we propose a new methodology based on fuzzy analytic hierarchy process. The proposed methodology enables multiple decision makers on evaluation and uses triangular fuzzy scale that includes both positive and negative fuzzy numbers. The methodology includes simple mathematical calculations, and it yields triangular fuzzy numbers of alternatives' weights. At the last step, obtained alternatives' weights are ranked by integral values method. In the empirical study, three e-commerce websites, which are the most famous in Turkey, are evaluated by the proposed methodology and fuzzy VIKOR methodology. The results of methodologies are compared.**

***Index Terms*— Website quality, AHP, VIKOR, Decision making, Fuzzy set theory, Multi-criteria decision making.**

I. INTRODUCTION

Internet has provided a convenient and effective channel for distributing information and services [1]. E- commerce is clarified as a medium for buying and selling of products and services via internet. E-commerce includes buying, selling, vendor-managed inventory, production management, and logistic [2].

E-commerce has become an important tool for companies all around the world. Therefore, many researchers have focused on factors that effects quality of e-commerce websites. Lee and Kozar [3] investigated web quality factors on e-commerce. Lightner [4] evaluated commerce websites and focused on customer satisfaction. Torkzadeh and Dhillon [5] developed means and fundamental objectives that influence e-commerce success.

Merwe and Bekker [6] developed a methodology for evaluating e-commerce websites, and they focused on communication with customers and facilitation on business transaction. Fich [7] used a systematic qualitative technique to evaluate the usability of commercial websites. Kaya [2] developed a fuzzy hybrid model to assess e-commerce websites.

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Bauer and Folk [8] developed a transaction process based model scale for measuring service quality in e-service. Su and Lin [9] evaluated quality of e-commerce websites in Taiwan.

There are different views in the literature on how website quality should be measured. Because of website quality measurement incorporates in both of tangible and intangible measures, it is regarded as a multi-criteria decision making (MCDM) problem. There are many methods available for solving MCDM problems in the literature. But Analytic hierarchy process (AHP), developed by Saaty [10] is one of the most practical method in the literature. The process makes it possible to incorporate judgments on tangible data as well as intangible data. AHP is based on establishing pair-wise comparison matrices by using the 1-9 scale to evaluate criteria and alternatives. AHP enables decision makers to structure a hierarchy in order to select the best one among various alternatives.

In many MCDM problems, crisp data do not suffice to model real life problems. Due to shortcomings incurred by subjectivity of human judgments and vagueness of data, the fuzzy set theory, developed by Zadeh [11], can be used in decision making processes. When decision makers make pair-wise comparisons in classical AHP, they may not assign crisp numerical values due to uncertain and insufficient information. Therefore classical AHP was combined with fuzzy set theory by Laarhoven and Pedrycz [12] for the first time. The most important problem of the method is related to the possibility of obtaining a normal and convex fuzzy number. The other problem of the method is that it requires cumbersome calculations. Buckley [13] used the geometrical mean method to produce fuzzy values. Chang [14] proposed a new approach involving triangular fuzzy number usage and extent analysis method for synthetic extent values of pair-wise comparisons. Cheng [15] proposed a new algorithm for evaluating naval tactical missile systems by the fuzzy analytical process [16]. Zeng et al. [17] developed a modified fuzzy AHP for the project risk assessment.

In this study, we proposed a modified fuzzy AHP based MCDM methodology. We aimed to build an understandable and applicable fuzzy AHP method for measuring e-commerce web site quality. In the proposed methodology, decision makers use not only positive fuzzy numbers but also negative fuzzy numbers in pair-wise comparison matrices. We used simple arithmetic operations to calculate importance weights of alternatives.

The VIKOR method a recently introduced new MCDM method developed to solve MCDM problems with conflicting

(Advance online publication: 27 February 2012)

and non-commensurable criteria [18]. Opricovic [19], Opricovic and Tzeng [20] developed VIKOR, the Serbian name: VlseKriterijumska Optimizacija I Kompromisno Resenje, which means multi-criteria optimization and compromise solution. VIKOR is a multi-attribute decision making technique which has a simple computation procedure that allows simultaneous consideration of the closeness to ideal and the anti-ideal alternatives [21]. Many studies have employed VIKOR method. Kuo et al. [22] used VIKOR and GRA techniques to evaluate service quality of airports under fuzzy enviroment. Opricovic [23] used fuzzy VIKOR for water resource planning. Chen and Wang [24] applied fuzzy VIKOR to supplier selection problem. Opricovic and Tzeng [25] made a comparison of VIKOR with preference ranking organization method for enrichment evaluations (PROMETHEE), ELECTRE and TOPSIS approaches.

The remainder of the paper is organized as follows: Section 2 introduces proposed model. Subsequently VIKOR methodology is described in Section 3. A case study is presented in Section 4. Finally, Section 5 presented the conclusions of the study.

II. PROPOSED METHODOLOGY

Step 1:Structure hierarchy

To start with, decision makers determine goal, criteria and alternatives of the problem in a hierarchical form. An established hierarchy has to give the whole details of information on the structure so that there should not be lack of fact about the problem.

Step 2: Make pairwise comparisons for factors

Decision makers are required to compare each factor in the hierarchy. Decision makers use the fuzzy scale shown in Table 1 to compare factors. They use experimental data, perception, background, knowledge, etc. to make comparisons. Because decision makers may have different viewpoints, they can use different linguistic variables in comparisons matrices. The weights (e) are allocated to decision makers on the basis of their knowledge, experience, etc. Suppose that *m* decision makers exist in the group and the *k*th decision maker E_k is assigned an decision maker weight e_k, where $e_k \in [0,1]$, $e_1 + e_2 + ... + e_m = 1$.

Step 3: Aggregate individual TFNs to group TFNs

The purpose of this step is to apply an acceptable operator to get a group preference from individual preferences. The aggregation of TFNs scores is performed by applying the fuzzy weighted triangular averaging operator, as defined by equation (1).

$$\tilde{a}_{ij} = \tilde{a}_{ij1} \otimes e_1 \oplus \tilde{a}_{ij2} \otimes e_2 \oplus ..... \oplus \tilde{a}_{ijm} \otimes e_m \quad (1)$$

where $\tilde{a}_{ij}$ is the aggregated fuzzy score for A_i - A_j comparisons, i,j=1,2,….,n; $\tilde{a}_{ij1}, \tilde{a}_{ij2}, ..., \tilde{a}_{ijm}$ are corresponding TFN scales assigned by decision makers

TABLE I
TRIANGULAR FUZZY CONVERSION SCALE

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(0, 0, 0)	(0, 0, 0)
Equally important	(0, 1, 3)	(-3, -1, 0)
Weakly important	(1, 3, 5)	(-5, -3, -1)
Strongly more important	(3, 5, 7)	(-7, -5, -3)
Very strongly more important	(5, 7, 9)	(-9, -7, -5)
Absolutely more important	(7, 9,9)	(-9, -9, -7)

$E_1, E_2, ..., E_m$,respectively. $\otimes$ and $\oplus$ indicates fuzzy multiplication and fuzzy addition operators, respectively.

Step 4: Convert negative fuzzy TFNs to positive TFNs.

Since the scores in the classical AHP are based on an exponential importance, we should calculate the corresponding exponential values of negative scores in our method. This conversion is obtained by equation (2).

$$\tilde{a}^*_{ij} = e^{(\tilde{a}_{ij}/4)} \quad (2)$$

where $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$

Step 5: Calculate the priority weights of factors

Consider a triangular fuzzy comparison matrix expressed by

$$\tilde{A} = (\tilde{a}_{ij}) = \begin{bmatrix} (1,1,1) & (l_{12}, m_{12}, u_{12}) & ... & (l_{1n}, m_{1n}, u_{1n}) \\ (l_{21}, m_{21}, u_{21}) & (1,1,1) & \cdots & (l_{2n}, m_{2n}, u_{2n}) \\ \vdots & \vdots & \ddots & \vdots \\ (l_{n1}, m_{n1}, u_{n1}) & (l_{n2}, m_{n2}, u_{n2}) & \cdots & (1,1,1) \end{bmatrix} \quad (3)$$

Where $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij}) = \tilde{a}_{ji}^{-1} = (1/u_{ji}, 1/m_{ji}, 1/l_{ji})$

for $i, j = 1, ..., n$ and $i \neq j$

Because our aim is to bring out a simplified fuzzy AHP, we avoid using a complicated normalization formula. A normalized matrix $\tilde{N}$ can be calculated as follows;

$$\tilde{N} = \left[\tilde{n}_{ij} \right]_{m \times n} \quad (4)$$

$$\tilde{n}_{ij} = \left(\frac{l_{ij}}{u_j^*}, \frac{m_{ij}}{u_j^*}, \frac{u_{ij}}{u_j^*} \right) \quad (5)$$

$$u_j^* = \max_i u_{ij}$$

The normalization method clarified above is to preserve the property that the ranges of normalized triangular fuzzy numbers belong to [0,1].

And the importance weights of the factors can be calculated as follows;

$$W_i^{'} = \frac{\sum_{j=1}^{n} \tilde{n}_{ij}}{\sum_{k=1}^{n} \sum_{j=1}^{n} n_{kj}} \qquad k=1,2,…,n \quad (6)$$

Step 6: Calculate final weights

In this step the rating of each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion. The local ratings are then multiplied by the weights of the criteria and aggregated to get global ratings. [26]

Step7: Compare the weights using a ranking method

In the last step, we rank the obtained fuzzy numbers. In order to rank the fuzzy numbers, we use the integral values ranking method developed by Liou and Wang [27] .

III. FUZZY VIKOR METHODOLOGY

The VlseKriterijumska Optimizacija I Kompromisno Resenje(VIKOR) method was developed for multi-criteria optimization of complex systems. It determines the compromise ranking list, the compromise solution, and the weight stability intervals for preference stability of the compromise solution obtained with the initial weights. VIKOR methodology focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. It introduces the multi-criteria ranking index based on the particular measure of ''closeness'' to the ''ideal'' solution [28]. First of all, experts identify the objective of the decision making process and define the problem scope in VIKOR methodology. Decision making is the process of defining the decision goals, gathering relevant information and selecting the optimal alternative [18, 29]. And then finite set of relevant attributes are defined. All criteria, sub-criteria and alternatives are determined and hierarchical form called ''value tree'' is structured. And then appropriate linguistic variables are identified. In this study Table 2 gives the linguistic scale for evaluation of criteria and Table 3 gives the linguistic scale for evaluation of criteria.

TABLE 2
FUZZY EVALUATION SCORES FOR THE WEIGHTS

Linguistic terms	Fuzzy score
Absolutely strong (AS)	(2,5/2,3)
Very strong (VS)	(3/2,2,5/2)
Fairly strong (FS)	(1,3/2,2)
Slightly strong (SS)	(1,1,3/2)
Equal (E)	(2/3,1,1)
Slightly Weak (SW)	(1/2,2/3,1)
Fairly Weak (FW)	(1/2, 2/3, 1)
Very weak (VW)	(2/5, 1/2, 2/3)
Absolutely weak (AW)	(1/3,2/5,1/2)

TABLE 3
FUZZY EVALUATION SCORES FOR THE ALTERNATIVES

Linguistic terms	Fuzzy score
Very poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Medium poor (MP)	(1,3,5)
Fair (F)	(3,5,7)
Medium good (MG)	(5,7,9)
Good (G)	(7,9,10)
Very good (VG)	(9,10,10)

Assuming that a decision group has K people, the ratings of alternatives with respect to each criterion can be calculated as ;

$$\tilde{x}_{ij} = \frac{1}{K}\left[\tilde{x}_{ij}^{1}(+)\tilde{x}_{ij}^{2}(+)...(+)\tilde{x}_{ij}^{K}\right] \tag{7}$$

where $\tilde{x}_{ij}^{K}$ is the rating of the Kth decision maker for ith alternative with respect to jth criterion.

After obtaining the weights of criteria and fuzzy ratings of alternatives with respect to each criterion, we can now express the fuzzy multi-criteria decision-making problem in matrix format as,

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \tag{8}$$

$$W = [w_1, w_2, ..., w_n],\ j = 1, 2, ..., n$$

where $\tilde{x}_{ij}$ is the rating of the alternative A_i with respect to criterion j (i.e. C_j) and w_j denotes the importance weight of C_j.

Next step is defuzzify the fuzzy decision matrix and fuzzy weight of the each criterion into crisp values. A fuzzy number $\tilde{C} = (c_1 + c_2 + c_3)$ can be transformed into a crisp number by employing the below equation [30].

$$P(\tilde{C}) = C = \frac{c_1 + 4c_2 + c_3}{6} \tag{9}$$

Next step is to determine the fuzzy best value (FBV, $\tilde{f}_j^*$) and fuzzy worst value (FWV, $\tilde{f}_j^-$) of all criterion functions.

$$\tilde{f}_j^* = \max_i \tilde{x}_{ij},\ j \in B;\ \ \tilde{f}_j^- = \min_i \tilde{x}_{ij},\ j \in C \tag{10}$$

Then, the values $\tilde{w}_j(\tilde{f}_j^* - \tilde{x}_{ij})/(\tilde{f}_j^* - \tilde{f}_j^-), \tilde{S}_i$ *and* $\tilde{R}_i$ are computed in order to obtain:

$$\tilde{S}_i = \sum_{j=1}^{n} \tilde{w}_j(\tilde{f}_j^* - \tilde{x}_{ij})/(\tilde{f}_j^* - \tilde{f}_j^-) \tag{11}$$

$$\tilde{R}_i = \max_j[\tilde{w}_j(\tilde{f}_j^* - \tilde{x}_{ij})/(\tilde{f}_j^* - \tilde{f}_j^-)] \tag{12}$$

where $\tilde{S}_i$ refers to the separation measure of A_i from the fuzzy best value, and $\tilde{R}_i$ to the separation measure of A_i from the fuzzy worst value

In the next step, $\tilde{S}^*, \tilde{S}^-, \tilde{R}^*, \tilde{R}^-$ *and* $\tilde{Q}_i$ values are calculated:

TABLE 4
COMPARISON MATRIX OF ALTERNATIVES RESPECT TO EASE OF NAVIGATION

Ease of navigation	Weights	A	B	C
A	0.5	(0, 0, 0)	(-7, -5, -3)	(-5, -3, -1)
	0.25	(0, 0, 0)	(-7, -5, -3)	(-7, -5, -3)
	0.25	(0, 0, 0)	(-5, -3, -1)	(-5, -3, -1)
B	0.5	(3, 5, 7)	(0, 0, 0)	(1, 3, 5)
	0.25	(3, 5, 7)	(0, 0, 0)	(1, 3, 5)
	0.25	(1, 3, 5)	(0, 0, 0)	(1, 3, 5)
C	0.5	(1, 3, 5)	(-5,-3,-1)	(0, 0, 0)
	0.25	(3, 5, 7)	(-5,-3,-1)	(0, 0, 0)
	0.25	(1, 3, 5)	(-5,-3,-1)	(0, 0, 0)

$$\tilde{S}^* = \min_i \tilde{S}_i, \quad \tilde{S}^- = \max_i \tilde{S}_i$$
$$\tilde{R}^* = \min_i \tilde{R}_i, \quad \tilde{R}^- = \max_i \tilde{R}_i \qquad (13)$$

$$\tilde{Q}_i = v(\tilde{S}_i - \tilde{S}^*)/(\tilde{S}^- - \tilde{S}^*) + (1-v)(\tilde{R}_i - \tilde{R}^*)/(\tilde{R}^- - \tilde{R}^*) \qquad (14)$$

The index $\min_i \tilde{S}_i$ and $\min_i \tilde{R}_i$ are related to a maximum majority rule, and a minimum individual regret of an opponent strategy, respectively. As well, *v* is introduced as weight of the strategy of the maximum group utility, usually *v* is assumed to be 0.5.

Then rank the alternatives, sorting by the values S, R, and Q, in decreasing order. The results are three ranking lists. Propose as a compromise solution the alternative (a'), which is ranked the best by the measure Q (minimum) if the following two conditions are satisfied:

C1. ''Acceptable advantage''

$$Q(a'') - Q(a') \geq DQ \qquad (15)$$

Where a'' is the alternative with second position in the ranking list by Q; DQ= 1/(J-1); and J is the number of alternatives.

C2. ''Acceptable stability in decision making''

Alternative a' must also be the best ranked by S or/and R. This compromise solution is stable within a decision making process, which could be: ''voting by majority rule'' (when v>0.5 is needed), ''by consensus'' v=0.5, or ''with vote'' (v<0.5). Here, v is the weight of the decision making strategy ''the majority of criteria'' (or ''the maximum group utility'')

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consist of:

- Alternative a' and a'' if only condition C2 is not satisfied, or
- Alternative $a', a'', ..., a^{(n)}$ if condition C1 is not satisfied; and $a^{(n)}$ is determined by the relation $Q(a^{(n)} - Q(a')) < DQ$ for maximum n(the position of these alternatives are ''in closeness'')

IV. AN APPLICATION

A. *Application of the Proposed Method*

In this section, the proposed methodology was applied for assessing quality of e-commerce web sites in Turkey. There are much e-commerce websites but we assessed three websites which are the most famous. Three web designers were utilized for assessing web sites via determined criteria. The criteria were initially developed based on literature review. We used five criteria and 20 sub-criteria, which were the most suitable for assessing Turkish e-commerce websites. Different weights were assigned to three decision makers according to their experiments and academic degree in web design. The weights were 0.5, 0.25, and 0.25, respectively. Later, the four levels hierarchy was established, which contains five criteria, 20 sub-criteria, and three alternatives, shown in Figure 1. Criteria are; ease of use (1) is main criterion, and sub-criteria are completing a transaction quickly (1a), ease of navigation (1b), easy to find needs (1c), ease of online transaction (1d), easy to get different pages in website (1e). Product (2) is the second main criterion, and sub-criteria are product detail (2a), product price detail (2b), product quality (2c), comment on products by customer (2d), competitive product price (2e). Security (3) is the third main criterion, and sub-criteria are Online purchase security (3a), protection personnel information (3b), privacy statement (3c). And the fourth main criterion is customer relation ship (4), and its sub-criteria are; quick response to customer demands (4a), direction of registration (4b), online customer service support and help (4c), online order status tracking (4d). And final main criterion is fulfillment (5), and sub-criteria are on-time delivery (5a), accurate delivery of products (5b), accurate billing (5c).

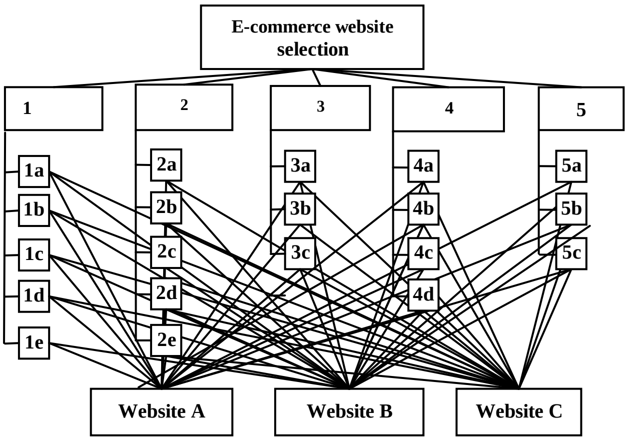

Fig. 1 Hierarchy for e-commerce website selection

Step 2: After we established the hierarchy, decision-makers evaluated all factors in the hierarchy. The comparison matrix of alternatives with respect to ''ease of navigation'' as shown in Table 4.

Step 3: The aggregation of the obtained scores was calculated by equation (1) as follows;

$$\tilde{a}_{21_{ease\,of\,navigation}} = 0.5 \otimes (3,5,7) \oplus 0.25(3,5,7) \oplus 0.25 \otimes (1,3,5)$$

$$\tilde{a}_{21_{ease\,of\,navigation}} = (2.5, 4.5, 6.5)$$

Similarly other aggregated scores of the hierarchy could also be obtained.

Step 4: Then the comparison matrices which include negative fuzzy numbers were converted to positive fuzzy numbers by using equation (2). Table 4 was converted as follows;

$$\tilde{a}^{*}_{21\ ease\,of\ navigation} = e^{(l_{21}, m_{22}, u_{23})/4}$$

$$\tilde{a}_{21_{ease\,of\ navigation}} = e^{(2.5, 4.5, 6.5)/4} = (1.86, 3.08,\ 5.07)$$

Other a_{ij} values of ease of navigation were given in Table 5.

TABLE 5
a_{ij} VALUES OF EASE OF NAVIGATION

Ease of navigation	A	B	C
A	(1, 1, 1)	(0.19, 0.32, 0.53)	(0.25, 0.41, 0.68)
B	(1.86, 3.08, 5.07)	(1, 1, 1)	(1.28, 2.11, 3.49)
C	(1.45, 2.39, 3.95)	(0.28, 0.47, 0.77)	(1, 1, 1)

Table 5 was normalized by using equation (5) as follows:

$$a_{21} = (1.86, 3.08, 5.07)/5.07 = (0.36,\ 0.60, 1)$$

Similarly other normalized a_{ij} values of ease of navigation were also obtained. The importance weights of the alternatives under ease of navigation were obtained by using equation (6). In this case, we obtained,

$$W_{Website\ A}^{'} = (0.80, 0.15, 0.30),\ W_{Website\,B}^{'} = (0.30, 0.54, 0.97),$$

$$W_{Website\ C}^{'} = (0.14, 0.30, 0.60)$$

All the importance weights of the hierarchy were obtained and then synthesized. Obtained importance weights of the alternatives are as follows;

$$W_{Website\ A} = (0.19, 0.52, 2.37),\ W_{Website\,B} = (0.05, 0.38, 2.83),$$

$$W_{Website\ C} = (0.04, 0.35, 2.71)$$

After obtaining fuzzy importance weights, the last step was performed, and the fuzzy weights were ranked by integral values method. The obtained results are shown in Table 6.

TABLE 6
RANKING OF THE ALTERNATIVES

Websites	I(ω)	Comparison
A-B	0.49	B> A
B-C	0.51	B > C
A-C	0.51	A > C

B. *Sensitivity Analysis*

In this section a sensitivity analysis was performed. We assigned different weights to decision makers and analyzed how much it would influence the final scores of alternatives. In the first case, the decision makers' weights were 0.5, 0.25, and 0.25, respectively and the final scores were obtained as $W_A = (0.19, 0.52, 2.37),\ W_B = (0.05, 0.38, 2.83),\ W_C = (0.04, 0.35, 2.71)$.

In the second case the decision makers' weights were assigned as 0.1, 0.1, and 0.8, respectively and the final scores were calculated as follows $W_A = (0.20, 0.54, 3.06),\ W_B = (0.04, 0.38, 2.82),\ W_C = (0.04, 0.34, 2.58)$. In the third case the decision makers' weights were assigned as 0.1, 0.8, and 0.1, respectively and the final scores were calculated as follows: $W_A = (0.19, 0.53, 2.21),\ W_B = (0.05, 0.39, 2.82),\ W_C = (0.04, 0.36, 2.81)$.

We observed that different decision makers' weights influence final weights, and our model senses to different conditions. And Figure 2 shows sensitivity analysis results.

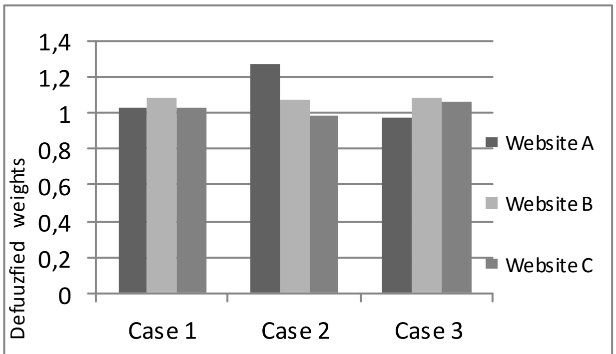

Fig. 2. Sensitivity Analysis Results

C. *Comparison with Fuzzy VIKOR*

In this sub-section, the obtained results by the proposed method are compared with the results of fuzzy VIKOR. Three experts use linguistic weighting variables shown in Table 2 to evaluate importance of the criteria. Table 7 shows the importance weights of the criteria. And decision makers use linguistic rating variables shown in Table 3 to evaluate the ratings of the alternatives. Table 8 shows the ratings of alternatives under various criteria.

TABLE 7
IMPORTANCE WEIGHTS OF CRITERIA FROM THREE DECISION MAKERS.

Criteria	Decision makers		
	DM1	DM2	DM3
1a	VW	SW	VW
1b	E	E	E
1c	SS	FS	FS
1d	SW	SW	SW
1e	AW	E	SW
2a	VS	FS	FS
2b	SS	SS	FS
2c	AS	FS	VS
2d	FS	FS	VS
2e	AS	VS	VS
3a	SS	SS	FS
3b	VS	FS	FS
3c	FS	VS	SS
4a	AS	AS	AS
4b	FS	VS	VS
4c	SS	VS	FS
4d	VS	FS	AS
5a	AW	VW	E
5b	VW	VW	E
5c	AW	SW	VW

TABLE 8
THE RATINGS OF ALTERNATIVES UNDER VARIOUS CRITERIA

	DM1			DM2			DMT3		
	A1	A2	A3	A1	A2	A3	A1	A2	A3
1a	P	F	MP	P	F	F	MP	MG	MP
1b	F	G	MP	P	G	P	MP	VG	MP
1c	F	F	F	G	G	MG	F	MG	MP
1d	G	MG	MG	MP	F	MG	F	G	G
1e	F	MP	P	MG	F	F	MG	MG	P
2a	MP	VG	MG	MP	G	F	P	MG	MP
2b	F	MP	F	G	MG	G	MG	G	F
2c	P	F	VG	MP	MG	VG	MP	G	VG
2d	F	MG	MP	MP	MP	VP	MG	MG	F
2e	MP	MP	MP	MP	MP	VP	MP	F	MP
3a	MP	VG	F	F	G	MP	MP	G	MP
3b	MG	G	MP	F	F	F	MP	MP	MP
3c	MP	G	MG	MP	P	MP	P	MG	MP
4a	F	F	F	MG	MG	F	MG	MG	MP
4b	MG	MG	MP	MG	MG	P	VG	VG	P
4c	P	G	F	P	MG	MG	P	F	F
4d	MP	G	MG	MP	F	G	MP	F	MG
5a	P	G	MG	MP	MP	VP	P	F	MP
5b	MG	MG	MP	F	F	F	F	G	F
5c	F	F	F	F	G	MP	F	VG	MP

Table 7 and Table 8 are converted to triangular fuzzy numbers by using Table 2 and Table 3. Then the aggregated weight of criteria and aggregated fuzzy ratings of alternatives are calculated to construct the fuzzy decision matrix, and determine the fuzzy weight of each criterion, as in Table 9.

TABLE 9
AGGREGATED FUZZY WEIGHT OF CRITERIA AND AGGREGATED FUZZY RATING OF ALTERNATIVES

		Alternatives		
	Weight	**A1**	**A2**	**A3**
1a	(0.43,0.56, 0.78)	(0.33,1.67,3.67)	(3.67, 5.67, 7,67)	(1.67, 3.67, 5.67)
1b	(0.61, 0.89, 1.00)	(1.33,3.00,5.00)	(7.67, 9.33, 9,33)	(1.00, 3.00, 5.00)
1c	(1.00, 1.33, 1.83)	(4.33,6.33,8.00)	(5.00, 7.00, 8,67)	(3.00, 5.00, 7.00)
1d	(0.50, 0.67, 1.00)	(3.67,5.67,7.33)	(5.00, 7.00, 8,67)	(5.67, 7.67, 9.33)
1e	(0.50, 0.69, 0.83)	(4.33,6.33,8.33)	(3.00, 5.00, 7,00)	(1.00, 2.33, 4.33)
2a	(1.17, 1.67, 2.17)	(0.67,2.33,4.33)	(7.00, 8.67, 9,67)	(3.00, 5.00, 7.00)
2b	(1.00, 1.17, 1.67)	(5.00,7.00,8.67)	(4.33, 6.33, 8,00)	(4.33, 6.33, 8.00)
2c	(1.50, 2.00, 2.50)	(0.67,2.33,4.33)	(5.00, 7.00, 8,67)	(9.00, 10.00, 10.00)
2d	(1.17, 1.67, 2.17)	(3.00,5.00,7.00)	(3.67, 5.67, 7,67)	(1.33, 3,.00,5.00)
2e	(1.67,2.17, 2.67)	(1.00,3.00,5.00)	(1.67, 3.67, 5,67)	(0.67, 2.33, 4.33)
3a	(1.00, 1.171.67)	(1.67,3.67,5.67)	(7.67, 9.33, 10,00)	(1.67, 3.67,5.67)
3b	(1.17, 1.67, 2.17)	(3.00,5.00,7.00)	(3.67,5.67, 7,33)	(1.67, 3.67, 5.67)
3c	(1.17, 1.50, 2.00)	(0.67,2.33,4.33)	(4.33, 6.33, 8,00)	(2.33, 4.33, 6.33)
4a	(2.00, 2.50, 3.00)	(4.33,6.33,8.33)	(4.33, 6.33, 8,33)	(2.33, 4.33, 6.33)
4b	(1.33, 1.83, 2.33)	(6.33,8.00,9.33)	(6.33, 8.00, 9,33)	(0.33, 1.67,3.67)
4c	(1.17, 1.50, 2.00)	(0.00,1.00,3.00)	(5.00, 7.00, 8,67)	(3.67, 5.67, 7.67)
4d	(1.50,2.00, 2.50)	(1.00,3.00,5.00)	(4.33, 6.33, 8,00)	(5.67,7.67, 9.00)
5a	(0.47, 0.63, 0.72)	(0.33,1.67,3.67)	(3.67, 5.67, 7,33)	(2.00, 3.67, 5.67)
5b	(0.49, 0.67, 0.78)	(3.67,5.67,7.00)	(5.00, 7.00, 8,67)	(2.33, 4.33, 6.33)
5c	(0.41, 0.52, 0.72)	(3.00,5.00, 7.67)	(6.33, 8.00, 9,00)	(1.67, 3.67, 5.67)

Then triangular fuzzy numbers are converted to crisp values by using equation (9). The crisp values for decision matrix and weight of each criterion are computed as shown in Table 10.

TABLE 11
THE VALUES OF $S_i, R_i, and\ Q$

	S_i	R_i	Q
A1	0.58	0.07	0.70
A2	0.11	0.04	0.00
A3	0.70	0.09	1.00

TABLE 10
CRISP VALUES FOR DECISION MATRIX AND WEIGHT OF EACH CRITERION

		Alternatives		
	Weight	**A1**	**A2**	**A3**
1a	0.57	1.77	5.66	3.66
1b	0.86	3.,05	9.05	3.00
1c	1.36	6.27	6.94	5.00
1d	0.69	5.61	6.94	7.61
1e	0.68	6.33	5.00	2.44
2a	1.67	2.38	8.55	5.00
2b	1.22	6.94	6.27	6.27
2c	2.00	2.38	6.94	9.83
2d	1.67	5.00	5.66	3.05
2e	2.17	3.00	3.66	2.38
3a	1.22	3.66	9.16	3.66
3b	1.67	5.00	5.61	3.66
3c	1.53	2.38	6.27	4.33
4a	2.50	6.33	6.33	4.33
4b	1.83	7.94	7.94	1.77
4c	1.53	1.16	6.94	5.66
4d	2.00	3.00	6.27	7.55
5a	0.62	1.77	5.61	3.72
5b	0.66	5.66	6.94	4.33
5c	0.54	5.00	7.88	3.66

Then, using equation (10)-(14), the values of $S_i, R_i, and\ Q$ are calculated for all alternatives as Table 11. In the calculations, weight of the strategy of the maximum group utility (v) is assumed to be 0.5. The ranking of the suppliers by $S_i, R_i, and\ Q$ in decreasing order is shown in Table 12.

TABLE 12
THE RANKING OF THE ALTERNATIVES BY $S_i, R_i, and\ Q$ IN DECREASING ORDER

	Ranking alternatives		
	1	2	3
S_i	A2	A1	A3
R_i	A2	A1	A3
Q	A2	A1	A3

According to Table 12, the alternative A2 is the best, A1 is the second, and A3 is the last ranked by Q. Also the conditions C1 and C2 are satisfied. So A2 is the best alternative.

V. CONCLUSION

E-commerce website quality involves both qualitative and quantitative factors. Therefore, it is considered in MCDM problems. In this study, we proposed a modified fuzzy AHP based MCDM methodology for assessing e-commerce website quality in Turkey. We collaborated with three web-designers in this study for assessing all factors in the hierarchy. Firstly, we developed five main criteria and 20 sub-criteria based on literature review and our own assessments. We established a four –levels hierarchy for e-commerce website evaluation. We got weights for alternatives by using our methodology. The proposed methodology offers certain advantages. The methodology enables decision makers to use not only positive fuzzy numbers but also negative fuzzy numbers to evaluate hierarchy. It uses understandable scale to compare factors. And it uses simple mathematical calculations to get importance weights. It follows the steps of the traditional AHP.

The e-commerce website selection problem was evaluated by fuzzy VIKOR as well. Comparison showed that both fuzzy VIKOR and the proposed method lead to same assessments.

We suggest that the proposed methodology in this study can handle the evaluation of the website quality problem effectively and efficiently. For further research, other MCDM techniques such as fuzzy ANP, fuzzy PROMETHEE, fuzzy ELECTRE, fuzzy TOPSIS can be applied and their results can be compared with that of proposed methodology.

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