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Rank B2C e-commerce websites in e-alliance based on AHP and fuzzy TOPSIS

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ABSTRACT

E-alliance is the union of e-commerce and its success and efficiency is related to comprehensive quality of e-commerce. Thus, ranking e-commerce websites in e-alliance is of importance, which is a multi-criteria decision-making (MCDM) problem. This paper proposes an evaluation model based on analytic hierarchy process (AHP), fuzzy sets and technique for order performance by similarity to ideal solution (TOPSIS), to tackle the issue in fuzzy environment. The AHP is applied to analyze the structure of ranking problem and to determine weights of the criteria, fuzzy sets is utilized to present ambiguity and subjectivity with linguistic values parameterized by triangular fuzzy numbers, and TOPSIS method is used to obtain final ranking. Case analysis is conducted to illustrate the utilization of the model for the problem. It demonstrates the effectiveness and feasibility of the proposed model.

1. Introduction

The advent of the Internet has led to the flourishing development of e-commerce. According to the nature of transactions, e-commerce can be classified into following types: business-to-business (B2B), business-to-consumer (B2C), consumer-to-consumer (C2C), consumer-to-business (C2B) et al. Many popular B2C e-commerce websites are operated well in the Internet. However, there are still some difficulties for users to conduct B2C e-commerce transaction. Finding right product in the B2C e-commerce websites mainly relies on web search engines such as Google and Yahoo. In order to find right products, users have to visit websites recommended by these engines one by one until they find suitable products (Kwon, Kim, Kim, & Kwak, 2008). The process is tedious and wastes time. Besides, for some small and medium e-commerce websites, it is impossible to complete with large e-commerce firms (Wang & Lin, 2009). One useful approach is to establish e-alliance. E-alliance is the union to support e-commerce transaction. Information of e-commerce websites can be presented in the form of e-alliance. As stated by Castellani et al. (2003), e-alliance is a software infrastructure. E-commerce strategic alliance model has been implemented into Taiwan tourism industry and achieved better performance (Huang, 2006).

E-commerce performance is related to the success and efficiency of B2C e-alliance. Thus, ranking e-commerce in e-alliance is very critical. The main purpose of this paper is to provide a useful solution for ranking e-commerce in e-alliance. Many factors influence the quality of e-commerce, which determines that the issue is multiple criteria decision-making (MCDM) (Vincke, 1992). There are many possible approaches to classify the MCDM methods. Belton and Stewart (2002) gave classification: Value measurement model such as multi-attribute utility theory (MAUT) and analytical hierarchy process (AHP); outranking models such as Elimination and (Et) Choice Translating Reality (ELECTRE) and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and at last, goal aspiration and reference level models such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The foundation of above theory is that the decision maker chooses the alternative for which the expected utility value is a maximum (Keeney & Raiffa, 1976). TOPSIS is often criticized for its inability to deal with vague and uncertain problems. However, fuzzy sets have the ability to present these problems and AHP is widely used for tackling MCDM problems in real situations (Chan & Kumar, 2007). Thus, AHP, fuzzy sets and TOPSIS are combined to rank e-commerce in e-alliance, which utilizes AHP to acquire criteria weights, fuzzy sets to describe vagueness with linguistic values and triangular fuzzy numbers, and TOPSIS to obtain the final ranking order of e-commerce websites.

The remainder of this study is structured as follows: Section 2 briefly describes e-commerce and e-alliance. In Section 3, comprehensive quality of e-commerce websites in e-alliance is discussed. AHP and TOPSIS are presented in Section 4. Fuzzy TOPSIS is proposed in Section 5. In Section 6, proposed model is demonstrated. Case analysis is conducted in Section 7. In Section 8, conclusion is discussed.

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2. E-commerce and e-alliance

E-commerce can be described as "any form of business transaction in which the parties interact electronically rather than by physical exchanges or direct physical contact" (ECOM, 1998). It refers to business activities involving consumers, manufacturers, service providers, and intermediaries using computer networks such as the Internet (Adam, Dogramaci, Gangopadhyay, & Yesha, 1999). The scope of e-commerce ranges from simple World Wide Web (WWW) to shared business processes and management information system (MIS) connecting different companies. E-commerce saves time and reduces the costs of business transactions, which makes business more practicable and efficient.

E-alliance is the union of e-commerce websites, shown in Fig. 1. It can bring much benefit to e-commerce websites if they join e-alliance. E-alliance can be used to gain access to needed resources, capture economies of scale, enter new markets, learn new skills or technology from partners, enhance usability and security, and improve competitiveness.

The form of B2C e-alliance is web page. By search related keywords, information from e-commerce websites can be demonstrated in e-alliance (Fig. 2). Users can buy products presented in the page, which is equal to purchase products in e-commerce websites. So, how to arrange information from e-commerce websites in e-alliance is very critical. Which display order can be chosen? As the more front the information is located, the more possible it will be paid attention from users. It is more likely that users will look through the information and buy products. So display order is of great importance. This depends on comprehensive quality of e-commerce websites in e-alliance.

3. Criteria influence comprehensive quality of e-commerce web sites in e-alliance

There is a lot of literature on e-commerce website quality evaluation. Ariga and Yoshida (1998) proposed an evaluation standard and checklist to read web pages critically as teaching materials for a network literacy course. Sumi and Yotsuya (2002) demonstrated a 20-item checklist based on a library classification system, concentrating on content reliability. A lot of research pay too much attention to website itself and neglect others which also have something to do with websites. In fact, comprehensive quality of website is related to product, design, technology, service quality and logistics illustrated in Fig. 3.

3.1. Product

Price of product can influence consumers' purchase no matter in e-commerce or supermarket. If price is very too high, consumer will not accept. Thus, price should be proper and acceptable. At the same time, when website displays abundant products, customer will browse it more possible and make transaction. Thus, product contains two criteria: price and abundance.

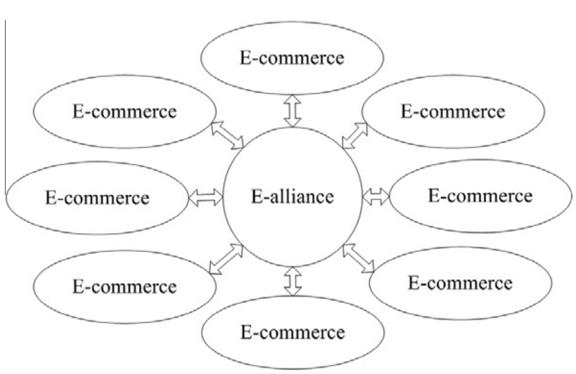

Fig. 1. E-alliance & e-commerce.

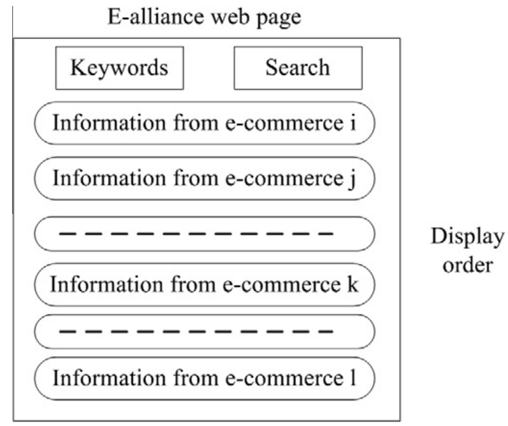

Fig. 2. E-commerce web sites information display order in e-alliance.

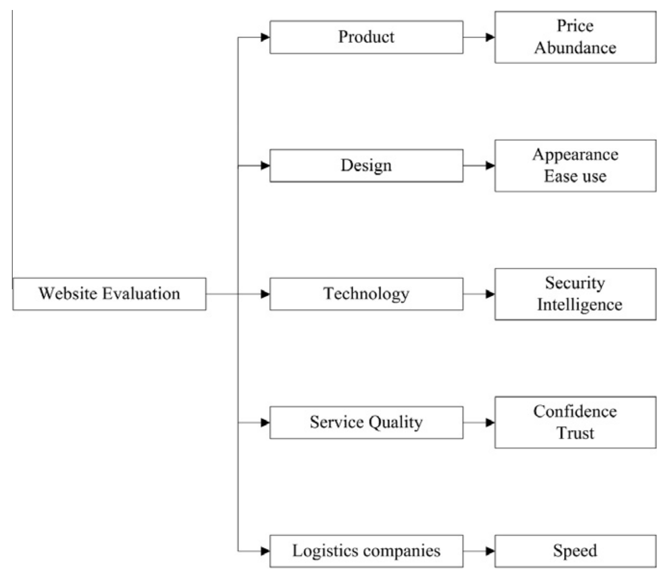

Fig. 3. Criteria influence web sites comprehensive quality.

3.2. Design

Before website is deployed in the Internet, it will be designed by developer. The more attractive website is, the more possible visitors will stay and make purchase. So, appearance is one criterion for website design. What's more, ease use is also related to website design. Ease use indicates that it is very easy to operate website and convenient to browse. Nielsen (Nielsen, 1999; Nielsen, Molich, Snyder, & Farrel, 2001; Nielsen & Tahir, 2001) described usability studies, and provided numerous instructions for making web pages more usable.

Based on above discussion, website design embodies appearance and ease use.

3.3. Technology

Website is an Internet platform, which allows consumers to purchase products. During the process, consumers may submit some sensitive information to website, which requires that website should have the ability to keep the information in the secret. The more secure website does, the more advantage website has.

In terms of online shopping activities, if websites can give some recommendation to consumers according to their browser habits and remember history transaction, it is certain that consumer will spend less time to find what they need and fulfill transactions. This is e-intelligence. Customers are more possibly fastened to website as the website offers e-intelligence.

According to above discussion, technology contains two criteria about the comprehensive quality of websites. There are security and intelligence.

3.4. Service quality

A good number of previous studies adopt service quality as a measure of evaluation websites. Yang, Wu, and Wang (2009) applied four criteria of service quality, which include reliability, responsiveness, assurance, and empathy, to measure the users' cognition of service quality in online channel. Keeney (1999) used a means-ends objectives network for Internet commerce. Devaraj, Fan, and Kohli (2002) reported results of a study that measured consumer satisfaction with the e-commerce channel through constructs prescribed by technology acceptance model, transaction cost analysis, and service quality. This study found service quality is a factor influencing customer's satisfaction. On the other hand, when the customers obtain better service quality such as special treatment benefits, they will feel more e-satisfaction; when customers perceive e-satisfaction of the website, they will be more e-loyalty; when the website is responsiveness, it will influence directly customers' e-loyalty (Lai, Chen, & Lin, 2007).

Based on above discussion, website service quality contains two elements about the comprehensive quality of websites. There are confident and trust.

3.5. Logistics

When customers submit order to website and finish payment, website will deliver the product to customer. In most cases, delivery will be conducted by Logistics Company. Obviously, every customer hopes that it can arrive as quickly as possible. The speed of Logistics Company will affect e-satisfaction. Thus, speed is one criterion for logistics.

According to above discussion, nine criteria influence comprehensive quality of e-commerce websites, which determine that the issue is MCDM. AHP and TOPSIS are widely used to tackle MCDM.

4. Methods

4.1. AHP method

AHP, developed by Saaty (1980), is used to tack MCDM in real applications (Gumus, 2009; Lin, Wang, Chen, & Chang, 2008). MCDM is denoted to screen, prioritize, rank, or select a set of alternatives under usually independent, incommensurate or conflicting attributes (Hwang & Yoon, 1981). The AHP is based on following steps:

Step 1: Compose AHP structure.
MCDM is structured as a hierarchy. The MCDM is decomposed into a hierarchy of interrelated decision elements. With the AHP, the objectives, criteria and alternatives are arranged in a hierarchical structure. Usually, a hierarchy has three levels demonstrated in Fig. 4: overall goal of the problem at the top, multiple criteria that define alternatives in the middle, and decision alternatives at the bottom (Albayrak & Erensal, 2004).

Step 2: Establish a pair-wise comparison decision matrix.
The second step is the pair comparison of criteria to determine the relative weight of criteria. The criteria are compared pair-wise according to their influence and based on the specified criteria in the higher level (Albayrak & Erensal, 2004).
In AHP, multiple pair-wise comparisons are from a standardized comparison scale of nine levels shown in Table 1. Suppose that $C = \{C_j | j = 1, 2 \dots n\}$ be the set of criteria. Evaluation matrix can be gotten, in which every element $a_{ij}(i, j = 1, 2 \dots n)$ represents the relative weights of the criteria illustrated:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & \dots \\ \dots & \dots & a_{ii} & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}, \tag{1}$$

Table 1
Standardized comparison scale of nine levels.

Definition	Value
Equal importance	1
Weak importance	3
Essential importance	5
Demonstrated importance	7
Extreme importance	9
Intermediate values	2, 4, 6, 8

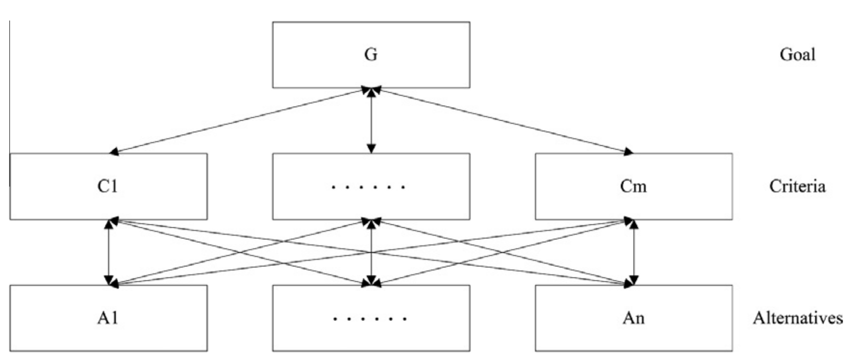

Fig. 4. AHP structure.

Table 2
The relationship between *RI* value and count of criterion.

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

where $a_{ij}(i, j = 1, 2 \ldots n)$ has comply with following condition:

$$a_{ij} = \frac{1}{a_{ji}}, \quad a_{ii} = 1, \quad a_{ij} > 0. \tag{2}$$

Step 3: Calculate criteria weight.
By the formula:

$$AW = \lambda_{\max} W. \tag{3}$$

The $\lambda_{\max}$ can be acquired. If the $\lambda_{\max}$ is equal to n and the rank of matrix A is n, A is consistent. In this case, the relative criteria can be discussed. The weight of each criterion will be calculated by normalizing any of the rows or columns of matrix A (Wang & Yang, 2007).

Step 4: Test consistency.
AHP must meet the requirement that matrix A is consistent. There are two parameters consistency index (CI) and consistency ratio (CR). Both of them are defined as following:

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1}, \tag{4}$$

$$\mathrm{CR} = \frac{\mathrm{CI}}{RI}, \tag{5}$$

where *RI* is random index. For different count of criteria, it has different value demonstrated in Table 2.
If CR is less than 0.10, the result can be acceptable and matrix A is sufficient consistency. Otherwise, we have to return to step 1 and repeat again.

4.2. TOPSIS

TOPSIS is proposed by Hwang and Yoon (1981). According to the theory, the best alternative should have two features: one is nearest to positive-ideal solution; the other is farthest from the negative-ideal solution (Ertugrul & Karakasoglu, 2007). The positive-ideal solution minimizes the cost criteria and maximizes the benefit criteria. It is consisted of all best values attainable from the criteria. At the same time, the negative-ideal solution is a solution that maximizes the cost criteria and minimizes the benefit criteria, which has all worst values attainable from the criteria (Wang, 2008; Wang & Elhag, 2006). TOPSIS is widely used to solve MCDM problems (Chu & Lin, 2002; Tsou, 2008; Wang & Elhag, 2006; Wang, Liu, & Zhang, 2005; Wang & Lee, 2009). TOPSIS consists of the following steps (Shyur & Shih, 2006):

Step 1: Construct a decision matrix.
If the count of criteria is n and the number of alternatives is m, decision matrix with m rows and n columns will be obtained as following:

Table 3
A typical multiple attribute decision problem.

	Criterion 1	Criterion 2	···	Criterion j	···	Criterion n
Alternative 1	f_{11}	f_{12}	···	f_{1j}	···	f_{1n}
Alternative 2	f_{21}	f_{22}	···	f_{2j}	···	f_{2n}
···	···	···	···	···	···	···
Alternative i	f_{i1}	f_{i2}	···	f_{ij}	···	f_{in}
···	···	···	···	···	···	···
Alternative m	f_{m1}	f_{m2}	···	f_{mj}	···	f_{mn}

In the Table 3, $f_{ij}(i = 1, 2 \ldots m; j = 1, 2 \ldots n)$ is a value indicating the performance rating of each alternative ith with respect to each criterion jth.

Step 2: Calculate the normalized decision matrix.
The normalized value f_{ij} is calculated as:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}} \quad i = 1, 2 \ldots m; \quad j = 1, 2 \ldots n. \tag{6}$$

Step 3: Calculate the weighted normalized decision matrix.
The matrix is from multiplying the normalized decision matrix by its associated weights as:

$$\upsilon_{ij} = w_j * r_{ij} \quad i = 1, 2 \ldots m; \quad j = 1, 2 \ldots n, \tag{7}$$

where w_j is the weight of the jth attribute or criterion, and $\sum_{j=1}^{n} w_j = 1$.

Step 4: Determine the positive-ideal and negative-ideal solutions.

$$A^* = \{\upsilon_1^*, \upsilon_2^*, \ldots, \upsilon_n^*\} = \{(\max_j \upsilon_{ij} | i \in I'), (\min_j \upsilon_{ij} | i \in I'')\} \quad i = 1, 2 \ldots m; \quad j = 1, 2 \ldots n, \tag{8}$$

$$A^- = \{\upsilon_1^-, \upsilon_2^-, \ldots, \upsilon_n^-\} = \{(\min_j \upsilon_{ij} | i \in I'), (\max_j \upsilon_{ij} | i \in I'')\} \quad i = 1, 2 \ldots m; \quad j = 1, 2 \ldots n, \tag{9}$$

where I' is associated with benefit criteria, and I'' is associated with cost criteria.

Step 5: Using the n-dimensional Euclidean distance to calculate the separation measures.
The separation of each alternative from the ideal solution is given as:

$$D_i^* = \sum_{j=1}^{n} d(\upsilon_{ij}, \upsilon_j^*) \quad i = 1, 2 \ldots m. \tag{10}$$

Similarly, the separation from the negative-ideal solution is given as:

$$D_i^- = \sum_{j=1}^{n} d(\upsilon_{ij}, \upsilon_j^-) \quad i = 1, 2 \ldots m. \tag{11}$$

Step 6: Calculate the relative closeness to the ideal solution.
The relative closeness of the alternative ith is defined as:

$$CC_i^* = \frac{D_i^-}{D_i^* + D_i^-} \quad i = 1, 2 \ldots m. \tag{12}$$

Step 7: Rank the preference order (Opricovic & Tzeng, 2007).
The CC_i^* is between 0 and 1. The larger CC_i^* is, the better alternative A_i is.

5. Proposed method

Although TOPSIS is very popular to solve MCDM problems, this approach also has some defects. In many real applications, it is difficult to handle ambiguous and vague issue for the method and mathematical models cannot cope with decision-makers' ambiguities, uncertainties and vagueness (Chan & Kumar, 2007). A better approach may be to use linguistic value rather than numerical value, which means that the ratings and weights of the criteria in the problem are evaluated by linguistic variables. Linguistic value can deal with ambiguities, uncertainties and vagueness. Fuzzy sets theory can be used to present linguistic value, which allows the decision-makers to incorporate unquantifiable information, incomplete information, non-obtainable information and partially ignorant facts into decision model (Kulak, Durmusoglu, & Kahraman, 2005). Thus, fuzzy TOPSIS is proposed to solve ranking and evaluating problems (Ashtiani, Haghighirad, Makui, & Montazer, 2009; Jahanshahloo, Lotfi, & Izadikhah, 2006; Wang & Elhag, 2006; Wang & Lee, 2009).

5.1. Fuzzy sets

The merit of using a fuzzy approach is to assign the relative importance of attributes using fuzzy values rather than mathematical values. Definition of fuzzy sets are discussed and presented in many literatures (Buckley, 1985; Chen, Lin, & Huang, 2006; Kaufmann & Gupta, 1985; Yang & Hung, 2007; Zadeh, 1965; Zimmermann, 1991).

Definition 1. A fuzzy set $\widetilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{a}}(x)$. It connects with each element x in X, a real number in the interval $[0,1]$. The function value $\mu_{\tilde{a}}(x)$ is termed the grade of membership of x in $\widetilde{A}$.

The present research focuses on triangular fuzzy numbers. A triangular fuzzy number $\widetilde{A}$ can be defined by a triplet (a_1,a_2,a_3), where a_3 is greater than a_2 and a_2 is greater than a_1. Mathematical form of triangular fuzzy is displayed in the following equation and Fig. 5.

$$\mu_{\tilde{a}}(x) = \begin{cases} 0, & x \leqslant a_1, \\ \frac{x-a_1}{a_2-a_1}, & a_1 < x \leqslant a_2, \\ \frac{a_3-x}{a_3-a_2}, & a_2 < x \leqslant a_3, \\ 0, & x > a_3. \end{cases} \quad (13)$$

Definition 2. Suppose $a = (a_1,a_2,a_3)$ and $b = (b_1,b_2,b_3)$ are two triangular fuzzy numbers, the distance between them is calculated as Eq. (14).

$$d(\tilde{a},\tilde{b}) = \sqrt{\frac{1}{3}\left[(a_1-b_1)^2 + (a_2-b_2)^2 + (a_3-b_3)^2\right]}. \quad (14)$$

Then, the operational laws of these two triangular fuzzy numbers are shown in Table 4.

5.2. Fuzzy TOPSIS

Fuzzy TOPSIS is that TOPSIS is extended to fuzzy environment. According to fuzzy sets and TOPSIS, fuzzy TOPSIS can be outlined as following:

Step 1: *Choose the linguistic values (x_{ij}; i = 1, 2 ... m; j = 1, 2 ... n) for alternatives with respect to criteria.*
The fuzzy linguistic rating x_{ij} preserves the property that the ranges of normalized triangular fuzzy numbers belong to $[0,1]$; thus, there is no need for normalization.

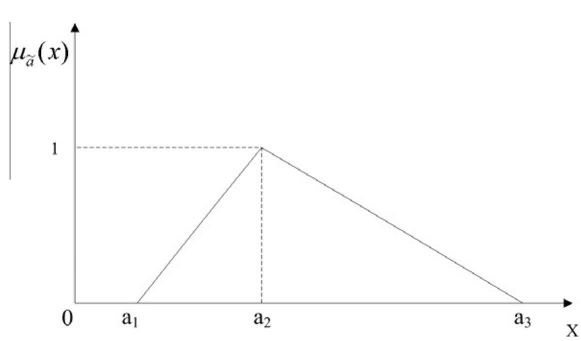

Fig. 5. Triangular fuzzy number.

Table 4
Operational laws of these two triangular fuzzy numbers.

Operational law	Expression
Addition	$\tilde{a}+\tilde{b} = (a_1,a_2,a_3)+(b_1,b_2,b_3) = (a_1+b_1, a_2+b_2, a_3+b_3)$
Subtraction	$\tilde{a}-\tilde{b} = (a_1,a_2,a_3)-(b_1,b_2,b_3) = (a_1-b_1, a_2-b_2, a_3-b_3)$
Multiplication	$\tilde{a}\times\tilde{b} = (a_1,a_2,a_3)\times(b_1,b_2,b_3) = (a_1\times b_1, a_2\times b_2, a_3\times b_3)$ $k\tilde{a} = k\times(a_1,a_2,a_3) = (k\times a_1, k\times a_2, k\times a_3)$
Division	$\tilde{a}\div\tilde{b} = (a_1,a_2,a_3)\div(b_1,b_2,b_3) = (a_1\div b_1, a_2\div b_2, a_3\div b_3)$
Inverse	$\tilde{a}^{-1} = (a_1,a_2,a_3)^{-1} = \left(\frac{1}{a_3},\frac{1}{a_2},\frac{1}{a_1}\right)$

Step 2: Construct the weighted normalized fuzzy decision matrix. The weighted normalized value υ_{ij} calculated by Eq. (15).

$$\upsilon_{ij} = x_{ij}\times w_j \quad i=1,2\ldots m; \quad j=1,2\ldots n, \quad (15)$$

where w_j can be obtained from AHP (Wang & Yang, 2007).

Step 3: Identify positive-ideal (A^*) and negative ideal (A^-) *solutions.*
The fuzzy positive-ideal solution (FPIS,A^*) and the fuzzy negative-ideal solution (FNIS,A^-) are demonstrated in the following equations:

$$A^* = \{\upsilon_1^*,\upsilon_2^*,\ldots,\upsilon_n^*\} = \{(\max_j \upsilon_{ij} | i\in I'), (\min_j \upsilon_{ij} | i \in I'')\} \quad i=1,2\ldots m; \quad j=1,2\ldots n, \quad (16)$$

$$A^- = \{\upsilon_1^-,\upsilon_2^-,\ldots,\upsilon_n^-\} = \{(\min_j \upsilon_{ij} | i\in I'), (\max_j \upsilon_{ij} | i \in I'')\} \quad i=1,2\ldots m; \quad j=1,2\ldots n, \quad (17)$$

where I′ is associated with benefit criteria, and I″ is associated with cost criteria.

Step 4: Calculate the distance of each alternative from A^* and A^- using the following equations.

$$D_i^* = \sum_{j=1}^{n} d(\upsilon_{ij},\upsilon_j^*) \quad i=1,2\ldots m, \quad (18)$$

$$D_i^- = \sum_{j=1}^{n} d(\upsilon_{ij},\upsilon_j^-) \quad i=1,2\ldots m. \quad (19)$$

Step 5: Calculate similarities to ideal solution by the following equations.

$$CC_i = \frac{D_i^-}{D_i^* + D_i^-}. \quad (20)$$

Step 6: Rank order.
Rank alternatives according to CC_i in descending order.

6. Proposed model

The proposed model for ranking e-commerce websites in e-alliance, composed of AHP and fuzzy TOPSIS approaches, has following three phases:

6.1. Criteria identification

In the first phase, websites and the criteria which will be used in ranking are determined and the decision hierarchy is formed. AHP model is established such that the objective is in the first level, criteria are in the second level and websites are in the third level.

6.2. Criteria weight calculation

In this phase, pair-wise comparison matrices are constructed to acquire the criteria weights. Experts make their evaluations using the scale displayed in Table 1, to determine the values of the

Table 5
Linguistic value and triangular fuzzy number.

Linguistic value	Triangular fuzzy number
Very low (VL)	(0,0,0.2)
Low (L)	(0,0.2,0.4)
Fairly low (FL)	(0.2,0.4,0.6)
Fairly high (FH)	(0.4,0.6,0.8)
High (H)	(0.6,0.8,1)
Very high (VH)	(0.8,1,1)

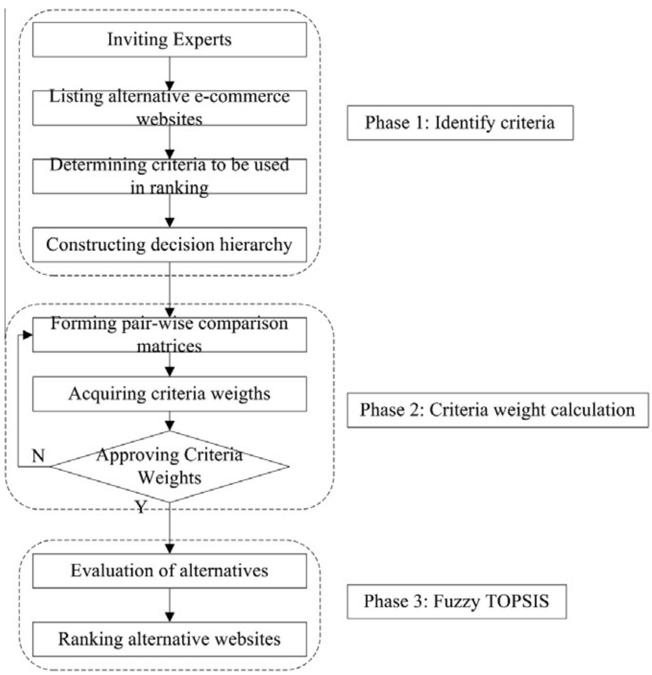

Fig. 6. Proposed model for ranking e-commerce web sites in e-alliance.

elements of pair-wise comparison matrices. Computing the arithmetic mean of the values gotten from their evaluations to avoid error, a final pair-wise comparison matrix will be established. The weights of the criteria are calculated based on this final matrix and will be approved by experts.

6.3. Evaluation of websites with fuzzy TOPSIS and determination of the final rank

Ranking websites is determined by using fuzzy TOPSIS in the third phase. Linguistic values are used for evaluation of websites. The relationship between linguistic values and triangular fuzzy numbers are shown in Table 5. Ranking websites is determined according to CC_i calculated by fuzzy TOPSIS in descending order. Fig. 6 presents the whole process.

7. Case analysis

Proposed model is used to rank e-commerce websites in e-alliance. The goal is to improve the efficiency of e-alliance. For the application, experts were invited from e-commerce field. Pair-wise comparison matrices used to calculate criteria weights were also proposed by these experts. The application is based on the phases provided in previous section and explained as following.

7.1. Phase 1: criteria identification

From above discussion, criteria to be used in the model include price (C1), abundance (C2), appearance (C3), ease use (C4), security (C5), intelligence (C6), confidence (C7), trust (C8), speed (C9). Five e-commerce websites form e-alliance. There are A1, A2, A3, A4, and A5. Thus, the result of decision hierarchy is demonstrated in Fig. 7.

There are three levels in the decision hierarchy. The overall goal of the decision process determined as “rank websites” is in the first level of the hierarchy. The criteria are on the second level and e-commerce websites are on the third level of the hierarchy.

7.2. Phase 2: criteria weight calculation

In this phase, experts are given the task of forming individual pair-wise comparison matrix by using the scale given in Table 1.

Table 6
Pair-wise comparison matrix for nine criteria.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	1.2	0.6	0.5	0.4	2.2	1.6	1.9	2.1
C2	0.9	1	0.8	0.7	0.3	1.8	1.5	1.7	2
C3	1.6	1.2	1	0.9	0.4	2.6	1.9	2.1	2.5
C4	1.7	1.4	1.2	1	0.9	3.2	2.2	2.7	3
C5	2.5	3.3	2.5	1.2	1	3.5	2.4	2.9	3.4
C6	0.5	0.6	0.4	0.3	0.3	1	0.9	0.7	0.6
C7	0.6	0.6	0.5	0.5	0.3	1.1	1	1.1	1.2
C8	0.5	0.6	0.5	0.4	0.4	1.3	0.9	1	1.2
C9	0.5	0.5	0.4	0.3	0.3	1.6	0.8	0.9	1

Table 7
Nine criteria weight and related parameter values.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
Weight	0.11	0.1	0.14	0.17	0.23	0.05	0.07	0.07	0.06
λ_{max}					9.07				
CI					0.011				
RI					1.45				
CR					0.08				

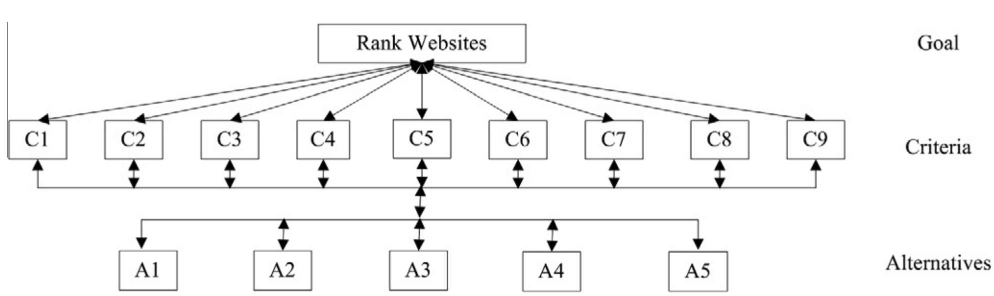

Fig. 7. Decision hierarchy for case analysis.

Table 8
Fuzzy evaluation result for five alternatives with nine criteria.

	A1	A2	A3	A4	A5
C1	L (0,0.2,0.4)	FL (0.2,0.4,0.6)	L (0,0.2,0.4)	L (0,0.2,0.4)	FL (0.2,0.4,0.6)
C2	H (0.6,0.8,1)	FH (0.4,0.6,0.8)	VH (0.8,1,1)	FH (0.4,0.6,0.8)	VH (0.8,1,1)
C3	VH (0.8,1,1)	H (0.6,0.8,1)	H (0.6,0.8,1)	VH (0.8,1,1)	VH (0.8,1,1)
C4	FL (0.2,0.4,0.6)	FH (0.4,0.6,0.8)	H (0.6,0.8,1)	FH (0.4,0.6,0.8)	FL (0.2,0.4,0.6)
C5	H (0.6,0.8,1)	VH (0.4,0.6,0.8)	VH (0.4,0.6,0.8)	VH (0.4,0.6,0.8)	VH (0.4,0.6,0.8)
C6	VL (0,0,0.2)	L (0,0.2,0.4)	FH (0.4,0.6,0.8)	L (0,0.2,0.4)	L (0,0.2,0.4)
C7	FH (0.4,0.6,0.8)	FH (0.4,0.6,0.8)	FL (0.2,0.4,0.6)	L (0,0.2,0.4)	FH (0.4,0.6,0.8)
C8	FH (0.4,0.6,0.8)	L (0,0.2,0.4)	FH (0.4,0.6,0.8)	FH (0.4,0.6,0.8)	H (0.6,0.8,1)
C9	H (0.6,0.8,1)	FH (0.4,0.6,0.8)	FH (0.4,0.6,0.8)	FH (0.4,0.6,0.8)	H (0.6,0.8,1)

Arithmetic means of these values are found to get the pair-wise comparison matrix on which there is a consensus (Table 6).

The results acquired from the calculation according to pair-wise comparison matrix are illustrated in Table 7.

Consistency ratio of the pair-wise comparison matrix is calculated as 0.08 < 0.10. Thus, the weights are consistent and they would be used in the ranking process.

7.3. Phase 3: evaluation of websites with fuzzy TOPSIS and determination of the final rank

Experts were asked to construct fuzzy evaluation matrix by linguistic variables presented in Table 5. It is formed by comparing five alternatives under nine criteria separately. The matrix is shown in Table 8. According to Eq. (15), fuzzy weighted decision matrix is demonstrated in Table 9.

It is presented that the every element in Table 9 is normalized positive triangular fuzzy numbers and their ranges belong to the closed interval [0,1]. Thus, there is no need for normalization. Now, we give following definition: fuzzy positive-ideal solution (FPIS,A^*) and fuzzy negative-ideal solution (FNIS,A^-) as $\tilde{\upsilon}_i^* = (1,1,1)$ and $\tilde{\upsilon}_i^- = (0,0,0)$ for benefit criterion, and $\tilde{\upsilon}_i^* = (0,0,0)$ and $\tilde{\upsilon}_i^- = (1,1,1)$ for cost criterion. In this issue, C2, C3, C4, C5, C6, C7, C8, C9 are benefit criteria whereas C1 is cost criteria. Their benefit and cost criterion of nine criteria are shown in Table 10.

The distance of each alternative from D^* and D^- can be calculated by Eqs. (18) and (19). In order to illustrate the calculation, D_1^*, D_1^- and CC_1 are presented as an instance as follows:

$$\begin{aligned} D_1^* = {} & \sqrt{\frac{1}{3}\left[(0-0)^2+(0-0.22)^2+(0-0.44)^2\right]} \\ & + \sqrt{\frac{1}{3}\left[(1-0.06)^2+(1-0.08)^2+(1-0.1)^2\right]} \\ & + \sqrt{\frac{1}{3}\left[(1-0.112)^2+(1-0.14)^2+(1-0.14)^2\right]} \\ & + \sqrt{\frac{1}{3}\left[(1-0.034)^2+(1-0.068)^2+(1-0.102)^2\right]} \\ & + \sqrt{\frac{1}{3}\left[(1-0.138)^2+(1-0.184)^2+(1-0.23)^2\right]} \\ & + \sqrt{\frac{1}{3}\left[(1-0)^2+(1-0)^2+(1-0.01)^2\right]} \\ & + \sqrt{\frac{1}{3}\left[(1-0.028)^2+(1-0.042)^2+(1-0.056)^2\right]} \\ & + \sqrt{\frac{1}{3}\left[(1-0.028)^2+(1-0.042)^2+(1-0.056)^2\right]} \\ & + \sqrt{\frac{1}{3}\left[(1-0.036)^2+(1-0.048)^2+(1-0.06)^2\right]} \\ = {} & 8.02, \end{aligned} \tag{21}$$

$$D_1^- = 1.59, \tag{22}$$

$$CC_1 = \frac{D_1^-}{D_1^* + D_1^-} = 0.198. \tag{23}$$

Table 10
$\tilde{\upsilon}_i^*$ and $\tilde{\upsilon}_i^-$ for nine criteria.

	$\tilde{\upsilon}_i^*$	$\tilde{\upsilon}_i^-$
C1	(0,0,0)	(1,1,1)
C2	(1,1,1)	(0,0,0)
C3	(1,1,1)	(0,0,0)
C4	(1,1,1)	(0,0,0)
C5	(1,1,1)	(0,0,0)
C6	(1,1,1)	(0,0,0)
C7	(1,1,1)	(0,0,0)
C8	(1,1,1)	(0,0,0)
C9	(1,1,1)	(0,0,0)

Table 11
Fuzzy TOPSIS result.

	D_1^*	D_1^-	CC_i
A1	8.02	1.59	0.198
A2	7.51	1.52	0.202
A3	7.41	1.61	0.217
A4	7.50	1.57	0.209
A5	7.74	1.65	0.213

Table 9
Result from fuzzy evaluation and weight for five alternatives with nine criteria.

	A1	A2	A3	A4	A5
C1	(0,0.022,0.044)	(0.022,0.044,0.066)	(0,0.022,0.044)	(0,0.022,0.044)	(0.022,0.044,0.066)
C2	(0.06,0.08,0.1)	(0.04,0.06,0.08)	(0.08,0.1,0.1)	(0.04,0.06,0.08)	(0.08,0.1,0.1)
C3	(0.112,0.14,0.14)	(0.084,0.112,0.14)	(0.084,0.112,0.14)	(0.112,0.14,0.14)	(0.112,0.14,0.14)
C4	(0.034,0.068,0.102)	(0.068,0.102,0.136)	(0.102,0.136,0.17)	(0.068,0.102,0.136)	(0.034,0.068,0.102)
C5	(0.138,0.184,0.23)	(0.092,0.138,0.184)	(0.092,0.138,0.184)	(0.092,0.138,0.184)	(0.092,0.138,0.184)
C6	(0,0,0.01)	(0,0.01,0.02)	(0.02,0.03,0.04)	(0,0.01,0.02)	(0,0.01,0.02)
C7	(0.028,0.042,0.056)	(0.028,0.042,0.056)	(0.014,0.028,0.042)	(0,0.014,0.028,)	(0.028,0.042,0.056)
C8	(0.028,0.042,0.056)	(0,0.014,0.028)	(0.028,0.042,0.056)	(0.028,0.042,0.056)	(0.042,0.056,0.07)
C9	(0.036,0.048,0.06)	(0.024,0.036,0.048)	(0.024,0.036,0.048)	(0.024,0.036,0.048)	(0.036,0.048,0.06)

Similar calculations can be fulfilled for the other websites and the results are illustrated in Table 11. According to CC_i values, the websites ranking in descending order is A3, A5, A4, A2 and A1.

8. Conclusion

The e-alliance performance is related to the quality of e-alliance, thus ranking e-alliance has significant impacts to the success and efficiency of e-alliance. Subjective or vague data must be considered during the process. Therefore, an effective ranking approach and model are essential to tackle the issue. A decision approach and model are proposed based on AHP and fuzzy TOPSIS. AHP is used to get weights of criteria, while fuzzy TOPSIS is utilized to rank e-commerce websites. The weights obtained from AHP are included in decision-making process by using them in fuzzy TOPSIS computations and ranking order is determined based on these weights.

Since the decisions will influence the efficiency and success of e-alliance, it is better to invite experts to operate. The accuracy of the decision could be improved. Besides, the difficulty in determining the parameters of most criteria forces us to utilize scientific methods. Therefore, development of a decision approach for ranking e-commerce in e-alliance is very useful and important.

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