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Multi-attribute Evaluation of Website Quality in E-business Using an Integrated Fuzzy AHP-TOPSIS Methodology

Tolga Kaya[*]
Management Engineering Department, Istanbul Technical University.
Macka, Besiktas, Istanbul, 34367, Turkey

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Abstract

Success of an e-business company is strongly associated with the relative quality of its website compared to that of its competitors. The purpose of this study is to propose a multi-attribute e-business website quality evaluation methodology based on a modified fuzzy TOPSIS approach. In the proposed methodology, weights of the evaluation criteria are generated by a fuzzy AHP procedure. In performance evaluation problems, the judgments of the experts may usually be vague in form. As fuzzy logic can successfully deal with this kind of uncertainty in human preferences, both classical TOPSIS and classical AHP procedures are implemented under fuzzy environment. The proposed TOPSIS-AHP methodology has successfully been applied to a multi-attribute website quality evaluation problem in Turkish e-business market. Nine sub-criteria under four main categories are used in the evaluation of the most popular e-business websites of Turkey. A sensitivity analysis is also provided.

Keywords: Website quality, e-business, fuzzy, multicriteria, TOPSIS, AHP

1. Introduction

E-business is any process that a business organization conducts over a computer-mediated network. Business organizations include any for-profit, governmental, or nonprofit entity. Examples of online e-business processes include purchasing, selling, vendor-managed inventory, production management, and logistics, as well as communication and support services, such as online training and recruiting. Users usually have no way to make judgments on the operations of an organization except through the experience of its public-facing services. Thus, the perception of an organization is heavily influenced by the user experience of its website. Measuring website quality is a crucial step for any type of organization in building a successful website. Even the best-designed e-business models may soon fall apart without devoting a significant amount of effort on establishing customer loyalty. In their quest to develop a loyal customer base, most e-business companies try their best to continually satisfy their customers and develop long-run relationships with them. Towards building this kind of relationships successful management of a high quality website is a must.[1-2]

Website quality assessment is a multicriteria evaluation problem which may not usually be as easy as it seems. Different disciplines define the notion of website quality in distinct ways. Within these definitions; usability of the interface, information value of the content provided, and the design of the site are among the most common evaluation themes.[3] In the last two decades, DeLone and Mclean's[4-6] multi-attribute model of information system (IS) success is widely used in assessing the quality of

[*]Corresponding author: kayatolga@itu.edu.tr, Tel: +90 212 2931300 Ext. 2789

websites and other areas of IS research. According to the model; information quality, system quality, use, user satisfaction, individual impact, and organizational impact are the main attributes which determine the success level of an IS.[7]

Methods based on fuzzy logic may be quite useful in undertaking difficulties in subjective assessment procedures. Linguistic variables can be converted to fuzzy numbers through the usage of fuzzy set theory. Fuzzy methods are purposely designed for complex evaluation problems which contain uncertainties. Hence, many researchers have attempted to use fuzzy multiple criteria decision making (MCDM) methods like AHP (Analytic Hierarchy Process), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) and VIKOR (VIšekriterijumsko-KOmpromisno-Rangiranje) for performance evaluation problems.[7-13]

TOPSIS is a frequently used decision-making technique due to its simultaneous consideration of the ideal and the anti-ideal solutions, and easy calculation procedure. Chu[14] presented a fuzzy TOPSIS model for facility location selection under group decisions. Chu and Lin[15] used the method for the problem of robot selection for a manufacturing company. Yong[16] presented a TOPSIS approach for selecting plant location under linguistic environments. Kahraman et al.[17] proposed a two phase multi-attribute decision-making approach for new product introduction. Kahraman et al.[18-19] used a hierarchical fuzzy TOPSIS model for the selection of the best information technologies and industrial robotic systems. Wang et al.[20] proposed a similar methodology for supplier selection. It is believed that an integrated TOPSIS-AHP methodology will successfully handle a website quality evaluation problem within the context of e-business in Turkey.

In this study, a modified fuzzy TOPSIS methodology is proposed to make a multi-attribute website quality evaluation among three leading e-business companies in Turkey. In the developed methodology, the experts' opinions on the importance of the evaluation attributes are transformed into criteria weights by a fuzzy AHP procedure. Although pairwise comparison approach of AHP is a demanding tool in terms of collecting input from the experts, the authors believe that it offers maximum insight, particularly in terms of assessing consistency of the experts' judgment. An application of the approach is presented in Turkish e-commerce market.

The rest of the paper is organized as follows: In Section 2, a brief literature review on commonly used evaluation criteria in e-business area is given. In the third section, an integrated fuzzy TOPSIS-AHP methodology is presented. In Section 4, the proposed methodology is applied to a website quality evaluation problem. In Section 5, a sensitivity analysis is realized. In the last section, concluding remarks are presented.

2. Literature Review

In the last ten years there has been an explosion in the use of the Internet. In the new economy, the Internet has become a powerful communication mechanism to facilitate the consummation and processing of business transactions. New terms have appeared in order to define the different types of business transactions more accurately. E-business is based on the exchange transactions which take place over the Internet primarily using digital technology. This covers all activities supporting market transactions including marketing, customer support, delivery and payment processes. One of the most important problems in e-business is the process of building and maintaining customer relationships through online activities to facilitate the exchange of ideas, products, and services that satisfy the goals of both parties. Therefore e-business managers devote an important part of their time to develop indicators to efficiently monitor their activities and adapt their business strategy according to the feedbacks.[6,21-23]

Wang and Huarng[24] identified nine factors that affect e-satisfaction: Website quality, price, merchandise availability, merchandise condition; delivery speed; merchandise return policy, customer support, e-mail confirmation of order, and promotion activities. Website quality has generally been recognized as a critical step to drive e-business. Empirical studies show that website quality has a direct and positive impact on customer satisfaction and e-business performance.[7,25] There are many studies in the literature which investigate the factors which determine website quality and its effects on e-commerce success: Bilsel et al.[8] made use of PROMETHEE and AHP methodologies in order to develop a fuzzy preference-ranking model for a quality evaluation of hospital web sites in Turkey. Lee and Kozar[7] used AHP for investigating the effect of website quality on e-business success. Bai et al.[25] investigated the impact of website quality on customer satisfaction and purchase intentions based on empirical evidence from Chinese e-commerce market. Harrison and Boonstra[26] presented an assessment model to assist airline companies in evaluating their online activities, including ticketing websites, on a financial, technical as well as a customer behavior level. Huang et al.[27] developed an e-commerce performance assessment model which uses TOPSIS, simple additive weighting (SAW), weighted product (WP), and other MCDM methodologies. Sun and Lin[11] evaluated the competitive advantages of shopping websites in Taiwan market using a fuzzy TOPSIS methodology.

Table 1 gives a summary of the attributes used in the website quality evaluation models on the literature:

Table 1: Website quality evaluation models in literature

	Attributes of website quality
Liu and Arnett[28]	System use, playfulness, design quality, information & service quality
Barnes and Vidgen[29]	Information, usability, design, trust, empathy
Argawal and Venkatesh[30]	Ease of use, content, promotion, made for the medium, emotion
Loiacono et al.[31]	Ease of use, usefulness, entertainment, complementary relationship
Koufaris et al.[32]	Perceived control, perceived usefulness, perceived ease of use, shopping enjoyment, concentration
Palmer[33]	Download speed, navigation & organization, responsiveness, information & content, interactivity
Torkzadeh and Dhillon[34]	Product choice, online payment, trust, shopping travel, shipping errors
Wu et al.[35]	Information content, cognitive outcomes, enjoyment, privacy, user empowerment, visual appearance, technical support, navigation, organization of information, credibility, impartiality
Webb and Webb[36]	Reliability, assured empathy, tangibility, navigability, relevant representation, accuracy, security, trustworthiness, perceived usability
Lee and Kozar[7]	Relevance, currency, understandability, empathy, reliability, responsiveness, navigability, response time, personalization, telepresence, security, awareness, reputation, price savings.
Bai et al.[25]	Functionality, usability, customer satisfaction
Sun and Lin[11]	Practicality, ease of use, use of time, communication, confidency, security, trust, familiarity, past experience, proficiency, information quality

3. An Integrated TOPSIS-AHP Methodology under Fuzzy Environment

Fuzzy numbers are a particular kind of fuzzy sets[37]. A fuzzy number is a fuzzy subset in the universe of discourse X that is both convex and normal. Fig. 1 shows a fuzzy number $\tilde{\tau}$ of the universe of discourse X which is both convex and normal[38].

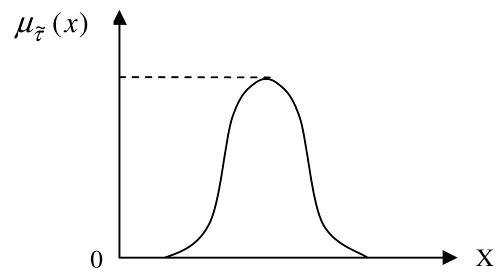

Figure 1: A Fuzzy Number $\tilde{\tau}$

The α-cut of a fuzzy number $\tilde{\tau}$ is defined

$$\tilde{\tau}^{\alpha} = \{x_i : \mu_{\tilde{\tau}}(x_i) \geq \alpha, x_i \in X\} \tag{1}$$

where $\lambda \in [0,1]$.

$\tilde{\tau}$ is a non-empty bounded closed interval contained in X and it can be denoted by $\tilde{\tau}^{\alpha} = [\tau_l^{\alpha}, \tau_u^{\alpha}]$, τ_l^{α} and τ_u^{α} are the lower and upper bounds of the closed interval, respectively. Fig. 2 shows a fuzzy number $\tilde{\tau}$ with α-cuts, where

$$\tilde{\tau}^{\alpha_1} = [\tau_l^{\alpha_1}, \tau_u^{\alpha_1}],\ \tilde{\tau}^{\alpha_2} = [\tau_l^{\alpha_2}, \tau_u^{\alpha_2}] \tag{2}$$

From Fig.2, we can see that if $\alpha_2 \geq \alpha_1$, then $\tau_l^{\alpha_2} \geq \tau_l^{\alpha_1}$ and $\tau_u^{\alpha_1} \geq \tau_u^{\alpha 2}$.[38]

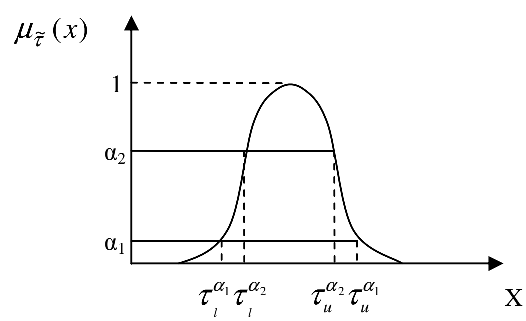

Figure 2: Fuzzy number $\tilde{\tau}$ with α-cuts.

A triangular fuzzy number (TFN) $\tilde{\tau}$ can be defined by a triplet (τ_1, τ_2, τ_3) shown in Fig. 3. The membership function $\mu_{\tilde{\tau}}(x)$ is defined as in Eq. (3):

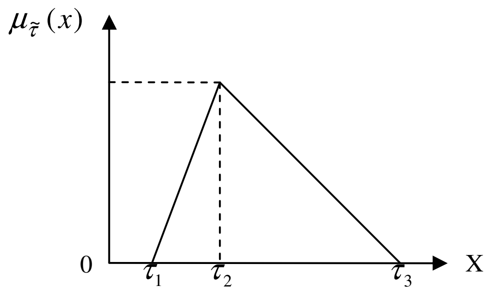

Figure 3: A triangular fuzzy number $\tilde{\tau}$

$$\mu_{\tilde{\tau}}(x) = \begin{cases} 0, & x_1 \le \tau_1 \\ \dfrac{x-\tau_1}{\tau_2-\tau_1}, & \tau_1 \le x \le \tau_2 \\ \dfrac{x-\tau_3}{\tau_2-\tau_3}, & \tau_2 \le x \le \tau_3 \\ 0, & x \ge \tau_3 \end{cases} \tag{3}$$

If $\tilde{\tau}$ is a fuzzy number and τ_l^{α} >0 for α ∈ [0,1], then $\tilde{\tau}$ is called a positive fuzzy number. Given any two positive fuzzy numbers $\tilde{\rho}$, $\tilde{\tau}$ and a positive real number r, the α-cut of two fuzzy numbers are $\tilde{\rho}^{\alpha} = \left[\rho_l^{\alpha}, \rho_u^{\alpha}\right]$ and $\tilde{\tau}^{\alpha} = \left[\tau_l^{\alpha}, \tau_u^{\alpha}\right]$ (α ∈ [0,1]) respectively. According to the interval of confidence, some main operations of positive fuzzy numbers $\tilde{\rho}$ and $\tilde{\tau}$ can be expressed as follows:[39]

$$(\tilde{\rho}(+)\tilde{\tau})^{\alpha} = \left[\rho_l^{\alpha} + \tau_l^{\alpha}, \rho_u^{\alpha} + \tau_u^{\alpha}\right], \tag{4}$$

$$(\tilde{\rho}(-)\tilde{\tau})^{\alpha} = \left[\rho_l^{\alpha} - \tau_u^{\alpha}, \rho_u^{\alpha} - \tau_l^{\alpha}\right], \tag{5}$$

$$(\tilde{\rho}(\cdot)\tilde{\tau})^{\alpha} = \left[\rho_l^{\alpha} \cdot \tau_l^{\alpha}, \rho_u^{\alpha} \cdot \tau_u^{\alpha}\right], \tag{6}$$

$$(\tilde{\rho}(:)\tilde{\tau})^{\alpha} = \left[\frac{\rho_l^{\alpha}}{\tau_u^{\alpha}}, \frac{\rho_u^{\alpha}}{\tau_l^{\alpha}}\right], \tag{7}$$

$$(\tilde{\rho}^{\alpha})^{-1} = \left[\frac{1}{\rho_u^{\alpha}}, \frac{1}{\rho_l^{\alpha}}\right], \tag{8}$$

$$(\tilde{\rho}(\cdot)r)^{\alpha} = \left[\rho_l^{\alpha} \cdot r, \rho_u^{\alpha} \cdot r\right], \tag{9}$$

$$(\tilde{\rho}(:)r)^{\alpha} = \left[\frac{\rho_l^{\alpha}}{r}, \frac{\rho_u^{\alpha}}{r}\right], \tag{10}$$

If $\tilde{n}$ is a triangular fuzzy number and $\tau_l^{\alpha} > 0,\ \tau_u^{\alpha} \le 1$ for α ∈ [0,1], then $\tilde{\tau}$ is called a normalized positive triangular fuzzy number.[40]

A linguistic variable is a variable whose values are linguistic terms[41]. The concept of linguistic variable is very useful in dealing with situations which are too complex or too ill-defined to be reasonably described in conventional quantitative expressions. The linguistic values can be represented by fuzzy numbers.

Let $\tilde{\rho} = (\rho_1, \rho_2, \rho_3)$ and $\tilde{\tau} = (\tau_1, \tau_2, \tau_3)$ be two triangular fuzzy numbers, then the vertex method is defined to calculate the distance between them as

$$d(\tilde{\rho}, \tilde{\tau}) = \sqrt{\frac{1}{3}\left[(\rho_1 - \tau_1)^2 + (\rho_2 - \tau_2)^2 + (\rho_3 - \tau_3)^2\right]} \tag{11}$$

Let $\tilde{\rho} = (\rho_1, \rho_2, \rho_3)$ be a triangular fuzzy number, according to the graded mean integration approach, a fuzzy number can be transformed into a crisp number by employing the below equation:[16]

$$P(\tilde{\rho}) = \rho = \frac{\rho_1 + 4\rho_2 + \rho_3}{6} \tag{12}$$

A modified fuzzy approach to the classical TOPSIS is proposed in this section. The importance weight of each criterion can be obtained by either directly assigning or indirectly using pairwise comparisons. In here, it is suggested that the decision makers use the linguistic variables (shown as Table 2) to evaluate the importance of the criteria. Chen[38] calculates the weight of each criterion by summing the assigned weights by experts and then dividing the sum by the number of experts as in Eq. (13):

$$\tilde{w}_{ij} = \frac{1}{K}\left[\tilde{w}_j^1(+)\tilde{w}_j^2(+)\ldots(+)\tilde{w}_j^K\right] \tag{13}$$

where $\tilde{w}_j^K$ is the importance weight of the K^{th} decision maker.

Since a comparison matrix divides the problem into sub-problems which can be solved easier, a pairwise comparison matrix in the AHP method can be considered a good way of determining the weights of the criteria. Therefore, we propose modifying the classical weighting procedure of TOPSIS methodology by using fuzzy comparison matrices. Chang's[42] extent analysis will be utilized for this purpose.

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)	(1, 1, 1)
Slightly Weak (SW)	(2/3, 1, 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)

The stages of Chang's[42] extent analysis approach can be summarized as follows: Letting $C_j = \{C_1, C_2, ..., C_n\}$ be a criteria set, extent analysis values for each criterion can be obtained as follows: Let $\tilde{M}_j$ ($j = 1,2,3,...,n$) be TFNs.
The value of fuzzy synthetic extent for the degree of possibility of $\tilde{M}_1 \geq \tilde{M}_2$ are defined, respectively, as

$$\tilde{S}_j = \sum_{j=1}^{n} \tilde{M}_j \otimes \left[\sum_{k=1}^{m} \sum_{j=1}^{n} \tilde{M}_j \right]^{-1} \quad (14)$$

In our case, $n=m$ since a comparison matrix for criteria always has to be a square matrix.

$$V(\tilde{M}_1 \geq \tilde{M}_2) = \sup_{x \geq y} \left[\min\left(\mu_{\tilde{M}_1}(x), \mu_{\tilde{M}_2}(y) \right) \right] \quad (15)$$

When (x, y) exists such that $x \geq y$ and $\mu_{\tilde{M}_1} = \mu_{\tilde{M}_2} = 1$, $V(\tilde{M}_1 \geq \tilde{M}_2) = 1$ is obtained. Since $\tilde{M}_1$ and $\tilde{M}_2$ are convex fuzzy numbers, the following principle of the comparison of fuzzy numbers is applied:

$$V(\tilde{M}_1 \geq \tilde{M}_2) = 1 \quad \text{iff} \quad m_1 \geq m_2 \quad (16)$$

and

$$V(\tilde{M}_2 \geq \tilde{M}_1) = hgt(\tilde{M}_1 \cap \tilde{M}_2) = \mu(d) \quad (17)$$

where d is the ordinate of the highest intersection point D between $\mu_{\tilde{M}_1}$ and $\mu_{\tilde{M}_2}$. When $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$, the following equation for the ordinate of the point D is given (see Fig. 4);

$$V(\tilde{M}_2 \geq \tilde{M}_1) = hgt(\tilde{M}_1 \cap \tilde{M}_2)$$
$$= \begin{cases} 0, & if \quad m_2 \geq m_1 \\ 1, & if \quad l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{cases} \quad (18)$$

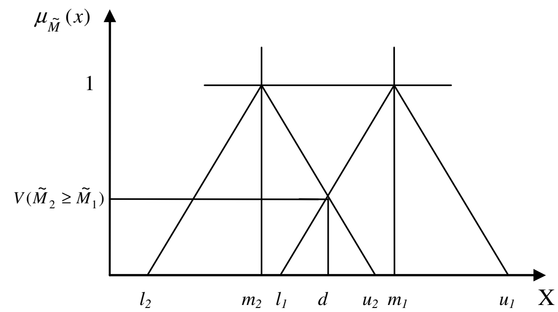

Figure 4: The intersection between $\tilde{M}_1$ and $\tilde{M}_2$

The values of $V(\tilde{M}_1 \geq \tilde{M}_2)$ and $V(\tilde{M}_2 \geq \tilde{M}_1)$ are required for comparing $\tilde{M}_1$ and $\tilde{M}_2$. The degree of possibility for a convex fuzzy number to be greater than p convex fuzzy numbers $(\tilde{M}_j, \ j = 1,2,3,...,n)$ is defined as

$$V(\tilde{M}_p \geq \tilde{M}_1, \tilde{M}_2, ..., \tilde{M}_{p-1}, \tilde{M}_{p+1}, ..., \tilde{M}_n)$$
$$= V\left[(\tilde{M}_p \geq \tilde{M}_1) \ and \ (\tilde{M}_p \geq \tilde{M}_2) and \ ... \ and \ (\tilde{M}_p \geq \tilde{M}_n)\right]$$
$$= \min V(\tilde{M}_p \geq \tilde{M}_j) = d(C_j), \quad j \neq p$$
(19)

Consequently, the weight vector $W' = (d'(C_1), d'(C_2), ..., d'(C_n))^T$, $j = 1,2,3,...,n$ is obtained. Finally, via normalization, the following normalized weight vector is obtained:

$$W = (d(C_1), d(C_2), ..., d(C_n))^T \quad (20)$$

Obtaining the weight vector via extent analysis, we can continue implementing the steps of fuzzy TOPSIS. In fuzzy TOPSIS, it is suggested that the decision makers use linguistic variables to evaluate the ratings of alternatives with respect to criteria. Table 3 gives the linguistic scale for evaluation of the alternatives. Assuming that a decision group has K people, the ratings of alternatives with respect to each criterion can be calculated as;[38]

$$\tilde{x}_{ij} = \frac{1}{K}\left[\tilde{x}_{ij}^{1}(+)\tilde{x}_{ij}^{2}(+)...(+)\tilde{x}_{ij}^{K}\right] \quad (21)$$

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

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)

Obtaining weights of the 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,

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}, \quad (22)$$

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

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. These linguistic variables can be described by triangular fuzzy numbers: $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$. Linear normalization will be used to transform the various criteria scales into a comparable scale because it does not need the complicated calculations of vector normalization. Therefore, we can obtain the normalized fuzzy decision matrix denoted by $\tilde{R}$.

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn}, \quad (23)$$

where B and C are the set of benefit criteria and cost criteria, respectively, and

$$\tilde{r} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), \quad j \in B; \quad (24)$$

$$\tilde{r} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), \quad j \in C; \quad (25)$$

$$c_j^* = \max_i c_{ij} \quad \text{if } j \in B; \quad (26)$$

$$a_j^- = \min_i a_{ij} \quad \text{if } j \in C. \quad (27)$$

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

Considering the different importance of each criterion, we can construct the weighted normalized fuzzy decision matrix as

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn}, \quad i = 1,2,...,m, \quad j = 1,2,...,n, \quad \text{where}$$

$$\tilde{v}_{ij} = \tilde{r}_{ij}(\cdot)d(C_j). \quad (28)$$

According to the weighted normalized fuzzy decision matrix, we know that the elements $\tilde{v}_{ij} \ \forall i, j$ are normalized positive triangular fuzzy numbers and their ranges belong to the closed interval [0, 1]. Then, we can define the fuzzy positive-ideal solution $(FPIS, A^*)$ and fuzzy negative-ideal solution $(FNIS, A^-)$ as

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, ..., \tilde{v}_n^*), \quad (29)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, ..., \tilde{v}_n^-), \quad (30)$$

where $\tilde{v}_j^* = (1,1,1)$ and $\tilde{v}_j^- = (0,0,0)$, $j = 1,2,...,n$. The distance of each alternative from A^* and A^- can be currently calculated as

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*), \ i = 1,2,...,m, \quad (31)$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-), \ i = 1,2,...,m, \quad (32)$$

where $d(\cdot,\cdot)$ is the distance measurement between two fuzzy numbers.

A closeness coefficient is defined to determine the ranking order of all alternatives once the d_i^* and d_i^- of each alternative A_i $(i = 1,2,...,m)$ are calculated. The closeness coefficient of each alternative is calculated as

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \quad i = 1,2,...,m. \quad (33)$$

Obviously, an alternative A_i is closer to $(FPIS, A^*)$ and farther from $(FNIS, A^-)$ as CC_i approaches to 1. Therefore, according to the closeness coefficient, we can determine the ranking order of all alternatives and select the best one from among a set of feasible alternatives.

To summarize the methodology, the steps of the multi-person multi-criteria decision making with a fuzzy set approach are given in the following.

Step 1: A group of decision-makers identifies the evaluation criteria.

Step 2: Appropriate linguistic variables for the weights of the criteria and the alternatives are chosen.

Step 3: A pairwise comparison matrix for the criteria is constructed and experts' linguistic evaluations are aggregated to get a mean value for each pairwise comparison.

Step 4. Chang's[42] extent analysis approach is used to obtain the weights of the criteria.

Step 5 Experts' linguistic evaluations with respect to each criterion are aggregated to get a mean value.

Step 6: Fuzzy decision matrix and the normalized fuzzy decision matrix are constructed for the implementation of TOPSIS.

Step 7: Weighted normalized fuzzy decision matrix is constructed.

Step 8: FPIS and FNIS are determined.

Step 9: The distance of each alternative from FPIS and FNIS are calculated, respectively.

Step 10: The closeness coefficient of each alternative is calculated.

Step 11: According to the closeness coefficient, the ranking order of all alternatives can be determined.

4. Website Quality Evaluation in Turkish e-business Market

Internet access has been available in Turkey since 1993. Cable Internet appeared in 1998. Asymmetric digital subscriber line (ADSL) was launched in 2003. The development in the Turkish telecoms market started increasing with the ending of fixed-line operator Turk Telekom's monopoly and the commencement of incumbent privatization. Currently, around 100 commercial Internet service providers in Turkey supply broadband connection. Internet usage level in Turkey is lower than the European Union (EU) average. Thus, Turkey occupies the seventh position among Internet top 10 European countries, having 26.5 million subscribers as of March 2009, overtaking Poland, Netherlands and Romania, while Germany, UK and France grab first, second and third places, respectively. As for the Internet penetration it marks significant growth of 1,225 %, rising from 2,000,000 (or 2.9%) in 2000 to 26,500,000 (34.5%) in 2009. However, Turkey still has just 6.6% of European total market share.

E-business in Turkey has been growing rapidly, though it had been fully established yet. Although most medium-sized and large companies have their own websites, they are used mainly for promotion rather than commercial transactions. Banking, where the main incentive is lower costs rather than increased sales however, is an exception. Most of the larger commercial banks in Turkey offer Internet-based banking services. As for the other companies offering online services, the most active are airlines, supermarket chains, and retailers of books and electrical goods. According to August 2009 figures there are 20153 online stores operating in Turkey. These e-stores realized 77.9 million transactions (total amount of which is around 3.5 billion USD) in the first 8 months of 2009. This figure indicates a 5% growth when the first eight months of the previous year is considered. Figure 5 gives the distribution of online stores by sectors in Turkey in 2009:

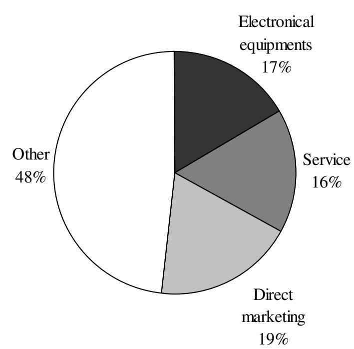

Figure 5. Sectoral distribution of e-stores in Turkey

It is expected that EU membership will become a driver for further reform Turkish e-business market. Currently users are reflecting increased acceptance of new technologies as the broadband market has experienced phenomenal growth.

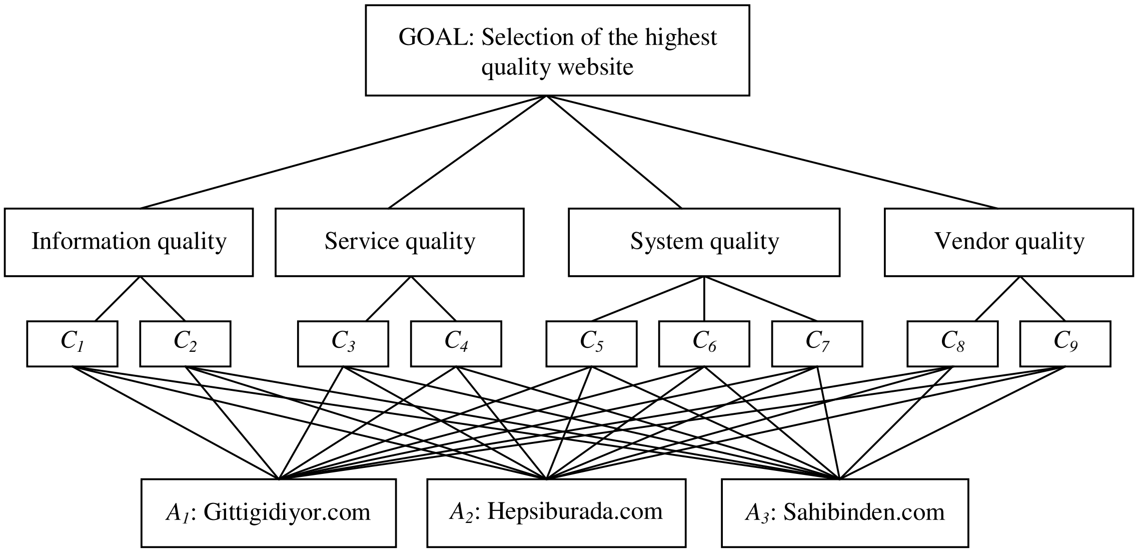

Figure 6. Hierarchical structure of the website quality evaluation problem

Table 4 Pairwise comparisons of website quality evaluation criteria

	C₁	***C₂***	***C₃***	***C₄***	***C₅***	***C₆***	***C₇***	***C₈***	***C₉***
C_1	**1**	E_1: SW E_2: VS E_3: SS	E_1: SW E_2: SS E_3: SS	E_1: FS E_2: AS E_3: SS	E_1: SS E_2: E E_3: VS	E_1: FS E_2: E E_3: VS	E_1: SW E_2: SS E_3: VS	E_1: VW E_2: SW E_3: E	E_1: FW E_2: E E_3: E
C_2	E_1: SS E_2: VW E_3: SW	**1**	E_1: E E_2: E E_3: E	E_1: SS E_2: E E_3: E	E_1: FS E_2: FW E_3: SS	E_1: SS E_2: SW E_3: SS	E_1: SW E_2: SW E_3: E	E_1: FW E_2: VW E_3: E	E_1: FW E_2: VW E_3: SS
C_3	E_1: SS E_2: SW E_3: SW	E_1: E E_2: E E_3: E	**1**	E_1: FS E_2: E E_3: E	E_1: FS E_2: FW E_3: SS	E_1: SS E_2: FW E_3: SS	E_1: SW E_2: SW E_3: SS	E_1: AW E_2: VW E_3: E	E_1: FW E_2: AW E_3: SS
C_4	E_1: FW E_2: AW E_3: SW	E_1: SW E_2: E E_3: E	E_1: FW E_2: E E_3: E	**1**	E_1: FS E_2: VW E_3: SS	E_1: SS E_2: SW E_3: SS	E_1: FW E_2: SW E_3: SS	E_1: AW E_2: VW E_3: E	E_1: VW E_2: VW E_3: E
C_5	E_1: SW E_2: E E_3: VW	E_1: FW E_2: FS E_3: SW	E_1: FW E_2: FS E_3: SW	E_1: FW E_2: VS E_3: SW	**1**	E_1: E E_2: SS E_3: E	E_1: FW E_2: SS E_3: VW	E_1: VW E_2: SW E_3: AW	E_1: FW E_2: SW E_3: E
C_6	E_1: FW E_2: E E_3: VW	E_1: SW E_2: SS E_3: SW	E_1: SW E_2: FS E_3: SW	E_1: SW E_2: SS E_3: SW	E_1: E E_2: SW E_3: E	**1**	E_1: FW E_2: FS E_3: VW	E_1: AW E_2: SW E_3: VW	E_1: VW E_2: FW E_3: SW
C_7	E_1: SS E_2: SW E_3: VW	E_1: SS E_2: SS E_3: E	E_1: SS E_2: SS E_3: SW	E_1: FS E_2: SS E_3: SW	E_1: FS E_2: SW E_3: VS	E_1: FS E_2: FW E_3:VS	**1**	E_1: SW E_2: FW E_3: E	E_1: SW E_2: FW E_3: FS
C_8	E_1: VS E_2: SS E_3: E	E_1: FS E_2: VS E_3: E	E_1: AS E_2: VS E_3: E	E_1: AS E_2: VS E_3: E	E_1: VS E_2: SS E_3: AS	E_1: AS E_2: SS E_3: VS	E_1: SS E_2: FS E_3: E	**1**	E_1: SS E_2: E E_3: SS
C_9	E_1: FS E_2: E E_3: E	E_1: FS E_2: VS E_3: SW	E_1: FS E_2: AS E_3: SW	E_1: VS E_2: VS E_3: E	E_1: FS E_2: SS E_3: E	E_1: VS E_2: FS E_3: SS	E_1: SS E_2: FS E_3: FW	E_1: SW E_2: E E_3: SW	**1**

Table 5 Fuzzy evaluation matrix for the weights

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	(1, 1, 1)	(1.06, 1.33, 1.67)	(0.89, 1, 1.33)	(1.33, 1.67, 2.17)	(1.17, 1.33, 1.67)	(1.17, 1.5, 1.83)	(1.06, 1.33, 1.67)	(0.69, 0.83, 0.89)	(1, 1, 1)
C_2	(0.69, 0.83, 1.06)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1.17)	(0.83, 1.06, 1.5)	(0.89, 1, 1.33)	(0.78, 1, 1)	(0.63, 0.72, 0.89)	(0.69, 0.83, 1.06)
C_3	(0.78, 1, 1.17)	(1, 1, 1)	(1, 1, 1)	(1, 1.17, 1.33)	(0.83, 1.06, 1.5)	(0.83, 0.89, 1.33)	(0.78, 1, 1.17)	(0.58, 0.63, 0.72)	(0.78, 1, 1.17)
C_4	(0.5, 0.69, 0.83)	(0.89, 1, 1)	(0.83, 0.89, 1)	(1, 1, 1)	(0.8, 1, 1.39)	(0.89, 1, 1.33)	(0.72, 0.89, 1.17)	(0.58, 0.63, 0.72)	(0.5, 0.69, 0.83)
C_5	(0.69, 0.83, 0.89)	(0.72, 1.06, 1.33)	(0.72, 1.06, 1.33)	(0.89, 1.22, 1.5)	(1, 1, 1)	(1, 1, 1.17)	(0.63, 0.72, 1.06)	(0.47, 0.63, 0.72)	(0.69, 0.83, 0.89)
C_6	(0.63, 0.72, 0.89)	(0.78, 1, 1.17)	(0.78, 1.17, 1.33)	(0.78, 1, 1.17)	(0.89, 1, 1)	(1, 1, 1)	(0.63, 0.89, 1.22)	(0.47, 0.63, 0.72)	(0.63, 0.72, 0.89)
C_7	(0.69, 0.83, 0.69)	(1, 1, 1.33)	(0.89, 1, 1.33)	(0.89, 1.17, 1.5)	(1.06, 1.5, 1.83)	(1, 1.39, 1.83)	(1, 1, 1)	(0.72, 0.89, 1)	(0.69, 0.83, 0.69)
C_8	(1.17, 1.33, 1.67)	(1.17, 1.5, 1.83)	(1.5, 1.83, 2.17)	(1.5, 1.83, 2.17)	(1.5, 1.83, 2.33)	(1.5, 1.83, 2.33)	(1, 1.17, 1.5)	(1, 1, 1)	(1.17, 1.33, 1.67)
C_9	(1, 1.17, 1.33)	(1.06, 1.5, 1.83)	(1.22, 1.67, 2)	(1.33, 1.67, 2)	(1, 1.17, 1.5)	(1.17, 1.5, 2)	(0.83, 1.06, 1.5)	(0.78, 1, 1)	(1, 1.17, 1.33)

* Consistency ratio (CR) for the defuzzified version of this matrix is 0.036<0.10

Table 6 Results of the fuzzy AHP procedure for the determination of the weights

	$\tilde{S}_j = \tilde{M}_j = \left(l_j, m_{j,}, u_j\right)$	$W'_j = d'(C_j)^T$	$W_j = d(C_j)^T$
C_1	(0.088, 0.125, 0.181)	0.72143	0.156
C_2	(0.071, 0.096, 0.137)	0.33246	0.072
C_3	(0.071, 0.097, 0.14)	0.3599	0.078
C_4	(0.065, 0.089, 0.127)	0.21925	0.047
C_5	(0.066, 0.097, 0.137)	0.33595	0.073
C_6	(0.062, 0.094, 0.129)	0.25308	0.055
C_7	(0.076, 0.113, 0.163)	0.57326	0.124
C_8	(0.109, 0.154, 0.224)	1	0.217
C_9	(0.09, 0.135, 0.194)	0.82231	0.178

Table 7 Evaluation scores of the alternatives

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	E_1: G E_2: G E_3: F	E_1: G E_2: MG E_3: VG	E_1: MG E_2: F E_3: MG	E_1: MG E_2: F E_3: MG	E_1: MG E_2: MG E_3: MG	E_1: F E_2: MG E_3: MP	E_1: F E_2: G E_3: MG	E_1: F E_2: P E_3: MP	E_1: MG E_2: VG E_3: MG
A_2	E_1: MG E_2: G E_3: MG	E_1: F E_2: G E_3: G	E_1: P E_2: MP E_3: P	E_1: G E_2: G E_3: MG	E_1: G E_2: G E_3: VG	E_1: MP E_2: F E_3: MP	E_1: MP E_2: F E_3: MG	E_1: F E_2: MP E_3: MP	E_1: G E_2: G E_3: G
A_3	E_1: F E_2: MP E_3: MG	E_1: G E_2: F E_3: F	E_1: MG E_2: MP E_3: G	E_1: F E_2: F E_3: F	E_1: F E_2: F E_3: F	E_1: F E_2: MG E_3: F	E_1: G E_2: MG E_3: MG	E_1: MG E_2: F E_3: G	E_1: VG E_2: VG E_3: VG

Table 8 Fuzzy normalized evaluation matrix for the website alternatives

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	(0.61, 0.82, 0.96)	(0.72, 0.9, 1)	(0.52, 0.76, 1)	(0.45, 0.66, 0.86)	(0.5, 0.7, 0.9)	(0.39, 0.65, 0.91)	(0.54, 0.75, 0.93)	(0.15, 0.35, 0.58)	(0.63, 0.8, 0.93)
A_2	(0.61, 0.82, 1)	(0.59, 0.79, 0.93)	(0.04, 0.2, 0.44)	(0.66, 0.86, 1)	(0.77, 0.93, 1)	(0.22, 0.48, 0.74)	(0.32, 0.54, 0.75)	(0.19, 0.42, 0.65)	(0.7, 0.9, 1)
A_3	(0.32, 0.54, 0.75)	(0.45, 0.66, 0.83)	(0.36, 0.6, 0.8)	(0.31, 0.52, 0.72)	(0.3, 0.5, 0.7)	(0.48, 0.74, 1)	(0.61, 0.82, 1)	(0.58, 0.81, 1)	(0.9, 1, 1)

Table 9 Fuzzy weighted decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	(0.09, 0.13, 0.15)	(0.05, 0.06, 0.07)	(0.04, 0.06, 0.08)	(0.02, 0.03, 0.04)	(0.04, 0.05, 0.07)	(0.02, 0.04, 0.05)	(0.07, 0.09, 0.12)	(0.03, 0.07, 0.12)	(0.11, 0.14, 0.17)
A_2	(0.09, 0.13, 0.16)	(0.04, 0.06, 0.07)	(0, 0.02, 0.03)	(0.03, 0.04, 0.05)	(0.06, 0.07, 0.07)	(0.01, 0.03, 0.04)	(0.04, 0.07, 0.09)	(0.04, 0.09, 0.14)	(0.12, 0.16, 0.18)
A_3	(0.05, 0.08, 0.12)	(0.03, 0.05, 0.06)	(0.03, 0.05, 0.06)	(0.01, 0.02, 0.03)	(0.02, 0.04, 0.05)	(0.03, 0.04, 0.05)	(0.08, 0.1, 0.12)	(0.12, 0.17, 0.22)	(0.16, 0.18, 0.18)

Though, in spite of the fact e-business in the country is constantly growing, it still remains limited. Nevertheless e-business progress shows optimistic signs, promising country to become one of the European leaders.

In this study, websites of the three e-business leaders in Turkey (A_1: gittigidiyor.com, A_2: hepsiburada.com, and A_3: sahibinden.com) are evaluated with respect to quality attributes. The phrase "gitti, gidiyor!" means "going, going, gone!" in Turkish language. "Hepsi burada" refer to "all in here" and "sahibinden" "for sale by owner (FSBO)", respectively. The three e-business companies considered in this study are among the first three in Turkey in terms of both hit statistics and revenue realized based on e-transactions. According to 2009 figures, all three are among the first 25 websites with respect to entry statistics.[43] The consideration set can be widened by adding other e-business companies operating in Turkey. However, we have not chosen to do so as none of these candidates are among the first 100 in terms of entry statistics and have comparable amounts of revenues with the three leaders we have chosen to evaluate. Figure 6 gives the hierarchical structure of the website quality evaluation problem formulated in this study. A simplified version of the model of Lee and Kozar[7] is used for evaluating the alternatives. Evaluation criteria are briefly explained below:

Information quality can be measured using information relevance, currency, and understandability.

Relevance and currency (C_1): This criterion includes relevant depth, completeness, and updating of the information provided by the e-business website.

Understandability (C_2): Understandability refers to ease of understanding and clearness of the information provided by the website.

Service quality refers to the overall support delivered by the Internet retailers. Service quality becomes more critical in e-business since online customers transact with unseen retailers. In this study reliability and empathy criteria are found to be applicable to measure e-business service quality.

Reliability (C_3): This criterion refers to the ability and willingness to perform the promised service dependably and accurately.

Empathy (C_4): Empathy refers to the caring and attention the online retailer provides its customer

Website system quality has been widely considered to have a significant effect on online customer satisfaction and amount of online purchases.[33,44] System quality can be measured by response speed, personalization, and security attributes.

Response speed (C_5): This criterion refers to the average response time of the website. Fast response is important to increase system quality.

Personalization (C_6): Personalization refers to the ability of providing online customers an individualized interface, effective one-to-one information, and customized service.

Security (C_7): Security is the ability of providing safety and protection to online customers who take the risk of disclosing their personal and financial information.

Internet vendor-specific quality factors like awareness and price competitiveness have also been considered crucial in providing e-business success.

Price savings (C_8): This criterion refers to the ability of lowering the cost of trade and providing online customers better prices.

Awareness (C_9): Website awareness is directly related to brand loyalty and network effects. Users prefer to select goods that have been selected by a large number of other users. Awareness of the website is increased when a critical mass that knows and wants to experience the website.[7]

After determining the evaluation criteria and the alternative set, the steps of the integrated fuzzy AHP-TOPSIS methodology is implemented. In order to determine the relative importance of each website evaluation criterion, the experts used a nine point scale which can be seen in Table 2. Each term is associated with a triangular fuzzy number. Table 4 gives the results of the pairwise comparisons of evaluation criteria made by three IS experts.

Using Table 2 and Table 4 we obtained the fuzzy evaluation matrix for the criteria weights as in Table 5. In order to obtain this matrix, the arithmetic means of the fuzzy scores in Table 4 are calculated. Next, in order to check the consistency ratio (CR) of the evaluation matrix, the graded mean integration approach (Eq. 12) is utilized for defuzzifying thematrix. CR for the crisp version of the evaluation matrix is calculated as 0.036 and it is less than 0.10. Thus, the comparison results can be considered consistent.

In the next step, using Eq. (14) fuzzy synthetic extent values $\tilde{S}_j$ for the evaluation criteria are produced. After obtaining the synthetic extent values, Eqs. (15-19) are used for calculating the weight vector. Finally, via normalization, the normalized weight vector is obtained as in Table 6.

Next step is the determination of the highest quality website using proposed fuzzy TOPSIS procedure. To do this, three experts evaluated the alternatives with respect to each criterion using Table 3. Table 7 gives the evaluation results made by three waste management experts. In the next step, computing the arithmetic means of the fuzzy evaluation results, the evaluation matrix is obtained. Then, Eqs. (24-27) are used to produce fuzzy normalized evaluation matrix as in Table 8. Following this step, the weighted normalized fuzzy decision matrix (see Table 9) is constructed utilizing Eq. (28). After obtaining the fuzzy weighted decision table, Eqs. (29-32) are used to calculate the distance of each alternative from the positive ideal $(FPIS, A^*)$ and negative ideal $(FNIS, A^-)$ solutions. Finally, Eq. (33) is used for calculating the closeness coefficient (CC_i) of each alternative.

Table 10 Fuzzy modified TOPSIS results

	d_i^-	d_i^*	CC_i
A_1	0.696	8.328	0.077
A_2	0.668	8.358	0.074
A_3	0.741	8.280	0.082

The results of the modified fuzzy TOPSIS analysis are summarized in Table 10. Based on CC_i values, the ranking of the alternatives in descending order are A_3, A_1, and A_2. According to the last step, the best alternative is A_3 (Sahibinden.com). The order of the rest is 'Gittigidiyor.com' and 'Hepsiburada.com'.

5. Sensitivity Analysis

A sensitivity analysis is conducted in order to see the robustness of the preference ranking among the alternative websites to changes in the criteria weights. Table 11 gives the composition of criteria weights in the considered cases. Figure 7 shows the order of the alternatives based on CC_i index values with respect to different weight configurations.

Figure 7 indicates that 'Sahibinden.com' is the best website in the current case (CS). In Case 1, 'Sahibinden.com' is still the best. As it seen in Table 11, the weight of the *price savings* criterion (C_8) is relatively higher in Case 1. 'Gittigidiyor.com' becomes the best quality e-business website in Case 2, Case 3, and Case 4. In Case 2, the weight of the *awareness* criterion (C_9) is relatively higher. In case 3, the prevailing criterion becomes the *response speed* (C_5). In Case 5, the criteria with the highest weights are *relevance and currency* (C_1) and *understandability* (C_2). In the last two cases, due to the changes in the weights of criteria shown in Table 11, 'Hepsiburada.com' becomes the website with the highest quality.

Table 11: Criteria weights with respect to the considered cases

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
CS	0.16	0.07	0.08	0.05	0.07	0.05	0.12	0.22	0.18
Case 1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Case 2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Case 3	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Case 4	0.22	0.22	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Case 5	0.08	0.08	0.08	0.22	0.22	0.08	0.08	0.08	0.08
Case 6	0.25	0.05	0.05	0.2	0.25	0.05	0.05	0.05	0.05

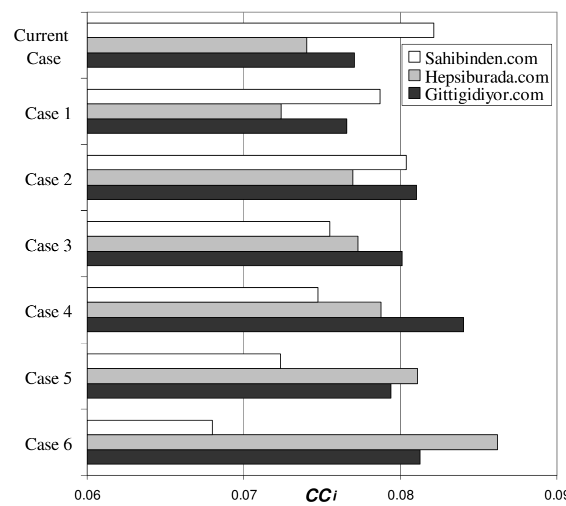

Figure 7. Sensitivity analysis

Sensitivity analysis shows that the ranking among the alternatives is quite sensitive to the changes in the weights of evaluation criteria.

6. Conclusions

In this paper a model for evaluating website quality within e-business context has been proposed. Website quality evaluation is a multi dimensional problem which both quantitative and qualitative attributes must be considered. Since qualitative criteria make the evaluation process hard and vague, it is easier to express the judgments of experts in fuzzy numbers rather than crisp numbers. The integrated fuzzy AHP-TOPSIS methodology proposed here employs linguistic variables in the evaluation of both attributes and alternatives. In determining the weights of the criteria, a fuzzy AHP procedure is utilized in order to allow pairwise comparisons. We modified Chen's[38] fuzzy TOPSIS weighting procedure by using the comparison matrices of Chang's[42] fuzzy AHP extension.

E-business in Turkey is a constantly growing sector which shows optimistic signs, promising the country to become one of the leaders in Europe. In this study, three Turkish e-business companies' websites are evaluated with respect to information quality, system quality, service quality, and vendor quality. A preference rank order among the e-business websites is maintained. Sensitivity analysis showed that the ranking among the websites could change due to the changes in the criteria weights.

The author believes that the fuzzy methodology proposed in this study can successfully handle the problem of website quality evaluation which contains complexity and imprecision. For further research, the results of this study may be compared with the results of other fuzzy MCDM methods like SAW, VIKOR, ELECTRE, or PROMETHEE. Moreover, the proposed website quality evaluation methodology may be applied to other sectors like music, airline, health, or banking.

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