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A Fuzzy Multi-Criteria Decision-Making Model for the Selection of Courier Service Providers: An Empirical Study from Shippers' Perspective in Taiwan

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The main purpose of this paper is to develop a fuzzy multi-criteria decision-making (FMCDM) model to support decisions on the selection of a suitable courier service provider (CSP). The emphasis of the systematic appraisal employed in the evaluation process is on trapezoidal fuzzy numbers and linguistic values characterised by trapezoidal fuzzy numbers, as well as the graded mean integration representation method. An empirical study with four alternatives, that is, DHL, FedEx, UPS, and Taiwan Post Office, is designed to demonstrate the FMCDM algorithm. Study results show that UPS and Taiwan Post Office are the best and worst CSPs, based on shippers' perceptions in Taiwan.
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INTRODUCTION

The use of courier service providers (CSPs) is growing very rapidly in the current decade. Many cargoes, such as gifts, samples, merchandises, books and documents, can be shipped by CSPs. Global networks of specialised services, for example high value-added logistics, transportation, related information services, international trade support and supply chain services, are the focus of today's CSPs. With the increasing emphasis on time and place utility, in terms of 'time-in-transit and consistency-of-service' (Stock and Lambert, 2001), more and more shippers are exploring CSP solutions to transport their cargoes, parcels, and documents quickly.

Since there are increasing needs to transport products quickly and with high levels of service consistency, choosing a suitable CSP is important in smoothing supply chain operations. However, experience has shown that the choice of a suitable CSP 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 (decision-makers) to devise, identify and recognise effective criteria, as well as evaluate questions of compatibility and feasibility prior to the choice of CSPs.

The decision for the choice of CSPs poses a multi-criteria problem. The goal of the multi-criteria decision-making (MCDM) method is to 'aid decision-makers in integrating objective measurements with value judgments' that are based not on individual opinions but on collective group ideas (Belton and Stewart, 2002). 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. The fuzziness-based multi-criteria decision-making (FMCDM) approach is designed to minimise such adverse conditions and strengthen the choice process.

In summary, the aim of this paper is to develop a FMCDM model to improve the quality of decision-making in choosing a suitable CSP. The main contribution of the paper is in the definition, conversion, and treatment of vague and complex multi-level criteria. Set memberships of fuzzy set theory are employed to develop a practical model for business purposes. The following section presents the research methodology. Consequently, a FMCDM algorithm is constructed, and a survey of choosing a CSP from shippers' perspective in Taiwan is empirically studied. Finally, some conclusions are made in the last section.

RESEARCH METHODOLOGY

In this section, some of the concepts and methods used in this paper are briefly introduced. These include the fuzzy set theory and the method of graded mean integration representation.

Fuzzy set theory

The fuzzy set theory (Zadeh, 1965) 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 probability distributions in terms of set memberships. Once determined and defined, sets of memberships in probability distributions can be effectively used in logical reasoning. Trapezoidal fuzzy numbers, the algebraic operations of fuzzy numbers, and linguistic values are the three major components and form the cornerstones of this section.

Trapezoidal fuzzy numbers

In a universe of discourse X, a fuzzy subset A of X is defined by a membership function $f_A(x)$, which maps each element x in X to a real number in the interval $[0, 1]$. The function value $f_A(x)$ represents the grade of membership of x in A.

A fuzzy number A (Dubois and Prade, 1978) in real line $\mathscr{R}$ is a trapezoidal fuzzy number if its membership function $f_A : \mathscr{R} \to [0, 1]$ is

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

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

The x in interval $[a, b]$ gives the maximal grade of $f_A(x)$, that is $f_A(x) = 1$; it is the most probable value of the evaluation data. In addition, c and d are the lower and upper bounds of the available area for the evaluation data. They are used to reflect the fuzziness of the evaluation data. The narrower the interval $[c, d]$, the lower the fuzziness of the evaluation data.

Trapezoidal fuzzy numbers are easy to use and interpret. For example, 'approximately 300' and 'approximately between 300 and 310' can be represented by (295, 300, 300, 306) and (295, 300, 310, 316), respectively. They can also be represented with more leeway by (290, 300, 300, 313) and (287, 300, 310, 324) respectively. In addition, a non-fuzzy number, an exact number a, can be represented by (a, a, a, a). For example, 'a value of 300' can be represented by (300, 300, 300, 300).

The algebraic operations of fuzzy numbers

Let $A_1 = (c_1, a_1, b_1, d_1)$ and $A_2 = (c_2, a_2, b_2, d_2)$ be fuzzy numbers. According to the extension principle (Zadeh, 1965), the algebraic operations of any two fuzzy numbers A_1 and A_2 can be expressed as

(1) Fuzzy addition, $\oplus$:

$$A_1 \oplus A_2 = (c_1 + c_2, a_1 + a_2, b_1 + b_2, d_1 + d_2);$$

(2) Fuzzy multiplication, $\otimes$:

$$k \otimes A_2 = (kc_2, ka_2, kb_2, kd_2), \quad k \in \Re,\ k \geq 0;$$

$$A_1 \otimes A_2 \cong (c_1c_2, a_1a_2, b_1b_2, d_1d_2), \quad c_1 \geq 0,\ c_2 \geq 0$$

Linguistic values

In fuzzy decision environments, two preference ratings can be used. They are fuzzy numbers and linguistic values characterised by fuzzy numbers. Depending on practical needs, decision-makers may apply one or both of them. In this paper, the weighting set $W = \{VL, L, M, H, VH\}$ and the rating set $S = \{VP, P, F, G, VG\}$ are used, where VL = very low, L = low, M = medium, H = high, VH = very high, VP = very poor, P = poor, F = fair, G = good, and VG = very good. Both sets are used to evaluate the weights of all criteria and sub-criteria, as well as the fuzzy ratings of alternatives against various sub-criteria above the alternative level. We define $VL = VP = (0, 0, 0.2, 0.3)$, $L = P = (0.2, 0.3, 0.4, 0.5)$, $M = F = (0.4, 0.5, 0.6, 0.7)$, $H = G = (0.6, 0.7, 0.8, 0.9)$, $VH = VG = (0.8, 0.9, 1, 1)$. These trapezoidal fuzzy numbers are referred to in Ghyym (1999).

Graded mean integration representation method

In a fuzzy decision-making environment, ranking the alternatives under consideration is essential. For matching the fuzzy MCDM algorithm developed in this paper, and solving the problem powerfully, the graded mean integration representation method, proposed by Chen and Hsieh (2000), is used to rank the final ratings of alternatives.

Let $A_i = (c_i, a_i, b_i, d_i)$, $i = 1, 2, \ldots, n$, be n trapezoidal fuzzy numbers. By the graded mean integration representation method, the graded mean integration representation $P(A_i)$ of A_i is

$$P(A_i) = \frac{c_i + 2a_i + 2b_i + d_i}{6} \tag{2}$$

Suppose $P(A_i)$ and $P(A_j)$ are the graded mean integration representations of the trapezoidal fuzzy numbers A_i and A_j, respectively. We define:

(1) $A_i > A_j \Leftrightarrow P(A_i) > P(A_j)$,
(2) $A_i < A_j \Leftrightarrow P(A_i) < P(A_j)$,
(3) $A_i = A_j \Leftrightarrow P(A_i) = P(A_j)$.

PROCEDURE FOR CHOOSING CSPs

The paper proposes a systematic approach for choosing CSPs using the concepts of fuzzy MCDM. Some steps are taken below to describe this. These include development of hierarchical structure, computation of aggregating evaluation ratings of all feasible alternatives, and choice of optimal alternative.

Development of hierarchical structure

When developing a hierarchical structure, forming a committee of decision-makers to select the evaluation criteria and identify the feasible alternatives is very important. It is well-known that a choice in a decision-making problem can be viewed as a collection of procedures that includes four elements, that is, decision-maker, alternatives, criteria, and decision rules. In this paper, a number of decision-makers are expected to address the fuzzy problem, involving compromise or trade-off solutions which, in the process of decision-making, have the characteristics or properties of bargaining. Then, a set of alternatives becomes both feasible to the decision-makers and known to them during the decision process. The feasibility of an alternative is defined by a variety of constraints such as physical availability, monetary resources, information constraints, and so on. Later, the evaluation criteria of every available alternative should be established, to evaluate the attractiveness of alternatives based on criteria values. Finally, a choice from two or more alternatives requires a decision rule, that is, the ranking rules mentioned above, so that decision-makers can make a best choice.

Numerous criteria need to be considered in a multi-criteria evaluation problem. The criteria used here derive from business publications, official Taiwanese sources and literature review (McGinnis, 1979; Lambert *et al*, 1993; Murphy *et al*, 1997; Bloomberg *et al*, 1998; Rolnicki, 1998; Kent and Parker, 1999; Stock and Lambert, 2001). Six criteria in the first hierarchy and thirty sub-criteria in the second hierarchy are suggested and their codes are shown in parentheses.

(1) Speed and reliability (C_1). This criterion includes four sub-criteria, that is, speed of transit (C_{11}), on-time and right delivery (C_{12}), transit time consistency (C_{13}), and capability of emergency processing in transit (C_{14}).
(2) Freight rates (C_2). This criterion includes three sub-criteria, that is, reasonableness of freight rate (C_{21}), flexibility of freight rate (C_{22}), and clear tariff (C_{23}).
(3) Safety (C_3). This criterion includes three sub-criteria, that is, processing attitude of customer's complaints (C_{31}), records, processing attitude and claims processing of freight loss and damage (C_{32}), and package material and cleanliness (C_{33}).

(4) Salesman factor (C_4). This criterion includes four sub-criteria, that is, understanding shippers' needs (C_{41}), quality of carrier salesmanship (C_{42}), professional capability (C_{43}), attitude and bearing of salesman and operating personnel (C_{44}).
(5) Service and convenience (C_5). This criterion includes nine sub-criteria, that is, convenient procedure of sending and receiving (C_{51}), convenient way of payment (C_{52}), service flexibility can match customers' needs (C_{53}), notify the sender of delivery time (C_{54}), shipment tracing service (C_{55}), providing related information service (C_{56}), assistance on related operating procedures (C_{57}), wide service channels and places (C_{58}), and diversified and complete service (C_{59}).
(6) Carrier considerations (C_6). This criterion includes seven sub-criteria, that is, goodwill and reputation (C_{61}), financial stability of carriers (C_{62}), operation and management capability (C_{63}), condition and availability of equipment and facilities (C_{64}), support with public welfare and recreational activities (C_{65}), advertising on public media (C_{66}), and willingness to continued improvement (C_{67}).

A hierarchy structure is the framework of system structure. It is not only useful in studying the interaction among the elements involved in each level, but it can also help decision-makers to explore the impact of different elements on the evaluated system. Figure 1 is a complete hierarchical structure of choosing CSPs with k criteria, $n_1 + \cdots + n_t + \cdots + n_k$ sub-criteria and m alternatives.

Computation of aggregating evaluation ratings of all feasible alternatives

Assume a committee of decision-makers. They are responsible for assessing the appropriateness of all feasible alternatives, under each of the sub-criteria above

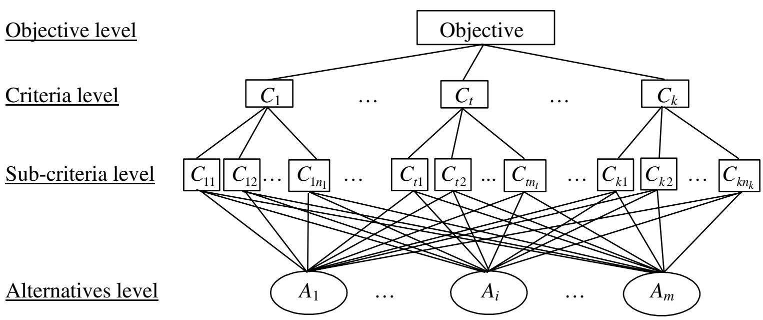

Figure 1: Hierarchy structure of choosing courier service providers

the feasible alternatives level, as well as the importance of all criteria and sub-criteria. For this, the weights and appropriateness should be modelled for computing the aggregating evaluation ratings. This is done as follows.

Let $w_{tq}=(c_{tq},a_{tq},b_{tq},d_{tq})$, $0\leq c_{tq}\leq a_{tq}\leq b_{tq}\leq d_{tq}\leq 1$, $t=1,2,\ldots,k$; $q=1,2,\ldots,n$ be the weight given to criterion C_t by the qth decision-maker. Then, the weight of C_t can be represented as $W_t=(c_t,a_t,b_t,d_t)$, where

$$c_t=\frac{1}{n}\sum_{q=1}^{n}c_{tq},\quad a_t=\frac{1}{n}\sum_{q=1}^{n}a_{tq},\quad b_t=\frac{1}{n}\sum_{q=1}^{n}b_{tq},\quad d_t=\frac{1}{n}\sum_{q=1}^{n}d_{tq}$$

Let $w_{tjq}=(c_{tjq},a_{tjq},b_{tjq},d_{tjq})$, $0\leq c_{tjq}\leq a_{tjq}\leq b_{tjq}\leq d_{tjq}\leq 1$, $t=1,2,\ldots,k$; $j=1,2,\ldots,n_t$; $q=1,2,\ldots,n$, be the weight given to criterion C_{tj} by the qth decision-maker. Then, the weight of C_{tj} can be represented as $w_{tj}=(c_{tj},a_{tj},b_{tj},d_{tj})$, where

$$c_{tj}=\frac{1}{n}\sum_{q=1}^{n}c_{tjq},\quad a_{tj}=\frac{1}{n}\sum_{q=1}^{n}a_{tjq},\quad b_{tj}=\frac{1}{n}\sum_{q=1}^{n}b_{tjq},\quad d_{tj}=\frac{1}{n}\sum_{q=1}^{n}d_{tjq}$$

Let $m_{itjq}=(c_{itjq},a_{itjq},b_{itjq},d_{itjq})$, $0\leq c_{itjq}\leq a_{itjq}\leq b_{itjq}\leq d_{itjq}\leq 1$, $i=1,2,\ldots,m$; $t=1,2,\ldots,k$; $j=1,2,\ldots,n_t$; $q=1,2,\ldots,n$, be the appropriateness rating assigned to alternative A_i by the qth decision-maker for criterion C_{tj}. Then, the appropriateness rating of alternative A_i can be represented as $M_{itj}=(c_{itj},a_{itj},b_{itj},d_{itj})$ where

$$c_{itj}=\frac{1}{n}\sum_{q=1}^{n}c_{itjq},\quad a_{itj}=\frac{1}{n}\sum_{q=1}^{n}a_{itjq},\quad b_{itj}=\frac{1}{n}\sum_{q=1}^{n}b_{itjq},\quad d_{itj}=\frac{1}{n}\sum_{q=1}^{n}d_{itjq}$$

The aggregation appropriateness rating of alternative A_i for the n_t sub-criteria under criterion C_t $(t=1,2,\ldots,k)$ can be denoted as:

$$\begin{aligned}R_{it}=&\frac{1}{n_t}\otimes[(M_{it1}\otimes W_{t1})\oplus(M_{it2}\otimes W_{t2})\oplus\cdots\oplus(M_{itj}\otimes W_{tj})\\&\oplus\cdots\oplus(M_{itn_t}\otimes W_{tn_t})]\end{aligned}\tag{3}$$

Because $M_{itj}=(c_{itj},a_{itj},b_{itj},d_{itj})$ and $W_{tj}=(c_{tj},a_{tj},b_{tj},d_{tj})$, we can denote $R_{it}\cong(Y_{it},Q_{it},G_{it},Z_{it})$ where

$$Y_{it}=\sum_{j=1}^{n_t}c_{itj}c_{tj}/n_t,\quad Q_{it}=\sum_{j=1}^{n_t}a_{itj}a_{tj}/n_t,\quad G_{it}=\sum_{j=1}^{n_t}b_{itj}b_{tj}/n_t,$$
$$Z_{it}=\sum_{j=1}^{n_t}d_{itj}d_{tj}/n_t,\quad \text{for } i=1,2,\ldots,m;\quad t=1,2,\ldots,k$$

Furthermore, the final aggregation appropriateness rating of alternative A_i can be denoted as:

$$F_i = \frac{1}{k} \otimes [(R_{i1} \otimes W_1) \oplus (R_{i2} \otimes W_2) \oplus \cdots \oplus (R_{it} \otimes W_t) \oplus \cdots \oplus (R_{ik} \otimes W_k)] \quad (4)$$

Since $Wj = (c_j, a_j, b_j, d_j)$, we can denote $F_i \cong (Y_i, Q_i, G_i, Z_i)$, where

$$Y_i = \sum_{t=1}^{k} Y_{it} c_t / k, \quad Q_i = \sum_{t=1}^{k} Q_{it} a_t / k, \quad G_i = \sum_{t=1}^{k} G_{it} b_t / k$$
$$Z_i = \sum_{t=1}^{k} Z_{it} d_t / k, \quad \text{for } i = 1, 2, \ldots, m$$

Choice of optimal alternative

By equation (2), the ranking value of the aggregation appropriateness rating of alternative A_i can be obtained and denoted as:

$$P(F_i) = \frac{Y_i + 2Q_i + 2G_i + Z_i}{6} \quad (5)$$

By the ranking rules proposed above, the final ranking values of the m alternatives can be obtained, and finally the decision-makers can choose the optimal alternative.

EMPIRICAL STUDY

In this section, an empirical study of choosing CSPs in Taiwan is carried out to demonstrate the computational process as described above. The process of the algorithm is empirically implemented, step by step, as follows.

Step 1: Questionnaire design. In this step, six criteria, thirty sub-criteria, and four alternatives, that is, DHL, FedEx, UPS, and Taiwan Post Office, were used to design the questionnaire and to obtain information on the importance of all criteria and sub-criteria, as well as on the appropriateness of all feasible alternatives, *versus* various sub-criteria above the feasible alternatives. We used 1,500 exporters and importers as the population, recorded in the '*Directory of Excellent Exporters and Importers in 2003, ROC*' (Ministry of Economic Affairs, 2004). The questionnaire was filled in by the export/import department of each company. In addition, the surveys were completed through phone calls and in-person interviews by the authors. The reliability, that is, Cronbach α, of the questionnaire was 0.9062. A total of 347 valid responses were collected, from the 1,500 exporters and importers, which represents 23.13% of the total population.

Step 2: We use the linguistic weighting set W and rating set S to evaluate the importance weights (W_t and W_{tj}) of all criteria and sub-criteria, as well as the appropriateness ratings (M_{itj}) of alternatives *versus* various sub-criteria. To sum up the results surveyed in the questionnaire, the importance weights and appropriateness ratings are shown in Tables 1–3, respectively.

Step 3: We calculate the aggregation evaluation ratings of all alternatives. By utilising equations (3) and (4), final aggregation appropriateness ratings of all alternatives can be obtained. Finally, by using equation (5), we obtain the ranking values of the aggregation appropriateness rating of all alternatives. The results are shown in Table 4. The ranking order for the four alternatives is DHL, FedEx, UPS, and Taiwan Post Office. Therefore, we recommend that UPS be the most appropriate CSP for the exporters and importers in Taiwan, based on the proposed FMCDM algorithm.

Table 1: Importance weights of criteria (W_t)

Criteria	Fuzzy weights	Criteria	Fuzzy weights
C_1	(0.729, 0.829, 0.929, 0.959)	C_4	(0.511, 0.611, 0.711, 0.793)
C_2	(0.665, 0.765, 0.865, 0.922)	C_5	(0.738, 0.838, 0.938, 0.967)
C_3	(0.759, 0.862, 0.965, 0.996)	C_6	(0.709, 0.806, 0.903, 0.936)

Table 2: Importance weights of all sub-criteria (W_{tj})

Sub-criteria	Fuzzy weights	Sub-criteria	Fuzzy weights
C_{11}	(0.738, 0.838, 0.938, 0.969)	C_{52}	(0.528, 0.628, 0.728, 0.810)
C_{12}	(0.737, 0.837, 0.937, 0.968)	C_{53}	(0.686, 0.786, 0.886, 0.934)
C_{13}	(0.692, 0.789, 0.886, 0.928)	C_{54}	(0.675, 0.775, 0.875, 0.924)
C_{14}	(0.673, 0.773, 0.874, 0.934)	C_{55}	(0.666, 0.766, 0.866, 0.914)
C_{21}	(0.715, 0.815, 0.915, 0.951)	C_{56}	(0.595, 0.695, 0.795, 0.861)
C_{22}	(0.701, 0.801, 0.901, 0.937)	C_{57}	(0.610, 0.710, 0.810, 0.876)
C_{23}	(0.633, 0.733, 0.833, 0.882)	C_{58}	(0.701, 0.801, 0.901, 0.941)
C_{31}	(0.742, 0.842, 0.942, 0.971)	C_{59}	(0.684, 0.784, 0.884, 0.930)
C_{32}	(0.706, 0.806, 0.906, 0.950)	C_{61}	(0.734, 0.834, 0.934, 0.964)
C_{33}	(0.657, 0.757, 0.857, 0.921)	C_{62}	(0.575, 0.675, 0.775, 0.840)
C_{41}	(0.594, 0.694, 0.794, 0.868)	C_{63}	(0.727, 0.827, 0.927, 0.959)
C_{42}	(0.435, 0.535, 0.635, 0.721)	C_{64}	(0.699, 0.799, 0.899, 0.945)
C_{43}	(0.439, 0.539, 0.639, 0.724)	C_{65}	(0.453, 0.553, 0.653, 0.743)
C_{44}	(0.444, 0.544, 0.644, 0.733)	C_{66}	(0.597, 0.697, 0.798, 0.870)
C_{51}	(0.707, 0.807, 0.907, 0.944)	C_{67}	(0.702, 0.802, 0.902, 0.949)

Table 3: Appropriateness ratings of four alternatives *versus* all sub-criteria (M_{itj})

Sub-criteria	DHL	FedEx	UPS	Taiwan post office
C_{11}	(0.675, 0.775, 0.875, 0.927)	(0.692, 0.792, 0.892, 0.941)	(0.692, 0.792, 0.892, 0.944)	(0.279, 0.355, 0.469, 0.554)
C_{12}	(0.661, 0.761, 0.861, 0.920)	(0.656, 0.756, 0.856, 0.915)	(0.699, 0.799, 0.899, 0.948)	(0.255, 0.333, 0.431, 0.512)
C_{13}	(0.622, 0.722, 0.822, 0.885)	(0.620, 0.720, 0.820, 0.884)	(0.70, 0.80, 0.90, 0.949)	(0.315, 0.402, 0.489, 0.565)
C_{14}	(0.666, 0.766, 0.866, 0.923)	(0.666, 0.766, 0.866, 0.923)	(0.696, 0.796, 0.896, 0.947)	(0.266, 0.343, 0.466, 0.561)
C_{21}	(0.612, 0.712, 0.812, 0.877)	(0.628, 0.728, 0.828, 0.888)	(0.698, 0.798, 0.898, 0.947)	(0.328, 0.418, 0.528, 0.618)
C_{22}	(0.659, 0.759, 0.859, 0.909)	(0.670, 0.770, 0.870, 0.920)	(0.689, 0.789, 0.889, 0.943)	(0.295, 0.376, 0.495, 0.587)
C_{23}	(0.633, 0.733, 0.833, 0.888)	(0.633, 0.733, 0.833, 0.891)	(0.692, 0.792, 0.892, 0.945)	(0.346, 0.436, 0.546, 0.631)
C_{31}	(0.660, 0.760, 0.860, 0.913)	(0.688, 0.788, 0.888, 0.937)	(0.699, 0.799, 0.899, 0.948)	(0.334, 0.422, 0.534, 0.623)
C_{32}	(0.669, 0.769, 0.869, 0.922)	(0.674, 0.774, 0.874, 0.928)	(0.694, 0.794, 0.894, 0.946)	(0.315, 0.398, 0.515, 0.605)
C_{33}	(0.616, 0.716, 0.816, 0.880)	(0.658, 0.758, 0.858, 0.913)	(0.704, 0.804, 0.904, 0.951)	(0.330, 0.421, 0.530, 0.617)
C_{41}	(0.590, 0.690, 0.790, 0.857)	(0.674, 0.774, 0.874, 0.926)	(0.711, 0.811, 0.911, 0.954)	(0.344, 0.438, 0.544, 0.629)
C_{42}	(0.527, 0.627, 0.727, 0.805)	(0.631, 0.731, 0.831, 0.892)	(0.701, 0.801, 0.901, 0.950)	(0.301, 0.388, 0.501, 0.591)
C_{43}	(0.527, 0.627, 0.727, 0.805)	(0.622, 0.722, 0.822, 0.885)	(0.692, 0.792, 0.892, 0.944)	(0.327, 0.414, 0.527, 0.614)
C_{44}	(0.508, 0.608, 0.708, 0.788)	(0.627, 0.727, 0.827, 0.891)	(0.70, 0.80, 0.90, 0.949)	(0.320, 0.408, 0.520, 0.608)
C_{51}	(0.567, 0.667, 0.767, 0.833)	(0.633, 0.733, 0.833, 0.895)	(0.703, 0.803, 0.903, 0.951)	(0.339, 0.430, 0.539, 0.625)
C_{52}	(0.629, 0.741, 0.854, 0.930)	(0.646, 0.746, 0.846, 0.903)	(0.709, 0.809, 0.909, 0.954)	(0.338, 0.432, 0.538, 0.625)
C_{53}	(0.620, 0.720, 0.820, 0.879)	(0.624, 0.724, 0.824, 0.888)	(0.695, 0.795, 0.895, 0.947)	(0.346, 0.439, 0.546, 0.637)
C_{54}	(0.646, 0.746, 0.846, 0.904)	(0.644, 0.744, 0.844, 0.904)	(0.695, 0.795, 0.895, 0.946)	(0.347, 0.439, 0.547, 0.634)
C_{55}	(0.599, 0.699, 0.799, 0.858)	(0.635, 0.735, 0.835, 0.893)	(0.710, 0.810, 0.910, 0.954)	(0.348, 0.443, 0.548, 0.635)
C_{56}	(0.572, 0.672, 0.772, 0.838)	(0.659, 0.759, 0.859, 0.915)	(0.708, 0.808, 0.908, 0.953)	(0.329, 0.420, 0.529, 0.617)
C_{57}	(0.605, 0.705, 0.805, 0.870)	(0.668, 0.768, 0.868, 0.919)	(0.702, 0.802, 0.902, 0.950)	(0.318, 0.406, 0.518, 0.606)
C_{58}	(0.621, 0.721, 0.821, 0.879)	(0.628, 0.728, 0.828, 0.891)	(0.699, 0.799, 0.899, 0.948)	(0.315, 0.402, 0.515, 0.603)
C_{59}	(0.649, 0.749, 0.849, 0.901)	(0.683, 0.783, 0.883, 0.930)	(0.708, 0.808, 0.908, 0.953)	(0.341, 0.433, 0.541, 0.629)
C_{61}	(0.573, 0.673, 0.773, 0.837)	(0.666, 0.766, 0.866, 0.916)	(0.704, 0.804, 0.904, 0.951)	(0.345, 0.438, 0.545, 0.632)
C_{62}	(0.597, 0.697, 0.797, 0.855)	(0.677, 0.777, 0.877, 0.927)	(0.708, 0.808, 0.908, 0.953)	(0.356, 0.449, 0.556, 0.640)
C_{63}	(0.604, 0.704, 0.804, 0.863)	(0.668, 0.768, 0.868, 0.918)	(0.705, 0.805, 0.905, 0.951)	(0.304, 0.392, 0.504, 0.594)
C_{64}	(0.557, 0.657, 0.757, 0.825)	(0.661, 0.761, 0.861, 0.914)	(0.696, 0.796, 0.896, 0.947)	(0.376, 0.470, 0.576, 0.660)
C_{65}	(0.594, 0.694, 0.794, 0.854)	(0.635, 0.735, 0.835, 0.895)	(0.708, 0.808, 0.908, 0.953)	(0.334, 0.428, 0.534, 0.622)
C_{66}	(0.589, 0.689, 0.789, 0.851)	(0.674, 0.774, 0.874, 0.924)	(0.693, 0.793, 0.893, 0.945)	(0.370, 0.463, 0.570, 0.657)
C_{67}	(0.569, 0.669, 0.769, 0.836)	(0.659, 0.759, 0.859, 0.912)	(0.698, 0.798, 0.898, 0.948)	(0.355, 0.448, 0.555, 0.641)

Table 4: Final aggregation appropriateness ratings and ranking value of four alternatives

Alternatives	$F_i \cong$	Ranking value	Ranking order
DHL	(0.277, 0.425, 0.617, 0.735)	0.516	3
FedEx	(0.293, 0.446, 0.644, 0.762)	0.539	2
UPS	(0.312, 0.471, 0.677, 0.794)	0.567	1
Taiwan post office	(0.144, 0.241, 0.391, 0.508)	0.319	4

CONCLUDING REMARKS

With the increasing emphasis on time and place utility and high levels of service consistency, more and more shippers are exploring a CSP to transport their products quickly and smoothen their operations. However, experience has shown that the choice of a suitable CSP is not easy and it involves a multiplicity of complex considerations. Our main interest is in choosing an appropriate CSP, from the shippers' perspective in Taiwan. In order to design a more effective evaluation process, we propose a systematic appraisal for choosing an appropriate CSP. The proposed methodologies and procedures have enabled us to successfully accomplish our goal. Very often, in such a selection, the assessment of alternatives and importance weights, are given in linguistic values. As a result, precision-based methods tend to be rather ineffective in quantifying imprecision or vagueness of linguistic assessment.

The concepts of trapezoidal fuzzy numbers and linguistic values characterised by trapezoidal fuzzy numbers have been employed to describe the subjective assessments of the importance weights of all criteria, and appropriateness ratings of all alternatives *versus* sub-criteria. This was done in a way that allowed the viewpoints of an entire decision-making body to be expressed without any constraints. Also, a powerful ranking method, the graded mean integration representation method was used to rank the final ratings of alternatives. Our empirical study showed that among four alternatives, that is, DHL, FedEx, UPS, and Taiwan Post Office, UPS may be the most appropriate CSP for the exporters and importers in Taiwan.

The ranking values of DHL, FedEx, and UPS were fairly close and consequently our results should be interpreted with a lot of caution. Having said this, however, the Taiwan Post Office should strive to improve its overall service quality – as perceived by Taiwanese shippers – it wants to catch up with its competitors.

Furthermore, the proposed model does not only overcome the limitations of crisp values, but it also facilitates computer-based implementation as a decision support system for choice in fuzzy environments. Finally, the proposed algorithm can also be applied in similar selection problems, such as partner selection in strategic alliances in liner shipping, port selection, and so on.

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