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Ranking B2C Web Sites with AHP and TOPSIS Under Fuzzy Environment

Bekir AĞIRGÜN

Military Academy, Institute of Defense Science

bekiragi@gmail.com

Abstract

Electronic commerce has changed the outlook of traditional business trading behavior. It is now common to see business-to-business (B2B), business-to-consumer (B2C) and consumer-to-consumer (C2C) commerce on the Internet. Furthermore, deciding the best alternative B2C web site has multi-level and multi-factor features. To tackle this problem, a conceptual framework was proposed. Then, fuzzy sets aided Analytical Hierarchy Process and Similarity to Ideal Solution were used to solve this problem. This paper will help managers to find out the consumers' expectations from a website while enhancing the capabilities of it.

Keywords:E-commerce, B2C, fuzzy sets, multi-criteria decision making, AHP, TOPSIS

B2C Web Sitelerinin AHS ve TOPSIS ile Bulanık Ortamda Sıralanması

Özet

Elektronik ticaret, geleneksel alım-satım alışkanlıklarını değiştirmiştir. Şimdilerde internet üzerinde, işletmeden işletmeye (B2B), işletmeden tüketiciye (B2C) ve tüketiciden tüketiciye (C2C) yönelen ticaret oldukça yaygınlaşmıştır. Bununla birlikte, alternatif web siteleri içerisinden en iyi B2C web sitesine karar verme işlemi çoklu seviye ve çoklu faktör özelliklerine sahiptir. Makalede, bu problemin çözümü için kavramsal bir model önerilmiştir. Bunun için, bulanık kümeler yardımıyla Analitik Hiyerarşi Süreci ve TOPSIS yöntemleri kullanılmıştır. Makale, web sitesi yöneticilerine, müşterilerin beklentilerini anlamanın yanısıra web sitesi bileşenlerinin geliştirilmesi yönünde yardımcı olacaktır.

Anahtar kelimeler: E-ticaret, B2C, Bulanık kümeler, Çok kriterli karar verme, AHS, TOPSIS

1. Introduction

Since the introduction of the first electronic web services in the mid-nineties of the last century, internet has provided new and vast business opportunities. Internet has changed not only the classical business environment but also transformed the consumers' habits. At the beginning of year 2012, 7.2 billion web sites are known to exist (http://www.worldwidewebsize.com). This indicates how e-business is spread all over the world. In business point of view, understanding the consumers' expectations for e-commerce web sites has become a critical factor for success on business. In that context, e-commerce refers to the buying and selling of products or services over electronic systems such as the Internet and other computer networks (http://en.wikipedia.org/wiki/Electronic_ commerce). In the last decade, numerous studies have been made on the web site quality and its impacts on business. Hasan and Abuelrub [1] proposed some criteria for evaluating the quality of web sites. Zhang and Dran [2] studied on the user perceptions of web sites and offered several criteria. Jarvenpaa and Todd [3] concentrated on identifying the factors that affect the willingness of consumers to engage in Internet shopping. Zhang and Li [4] have proposed a taxonomy of consumer online shopping attitudes and consumer behavior. Liao, Palvia and

Lin [5] have shown that consumers' behavioral intentions to continue using a B2C (Business to Consumer) web site are determined by perceived usefulness, trust, and habit. Stefani and Xenos [6] have proposed a weighted model which uses the external quality characteristics and sub-characteristics of ISO-9126 as a baseline for further decomposition into technical and user-oriented features. Iwaarden et al. [7] made a factor analysis on web quality aspects.

The B2C web sites ranking problem has multi-level and multi-factor features. Such difficulties can be regarded as multiple criteria decision making (MDCM). A considerable number of decision models have been developed based on the MCDM theory, such as AHP (Analytical Hierarchy Process) [8], ANP (Analytical NetworkProcess) [9], TOPSIS (Similarity to Ideal Solution) [10], VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) [11], ELECTRE (ELimination Et Choix Traduisant la REalité) [12], PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) [13]. In addition to these ones, numerous hybrid methods exist as well. However, in real life the available information in a MCDM process is usually uncertain, vague, or imprecise, and the criteria are not necessarily independent. To tackle the vagueness in information and the essential fuzziness of human judgment/preference, fuzzy set theory was proposed by Zadeh in 1965 [14]. Besides, Bellman and Zadeh [15] were the first to introduce the theory of fuzzy sets in problems of multi-criteria decision making as an effective approach to treat vagueness, lack of knowledge and ambiguity inherent in the human decision making process which are known as fuzzy multi-criteria decision making (FMCDM).

The main objective of this study is to evaluate different B2C web sites from where consumers can buy their needs in contentment. This study consists of two steps; in the first step fuzzy AHP (FAHP) is used to determine the relative weights of the evaluation criteria. In the second step, fuzzy TOPSIS (FTOPSIS) method is applied to rank the alternatives. These two approaches are used because of several reasons. (a) The reasoning in fuzzy logic is similar to human reasoning. It allows for approximate values and inferences as well as incomplete or ambiguous data (fuzzy data) as opposed to only relying on crisp data (binary yes/no choices). Fuzzy logic is able to process incomplete data and provide approximate solutions to problems that are difficult to solve with other methods [16]. (b) FAHP and FTOPSIS methodologies are easy to understand and use. (c) Using only FAHP might mislead the analysts. For further analysis, FTOPSIS is offered. In order to evaluate the web sites, the attributes of five B2C web sites which are hosted in Turkey were used. The web sites were evaluated in terms of five main criteria; ease of use, product, security, customer relationship and fulfillment which all totally have 20 sub-criteria.

The rest of the paper is organized as follows: In the Material and Methods section; FAHP and FTOPSIS methods are defined. In Results and Discussion section; the application of two methods are demonstrated and the results are discussed. Conclusion is given in the final section.

2. Materials and Methods

In this section; preliminary of fuzzy sets, FAHP and FTOPSIS methods are explained. The AHP, first introduced by Saaty, is the one of the most widely adopted MCDM methods. It decomposes a problem into several levels of making up a hierarchy where each decision element is considered to be independent. The distinct strength of method lies in the effective manipulation of quantitative criteria as well as qualitative ones [17]. Furthermore, Saaty's AHP has some shortcomings which can be summarized as follows; (a) The AHP method is mainly used in nearly crisp decision applications, (b) The AHP method creates and deals with a very unbalanced scale of judgment, (c) The AHP method does not take into account the uncertainty associated with the mapping of one's judgment to a number, (d) Ranking of the AHP method is rather imprecise (e) The subjective judgment, selection and preference of decision-makers have great influence on the AHP method [18]. To overcome these problems, several researchers integrated fuzzy theory with AHP to improve the uncertainty. The earliest research in FAHP appeared in Van Laarhoven and Pedrycz [19], which compared fuzzy ratios described by triangular membership functions and the logarithmic least squares method to obtain element sequencing. Buckley [20] used the geometrical mean method to produce fuzzy values. Chang [21] introduced a new approach for handling fuzzy AHP with the use of both triangular fuzzy numbers for pair-wise comparison scale of fuzzy AHP, and the extent analysis method. Mon [22] presented a method for evaluating weapon systems using fuzzy AHP based on entropy weight calculations. Chen [23] proposed a modified method using simplified fuzzy number arithmetic operations rather than the complicated entropy weight calculations in [22]. Cheng [24], proposed an algorithm for evaluating naval tactical missile systems by the fuzzy AHP method and entropy concepts to calculate aggregate weights. FAHP approach has been applied to various problems ranging from facility location selection [25] to performance evaluation [26]. Recently, various application studies have been made using FAHP method integrated with other methodologies. Büyüközkan and Çiftçi [27] have studied on electronic service quality based on SERVQUAL via FAHP and FTOPSIS method. In Sun's paper [28], an evaluation study was performed for notebook companies by means of FAHP and FTOPSIS method. Another notable study was made by Dağdeviren, Yavuz and Kılınç [29]. In their study, AHP and TOPSIS methods were used for light weapon selection with six different criteria under fuzzy environment.

2.1 Fuzzy sets

Definition 1. A fuzzy set $\tilde{a}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{a}}(x)$, which associates with each element x in X a real number interval [0,1]. The function value $\mu_{\tilde{a}}(x)$ is termed the grade membership of x in $\tilde{a}$ [14]. In this study, the triangular fuzzy number is used. A triangular fuzzy number (TFN) $\tilde{M}$ can be defined by a triplet (l, m, u). The parameters denote "the smallest possible value", "the most promising value" and "the largest possible value that describe a fuzzy event.

Each TFN can be defined as;

$$\mu(x \mid \tilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \le x \le m, \\ (u-x)/(u-m), & m \le x \le u, \\ 0, & x > u. \end{cases} \tag{1}$$

Definition 2. Let $\tilde{a} = (l_1, m_1, u_1)$ and $\tilde{b} = (l_2, m_2, u_2)$ be two TFN. Then a vertex method is defined to calculate the distance between them.

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}\left[(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2\right]} \tag{2}$$

Definition 3. The basic operations on TFN are;

For addition;

$$\tilde{a} \oplus \tilde{b} = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{3}$$

For multiplication;

$$\tilde{a} \otimes \tilde{b} = (l_1 \text{x}\, l_2, m_1 \text{x}\, m_2, u_1 \text{x}\, u_2) \tag{4}$$

2.2 Fuzzy Analytic Hierarchy Process

Let $X = \{x_1, x_2, ..., x_n,\}$ be an object set, and $U = \{u_1, u_2, ..., u_m,\}$ be a goal set. According to Chang's [21] extent analysis, each object is taken and extent analysis for each goal, g_i, is performed respectively. Therefore m extent analysis values for each object can be obtained with the following signs:

$$M_{g_i}^1, M_{g_i}^1, ..., M_{g_i}^1 \quad i = 1,2, \ ..., n \tag{5}$$

The steps of Chang's extent analysis are given as following;

Step 1. The value of fuzzy synthetic extent withrespecttothe i thobject is defined as

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} \tag{6}$$

To obtain $\sum_{j=1}^{m} M_{g_i}^j$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that;

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \quad \sum_{j=1}^{m} m_j, \quad \sum_{j=1}^{m} u_j \right) \tag{7}$$

And to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1}$, perform the fuzzy addition operation of $M_{g_i}^j \quad (j = 1,2,...,m)$ values such that;

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \quad \sum_{i=1}^{n} m_i, \quad \sum_{i=1}^{n} u_i \right) \tag{8}$$

and then, compute the inverse of the vector in Eq.(8) such that;

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \quad \frac{1}{\sum_{i=1}^{n} m_i}, \quad \frac{1}{\sum_{i=1}^{n} l_i} \right) \tag{9}$$

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

$$V(M_2 \geq M_1) = \sup_{y \geq x} \left\lfloor \min(\mu_{M_1}(x), \mu_{M_2}(y) \right\rfloor \tag{10}$$

And can be equivalently expressed as follows;

$$V(M_2 \geq M_1) = height(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1, & if \ m_2 \geq m_1, \\ 0 & if \ l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise, \end{cases} \tag{11}$$

In order to compare M_1 and M_2, boththevalues of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$ are needed.

Step 3. The degree of possibility for a convex fuzzy number to be greaterthan k convex fuzzy numbers $M_1 \ (i=1,2...,k)$ can be defined by;

$$V(M \geq M_1, M_2, ..., M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } ..., (M \geq M_k)] = \min V(M \geq M_i) \quad i = 1,2, \ ..., k. \tag{12}$$

Assume that;

$$d'(A_i) = \min V(S_i \geq S_k) \text{ for } k = 1,2,...,n; k \neq i. \tag{13}$$

Then the vector is given by;

$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T$ where $A_i \ (i = 1,2,...,n)$ are n elements.

Step 4. Via normalization, the normalized weight vectors are;

$W = (d(A_1), d(A_2), ..., d(A_n))^T$ where W is non-fuzzynumber.

2.3 Fuzzy TOPSIS

TOPSIS was proposed by Hwang and Yoon [10] to determine the best alternative based on the concepts of the compromise solution. The compromise solution can be regarded as choosing the solution with the shortest Euclidean distance from the ideal solution and the farthest Euclidean distance from the negative ideal solution [30]. However, it is often difficult for a decision-maker to assign a precise performance rating to an alternative for the attributes under consideration. The merit of using a fuzzy approach is to assign the relative importance of attributes using fuzzy numbers instead of precise numbers. This section extends the TOPSIS to the fuzzy environment. The mathematics concept was borrowed from Yang and Hung [31].

The procedures of FTOPSIS can be described as follows.

The fuzzy MADM can be concisely expressed in matrix format as Eqs. (14) and (15).

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & C_3 & \cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \tilde{x}_{13} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \tilde{x}_{23} & \cdots & \tilde{x}_{2n} \\ \tilde{x}_{31} & \tilde{x}_{32} & \tilde{x}_{33} & \cdots & \tilde{x}_{3n} \\ \vdots & \vdots & \vdots & & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \tilde{x}_{m3} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array} \tag{14}$$

$$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, ..., \tilde{w}_n] \tag{15}$$

Where $\tilde{x}_{ij}, i = 1,2,...m, \quad j = 1,2,...,n$ and $\tilde{w}_j, j = 1,2,...n$ are linguistic triangula rnumbers, $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ and $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$. Note that $\tilde{x}_{ij}$ is the performance rating of the i th alternative, A_i, with respect to j th attribute, C_j and $\tilde{w}_j$ represents the weight of the j th attribute, C_j.The normalized fuzzy decision matrix denoted by $\tilde{R}$ is defined as;

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn}. \tag{16}$$

The weighted fuzzy normalized decision matrix is shown as;

$$\tilde{V} = \begin{bmatrix} \tilde{w}_1\tilde{r}_{11} & \tilde{w}_2\tilde{r}_{12} & \cdots & \tilde{w}_j\tilde{r}_{1j} & \cdots & \tilde{w}_n\tilde{r}_{1n} \\ \tilde{w}_1\tilde{r}_{21} & \tilde{w}_2\tilde{r}_{22} & \cdots & \tilde{w}_j\tilde{r}_{2j} & \cdots & \tilde{w}_n\tilde{r}_{2n} \\ & & & & & \\ \tilde{w}_1\tilde{r}_{i1} & \tilde{w}_2\tilde{r}_{i2} & \cdots & \tilde{w}_j\tilde{r}_{ij} & \cdots & \tilde{w}_n\tilde{r}_{in} \\ & & & & & \\ \tilde{w}_1\tilde{r}_{m1} & \tilde{w}_1\tilde{r}_{m1} & \cdots & \tilde{w}_j\tilde{r}_{mj} & \cdots & \tilde{w}_n\tilde{r}_{mn} \end{bmatrix} \quad (17)$$

In this study $\tilde{w}_j$ is a real number that was calculated by FAHP and $\sum_{j=1}^{n} \tilde{w}_j = 1$

Given the above fuzzy theory, the FTOPSIS procedure is defined as follows:

Step 1. Choose the linguistic ratings $(\tilde{x}_{ij}, i = 1,2,...,m, j = 1,2,...,m)$ for alternatives and the appropriate linguistic variables $(\tilde{w}_j, j = 1,2,..,n)$ for the weight of the criteria.

The fuzzy linguistic rating, $\tilde{x}_{ij}$, preserves the property that the ranges of normalized triangular fuzzy numbers belong to [0,1]; thus, there is no need for normalization procedure. For this instance, the $\tilde{D}$ is defined by Eq. (14) is equivalent to the $\tilde{R}$ defined by Eq. (16).

Step 2. Construct the weighted normalized fuzzy decision matrix. The weighted normalized value $\tilde{V}$ is calculated by Eq.(17).

Step 3. Identify positive-ideal solution $(FPIS, A^*)$ and the fuzzy negative-ideal solution $(FNIS, A^-)$ are shown as Eqs.(18-19);

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, ..., \tilde{v}_n^*) = \left\{ \left(\max_i v_{ij} \mid i = 1,2,...,m \right), j = 1,2,...,n \right\} \quad (18)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, ..., \tilde{v}_n^-) = \left\{ \left(\min_i v_{ij} \mid i = 1,2,...,m \right), j = 1,2,...,n \right\} \quad (19)$$

Step 4. Calculate separation measures. The distance of each alternative from A^* and A^- can be currently calculated using Eqs.(20-21)

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*), i = 1,2,...,m, \quad (20)$$

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

Step 5. Calculate similarities to ideal solution. This step solves the similarities to an ideal solution by Eq.(22):

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad (22)$$

Step 6. Rank preference order. Choose an alternative with maximum CC_i^* or rank alternatives according to CC_i^* in descending order.

3. Application of proposed model

3.1. Implementation of the proposed model for ranking B2C web sites

The proposed model for ranking B2C web sites is composed of FAHP and FTOPSIS approaches which have the following procedures. Figure 1 shows the proposed model.

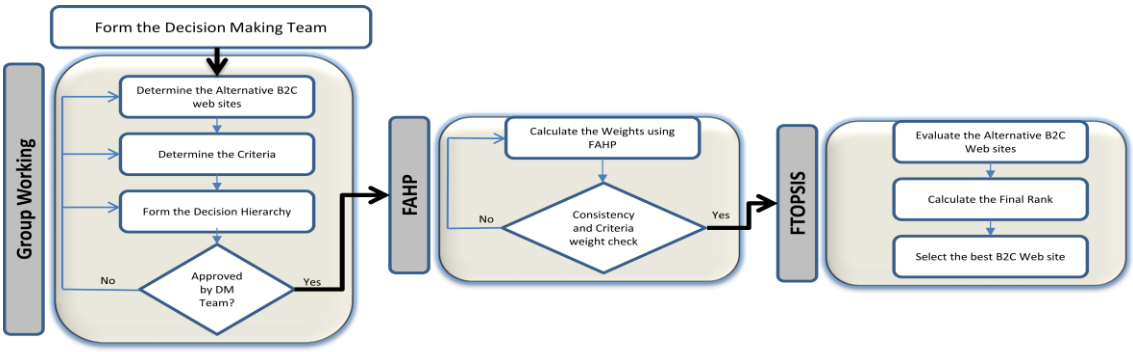

Figure 1. Proposed Approach

3.1.1. Group Working

In the first phase, B2C websites and the criteria to be used in ranking and decision hierarchy were determined. Formal AHP model was established such that the goal is in the first level, while criteria and the alternatives are in the second and the third levels respectively.

Thegroup of experts decided the criteria to be as follows; (1) Ease of Use (1.1) Completing a transaction quickly, (1.2) Ease of navigation, (1.3) Easy to find needs, (1.4) Ease of Online transaction, (1.5) Easy to get different pages in website (2) Product, (2.1) Product detail, (2.2) Product Price detail, (2.3) Product Quality, (2.4) Comment on products by customer (2.5) Competitive product price (3) Security (3.1) Online purchase security, (3.2) Protection of personal information, (3.3) Privacy statement, (4) Customer relationship (4.1) Quick response to customer demands, (4.2) Direction of registration, (4.3) Online customer service support and help (4.4) Online order status tracking (5) Fulfillment, (5.1) On-time delivery, (5.2) Accurate delivery of products, (5.3) Accurate billing. The hierarchy of the problem is shown in Figure 2. From now on, the criteria above will be represented by C_i.

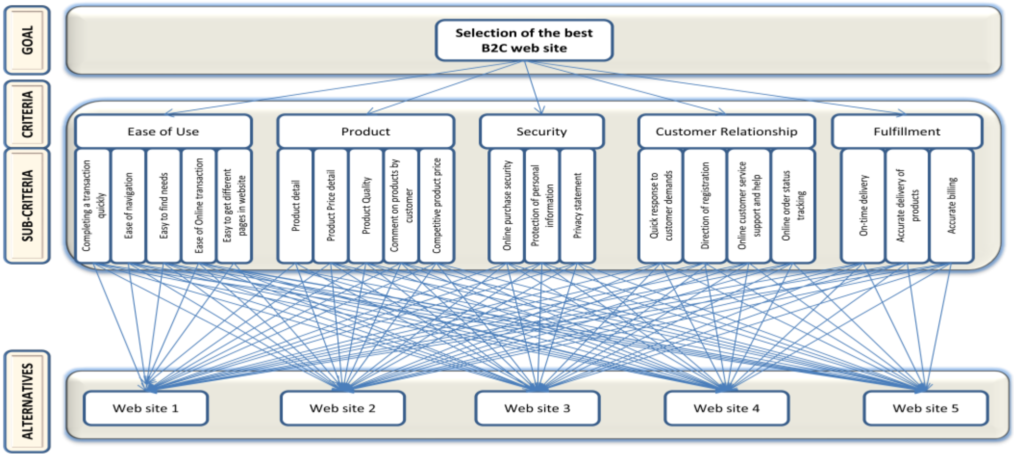

Figure 2. Hierarchy of the problem

3.1.2. FAHP-Criteria Weight Calculation

In this stage, fuzzy analytical hierarchy process was used. Ten experts made pair-wise comparisons in order to obtain the criteria weights. The consistency of pair-wise comparisons has been checked. They used the scale represented in Table 1. In order to form a final pair-wise comparison matrix, arithmetic means of the values obtained from each pair-wise comparison were calculated. The final matrix was approved by the experts. The pair-wise comparison matrix for five criteria is shown in Table 2. At this stage, the expert group also made the pair-wise comparisons for the sub-criteria and the alternatives. Summary of the evaluation criteria weights are given Table 3.

Table 1. Definition and membership function of fuzzy scale for importance of the criteria

Intensity of importance	Fuzzy number	Definition	Membership Function	
			Triangular Fuzzy Scale	**Triangular fuzzy reciprocal scale**
9	$\tilde{9}$	Extremely more importance	(1,1,1)	(1,1,1)
7	$\tilde{7}$	Very strong importance	(2/3,1,3/2)	(2/3,1,3/2)
5	$\tilde{5}$	Strongly importance	(3/2,2,5/2)	(2/5,1/2,2/3)
3	$\tilde{3}$	Moderate importance	(5/2,3,7/2)	(2/7,1/3,2/5)
1	$\tilde{1}$	Equal importance	(7/2,4,9/2)	(2/9,1/4,2/7)

Table 2. Pair-wise comparison matrix for five criteria

	C1	**C2**	**C3**	**C4**	**C5**
C1	1,1,1	2/3,1,3/2	2/5,1/2,2/3	2/3,1,3/2	2/3,1,3/2
C2	2/3,1,3/2	1,1,1	2/3,1,3/2	2/3,1,3/2	1,1,1
C3	3/2,2,5/2	2/3,1,3/2	1,1,1	3/2,2,5/2	2/3,1,3/2
C4	2/3,1,3/2	2/3,1,3/2	2/5,1/2,2/3	1,1,1	2/3,1,3/2
C5	2/3,1,3/2	1,1,1	2/3,1,3/2	2/3,1,3/2	1,1,1

Table 3. Summary of the evaluation criteria weights

Criteria	*Local Importance*	*Sub-Criteria*	*Local Importance*	*Global Importance*
Ease of Use (C1)	0.1701	Completing a transaction quickly	0.2464	0.0419
		Ease of navigation	0.0000	0.0000
		Easy to find needs	0.0000	0.0000
		Ease of Online Transaction	**0.7536**	**0.1282**
		Easy to get different pages in website	0.0000	0.0000
Product (C2)	0.1908	Product detail	0.0000	0.0000
		Product price detail	0.0892	0.0170
		Product quality	**0.5629**	**0.1074**
		Comment on products by customer	0.2102	0.0401
		Competitive product price	0.1377	0.0263
Security (C3)	0.2784	Privacy statement	0.4565	0.1271
		Protection of personal information	0.0000	0.0000
		Online purchase security	**0.5435**	**0.1513**
Customer relationship (C4)	0.1701	Quick response to customer demands	**0.5571**	0.0947
		Direction of registration	0.0000	0.0000
		Online customer service support and help	0.4429	0.0753
		Online order status tracking	0.0000	0.0000
Fulfillment (C5)	0.1908	On-time delivery	0.0000	0.0000
		Accurate delivery of products	**0.5000**	**0.0954**
		Accurate billing	**0.5000**	**0.0954**

3.1.3. FTOPSIS-Evaluation of the B2C websites

In this stage, web sites will be ranked according to their CC_i (satisfaction degree) values. Table 4 shows the relationship between linguistic values and TFN. Figure 3 shows the fuzzy triangular membership function.

Table 4. Transformation of TFN for FTOPSIS

Rank	Sub-criteria Grade	Membership function
Very Low (VL)	1	(0.00,0.10,0.25)
Low (L)	2	(0.15,0.30,0.45)
Medium (M)	3	(0.35,0.50,0.65)
High (H)	4	(0.55,0.70,0.85)
Very High (VH)	5	(0.75,0.90,1.00)

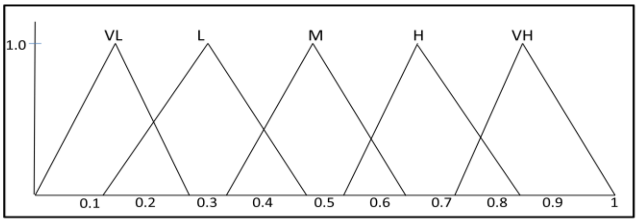

Figure 3. Fuzzy triangular membership function

The first step while ranking the websites is to form the decision making matrix. This is shown in Table 5. In order to transform the performance ratings to fuzzy linguistic variables, the performance ratings in Table 5 are normalized into the [0,1] range with Eq (23-24).

Table 5. Decision matrix

Alternatives	**C1**	**C2**	**C3**	**C4**	**C5**
Web site 1	0.1345	0.1964	0.2256	0.2694	0.1430
Web site 2	0.4215	0.2930	0.2851	0.2123	0.1547
Web site 3	0.0300	0.1097	0.1359	0.1762	0.0632
Web site 4	0,0000	0.0507	0.1359	0.1402	0.2150
Web site 5	0.4140	0.3503	0.2176	0.2020	0.4242
Weight	0.1701	0.1908	0.2784	0.1701	0.1908

The larger the better criteria (the larger the rating, the greater the importance, benefit);

$$r_{ij} = \frac{[x_{ij} - \min\{x_{ij}\}]}{[\max\{x_{ij}\} - \min\{x_{ij}\}]} \tag{23}$$

The smaller the better criteria (the smaller the rating, the greater the importance, cost);

$$r_{ij} = \frac{[\max\{x_{ij}\} - x_{ij}]}{[\max\{x_{ij}\} - \min\{x_{ij}\}]} \tag{24}$$

Table 6. Normalized decision matrix and corresponding linguistic variables

	C1	C2	C3	C4	C5
Web site 1	0.3192 ***L***	0.4861 ***M***	0.6010 ***M***	1 ***VH***	0.2208 ***L***
Web site 2	1 ***VH***	0.8089 ***H***	1 ***VH***	0.5580 ***M***	0.2534 ***L***
Web site 3	0.0712 ***VL***	0.1968 ***VL***	0 ***VL***	0.2786 ***L***	0 ***VL***
Web site 4	0 ***VL***	0 ***VL***	0 ***VL***	0 ***VL***	0.4204 ***M***
Web site 5	0.9821 ***VH***	1 ***VH***	0.5476 ***M***	0.4784 ***M***	1 ***VH***
Weight	0 ***VL***	0.1912 ***VL***	1 ***VH***	0 ***VL***	0.1912 ***VL***

For this study; the criteria are considered to be classified as "benefit". Then, all calculations were made through this assumption. The fuzzy decision matrix, including weights, were normalized via Eq.(23). After calculating the normalized decision matrix, the values were turned into linguistic variables by means of the scale shown in Figure 3. Both the results and the corresponding linguistic variables that are defined for FTOPSIS are shown in Table 6. Then the weighted fuzzy normalized decision matrix was calculated via Eq.(17). Results are shown in Table 7.

In order to illustrate steps 4 and 5, CC_1 value needs the following calculations;

$$d_1^* = \sqrt{\frac{1}{3}[(1-0)^2 + (1-0.03)^2 + (1-0.1125)^2} + \sqrt{\frac{1}{3}[(1-0)^2 + (1-0.05)^2 + (1-0.163)^2}$$

$$+\sqrt{\frac{1}{3}[(1-0.2526)^2 + (1-0.45)^2 + (1-0.65)^2} + \sqrt{\frac{1}{3}[(1-0)^2 + (1-0.09)^2 + (1-0.25)^2}$$

$$+\sqrt{\frac{1}{3}[(1-0)^2 + (1-0.03)^2 + (1-0.1125)^2} + \sqrt{\frac{1}{3}[(1-0)^2 + (1-0.09)^2 + (1-0.25)^2} = 1.95$$

$$d_1^- = \sqrt{\frac{1}{3}[(0-0)^2 + (0-0.03)^2 + (0-0.1125)^2} + \sqrt{\frac{1}{3}[(0-0)^2 + (0-0.05)^2 + (0-0.163)^2}$$

$$+\sqrt{\frac{1}{3}[(0-0.2526)^2 + (0-0.45)^2 + (0-0.65)^2} + \sqrt{\frac{1}{3}[(0-0)^2 + (0-0.09)^2 + (0-0.25)^2}$$

$$+\sqrt{\frac{1}{3}[(1-0)^2 + (1-0.03)^2 + (1-0.1125)^2} + \sqrt{\frac{1}{3}[(1-0)^2 + (1-0.09)^2 + (1-0.25)^2} = 0.523$$

By means of Eq.(22);

$$CC_1 = \frac{d_1^-}{d_1^* + d_1^-} = \frac{0.523}{0.523 + 1.95} = 0.2114$$

Other calculations were applied in the same way. The final results are shown in Table 7. Based on the table, the rank of the B2C web sites are as follows;

Web site 2 > Web site 5 > Web site 1 > Web site 4 > Web site 3

Table 7. Weighted evaluation and corresponding satisfaction degree (CC_i) of B2C websites

	C1	C2	C3	C4	C5	d_1^*	d_1^-	CC_i
Web site 1	(0, 0.03, 0.113)	(0, 0.05, 0.1635)	(0.263, 0.45, 0.65)	(0, 0.09, 0.250)	(0, 0.03,0.113)	1.9511	0.5230	0.2114
Web site 2	(0, 0.09, 0.250)	(0, 0.07, 0.213)	(0.563, 0.81, 1)	(0, 0.05, 0.163)	(0, 0.03, 0.113)	1.8651	0.8440	0.3115
Web site 3	(0, 0.01, 0.063)	(0, 0.01, 0.063)	(0.000, 0.09, 0.25)	(0, 0.03, 0.113)	(0, 0.01, 0.063)	2.1367	0.1790	0.0773
Web site 4	(0, 0.01, 0.063)	(0, 0.01, 0.063)	(0.000, 0.09, 0.25)	(0, 0.01, 0.063)	(0, 0.05, 0.163)	2.1270	0.1928	0.0831
Web site 5	(0, 0.09, 0.250)	(0, 0.09, 0.250)	(0.263, 0.45, 0.65)	(0, 0.05, 0.163)	(0, 0.09, 0.250)	1.8925	0.5582	0.2278
$A*$	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)			
A^-	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)			

4. Results

Preference orders for websites in different MCDM approaches are shown in Table 8. The weights obtained from FAHP method directly affected the cumulative result. For the instance of imprecise or vague performance ratings, the fuzzy sets were utilized.

This study not only deals with the ranking of the B2C websites, but also provides the website managers a better understanding of the people's perceptions of those websites. In this context, a balance should be established between the website security and the ease of use. This, at the same time, will encourage people to shop online. Moreover, enhancing both the customer relationships and fulfillment will provide customer loyalty and improve the quality of service. Another important issue is the warranty terms and conditions. Explaining the warranty terms and conditions of the products sold definitely and clearly to the customers and offering them not only the legal rights but also some extended warranty options will create a positive change in online shopping habits.

Table 8. Preference order for websites in different MCDM approaches.

Preference order	1	2	3	4	5
FTOPSIS (Unweighted)	Web site 5	Web site 2	Web site 1	Web site 4	Web site 3
FAHP	Web site 2	Web site 5	Web site 1	Web site 4	Web site 3
FANP	Web site 5	Web site 2	Web site 1	Web site 3	Web site 4
FAHP+TOPSIS	Web site 5	Web site 2	Web site 1	Web site 4	Web site 3
FAHP+FTOPSIS	Web site 2	Web site 5	Web site 1	Web site 4	Web site 3

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