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Full Length Research Paper

Preference analysis of sea-air multimodal logistic system using the fuzzy multicriteria q-analysis procedure

Kuo-Liang Lee

Department of Marketing and Supply Chain management, Overseas Chinese University, Taiwan.
E-mail: lee.kl@ocu.edu.tw. Tel: +886-4-27016855 ext. 2191.

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This paper concerns two important issues regarding the criteria that multinational corporations (MNCs) consider important, the competitive preference of location developing sea-air multimodal logistic system (SA-M-LS) in Pacific-Asian region. To deal with the imprecision or vagueness nature of the linguistic evaluation, the objectives have been accomplished in this paper by employing two complementary methods: MNCs in logistics arena were surveyed to decide the criteria and estimate the weight using the fuzzy SAW, and a fuzzy multiple criteria Q-analysis (MCQA) procedure was proposed to assess the preference for cities developing SA-M-LS. Each location has different competitive conditions to develop suitable type of SA-M-LS. Finally, the research findings and discussion are proposed for location developing SA-M-LS.

Key words: Sea-air multimodal system (SA-M-LS), competitive preference, fuzzy MCQA procedure.

INTRODUCTION

The logistics service and globalization has shifted from anticipatory logistics to a response-based logistics that emphasizes on a response to customer requirement. Multinational Corporations (MNCs) had decided to concentrate on logistics functions in several particular air/sea port cities. In order to introduce the global logistic system, it is important challenge for government authorities and MNCs. Many port cities have made an effort to establish sea-air multimodal logistic system (SA-M-LS) in order to attract MNCs and logistic service providers (LSPs) to distribute international commodities through the SA-M-LS to provide logistics services (Lu, 2003; Lee, 2007; Lee, 2010). MCQA model is used to address multiple criteria and multiple aspects decision making problems. The preference evaluation of sea-air multimodal global logistic hub is a multiple criteria decision-making (MCDM) problem. However, the criteria of sea-air multimodal global logistic hub competition differ according to the criteria for judging subjects, circumstances, the degree of knowledge, etc (Oum and Park, 2004; Tai and Hwang, 2005; Lee et al., 2005). Also, their degree of strength is to be changed as per the different ways of thinking in depth. By incorporating the performance fuzziness measurement and fuzziness multicriteria grade classification method initiated by Teng (1997), this paper is intended to use fuzzy MCQA method to improve the performance judgment of decision-makers for better availability of MCQA.

Many researches have examined determinants affecting firms' evaluation in specific type of operations, logistics, distribution, or transshipment centers in particular regions (Lee et al., 2005; Oum and Park, 2004; Tai and Hwang, 2005; Yeo and Song, 2003). By analyzing these papers, it could be found that they selected several alternative locations to assess the preference relations of particular mode of logistic center. To our knowledge, however, there have been few empirical studies examining different types of SA-M-LS among the potentially competing locations. This paper aims to evaluate the preference relations for location developing SA-M-LS in Pacific Asia region from the perspective of LSPs.

Specification of sea-air multimodal logistics system

Figure 1 showed the activities of location developing SA-M-LS by addressing inbound, operations, and outbound logistics stages. The three stages satisfy different logistics functions: (1) supply side (international material and semi-product and production supply marketplace)

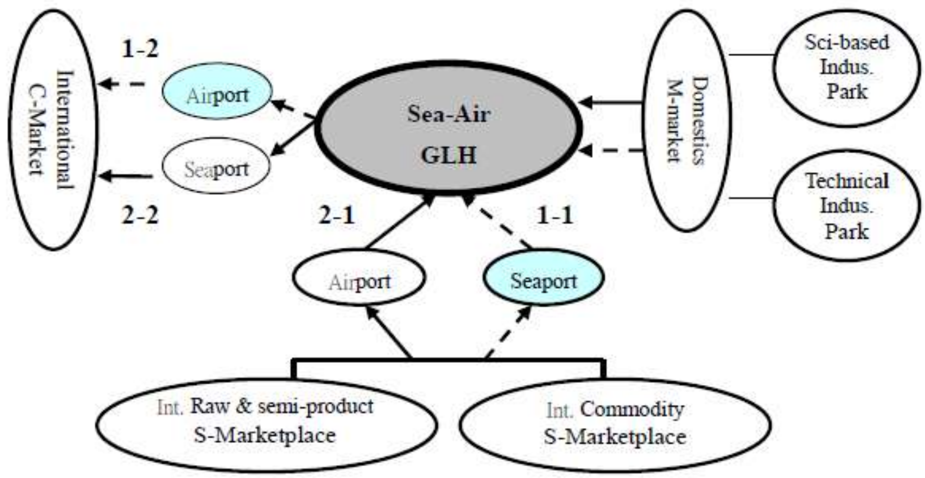

Figure 1. Activities of sea-air multimodal logistics system.
GLH: Global l Logistics Hub, S-Market: Supply Marketplace, M-Market: Manufacturing Marketplace, C-Market: Customer Marketplace.

provides the purchasing function on material, semi-product, and product cargos; (2) operation side (SA-M-LS) achieves the storage, reprocessing, and distribution functions from supply side to demand side (international consumer market), which relying on location's environmental factors such as port (air and sea) and manufacturing industries; and (3) demand side (including international customer market) satisfies consumption and re-processing demand.

By designating transshipment and reprocessing export (re-export) types of SA-M-LS, the classification of SA-M-LS types was distinguished by the viewpoint of functions and value-adding. The distinctive operational features of the two types, together with their specific logistics networks, are described below:

Type 1: Transshipment type of SA-M-LS

The transshipment type SA-M-LS presents a type of international goods distribution for global logistics activities; it provides several main functions in an integrated logistics system, such as transportation, storage, consolidation, and distribution functions. In response to satisfy the role of transshipment function, several ports have been provided the logistics hub or distribution center facilities (Lu, 2003).

Type 2: Reprocessing export type of SA-M-LS (re-export type)

This type is integrated in an effort to create an even higher value added service for material and semi-product cargos. By providing this type of logistic service, local hi-tech MC (such as science based industrial parks, hi-tech industrial parks), DC, and both sea/air ports can be integrated into the function activities of transportation, warehousing, hi-tech reprocessing, and distribution. Typical application is showed in northern area of Taiwan. The HP enterprise ordered from the OEM manufacturer in Taiwan, depending on the location advantage of port condition (Taoyan international airport and Keelung international port) and hi-tech industrial condition (Shin-Gu science-based industrial park and Taoyan technical indusial park).

In consideration with the critical conditions of two types of SA-M-LS, the major measurement of key criteria in terms of distance from main international raw and semi-product supply market, distance between airport and seaport, efficiency of air/sea port, transshipment cost of sea-air multimodal, reprocessing cost of domestic M-market, reprocessing quality of domestic M-market, distance between sea/air port and M-market, and distance to main Int. consumer market. The criteria were viewed as relevant by 25 logistics service providers and accepted as possessing content validity (Lee, 2010). Based on the literatures review of criteria considered important to firms when making decisions on selecting from the perspective of logistics service providers (Ding, 2010; Lin and Lee, 2010), the 8 criteria (Table 1) were used for inclusion in the present study's questionnaire survey. Amongst the evaluation criteria required to setup two types of SA-M-LS, the efficiency from main international raw and semi-product supply market, efficiency between airport and seaport, efficiency of air/sea port, transshipment cost of sea-air multimodal, and efficiency to main international consumer market are both common evaluation criteria, while other three criteria are determined as per the re-export type of SA-M-LS.

METHODOLOGY

By incorporating the performance fuzziness measurement and

Table 1. Evaluation criteria of two types of SA-M-LS.

Criteria	Types	
	Transshipment	**Re-export**
Efficiency from main International raw and semi-product supply market (C_1)	0	0
Efficiency between airport and seaport (C_2)	0	0
Efficiency of air/sea port (C_3)	0	0
Transshipment cost of sea-air multimodal (C_4)	0	0
Reprocessing cost of domestic M-market (C_5)		0
Reprocessing quality of domestic M-market (C_6)		0
Efficiency between sea/air port and M-market (C_7)		0
Efficiency to main Int. consumer market (C_8)	0	0

fuzziness multi-criteria grade classification method initiated by Teng (1997), this paper is intended to use MCQA to improve the performance judgment of decision-makers for better availability of MCQA.

Fuzzy measurement of location performance

Assuming there are found *n* alternatives $A = \{A_i \mid i = 1,2,\ldots,n\}, (n \geq 1)$ under *m* evaluation criteria $C = \{C_j \mid j = 1,2,\ldots,m\}, (m \geq 2)$, if the performance value measured by every evaluation criteria is classified into *p* grades $R = \{R_k \mid k = 1,2,\ldots,p\}, (p \geq 2)$, grade R_{ijk} of subjective judgment of responders upon A_i location under C_j criteria is represented below:

$$R_{ijk} = \{R_k \mid k = 1,2,\ldots,p\}, \quad \forall i, j \tag{1}$$

Where, R_{ij1} is represented by a higher degree of satisfaction of subjective judgment made by responders upon A_i alternative under C_j criteria, R_{ij2} is represented by a next higher degree of satisfaction and R_{ijp} by rather dissatisfaction, and the like. Under every evaluation criteria, the linguistic variables, such as "very satisfactory", "satisfactory", "ordinarily acceptable", "dissatisfactory" and "rather dissatisfactory", are fuzzy linguistics that can be represented by fuzzy numbers. Formerly, many scholars took up the position that "linguistic variables" could be converted into scale fuzzy numbers, but gave no detailed description of how to determine scale fuzzy numbers (Yeo and Song, 2003). The research of Saaty (1980) showed that five scales are a basic judgment method for the human beings. Thus, during the evaluation of alternatives, the satisfaction grade of the performance value under various criteria can be classified into "very good", "good", "medium", "poor" and "very poor", and represented by $R = \{R_1, R_2, R_3, R_4, R_5\}$. Meanwhile, performance values of five grades can be represented by triangular fuzzy numbers, that is. $\tilde{R}_k$ (k=1,2,…,5) showing the fuzzy performance value of *k* grade for the alternatives. The fuzzy performance value of *k* grade is measured as [0, 100], the rating interval of $\tilde{R}_k$ is represented by the following formula:

$$\tilde{R}_k = (x_{ka}, x_{kb}, x_{kc}) \tag{2}$$

Where, x_{ka}, x_{kb}, x_{kc} are optional values within [0, 100], and meet the condition of $x_{kc} \geq x_{kb} \geq x_{ka}$. This fuzzy number shows that, from the perspective of the responder, the performance value of R_k grade is between x_{ka}~x_k, and the crisp performance value is x_{kb}. The membership function $u_{\tilde{R}_k}(x)$ of fuzzy performance value $\tilde{R}_k$ of R_k grade can be expressed by the following formula:

$$u_{\tilde{R}_k}(x) = \begin{cases} 0 & , \quad x < x_{ka} \\ \dfrac{x - x_{ka}}{x_{kb} - x_{ka}} & , \quad x_{ka} \leq x < x_{kb} \\ 1 & , \quad x = x_{kb} \\ \dfrac{x_{kc} - x}{x_{kc} - x_{kb}} & , \quad x_{kb} < x \leq x_{kc} \\ 0 & , \quad x > x_{kc} \end{cases} \tag{3}$$

According to the study and analysis of Saaty (1980) the people will find it difficult to clearly judge adjacent scales, but easy to distinguish separated ones. For example, it is difficult to distinguish the satisfaction grades of "very good" and "good", but easy to distinguish "very good" and "medium" clearly. In other words, there is a fuzzy interval between adjacent grades other than separated ones. For this reason, this paper has defined five satisfaction grades of fuzzy performance values as shown in Figure 2.

Fuzzy grade classification method

Assuming there are *N* responders expressed by $E = \{E_h \mid h = 1,2,\ldots,N\}$, the fuzzy performance values of A_i location under C_j criteria are represented by $\tilde{r}_{ij}$ (i = 1,2,…, n; j = 1,2,…, m), so it is possible to measure the percentage of every grade of responders amongst gross number as detailed below:

$$\tilde{r}_{ij} = \sum_{k=1}^{5} \left(\frac{N_{ijk}}{N_{ij}} \right) \otimes \tilde{R}_k \quad , \quad \forall i, j \tag{4}$$

$$N_{ij} = \sum_{k=1}^{5} N_{ijk} \quad , \quad \forall i \tag{5}$$

Where, N_{ijk} is represented by the number of responders who judge the performance value of A_i location as R_k grade under C_j criteria, and N_{ij} by the total responders. In case every responder make

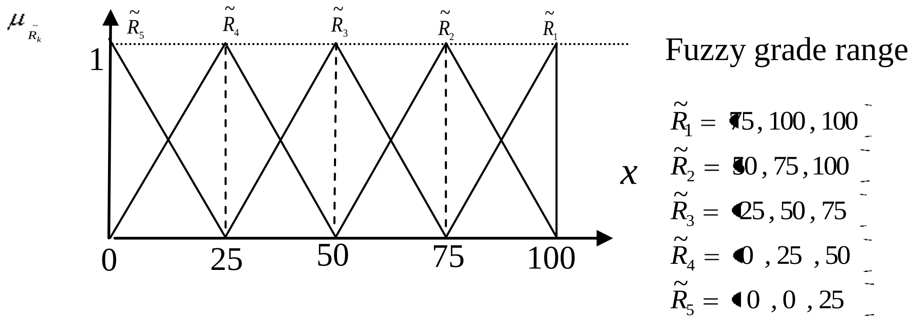

Figure 2. Grade fuzzy number $\tilde{R}_k$.

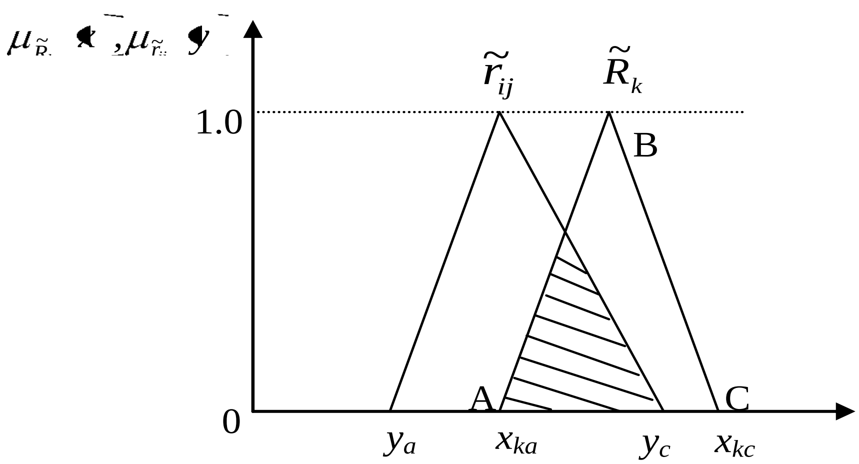

Figure 3. R_k grade attribution.

judgment, $N = N_{ij}$. In case some responders cannot make judgment, $N_{ij} < N_0$. $\tilde{\sum}$ indicates fuzzy summation and symbol $\otimes$ indicates fuzzy multiplication. Once the responders have finished the evaluation of alternative locations, the preference structure matrix $\tilde{P}$ can be obtained as;

$$\tilde{P} = \left[\tilde{r}_{ij}\right]_{i \times j} \quad , \quad \forall\, i, j \tag{6}$$

As N_{ijk} and N_{ij} are constants, the fuzzy value $\tilde{r}_{ij}$ still belongs to triangular fuzzy numbers [18]. It is required to compare $\tilde{r}_{ij}$ and $\tilde{R}_k$ fuzzy numbers to determine which grade $\tilde{r}_{ij}$ belongs to. In other words, it is possible to judge based upon the percentage of the area of $\tilde{r}_{ij}$ fuzzy numbers among the area of $\tilde{R}_k$ fuzzy numbers, that is, obtaining the value α_{ijk} of R_k grade as shown in Figure 3. The area of $\tilde{r}_{ij}$ among $\tilde{R}_k$ is represented by the oblique shadow. After obtaining the area of oblique shadow among $\tilde{R}_k$ grade (that is, percentage of triangle ABC), it is possible to gain the grade value α_{ijk}, which can be shown by the ratio between two ordinary integrals of membership functions as below:

$$\alpha_{ijk} = \frac{\int_{y \in D_k} u_{\tilde{r}_{ij}}(y)\,dy}{\int_{x \in D_k} u_{\tilde{R}_k}(x)\,dx} \quad , \forall\, i, j, k \tag{7}$$

Where, $u_{\tilde{r}_{ij}}(y)$ is membership function of fuzzy number $\tilde{r}_{ij}$ and $u_{\tilde{R}_k}(x)$ is membership function of grade fuzzy number $\tilde{R}_k$ with overlapped fuzzy interval as $D_k = [\,x_{ka}, y_c\,]$.

In order to identify p grades, (ρ -1) evaluation grade groups' comprising every two adjacent grades is created:

$$\begin{aligned} R_1' &= R_1, R_2 \text{ or } R_3 \text{ or} \ldots \text{or } R_p \\ R_2' &= R_2, R_3 \text{ or } R_4 \text{ or} \ldots \text{or } R_p \\ &\vdots \\ R_{p-1}' &= R_{p-1}, R_p \end{aligned}$$

The fuzzy value $\tilde{r}_{ij}$ may be evaluated according to $R_1', R_2', \ldots, R_{p-1}'$

grades, and the corresponding membership grade $\beta_1, \beta_2, \ldots, \beta_{p-1}$ can be obtained with the grades classified as per the following rule:

$$\beta_1 \geq M \quad then \ \ \tilde{r}_{ij} \in R_1 \ ; \ otherwise$$
$$\beta_2 \geq M \quad then \ \ \tilde{r}_{ij} \in R_2 \ ; \ otherwise$$
$$\vdots$$
$$(p-1) \ \ \beta_{p-1} \geq M \quad then. \ \ \tilde{r}_{ij} \in R_{p-1}; \ otherwise \ \ \tilde{r}_{ij} \in R_p$$

Where M represented the threshold value of membership grade of grade $R_1', R_2', \ldots, R_{p-1}'$

For example, there are only two grades *R*= {*R1, R2}*, when the membership grade of grade R_1 reaches the threshold value *M*, the fuzzy value $\tilde{r}_{ij}$ under c_j criteria belongs to grade R_1, or otherwise to grade R_2. As *M* value exceeds a half or two-third in principle, *M* value is often 0.5 or 0.7. Assuming β_1 and β_2 respectively represents the membership grade of $\tilde{r}_{ij} \in R_1$ and $\tilde{r}_{ij} \in R_2$, and β1+β2=1, there will be found following three cases:

$$\beta_1 > M \ , \text{then} \ \tilde{r}_{ij} \in R_1$$
$$\beta_1 = M \ , \text{then} \ \tilde{r}_{ij} \in R_1 \text{ or } \tilde{r}_{ij} \in R_2$$
$$\beta_2 > M \ , \text{then} \ \tilde{r}_{ij} \in R_2$$

And, when the grade is classified into three variables: R = {R_1, R_2, R_3} the grade classification of fuzzy value $\tilde{r}_{ij}$ may be evaluated as per two grade classification modes, that is $R_1' = \{R_1, R_2 \text{ or } R_3\}$, $R_2' = \{R_2 \text{ or } R_3\}$. Meanwhile, it is possible to search respective membership grade ($\beta_1, \bar{\beta}_1$), ($\beta_2, \bar{\beta}_2$), and $\beta_1 + \bar{\beta}_1 = 1$, $\beta_2 + \bar{\beta}_2 = 1$. Thus, the grade classification can be further implemented based upon β_1 and β_2 as detailed below:

$$\beta_1 \geq M, \text{then} \ \tilde{r}_{ij} \in R_1$$
$$\bar{\beta}_1 \geq M \ , \text{then} \ \tilde{r}_{ij} \in R_2 \ or \ \tilde{r}_{ij} \in R_3, \ depond \ on \ \beta_2$$
$$\beta_2 \geq M \ , \ then. \ \tilde{r}_{ij} \in R_2$$
$$\bar{\beta}_2 \geq M \quad , \ then \ \ \tilde{r}_{ij} \in R_3$$

Under the precondition that the membership grade of *p* grades summation is 1 according to various grade levels α_{ijk}, the membership grade of various grades β_{ijk} (*i* =1,2,…, *n*; *j* =1,2,…, *m*; *k* =1,2,…, *p*) can be obtained from the following formula:

$$\beta_{ij1} = \sum_{k=1}^{1} \alpha_{ijk} \Big/ \sum_{k=1}^{p} \alpha_{ijk}$$
$$\beta_{ij2} = \sum_{k=1}^{2} \alpha_{ijk} \Big/ \sum_{k=1}^{p} \alpha_{ijk} \qquad (8)$$
$$\vdots$$
$$\beta_{ij(p-1)} = \sum_{k=1}^{p-1} \alpha_{ijk} \Big/ \sum_{k=1}^{p} \alpha_{ijk}$$
$$\beta_{ijp} = 1$$

Fuzzy weight

People will find it hard to clearly judge adjacent scales, but easy to distinguish separated ones in accordance with the study of Zadeh (1965).Such as it is difficult to distinguish the satisfaction grades of "very good" and "good", but easy to distinguish "very good" and "medium" clearly. That is to say, there is a fuzzy interval between adjacent grades other than separated ones. Therefore, the five satisfaction grades of fuzzy performance values were defined shown in Figure 2**.** In addition, the evaluation scale [0, 100] can be converted into [0, 1] to facilitate the calculation. As noted earlier, there is a fuzzy interval between adjacent grades, but not between non-adjacent grades. Figure 2 presents the satisfaction grades of fuzzy performance values. The evaluation scale [0, 100], can be converted into [0, 1] to facilitate calculation.

This paper has classified the importance level of evaluation criteria into five grades, that is. "absolute importance", "demonstrated importance", "essential importance", "weak importance" and "importance". All of them can be represented by $V = \{V_l | l = 1,2,\ldots,5\}$, where, V_1 indicates "absolute importance", V_2 "demonstrated importance" and the like. As "absolute importance", "demonstrated importance", "essential importance", "weak importance" and "importance" are still fuzzy linguistics. The triangular fuzzy numbers $\tilde{V} = \{\tilde{V}_l | l = 1,2,\ldots,5\}$ is adopted to represent the scores of five grades, with the corresponding fuzzy numbers shown in Figure 3, wherein only $\tilde{R}_k$ is converted into $\tilde{V}_l$. With the introduction of [0, 100] measurement scale, the fuzzy weight of *l* grade can be represented by $\tilde{V}_l$ = (x_{la} , x_{lb} , x_{lc}), of which x_{la} , x_{lb} , x_{lc} are optional values within [0, 100], and meet the condition of $x_{lc} \geq x_{lb} \geq x_{la}$.

It is assumed that *N* logistics professionals judge the importance level of evaluation criteria as V_l (*l* =1, 2,…, 5) grades, which is represented by Y_{hj} as:

$$Y_{hj} = V_l \quad , j = 1,2,\ldots,m \ ; \ h = 1,2,\ldots,N \ ; \ l = 1,2,\ldots,5 \qquad (9)$$

The grade judgment matrix of *N* logistics professionals can be represented by *Y* as:

$$Y = [Y_{hj}]_{N \times m} \qquad (10)$$

It is possible to obtain the grade of consensus weight under every evaluation criteria in accordance with the grade matrix *Y* of importance level and majority rule. Take $Z[V_l]_j$ as the number from *N* logistics professionals who judge the importance under C_j criteria as grade V_l, and take $Z[\sum V_l]_j$ as the number of professionals with their judgment grade V_1 summated to grade V_l, namely:

$$Z[\sum V_l]_j = \sum_{g=1}^{l} Z[V_g]_j \quad , \quad \forall \ j \qquad (11)$$

Suppose the importance level of consensus judgment under C_j evaluation criteria is judged as grade V_1, it shows that the importance level under C_j evaluation criteria meets grades from V_2 to V_v. That is to say, the grade V_1 includes grades V_2 ~V_v. If the importance level of common understanding under C_j evaluation criteria is judged as grade V_2, it shows that the importance level under C_j evaluation criteria meets the grades from V_3 to V_v apart from grade V_1. Namely, the grade V_2 implies grades V_3 ~V_v apart from grade V_1. $Z[\sum V_l]_j$ must exceed a certain majority value *M* in accordance with the majority rule, namely

$$Z[\sum V_l]_j \geq M \quad (12)$$

Where, M value can be jointly agreed upon by N logistics professionals. M value can be determined by the following formula with the introduction of majority rule (Teng and Tzeng, 1998):

$$M = \begin{cases} (N/2)+1 & , N \text{ is even number} \\ ((N-1)/2)+1 & , N \text{ is odd number} \end{cases} \quad (13)$$

Depending upon the level of consensus, the majority rule can also incorporate those over two-third or three-fourth. And, it is possible to obtain grade V_u of consensus for the importance level of C_j criteria in accordance with the analysis of majority rule, and convert it into the fuzzy weight under this criteria, that is. $\tilde{w}_j$:

$$\tilde{w}_j = V_u \quad , \quad V_u \in V \quad , u = 1,2,\ldots,5 \quad (14)$$

Fuzzy MCQA model

It is assumed that the grade R_k, grade R_{ijk} within preference structure matrix $\tilde{PR}$ can be represented by 1, otherwise, represented by 0.Then, the preference structure matrix within formula (14) can be converted into the following p 0-1 type incidence matrix B_{R_k} $(k = 1,2,\ldots,p)$:

$$B_{R_k} = [b_{ij}]_{i \times j} \quad \forall i \ , j \ , k \quad (15)$$

$$b_{ij} = \begin{cases} 0 \ , & if \ \tilde{R}_{ijk} < \tilde{R}_k \\ 1 \ , & if \ \tilde{R}_{ijk} \geq \tilde{R}_k \end{cases} \quad (16)$$

Depending upon the incidence matrix of every grade, it is possible to obtain and meet the criteria number matrix of this grade via q-connectivity, that is. obtaining the following q-connectivity matrix

S^{R_k} (k = 1, 2,…, p):

$$S^{R_k} = B_{R_k} (B_{R_k})^T - e^T e \quad (17)$$

Where, S^{R_k} : under R_k grade q - connectivity matrix

$(B_{R_k})^T$: the transfer matrix of incidence matrix

Based on the q-connectivity matrix, preference structure matrix and fuzzy weight, it is possible to obtain fuzzy project satisfaction index $\tilde{PS}_i$ and fuzzy project comparison index $\tilde{PC}_i$ for various locations, each of which is defined below:

$$\tilde{PS}_i = \sum_k \tilde{R}_k \otimes \tilde{T}_{ik} \quad , \quad \forall i \quad (18)$$

$$\tilde{T}_{ik} = \sum_j b_{ij}^k \otimes \tilde{w}_j \quad , \forall i, k \quad (19)$$

$$\tilde{PC}_i = \sum_k \tilde{R}_k [\hat{q}_{iR_k} - q^*_{iR_k}] \quad , \quad \forall i \quad (20)$$

$$q^*_{iR_k} = \max_{\substack{i'=1,2,\ldots,n \\ i \neq i'}} imum S^{R_k} (i, i') \quad (21)$$

$$\hat{q}_{iR_k} = S^{R_k} (i, i) \quad (22)$$

Where;

$\hat{q}_{iR_k} = S^{R_k} (i, i)$ is represented by the dimension of A_i alternative under grade R_k and $q^*_{iR_k} = \text{maximum}_{\substack{i'=1,2,\ldots,n \\ i \neq i'}} S^{R_k} (i, i')$ is presented by the maximum dimension of all alternatives under grade R_k.

The fuzzy project satisfaction index indicates the comprehensive satisfaction of logistics professionals upon A_i, the bigger the criteria the better the performance is. It is required to obtain the fuzzy comparison index so as to compare the alternatives, as fuzzy project satisfaction index can only measure the absolute satisfaction of various alternatives rather than the relative satisfaction. However, pairwise comparison method will complicate the calculation. In an effort to simplify the mathematical operation, it is often assumed that preference transitivity will occur (Starr and Zeleny, 1997). With a view to the fuzzy MCQA method in this paper, it is also suppose the preference transitivity will take place. Hence, when obtaining the value of $\tilde{PC}_i$, it is only required to find out maximum $q^*_{iR_k}$ for comparison with $\hat{q}_{iR_k}$, without consideration of complex pairwise comparison method.

Both $\tilde{PS}_i$ and $\tilde{PC}_i$ belong to fuzzy numbers so defuzzier shall be required, it is unlikely to compare them directly as crisp values.

This paper will convert the fuzzy numbers of $\tilde{PS}_i$ and $\tilde{PC}_i$ into real numbers based upon the ranking method of fuzzy numbers for Kim-Park modified by Teng and Tzeng (1996). Take $\tilde{PH}_i$ as the general expression of $\tilde{PS}_i$ and $\tilde{PC}_i$ as shown in Equation 23:

$$\tilde{PH}_i = (LH_i, MH_i, RH_i) \quad i = 1,2,\ldots,n \quad (23)$$

While the greater the interval of LH_i, MH_i the greater the negative assessment of location A_i. The greater the interval of MH_i, RH_i higher the positive assessment of location A_i.

Give S as the range of all alternative' $\tilde{PH}_i$ measurement values as well as an universe of discourse, of which s is an element of set S showing an optional value within the range of S. Take α_i value between〔0, 1〕as the optimistic attitude of experts upon alternatives whereas (1-α_i) shows their pessimistic attitude. It is assumed that $u_o(\tilde{PH}_i)$ represents the optimistic membership grade of the fuzzy satisfaction index in A_i, and $u_p(\tilde{PH}_i)$ represents the pessimistic membership grade, $u_T(\tilde{PH}_i)$ value can be obtained from the following formula:

$$\mu_T\left(\tilde{PH}_i\right) = \alpha_i \mu_o\left(\tilde{PH}_i\right) + (1-\alpha_i)\mu_p\left(\tilde{PH}_i\right) \quad , \quad i = 1,2,\ldots,n \tag{24}$$

$$\alpha_i = (RH_i - MH_i) / (RH_i - LH_i) \;, \quad \forall\, i \tag{25}$$

$$\mu_o\left(\tilde{PH}_i\right) = (s_{2_i} - s_{\min}) / (s_{\max} - s_{\min}) \;, \;\forall\, i \tag{26}$$

$$\mu_p\left(\tilde{PH}_i\right) = 1 - \left[(s_{\max} - s_{2_i}) / (s_{\max} - s_{\min})\right], \;\forall\, i \tag{27}$$

$$s_{1_i} = \frac{s_{\max} RH_i - s_{\min} MH_i}{(RH_i - MH_i) + (s_{\max} - s_{\min})} \tag{28}$$

$$s_{2_i} = \frac{s_{\max} MH_i - s_{\min} LH_i}{(MH_i - LH_i) + (s_{\max} - s_{\min})} \tag{29}$$

$$s_{\max} = \sup\ S \tag{30}$$

$$s_{\min} = \inf\ S \tag{31}$$

$$S = \bigcup_{i \in A} \tilde{PH}_i \tag{32}$$

where s_{1_i} is an element of set *S* showing an optional value within the range of MH_i, RH_i, and s_{2_i} is an element of set *S* showing an optional value within the range of LH_i, MH_i.

As for the fuzzy MCQA model in this paper, the author attempts to, based upon the defuzzier value of $\tilde{PS}_i$ and $\tilde{PC}_i$, obtain the evaluation ranking of alternatives via MCQA concept. A_i project rating index PRI_i, can be obtained from the following formula:

$$PRI_i = \left[\left(1 - u_T\left(\tilde{PS}_i\right)\right)^r + \left(1 - u_T\left(\tilde{PC}_i\right)\right)^r\right]^{1/r}, \forall\, i \tag{33}$$

The smaller PRI_i value is, the closer it indicates the distance between alternative's vector and ideal vector, that is. the better the alternative is, otherwise, the worse the alternative is. As the concept of Euclidean distance is applied to formula (32), *r* value is often determined as 2.

Empirical study

In this study, the locations developing SA-M-LS in Singapore (A_1), Hong Kong (A_2), Taipei(A_3), Shanghai(A_4), and Seoul(A_5) 5 candidates in Pacific Asia region are evaluated by comparing respondents' satisfaction with their ability to meet each evaluation criteria.

Company characterization

The sampled MNCs operate in logistic professionals. Due to limitations of finance and time, the questionnaire survey was sent to the 200 managers of international logistics service providers (sea/air carriers and forwarders), survey participants were from leading firms in 2009 with good export and import performance and the members of the International Logistics Association in Taiwan. As suggested by Alam (2009), there is a need to revise the questionnaire with responses and change of time, revised questionnaire was sent to a manager in each of our target sample MNCs by post-mail, email or interview. In order to encourage potential respondents' participation, respondents were offered a copy of the results upon completion of the study. The initial mailing elicited 27 usable responses. A follow-up mailing was sent two weeks after the initial mailing. An additional 12 usable responses were returned, bringing the total number of usable responses to 47. The overall response rate for this study was 23 percent. Survey respondents are categorized by industry in Table 2. Results show that the 19.1% of survey participants were from air carriers, 34.0% were sea carriers, and 46.9% were sea/air freight forwarders.

Evaluation approach

The hierarchical structure of locations developing SA-M-LS is constructed in accordance with the evaluation criteria in Figure 4, and five alternative cities are selected about the decision making of SA-M-LS, A_1~A_5, respectively. Based on the Table 1, the hierarchical structure of the evaluation criteria for firms selecting the location of four different types of logistics parks was constructed as shown in Figure 4. These criteria include: Efficiency from main Int. raw & semi-product supply market (C_1), Efficiency between airport and seaport (C_2), Efficiency of air/sea port (C_3), Transshipment cost of sea-air multimodal (C_4), Reprocessing cost of domestic, M-market (C_5),

Reprocessing quality of domestic M-market (C_6), Efficiency between sea/air port and M-market (C_7), and Efficiency to main Int. consumer market (C_8).

This evaluation approach in collaboration with fuzzy measurement, fuzzy grade classification, fuzzy weight, and MCQA method was used to empirical study. As the evaluation criteria under research and discussion, it is intended to collect the actual quantification and qualification performance value of various alternative locations in order to facilitate the decision-making of SA-M-LS. However, as the different satisfaction of logistics professionals upon actual performance value, this evaluation is scheduled to measure their satisfaction via fuzzy measurement method, and then classify the grade of performance value via fuzzy grade classification method. In an effort to assess the importance level of evaluation criteria, this study tries to obtain the fuzzy weight via majority rule. And, based upon the fuzzy grade and fuzzy weight as well as MCQA method, this evaluation has acquired various locations' fuzzy project satisfaction index and fuzzy project comparison index, and finally defuzzier them via fuzzy ranking method to get various locations' Project Rating Index (PRI). The framework of decision-making for i SA-M-LS location is shown in Figure 5.

RESULTS

The satisfaction grade of the evaluation criteria of various potential locations can be classified into "very good (R1)", "good (R2)", "medium (R3)", "poor (R4)" and "very poor (R5)". The logistics professionals tend to estimate the performance value and judge the satisfaction grade as

Table 2. Sample firms.

Characteristics	Number of respondents	Percentage of respondents
Air carriers	9	19.1
Sea carriers	16	34.0
Air/sea Freight forwarders	22	46.9
Total	47	100

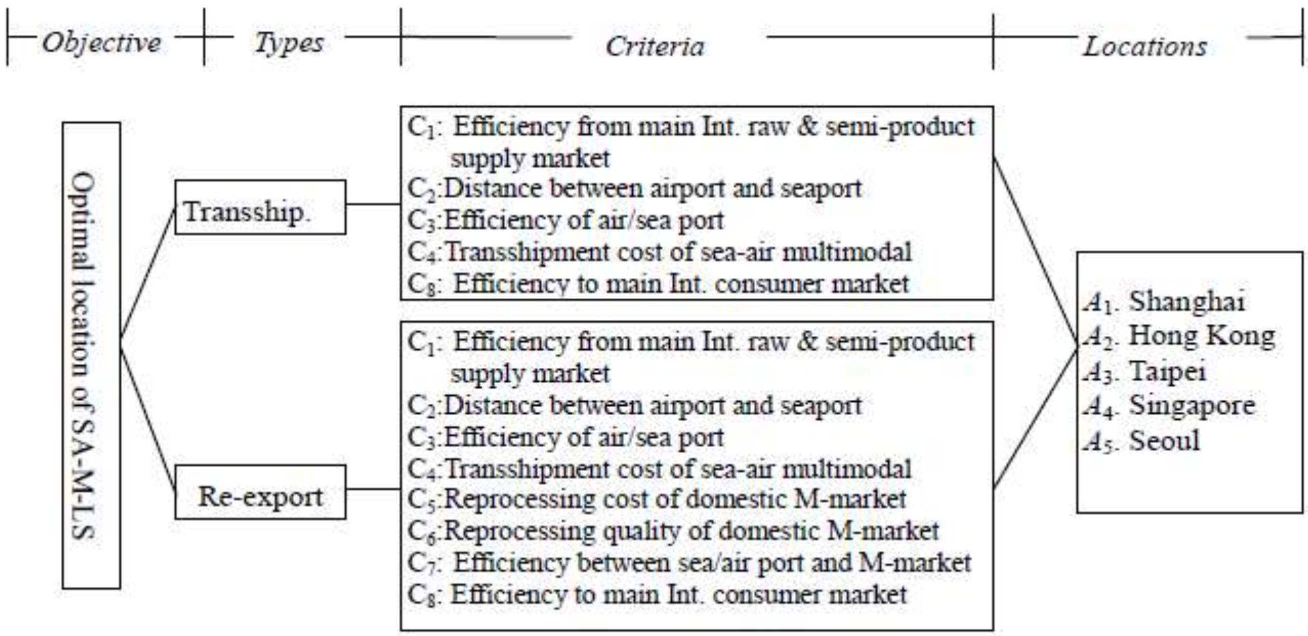

Figure 4. The evaluative structure of SA-M-LS.

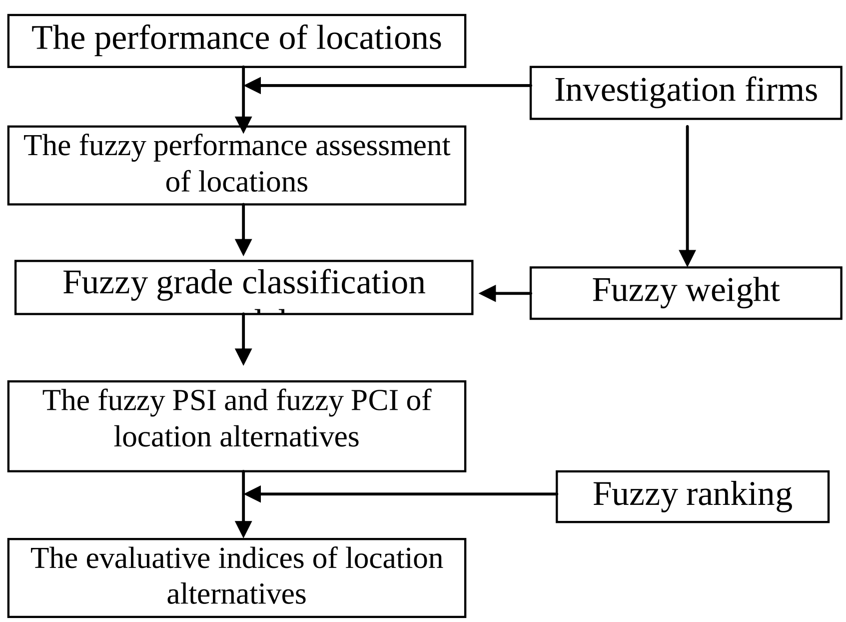

Figure 5. Decision making approach about SA-M-LS location.

Table 3. The classification contribution of alternative locations in each criterion.

Locations	Criteria							
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1. Shanghai	R_3	R_5	R_5	R_2	R_3	R_3	R_4	R_2
A_2. Hong Kong	R_4	R_5	R_5	R_2	R_2	R_3	R_2	R_3
A_3. Taipei	R_3	R_2	R_3	R_4	R_4	R_4	R_3	R_2
A_4. Singapore	R_3	R_3	R_2	R_4	R_5	R_3	R_4	R_4
A_5. Seoul	R_2	R_2	R_3	R_4	R_3	R_4	R_3	R_3

Table 4. The consensus grade and fuzzy weight of criteria C_j .

Criteria	Consensus grade	Fuzzy weight
C_1	V_2	(0.5,0.75,1.0)
C_2	V_1	(0.75,1.0,1.0)
C_3	V_1	(0.75,1.0,1.0)
C_4	V_2	(0.5,0.75,1.0)
C_5	V_2	(0.5,0.75,1.0)
C_6	V_1	(0.75,1.0,1.0)
C_7	V_3	(0.25,0.5,0.75)
C_7	V_4	(0.0,0.25,0.5)

Table 5. PSI and PCI value of transshipment type of SA-M-LS.

Location (A_i)	$\tilde{PS}_i$	$\mu_T(\tilde{PS}_i)$	$\tilde{PC}_i$	$\mu_T(\tilde{PC}_i)$
A_1. Shanghai	(1.50, 2.25, 2.81)	0.68	(0.50, 0.75, 1.00)	0.70
A_2. Hong Kong	(1.13, 1.69, 2.19)	0.50	(0.50, 0.75, 1.00)	0.39
A_3. Taipei	(1.88, 2.75, 3.44)	0.69	(0.00, 0.00, 0.00)	0.00
A_4. Singapore	(0.88, 1.38, 1.81)	0.59	(0.50, 0.75, 1.00)	0.70
A_5. Seoul	(0.63, 0.99, 0.94)	0.19	(0.00, 0.00, 0.00)	0.00

Remark: PSI: Project Satisfaction Index; PCI: Project Comparison Index.

one evaluation criterion particular to a suitable alternative. As the different preference of every logistics professional, the fuzzy measurement method was utilized to assess the preference and the fuzzy grade classification method obtained the grade of potential locations under every evaluation criteria, with the detailed results listed in Figure 4.

In consideration of the results listed in Tables 3 and 4, as well as the evaluation criteria of transshipment and re-export types of SA-M-LS. The four groups of fuzzy project satisfaction index ($\tilde{PS}_i$), fuzzy project comparison index ($\tilde{PC}_i$), and corresponding crisp values ($\mu_T(\tilde{PS}_i)$, $\mu_T(\tilde{PC}_i)$) via fuzzy MCQA method (Tables 5 and 6) is possible to analyze and obtain. Then, the project rating index (*PRI*) of various potential locations can be obtained from formula (32) according to the crisp value of $\tilde{PS}_i$ and $\tilde{PC}_i$. Given the same importance of two types of SA-M-LS, it is possible to calculate the gross project rating index of various potential locations, the smaller the value, the better the results are. Therefore, the ranking of priority of various potential SA-M-LS locations can be obtained as the results listed in Table 7. There can be found the satisfaction grade of 25 logistics professionals upon 5 potential locations of SA-M-LS, of which the priority are CFS of Shanghai (A_1), Singapore (A_4), Hong Kong (A_2), Taipei (A_3), and Seoul (A_5).

DISCUSSION

The competitiveness of location determinants

A sensitivity analysis was discussed to understand any influence upon the preference analysis of SA-M-LS.

Table 6. PSI and PCI value of re-export type of SA-M-LS.

Location (A_i)	$\tilde{PS}_i$	$\mu_T(\tilde{PS}_i)$	$\tilde{PC}_i$	$\mu_T(\tilde{PC}_i)$
A_1. Shanghai	(1.50, 2.31, 3.06)	0.58	(1.00, 1.50, 2.00)	0.70
A_2. Hong Kong	(0.88, 1.31, 1.69)	0.35	(0.50, 0.75, 1.00)	0.39
A_3. Taipei	(1.13, 1.69, 2.19)	0.41	(0.00, 0.00, 0.00)	0.00
A_4. Singapore	(0.88, 1.31, 1.56)	0.54	(0.50, 0.75, 1.00)	0.70
A_5. Seoul	(1.13, 1.69, 2.19)	0.41	(0.00, 0.00, 0.00)	0.00

Remark: PSI: Project Satisfaction Index; PCI: Project Comparison Index.

Table 7. Priority for location developing SA-M-LS in Pacific Asia region.

Location (A_i)	Transshipment	Re-export	$TPRI_i$	Priority
	PRI_i (priority)	PRI_i (priority)		
A_1. Shanghai	0.44 (1)	0.51 (1)	0.95	1
A_2. Hong Kong	0.79 (3)	0.89 (3)	1.68	3
A_3. Taipei	1.05 (4)	1.16 (4)	2.21	4
A_4. Singapore	0.50 (2)	0.55 (2)	1.05	2
A_5. Seoul	1.28 (5)	1.16 (4)	2.44	5

Table 8. Locations preference analysis with single type of SA-M-LS.

Locations	Transshipment type				Re-export type			
	0.5*	0.6*	0.7*	0.8*	0.5*	0.6*	0.7*	0.8*
A_1. Shanghai	1	1	2	2	1	1	1	1
A_2. Hong Kong	3	3	4	4	2	2	2	2
A_3. Taipei	4	4	5	5	4	4	3	3
A_4. Singapore	2	2	1	1	3	3	5	5
A_5. Seoul	5	5	3	3	5	5	4	4

*Showed the weight variety of important degree at each type of SA-M-LS.

Based upon the various cases of combinations, that is, most important for a single type of SA-M-LS, or most important for two types of SA-M-LS, this paper has analyzed the change of preference analysis of various potential locations. In the case of most importance for a single type of SA-M-LS, it is assumed that the importance weight of the most important SA-M-LS is available with 0.5, 0.6, and 0.7 and 0.8; the other SA-M-LS share the remaining weight (calculated by weight summation 1). Hence, the priority of 5 SA-M-LS locations can be obtained as listed in Table 8. Respondents viewed that the preference relations are Shanghai (A1), Singapore (A4), and Hong Kong (A2) when the importance weight of transshipment type of SA-M-LS is 0.5 * ~0.8 * . From the respective of re-export type of SA-M-LS, the preference relations are Shanghai (A1), Hong Kong (A2), and Taipei (A3) when the importance weight is 0.5 * ~0.8 * .

From the perspectives of competitive relations on each type of SA-M-LS, the relations in accordance with the priorities of ranking order are rearranged as shown in Figure 6. It can be found that there are competitive gaps for each location developing the two types of SA-M-LS. Several studies (Lee et al., 2005; Oum and Park, 2004; Tai and Hwang, 2005; Yeo and Song, 2003; Lee and Lin, 2008; Lee et al., 2009; Lee, 2010) have examined determinants affecting MNC evaluation of operations, logistics, distribution, and transshipment centers in Pacific Asia regions. They has generally selected several different candidate locations in specific regions and assessed their preference relations as the foundation for proposing relation strategies. Shanghai always located in third position, lagged in the Singapore and Hong Kong. However, due to the economical and industrial development in the Yangtze River Delta, the usage of Yang-Shan port, and the development of Pudon and Hongqiao airport, Shanghai shows the strongest competitiveness on the transshipment and re-export types of SA-M-LS. As the excellent sea-air transportation conditions and the weakness on the hi-tech industrial foundation, Singapore keeps the enough competitiveness on the transshipment type of SA-M-LS on Asia-European marketplace, but has

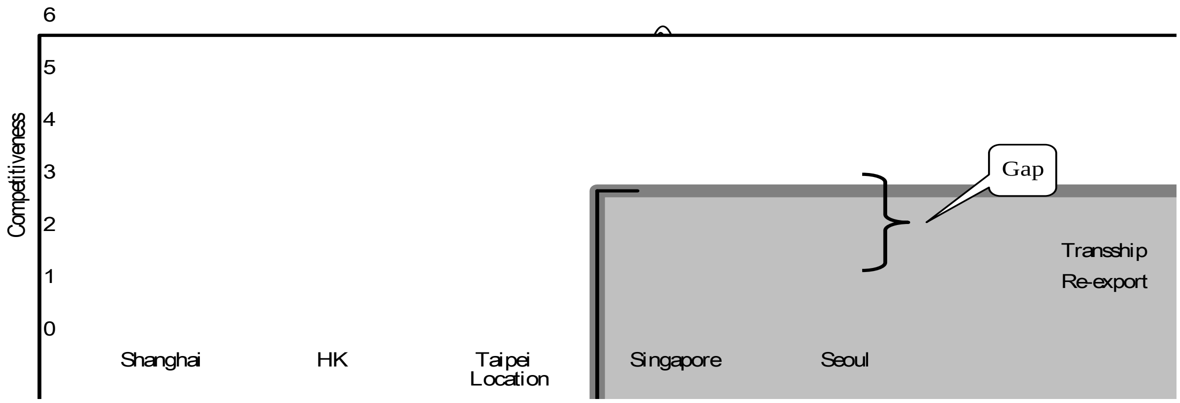

Figure 6. The preference relation of SA-M-LS in Pacific Asia region.

Table 9. The performance of SA-M-LS in Pacific Asia region.

Criteria	A_1. Shanghai	A_2. HK	A_3. Taipei	A_4. Singapore	A_5. Seoul
Internal environment					
Transportation efficiency between airport and seaport (C_2)	+		-	+	-
Efficiency of air/sea port (C_3)	-	+	-	+	
Transshipment cost of sea-air multimodal (C_4)	+		-	+	-
Reprocessing cost of domestic M-market (C_5)	+	+		-	-
Reprocessing quality of domestic M-market (C_6)	-		+	-	+
Transportation efficiency between sea/air port and M-market (C_7)		+	-	-	
External environment					
Transportation efficiency from main International raw and semi-product supply market (C_1)		-	-	-	-
Transportation efficiency to main Int. consumer market (C_8)	+	-		+	-

" + " advantage and " - "disadvantage.

The decision of advantage and weak refers to the fuzzy performance value of appendix A, B.

weakness on re-export type of SA-M-LS. HK holds the enough competitiveness to develop the re-export type of SA-M-LS due to near the hi-tech industrial environment in the Pearl-River Delta, on southern-China marketplace, and the excellent sea-air transportation conditions. As Taiwan and China had signed the Economic Cooperation Framework Agreement (ECFA) in 2010, one of mode of free trade agreement, and there are closer relationship of upstream and downstream of industrial supply chain, Taipei also has the enough competitiveness on the re-export type of SA-M-LS.

Furthermore to analyze the environmental conditions (Tables 9) among locations, Shanghai has an absolute advantage for developing SA-M-LS in internal environment ('transportation efficiency between airport and and seaport', 'transshipment cost of sea-air multimodal', 'reprocessing cost of domestic M-market',) and external environment ('transportation efficiency to main Int. consumer market'), but has the weakness in internal environment ('efficiency of air/sea port', 'reprocessing quality of domestic M-market'). HK showed the advantage in internal conditions ('efficiency of air/sea port', 'reprocessing cost of domestic M-market', 'transportation efficiency between sea/air port and M-market') and weakness in internal conditions ('transportation efficiency from main International raw and semi-product', 'transportation efficiency to main Int. consumer market'). As the hi-tech industrial cluster environment and location, Taipei has absolute advantage in internal environment of 'reprocessing quality of domestic M-market' and external environment of 'efficiency to main International consumer market'. However, Taipei has more weakness in internal

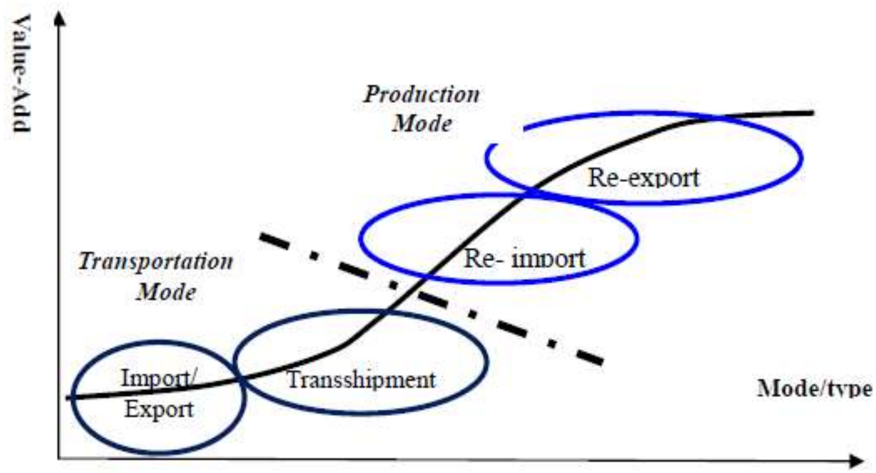

Figure 7. The models of SA-M-LS.

environment conditions including, 'transportation efficiency between airport and seaport', 'efficiency of air/sea port', 'efficiency of air/sea port', 'transshipment cost of sea-air multimodal', 'transportation efficiency between sea/air port and M-market') and environment ('transportation efficiency from main International raw and semi-product supply market'). Singapore showed a competitive advantage in the internal environment ('transportation efficiency between airport and seaport', 'efficiency of air/sea port', 'transshipment cost of sea-air multimodal') and external environment ('transportation efficiency to main Int. consumer market'). And, it exist several weaknesses in internal environment ('reprocessing cost of domestic M-market', 'reprocessing quality of domestic M-market', 'transportation efficiency between sea/air port and M-market') and external environment ('Transportation efficiency from main Int. raw & semi-product supply market'). Finally, as the hi-tech industrial cluster environment and the strongly competition of China, Seoul has advantage in the internal environment ('reprocessing quality of domestic M-market') and more weakness in internal environment ('transportation efficiency between airport and seaport', 'transshipment cost of sea-air multimodal', 'reprocessing cost of domestic M-market') and external environment ('efficiency from main International raw and semi-product supply market', 'efficiency to main Int. consumer market').

Strategic suggestion

A list was constructed to present the specification of SA-M-LS in Figure 7 (Lee, 2007). It showed that there are different functions, key factors, value-adding and level relations for supporting the evaluation of various types of SA-M-LS. Both import/export and transshipment types of SA-M-LS provide the similar functional service (transportation, warehousing and distribution) and key factors (air/sea port、inbound/outbound transportation), but show the different competitive modes. It provides lower value-added for location developing transportation mode of SA-M-LS. Comparison of the re-import and re-export (including initial and deep) types of SA-M-LS, it shows the additional function (from raw to deep reprocessing) and key factor (initial or hi-tech manufacturing industries) requirement than the previous two types, and they belong to different competitive levels. Therefore, it creates middle or higher value-added service for location developing production mode of SA-M-LS.

Referring to the analysis of Figure 6 and Figure 7, the strategies are suggested as shown in Table 10.In accordance with the competitive conditions each location and key factors for location developing transshipment and re-export types of SA-M-LS. Shanghai and HK are suggested to develop both transportation and production modes of SA-M-LS on their competitiveness of transportation and industrial key factors. Furthermore, the strategies for Shanghai are proposed to upgrade the performance of 'efficiency of air/sea port' on

Pudon/Hongqiao airport and Shanghai port, and 'reprocessing quality of domestic M-market' on hi-tech industrial park, such as Kunshan and Soochow area. The strategies for HK are suggested to upgrade the performance of 'transportation efficiency from main International raw and semi-product supply market 'and 'transportation efficiency to main Int. consumer market' on HK seaport and airport.

Taipei and Seoul are suggested to develop production modes of SA-M-LS on their competitiveness of industrial key factors. According to this, the strategy for Taipei is proposed to upgrade the performance of 'transportation efficiency between sea/air port and M-market' among Taoyuan airport, Keelung-seaport, and hi-tech industrial park in northern Taiwan. And, the strategy for Seoul is suggested to upgrade the performance of 'transportation

Table 10. Suggestion strategies for location developing SA-M-LS.

Mode location	Competitive conditions	Transportation	Production
		KF : C_2, C_3, C_4, C_8	KF: C_1, C_5, C_6 , C_7, C_8
Shanghai	H: C_2, C_4 , C_5, C_8 M: C_1, C_7	◎	◎
HK	H: C_3, C_5, C_7 M: C_2, C_4 , C_6,	◎	◎
Taipei	H: C_6, M: C_5, C_8		◎
Singapore	H: C_2, C_3 , C_4, C_8 M:	◎	
Seoul	H: C_6 M: C_3 ,C_7		◎

KF: Key Factors; H: high competitiveness; M: middle competitiveness.

efficiency between airport and seaport', 'transportation seaport', 'transportation efficiency to main Int. consumer market' of Seoul airport, Busan seaport, and reduce the 'reprocessing cost of domestic M-market' on hi-tech industrial park in Seoul. Singapore has the strongly competitiveness of transportation key factors on its airport and seaport conditions than the other's locations, hence, it is suggested to develop transportation modes of SA-M-LS.

Conclusion

The preference analysis for developing SA-M-LS should take into account the influence of multiple criteria and uncertainties. Therefore, the fuzzy MCQA procedure is used to assess the preference for developing SA-M-LS in Pacific Asia region. As the traditional MCQA method not allows the decision-makers to make subjective judgment via linguistics variables of fuzziness in nature. With the usage of fuzzy MCQA procedure in collaboration with fuzzy grade measurement, fuzzy grade classification and MCQA method, the decision-makers are only required to judge the satisfaction grade of alternatives rather than granting scores, thereby making judgment in a time saving and efficient way while maintaining the advantages of traditional MCQA method.

There are different competitive conditions for specific location developing its suitable type of SA-M-LS. The two (transshipment and re-export) types of SA-M-LS that integrated the activities of logistics functions and cargo flows were identified as the foundation to assess the preference for location developing suitable function's SA-M-LS. Five potential locations in Pacific Asia region were subsequently compared as SA-M-LS based on respondents' perceptions of their ability to meet evaluation criteria. Results show that Shanghai, Singapore, and Hong Kong were respondents' preferred investment location. And, each location's strategies are suggested in accordance with its suitable mode of SA-M-LS.

Each location has different competitive conditions to develop suitable type of SA-M-LS. The strategies are suggested in accordance with the competitive conditions each location and key factors for developing transshipment and re-export types of SA-M-LS. Shanghai and HK are suggested to develop both transportation and production modes of SA-M-LS. Singapore is suggested to develop transportation modes of SA-M-LS. Taipei and Seoul are suggested to develop production modes of SA-M-LS.

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