Fuzzy MCDM Approach for E-Commerce Websites Selection Design

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Abstract: *This paper presents a fuzzy multiple-criteria analysis approach for E-commerce website evaluation. After comparing with the existing main methods, an E-commerce websites evaluation model has been constructed, and the design process has been presented. For E-commerce website evaluation, relitives of experts, owners and users can just give linguistic comparing descriptions of evaluation criteria. The Fuzzy Analytic Hierarchy Process (FAHP) method is used to determine the weights for criteria among experts. Incorporated the attitudes of decision makers towards preference, a crisp overall performance value is obtained for each alternative based on the concept of Fuzzy Multiple-Criteria Decision Making (FMCDM). A case study consisting of five experts' interviews illustrates the proposed method.*

***Keywords*:** Website evaluation; AHP; Fuzzy logic; MCDM

1. INTRODUCTION

Nowadays, economic commerce (E-commerce) provides more convenient, faster and cheaper way of shopping, internet banking, employing etc. And E-commerce website has become a significant selling way of almost all enterprises. As the result, it becomes necessary for both companies and customers to evaluate the e-commerce websites. However evaluation of an e-commerce website is not familiar with most of enterprises. It includes quite a lot of technical and professional knowledge.

As well as the evaluation method is not the tradition one which is using Boolean logic. However it is a kind of logic related artificial fuzzy logic [1]. Fuzzy logic reflects how people think. It attempts to model our sense of words, our decision making and our common sense.

In the evaluation process, there are many criteria and even sub-criteria. After comparison with current E-commerce websites evaluation methods, it was found that it is natural to bring in Analytic hierarchy process (AHP) [2], which is one of the most commonly used multiple-criteria decision making methods. To achieve the previous two aims, we decided to research an approach of evaluating e-commerce website based on Fuzzy Analytic Hierarchy Process (FAHP). We divided decision makers as three groups: experts, owners and users. Furthermore the construction of the proposed model and the whole designing process has been presented. Along with a case study is undertaken to determine the weights of criteria and sub-criteria for e-commerce website evaluation.

2. ANALYSIS OF E-COMMERCE WEBSITES EVALUATION

2.1 E-commerce website

Electronic commerce, commonly known as e-commerce, eCommerce or e-comm, refers to the buying and selling of products or services over electronic systems such as the Internet and other computer networks. However, the term may refer to more than just buying and selling products online. It also includes the entire online process of developing, marketing, selling, delivering, servicing and paying for products and services.

By the end of 2000, many European and American business companies offered their services through the World Wide Web. Since then people began to associate a word "ecommerce" with the ability of purchasing various goods through the Internet using secure protocols and electronic payment services.

While E-commerce application is a complex system, for businesses, the E-commerce website plays different roles in the following aspects. So E-commerce websites take important positions in the whole E-commerce field.

2.2 The importance of evaluating E-commerce websites

After observing a turbulent e-business environment with the burst of the dot.com bubble, companies realized that e-business is not a magic bullet and a license.

The importance of evaluating E-commerce websites success has long been recognized by both E-commerce websites researchers and practitioners. Evaluation is a challenging task because information systems are complex socio-technical entities, E-commerce website investment is related to intangible benefits and indirect costs, and financial data to measure impact of E-commerce websites typically are not accumulated.

Evaluation is the comparison of actual impacts against strategic plans. It looks at original objectives, at what was accomplished and how it was accomplished. It can be formative that is taking place during the life of a project or organization, with the intention of improving the strategy or way of functioning of the project or organization. It can also be summative, drawing lessons from a completed project or an organization that is no longer functioning. Evaluation is inherently a theoretically informed approach (whether explicitly or not), and consequently a definition of evaluation would have be tailored to the theory, approach, needs, purpose and methodology of the evaluation itself. Commonly the aim is to gain the weight over all criteria. Therefore, we constructed the evaluation process as the below, in which Z_E refers to the evaluation process, A refers to major evaluation algorithm, and R stands for the weighting result.

$$Z_E \xrightarrow{A} R, \quad (1)$$

In general, two approaches are widely known: quantitative and qualitative. For quantitative methods, R as weights can be calculated through several mathematical A and Z_E can be described as

$$Z_E = (S, d), \quad (2)$$

where S stands for structure of the evaluation method and d stands for data used in evaluation process; for qualitative methods, R can be judged as "how good (bad) is it".

2.3 Main methods evaluating e-commerce

It has been found that several quantitative methods have been used in evaluating e-commerce websites. [3] and [4] used Quality Evaluation Method (QEM) to measure the functionality (global search, navigability and content relevancy), usability (site map, addresses directory), efficiency and site reliability of websites. The method was also used by [5] to evaluate product quality. Another method known as Analytic Hierarchy Process (AHP), developed first by Satty in 1971 was used to solve the scarce resources allocation and planning needs for the military. AHP later had become one of the most widely used tools for making decisions based on multiple-criteria. Grey analysis method (GA) was used to measure the distance between the set of every evaluation object's scores and the set of the best score of each criterion, and choose the object whose distance is the shortest to be the best website. It found that this method gave near value of evaluation [6].

Another important method was Data Envelopment Analysis (DEA). This method was used to evaluate multiple-criterion problems and improve the efficiencies. According to [7], DEA is a powerful quantitative, analytical method for measuring and evaluating performance.

In terms of qualitative methods several methods have been found. Zadeh initiated the fuzzy set theory and Bellman presented some applications of fuzzy theories to the various decision-making processes in a fuzzy environment [8]. Fuzzy theory is widely applicable in information gathering, modeling, analysis, optimization, control, decision making and supervision. Fuzzy is used in support of linguistic variables and there is uncertainness in the problem.

Barnes[9] designed a "WebQual" system to assess E-commerce quality, with no interests on quantity considering; Miranda[10] designed a quality evaluation method with criteria of functionality, usability, efficiency and reliability, but it can not combine experts opinions; Abd El-Aleem [8] constructed a mathematical model to compare website traffic, but had not covered the synthesizing the weights of several experts; Chu[11] presented the ranking of websites from best to worst using fuzzy logic, however could not know the absolute value of each website; and Hung[12] developed an evaluation instrument for E-commerce websites, which was only user's satisfaction from the first-time buyer's view and discussed less about quality analysis.

In terms of best evaluation method, it is difficult to pin point which is the best, quantitative or qualitative? This is because each has its advantages and disadvantages and researchers are experts in their own way and chose to evaluate based on their own expertise in analysis. In terms of measurements, which of the five categories is the best measurement? It is definitely an ideal if a comprehensive measurement is incorporated in an evaluation.

2.4 Proposed methods evaluating e-commerce

Since the criteria of E-commerce websites evaluation have diverse significance and meanings, we cannot assume that each evaluation criteria is of equal importance. There are many methods that can be employed to determine weights such as the eigenvector method, weighted least square method, entropy method, AHP (Analytic Hierarchy Process), and LINMAP (linear programming techniques for Multidimensional of Analysis Preference). The selection of method depends on the nature of the problem. To evaluate E-commerce websites is a complex and wide-ranging problem, so this problem requires the most inclusive and flexible method. In (2), d's domain has been define as D, which has been shown below:

$$D = N \cup P \cup L, d \in D, \quad (3)$$

where N stands for numeral set, P stands for parameter set, and L stands for linguistic description set. However, in operation process of applying AHP method, it is more easy and humanistic for evaluators to assess "criterion A is much more important than criterion B" than to consider "the importance of principle A and principle B is seven to one". Hence, Buckley [13] extended Saaty's AHP to the case where the evaluators are allowed to employ fuzzy ratios in place of exact ratios to handle the difficulty for people to assign exact ratios when comparing two criteria and derive the fuzzy weights of criteria by geometric mean method. Therefore, in this study, we employ Buckley's method, FAHP, to fuzzify hierarchical analysis by allowing fuzzy numbers for the pairwise comparisons and find the fuzzy weights. In this section, we briefly review concepts for fuzzy hierarchical evaluation.

3. DESIGN OF E-COMMERCE WEBSITES SELECTION MODEL

The purpose of this section is to establish a hierarchical structure for solve the evaluation problem of E-commerce websites evaluation. The contents include two subsections: hierarchical structure of evaluation criteria and determining the weights of evaluation criteria.

3.1 Hierarchical structure of selection criteria

Design, reliability and usability are three criteria based on which the evaluation is performed. For each criterion, four sub-criteria have been considered [1]. In the last part of rules matching, there are four criteria for each standard and five assess characters for each criterion. Table 1 shows the hierarchical structure with criteria, sub-criteria and explanation. [14].

3.2 Determining weights of the evaluation criteria

3.2.1 General definitions and notifications

1) *Fuzzy number*

A fuzzy number is an extension of a regular number in the sense that it does not refer to one single value but rather to a connected set of possible values, where each possible value has its own weight between 0 and 1. This weight is called the membership function. A fuzzy number is thus a special case of a convex fuzzy set [15]. According to the definition of Laarhoven[16], a triangular fuzzy number (TFN) should possess the following basic features.

A fuzzy number $\tilde{A}$ on R to be a TFN if its membership function $\mu_{\tilde{A}}(x): R \to [0,1]$ is equal to (4).

Table 1. The hierarchical structure for E-commerce website selection

Criteria	Sub-criteria
Usability (C_1)	Accuracy (C_{11})
	Authority (C_{12})
	Current information (C_{13})
	Efficiency (C_{14})
Reliability (C_2)	Security (C_{21})
	Functionality (C_{22})
	Integrity (C_{23})
	Navigation (C_{24})
Design (C_3)	Aesthetic features (C_{31})
	Contents (C_{32})
	Layout (C_{33})
	Standard conformance (C_{34})

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-L)/(M-L), & L \le x \le M, \\ (U-x)/(U-M), & M \le x \le U, \\ 0, & otherwise, \end{cases} \quad (4)$$

where L and U stand for the lower and upper bounds of the fuzzy number $\tilde{A}$, respectively, and M for the modal value (see Figure 1). The TFN can be denoted by $\tilde{A} = (L, M, U)$ and the following is the operational laws of two TFNs $\tilde{A}_a = (L_a, M_a, U_a)$ and $\tilde{A}_b = (L_b, M_b, U_b)$, as shown [17]:

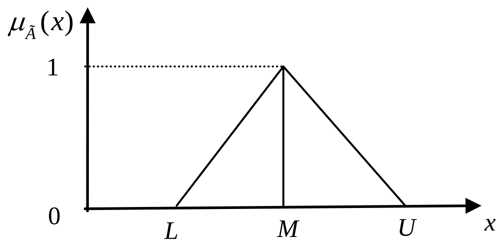

Fig.1 – The membership function with the triangular fuzzy number.

Addition of a fuzzy number $\oplus$

$$\tilde{A}_a \oplus \tilde{A}_b = (L_a, M_a, U_a) \oplus (L_b, M_b, U_b) = (L_a + L_b, M_a + M_b, U_a + U_b), \quad (5)$$

Multiplication of real number k and a fuzzy number

$$k \bullet \tilde{A} = k \bullet (L, M, U) = (kL, kM, kU), \quad (6)$$

Subtraction of a fuzzy number

$$\tilde{A}_a \Theta \tilde{A}_b = (L_a, M_a, U_a) \Theta (L_b, M_b, U_b) = (L_a - L_b, M_a - M_b, U_a - U_b), \quad (7)$$

Multiplication of a fuzzy number

$$\tilde{A}_a \otimes \tilde{A}_b = (L_a, M_a, U_a) \otimes (L_b, M_b, U_b) = (L_a L_b, M_a M_b, U_a U_b), \quad for\, L_i > 0, M_i > 0, U_i > 0. \quad (8)$$

Division of a fuzzy number

$$\tilde{A}_a \Delta \tilde{A}_b = (L_a, M_a, U_a) \Delta (L_b, M_b, U_b) = (L_a/U_b, M_a/M_b, U_a/L_b), \quad for\ L_i > 0, M_i > 0, U_i > 0. \quad (9)$$

Reciprocal of a fuzzy number

$$\tilde{A}^{-1} = (L, M, U)^{-1} = (1/U, 1/M, 1/L), \quad for\ L > 0, M > 0, U > 0. \quad (10)$$

2) Linguistic variables

According to Zadeh [18], it is very difficult for conventional quantification to express reasonably those situations that are overtly complex or hard to define; so the notion of a linguistic variable is necessary in such situation. A linguistic variable is a variable whose values are words or sentences in a natural or artificial language. Here, we use this kind of expression to compare two building E-commerce websites evaluation criteria by five basic linguistic terms, as “absolutely important,” “very strongly important,” “essentially important,” “weakly important” and “equally important” with respect to a fuzzy five level scale (see Figure 2) [19]. In this paper, the computational technique is based on the following fuzzy numbers defined by Mon et al. [20] in Table 2. Here each membership function (scale) is defined by three parameters of the symmetric triangular fuzzy number, the left point, middle point and right point of the range over which the function is defined. The use of linguistic variables is currently widespread and the linguistic effect values of E-commerce websites found in this study are primarily used to assess the linguistic ratings given by the evaluators.

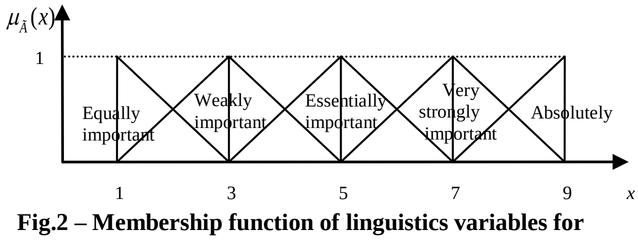

Fig.2 – Membership function of linguistics variables for comparing two criteria.

3) Ranking the fuzzy number

The result of the fuzzy synthetic decision reached by each alternative is a fuzzy number. Therefore, it is necessary that a nonfuzzy ranking method for fuzzy numbers be employed for comparison of each E-commerce websites. In other words, the procedure of defuzzification is to locate the Best Nonfuzzy Performance value (BNP). Methods of such defuzzified fuzzy ranking generally include mean of maximal (MOM), center of area (COA), and a-cut. To utilize the COA method to find out the BNP is a simple and practical method, and there is no need to bring in the preferences of any evaluators, so it is used in this study. The BNP value of the fuzzy number $\tilde{R}_i$ can be found by the following equation:

$$BNP_i = \left[(UR_i - LR_i) + (MR_i - LR_i)\right] / 3 + LR_i \ \forall i, \qquad (11)$$

Table 2. Fuzzy scale and linguistic expression of relative importance between two criteria and performance values

Intensity of importance	Fuzzy number	Definition of linguistic scale
1	$\tilde{1}$	Equal importance; *very poor*
3	$\tilde{3}$	Weak importance of one over another; *poor*
5	$\tilde{5}$	Essentially important; *normal*
7	$\tilde{7}$	Very strongly important; *good*
9	$\tilde{9}$	Absolutely important; *very good*
2, 4, 6, 8	$\tilde{2}, \tilde{4}, \tilde{6}, \tilde{8}$	Intermediate values between two adjacent judgments

3.2.2 Fuzzy analytic hierarchy process

The procedure for determining the evaluation criteria weights by FAHP can be summarized as follows:

Step 1. Construct pairwise comparison matrices among all the elements/criteria in the dimensions of the hierarchy system. Assign linguistic terms to the pairwise comparisons by asking which is the more important of each two elements/criteria, such as

$$\tilde{A} = [\tilde{a}_{ij}] = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} \end{array} = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & 1 \end{bmatrix} \end{array} \qquad (12)$$

where

$$\tilde{a}_{ij} = \begin{cases} \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9} & \text{i is importance than j;} \\ 1 & i = j; \\ \tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} & \text{i is less importance than j.} \end{cases}$$

Step 2. To use geometric mean technique to define the fuzzy geometric mean and fuzzy weights of each criterion by Buckley [3] as follows:

$$\tilde{r}_i = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \cdots \otimes \tilde{a}_{in})^{1/n}, \qquad (13)$$
$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \cdots \oplus \tilde{r}_n)^{-1},$$

where $\tilde{a}_{in}$ is fuzzy comparison value of criterion i to criterion n, thus, $\tilde{r}_i$ is geometric mean of fuzzy comparison value of criterion i to each criterion, $\tilde{w}_i$ is the fuzzy weight of the *i*th criterion, can be indicated by a TFN, $\tilde{w}_i = (Lw_i, Mw_i, Uw_i)$. Here Lw_i, Mw_i and Uw_i stand for the lower, middle and upper values of the fuzzy weight of the *i*th criterion.

3.3 Fuzzy multiple criteria decision-making

Bellman and Zadeh [18] were the first to probe into the DM problem under a fuzzy environment and they heralded the initiation of FMCDM. This analysis method has been widely used to deal with DM problems involving multiple criteria evaluation/selection of alternatives. This study uses this method to evaluate the E-commerce website alternatives performance and rank the priority for them accordingly.

Using the measurement of linguistic variables to demonstrate the criteria performance (effect-values) by expressions such as “very good,” “good,” “fair,” “poor,” “very poor,” the evaluators are asked for conduct their subjective judgments, and each linguistic variable can be indicated by a TFN within the scale range 0-100, as shown in Figure 3. In addition, the evaluators can subjectively assign their personal range of the linguistic variable that can indicate the membership functions of the expression values of each evaluator. Take $\tilde{E}_{ij}^k$ to indicate the fuzzy performance value of evaluator *k* towards alternative *i* under criterion *j*, and all of the evaluation criteria will be indicated by $\tilde{E}_{ij}^k = (LE_{ij}^k, ME_{ij}^k, UE_{ij}^k)$. Since the perception of each evaluator varies according to the evaluator_s experience and knowledge, and the definitions of the linguistic variables vary as well, this study uses the notion of average value to integrate the fuzzy judgment values of m evaluators, that is,

$$\tilde{E}_{ij}^k = (1/m) \otimes (\tilde{E}_{ij}^1 \oplus \tilde{E}_{ij}^2 \oplus \cdots \oplus \tilde{E}_{ij}^m) \qquad (14)$$

The sign $\otimes$ denotes fuzzy multiplication, the sign $\oplus$ denotes fuzzy addition, $\tilde{E}_{ij}$ shows the average fuzzy number of the judgment of the decision-makers, which can be displayed by a triangular fuzzy number as $\tilde{E}_{ij} = (LE_{ij}, ME_{ij}, UE_{ij})$. The end-point values LE_{ij}, ME_{ij} and UE_{ij} can be solved by the method put forward by Buckley [6], that is,

$$LE_{ij} = \left(\sum_{k=1}^{m} LE_{ij}^k\right) \Big/ m;$$
$$ME_{ij} = \left(\sum_{k=1}^{m} ME_{ij}^k\right) \Big/ m; \qquad (15)$$
$$UE_{ij} = \left(\sum_{k=1}^{m} UE_{ij}^k\right) \Big/ m$$

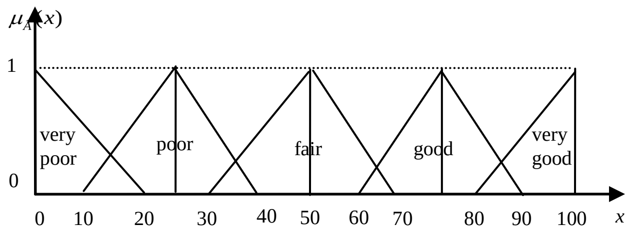

Fig. 3 – Example of membership function of linguistic variables for measuring

4. CASE OF F-MCMD TO E-COMMERCE WEBSITES SELECTION

In this section, an example of the application of FAHP to determine the weights of criteria and sub-criteria for

E-commerce website evaluation is given to demonstrate this approach.

The overall goal has been stated as determining the weights of criteria and sub-criteria for E-commerce website evaluation. Based on Matlab, a general consensus among experts can be synthesized. To determine the relative importance of the evaluation criteria C_1-C_3, they were pair-wise compared with respect to the goal by using the triangular fuzzy numbers.

According to the formulated structure of building E-commerce websites evaluation, the weights of the criteria hierarchy can be analyzed. The simulation process was followed by a series of interviews with decision-making group experts. Weights were obtained by using the FAHP method. The following example demonstrates the computational procedure of the weights of criteria for experts:

(1) According to the interviews with five experts about the importance of evaluation dimensions, afterward the pairwise comparison matrices of dimensions(criteria) can be achieved as follows:

$$\begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & poor & good \\ & 1 & poor \\ & & 1 \end{bmatrix} \end{array} \qquad \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & very\_poor & normal \\ & 1 & poor \\ & & 1 \end{bmatrix} \end{array}$$

experts_1 experts_2

$$\begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & less\_poor & good \\ & 1 & poor \\ & & 1 \end{bmatrix} \end{array} \qquad \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & less\_poor & very\_good \\ & 1 & normal \\ & & 1 \end{bmatrix} \end{array}$$

experts_3 experts_4

$$\begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & less\_normal & very\_poor \\ & 1 & less\_very\_poor \\ & & 1 \end{bmatrix} \end{array}$$

experts_5

(2) Applying the fuzzy numbers defined in Table 1, the linguistic scales can be transferred to the corresponding fuzzy numbers as below:

$$\begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & \tilde{3} & \tilde{7} \\ \tilde{3}^{-1} & 1 & \tilde{3} \\ \tilde{7}^{-1} & \tilde{3}^{-1} & 1 \end{bmatrix} \end{array} \qquad \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & \tilde{1} & \tilde{5} \\ \tilde{1}^{-1} & 1 & \tilde{3} \\ \tilde{5}^{-1} & \tilde{3}^{-1} & 1 \end{bmatrix} \end{array}$$

experts_1 experts_2

$$\begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & \tilde{3}^{-1} & \tilde{7} \\ \tilde{3} & 1 & \tilde{3} \\ \tilde{7}^{-1} & \tilde{3}^{-1} & 1 \end{bmatrix} \end{array} \qquad \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & \tilde{3}^{-1} & \tilde{9} \\ \tilde{3} & 1 & \tilde{5} \\ \tilde{9}^{-1} & \tilde{5}^{-1} & 1 \end{bmatrix} \end{array}$$

experts_3 experts_4

$$\begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & \tilde{5}^{-1} & \tilde{1} \\ \tilde{5} & 1 & \tilde{1}^{-1} \\ \tilde{1}^{-1} & \tilde{1} & 1 \end{bmatrix} \end{array}$$

experts_5

(3) Computing the elements of synthetic pairwise comparison matrix by using the geometric mean method suggested by Buckley [13]: that is $\tilde{a}_{ij} = (\tilde{a}_{ij}^1 \otimes \tilde{a}_{ij}^2 \otimes \tilde{a}_{ij}^3 \otimes \tilde{a}_{ij}^4 \otimes \tilde{a}_{ij}^5)^{1/5}$, for $\tilde{a}_{12}$ as an example:

$$\begin{aligned} \tilde{a}_{12} &= (\tilde{3} \otimes \tilde{1} \otimes \tilde{3}^{-1} \otimes \tilde{3}^{-1} \otimes \tilde{5}^{-1})^{1/5} \\ &= ((1,3,5) \otimes (1,1,3) \otimes (\frac{1}{5},\frac{1}{3},1) \otimes (\frac{1}{5},\frac{1}{3},1) \otimes (\frac{1}{7},\frac{1}{5},\frac{1}{3}))^{1/5} \\ &= ((1 \times 1 \times \frac{1}{5} \times \frac{1}{5} \times \frac{1}{7})^{1/5}, (3 \times 1 \times \frac{1}{3} \times \frac{1}{3} \times \frac{1}{5})^{1/5}, (5 \times 3 \times 1 \times 1 \times \frac{1}{3})^{1/5}) \\ &= (0.356, 0.582, 1.380) \end{aligned}$$

It can be obtained the other matrix elements by the same computational procedure, therefore, the synthetic pairwise comparison matrices of the five representatives will be constructed as follows:

$$\begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 1 & (0.356, 0.582, 1.380) & (0.181, 0.214, 0.336) \\ (0.725, 1.718, 2.809) & 1 & (1, 2.667, 3.876) \\ (2.976, 4.673, 5.525) & (0.258, 0.375, 1) & 1 \end{bmatrix} \end{array}$$

(4) To use Eq. (13) to obtain the fuzzy weights of dimensions for owners group, that is:

$$\begin{aligned} \tilde{r}_1 &= (\tilde{a}_{11} \otimes \tilde{a}_{12} \otimes \tilde{a}_{13})^{1/3} \\ &= ((1, 1, 1) \otimes (0.356, 0.582, 1.380) \otimes (0.181, 0.214, 0.336))^{1/3} \\ &= ((1 \times 0.356 \times 0.181)^{1/3}, (1 \times 0.582 \times 0.214)^{1/3}, (1 \times 1.380 \times 0.336)^{1/3}) \\ &= (0.401, 0.499, 0.774) \end{aligned}$$

Likewise, we can obtain the remaining $\tilde{r}_2 = (0.898, 1.661, 2.237)$ and $\tilde{r}_3 = (0.916, 1.206, 1.768)$.

For the weight of each dimension, they can be done as follows :

$$\begin{aligned} \tilde{w}_1 &= \tilde{r}_1 \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \tilde{r}_3)^{-1} \\ &= (0.401, 0.499, 0.774) \otimes ((0.401, 0.499, 0.774) \\ &\quad \oplus (0.898, 1.661, 2.237) \oplus (0.916, 1.206, 1.768))^{-1} \\ &= (0.401, 0.499, 0.774) \otimes (1/(0.774 + 2.237 + 1.768), \\ &\quad 1/(0.499 + 1.661 + 1.206), 1/(0.401 + 0.898 + 0.916)) \\ &= (0.401, 0.499, 0.774) \otimes (0.209, 0.297, 0.451) \\ &= (0.084, 0.148, 0.349) \end{aligned}$$

Similarly, $\tilde{w}_2 = (0.188, 0.493, 1.009)$ and $\tilde{w}_3 = (0.191, 0.358, 0.797)$.

(5) To employ the COA method to compute the BNP value of the fuzzy weights of each dimension:

To take the BNP value of the weight of usability (C_1) for experts as an example, the calculation is as follows.

$$\begin{aligned} BNP_{w_1} &= [(UR_1 - LR_1) + (MR_1 - LR_1)]/3 + LR_1 \\ &= [(0.349 - 0.084) + (0.148 - 0.084)]/3 + 0.084 \\ &= 0.194 \end{aligned}$$

Likewise $BNP_{w_2} = 0.563$, $BNP_{w_3} = 0.449$ and the weights for the remaining sub-criteria can be found as shown in Table 3. However, for limitation of article space, we omitted fuzzy weights of the other two groups and average of the three, but we listed the overall weights of subcriteria in Table 3.

Table 3. Weights of criteria and sub-criteria

Cri-teria	**Weights of groups**			**sub-criteri a**	**Overall weights of sub-**
	experts	**owners**	**users**		

					criteria
C_1	0.194	0.117	0.327	C_{11}	0.053
				C_{12}	0.076
				C_{13}	0.033
				C_{14}	0.032
C_2	0.563	0.386	0.367	C_{21}	0.119
				C_{22}	0.065
				C_{23}	0.100
				C_{24}	0.279
C_3	0.449	0.446	0.253	C_{31}	0.153
				C_{32}	0.132
				C_{33}	0.089
				C_{34}	0.075

5. CONCLUSION

The reason of this study was to develop a scientific framework for the E-commerce websites evaluation. In commercial area, E-commerce website is a highly professional service, which involves significant information of company and clients, transaction functions and amount of specialized effort. Although judging the quality of the E-commerce websites may be subjective, evaluation of the E-commerce websites is even more so. In current methods of E-commerce websites evaluation, company agencies rely only on a panel of experts to perform the evaluation, neglecting the fuzziness of subjective judgment and other relative interest groups perception in this process. Thus, an effective evaluation procedure is essential to promote the decision quality. This work examines this group decision-making process and proposes a multiple-criteria framework for E-commerce websites evaluation. To deal with the qualitative attributes in subjective judgment, this work employs FAHP to determine the weights of decision criteria for each relative expert representative. This process enables decision makers to formalize and effectively solve the complicated, multiple-criteria and fuzzy perception problem of most appropriate E-commerce websites evaluation. A case study of proposed E-commerce websites evaluation is used to demonstrate the approach. The basic concepts applied were understandable to the decision making groups, and the computation required is straightforward and simple. It will also support making critical decisions during the selecting in MCDM field.

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