A QUALITATIVE-QUANTITATIVE FUZZY EVALUATION MODEL FOR SELECTING AN INTERNATIONAL OCEAN FREIGHT LOGISTICS PROVIDER

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SUMMARY

To ensure the best possible integrated logistics service performance, how to select an international ocean freight logistics provider (IOFLP) suitable for shippers is an important issue. The main purpose of this paper is to construct a qualitative-quantitative fuzzy multiple criteria decision-making (MCDM) evaluation model to empirically select an optimal IOFLP. After reviewing the literature and gathering experts' opinions, 23 criteria in five assessment aspects suitable for the selection of an IOFLP were obtained. The study then constructed a fuzzy MCDM selection model based on quantitative-qualitative criteria, and conducted a questionnaire survey of import/export shippers in Taiwan in order to interpret the operating processes of the proposed model. The empirical results indicated that company *P* was the IOFLP considered optimal by the shippers in Taiwan. Moreover, the proposed qualitative-quantitative fuzzy MCDM method and research methodology in this study can be employed as a practical tool for business applications in the future.

1. INTRODUCTION

In today's international markets, enterprises must have a sure grasp of the many mutually-interacting competition factors in this uncertain business environment if they are to effectively provide consumers the most suitable products and services, satisfy customers' need for a quick response, and thereby develop new customers and ensure existing customers' repeat purchase intention (Javed and Wu, 2020). As a response to customers' time-sensitive needs, there has been a growing trend toward outsourcing of logistics among international enterprises, and this outsourcing enables companies to reduce their costs while increasing their efficiency (Ali and Kaur, 2018; Song et al., 2021). As a result, international freight logistics providers (IFLPs) (Large, 2017; Żak and Galińska, 2018) offering good timeliness and convenience have grown in importance. These IFLPs chiefly provide specialized international freight logistics services to companies wishing to outsource their logistics needs, and therefore play the role of a third party between buyers and sellers (Barker et al., 2021; Large, 2017). As a consequence, IFLPs are commonly known as third-party logistics providers ("3PLs") (Ali and Kaur, 2018; Barker et al., 2021; Large, 2017). Some IFLPs even provide integrated services that include finance, insurance, transport, and warehousing, supply chain management system consulting, and integrated supply chain solutions, and IFLPs of this type can be termed integrated fourth-party logistics providers ("4PLs") (Khan and Yu, 2019; Neise, 2018; Varun, 2019).

In the container transport market, in spite of the fact that ocean carriers are major players in the container shipping community (Martin and Thomas, 2001), IFLPs also play a very important 3PL role in marine logistics chains by ensuring that cargoes are effectively and efficiently assembled and handed over to container carriers for shipping (Neise, 2018). IFLPs may also play a 4PL role by providing effective supply chain management services to cargo owners. This suggests that IFLPs indeed occupy a crucial position in international container logistics. It should also be noted that businesses such as non-vessel operating common carriers (NVOCC), ocean freight forwarders (OFF), ocean transportation intermediaries (OTI), multimodal transport operators (MTO), and intermodal marketing companies (IMC) also provide integrated IFLP services in marine transport chains (Clott, 2018; Clott et al., 2018; Dua and Sinha, 2019; McCarthy, 2017; Varun, 2019). This paper includes all of these service providers in the broad category of international ocean freight logistics providers (IOFLPs).

IOFLPs are chiefly responsible for arranging import/export cargo transport for shippers. They consolidate cargo owners' miscellaneous goods as full container loads, which they turn over to the actual carriers for safe and effective transport to the destination. However, with the growing demand for international trade and logistics services in the wake of surging international transport, IOFLPs have expanded their services beyond the conventional intermediary or carrier role played by OFFs or NVOCCs, and have entered such logistics-related areas as integrated international shipping, logistics distribution, storage management, and distribution processing. Because IOFLPs seek to fulfill shippers' global logistics service goals, and to provide optimal integrated shipping services, they are gradually developing into all-round international logistics firms and integrated global logistics providers (Barker et al., 2021; Fanam and Ackerly, 2019; Liu and Lee, 2018).

Because companies in the upstream, mid-stream, and downstream segments of international logistics supply chains all have opportunities to use IOFLPs' services, many large IOFLPs are able to offer customized logistics services and operating activities. Furthermore, IOFLPs often also offer professional consulting services, can resolve enterprises' international logistics and distribution problems, and can thereby reduce the unnecessary waste of resources. As a result, IOFLPs and these enterprises commonly form close long-term partnerships emphasizing mutual benefit (Ding et al., 2017). Nevertheless, IOFLPs provide a wide variety of logistics services, and different enterprises' dependence on logistics services differ. What kinds of logistics services are truly needed by enterprises? What methods and standards should enterprises use to assess and select IOFLPs? These are unquestionably research topics of considerable importance.

When operating in a highly competitive business environment, enterprises must face uncertainty in the environment and time pressure when selecting an IOFLP, and must take numerous selection criteria into consideration. The selection of an IOFLP therefore has the characteristics of a multiple criteria decision-making (MCDM) problem (Ding and Liang, 2005). In addition, group decision-making and changes in the environment can cause the weights and importance of various criteria to be highly fuzzy and variable. Under these circumstances, conventional decision-making methods are inadequate to deal with the fuzziness of criteria weights and express the imprecision that occurs during the transmission of information in the decision-making process. Such methods consequently cannot fully express every assessment solution or the information implicit in decision-making criteria. Moreover, to appropriately integrate the opinions of the decision-making group or committee composed of decision-making units, and find the optimal solution, the alternative solutions must be scored and ranked. Hence, this study's goal was therefore to use fuzzy set theory (Zadeh, 1965) in conjunction with MCDM to establish an IOFLP selection model, and use this model to help international companies to find optimal IOFLPs in a fuzzy environment.

The economy of Taiwan is oriented mainly towards import and export trade. Taiwan has achieved good results in the global shipping industry due to the utilization of government resources in cooperation with private enterprises. According to UNCTAD (2020) data, the achievements include: (1) In terms of dead-weight tonnage, Taiwan's fleet accounts for 2.48% of the world's total and ranks 12th in the world. From the perspective of ship-owning economies, Taiwan accounts for 1.493% of the world's total, ranking 18th in the world. (2) In terms of port calls and median time spent in port by container ships, Taiwan accounts for 3.53% of the world's total and is the fifth largest in the world. (3) Taiwan's top three container shipping companies are among the world's top 20, including Evergreen Marine Corp., Yang Ming Marine Transport Corp., and Wan Hai Lines Ltd. In addition, T.S. Lines Ltd., the fourth largest container carrier in Taiwan, ranks 21st globally. (4) The cumulative Taiwan container throughput is approximately 14.6 million TEUs, of which approximately 9.62 million TEUs is via Kaohsiung Port, which ranks 15th in the world. In addition, according to the data from Taiwan's Ministry of Finance and WTO, Taiwan's total trade value in 2020 ranked 17th in the world, and in terms of export and import value, it ranks 15th and 18th, respectively. Whether these import and export trades can effectively achieve international distribution tasks is mainly achieved through IOFLPs－the main shipping assistants of container carriers. Based on this, this study intends to use the proposed fuzzy MCDM method to evaluate the top three IOFLPs in Taiwan, and the information obtained will be used as a reference for Taiwanese enterprises and manufacturers to select IOFLPs in the future.

The first section provides background information concerning this issue, the following section describes the research method, the third section presents the procedures of the proposed fuzzy MCDM method, the fourth section consists of an empirical study, and the final section presents conclusions.

2. RESEARCH METHOD

Fuzzy set theory was proposed by Zadeh in 1965. Zadeh believed that people's thinking, inferences, and understanding of the things around them inevitably contains a considerable degree of fuzziness. As a consequence, conventional analytical methods relying on precise values to perform forecasting and estimation are not adequately suited to solving problems that are characterized by variability and complexity and are generated by human-centered systems. Accordingly, in view of fuzzy analytical methods effectiveness at dealing with fuzzy decision-making situations, we use a fuzzy analytical method instead of conventional numerical methods in this study. Trapezoidal fuzzy numbers and their algebraic operations, linguistic variables, and ranking method are the three major components of our approach, and form the cornerstones of this section.

2.1 TRAPEZOIDAL FUZZY NUMBERS AND THEIR ALGEBRAIC OPERATIONS

In a universe of discourse *X*, a fuzzy subset $\tilde{A}$ of *X*, then $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) \mid x \in X\}$. It is defined by a membership function $\mu_{\tilde{A}}(x)$, which maps each element *x* in *X* to a real number in the interval $[0, 1]$. The function value $\mu_{\tilde{A}}(x)$ represents the grade of membership of *x* in $\tilde{A}$. As the value of $\mu_{\tilde{A}}(x)$ approaches 1, the higher the grade of membership of *x* in $\tilde{A}$.

Assuming that the membership function of a fuzzy number $\tilde{A}$ [24] is $\mu_{\tilde{A}} : \Re \rightarrow [0, 1]$, we have as shown in equation (1):

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-a)/(b-a), & a \le x \le b \\ 1, & b \le x \le c \\ (x-d)/(c-d), & c \le x \le d \\ 0, & otherwise \end{cases} \quad (1)$$

here $-\infty < a \le b \le c \le d < \infty$, which implies that this fuzzy number is a trapezoidal fuzzy number. The trapezoidal fuzzy number $\tilde{A}$ is represented as (a, b, c, d), and recorded as $\tilde{A} = (a, b, c, d)$.

In this study, the extension principle (Zadeh, 1965) is employed to perform algebraic operations involving trapezoidal fuzzy numbers. Let $\tilde{A}_1 = (a_1, b_1, c_1, d_1)$ and $\tilde{A}_2 = (a_2, b_2, c_2, d_2)$ be trapezoidal fuzzy numbers. The algebraic operations of any two trapezoidal fuzzy numbers $\tilde{A}_1$ and $\tilde{A}_2$ can be expressed as:

- Fuzzy addition, $\oplus$:

$$\tilde{A}_1 \oplus \tilde{A}_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2, d_1 + d_2);$$

- Fuzzy subtraction, $\ominus$:

$$\tilde{A}_1 \ominus \tilde{A}_2 = (a_1 - d_2, b_1 - c_2, c_1 - b_2, d_1 - a_2);$$

- Fuzzy multiplication, $\otimes$:

$$k \otimes \tilde{A}_2 = (ka_2, kb_2, kc_2, kd_2),\ k \in \Re, k \ge 0;$$
$$\tilde{A}_1 \otimes \tilde{A}_2 \cong (a_1a_2, b_1b_2, c_1c_2, d_1d_2),\ a_1 \ge 0, a_2 \ge 0;$$

- Fuzzy division, $\varnothing$:

$$(\tilde{A}_1)^{-1} = (a_1, b_1, c_1, d_1)^{-1} = (1/d_1, 1/c_1, 1/b_1, 1/a_1),\ a_1 > 0;$$
$$\tilde{A}_1 \varnothing \tilde{A}_2 \cong (a_1/d_2, b_1/c_2, c_1/b_2, d_1/a_2),\ a_1 \ge 0, a_2 > 0.$$

2.2 LINGUISTIC VARIABLE

Zadeh (1975; 1976) also proposed the concept of linguistic variables, which provide a convenient quantitative syntax to describe problems that are highly complex or poorly defined. Linguistic variables involve the use of natural language words or phrases to express variables. For instance, "importance" constitutes a linguistic variable, and has a linguistic, and not numerical, value, such as extremely important, important, average, not important, and extremely unimportant. Linguistic values can express the approximate reasoning in fuzzy set theory in a rational manner.

In a fuzzy decision-making environment, there are two types of preference scales that can be used to assess the importance of criteria (or sub-criteria) and assess the appropriateness ratings of all alternatives under each sub-criterion (Ghyym, 1999; Liu et al., 2020). One type uses trapezoidal fuzzy numbers, and the other uses linguistic values expressed as trapezoidal fuzzy numbers; decision-makers (DMs) or decision-making groups can select one type according to need, or also opt to use both types. This paper employs "degree of importance" to assess the weights of all criteria and sub-criteria, and uses "appropriateness ratings" to assess the performance values of all alternatives under all sub-criteria. This paper uses trapezoidal fuzzy numbers to convey the linguistic values of "degree of importance" and "appropriateness ratings." For example, "degree of importance" has the linguistic value set *W*={extremely unimportant, unimportant, medium, important, extremely important}, "appropriateness ratings" has the linguistic value set *S*={extremely poor, poor, fair, good, extremely good}. The membership function of the linguistic values contained in sets *W* and *S* can be defined as: extremely unimportant (*EU*) = extremely poor (*EP*) = (0, 0, 0.2, 0.3); unimportant (*U*) = poor (*P*) = (0.2, 0.3, 0.4, 0.5); medium (*M*) = fair (*F*) = (0.4, 0.5, 0.6, 0.7); important (*I*) = good (*G*) = (0.6, 0.7, 0.8, 0.9); and extremely important (*EI*) = extremely good (*EG*) = (0.8, 0.9, 1, 1) (Ghyym, 1999).

2.3 RANKING FUZZY NUMBERS WITH MAXIMIZING AND MINIMIZING SETS

This paper employed the ranking method developed by Chen (1985), Kim and Park (1990), and Chang and Chen (1994) due to the method's ease of use and great power.

Let $\tilde{A}_i,\ i = 1, 2, \ldots, n,$ be the fuzzy numbers. The membership functions can be denoted by $\mu_{\tilde{A}_i}(x)$. We define the maximizing set $\tilde{H} = \{(x, \mu_{\tilde{H}}(x)) \mid x \in R\}$ as

$$\mu_{\tilde{H}}(x) = \begin{cases} (x - x_0)/(x_1 - x_0), & x \in [x_0, x_1], \\ 0, & otherwise, \end{cases}$$

and the minimizing set $\tilde{D} = \{(x, \mu_{\tilde{D}}(x)) \mid x \in R\}$ as

$$\mu_{\tilde{D}}(x) = \begin{cases} (x - x_1)/(x_0 - x_1), & x \in [x_0, x_1], \\ 0, & otherwise, \end{cases}$$

where $x_0 = \inf G,\quad x_1 = \sup G,\quad G = \bigcup_{i=1}^{n} G_i$ and $G_i = \{x \mid \mu_{\tilde{A}_i}(x) > 0\},\ i = 1, 2, \ldots, n.$

Then, the value of optimistic ranking (which we can call the optimistic utility value) $V_{\tilde{H}}^{o}(\tilde{A}_i)$ and the value of pessimistic ranking (which we can call the pessimistic utility value) $V_{\tilde{D}}^{p}(\tilde{A}_i)$ of the fuzzy numbers $\tilde{A}_i$ can be denoted by

$$V_{\tilde{H}}^{o}(\tilde{A}_i) = \sup_x \left(\mu_{\tilde{A}_i}(x) \wedge \mu_{\tilde{H}}(x)\right) \quad (2)$$

and

$$V_{\tilde{D}}^{p}(\tilde{A}_i) = \sup_x \left(\mu_{\tilde{A}_i}(x) \wedge \mu_{\tilde{D}}(x)\right) \quad (3)$$

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

Finally, we can define the ranking value $V^R(\tilde{A}_i)$ of fuzzy numbers $\tilde{A}_i$ as

$$V^R(\tilde{A}_i) = \alpha V_{\tilde{H}}^{o}(\tilde{A}_i) + (1-\alpha) V_{\tilde{D}}^{p}(\tilde{A}_i),\ 0 \le \alpha \le 1 \quad (4)$$

In the foregoing equation, the α value can be interpreted as the DMs' total risk attitude index (TRAI), and TRAI reflects assumption of risk by DMs. If $\alpha < 0.5,$ this indicates that the DMs' overall risk attitude is pessimistic, and the DMs are risk-averse. If $\alpha = 0.5,$ this indicates that the DMs' overall risk attitude is moderate, and the DMs are risk-neutral. If $\alpha > 0.5,$ this indicates that the DMs' overall risk attitude is optimistic, and the DMs are risk-lovers. Here risk attitude refers to the DMs' intention to assume risk and preference for assuming risk. This intention to assume risk or avoid risk will influence the degree to which organization members perceive time, cost, service, and various kinds of information. Generally speaking, managers who are willing to assume risk are typically very active, make quick decisions, use relatively little intelligence to shape their decisions, and display excellent work performance; managers who are unwilling to assume risk typically display the opposite characteristics. This reflects how much information managers gather before making a decision. When a manager with a high-risk preference makes a decision or drafts a policy, that person will spend relatively little time gathering information, but the correctness or quality of the manager's decision will not necessarily be poor.

The effect of DMs' TRAI in group decision-making is an important topic. Ghyym (1999) conducted a comparative study of the comparative method of assessing DMs' risk attitude. In general, two methods can be used to determine the α value. The first approach is to let a single DM determine the α value on the basis of subjective perception during the data output stage (Kim and Park, 1990). For example, a DM may decide on an α value of 0.25, 0.5, or 0.85, etc. However, this approach is difficult to apply to situations involving a large decision-making group. Chang and Chen (1994) therefore proposed an alternative approach in which the determination of α is made by the whole group of DMs during the data input stage, which can directly convey the assumption of risk by the decision-making group. Because the approach proposed by Chang and Chen (1994) seems very reasonable, this method of determining α is used in this paper to assess the TRAI of the DMs or decision-making group.

Furthermore, the ranking of the trapezoidal fuzzy numbers $\tilde{A}_i$ and $\tilde{A}_j$ is defined and based on the following rules:

- $\tilde{A}_i > \tilde{A}_j \Leftrightarrow V^R(\tilde{A}_i) > V^R(\tilde{A}_j)$
- $\tilde{A}_i < \tilde{A}_j \Leftrightarrow V^R(\tilde{A}_i) < V^R(\tilde{A}_j)$
- $\tilde{A}_i = \tilde{A}_j \Leftrightarrow V^R(\tilde{A}_i) = V^R(\tilde{A}_j)$

Let $\tilde{A}_i = (a_i, b_i, c_i, d_i),\quad i = 1, 2, \ldots, n,$ be n trapezoidal fuzzy numbers. By employing the equations (1), (2), (3) and (4), the ranking value $V^R(\tilde{A}_i)$ of the trapezoidal fuzzy number $\tilde{A}_i$ can be denoted by

$$\begin{aligned} V^R(\tilde{A}_i) &= \alpha\left[\frac{d_i - x_0}{x_1 - x_0 - c_i + d_i}\right] \\ &\quad + (1-\alpha)\left[1 - \frac{x_1 - a_i}{x_1 - x_0 + b_i - a_i}\right] \end{aligned} \quad (5)$$

where $x_0 = \min\{a_1, a_2, \ldots, a_n\},\quad x_1 = \max\{d_1, d_2, \ldots, d_n\}$ and $0 \le \alpha \le 1.$

After deriving α, the ranking value can be obtained from formula (5). The ranking order of the *n* trapezoidal fuzzy numbers can now be determined using this ranking rule.

3. PROCEDURES OF THE PROPOSED FUZZY MCDM METHOD

To ensure that the model is easy to apply and complies with scientific principles, this section constructs a systematic fuzzy MCDM evaluation model that can be used to resolve the IOFLP selection problem. The model's evaluation steps are as follows:

(1) Organization of an evaluation committee.
(2) After review of relevant literature and consideration of the opinions of scholars and industry personnel, drafting of IOFLP assessment criteria.
(3) Construction of a hierarchical framework.
(4) Use of the linguistic value of "degree of importance" to assess all criteria and sub-criteria, and derive the fuzzy weights of all criteria and sub-criteria.
(5) Use of the linguistic value of "appropriateness ratings" to assess the performance values of all alternatives under all sub-criteria, and then derive the fuzzy rating values under each assessment sub-criteria for all feasible alternatives.
(6) Calculation of the overall appropriateness rating value of each feasible alternative after assigning fuzzy weights.
(7) Using the trapezoidal fuzzy numbers ranking method, ranking of the overall fuzzy appropriateness rating value of each feasible alternative, and selection of the most suitable IOFLP company.

3.1 PRELIMINARY SELECTION OF CRITERIA

The factors influencing selection of an IOFLP are complex and broad in scope. This paper arrived at the 5 major assessment criteria of price, trustworthiness, timeliness, convenience, and service after reviewing the domestic and foreign literature and consulting experts' views in interviews. A review of the literature on these assessment criteria and sub-criteria are presented in the following paragraph. To confirm whether the text of these assessment criteria and sub-criteria are clearly expressed, in this study, we invited two university professors engaged in container shipping research and three IOFLPs industry professionals to develop these assessment criteria and sub-criteria. As a result, several assessment sub-criteria were also found under each assessment criterion, and this paper ultimately gathered 5 preliminary assessment criteria and 23 assessment sub-criteria.

(1) Price (C_1): This criterion includes 5 sub-criteria (Chen et al., 2017; Fanam and Ackerly, 2019; Huang et al., 2019; Miller et al., 2013; Singh and Sharma, 2014; Singh et al., 2018a; Singh et al., 2018b; Subhashini and Preetha, 2018; Yang and Chang, 2019; Yang and Lirn, 2017), *i.e*., transport fee rate (C_{11}), local export expenses (such as terminal handling charges, document fees, and customs declaration fees, etc.) (C_{12}), level of discount on freight and charges (C_{13}), level of flexibility in time frame for settlement of transport fees (C_{14}), and level of validity period of quoted price (C_{15}).

(2) Trustworthiness (C_2): This criterion includes 4 sub-criteria (Chen et al., 2017; Chou, 2018; Ergin, 2021; Fanam and Ackerly, 2019; Huang et al., 2019; Song and Yeo, 2017; Subhashini and Preetha, 2018; Yang and Chang, 2019; Yang and Lirn, 2017), *i.e*., goodwill and reputation (C_{21}), whether proactively informs customer of changes in sailing information (C_{22}), level of cargo damage claim settlement speed and reasonable degree of claim amount (C_{23}), and trustworthiness of sales personnel (C_{24}).

(3) Timeliness (C_3): This criterion includes 5 sub-criteria (Agrawal et al., 2016; Chen et al., 2017; Chou, 2018; Fanam and Ackerly, 2019; Huang et al., 2019; Murfield et al., 2017; Singh et al., 2018a; Sohn et al., 2017; Song and Yeo, 2017; Subhashini and Preetha, 2018; Yang and Chang, 2019; Yang and Lirn, 2017), *i.e*., level of frequency of sailings (C_{31}), cargo space acquisition (C_{32}), transit time (C_{33}), level of terminal handling speed (C_{34}), and level of speed of responses to price quotes and related questions (C_{35}).

(4) Convenience (C_4): This criterion includes 4 sub-criteria (Chou, 2018; Ergin, 2021; Fanam and Ackerly, 2019; Huang et al., 2019; Singh et al., 2018a; Song and Yeo, 2017; Subhashini and Preetha, 2018; Yang and Chang, 2019; Yang and Lirn, 2017), *i.e*., simplicity of consignment procedures (C_{41}), provision of multimodal transport (C_{42}), level of cargo status tracking ability (C_{43}), and provision of a sufficient number of empty containers and number of available container types (C_{44}).

(5) Service (C_5): This criterion includes 5 sub-criteria (Agrawal et al., 2016; Chen et al., 2017; Chou, 2018; Ergin, 2021; Fanam and Ackerly, 2019; Huang et al., 2019; Miller et al., 2013; Singh and Sharma, 2014; Singh et al., 2018a; Song and Yeo, 2017; Yang and Chang, 2019; Yang and Lirn, 2017; Zailani et al., 2018), *i.e*., quality of service from office customer service personnel (OP & CS) (C_{51}), document speed and correctness (C_{52}), degree of cooperation from overseas agents or subsidiaries (C_{53}), provision of professional transport consulting (such as concerning international trade and insurance, etc.) (C_{54}), and whether company provides customized service (C_{55}).

MCDM assessment criteria can generally be classified as two types (Ding and Liang, 2005; Ding, 2011): (1) qualitative criteria: criteria with linguistic or qualitative definitions, which are also known as subjective criteria, and (2) quantitative criteria: criteria that can be defined as monetary or quantitative terms, which are also known as objective criteria. Among the 23 sub-criteria in this paper, marine transport fee rate (C_{11}), local export expenses (C_{12}), and transit time (C_{33}) constitute quantitative criteria, and the remainder are qualitative criteria.

3.2 HIERARCHICAL FRAMEWORK

A hierarchical framework can be used to research the interactions between elements at different levels, and their impact on the system. The number of hierarchical levels will depend on the complexity of the system and analytical needs (Ding and Liang, 2005; Ding, 2011). The hierarchical framework shown in Fig. 1 provided the basis for IOFLP selection in this paper. Within this framework, the first level constitutes the goal, which is to select the most suitable of the IOFLPs being assessed, while also ranking the IOFLPs in terms of their superiority; the second level consists of the k main assessment criteria used to select an IOFLP; the third layer consists of $n_1+\cdots+n_t+\cdots+n_k$ sub-criteria below the main assessment criteria; and the fourth level consists of m feasible alternatives.

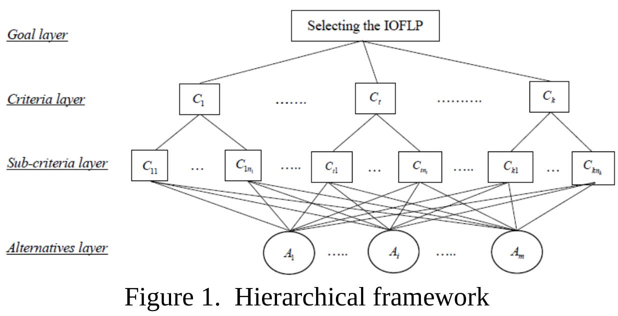

Figure 1. Hierarchical framework

3.3 DERIVING THE FUZZY WEIGHTS OF ALL CRITERIA AND SUB-CRITERIA

Let $\tilde{W}_t^p = (a_t^p, b_t^p, c_t^p, d_t^p), \quad t = 1, 2, \ldots, k; \quad p = 1, 2, \ldots, n,$ where this indicates the weight C_t assigned to a certain assessment criterion by decision-maker D_p. We now use the arithmetic mean to calculate the weight $\tilde{W}_t$ of the assessment criterion C_t, where

$$\tilde{W}_t = 1/n \otimes \left(\tilde{W}_t^1 \oplus W_t^2 \oplus \cdots \oplus \tilde{W}_t^n\right).$$

According to the extension principle (Zadeh, 1965) that if we let $\tilde{W}_t = (a_t, b_t, c_t, d_t),$ then

$$a_t = \frac{1}{n}\sum_{p=1}^{n} a_t^p, \; b_t = \frac{1}{n}\sum_{p=1}^{n} b_t^p, \; c_t = \frac{1}{n}\sum_{p=1}^{n} c_t^p, \; d_t = \frac{1}{n}\sum_{p=1}^{n} d_t^p.$$

Now let $\tilde{W}_{tj}^p = (a_{tj}^p, b_{tj}^p, c_{tj}^p, d_{tj}^p), \quad t = 1, 2, \ldots, k;$ $j = 1, 2, \ldots, n_t; \quad p = 1, 2, \ldots, n,$ which indicates the weight assigned to a certain sub-criterion C_{tj} by decision-maker D_p. We now use the arithmetic mean to calculate the weight $\tilde{W}_{tj}$ of sub-criterion C_{tj}, where

$$\tilde{W}_{tj} = 1/n \otimes \left(\tilde{W}_{tj}^1 \oplus W_{tj}^2 \oplus \cdots \oplus \tilde{W}_{tj}^n\right).$$

We know from the extension principle that if we let $\tilde{W}_{tj} = (a_{tj}, b_{tj}, c_{tj}, d_{tj}),$ then

$$a_{tj} = \frac{1}{n}\sum_{p=1}^{n} a_{tj}^p, \; b_{tj} = \frac{1}{n}\sum_{p=1}^{n} b_{tj}^p, \; c_{tj} = \frac{1}{n}\sum_{p=1}^{n} c_{tj}^p, \; d_{tj} = \frac{1}{n}\sum_{p=1}^{n} d_{tj}^p.$$

3.4 DERIVING THE FUZZY RATING VALUES UNDER ALL SUB-CRITERIA FOR ALL FEASIBLE ALTERNATIVES

Because the assessment criteria in this paper consisted of both qualitative criteria and quantitative criteria, this section's treatment of the fuzzy rating values of all feasible alternatives under each sub-criterion employs the two methods explained below:

Case 1: For the qualitative criteria

Let $\tilde{O}_{itj}^p = (a_{itj}^p, b_{itj}^p, c_{itj}^p, d_{itj}^p), \quad i = 1, 2, \ldots, m; \quad t = 1, 2, \ldots, k;$ $j = 1, 2, \ldots, n_t; \quad p = 1, 2, \ldots, n,$ which represents the appropriateness rating relative to a certain sub-criterion C_{tj} assigned by decision-maker D_p to feasible alternative A_i. We can now use the arithmetic mean to calculate the fuzzy rating value $\tilde{O}_{itj}$ relative to a certain sub-criterion C_{tj} of feasible alternative A_i, where

$$\tilde{O}_{itj} = 1/n \otimes \left(\tilde{O}_{itj}^1 \oplus \tilde{O}_{itj}^2 \oplus \cdots \oplus \tilde{O}_{itj}^n\right).$$

We know from the extension principle that if we let $\tilde{O}_{itj} = (a_{itj}, b_{itj}, c_{itj}, d_{itj}),$ then

$$a_{itj} = \frac{1}{n}\sum_{p=1}^{n} a_{itj}^p, \; b_{itj} = \frac{1}{n}\sum_{p=1}^{n} b_{itj}^p, \; c_{itj} = \frac{1}{n}\sum_{p=1}^{n} c_{itj}^p,$$
$$d_{itj} = \frac{1}{n}\sum_{p=1}^{n} d_{itj}^p.$$

Case 2: For the quantitative criteria

Under quantitative criteria, the fuzzy rating values of each feasible alternative can be obtained using the following methods (Ding and Liang, 2005):

(1) If the fuzzy rating value can be effectively obtained via numerical assessment, then it can be directly expressed as a trapezoidal fuzzy number. For example, if the transport fee rate is roughly between 100 and 110, then the appropriateness rating value can be expressed as the trapezoidal fuzzy number (96, 100, 110, 113).

(2) When employing multi-period historical data, the following method can be used to perform conversion: Let $o_1, o_2, \ldots, o_z$ be the transport fee rate during past period *z*, then the fuzzy rating value of the transport fee rate can be expressed as (e, f, g, h). Here $e = \min\{o_1, o_2, \ldots, o_z\}$, $h = \max\{o_1, o_2, \ldots, o_z\}$, and f and g can be respectively expressed as the first and third quartiles (Q_1 and Q_3) of all transport fee rates. For example, when there are 11 sets of transport fee rate data, which have the values of 31, 33, 35, 36, 39, 40, 41, 42, 43, 47, and 49, then the appropriateness rating value can be expressed as the trapezoidal fuzzy numbers $(31, 35, 43, 49)$.

3.5 CALCULATION OF THE OVERALL FUZZY RATING VALUES OF ALL ALTERNATIVES

Let $\tilde{W}_t = (a_t, b_t, c_t, d_t), \quad t = 1, 2, \ldots, k,$ which represents the fuzzy weight of the k^{th} criterion; $\tilde{W}_{tj} = (a_{tj}, b_{tj}, c_{tj}, d_{tj}),$ $t = 1, 2, \ldots, k; \quad j = 1, 2, \ldots, n_t,$ represents the fuzzy weight of the j^{th} sub-criterion C_{tj} under t^{th} criterion C_t; and $\tilde{O}_{itj} = (a_{itj}, b_{itj}, c_{itj}, d_{itj}), \quad i = 1, 2, \ldots, m; \quad t = 1, 2, \ldots, k;$ $j = 1, 2, \ldots, n_t,$ represents the original fuzzy rating value of feasible alternative A_i relative to sub-criteria C_{tj}. In order to effectively integrate positive criteria (also known as benefit criteria) with negative criteria (also known as cost criteria), let $x_{tj} = \max_i\{d_{itj}\}, \quad y_{tj} = \min_i\{a_{itj}\}$, and represent the standardized fuzzy rating value of the i^{th}

feasible alternative A_i relative to sub-criterion C_{tj} as $\tilde{S}_{itj}$, then

(1) Positive criteria can be expressed as

$$\tilde{S}_{itj} = (q_{itj}, r_{itj}, u_{itj}, v_{itj}) = \left(\frac{a_{itj}}{x_{tj}}, \frac{b_{itj}}{x_{tj}}, \frac{c_{itj}}{x_{tj}}, \frac{d_{itj}}{x_{tj}} \right) \quad (6)$$

(2) Negative criteria can be expressed as

$$\tilde{S}_{itj} = (q_{itj}, r_{itj}, u_{itj}, v_{itj}) = \left(\frac{y_{tj}}{d_{itj}}, \frac{y_{tj}}{c_{itj}}, \frac{y_{tj}}{b_{itj}}, \frac{y_{tj}}{a_{itj}} \right) \quad (7)$$

Continuing, we calculate the fuzzy rating value of feasible alternative A_i relative to the n_t sub-criteria under the t^{th} ($t = 1, 2, \ldots, k$) assessment criterion, which is expressed as $\tilde{S}_{it}$, so that

$$\tilde{S}_{it} = \frac{1}{n_t} \otimes \begin{bmatrix} (\tilde{W}_{t1} \otimes \tilde{S}_{it1}) \oplus (\tilde{W}_{t2} \otimes \tilde{S}_{it2}) \oplus \cdots \\ \oplus (\tilde{W}_{tj} \otimes \tilde{S}_{itj}) \oplus \cdots \oplus (\tilde{W}_{tn_t} \otimes \tilde{S}_{itn_t}) \end{bmatrix} \quad (8)$$
$$t = 1, 2, \ldots, k; \quad i = 1, 2, \ldots, m.$$

We know from the extension principle that if we let $\tilde{S}_{it} \cong (Q_{it}, R_{it}, U_{it}, V_{it}), \ t = 1, 2, \ldots, k; \ i = 1, 2, \ldots, m,$ then

$$Q_{it} = \frac{1}{n_t} \sum_{j=1}^{n_t} a_{tj} q_{itj}, \ R_{it} = \frac{1}{n_t} \sum_{j=1}^{n_t} b_{tj} r_{itj}, \ U_{it} = \frac{1}{n_t} \sum_{j=1}^{n_t} c_{tj} u_{itj},$$
$$V_{it} = \frac{1}{n_t} \sum_{j=1}^{n_t} d_{tj} v_{itj}.$$

Proceeding in this manner, we calculate the overall fuzzy rating values of the feasible alternatives A_i relative to all k assessment criteria, which is expressed as $\tilde{S}_i$, so that

$$\tilde{S}_i = \frac{1}{k} \otimes \begin{bmatrix} (\tilde{W}_1 \otimes \tilde{S}_{i1}) \oplus (\tilde{W}_2 \otimes \tilde{S}_{i2}) \oplus \cdots \\ \oplus (\tilde{W}_t \otimes \tilde{S}_{it}) \oplus \cdots \oplus (\tilde{W}_k \otimes \tilde{S}_{ik}) \end{bmatrix} \quad (9)$$
$$i = 1, 2, \ldots, m.$$

We know from the extension principle that if we let $\tilde{S}_i \cong (Q_i, R_i, U_i, V_i), \ i = 1, 2, \ldots, m,$ then

$$Q_i = \frac{1}{k} \sum_{t=1}^{k} a_t Q_{it}, \ R_i = \frac{1}{k} \sum_{t=1}^{k} b_t R_{it}, \ U_i = \frac{1}{k} \sum_{t=1}^{k} c_t U_{it},$$
$$V_i = \frac{1}{k} \sum_{t=1}^{k} d_t V_{it}.$$

3.6 RANKING TO SELECT THE OPTIMAL ALTERNATIVE

Using the formula (5) of ranking method, we can derive the rank of the overall fuzzy rating values S_i of feasible alternatives A_i, which is expressed as $V^R(\tilde{S}_i)$, employing the following formula:

$$V^R(\tilde{S}_i) = \alpha \left[\frac{V_i - x_0}{x_1 - x_0 - U_i + V_i} \right] + (1 - \alpha) \left[1 - \frac{x_1 - Q_i}{x_1 - x_0 + R_i - Q_i} \right] \quad (10)$$

where $x_0 = \min\{Q_1, Q_2, \ldots, Q_m\}, \ x_1 = \max\{V_1, V_2, \ldots, V_m\},$ $i = 1, 2, \ldots, m,$ and $0 \le \alpha \le 1.$

In formula (10), α is the TRAI of the group of DMs, and represents the risk attitude of the decision-making group. This study used all of the assessment data for all criteria layer, sub-criteria layer and alternatives layer during the data input stage (Chang and Chen, 1994) to determine the TRAI, which can be expressed as

$$\alpha = \frac{\alpha_1 + \alpha_2 + \alpha_3}{k + \sum_{t=1}^{k} n_t + m \times \sum_{t=1}^{k} n_t} \quad (11)$$

where

$$\alpha_1 = \sum_{t=1}^{k} \left(\frac{b_t - a_t}{(d_t - c_t) + (b_t - a_t)} \right),$$
$$\alpha_2 = \sum_{t=1}^{k} \sum_{j=1}^{n_t} \left(\frac{b_{tj} - a_{tj}}{(d_{tj} - c_{tj}) + (b_{tj} - a_{tj})} \right),$$
$$\alpha_3 = \sum_{i=1}^{m} \sum_{t=1}^{k} \sum_{j=1}^{n_t} \left(\frac{r_{itj} - q_{itj}}{(v_{itj} - u_{itj}) + (r_{itj} - q_{itj})} \right).$$

When formula (11) is substituted into formula (10), we can obtain the $V^R(\tilde{S}_i)$ value of alternatives A_i. Based on the ranking rules, the optimal IOFLP can be selected by the decision committee.

4. EMPIRICAL STUDY

This section performs empirical analysis of a cargo owner's selection of the optimal company from among Taiwan's three leading IOFLPs, and thereby verify the quantitative-qualitative fuzzy MCDM selection model proposed in this paper. The steps and operations are described as follows:

4.1 QUESTIONNAIRE DESIGN AND RECOVERY

We assume that a shipper wishes to select one of Taiwan's three leading IOFLPs (designated companies *D*, *O*, and *P*) to serve as its future partner. Brief information about three leading IOFLPs are as follows: Company *D* has nearly 100 branches around the world, and its global agency network exceeds 600. Company *D* is a dynamic and innovative IOFLP in Taiwan, and its vision is to become a global logistics integration expert. Company *O* has been established for about 20 years, and it has worked closely with more than 400 agents around the world, especially in Southeast Asia. Company *O*'s vision is to become an Asian inter-regional logistics integrator, and it is a young rising star among Taiwan's IOFLP. Company *P* has an annual transportation volume of 500,000 TEUs and is a leading IOFLP with revenue and economies of scale in Taiwan. Company *P* has a long history of establishment. Company *P* has branches in major cities in the United States, Northeast Asia, China, Southeast Asia, and other places. Company *P* has built a complete and dense global agency network globally.

This study used five assessment criteria, 23 sub-criteria, and three selection alternatives to construct a hierarchical structure, as shown in Figure 2. Furthermore, Figure 2 was used to design a questionnaire, which was subsequently used to obtain the weights of all criteria and sub-criteria, and determine the performance values of the three alternatives relative to all assessment sub-criteria.

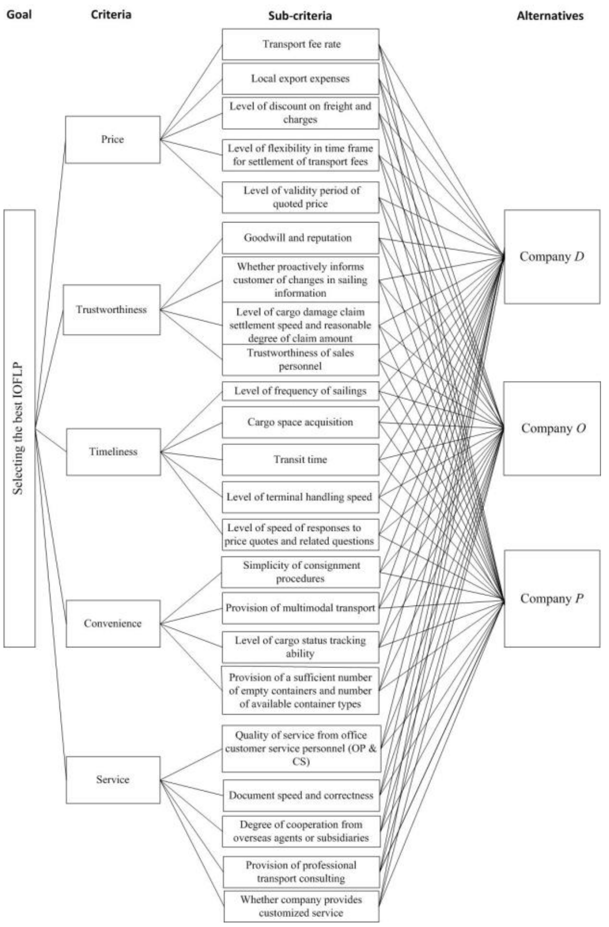

Figure 2. Hierarchical structure for selecting the IOFLPs

This paper issued 160 questionnaires to import/export firms, which were given approximately 2 months to fill them out. Visits, e-mail, and telephone calls were employed to urge completion of the questionnaires. A total of 125 valid questionnaires were recovered, for an effective recovery rate of 78.125%. The questionnaire had a Cronbach's α of 0.891, which indicated that the questionnaire had a high level of reliability (Hair et al., 2018). Moreover, the basic statistics of the responses for each question in those valid questionnaires is provided, as shown in Table 1.

Table 1. The basic statistics of the responses

Sub-criteria	Min	Max	Standard deviation	Frequency (%)				
				1	2	3	4	5
C_{11}	3	5	0.734	0	0	15.2	32.00	52.8
C_{12}	1	5	0.869	0.8	2.4	22.4	37.6	36.8
C_{13}	2	5	0.774	0	2.4	13.6	41.6	42.4
C_{14}	2	5	0.815	0	3.2	24.8	43.2	28.8
C_{15}	2	5	0.825	0	1.6	28.8	36.8	32.8
C_{21}	2	5	0.752	0	2.4	25.2	48.8	33.6
C_{22}	2	5	0.676	0	0.8	8.0	29.6	61.6
C_{23}	3	5	0.566	0	0	4.0	32.0	64.0
C_{24}	3	5	0.502	0	0	1.6	29.6	68.8
C_{31}	1	5	0.724	0.8	0	18.4	53.6	27.2
C_{32}	3	5	0.628	0	0	7.2	35.2	57.6
C_{33}	2	5	0.769	0	2.4	24.0	48.0	25.6
C_{34}	2	5	0.734	0	1.6	16.0	48.8	33.6
C_{35}	3	5	0.601	0	0	5.6	36.8	57.6
C_{41}	3	5	0.643	0	0	12.0	53.6	34.4
C_{42}	2	5	0.790	0	4.0	20.0	49.6	26.4
C_{43}	3	5	0.634	0	0	8.0	43.2	48.8
C_{44}	3	5	0.573	0	0	4.0	46.4	49.6
C_{51}	3	5	0.572	0	0	4.0	36.8	59.2
C_{52}	3	5	0.512	0	0	1.6	32.8	65.6
C_{53}	3	5	0.645	0	0	8.8	42.4	48.8
C_{54}	3	5	0.681	0	0	12.8	44.8	42.4
C_{55}	2	5	0.767	0	2.4	19.2	48.0	30.4

4.2 CALCULATION OF THE FUZZY WEIGHTS OF ALL CRITERIA AND SUB-CRITERIA

The trapezoidal fuzzy numbers corresponding to the linguistic variables and the weight calculation formulas were used in conjunction with data from the 125 valid questionnaires to calculate the fuzzy weights of the 5 assessment criteria and 23 sub-criteria. The results were as shown in Table 2 and Table 3. To understand the importance of each assessment criterion and sub-criterion, this article used formula (5) to defuzzy these fuzzy weights to obtain the crisp values. Then we can know how important it is for the shippers to choose the IOFLPs. The results are shown in the right column of Table 2 and Table 3.

Table 2. The fuzzy weights of the 5 criteria and its defuzzification

Criteria	Fuzzy weights	Defuzzification
C_1	(0.704, 0.804, 0.904, 0.942)	0.7101
C_2	(0.739, 0.839, 0.939, 0.966)	0.7619
C_3	(0.706, 0.806, 0.906, 0.947)	0.7139
C_4	(0.674, 0.774, 0.874, 0.930)	0.6718
C_5	(0.709, 0.809, 0.909, 0.950)	0.7184

Table 3. The fuzzy weights of the 23 sub-criteria and its defuzzification

Sub-criteria	Fuzzy weights	Defuzzification
C_{11}	(0.675, 0.775, 0.875, 0.922)	0.7237
C_{12}	(0.614, 0.714, 0.814, 0.878)	0.6484
C_{13}	(0.648, 0.748, 0.848, 0.906)	0.6904
C_{14}	(0.595, 0.695, 0.795, 0.866)	0.6270
C_{15}	(0.603, 0.703, 0.803, 0.870)	0.6355
C_{21}	(0.627, 0.727, 0.827, 0.894)	0.6093
C_{22}	(0.704, 0.804, 0.904, 0.942)	0.6983
C_{23}	(0.720, 0.820, 0.920, 0.956)	0.7192
C_{24}	(0.734, 0.834, 0.934, 0.966)	0.7374
C_{31}	(0.613, 0.713, 0.813, 0.886)	0.6175
C_{32}	(0.701, 0.801, 0.901, 0.943)	0.7169
C_{33}	(0.594, 0.694, 0.794, 0.868)	0.5956
C_{34}	(0.629, 0.729, 0.829, 0.895)	0.6341
C_{35}	(0.704, 0.804, 0.904, 0.946)	0.7207
C_{41}	(0.645, 0.745, 0.845, 0.910)	0.6592
C_{42}	(0.597, 0.697, 0.797, 0.870)	0.6041
C_{43}	(0.682, 0.782, 0.882, 0.933)	0.7017
C_{44}	(0.691, 0.791, 0.891, 0.942)	0.7131
C_{51}	(0.710, 0.810, 0.910, 0.951)	0.7088
C_{52}	(0.728, 0.828, 0.928, 0.962)	0.7311
C_{53}	(0.680, 0.780, 0.880, 0.931)	0.6730
C_{54}	(0.659, 0.759, 0.859, 0.917)	0.6490
C_{55}	(0.613, 0.713, 0.813, 0.882)	0.5973

According to Table 2, trustworthiness (C_2) is the most important assessment criterion for shippers. The three criteria of price (C_1), timeliness (C_3), and service (C_5) are of similar importance to shippers. Convenience (C_4) is the least valued by shippers. According to the data in Table 3, the ‘transport fee rate (C_{11}),’ ‘trustworthiness of sales personnel (C_{24}),’ ‘level of speed of responses to price quotes and related questions (C_{35}),’ ‘provision of a sufficient number of empty containers and number of available container types (C_{44}),’ and ‘document speed and correctness (C_{52})’ are the most important sub-criteria for evaluation under the five assessment criteria. While the ‘level of flexibility in time frame for settlement of transport fees (C_{14}),’ ‘goodwill and reputation (C_{21}),’ ‘transit time (C_{33}),’ ‘provision of multimodal transport (C_{42}),’ and ‘whether the company provides customized service (C_{55})’ are found to be the least important evaluation sub-criteria under the five assessment criteria.

4.3 ESTIMATION OF THE FUZZY RATING VALUES OF THE 3 SELECTION ALTERNATIVES RELATIVE TO ALL SUB-CRITERIA

Among the sub-criteria assessed in this paper, the 3 quantitative criteria marine transport fee rate (C_{11}), local export expenses (C_{12}), and transit time (C_{33}) constitute negative criteria (*i.e.*, cost criteria), and the remaining 20 qualitative criteria constitute positive criteria (*i.e.*, benefit criteria). The method described in the Section 3 is therefore used to obtain the original fuzzy rating value (O_{itj}), and the results are shown in Table 4. The method of integrating positive and negative criteria (*i.e.* formulas (6) and (7)) is then used to obtain the standardized fuzzy rating values (S_{itj}), which are shown in Table 5.

Table 4. The original appropriateness ratings of three alternatives versus 23 sub-criteria (O_{itj})

Sub-criteria	*D*	*O*	*P*
C_{11}	(4000, 4100, 4200, 4350)	(4000, 4100, 4200, 4350)	(3900, 4100, 4150, 4300)
C_{12}	(360, 370, 370, 380)	(360, 370, 370, 370)	(360, 370, 370, 375)
C_{13}	(0.501, 0.60, 0.701, 0.792)	(0.501, 0.581, 0.681, 0.773)	(0.562, 0.621, 0.722, 0.807)
C_{14}	(0.518, 0.60, 0.698, 0.792)	(0.510, 0.590, 0.690, 0.784)	(0.555, 0.635, 0.736, 0.819)
C_{15}	(0.533, 0.612, 0.713, 0.805)	(0.523, 0.602, 0.703, 0.794)	(0.549, 0.629, 0.729, 0.817)
C_{21}	(0.605, 0.685, 0.786, 0.863)	(0.566, 0.647, 0.747, 0.832)	(0.597, 0.695, 0.797, 0.869)
C_{22}	(0.552, 0.652, 0.752, 0.834)	(0.554, 0.654, 0.754, 0.834)	(0.586, 0.686, 0.786, 0.861)
C_{23}	(0.504, 0.604, 0.704, 0.794)	(0.510, 0.590, 0.690, 0.782)	(0.526, 0.605, 0.706, 0.796)
C_{24}	(0.563, 0.635, 0.735, 0.818)	(0.565, 0.636, 0.737, 0.819)	(0.5904, 0.662, 0.763, 0.837)
C_{31}	(0.568, 0.632, 0.732, 0.820)	(0.552, 0.616, 0.716, 0.808)	(0.594, 0.658, 0.758, 0.840)
C_{32}	(0.579, 0.643, 0.744, 0.827)	(0.555, 0.619, 0.719, 0.808)	(0.595, 0.658, 0.760, 0.841)
C_{33}	(14, 14, 15, 16)	(14, 14, 15, 16)	(14, 14, 15, 15)
C_{34}	(0.558, 0.631, 0.731, 0.819)	(0.531, 0.603, 0.703, 0.794)	(0.568, 0.640, 0.740, 0.824)
C_{35}	(0.566, 0.639, 0.739, 0.819)	(0.539, 0.639, 0.739, 0.822)	(0.592, 0.665, 0.765, 0.841)
C_{41}	(0.578, 0.650, 0.750, 0.832)	(0.552, 0.624, 0.724, 0.811)	(0.589, 0.661, 0.761, 0.841)
C_{42}	(0.538, 0.638, 0.738, 0.822)	(0.538, 0.618, 0.718, 0.803)	(0.573, 0.652, 0.753, 0.832)
C_{43}	(0.573, 0.653, 0.753, 0.837)	(0.542, 0.642, 0.742, 0.827)	(0.590, 0.671, 0.771, 0.848)
C_{44}	(0.558, 0.631, 0.731, 0.816)	(0.546, 0.626, 0.726, 0.814)	(0.592, 0.664, 0.765, 0.844)
C_{51}	(0.60, 0.672, 0.773, 0.849)	(0.578, 0.650, 0.750, 0.832)	(0.582, 0.682, 0.782, 0.860)
C_{52}	(0.592, 0.673, 0.773, 0.851)	(0.587, 0.668, 0.768, 0.848)	(0.613, 0.685, 0.785, 0.863)
C_{53}	(0.557, 0.657, 0.757, 0.838)	(0.571, 0.644, 0.744, 0.828)	(0.586, 0.657, 0.758, 0.842)

C_{54}	(0.547, 0.646, 0.747, 0.828)	(0.568, 0.640, 0.740, 0.824)	(0.562, 0.661, 0.762, 0.842)
C_{55}	(0.525, 0.625, 0.725, 0.810)	(0.501, 0.601, 0.701, 0.790)	(0.550, 0.631, 0.731, 0.815)

Table 5. The standardized appropriateness ratings of three alternatives versus 23 sub-criteria (S_{itj})

Sub-criteria	*D*	*O*	*P*
C_{11}	(0.897, 0.929, 0.951, 0.975)	(0.897, 0.929, 0.951, 0.975)	(0.907, 0.940, 0.951, 1)
C_{12}	(0.947, 0.973, 0.973, 1)	(0.973, 0.973, 0.973, 1)	(0.960, 0.973, 0.973, 1)
C_{13}	(0.621, 0.744, 0.869, 0.982)	(0.631, 0.720, 0.844, 0.959)	(0.696, 0.770, 0.895, 1)
C_{14}	(0.633, 0.730, 0.853, 0.968)	(0.624, 0.720, 0.843, 0.958)	(0.678, 0.775, 0.899, 1)
C_{15}	(0.652, 0.749, 0.873, 0.985)	(0.640, 0.737, 0.861, 0.972)	(0.672, 0.770, 0.892, 1)
C_{21}	(0.696, 0.789, 0.904, 0.993)	(0.652, 0.744, 0.860, 0.958)	(0.687, 0.80, 0.917, 1)
C_{22}	(0.641, 0.757, 0.874, 0.969)	(0.643, 0.759, 0.876, 0.969)	(0.680, 0.797, 0.913, 1)
C_{23}	(0.633, 0.759, 0.884, 0.997)	(0.641, 0.742, 0.867, 0.983)	(0.661, 0.760, 0.888, 1)
C_{24}	(0.673, 0.758, 0.879, 0.977)	(0.675, 0.759, 0.881, 0.979)	(0.705, 0.791, 0.911, 1)
C_{31}	(0.677, 0.753, 0.872, 0.977)	(0.658, 0.734, 0.853, 0.963)	(0.707, 0.784, 0.903, 1)
C_{32}	(0.689, 0.764, 0.884, 0.983)	(0.660, 0.735, 0.855, 0.961)	(0.708, 0.782, 0.903, 1)
C_{33}	(0.875, 0.933, 1, 1)	(0.875, 0.933, 1, 1)	(0.933, 0.933, 1, 1)
C_{34}	(0.678, 0.765, 0.886, 0.993)	(0.645, 0.732, 0.853, 0.964)	(0.689, 0.776, 0.898, 1)
C_{35}	(0.673, 0.759, 0.878, 0.973)	(0.641, 0.760, 0.879, 0.977)	(0.704, 0.790, 0.909, 1)
C_{41}	(0.687, 0.773, 0.892, 0.989)	(0.656, 0.742, 0.861, 0.964)	(0.70, 0.785, 0.905, 1)
C_{42}	(0.647, 0.767, 0.887, 0.989)	(0.647, 0.743, 0.863, 0.966)	(0.689, 0.785, 0.906, 1)
C_{43}	(0.675, 0.770, 0.888, 0.987)	(0.639, 0.757, 0.875, 0.975)	(0.696, 0.791, 0.909, 1)
C_{44}	(0.661, 0.747, 0.865, 0.967)	(0.646, 0.741, 0.860, 0.964)	(0.701, 0.786, 0.905, 1)
C_{51}	(0.698, 0.781, 0.898, 0.987)	(0.672, 0.756, 0.872, 0.968)	(0.677, 0.793, 0.910, 1)
C_{52}	(0.686, 0.779, 0.895, 0.986)	(0.680, 0.774, 0.890, 0.982)	(0.710, 0.794, 0.910, 1)
C_{53}	(0.661, 0.780, 0.899, 0.995)	(0.678, 0.764, 0.883, 0.984)	(0.696, 0.781, 0.90, 1)
C_{54}	(0.650, 0.767, 0.887, 0.983)	(0.674, 0.759, 0.879, 0.978)	(0.667, 0.784, 0.904, 1)
C_{55}	(0.644, 0.766, 0.889, 0.993)	(0.614, 0.737, 0.860, 0.969)	(0.675, 0.773, 0.896, 1)

Table 6. The overall fuzzy rating values of three alternatives versus 23 sub-criteria (S_{it})

S_{D1}	(0.4718, 0.6010, 0.7480, 0.8724)	S_{O1}	(0.4738, 0.5944, 0.7403, 0.8642)	S_{P1}	(0.4923, 0.6158, 0.7628, 0.8884)
S_{D2}	(0.4593, 0.6092, 0.7930, 0.9244)	S_{O2}	(0.4546, 0.5981, 0.7809, 0.9137)	S_{P2}	(0.4757, 0.6263, 0.8129,0.9395)
S_{D3}	(0.4636, 0.5929, 0.7655, 0.8940)	S_{O3}	(0.4485, 0.5808, 0.7519, 0.8829)	S_{P3}	(0.4826, 0.6067, 0.7816, 0.9076)
S_{D4}	(0.4366, 0.5759, 0.7537, 0.8981)	S_{O4}	(0.4229, 0.5622, 0.7383, 0.8839)	S_{P4}	(0.4555, 0.5931, 0.7737, 0.9138)
S_{D5}	(0.4535, 0.6029, 0.7847, 0.9182)	S_{O5}	(0.4507, 0.5901, 0.7701, 0.9066)	S_{P5}	(0.4648, 0.6110, 0.7939, 0.9286)

4.4 CALCULATION OF THE OVERALL FUZZY RATING VALUES OF THE 3 SELECTION ALTERNATIVES

Formulas (8) and (9) were used to derive the overall fuzzy rating values (S_{it}) of the 3 selection alternatives relative to the 23 sub-criteria and the overall fuzzy rating values (S_i) of the 3 selection alternatives, and obtained the results shown in Table 6 and Table 7.

Table 7. The overall fuzzy rating values of three alternatives (S_i)

S_D	(0.3230, 0.4811, 0.6973, 0.8537)
S_O	(0.3182, 0.4721, 0.6858, 0.8432)
S_P	(0.3351, 0.4926, 0.7118, 0.8672)

4.5 SELECTION OF THE OPTIMAL IOFLP COMPANY

The formula (11) is first used to obtain the risk attitude indicator of all respondents (the α value) as follows:

$$\alpha = \frac{3.5715 + 14.9374 + 32.9750}{5 + 23 + 3 \times 23} = 0.5308.$$

The fact that α >0.5 indicated that the overall risk attitude of the DMs was optimistic, and the decision-making group consisted of risk-lovers.

Formula (10) was then used to perform the following calculations:

$$x_0 = \min\{0.3351, 0.3230, 0.3182\} = 0.3182,$$
$$x_1 = \max\{0.8672, 0.8537, 0.8432\} = 0.8672,$$

$$V^R(\tilde{S}_D) = (0.5308)\left[\frac{0.8537-0.3182}{0.8672-0.3182-0.6973+0.8537}\right] + (1-0.5308)\left[1-\frac{0.8672-0.3230}{0.8672-0.3182+0.4811-0.3230}\right] = 0.54038,$$

$$V^R(\tilde{S}_O) = (0.5308)\left[\frac{0.8432-0.3182}{0.8672-0.3182-0.6858+0.8432}\right] + (1-0.5308)\left[1-\frac{0.8672-0.3182}{0.8672-0.3182+0.4721-0.3182}\right] = 0.53389,$$

$$V^R(\tilde{S}_P) = (0.5308)\left[\frac{0.8672-0.3182}{0.8672-0.3182-0.7118+0.8672}\right] + (1-0.5308)\left[1-\frac{0.8672-0.3351}{0.8672-0.3182+0.4926-0.3351}\right] = 0.55141.$$

Finally, since the ranking order of the three IOFLPs in terms of overall fuzzy rating value was $V^R(\tilde{S}_P) > V^R(\tilde{S}_D) > V^R(\tilde{S}_O)$, in accordance with the ranking rules, we obtained the result that company *P* was the best choice, and was followed by company *D*, with company *O* being worst. Accordingly, this paper recommends that company *P* is the optimal IOFLP for shippers in Taiwan.

Moreover, this article believes that it is necessary to explain why the shippers would choose company *P*. Because company *P* upholds the business philosophy of quality, efficiency, innovation, customer response, education, and implementation, it provides customers with fast, safe, reliable and accurate professional services.

- Quality: Through continuous on-the-job professional training, Company *P* allows customers to experience its high-quality and reliable all-round services.
- Efficiency: Require employees to shorten unnecessary tedious processes and customers' waiting time in the shortest time, and provide customers with the correct quality of service at any time.
- Innovation: Company *P* will review and improve the internal and external corporate processes and service quality at any time, in order to continuously improve and build a complete global route service.
- Customer response: Company *P* attaches great importance to the opinions of customers and requires employees to respond to customers' consultations and suggestions on related shipping issues in a timely manner.
- Education: Company *P* uses a complete education and training program to cultivate the professional capabilities of its employees.
- Implementation: Company *P* emphasizes the importance of work and execution, and employees can give priority to the company's interests and the demand-oriented for customers.

Based on the above-mentioned business philosophy, company *P* has many niches to offer to shippers, such as: (a) AEO-certified operators and top 500 service industry company to provide supply chain security and service quality assurance. (b) The cargo capacity is very large for shipping carriers and container terminals, which can provide customers with the most competitive prices and the best service quality. (c) It has a dense and complete network of contacts all over the world, and each agent has good credit and experience. (d) A legal department with professional qualities can provide the most complete assistance and consultation for clients' legal issues at any time. (e) With dense shipping schedules and dense routes, company *P* cooperates with major global shipping companies to provide cargo owners with multiple choices. (f) Provide high-quality combined transport services. (g) The information equipment and software are complete, and the information operations are all computerized to provide complete information services. Because of these niches and business ideas, many shippers in Taiwan tend to choose company *P* as their shipping partner.

Company *P* is the most preferred transportation partner for shippers, nevertheless, many shippers also choose the services provided by Company *D* and Company *O*. In particular, Company *D* has a dense layout in China and Southeast Asia, and Company *O* also has a significant stronghold in Southeast Asia. Although the establishment time and scale of these two IOFLPs are not as good as those of Company *P*, these two companies are currently the leader of IOFLPs in Taiwan. We believe that they will use the leader-Company *P* as the benchmark in their respective logistics areas and global or regional layout planning, set corporate goals through strategic planning, and strive to achieve the transport logistics tasks entrusted by the shippers.

5. CONCLUSIONS

In view of the current great need for value-added logistics service from international shippers, the content of conventional international logistics service is insufficient for today's logistics activities. How to achieve global logistics service goals, provide optimal integrated transport services, and become an integrated logistics provider has consequently become an important research topic. In order to provide integrated logistics services, IOFLPs must offer numerous customized logistics services and operating activities to enterprises in international shipping logistics supply chains, and must also provide highly professional consulting services if they wish to establish long-term strategic partnerships with shippers. In this context, selection of IOFLPs meeting international enterprises' needs can help improve the overall effectiveness of international integrated logistics.

The main purpose of this paper was therefore to construct a model for the selection of an optimal IOFLP, which will allow enterprises operating in a fuzzy environment to locate optimal partners. Five preliminary assessment aspects and 23 assessment sub-criteria suitable for selection of IOFLPs were first obtained from a review of the literature and experts' opinions, and the assessment criteria included both quantitative and qualitative criteria. In the next step, this study constructed a fuzzy MCDM selection model based on quantitative-qualitative criteria. The final step consisted of an empirical study using the model to select from among three leading IOFLPs in Taiwan from the perspective of the import/export firms. In this step, a questionnaire survey of import/export shippers in Taiwan was used to determine which IOFLP had the best performance in the eyes of the shippers. The empirical results indicated that the shippers believed company *P* to be the optimal IOFLP firm. The analytical process and results in this study can provide import/export firms in Taiwan with a reference for the selection of IOFLPs. In addition, the trustworthiness is the most important assessment criterion for shippers. The 'transport fee rate,' 'trustworthiness of sales personnel,' 'level of speed of responses to price quotes and related questions,' 'provision of a sufficient number of empty containers and number of available container types,' and 'document speed and correctness' are the most important evaluation elements under the five assessment criteria. Since the period of this survey—from January to April 2021—the world is facing a period of lack of containers, lack of space, port congestion, high freight rates, and imbalances in the transportation logistics chain. Therefore, judging from the evaluation criteria accepted by the cargo owners, it should be quite in line with the current situation.

Furthermore, in order to facilitate smoothly evaluating the process concerning MCDM issues, measuring the performance values of the alternatives versus all criteria will be an important evaluation step. Generally speaking, the evaluation criterion is a measurement standard for assisting decision-making, which makes decision-making more specific. Without correct measurement, there will be no correct decision. In this study, some performance values of the alternatives versus criteria to be evaluated, namely the qualitative criteria, cannot be expressed in quantity, but others, namely quantitative criteria, can be expressed directly in quantity. In order to correctly measure these qualitative criteria, in this study, the fuzzy set theory is adopted to perform quantitative measurement, so as to evaluate the performance values of feasible alternatives versus all qualitative criteria and quantitative criteria, finally determining the best alternative. However, the classification of criteria does not mean that all MCDM problems must cover both qualitative criteria and quantitative criteria. The classification of criteria depends on the characteristics of the problem. As far as the 23 evaluation criteria in this study are concerned, three of them are quantitative and the remaining 20 are qualitative. Among these 20 qualitative criteria, some evaluation criteria are clearly attributable to be qualitative (such as 'trustworthiness of sales personnel (C_{24})' and 'provision of professional transport consulting (C_{54})'), while some evaluation criteria appear to be quantitative but actually qualitative (such as 'level of discount on freight and charges (C_{13})' or 'level of frequency of sailings (C_{31})'). Therefore, if the evaluation criteria are described as "discount on freight and charges" or "frequency of sailings," these criteria will be classified as quantitative ones, and in this case, the method of measuring performance values can be processed by using historical data instead of questionnaire data. Conversely, if the evaluation criteria are described as "level of discount on freight and charges" or "level of frequency of sailings," these criteria will be classified as qualitative ones, and the method of measuring performance values can be processed by using questionnaire data. The processing method above is referred in detail in Section 3.4.

In addition, the fuzzy MCDM model proposed in this study is considered to possess the following advantages::

(1) Assessment criteria are evaluation standards assisting decision-making. The assessment criteria in this study consisted of both quantitative and qualitative criteria, which can make a decision-making problem more concrete.
(2) In order to assess the performance value of each alternative relative to all sub-criteria, and better reflect the actual circumstances, benefit criteria and cost criteria were employed in tandem.
(3) The proposed model is not only free from the limitations of crisp values, but can also be implemented as a computer-based decision support system for selecting the optimal IOFLP in a fuzzy

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