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A NUMERICAL STUDY ON ASSESSING TRUSTED BRAND FOR CONTAINER SHIPPING COMPANIES BY USING FUZZY MCDM APPROACH

Ji-Feng Ding

Key words: trusted brand, fuzzy, MCDM.

ABSTRACT

The main purpose of this paper is to develop a fuzzy multiple criteria decision-making (MCDM) approach to assess the trusted brand for container shipping companies and to illustrate the computing process by using a numerical study. Firstly, some of the theoretical methodologies used in this research are introduced. Secondly, a step-by-step fuzzy MCDM algorithm, including five systematic procedures, is proposed. Finally, a hypothetical and numerical example of assessing trusted brand is studied to demonstrate the computational process of the proposed fuzzy MCDM algorithm. Besides, the merit of this paper with its methodologies can be employed as a practical tool for empirical application in the future study.

I. INTRODUCTION

A brand name expresses the value of customers' perceptions that exist in customers' mind. Many scholars [1-3, 13, 20] have been devoted to this brand issue, which they believed that a strong brand name could be endurably created margins of profit to keep the competitive advantage. Besides, high brand reputation can also bring the advantage on better customer image, superior marketing place, lower marketing expenditures, and switching cost. In fact, the brand name has been influenced the purchasing behavior in the marketing procedure. In truth, a brand name plays an important role when a company engages the analysis of differentiation strategy and assessment of customer's value proposition and corporate reputation.

In recent years, much attention has been devoted to the trusted brand names by many mass communication and media. Especially, Reader Digest firstly embarked on the survey of European Trusted Brands [21] in 2000. It has been continuing to survey till now and expanding the assessment to Australia and Asia markets. Seven countries, i.e. India, Hong Kong, Malaysia, Philippines, Singapore, Taiwan, and Thailand etc., are selected to survey in Asia markets. Recently, the Gold and Platinum Trusted Brands Award Winners of Taiwan are announced on April 2010. Ten different categories with 42 industries, e.g. bank, insurance company, telecom company, mobile service provider, airline, air freight/courier service, hospital, supermarket store, personal computer, car, milk, toothpaste etc., are evaluated by the questionnaires and telephone interviews from across Taiwan. Customers were asked to assign a score for each brand for six core criteria [21], i.e. trustworthiness and credibility, quality, value, understanding of consumer needs, innovative, and social responsibility.

'Formosa' is an alias for Taiwan - an island surrounded by water on four sides. Most goods and materials are shipped by sea transport in here. When the goods are produced to export and import, the distribution of the consignment using container shipping transport is appeared. There are three famous container shipping companies (CSCs), i.e. Evergreen Line, Yang Ming Line, and Wan Hai Lines, which are the top three ocean-going container operators in Taiwan as well as the top 4, 15, and 21, respectively, of the world in June 2011. The container shipping industry plays an important role in global shipping logistics service, especially in Taiwan. However, the trusted brand of such major ocean shipping service has not been measured in this survey of Taiwanese Trusted Brands Award. Therefore, assessing the trusted brand for CSCs is essential to study.

Since evaluating the CSCs with trusted brand is beneficial for smoothing the behavior of purchasing process to shippers. However, experience has shown that the evaluating trusted brand among container carriers is no easy matter. It involves a multitude of complex considerations and a decision-making tool is therefore crucial. It is thus imperative for shippers to devise, identify and recognize effective criteria,

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as well as to evaluate questions of compatibility and feasibility prior to the evaluation of trusted brand among CSCs.

The evaluation of trusted brand among CSCs poses a unique characteristic of multiple criteria decision-making (MCDM). The criteria are usually subjective in nature and often changing with the decision-making conditions, which creates the fuzzy and uncertain nature among the criteria and the importance weights of the criteria. Further, there are situations in which information is incomplete or imprecise or views that are subjective or endowed with linguistic characteristics creating a fuzzy decision-making environment [8, 10, 18]. Therefore, in the light of this, the fuzziness-based [23] MCDM approach is designed to minimize such adverse conditions and strengthen the evaluation process. And then a numerical study will be illustrated to demonstrate the computing process in the following. It is suggested that an empirical survey can be gone forward with this approach in the future in Taiwan.

In summary, the aim of this paper is to develop a fuzzy MCDM approach to assess the trusted brand for CSCs and to illustrate the computing process by using a numerical study. The theoretical concepts of research are presented in Section 2. In the third section, a fuzzy MCDM approach for assessing the trusted brand is constructed. A numerical example is studied in Section 4. Finally, conclusions are made in the last section.

II. THEORETICAL CONCEPTS OF RESEARCH

In this section, some of the theoretical concepts and methods used in this paper are briefly introduced. These include the triangular fuzzy numbers and algebraic operations, linguistic variables, similarity aggregation method, and a ranking method.

1. Triangular Fuzzy Numbers and Algebraic Operations

The fuzzy set theory [23] is designed to deal with the extraction of the primary possible outcome from a multiplicity of information that is expressed in vague and imprecise terms. Fuzzy set theory treats vague data as possibility distributions in terms of set memberships. Once determined and defined, the sets of memberships in possibility distributions can be effectively used in logical reasoning. Triangular fuzzy numbers and the algebraic operations of fuzzy numbers are two major components of this section as follows.

A fuzzy number A [12] in real line $\Re$ is a triangular fuzzy number if its membership function f_A: $\Re \rightarrow [0, 1]$ is

$$f_A(x) = \begin{cases} (x-c)/(a-c), & c \le x \le a \\ (x-b)/(a-b), & a \le x \le b \\ 0, & otherwise \end{cases} \tag{1}$$

with $-\infty < c \le a \le b < \infty$. The triangular fuzzy number can be denoted by (c, a, b).

The Zadeh's extension principle [23] and the Chen's function principle [5] are employed to proceed with the algebraic operations of fuzzy numbers. In this paper, we used the Chen's function principle. The merit of the function principle not only does not change the type of membership function of fuzzy number after operations, but also can reduce the troublesomeness and tediousness of operations. Let $A_1 = (c_1, a_1, b_1)$ and $A_2 = (c_2, a_2, b_2)$ be fuzzy numbers. The algebraic operations of any two fuzzy numbers A_1 and A_2 can be expressed as

- Fuzzy addition, $\oplus$:

$$A_1 \oplus A_2 = (c_1 + c_2, a_1 + a_2, b_1 + b_2),$$

where c_1, a_1, b_1, c_2, a_2, and b_2 are any real numbers.

- Fuzzy multiplication, $\otimes$:

$$A_1 \otimes A_2 = (c_1 c_2, a_1 a_2, b_1 b_2),$$

where c_1, a_1, b_1, c_2, a_2, and b_2 are all nonzero positive real numbers.

- Fuzzy division, $\varnothing$:

$$(A_1)^{-1} = (c_1, a_1, b_1)^{-1} = (1/b_1, 1/a_1, 1/c_1),$$

where c_1, a_1, and b_1 are all positive real numbers or all negative real numbers.

$$A_1 \varnothing A_2 = (c_1/b_2,\ a_1/a_2,\ b_1/c_2),$$

where c_1, a_1, b_1, c_2, a_2, and b_2 are all nonzero positive real numbers.

2. Linguistic Variables

In fuzzy decision environments, two preference ratings can be used. They are fuzzy numbers and linguistic values characterized by fuzzy numbers [24-26]. Depending on practical needs, decision-makers may apply one or both of them. That is, the importance weight of criteria (or the performance values of alternatives) can be obtained by either directly assigning weights (or the performance values) or indirectly using pair-wise comparisons [19]. Another way about the weighting sets can be used to analytically express the linguistic values about the importance of the criteria. The rating sets can use as the same way about the goodness of the alternatives against various criteria above the alternative layer.

In this paper, the importance weights of criteria are obtained by directly assigning weights by experts. The set of performance values of alternatives (i.e. the rating set) is defined as S = {AP, VP, P, F, G, VG, AG}; where AP = Absolutely Poor, VP = Very Poor, P = Poor, F = Fair, G = Good, VG = Very Good, and AG = Absolutely Good. Here, we define the linguistic values of AP = (0, 0, 0), VP = (0, 0, 0.25), P = (0, 0.25, 0.5), F = (0.25, 0.5, 0.75), G = (0.5, 0.75, 1), VG = (0.75, 1, 1), and AG = (1, 1, 1), respectively. These triangular fuzzy numbers are referred to in Ghyym [14].

3. Similarity Aggregation Method

In the real world, there are different opinions between experts or decision-makers. How to integrate these opinions to obtain the consensus degree is an important issue in the fuzziness environment, hence the similarity measure approach [9, 11, 15, 16, 22] can be solved this situation. In the light of this, a suitable method, similarity aggregation method (SAM), proposed by Hsu and Chen [16] in 1996, is used to obtain the importance of criteria in this paper. However, the agreement degree measure function in Hsu and Chen's method is not easy to calculate. Therefore, a modified method, the similarity with graded mean integration representation distance (SGMIRD) method, proposed by Chen and Hsieh [7] in 2000, is used to instead the Hsu and Chen's method. This will be drawn in the following Step 2.

The SAM is a weighted approach, which considered two critical factors, i.e. the relative agreement degree and the degree of importance of each expert, to obtain the consensus degree. The procedure of the SAM can be summarized as follows.

Step 1. Obtain the triangular fuzzy numbers $A_i = (c_i, a_i, b_i)$, $i = 1, 2, \ldots, n$ of each expert E_i. However, two assumptions need to state. Fist one is assumed that there is a common intersection between two triangular fuzzy numbers at some α-level cut, where $\alpha \in (0, 1]$. Secondly, if there is no intersection between each expert, the Delphi method is suggested to adjust the estimation.

Step 2. Calculate the agreement degree $S(A_i, A_j)$ of the opinions between each pair of experts. Define the agreement degree measure function of the two experts E_i and E_j as

$$S(A_i, A_j) = \frac{\int_x (\min\{f_{A_i}(x),\ f_{A_j}(x)\})dx}{\int_x (\max\{f_{A_i}(x),\ f_{A_j}(x)\})dx} \tag{2}$$

If the numerator and denominator are very close, this implies there have the higher percentage of the overlap, and then the higher agreement degree can be evaluated. If two experts have the same consistency for the estimation, i.e. two fuzzy numbers $A_i = A_j$, then the $S(A_i, A_j) = 1$.

However, the above Eq. (2) can not be easily calculated, therefore, the SGMIRD method will be used to improve this drawback and quickly to obtain the value of $S(A_i, A_j)$ in this step. That is, let $A_i = (c_i, a_i, b_i)$, $i = 1, 2, \ldots, n$, be n triangular fuzzy numbers. By the SGMIRD method, the similarity between A_i and A_j is

$$S(A_i, A_j) = \frac{1}{1 + d(A_i, A_j)} = \frac{1}{1 + \left|P(A_i) - P(A_j)\right|} \tag{3}$$

where $d(A_i, A_j)$ is the graded mean integration representation distance of A_i and A_j, respectively. Here, the $P(A_i)$ and $P(A_j)$ are the graded mean integration representation (GMIR) of A_i and A_j, respectively. By using the GMIR method, proposed by Chen and Hsieh [7] in 2000, the GMIR $P(A_i)$ and $P(A_j)$ of A_i and A_j can be expressed as

$$P(A_i) = \frac{c_i + 4a_i + b_i}{6} \tag{4}$$

and

$$P(A_j) = \frac{c_j + 4a_j + b_j}{6} \tag{5}$$

Step 3. Construct the agreement matrix (AM). If the agreement degrees between all experts are evaluated, then an AM can be constructed. We define

$$AM = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{ij} & \cdots & S_{1n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ S_{i1} & S_{i2} & \cdots & S_{ij} & \cdots & S_{in} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ S_{n1} & S_{n2} & \cdots & S_{nj} & \cdots & S_{nn} \end{bmatrix} \tag{6}$$

where $S_{ij} = S(A_i, A_j)$, if $i \neq j$; and $S_{ij} = 1$, if $i = j$.

Step 4. Calculate the average agreement degree $A(E_i)$ of expert E_i. Using the AM to obtain the average agreement degree as

$$A(E_i) = \frac{1}{n-1}\sum_{\substack{j=1 \\ j\neq i}} S_{ij} \tag{7}$$

Step 5. Calculate the relative agreement degree RAD_i of expert E_i. Using Step 4 to obtain the relative agreement degree as

$$RAD_i = \frac{A(E_i)}{\sum_{i=1}^{n} A(E_i)} \tag{8}$$

Step 6. Suppose the relative importance weight Ω_i of each expert E_i. Then, define the degree of importance w_i of expert E_i as

$$w_i = \frac{\Omega_i}{\sum_{i=1}^{n} \Omega_i} \tag{9}$$

Note: If the importance of each expert is equal, then $w_1 = w_2 = \cdots = w_n = 1/n$.

Step 7. Calculate the consensus degree coefficient CDC_i of expert E_i. Integrating Step 5 and Step 6, define the consensus degree coefficient as

$$CDC_i = \kappa \cdot w_i + (1-\kappa) \cdot RAD_i, \text{where } 0 \le \kappa \le 1 \quad (10)$$

Step 8. Aggregate the fuzzy opinions by the consensus degree coefficient CDC_i of expert E_i. By using Step 7, let $\hat{A}$ be the overall fuzzy number of combining experts' opinions, we can define

$$\hat{A} = \sum_{i=1}^{n} (CDC_i \otimes A_i) \quad (11)$$

4. Ranking Method

In order to obtain a ranking method to implement easily and powerfully, a method is proposed and developed by the author with the combination of the methods proposed by Chen [6], Kim and Park [17], and Chang and Chen [4].

Let A_i, $i = 1, 2, \ldots, n$, be fuzzy numbers with membership functions f_{A_i} respectively. Define the maximizing set $M = \{(x, f_M(x)) \mid x \in R\}$ with

$$f_M(x) = \begin{cases} (x - x_1)/(x_2 - x_1), & x \in [x_1, x_2], \\ 0, & otherwise, \end{cases} \quad (12)$$

and the minimizing set $G = \{(x, f_G(x)) \mid x \in R\}$ with

$$f_G(x) = \begin{cases} (x - x_2)/(x_1 - x_2), & x \in [x_1, x_2], \\ 0, & otherwise, \end{cases} \quad (13)$$

where $x_1 = \inf D$, $x_2 = \sup D$, $D = \bigcup_{i=1}^{n} D_i$, and $D_i = \{x \mid f_{A_i}(x) > 0\}$, $i = 1, 2, \ldots, n$.

Define the optimistic ranking value (i.e. the optimistic utility) $U_M(A_i)$ and the pessimistic ranking value (i.e. the pessimistic utility) $U_G(A_i)$ of the fuzzy numbers A_i as

$$U_M(A_i) = \sup_x (f_{A_i}(x) \wedge f_M(x)) \quad (14)$$

and

$$U_G(A_i) = \sup_x (f_{A_i}(x) \wedge f_G(x)) \quad (15)$$

where $\wedge$ means the minimum operation and $i = 1, 2, \ldots, n$.

Then, define the ranking value $U_T(A_i)$ of fuzzy numbers A_i is defined as

$$U_T(A_i) = \rho U_M(A_i) + (1-\rho) U_G(A_i), \quad 0 \le \rho \le 1. \quad (16)$$

The value ρ can be referred to as the total risk attitude index of decision-makers. A larger ρ indicates a larger degree of optimism. If $\rho > 0.5$, it implies that the total risk attitude of decision-makers is optimistic. When $\rho = 1$, it shows the absolutely optimistic attitude. If $\rho = 0.5$, the total risk attitude of decision-makers is neutral (moderate). When $\rho < 0.5$ and $\rho = 0$, they refect the attitudes of decision-makers are pessimistic and absolutely pessimistic, respectively.

The value ρ can be determined by two procedures. First way is that decision-makers give the value ρ at the data output stage [17], e.g., $\rho = 0.25, 0.5, 0.75$. However, it is difficult to apply this procedure directly in multiple decision-makers problem. Hence, Chang and Chen [4] suggested a reasonable way to evaluate ρ through the evaluation data conveyed by the decision-makers at the data input stage. A comparison of measures for characterizing decision-maker's attitudes toward risk has been proposed by Ghyym [14]. In this paper, the method developed by Chang and Chen [4] is cited to find the total risk attitude index ρ.

Define the ranking of the triangular fuzzy numbers A_i and A_j based on the following rules:

(1) $A_i > A_j \Leftrightarrow U_T(A_i) > U_T(A_j)$,

(2) $A_i < A_j \Leftrightarrow U_T(A_i) < U_T(A_j)$, and

(3) $A_i = A_j \Leftrightarrow U_T(A_i) = U_T(A_j)$.

Let $A_i = (c_i, a_i, b_i)$, $i = 1, 2, \ldots, n$, be n triangular fuzzy numbers. By using Eqs. (1), (14), (15) and (16), the ranking value $U_T(A_i)$ of the triangular fuzzy number A_i can be obtained

$$U_T(A_i) = \rho \left[\frac{b_i - x_1}{x_2 - x_1 - a_i + b_i} \right] + (1-\rho) \left[1 - \frac{x_2 - c_i}{x_2 - x_1 + a_i - c_i} \right] \quad (17)$$

where $x_1 = \min\{c_1, c_2, \ldots, c_n\}$, $x_2 = \max\{b_1, b_2, \ldots, b_n\}$, and $0 \le \rho \le 1$.

Then, based on the ranking rules described above, the ranking of the n triangular fuzzy numbers can be effectively determined.

III. THE FUZZY MCDM APPROACH

A stepwise description of the fuzzy MCDM approach for assessing trusted brand for CSCs is proposed in the following.

1. Development of Assessing Criteria and Alternatives

The concepts of hierarchical structure analysis with two distinct layers, i.e. criteria layer and alternatives layer, are used in this paper. There are k criteria (represented as C_t, $t = 1, 2, \ldots, k$) and m alternatives (represented as A_i, $i = 1, 2, \ldots, m$) in the hierarchical structure. As mentioned in Section I and according to the questionnaire of Reader Digest in 2009, six criteria [21] are evaluated in this paper. The code names are shown in parentheses and some descriptions of criteria are made after the headline. All the six core criteria are subjective. They are

1. Trustworthiness and credibility (C_1). The brand is believable, safe to use, and consistently delivers on the promises it makes.
2. Quality (C_2). The products offered by the brand are well-made and well-designed.
3. Value (C_3). The brand offers good value for money.
4. Understanding of consumer needs (C_4). The brand regularly demonstrates that it responds to and satisfies your changing.
5. Innovative (C_5). The brand regularly introduces new products, features of services.
6. Social responsibility (C_6). The brand supports the community, the environment, and its employees, and practices good corporate ethics.

2. Estimation of Fuzzy Weights of Six Criteria

The fuzzy weights of criteria are assessed by the industrial experts and academic professionals rather than by the shippers in this paper. This is because the importance of criterion among the shippers is different. To integrate the consensus of opinions of experts, therefore, as mentioned in sub-section 3 of Section II, the SAM approach is used to obtain the weights of six criteria.

3. Estimation of Fuzzy Ratings of All Alternatives versus All Criteria

The arithmetic mean method is used to obtain the average fuzzy ratings of all alternatives versus all criteria. The linguistic variables of the preference rating set, mentioned in the sub-section 2 of Section II, are assisted in obtaining the fuzzy ratings by shippers.

Let $s_{it}^h = (c_{it}^h, a_{it}^h, b_{it}^h)$, $i = 1, 2, \ldots, m$; $t = 1, 2, \ldots, k$; $h = 1, 2, \ldots, n$, be the appropriateness rating assigned to alternative A_i by the h^{th} shippers for criterion C_t. Then, the appropriateness rating of alternative A_i can be represented as

$$S_{it} = 1/n \otimes \left(s_{it}^1 \oplus s_{it}^2 \oplus \cdots \oplus s_{it}^n\right) = (q_{it}, o_{it}, p_{it}) \tag{18}$$

where $q_{it} = \frac{1}{n}\sum_{h=1}^{n} c_{it}^h$, $o_{it} = \frac{1}{n}\sum_{h=1}^{n} a_{it}^h$, $p_{it} = \frac{1}{n}\sum_{h=1}^{n} b_{it}^h$.

4. Aggregation of Evaluating Ratings of All Alternatives

By using the SAM approach mentioned in sub-section 2 of Section III, let $W_t = (c_t, a_t, b_t)$, $t = 1, 2, \ldots, k$, be the weight of the criterion C_t on the criteria layer. By using the method of sub-section 3 of Section III, let $S_{it} = (q_{it}, o_{it}, p_{it})$, $i = 1, 2, \ldots, m$; $t = 1, 2, \ldots, k$, be the appropriateness rating of the alternative A_i versus all criteria. Then the aggregation of appropriateness rating of alternative A_i for all criteria C_t ($t = 1, 2, \ldots, k$) can be denoted as

$$R_i = \frac{1}{k} \otimes \left[\left(S_{i1} \otimes W_1\right) \oplus \cdots \oplus \left(S_{it} \otimes W_t\right) \oplus \cdots \oplus \left(S_{ik} \otimes W_k\right)\right],$$

$$i = 1, 2, \ldots, m. \tag{19}$$

Since $W_t = (c_t, a_t, b_t)$, $t = 1, 2, \ldots, k$, we can denote $R_i = (Y_i, Q_i, Z_i)$, where $Y_i = \sum_{t=1}^{k} q_{it}\, c_t / k$, $Q_i = \sum_{t=1}^{k} o_{it}\, a_t / k$, $Z_i = \sum_{t=1}^{k} p_{it}\, b_t / k$.

5. Rank of the Trusted Brands

Using the ranking method proposed in sub-section 4 of Section II, the ranking value $U_T(R_i)$ of the aggregation of appropriateness rating of alternative A_i versus all criteria can be obtained by

$$U_T(R_i) = \rho\left[\frac{Z_i - x_1}{x_2 - x_1 - Q_i + Z_i}\right] + (1-\rho)\left[1 - \frac{x_2 - Y_i}{x_2 - x_1 + Q_i - Y_i}\right] \tag{20}$$

where $i = 1, 2, \ldots, m$, $x_1 = \min\{Y_1, Y_2, \ldots, Y_m\}$, and $x_2 = \max\{Z_1, Z_2, \ldots, Z_m\}$.

Let $A = (c, a, b)$ be the appropriateness rating obtained by using the aggregation methods proposed in sub-section 3 of Section III. Based on the method developed by Chang and Chen [4], $T = (a - c)/(b - c)$ can be considered as all shippers' total risk attitude index for the appropriateness rating. By using this concept, thus, the value ρ can be evaluated by the data input stage procedure [4]. For the fuzzy MCDM algorithm presented in this paper, we can accumulate the value ρ of the fuzzy ratings of all shippers for all alternatives versus all criteria. Then the total risk attitude index ρ of all shippers can be obtained by

$$\rho = \frac{\sum_{h=1}^{n}\sum_{i=1}^{m}\sum_{t=1}^{k}\left(\frac{a_{it}^h - c_{it}^h}{b_{it}^h - c_{it}^h}\right)}{n \times m \times k} \tag{21}$$

Finally, by Eqs. (20) and (21), the final ranking values $U_T(R_i)$ of the m alternatives can be obtained. Based on the ranking rules proposed in sub-section 4 of Section II, the rank of trusted brands can be assessed.

IV. NUMERICAL STUDY

In this section, a hypothetical example of assessing trusted brand for CSCs is to study and demonstrate the computational process of the proposed fuzzy MCDM algorithm, step by step, as follows.

Table 1. The directly assigned fuzzy numbers of three experts.

	E_1	E_2	E_3
Very high (*VH*)	$VH_1 = (4, 4.25, 5)$	$VH_2 = (3.8, 4.45, 5)$	$VH_3 = (3.9, 4.5, 5)$
High (*H*)	$H_1 = (3.5, 3.6, 4)$	$H_2 = (3.4, 3.5, 3.8)$	$H_3 = (3.5, 3.8, 3.9)$
Medium (*M*)	$M_1 = (2.5, 2.85, 3.5)$	$M_2 = (2.75, 3.2, 3.4)$	$M_3 = (3, 3.25, 3.5)$
Low (*L*)	$L_1 = (1.5, 2.1, 2.5)$	$L_2 = (2, 2.5, 2.75)$	$L_3 = (2, 2.5, 3)$
Very low (*VL*)	$VL_1 = (1, 1.4, 1.5)$	$VL_2 = (1, 1.5, 2)$	$VL_3 = (1, 1.45, 2)$

Table 2. The linguistic weighting values of six criteria of three experts.

	E_1	E_2	E_3
C_1	VH_1	VH_2	VH_3
C_2	VH_1	VH_2	VH_3
C_3	H_1	H_2	H_3
C_4	H_1	H_2	M_3
C_5	M_1	M_2	L_3
C_6	H_1	H_2	M_3

Step 1. Assume that the trusted brands for CSCs are assessed by an impartial survey company, e.g. Reader Digest. Three candidates, i.e., A_1, A_2, and A_3, are chosen after a preliminary screening for further evaluation. A committee of three experts, i.e., E_1, E_2, and E_3, has been formed to determine the six criteria weights by using the SAM approach. A numerous shippers are requested for voting their perceived ratings on the three brands. For easily computing process, ten shippers are used as an example.

Step 2. Three experts directly assigned their importance scales characterized by fuzzy numbers, as shown in Table 1. Then three experts start to evaluate the importance weights of six criteria by using Delphi method [16] to adjust the estimation, as shown in Table 2.

In our case, the author used the criterion C_1 in Table 1 as an example for illustrating the computing process of the SAM approach, as mentioned in sub-section 3 of Section II. That is $VH_1 = A_1 = (4, 4.25, 5)$, $VH_2 = A_2 = (3.8, 4.45, 5)$, and $VH_3 = A_3 = (3.9, 4.5, 5)$, respectively. The process can be computed as follows.

(1) The agreement degrees between three experts can be calculated as follows, i.e.,

$$S(A_1, A_2) = \frac{1}{1+\left|\frac{4+(4*4.25)+5}{6} - \frac{3.8+(4*4.45)+5}{6}\right|}$$
$$= 0.9091 = S(A_2, A_1),$$

$$S(A_1, A_3) = S(A_3, A_1) = 0.8696, \text{ and}$$

$$S(A_2, A_3) = S(A_3, A_2) = 0.9524.$$

(2) The agreement matrix can be expressed as

$$\begin{bmatrix} 1 & 0.9091 & 0.8696 \\ 0.9091 & 1 & 0.9524 \\ 0.8696 & 0.9524 & 1 \end{bmatrix}.$$

(3) The average agreement degrees of three experts are $A(E_1) = 0.8893$, $A(E_2) = 0.9307$, and $A(E_3) = 0.9110$, respectively.

(4) The relative agreement degrees of three experts are $RAD_1 = 0.3256$, $RAD_2 = 0.3408$, and $RAD_3 = 0.3336$, respectively.

(5) If we consider each expert has different importance degree, then the relative importance weight of each expert will be calculated by using Step 6 of sub-section 3 of Section II. That is, suppose expert E_1 is the most important expert; i.e., $\Omega_1 = 1$. And the relative importance weights of experts E_2 and E_3 to E_1 can be compared to draw out $\Omega_2 = 0.65$, and $\Omega_3 = 0.85$, respectively. Then we can calculate three experts' degrees of importance are $w_1 = 0.4$, $w_2 = 0.26$, and $w_3 = 0.34$, respectively.

(6) If we consider the degree of importance is more important than relative agreement degree, the $\kappa = 0.4$ can be set by the author. Then, the consensus degree coefficients of three experts are $CDC_1 = 0.3554$, $CDC_2 = 0.3085$, and $CDC_3 = 0.3361$, respectively.

(7) Finally, the overall fuzzy number of combining three experts' opinions is $\hat{A}_{C_1} = (3.9047, 4.3957, 5)$. The GMIR value is $P(\hat{A}_{C_1}) = \frac{3.9047+(4*4.3957)+5}{6} = 4.4146.$

By using the above computing process, we can obtain the other five overall fuzzy numbers of criteria C_2 to C_6. They

Table 3. The perceived ratings of three brands versus six criteria by ten shippers.

Criteria	Shipper (S^h)	Container shipping company			Criteria	Shipper (S^h)	Container shipping company		
		A_1	A_2	A_3			A_1	A_2	A_3
C_1	$h = 1$	*AP*	*AG*	*G*	C_4	$h = 1$	*P*	*G*	*VG*
	$h = 2$	*AG*	*F*	*AG*		$h = 2$	*G*	*AG*	*G*
	$h = 3$	*G*	*G*	*G*		$h = 3$	*F*	*F*	*AG*
	$h = 4$	*AP*	*G*	*VG*		$h = 4$	*G*	*G*	*AG*
	$h = 5$	*VG*	*G*	*G*		$h = 5$	*AP*	*F*	*G*
	$h = 6$	*AP*	*P*	*G*		$h = 6$	*G*	*G*	*AG*
	$h = 7$	*AG*	*G*	*AG*		$h = 7$	*F*	*F*	*AG*
	$h = 8$	*F*	*AG*	*VG*		$h = 8$	*P*	*G*	*G*
	$h = 9$	*G*	*VG*	*AG*		$h = 9$	*AP*	*VG*	*VG*
	$h = 10$	*AG*	*F*	*AG*		$h = 10$	*F*	*AG*	*AG*
C_2	$h = 1$	*AP*	*G*	*G*	C_5	$h = 1$	*P*	*F*	*G*
	$h = 2$	*G*	*G*	*VG*		$h = 2$	*G*	*G*	*G*
	$h = 3$	*G*	*P*	*AG*		$h = 3$	*AP*	*P*	*AG*
	$h = 4$	*P*	*P*	*G*		$h = 4$	*F*	*G*	*G*
	$h = 5$	*G*	*G*	*AG*		$h = 5$	*G*	*F*	*G*
	$h = 6$	*AP*	*AG*	*AG*		$h = 6$	*P*	*G*	*AG*
	$h = 7$	*VG*	*F*	*G*		$h = 7$	*P*	*P*	*VG*
	$h = 8$	*G*	*G*	*VG*		$h = 8$	*G*	*G*	*G*
	$h = 9$	*F*	*VG*	*G*		$h = 9$	*F*	*AG*	*G*
	$h = 10$	*AP*	*G*	*AG*		$h = 10$	*AP*	*VG*	*G*
C_3	$h = 1$	*G*	*F*	*AG*	C_6	$h = 1$	*AP*	*G*	*G*
	$h = 2$	*AG*	*G*	*G*		$h = 2$	*G*	*VG*	*AG*
	$h = 3$	*AP*	*P*	*G*		$h = 3$	*F*	*G*	*AG*
	$h = 4$	*P*	*AG*	*VG*		$h = 4$	*AP*	*VG*	*G*
	$h = 5$	*F*	*P*	*G*		$h = 5$	*AP*	*G*	*VG*
	$h = 6$	*G*	*G*	*AG*		$h = 6$	*F*	*G*	*AG*
	$h = 7$	*G*	*F*	*AG*		$h = 7$	*P*	*VG*	*G*
	$h = 8$	*AP*	*G*	*G*		$h = 8$	*G*	*AG*	*VG*
	$h = 9$	*G*	*VG*	*G*		$h = 9$	*AP*	*G*	*G*
	$h = 10$	*AP*	*G*	*G*		$h = 10$	*AP*	*VG*	*G*

are $\hat{A}_{C_2}$ = (3.9047, 4.3957, 5), $\hat{A}_{C_3}$ = (3.4699, 3.6365, 3.9066), $\hat{A}_{C_4}$ = (3.3068, 3.4553, 3.7754), $\hat{A}_{C_5}$ = (2.4141, 2.8428, 3.3082), and $\hat{A}_{C_6}$ = (3.3068, 3.4553, 3.7754), respectively. Then the GMIR values of these five overall fuzzy numbers are $P(\hat{A}_{C_2}) = 4.4146$, $P(\hat{A}_{C_3}) = 3.6537$, $P(\hat{A}_{C_4}) = 3.4839$, $P(\hat{A}_{C_5}) =$ 2.8489, and $P(\hat{A}_{C_6}) =$ 3.4839, respectively. Hence, we can obtain the crisp weights of these six criteria by using the arithmetic average method. They are W_{C_1} = 4.4146/(4.4146 + 4.4146 + 3.6537 + 3.4839 + 2.8489 + 3.4839) = 0.1980, W_{C_2} = 0.1980, W_{C_3} = 0.1638, W_{C_4} = 0.1562, W_{C_5} = 0.1278, and W_{C_6} = 0.1562, respectively.

Step 3. In our case, ten shippers are requested for voting their perceived ratings on the three brands by using the linguistic values mentioned in sub-section 2 of Section II. The results are shown in Table 3. Then we can obtain the appropriateness ratings of three container shipping companies (S_{it}), the results are shown in Table 4.

Step 4. Integrating Step 2 and Step 3 to calculate the aggregation of appropriateness ratings of three container shipping companies versus six criteria (R_i), the results are shown in Table 5.

Step 5. By using the Eq. (21), we can obtain total risk attitude index ρ = 0.417 of ten shippers. The risk-bearing attitude of ten shippers trends towards pessimistic, which is based upon the procedure of data input stage. Then, by utilizing the Eq. (20), we can obtain x_1 = min{0.0493, 0.0841, 0.1203} = 0.0493, and x_2 = max{0.0994, 0.150, 0.1667} = 0.1667, respectively. Finally, we can obtain

Table 4. The appropriateness ratings of three container shipping companies.

Criteria	A_1	A_2	A_3
C_1	(0.5, 0.6, 0.675)	(0.525, 0.725, 0.9)	(0.75, 0.9, 1)
C_2	(0.3, 0.475, 0.625)	(0.45, 0.675, 0.875)	(0.75, 0.9, 1)
C_3	(0.325, 0.475, 0.625)	(0.425, 0.65, 0.85)	(0.675, 0.85, 1)
C_4	(0.225, 0.425, 0.625)	(0.55, 0.75, 0.925)	(0.8, 0.925, 1)
C_5	(0.2, 0.4, 0.6)	(0.425, 0.65, 0.85)	(0.625, 0.825, 1)
C_6	(0.15, 0.275, 0.4)	(0.65, 0.875, 1)	(0.7, 0.875, 1)

Table 5. Aggregation of appropriateness ratings of three companies versus six criteria.

R_1	R_2	R_3
(0.0493, 0.0752, 0.0994)	(0.0841, 0.1201, 0.150)	(0.1203, 0.1470, 0.1667)

$$U_T(R_1) = (0.417)\left[\frac{0.0994-0.0493}{0.1667-0.0493-0.0752+0.0994}\right] + (1-0.417)\left[1-\frac{0.1667-0.0493}{0.1667-0.0493+0.0752-0.0493}\right] = 0.25291,$$

$U_T(R_2) = 0.55416$, and

$U_T(R_3) = 0.75235$.

We can see that the order of final ranking value of fuzzy overall evaluation for three container shipping companies is $U_T(R_3) > U_T(R_2) > U_T(R_1)$. It is obvious, based on the ranking rules proposed in sub-section 4 of Section II, the best trusted brand is company A_3. Therefore, the company A_3 is the most trusted brand based on the proposed fuzzy MCDM algorithm.

V. CONCLUSIONS

The brand name has been influenced the purchasing behavior in the marketing procedure. Plus, much attention has been devoted to the trusted brand names in different industries. However, the trusted brand of container shipping industry has not been measured in the related survey in Taiwan. Therefore, we try to provide and develop an evaluation model to assess the trusted brand for container shipping companies. Since the evaluation process involves a MCDM situation, where fills with information of ambiguous and fuzzy environment. In the light of this, the main purpose of this paper is to develop a fuzzy MCDM approach to assess the trusted brand for container shipping companies and to illustrate the computing process by using a numerical study.

In summary, some of the theoretical concepts and methods used in this research are firstly introduced. These methodologies include triangular fuzzy numbers, algebraic operations, linguistic variables, SAM approach, and a ranking method. Secondly, a step-by-step fuzzy MCDM algorithm, including five systematic procedures, is proposed. In Step 1, the assessing criteria are cited from Reader Digest. In Step 2, the estimations of six criteria weights are obtained by SAM approach via committee experts. In Step 3, the evaluations of performance values for all alternatives versus six criteria are obtained by shippers. In Step 4, the evaluating ratings of all alternatives are aggregated. In Step 5, the best trusted brand can be obtained by using the ranking method. Finally, a hypothetical and numerical example of assessing trusted brand is studied to demonstrate the computational process of the proposed fuzzy MCDM algorithm. Besides, the merit of this fuzzy MCDM algorithm in this paper with its methodologies can be employed as a practical tool for empirically business application in the future study. Furthermore, the proposed algorithm can also be applied in the similar problems, such as customer relationship excellent award, service quality award, and so on.

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