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Shu-Chen Lin

Department of marketing and supply chain management, Overseas Chinese University, Taichung County, Taiwan, R.O.C., shuchen@ocu.edu.tw

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Shu-Chen Lin

Key words: competition location decision, international transport logistics system, fuzzy set theory, α -cut.

ABSTRACT

This paper evaluates competition location decisions in a fuzzy environment and assesses international transport logistics service systems using a fuzzy model. First, the study introduces the concepts of fuzzy set theory. Second, a step-by-step fuzzy algorithm, including ten systematic procedures, is effectively represented and processed to assure convincing and effective decision making. Third, three major competitive locations in the Pacific Asia region are presented as examples to analyze the rank order and competitive scenario of international transport logistics service systems. Finally, the operations of fuzzy numbers and α -cut can be adopted as a practical tool for empirical applications in future studies.

I. INTRODUCTION

Globalization and increased competitive pressures have prompted many firms to develop logistics as part of their corporate strategy for cost and service advantages (McGinnis and Kohn, 2002). Worldwide industry provides multinational corporations (MNCs) with opposing pressures (Porter, 1986). One Pressures, such as local government demands, country differences in industry costs, skills, and customer sophistication, prompt companies to decentralize business activities in each market. Other pressures, such as customer demands, cost reductions, and the need for innovation, prompt firms to centralize business activities to achieve global economies of scale, scope, and learning. Therefore, managers of MNCs competing in global industries face the dilemma of geographic dispersion or global (or at least regional) integration of business

activities (Tao and Park, 2004).

The significant role of logistics in a firm's survival and prosperity creates complexity for MNC management of global firms and in the decision concerning the extent of distribution center consolidation (Pralhad and Doz, 1987; Vos and Berg, 1996). Hence, the decision by MNCs to concentrate logistics functions in particular locations (cities) is critical for hub economies. Moreover, the role of international transport logistics service systems as the home base of MNCs and providers of merchandise transportation, reprocessing, and distribution has become increasingly important.

The development of an effective international transport logistics service system in a territory requires the design and implementation of government strategies to attract MNCs (Sheu, 2004; Tao and Park, 2004). Therefore, locations (cities) strive to strengthen logistics functions and activities.

Most of the substantial research on operational modes for logistics activities is devoted to specific topics such as origins and destinations (O/D) of cargos, systematic developments, supply chains, and resource sharing (Picard, 1983; Piet et al., 1995; Chopra, 2003; Sheu, 2004), and substantial research addresses operational types of logistics activities. Traditionally, the import, export, and transshipment mode categories are determined by the various origins and destinations of conventional cargos. However, from the value-added perspective, Piet et al., (1995) logistics chains are composed of three logistics sub-chains, which include supply, manufacturing, and distribution logistics chains. Hence, currently, to increase competitive advantage, international transport logistics service systems providing import/export and transshipment services engage in multi-country consolidation and warehousing functions and integrate manufacturing industries to provide high value-adding, deep reprocessing services to cargos. The provision of these services requires that governments grasp the critically competitive relationships dependent on the competitive factors that affect MNC location selection and the most suitable type of international transport logistics service system for the MNC.

The selection of the international transport logistics service

Paper submitted 07/24/14; revised 01/29/15; accepted 05/11/15. Author for correspondence: Shu-Chen Lin (e-mail: shuchen@ocu.edu.tw).

Department of marketing and supply chain management, Overseas Chinese University, Taichung County, Taiwan, R.O.C.

system location for MNCs, which includes the international logistics service provider, from among two or more factors represents a multiple factors decision-making (MCDM) problem. However, the factors of international transport logistics service system competition differ according to the factors for assessing subjects, circumstances, or the extent of knowledge. Additionally, the degree of strength of the factors changes with different approaches to in-depth thinking. Moreover, the factors are mixed with quantitative and qualitative values and have reciprocal organic and complex relationships with one another; the factors have complex and organic relationship problems. Under many conditions, the values for qualitative factors are often imprecisely defined for decision makers. Additionally, the desired values and importance weighting of factors are usually described in linguistic terms, for example, low, medium, high, or very high. The process of quantifying the rating of each alternative location selection problem and the precision-based methods stated are inadequate for the location selection problem. Fuzzy set theory was developed based on the premise that the core elements of human thinking are not numbers but linguistic terms or labels of fuzzy sets (Zadeh, 1965; Bellman and Zadel, 1970). Therefore, a fuzzy decision-making method under multiple factors considerations is required to integrate various linguistic assessments and weights to evaluate location suitability and determine the optimal selection (Chen et al., 1985).

In conventional precision-based alternative location decisions, total revenue, cost, and other economic considerations are expressed in crisp values (Dubois and Prade, 1978; Au and Au, 1983; Mansfield, 1985; Targuin and Blank, 1989; Park et al., 1990; Liou and Wang, 1992). However, it is often difficult to obtain the exact assessment data, such as total revenue, gross income, expenses, depreciation, salvage value, and inflation rate, because of incomplete or uncertain information. Hence, precision-based evaluation may not be practical.

Decision makers tend to base assessments on their knowledge, experience, and subjective judgment when evaluating alternative locations. Linguistic terms, for example, “approximately between \$410,000 and \$420,000” and “about \$6,000” are frequently used to convey estimations. Thus, fuzzy set theory can play a significant role in this type of decision-making environment.

Fuzzy set theory was introduced by Zadeh (1965) and is applied to problems with a level of vagueness. Linguistic values are accurately represented by the approximate reasoning of fuzzy set theory (Zadeh, 1975, 1976). To effectively manage the ambiguities in the process of linguistic estimations, the triangular fuzzy numbers are used to characterize fuzzy measures of linguistic values. An algorithm that measures the competition location’s fuzzy net present value and fuzzy scores with respect to strategic factors are proposed in this study to facilitate the process of optimal competition location selection.

II. SPECIFICATIONS FOR INTERNATIONAL TRANSPORT LOGISTICS SERVICE SYSTEMS

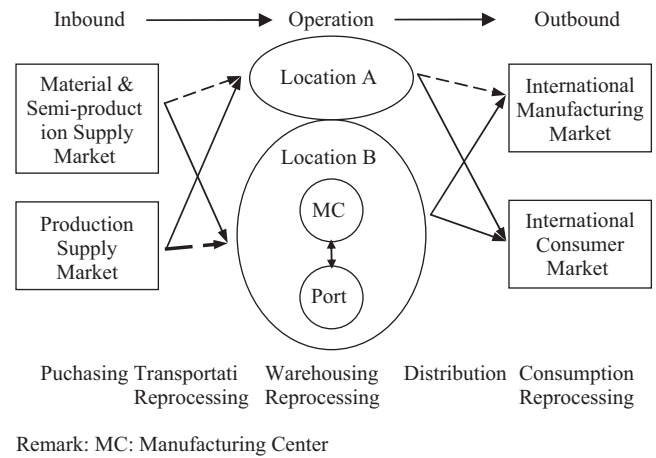


Fig. 1. The competitive scenario of location developing GLH.

Fig. 1 shows the competitive scenario of location development for international transport logistics service systems by addressing the inbound, operations, and outbound logistics stages (Lee et al., 2001). In analyzing the location competition for distribution parks, it is important to evaluate the logistics activities in various locations. The managerial decision depends on the competitive conditions of a given location’s environment. Distribution parks are distinguished by the viewpoints of value-added and location competition. The three stages satisfy different logistics functions: (1) Supply side (including the international material and semi-product and production supply marketplace) satisfies the purchasing function for material, semi-product, and product cargos. (2) Operation side provides the functions of transportation from the supply side, storage, reprocessing, and distribution to the demand side, which relies on the location’s environmental factors such as ports (air or sea) and manufacturing industries (MC). (3) Demand side (including the international consumer and manufacturing marketplace) provides consumption and re-processing functions.

It is important to adequately evaluate the level of increased value of logistics activity in various Locations when analyzing the location competition for international transport logistics service system because the increased value depends on the competitive conditions of the location environment. The attraction of value-added activities influences the production, employment, income, prices, balance of payments, economic growth, and welfare of the recipient country in a positive direction (Tatoglu and Glaister, 1998; Erdal and Tatoglu, 2002). Therefore, the location should provide suitable value-added logistics services through the establishment of suitable modes for the international transport logistics service system. Therefore, by designating transshipment and deep reprocessing export (deep re-export), we distinguish international transport logistics service system competitive modes from a value-adding perspective and the international location’s competition. We illustrate the competitive relevance of international transport logistics service systems by addressing the

Table 1. The development stages of port.

Type	Functional activities	Location environmental factors
Transshipment	Transportation + Storage + Consolidation + Distribution	Port Warehousing
Deep reprocessing	Transportation + Storage + Hi-tech level reprocessing + Distribution	Port Warehousing Distribution center (DC) Hi-tech manufacturing industries

inbound logistics, operations, and outbound logistics stages. The distinct operational features of the two types of systems and their specific logistics networks are described below (and are shown in Table 1).

Type 1: Transshipment type

The transshipment type of international transport logistics service systems represents international goods distribution for global logistics activities. Transshipment provides several main functions in an integrated logistics system such as transportation, storage, consolidation, and distribution. Several ports have provided the logistics hub or distribution center facilities to satisfy the function of transshipment such as Kepple Distri-park (Singapore), Hong Kong International Distribution Center (Hong Kong), and Port Cargo Center (Yokohama) (Lu, 2003).

Kaohsiung city in southern Taiwan was the largest port in Taiwan and was ranked sixth among world container ports in 2004 (Kaohsiung Port Authority, 2014). The city has an excellent location with the shortest average distance from other main ports in the Pacific Asia region and port conditions, such as warehousing and distribution facilities, suitable for the development of the transshipment type of international transport logistics service systems.

According to the statistics of Kaohsiung Port Corporation in 2014, the annual container volume is 10.5933 million TEUs and the transshipment volume is 5.01 million TEUs (47.32% of the total container volume). Therefore, the Kaohsiung Port is still with the hub-port position in Pacific Asia region.

Type 2: Deep re-processing export GLH (deep re-export type)

This type of system is integrated in an effort to create greater value-added service for material and semi-product cargos. By providing this type of logistic service, local hi-tech MCs (such as science-based industrial parks, hi-tech industrial parks), DCs, and ports can be integrated into the function activities of transportation, warehousing, hi-tech reprocessing, and distribution. We illustrate the types of international transport logistics service systems that are typically used by Taiwanese high-tech manufacturing firms: the HP enterprise manufacturer in Taiwan, the Taiwan Direct Shipped (TDS) type (David, et., 2005), depends on orders from the OEM, the location

advantage of transshipment conditions, and the parts of the OEM that may come from several areas.

The integration of environmental conditions of various types of international transport logistics service systems will cause a variety of location conditions to determine the suitable function of GLH. Location conditions cause international firm location decision-making of a different type. Transshipment represents the transshipment center function, which transits cargo to various regional locations and is the main condition of this type of international transport logistics service system. Port, warehousing, and distribution center are the key factors in developing the transshipment of the international transport logistics service system, and the port, warehousing, distribution center, and hi-tech manufacturing industries (i.e., science-based technology parks, reprocessing export centers, and industrial zones) are the key factors of the deep re-export type.

III. FUZZY SET THEORY

Fuzzy set theory was presented by Zadeh (1965) to tackle the problems in which the uncertainties and ambiguities exist. In this section, some related notation and concepts used in this paper will be briefly introduced.

1. Fuzzy Number

A fuzzy number A is a special fuzzy subset of real number with membership function f_A which possesses the following properties: (1) f_A is a continuous mapping from \mathfrak{R} (real line) to a closed interval $[0,1]$; (2) $f_A(x) = 0$ for all $x \in (-\infty,c] \cup [b,\infty)$; (3) $f_A(x)$ is strictly increasing on $[c, a]$ and strictly decreasing on $[d, b]$, and (4) $f_A(x) = 1$ for all $x \in [a, d]$.

Given $c > -\infty$ and $b < \infty$, when $a = d$, and f_A has two straight line segments in $[c, a]$ and $[d, b]$, then A is a triangular fuzzy number. In this paper, the triangular fuzzy number is used to evaluate the fuzzy data. A fuzzy number A in \mathfrak{R} (real line) is a triangular fuzzy number, if its membership function $f_A: \mathfrak{R} \rightarrow [0,1]$ is equal to

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

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

The parameter a gives the maximal grade of $f_A(x)$, i.e., $f_A(a) = 1$; it is the most probable value of the evaluation data. In addition, ' c ' and ' b ' 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 $[c, b]$, the lower the fuzziness of the evaluation data. The triangular fuzzy numbers are easy to use and easy to interpret. For example, 'approximately equal to '700' can be represented by (695,700,708) and it can be represented more blurred by (698,700,703). In addition, the non-fuzzy number, an exact

number, ‘ a ’ can be represented by (a, a, a) . For example, ‘700’ can be represented by $(700, 700, 700)$.

2. Operations of Fuzzy Numbers with α -cut

Suppose that A is a fuzzy number with membership function f_A , then the set $A^\alpha = \{x \in X | f_A(x) \geq \alpha, 0 \leq \alpha \leq 1\}$ is call the α -cut of fuzzy number A . And, denoted it by $A^\alpha = [A_l^\alpha, A_u^\alpha]$. A_l^α and A_u^α are the lower and upper bounds of the assessment data with ‘grade of membership’ α . If $A = (c, a, b)$ is a triangular fuzzy number, then $A_l^\alpha = c + (a - c)\alpha$, $A_u^\alpha = b + (a - b)\alpha$. If $A_l^\alpha > 0$, for all $\alpha \in [0, 1]$, call A is a positive fuzzy number. Based on the definition stated as above, the operations of addition, subtraction, multiplication, division and inverse of positive fuzzy numbers can be tackled by using the α -cut.

Let A and B be two positive fuzzy numbers. $A^\alpha = [A_l^\alpha, A_u^\alpha]$ and $B^\alpha = [B_l^\alpha, B_u^\alpha]$ are the α -cut of A and B , respectively. Then, by the vertex method (Choobineh and Li, 1990), the following operations are true:

Addition \oplus

$$(A \oplus B)^\alpha = [A_l^\alpha + B_l^\alpha, A_u^\alpha + B_u^\alpha]$$

$$(k \oplus A)^\alpha = [k + A_l^\alpha, k + A_u^\alpha], k \in \mathfrak{R}$$

Subtraction \ominus

$$(A \ominus B)^\alpha = [A_l^\alpha - B_u^\alpha, A_u^\alpha - B_l^\alpha]$$

$$(k \ominus A)^\alpha = [k - A_u^\alpha, k - A_l^\alpha], k \in \mathfrak{R}$$

Multiplication \otimes

$$(k \otimes A)^\alpha = [kA_l^\alpha, kA_u^\alpha], k \in \mathfrak{R} \text{ and } k > 0$$

$$(A \otimes B)^\alpha = [A_l^\alpha B_l^\alpha, A_u^\alpha B_u^\alpha]$$

Division \oslash

$$(A \oslash B)^\alpha = [A_l^\alpha / B_u^\alpha, A_u^\alpha / B_l^\alpha]$$

Inverse

$$(A^{-1})^\alpha = [(A_u^\alpha)^{-1}, (A_l^\alpha)^{-1}].$$

3. Ranking Fuzzy Numbers

In competition location decision analysis, ranking the competition locations under consideration is important. Many methods of ranking fuzzy numbers have been proposed (Buckley, 1984; Bortolan and Deani, 1985; Choobineh and Li, 1990; Frank, 1991; Choobineh and Behrens, 1992; Campbell, 2002). However, certain shortcomings of some of the methods have been reported in papers (Bortolan and Deani, 1985;

Campbell, 2002). For effectiveness in problem solving, a method based on the concepts developed by (Choobineh and Li, 1990; Frank, 1991) is used.

Let $A_i, i = 1, 2, \dots, n$, be n fuzzy numbers with membership functions $f_{A_i}(x)$. Define the left and right membership functions of $f_{A_i}(x)$ by $f_{A_i}^L(x) = f_{A_i}(x), x \in [c_i, a_i]$ and $f_{A_i}^R(x) = f_{A_i}(x), x \in [d_i, b_i]$, respectively. Suppose $g_{A_i}^L$ is the inverse function of $f_{A_i}^L$, and $g_{A_i}^R$ is the inverse function of $f_{A_i}^R$, then the right integral value of fuzzy number A_i , is defined as

$$RI(A_i) = \int_0^1 [b - g_{A_i}^R(y)] dy, \tag{2}$$

and the left integral value of A_i is defined as

$$LI(A_i) = \int_0^1 [g_{A_i}^L(y) - c] dy \tag{3}$$

The ranking value of fuzzy number A_i , denoted by $R(A_i)$, is defined as

$$R(A_i) = \{1 - [RI(A_i) - LI(A_i)] / (b - c)\} / 2 \tag{4}$$

where $c = \min\{c_1, c_2, \dots, c_n\}$, and $b = \max\{b_1, b_2, \dots, b_n\}$.

Let $A_i = (c_i, a_i, b_i), i = 1, 2, \dots, n$, be n triangular fuzzy numbers. By using Eqs. (1), (2), and (3), the right integral value and left integral value of fuzzy number A_i can be obtained:

$$RI(A_i) = b - (a_i + b_i) / 2 \tag{5}$$

and

$$LI(A_i) = (a_i + c_i) / 2 - c \tag{6}$$

Then, by Eqs. (4), (5), and (6), the ranking value $R(A_i)$ of triangular fuzzy number A_i can be obtained:

$$R(A_i) = (c_i + 2a_i + b_i - 4c) / [4(b - c)], \tag{7}$$

where $c = \min\{c_1, c_2, \dots, c_n\}$, and $b = \max\{b_1, b_2, \dots, b_n\}$.

Define the fuzzy ranking of A_i and A_j as:

$$A_i > A_j \Leftrightarrow R(A_i) > R(A_j),$$

$$A_i = A_j \Leftrightarrow R(A_i) = R(A_j),$$

$$A_i < A_j \Leftrightarrow R(A_i) < R(A_j).$$

By using Eq. (7), one can easily calculate the ranking values of the n triangular fuzzy numbers. Then based on the ranking rule described above, the ranking of the n triangular fuzzy numbers can be effectively determined.

Combining the operation of α -cut of fuzzy number, the proposed ranking method can be used to deal with the ranking of fuzzy numbers with any type.

IV. FUZZY ALGORITHM OF COMPETITIVE LOCATION EVALUATION DECISION

In this section, a systematic algorithm for ILSPs to make competitive location evaluation decision under fuzzy environment is presented. The stepwise description of proposed algorithm can be briefly summarized as:

- (1) Determine the ILSPs goals and objectives.
- (2) Select all competitive locations suitable to the ILSPs goals and objectives.
- (3) Identify the required economic factors associated with competition location evaluation.
- (4) Calculate the fuzzy net present value ($FNPV_i$) of all competition locations.
- (5) Calculate the normalized ranking values ($EFRV_i$) of all competition locations.
- (6) Identify the required strategy factors associated with competition location evaluation.
- (7) Assign importance weights to the strategic factors and the fuzzy scores of the competition locations versus various strategic factors.
- (8) Calculate the strategic factors ranking values ($SCRV_i$) of all competition locations.
- (9) Calculate the final ranking values (FRV_i) of all competition locations.
- (10) Select the optimal competition location.

1. Identify Economic Factors and Calculate the Normalized Ranking Values of Fuzzy Net Present Values of All Competition Locations

In this study, the competitive factors developed by Lee, et al. (2007) were used to evaluate the competitive locations. In this paper, the economic factors considered for competitive location selection contain five elements. They are port cost, reprocessing tax, depreciation, reprocessing-transshipment cost, and total revenue. Besides, economic consideration parameters (e.g. income tax, inflation, and inflation rate) are also considered. Thus, the fuzzy net present value can be calculated by utilizing the five elements.

The fuzzy net present value after tax, $FNPV$, can be calculated by the following equation.

$$FNPV = \sum_{j=1}^n [\ominus FPC_j \ominus FRT_j \oplus FD_j \otimes (1 \ominus i_j) \ominus FRTC_j \otimes i_j \oplus FTRV_j \otimes (1 \ominus i_j)] \otimes (1 \oplus d_j)^{-j} \otimes (1 \oplus f_j)^{-j} \quad (8)$$

where

$j = 1, 2, \dots, n$ (project planning horizon in years),
 i_j = annual fuzzy tax rate at period j ,
 d_j = annual fuzzy inflation free rate at period j ,
 f_j = annual fuzzy inflation rate at period j ,
 FPC_j = fuzzy port(sea and air) cost at period j ,
 FRT_j = fuzzy reprocessing tax at competitive location j ,
 FD_j = fuzzy depreciation at period j ,
 $FRTC_j$ = fuzzy reprocessing-transshipment cost at period j ,
 $FTRV_j$ = fuzzy total revenue at period j .

To effectively represent the α -cuts of $FNPV$, define the α -cuts of i_j , d_j , f_j , FPC_j , FRT_j , FD_j , $FRTC_j$, and $FTRV_j$ as follows.

$$\begin{aligned} i_j^\alpha &= [i_{jl}^\alpha, i_{ju}^\alpha], \quad d_j^\alpha = [d_{jl}^\alpha, d_{ju}^\alpha], \quad f_j^\alpha = [f_{jl}^\alpha, f_{ju}^\alpha], \\ FPC_j^\alpha &= [FPC_{jl}^\alpha, FPC_{ju}^\alpha], \quad FRT_j^\alpha = [FRT_{jl}^\alpha, FRT_{ju}^\alpha], \\ FD_j^\alpha &= [FD_{jl}^\alpha, FD_{ju}^\alpha], \\ FRTC_j^\alpha &= [FRTC_{jl}^\alpha, FRTC_{ju}^\alpha], \quad FTRV_j^\alpha = [FTRV_{jl}^\alpha, FTRV_{ju}^\alpha]. \end{aligned}$$

Then, by using the results of fuzzy operation with α -cut presented in section 2.3, the α -cut of $FNPV$, $FNPV^\alpha = [FNPV_l^\alpha, FNPV_u^\alpha]$, can be obtained:

$$\begin{aligned} FNPV_l^\alpha &= \sum_{j=1}^n [-FPC_{ju}^\alpha - FRT_{ju}^\alpha + FD_{jl}^\alpha(1 - i_{ju}^\alpha) - FRTC_{ju}^\alpha(i_{ju}^\alpha) \\ &\quad + FTRV_{jl}^\alpha(1 - i_{ju}^\alpha)](1 + d_{ju}^\alpha)^{-j}(1 + f_{ju}^\alpha)^{-j} \quad (9) \end{aligned}$$

and

$$\begin{aligned} FNPV_u^\alpha &= \sum_{j=1}^n [-FPC_{jl}^\alpha - FRT_{jl}^\alpha + FD_{ju}^\alpha(1 - i_{jl}^\alpha) - FRTC_{jl}^\alpha(i_{jl}^\alpha) \\ &\quad + FTRV_{ju}^\alpha(1 - i_{jl}^\alpha)](1 + d_{jl}^\alpha)^{-j}(1 + f_{jl}^\alpha)^{-j} \quad (10) \end{aligned}$$

Let $FNPV_i$, $i = 1, 2, \dots, m$, be the fuzzy net present values of m competition locations. When the membership functions of all elements in Eq. (8) are identified, one can then use the α -cuts of these elements and Eqs. (9) and (10) to obtain the corresponding α -cuts of $FNPV_i$.

By choosing two or more α values (e.g. $\alpha = 0, 0.5$, or 1), and find the corresponding α -cuts by using Eqs. (9) and (10), thus the membership functions of $FNPV_i$ can be constructed by these closed intervals characterized by $FNPV_i^\alpha$ and $FNPV_u^\alpha$. Virtually, the more the α -cuts, the better the representation of $FNPV_i$.

Combining the α -cut operation of fuzzy number, Eqs. (5), (6), and (7), the ranking value $R(FNPV_i)$ of the fuzzy net present value of competition location i can be obtained.

To make the ranking values comparable, the normalized

ranking values of all competition locations can be calculated as follows:

$$EFRV_i = R(FNPV_i) / \sum_{i=1}^m R(FNPV_i) \quad (11)$$

2. Calculate the Strategic Factors Ranking Value of All Competition Locations

In addition to the economic factors, many potential strategic factors according to Lin et al. (2006) of measuring the logistics competition ability, e.g. ability to integrate with industrial cluster environment, political, economic and society stability, regional industrial competition, information abilities, density of shipping line, etc., are considered for competition location selection. Note that certain factors could be omitted or expanded depending on the type of proposed project planning.

In this paper, triangular fuzzy numbers are used to evaluate the fuzzy scores of the competition locations versus various strategic factors.

Let $T_{ik} = (q_{ik}, o_{ik}, p_{ik})$, $i = 1, 2, \dots, m$; $k = 1, 2, \dots, r$, denote the fuzzy score of competition location i versus the k -th strategic factor. Let $0 \leq w_k \leq 1$ be the real value weighting given to k -th strategic factor. Thus, the weighted fuzzy score S_i of i -th competition location can be obtained by fuzzy weighting arithmetic operation

$$S_i = (w_1 \otimes T_{i1}) \oplus (w_2 \otimes T_{i2}) \oplus \dots \oplus (w_r \otimes T_{ir})$$

By the extension principle (Zadeh, 1975), S_i is also a triangular fuzzy number, that is

$$S_i = (\sum_{k=1}^r w_k q_{ik}, \sum_{k=1}^r w_k o_{ik}, \sum_{k=1}^r w_k p_{ik}), \quad (12)$$

By using Eq. (7), the ranking value $R(S_i)$ of the weighted fuzzy score S_i can be obtained, that is

$$R(S_i) = (\sum_{k=1}^r w_k q_{ik} + 2 \sum_{k=1}^r w_k o_{ik} + \sum_{k=1}^r w_k p_{ik} - 4q) / [4(p - q)] \quad (13)$$

where

$$q = \min_i \{ \sum_{k=1}^r w_k q_{ik}, \sum_{k=1}^r w_k o_{ik}, \sum_{k=1}^r w_k p_{ik} \}$$

and

$$p = \max_i \{ \sum_{k=1}^r w_k q_{ik}, \sum_{k=1}^r w_k o_{ik}, \sum_{k=1}^r w_k p_{ik} \}$$

To make the ranking values comparable, the ranking value of the strategic factors for each competition location is normalized:

$$SCRV_i = R(S_i) / \sum_{i=1}^m R(S_i) \quad (14)$$

3. Calculate the Final Ranking Values

If the economic and strategic factors are not equally important, then a weighting factor β is assigned to the economic factors, and $1-\beta$ is assigned to strategic factors. Thus, the final ranking value FRV_i of the i -th competition location can be defined as

$$FRV_i = \beta \times EFRV_i + (1-\beta) \times SCRV_i, \quad 0 \leq \beta \leq 1 \quad (15)$$

By using Eq. (15), the final ranking values of the m competition locations can easily be obtained. Based on these ranking values, the decision-maker can determine the most suitable competition location.

V. LOCATION SELECTING IN PACIFIC ASIA REGION

Major ports in the Far East region have expanded rapidly with strong economic development since the early 1980s and a shift in the global center of manufacturing to Asia. Asian container firms will increase their total annual container handling volumes from approximately 107 million TEUs in 2000 to between 254 million and 306 million TEUs in 2015. According to a report by Ocean Shipping Consultants, total container transshipment in the Middle East and South Asia is forecast to increase by 83-140 per cent over 2006-15, to 23.20-30.43 m TEUs, and by a further 31-39 per cent over 2015-20, to 30.28-42.29 m TEUs. This trend will heighten competitive pressures on the major port or city locations in the Pacific Asia region. Hence, the decision of logistics service providers (ILSPs) and international firms to concentrate logistics functions in a particular international transport logistics hub in the Far East region is critical to the economy of the hub location. Thus the role of the international transport logistics hub as a home base for merchandise transportation, reprocessing, and distribution has become increasingly important. From the viewpoint of international competition of transport logistics service systems, location competition in transshipment and reprocessing export functions is particularly significant in the Pacific Asia region.

An optimal location for the effective development of an international transport logistics service system in the Pacific Asia region requires a governor that appreciates the competitiveness among the locations and the need to design and implement strategies to attract MNCs (Sheu, 2004; Tao and Park, 2004). Suppose three competitive locations L_1 , L_2 , and L_3 in the Pacific Asia region to analyze the rank order and competitive scenario of international transport logistics service system.

International logistics service providers (ILSPs) engage in evaluating competition locations and provide assessments based on their knowledge, experience, and subjective judgment.

Table 2. The fuzzy port cost, reprocessing tax, reprocessing-transshipment cost and total revenue of various competition locations at different period (\$10⁶).

Economic factors	j	L_1	L_2	L_3
Fuzzy port (Sea and Air) cost at period j	1	(0.42,0.45,0.50)	(0.65,0.70,0.75)	(0.78,0.80,0.83)
	2	(0.45,0.48,0.52)	(0.70,0.74,0.76)	(0.84,0.87,0.88)
	3	(0.55,0.58,0.60)	(0.78,0.80,0.85)	(0.87,0.92,0.93)
Fuzzy reprocessing tax at competitive location j	1	(0.30,0.32,0.35)	(0.45,0.47,0.50)	(0.58,0.59,0.60)
	2	(0.35,0.36,0.38)	(0.44,0.47,0.50)	(0.54,0.57,0.58)
	3	(0.45,0.48,0.52)	(0.48,0.50,0.53)	(0.57,0.62,0.64)
Fuzzy reprocessing-transshipment cost at period j	1	(21.0,23.0,25.0)	(22.0,24.0,25.0)	(23.0,24.0,26.0)
	2	(23.8,24.4,25.2)	(23.5,24.5,25.3)	(22.6,24.2,26.5)
	3	(24.2,25.0,26.5)	(24.5,25.0,26.8)	(25.2,25.8,26.4)
Fuzzy total revenue at period j	1	(295,305,309)	(265,270,275)	(278,280,283)
	2	(308,312,315)	(270,274,276)	(284,287,288)
	3	(315,317,319)	(278,280,285)	(287,292,293)

Table 3. The α -cuts of economic consideration parameters.

α	$i^\alpha = [i_l^\alpha, i_u^\alpha]$	$d^\alpha = [d_l^\alpha, d_u^\alpha]$	$f^\alpha = [f_l^\alpha, f_u^\alpha]$
0	[0.16,0.23]	[0.12,0.12]	[0.048,0.053]
0.5	[0.18,0.215]	[0.12,0.12]	[0.049,0.052]
1	[0.20,0.20]	[0.12,0.12]	[0.05,0.05]

ILSPs face an uncertain and complex environment when processing competition locations programs. The competitive advantages of ILSPs are linked to the competition locations decision. Therefore, it is important for decision makers to apply a systematic approach to evaluate the competition locations decision problem. This paper considers a model to construct an algorithm that measures the competition location's fuzzy net present value and fuzzy scores with respect to strategic factors proposed to facilitate the decision-making process for optimal competition location selection. Then, a hypothetical selection problem was designed to demonstrate the computational process of this competition location selection algorithm. The exact steps are shown below.

Step 1 and step 2.

Suppose the ILSPs need to select the optimal competition location. After preliminary screening, three competition locations, L_1 , L_2 , and L_3 remain for further evaluation.

Step 3.

The planning horizon is a three-year period. The economic factors include the port's rate, reprocessing tax, depreciation, fuzzy reprocessing cost, fuzzy transshipment cost, and fuzzy total revenue. The strategic factors include the ability to integrate with the industrial cluster environment; the political, economic, and societal stability; regional industrial competition; information abilities, and the density of the shipping line.

Step 4.

Table 2 shows the economic factors, fuzzy port (sea and air) cost, fuzzy reprocessing tax, fuzzy reprocessing-transshipment cost, and fuzzy total revenue of three competition locations. The ILSPs' annual fuzzy income tax rate is approximately 20%, i.e. $i_1 = i_2 = i_3 = (0.16, 0.20, 0.23)$. The ILSPs' annual fuzzy inflation free discount rate on investment is assumed to be 12%, i.e. $d_1 = d_2 = d_3 = (0.12, 0.12, 0.12)$. And the annual fuzzy inflation rate is assumed to be approximately 5%, i.e. $f_1 = f_2 = f_3 = (0.048, 0.05, 0.053)$. Besides, assume that competition locations are with no depreciation, because it is little effect in total cost.

Step 5.

The α -cuts, at $\alpha = 0, 0.5$, and 1 from each of the three membership functions of annual fuzzy income tax rate, annual fuzzy inflation free discount rate and annual fuzzy inflation rate are shown in Table 3. And the α -cuts, at $\alpha = 0, 0.5$, and 1 from each of the four membership functions of various economic factors at different period are shown in Tables 4 and 5, respectively. For a given α -cuts and by the Eqs. (9) and (10), the α -cuts of fuzzy net present value $FNPV$ of various competition locations can be obtained as shown in Table 6.

Step 6.

According to the α -cuts of $FNPV_i$ of various competition locations shown in Table 6, we can obtain:

Table 4. The α -cuts, at $\alpha = 0, 0.5,$ and 1 from the membership functions of various competition location's $FRTC_j, FPC_j, FRT_j, j = 1, 2, 3.$

α -cuts of $FRTC_j$	α	j	L_1	L_2	L_3
$FRTC_j^\alpha = [FRTC_{jl}^\alpha, FRTC_{ju}^\alpha]$	0	1	[21.00,25.00]	[22.00,25.00]	[23.00,26.00]
		2	[23.80,25.20]	[23.50,25.30]	[22.60,26.50]
		3	[24.20,26.50]	[24.50,26.80]	[25.20,26.40]
	0.5	1	[22.00,24.00]	[23.00,24.50]	[23.50,25.00]
		2	[24.10,24.80]	[24.00,24.90]	[23.40,25.35]
		3	[24.60,25.75]	[24.75,25.90]	[25.50,26.10]
	1	1	[23.00,23.00]	[24.00,24.00]	[24.00,24.00]
		2	[24.40,24.40]	[24.50,24.50]	[24.20,24.20]
		3	[25.00,25.00]	[25.00,25.00]	[25.80,25.80]
$FPC_j^\alpha = [FPC_{jl}^\alpha, FPC_{ju}^\alpha]$	0	1	[0.42,0.50]	[0.65,0.75]	[0.78,0.83]
		2	[0.45,0.52]	[0.70,0.76]	[0.84,0.88]
		3	[0.55,0.60]	[0.78,0.85]	[0.87,0.93]
	0.5	1	[0.435,0.475]	[0.675,0.725]	[0.790,0.815]
		2	[0.465,0.500]	[0.720,0.750]	[0.855,0.875]
		3	[0.565,0.590]	[0.790,0.825]	[0.895,0.925]
	1	1	[0.45,0.45]	[0.70,0.70]	[0.80,0.80]
		2	[0.48,0.48]	[0.74,0.74]	[0.87,0.87]
		3	[0.58,0.58]	[0.80,0.80]	[0.92,0.92]
$FRT_j^\alpha = [FRT_{jl}^\alpha, FRT_{ju}^\alpha]$	0	1	[0.30,0.35]	[0.45,0.50]	[0.58,0.60]
		2	[0.35,0.38]	[0.44,0.50]	[0.54,0.58]
		3	[0.45,0.52]	[0.48,0.53]	[0.57,0.64]
	0.5	1	[0.310,0.335]	[0.460,0.485]	[0.585,0.595]
		2	[0.355,0.370]	[0.455,0.485]	[0.555,0.575]
		3	[0.465,0.500]	[0.490,0.515]	[0.595,0.630]
	1	1	[0.32,0.32]	[0.47,0.47]	[0.59,0.59]
		2	[0.36,0.36]	[0.47,0.47]	[0.57,0.57]
		3	[0.48,0.48]	[0.50,0.50]	[0.62,0.62]

Table 5. The α -cuts, at $\alpha = 0, 0.5,$ and 1 from the membership functions of various competition location's fuzzy total revenue $FTRV_j, j = 1, 2, 3.$

α -cuts of $FTRC_j$	α	j	L_1	L_2	L_3
$FTRV_j^\alpha = [FTRV_{jl}^\alpha, FTRV_{ju}^\alpha]$	0	1	[295,309]	[265,275]	[278,283]
		2	[308,315]	[270,276]	[284,288]
		3	[315,319]	[278,285]	[287,293]
	0.5	1	[300,307]	[267.5,272.5]	[279,281.5]
		2	[310,313.5]	[272,275]	[285.5,287.5]
		3	[316,318]	[279,282.5]	[289.5,292.5]
	1	1	[305,305]	[270,270]	[280,280]
		2	[312,312]	[274,274]	[287,287]
		3	[317,317]	[280,280]	[292,292]

Table 6. The α -cuts, at $\alpha = 0, 0.5,$ and 1 of $FNPV_i$ of L_1, L_2 and $L_3.$

α -cuts of $FNPV_i$	α	L_1	L_2	L_3
$FNPV_i^\alpha = [FNPV_{il}^\alpha, FNPV_{iu}^\alpha]$	0	[496.08,569.06]	[438.08,497.90]	[457.07,519.01]
	0.5	[513.24,550.18]	[451.45,484.38]	[471.15,502.57]
	1	[531.46,531.46]	[466.54,466.54]	[486.20,486.20]

Table 7. The weights and fuzzy (or non-fuzzy) scores of the three competition locations L_1 , L_2 and L_3 .

Strategic factors	weight	L_1	L_2	L_3
ability to integrate with Industrial cluster environment	0.20	approximately 85 (80,85,88)	approximately 77 (76,77,80)	approximately 80 (76,80,83)
political; economic; society stability	0.15	approximately 70 (67,70,72)	approximately 75 (73,75,78)	approximately 79 (76,79,81)
regional industrial competition	0.25	approximately 83 (83,83,83)	approximately 87 (85,87,89)	approximately 82 (80,82,85)
information abilities	0.20	approximately 86 (82,86,87)	approximately 85 (80,85,88)	approximately 80 (77,80,82)
density of shipping line	0.20	approximately 87 (85,87,90)	approximately 81 (81,81,81)	approximately 78 (73,78,81)

$$c = \min\{496.08, 438.08, 457.07\} = 438.08,$$

and

$$b = \max\{569.06, 497.90, 519.01\} = 569.06.$$

By using the α -cut operation of fuzzy number, Eqs. (5), (6), and (7), the ranking value of each competition location's fuzzy net present value can be obtained:

$$R(FNPV_1) = 0.7160, R(FNPV_2) = 0.2253, R(FNPV_3) = 0.3734.$$

By using Eq. (11), the economic factors ranking values are

$$EFRV_1 = 0.5446, EFRV_2 = 0.1714, EFRV_3 = 0.2840.$$

Step 7.

The real value weights of the strategic factors and the fuzzy scores of the competition locations under the various strategic factors are shown in Table 7.

Step 8.

By using Eq. (12), the weighted fuzzy scores (S) of competition location L_i for strategic factors are as follows:

$$S_1 = (80.20, 82.85, 84.55),$$

$$S_2 = (79.60, 81.60, 83.75),$$

$$S_3 = (76.60, 79.95, 82.60).$$

By using Eq. (13), the ranking value $R(S)$ of weighted fuzzy score S can be obtained. The results are:

$$R(S_1) = 0.7563, R(S_2) = 0.6336, R(S_3) = 0.3994.$$

By using Eq. (14), the strategic factors ranking values are

$$SCRV_1 = 0.4227, SCRv_2 = 0.3541, SCRv_3 = 0.2232.$$

Step 9.

By using Eq. (15) and taking $\beta = 0.7$, the final ranking values can be obtained:

$$FRV_1 = 0.5080, FRV_2 = 0.2262, FRV_3 = 0.2658.$$

Step 10.

The ranking order of three competition locations is L_1 , L_3 , and L_2 . Therefore, it is obvious that the suitable selection is competition location L_1 .

VI. CONCLUSION

This study proposes a fuzzy algorithm model to evaluate competition location decisions in a fuzzy environment and assesses international transport logistics service systems. However, the project selection of international transport logistics service systems container shipping has not been measured in the related survey in the Pacific Asia region. The precise evaluation of the relevant data such as port rate, reprocessing tax, depreciation, fuzzy reprocessing cost, and transshipment cost is often difficult. Hence, the conventional precision-based competition location decision methods are less effective in conveying the imprecise or vague nature of the decision environment. The concepts of fuzzy numbers and linguistic values are used in the current study's model to assess the economic and strategic factors whereby the viewpoints of an entire decision-making body can be expressed without any constraints.

The competition location selection algorithm manages the conventional precision-based (non-fuzzy) problem and the decision makers to facilitate suitable decisions in a fuzzy environment. Thus, by conducting fuzzy or non-fuzzy assessments, the decision makers can obtain the optimal competition location automatically.

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