A Fuzzy MCDM Model to Evaluate Investment Risk of Location Selection for Container Terminals

JI-FENG DING [1,*] and CHIEN-CHANG CHOU [2]
[1] Department of Aviation and Maritime Transportation Management
Chang Jung Christian University
Gui-Ren, Tainan 71101
[2] Department of Shipping Technology
National Kaohsiung Marine University
Chi-Chin, Kaohsiung 80543
TAIWAN
[*] Corresponding author: jfding@mail.cjcu.edu.tw

Abstract: - The main purpose of this paper is to develop a fuzzy multiple criteria decision-making (MCDM) model to evaluate the investment risk of location selection for container terminals. Firstly, some concepts and methods used to develop a fuzzy MCDM algorithm are briefly introduced. Secondly, a step-by-step fuzzy MCDM algorithm based on the concept of integral value is proposed. Finally, a numerical example with a hierarchy structure of four criteria, twenty-two sub-criteria, and three alternatives is illustrated by using the proposed fuzzy MCDM approach. Furthermore, the proposed model can facilitate its implementation as a computer-based decision support system in a fuzzy environment.

Key-Words: - Fuzzy MCDM; Investment risk; Location selection; Container terminal

1 Introduction

Fast development of the container transport system was boosting at the period of nineteen eighties [1]. Nowadays, the rapid growths of container ports in the world are gradually focused by the shipping and port logistics industries. The container port is a nodal point to handle container cargo to offer value-added services such as collection, warehousing, packing, and distribution among international trade and logistics systems. When the global container shipping transport network is emerged, the container port in the nodal points has been becoming to strengthen her competitive ability to withstand the keen environment, where the risks and uncertainties are greater than before [2]. The keen competition and many structural changes with global challenges have arisen among port and shipping chains focusing on landside and seaside competitions and business logistics [2, 3]. In particular, container transport demands required efficient integrated moves, premium package services, and make the best use of available model transport operations and container terminals. Hence, the role of container terminals as home bases for merchandise transportation has become increasingly important.

Investing a suitable container terminal for a container shipping company is an important issue. How to reduce the international logistics operation cost, however, an evaluation of investment risk of location selection for container terminals is the most critical task [4] for a container shipping company. Since the evaluation of investment risk of location selection for container terminals is crucial; however, experience has shown that it is no easy matter. It involves a multiplicity of complex considerations and poses a unique characteristic of multiple criteria decision-making (MCDM). The criteria are usually subjective in nature and often changing with the decision-making conditions, which creates the fuzzy and uncertain nature among the criteria and the importance weights of the criteria. Further, there are situations in which information is incomplete or imprecise or views that are subjective or endowed with linguistic characteristics creating a fuzzy decision-making environment [5-10]. The authors, therefore, adopt the fuzzy set theory [11], combing with MCDM method, e.g. [4, 5, 12, 13], as an evaluation tool to improve the quality of the study. In the light of this, a fuzzy MCDM model is used to evaluate the investment risk of location selection for container terminals.

In short, the aim of this paper is to develop a fuzzy MCDM model to improve the quality of decision-making in evaluating investment risk of location selection for container terminals. We will describe step-by-step procedures to evaluate this issue in the follows. The following section (Section 2) presents the research methods. Consequently, the fuzzy MCDM model is proposed in Section 3. A numerical study is made in Section 4. Finally, a conclusion is drawn in the last section.

2 Research Methods

In this section, some of the concepts and research methods used in this paper are briefly introduced as follows.

2.1 Triangular fuzzy numbers and the algebraic operations

The fuzzy set theory [11] is designed to deal with the extraction of the primary possible outcome from a multiplicity of information that is expressed in vague and imprecise terms. Fuzzy set theory treats vague data as probability distributions in terms of set memberships. Once determined and defined, sets of memberships in probability distributions can be effectively used in logical reasoning.

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

A fuzzy number *A* [15] in real line $\Re$ is a triangular fuzzy number if its membership function $f_A : \Re \rightarrow [0, 1]$ is

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

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

According to the extension principle [11], let $A_1 = (c_1, a_1, b_1)$ and $A_2 = (c_2, a_2, b_2)$ be fuzzy numbers, the algebraic operations of any two fuzzy numbers A_1 and A_2 can be expressed as

- Fuzzy addition:
  $A_1 \oplus A_2 = (c_1 + c_2, a_1 + a_2, b_1 + b_2)$,
- Fuzzy subtraction:
  $A_1 \ominus A_2 = (c_1 - b_2, a_1 - a_2, b_1 - c_2)$,
- Fuzzy multiplication:
  (i) $k \otimes A_2 = (kc_2, ka_2, kb_2), k \in \Re,\ k \ge 0$;
  (ii) $A_1 \otimes A_2 \cong (c_1c_2, a_1a_2, b_1b_2),$
  $c_1 \ge 0,\ c_2 \ge 0$,
- Fuzzy division:
  (i) $(A_1)^{-1} = (c_1, a_1, b_1)^{-1}$
  $\cong (1/b_1, 1/a_1, 1/c_1), c_1 > 0$;
  (ii) $A_1 \varnothing A_2 \cong (c_1/b_2, a_1/a_2, b_1/c_2),$
  $c_1 \ge 0, c_2 > 0.$

2.2 Linguistic values

In fuzzy decision environments, two preference ratings can be used. They are fuzzy numbers and linguistic values characterized by fuzzy numbers [16]. Depending on practical needs, decision-makers (DMs) may apply one or both of them. In this paper, the weighting set and rating set are used to analytically express the linguistic values and describe how important and how good of the involved criteria, sub-criteria, and alternatives against various sub-criteria above the alternative level are.

In this paper, the weighting set *W*={*VL*, *L*, *M*, *H*, *VH*} and the appropriateness rating set *S*={*VP*, *P*, *F*, *G*, *VG*} are used, where *VL*=Very Low, *L*=Low, *M*=Medium, *H*=High, *VH*=Very High, *VP*=Very Poor, *P*=Poor, *F*=Fair, *G*=Good, and *VG*=Very Good. Both sets are used to evaluate the weights of all criteria and sub-criteria, as well as the fuzzy ratings of alternatives against various sub-criteria above the alternative level. We define *VL*=*VP*=(0, 0, 0.25), *L*=*P*=(0, 0.25, 0.5), *M*=*F*=(0.25, 0.5, 0.75), *H*=*G*=(0.5, 0.75, 1), and *VH*=*VG*=(0.75, 1, 1). These triangular fuzzy numbers are referred to the study of Ghyym [17].

2.3 Ranking method

For matching the following fuzzy MCDM algorithm developed in this paper, a systematic method based on the concepts of integral value [18] is used to rank the final ratings.

Let $f_A^L(x) = (x-c)/(a-c), c \le x \le a,$ and $f_A^R(x) = (x-b)/(a-b), a \le x \le b,$ are the left and right membership function of fuzzy number *A*, respectively. Suppose that g_A^L and g_A^R are the inverse function of f_A^L and f_A^R, respectively. Then, we can obtain

$g_A^L(y) = c + (a-c)y$ and

$g_A^R(y) = b + (a-b)y$.

Define the left and right integral values of *A* as

$I^L(A) = \int_0^1 g_A^L(y)dy = (c+a)/2$ and

$I^R(A) = \int_0^1 g_A^R(y)dy = (a+b)/2$.

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

$$R(A_i) = \beta I^R(A_i) + (1-\beta) I^L(A_i) \quad 0 \le \beta \le 1. \quad (1)$$

The value β can be referred to as the DM's risk attitude index. If β<0.5, β=0.5, and β>0.5, respectively, it implies that the DM is a risk-averter (pessimism), risk-neuter (moderatism), and risk-lover (optimism), respectively.

The value β can be determined by two procedures. First way is that DM gives the value β at the data output stage [19], e.g., β=0.2, 0.5, 0.75. However it is difficult to apply this procedure directly in multiple DMs problem. Hence, Chang and Chen [20] suggested that it is reasonable to evaluate β through the evaluation data conveyed by the DMs at the data input stage. In this paper, the method developed by Chang and Chen [20] is cited to find the total risk attitude index β.

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

- $A_i > A_j \Leftrightarrow R(A_i) > R(A_j)$,
- $A_i < A_j \Leftrightarrow R(A_i) < R(A_j)$,
- $A_i = A_j \Leftrightarrow R(A_i) = R(A_j)$.

Let $A_i = (c_i, a_i, b_i)$, $i = 1, 2, \ldots, n$, be n fuzzy numbers. The ranking value of the fuzzy number A_i can be obtained as

$$R(A_i) = \beta[(a_i + b_i)/2] + (1-\beta)[(c_i + a_i)/2] \quad (2)$$

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

3 The Proposed Fuzzy MCDM Algorithm

A systematic model of the fuzzy MCDM algorithm is proposed in this section. The steps to be taken are described below.

Step 1: Development of hierarchical structure

The concepts of hierarchical structure analysis with three distinct layers, i.e. criteria layer, sub-criteria layer, and alternatives layer, are used in this paper. In this paper, there are k criteria (i.e., C_t, $t = 1, 2, \ldots, k$), $n_1 + \cdots + n_t + \cdots + n_k$ sub-criteria (i.e., $C_{11} \cdots C_{1n_1} \cdots C_{t1} \cdots C_{tn_t} \cdots C_{k1} \cdots C_{kn_k}$), and m alternatives (i.e., A_i, $i = 1, 2, \ldots, m$) in the hierarchical structure.

As regards to the evaluation criteria and sub-criteria, the authors referred some literature, which are made known in academic and management publications [4, 12, 13, 21-33]. Here, the four major criteria and twenty-two sub-criteria would be employed in this paper. The code names of these criteria and sub-criteria are shown in parentheses.

(1) Risk of the growth of shipping transport (C_1). This criterion includes three sub-criteria, that is, risk of the present volume of containers (C_{11}), risk of the potential volume of containers in the future (C_{12}), risk of shipping trade uncertainty (C_{13}), risk of sufficient source of goods (C_{14}), and risk of economic productivity of homeland (C_{15}).

(2) Risk of cost (C_2). This criterion includes five sub-criteria, that is, risk of the exchange rate between currencies (C_{21}), risk of the labor cost (C_{22}), risk of the land cost (C_{23}), risk of the transport cost (C_{24}), and risk of the related operation cost (C_{25}).

(3) Risk of government policies (C_3). This criterion includes six sub-criteria, that is, risk of the government efficiency (C_{31}), risk of the cooperation relationships between government and companies (C_{32}), risk of the tax break (C_{33}), risk of the trade preferential treatment (C_{34}), risk of the laws and regulations on investment (C_{35}), and risk of the social and political stability (C_{36}).

(4) Other risk (C_4). This criterion includes six sub-criteria, that is, risk of the availability of land (C_{41}), risk of the infrastructure quality (C_{42}), risk of the labor quality (C_{43}), risk of the trade liberalization (C_{44}) risk of the efficiency of customs (C_{45}), and risk of the private ownership of enterprise (C_{46}).

Step 2: Computation of aggregating evaluation ratings of all alternatives

Let $w_{tq} = (c_{tq}, a_{tq}, b_{tq})$, $0 \le c_{tq} \le a_{tq} \le b_{tq} \le 1$, $t = 1, 2, \ldots, k$; $q = 1, 2, \ldots, n$, be the weight given to criterion C_t by the q^{th} DM. Then, the weight of C_t can be represented as

$$W_t = (c_t, a_t, b_t), \text{ where } c_t = \frac{1}{n}\sum_{q=1}^{n} c_{tq},$$

$$a_t = \frac{1}{n}\sum_{q=1}^{n} a_{tq}, \; b_t = \frac{1}{n}\sum_{q=1}^{n} b_{tq}.$$

Let $w_{tjq} = (c_{tjq}, a_{tjq}, b_{tjq})$, $0 \le c_{tjq} \le a_{tjq} \le b_{tjq} \le 1$, $t = 1, 2, \ldots, k$; $j = 1, 2, \ldots, n_t$; $q = 1, 2, \ldots, n$, be the weight given to criterion C_{tj} by the q^{th} DM. Then, the weight of C_{tj} can be represented as

$W_{tj} = (c_{tj}, a_{tj}, b_{tj}),$ where $c_{tj} = \frac{1}{n}\sum_{q=1}^{n} c_{tjq},$

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

Let $m_{itjq} = (c_{itjq}, a_{itjq}, b_{itjq}),$ $0 \le c_{itjq} \le a_{itjq} \le b_{itjq} \le 1,$ $i = 1, 2, \ldots, m;$ $t = 1, 2, \ldots, k;$ $j = 1, 2, \ldots, n_t;$ $q = 1, 2, \ldots, n,$ be the appropriateness rating assigned to alternative A_i by the q^{th} DM for criterion C_{tj}. Then, the appropriateness rating of alternative A_i can be represented as

$M_{itj} = (c_{itj}, a_{itj}, b_{itj}),$ where $c_{itj} = \frac{1}{n}\sum_{q=1}^{n} c_{itjq},$

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

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

$$R_{it} = \frac{1}{n_t} \otimes \begin{bmatrix} (M_{it1} \otimes W_{t1}) \oplus (M_{it2} \otimes W_{t2}) \\ \oplus \cdots \oplus (M_{itj} \otimes W_{tj}) \oplus \cdots \oplus \\ (M_{itn_t} \otimes W_{tn_t}) \end{bmatrix}$$

Because $M_{itj} = (c_{itj}, a_{itj}, b_{itj})$ and $W_{tj} = (c_{tj}, a_{tj}, b_{tj}),$ we can denote

$R_{it} \cong (Y_{it}, Q_{it}, G_{it})$, where $Y_{it} = \sum_{j=1}^{n_t} c_{itj}\, c_{tj} / n_t,$

$Q_{it} = \sum_{j=1}^{n_t} a_{itj}\, a_{tj} / n_t,$ $G_{it} = \sum_{j=1}^{n_t} b_{itj}\, b_{tj} / n_t,$ for $i = 1, 2, \ldots, m;\ t = 1, 2, \ldots, k.$

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

$$F_i = \frac{1}{k} \otimes \begin{bmatrix} (R_{i1} \otimes W_1) \oplus (R_{i2} \otimes W_2) \\ \oplus \cdots \oplus (R_{it} \otimes W_t) \oplus \cdots \oplus \\ (R_{ik} \otimes W_k) \end{bmatrix}$$

Because $W_t = (c_t, a_t, b_t),$ we can denote

$F_i \cong (Y_i, Q_i, G_i)$, where $Y_i = \sum_{t=1}^{k} Y_{it}\, c_t / k,$

$Q_i = \sum_{t=1}^{k} Q_{it}\, a_t / k,$ $G_i = \sum_{t=1}^{k} G_{it}\, b_t / k,$ for $i = 1, 2, \ldots, m.$

Step 3: Choice of optimal alternative

Let $A=(c, a, b)$ be the importance weight or appropriateness rating obtained by using the aggregation method proposed in Step 2. Based on the method developed by Chang and Chen (1994), the value of $\gamma=(a-c)/[(a-c)+(b-a)]$ can be considered as all DMs' total risk attitude index for someone importance weight or appropriateness rating. Hence, for the fuzzy MCDM algorithm presented in this paper, the total risk attitude index β of all DMs can be obtained by

$$\beta = \frac{\beta_1 + \beta_2 + \beta_3}{(k \times n) + (n \times \sum_{t=1}^{k} n_t) + (m \times n \times \sum_{t=1}^{k} n_t)},$$

where $\beta_1 = \sum_{t=1}^{k}\sum_{q=1}^{n} \frac{a_{tq} - c_{tq}}{(a_{tq} - c_{tq}) + (b_{tq} - a_{tq})},$

$$\beta_2 = \sum_{t=1}^{k}\sum_{j=1}^{n_t}\sum_{q=1}^{n} \frac{a_{tjq} - c_{tjq}}{(a_{tjq} - c_{tjq}) + (b_{tjq} - a_{tjq})},$$

$$\beta_3 = \sum_{i=1}^{m}\sum_{t=1}^{k}\sum_{j=1}^{n_t}\sum_{q=1}^{n} \frac{a_{itjq} - c_{itjq}}{(a_{itjq} - c_{itjq}) + (b_{itjq} - a_{itjq})}.$$

Finally, by using the above equations, we can calculate the left integral value, right integral value and all DMs' risk attitude index β. By using the equation (1), the final ranking values of the m alternatives can be obtained; and then we can select the optimal alternative.

4 A Numerical Study

In this section, a numerical example of evaluating investment risk of location selection for container terminals is studied to demonstrate the computational process of the proposed fuzzy MCDM algorithm, step by step, as follows.

Step 1. Assume that a container shipping company needs to evaluate the investment risk of location selection for container terminals. Four major criteria and twenty-two sub-criteria are suggested. Assume three candidate locations of international container ports at Southern China, including Hong Kong (*HK*), Shenzhen (*SZ*), and Guangzhou (*GZ*), are chosen after preliminary screening for further evaluation. A committee of three DMs, i.e., E_1, E_2, and E_3, respectively, has been formed to evaluate the best location among three container ports.

Step 2. Three DMs use linguistic values of weighting set to evaluate the importance weights of all criteria and all sub-criteria. To sum up the results of the importance weights of all criteria and sub-criteria are shown in Table 1. Similarly, the appropriateness ratings of three candidates versus all sub-criteria can be obtained by the step 2 of the proposed fuzzy MCDM algorithm, the results are shown in Table 2.

Table 1. The fuzzy weights of all criteria and sub-criteria.

Criteria / Sub-criteria	DM	Linguistic values	Fuzzy weights	Criteria / Sub-criteria	DM	Linguistic values	Fuzzy weights
C_1	E_1	*H*	(0.5, 0.75, 0.917)	C_{25}	E_1	*H*	(0.417, 0.667, 0.917)
	E_2	*VH*			E_2	*M*	
	E_3	*M*			E_3	*H*	
C_2	E_1	*M*	(0.417, 0.667, 0.917)	C_{31}	E_1	*VH*	(0.583, 0.833, 0.917)
	E_2	*H*			E_2	*VH*	
	E_3	*H*			E_3	*M*	
C_3	E_1	*M*	(0.333, 0.583, 0.833)	C_{32}	E_1	*M*	(0.583, 0.833, 0.917)
	E_2	*M*			E_2	*VH*	
	E_3	*H*			E_3	*VH*	
C_4	E_1	*M*	(0.25, 0.5, 0.75)	C_{33}	E_1	*M*	(0.167, 0.417, 0.667)
	E_2	*M*			E_2	*M*	
	E_3	*M*			E_3	*L*	
C_{11}	E_1	*VH*	(0.583, 0.833, 0.917)	C_{34}	E_1	*M*	(0.167, 0.417, 0.667)
	E_2	*M*			E_2	*M*	
	E_3	*VH*			E_3	*L*	
C_{12}	E_1	*M*	(0.417, 0.667, 0.917)	C_{35}	E_1	*H*	(0.5, 0.75, 1)
	E_2	*H*			E_2	*H*	
	E_3	*H*			E_3	*H*	
C_{13}	E_1	*L*	(0.167, 0.417, 0.667)	C_{36}	E_1	*L*	(0.083, 0.333, 0.583)
	E_2	*H*			E_2	*L*	
	E_3	*L*			E_3	*M*	
C_{14}	E_1	*M*	(0.167, 0.333, 0.583)	C_{41}	E_1	*H*	(0.333, 0.583, 0.833)
	E_2	*M*			E_2	*L*	
	E_3	*VL*			E_3	*H*	
C_{15}	E_1	*H*	(0.25, 0.5, 0.75)	C_{42}	E_1	*H*	(0.667, 0.917, 1)
	E_2	*L*			E_2	*VH*	
	E_3	*M*			E_3	*VH*	
C_{21}	E_1	*VH*	(0.583, 0.833, 0.917)	C_{43}	E_1	*M*	(0.167, 0.417, 0.667)
	E_2	*VH*			E_2	*M*	
	E_3	*M*			E_3	*L*	
C_{22}	E_1	*L*	(0.167, 0.417, 0.667)	C_{44}	E_1	*VH*	(0.583, 0.833, 1)
	E_2	*H*			E_2	*H*	
	E_3	*L*			E_3	*H*	

Table 1. The fuzzy weights of all criteria and sub-criteria (Continued).

Criteria / Sub-criteria	DM	Linguistic values	Fuzzy weights	Criteria / Sub-criteria	DM	Linguistic values	Fuzzy weights
C_{23}	E_1	*M*	(0.5, 0.75, 0.917)	C_{45}	E_1	*M*	(0.333, 0.583, 0.75)
	E_2	*VH*			E_2	*VH*	
	E_3	*H*			E_3	*L*	
C_{24}	E_1	*M*	(0.5, 0.75, 0.917)	C_{46}	E_1	*M*	(0.5, 0.75, 0.917)
	E_2	*H*			E_2	*H*	
	E_3	*VH*			E_3	*VH*	

Table 2. The appropriateness ratings of three candidates versus all sub-criteria.

Sub-criteria	DM	Linguistic values			Fuzzy ratings		
		HK	*SZ*	*GZ*	*HK*	*SZ*	*GZ*
C_{11}	E_1	*P*	*VP*	*G*	(0.167, 0.333, 0.583)	(0.333, 0.583, 0.833)	(0, 0.083, 0.333)
	E_2	*G*	*VP*	*G*			
	E_3	*VP*	*P*	*P*			
C_{12}	E_1	*G*	*P*	*F*	(0.583, 0.833, 1)	(0.083, 0.167, 0.417)	(0, 0.167, 0.417)
	E_2	*G*	*P*	*VP*			
	E_3	*VG*	*VP*	*VP*			
C_{13}	E_1	*G*	*G*	*P*	(0.667, 0.917, 1)	(0, 0.083, 0.333)	(0.417, 0.667, 0.833)
	E_2	*VG*	*VG*	*VP*			
	E_3	*VG*	*P*	*VP*			
C_{14}	E_1	*VG*	*VP*	*VP*	(0.667, 0.917, 1)	(0.417, 0.583, 0.75)	(0, 0.083, 0.333)
	E_2	*G*	*VP*	*G*			
	E_3	*VG*	*P*	*VG*			
C_{15}	E_1	*VG*	*F*	*F*	(0.667, 0.917, 1)	(0.25, 0.417, 0.667)	(0.167, 0.333, 0.583)
	E_2	*VG*	*VP*	*VP*			
	E_3	*G*	*F*	*G*			
C_{21}	E_1	*VG*	*P*	*G*	(0.667, 0.917, 1)	(0.5, 0.75, 0.917)	(0, 0.167, 0.417)
	E_2	*G*	*P*	*VG*			
	E_3	*VG*	*VP*	*F*			
C_{22}	E_1	*F*	*VP*	*P*	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.667)	(0.417, 0.583, 0.75)
	E_2	*F*	*G*	*P*			
	E_3	*F*	*VG*	*VG*			
C_{23}	E_1	*P*	*VP*	*VP*	(0.333, 0.583, 0.75)	(0.167, 0.333, 0.583)	(0.167, 0.333, 0.583)
	E_2	*F*	*P*	*G*			
	E_3	*VG*	*G*	*P*			
C_{24}	E_1	*G*	*G*	*VP*	(0.417, 0.667, 0.833)	(0.083, 0.167, 0.417)	(0.667, 0.917, 1)
	E_2	*VG*	*VG*	*F*			
	E_3	*P*	*VG*	*VP*			

Table 2. The appropriateness ratings of three candidates versus all sub-criteria (Continued).

Sub-criteria	DM	Linguistic values			Fuzzy ratings		
		HK	*SZ*	*GZ*	*HK*	*SZ*	*GZ*
C_{24}	E_1	*G*	*G*	*VP*	(0.417, 0.667, 0.833)	(0.083, 0.167, 0.417)	(0.667, 0.917, 1)
	E_2	*VG*	*VG*	*F*			
	E_3	*P*	*VG*	*VP*			
C_{25}	E_1	*G*	*VG*	*G*	(0.583, 0.833, 1)	(0.5, 0.75, 0.917)	(0.667, 0.917, 1)
	E_2	*G*	*VG*	*F*			
	E_3	*VG*	*G*	*VG*			
C_{31}	E_1	*G*	*VG*	*P*	(0.583, 0.833, 1)	(0.25, 0.417, 0.583)	(0.333, 0.5, 0.667)
	E_2	*G*	*F*	*VP*			
	E_3	*VG*	*VP*	*VG*			
C_{32}	E_1	*VG*	*P*	*F*	(0.667, 0.917, 1)	(0.333, 0.5, 0.667)	(0.25, 0.417, 0.583)
	E_2	*G*	*VP*	*VG*			
	E_3	*VG*	*VG*	*VP*			
C_{33}	E_1	*VG*	*VG*	*G*	(0.667, 0.917, 1)	(0.5, 0.75, 1)	(0.667, 0.917, 1)
	E_2	*G*	*G*	*G*			
	E_3	*VG*	*VG*	*G*			
C_{34}	E_1	*VG*	*G*	*VP*	(0.333, 0.5, 0.667)	(0.167, 0.333, 0.583)	(0.5, 0.75, 1)
	E_2	*F*	*G*	*G*			
	E_3	*VP*	*G*	*P*			
C_{35}	E_1	*P*	*VG*	*VG*	(0.083, 0.25, 0.5)	(0.25, 0.417, 0.583)	(0.667, 0.917, 1)
	E_2	*VP*	*VG*	*P*			
	E_3	*F*	*G*	*VP*			
C_{36}	E_1	*VP*	*VP*	*F*	(0.167, 0.25, 0.5)	(0.083, 0.333, 0.583)	(0.167, 0.25, 0.5)
	E_2	*G*	*G*	*P*			
	E_3	*VP*	*VP*	*P*			
C_{41}	E_1	*P*	*P*	*G*	(0.083, 0.25, 0.5)	(0.333, 0.5, 0.75)	(0.167, 0.333, 0.583)
	E_2	*F*	*G*	*VP*			
	E_3	*VP*	*VP*	*G*			
C_{42}	E_1	*P*	*F*	*P*	(0.25, 0.417, 0.583)	(0.167, 0.333, 0.583)	(0.5, 0.75, 0.917)
	E_2	*VP*	*G*	*G*			
	E_3	*VG*	*VG*	*VP*			
C_{43}	E_1	*F*	*VP*	*P*	(0.417, 0.667, 0.833)	(0.25, 0.5, 0.667)	(0.25, 0.417, 0.583)
	E_2	*VG*	*VG*	*P*			
	E_3	*F*	*P*	*VG*			
C_{44}	E_1	*G*	*P*	*VP*	(0.5, 0.75, 1)	(0, 0.083, 0.333)	(0.167, 0.333, 0.583)
	E_2	*G*	*VP*	*VP*			
	E_3	*G*	*G*	*P*			
C_{45}	E_1	*VP*	*G*	*P*	(0.167, 0.333, 0.583)	(0, 0.167, 0.417)	(0.417, 0.667, 0.833)
	E_2	*G*	*VG*	*P*			
	E_3	*P*	*P*	*VP*			

Table 2. The appropriateness ratings of three candidates versus all sub-criteria (Continued).

Sub-criteria	DM	Linguistic values			Fuzzy ratings		
		HK	*SZ*	*GZ*	*HK*	*SZ*	*GZ*
C_{46}	E_1	*VG*	*G*	*G*	(0.333, 0.583, 0.75)	(0.417, 0.667, 0.833)	(0.333, 0.583, 0.833)
	E_2	*P*	*G*	*VG*			
	E_3	*F*	*P*	*P*			

Step 3. By using the equation β of the step 2 of the proposed fuzzy MCDM algorithm, we can obtain three DMs' total risk attitude index β=0.5435, where the β_1=9, β_2=40.5, and β_3=100.5, respectively. The risk-bearing attitude of the DMs trends towards optimistic, which is based upon the procedure of data input stage. Furthermore, the left integral values, right integral values and final ranking values can be obtained by using the equation (2). The results are shown in Table 3. The ranking order of three candidates is *HK*, *GZ*, and *SZ*. Therefore, it is obvious that the optimal selection is candidate *HK* – i.e., the port of Hong Kong.

Table 3. Ranking value of three candidates

Candidates	Right integral values	Left integral values	Final ranking values	Ranking order
HK	0.15855	0.41605	0.29850	1
SZ	0.10110	0.30780	0.21344	3
GZ	0.11380	0.33575	0.23443	2

5 Conclusion

Due to the fact that the role of container terminals as home bases for merchandise transportation has become increasingly important. Investing a suitable container terminal for a container shipping company is an important issue. Hence, an evaluation of investment risk of location selection for container terminals is the most critical task for a container shipping company. This paper intends to improve the quality of decision-making in evaluating this theme. The main purpose of this paper is to propose a fuzzy MCDM model to evaluate the investment risk of location selection for container terminals.

To effectively evaluate the investment risk of location selection for container terminals, a systematically fuzzy MCDM model is proposed. At first, a hierarchy structure is developed. Then, we calculate the final aggregation ratings of all alternatives. In addition, a ranking method based on the concepts of integral value is used to rank the final ratings. Finally, a step by step numerical example is illustrated to study the computational process of the fuzzy MCDM algorithm. Furthermore, the proposed model not only releases the limitation of crisp values, but also facilitates its implementation as a computer-based decision support system in a fuzzy environment.

References:

[1] UNCTAD, "Technical note: fourth-generation port," *UNCTAD Port Newsletter*, No.19, 1999, pp. 9-12.

[2] T. Heaver, H. Meersman, F. Moglia and E. V. D. Voorde, "Co-operation and Competition in International Container Transport: Strategies for Ports," *Maritime Policy and Management*, Vol.28, No.3, 2001, pp. 293-305.

[3] J. F. Ding, "Identifying Key Capabilities to Determine Core Competence for Ocean Carrier-based Logistics Service Providers," *International Journal of Innovative Computing, Information & Control*, Vol.5, No.9, 2009, pp. 2627-2644.

[4] C. C. Chou, "An Evaluation of Investment Risk for Container Port Wharf Using Fuzzy Multiple-criteria Decision-making Approach," *ICIC Express Letters*, Vol.3, No.3(B), 2009, pp. 683-688.

[5] J. F. Ding, "Using Fuzzy MCDM to Select Partners of Strategic Alliances for Liner Shipping," *Information Sciences*, Vol.173, No.1-3, 2005, pp. 197-225.

[6] H. Wang, G. Qian and X. Feng, "An Intuitionistic Fuzzy AHP based on Synthesis of Eigenvectors and Its Application," *Information Technology Journal*, Vol.10, No.10, 2011, pp. 1850-1866.

[7] V. Marques, J. T. Farinha and A. Brito, "Case-based Reasoning and Fuzzy Logic in Fault Diagnosis," *WSEAS Transactions on Computers*, Vol.8, No.8, 2009, pp. 1408-1417.
[8] J. H. Cheng and C. H. Tang, "An Application of Fuzzy Delphi and Fuzzy AHP for Multi-criteria Evaluation of Bicycle Industry Supply Chains," *WSEAS Transactions on Systems and Control*, Vol.4, No.1, 2009, pp. 21-34.
[9] M. A. Hajeeh, "Water Desalination Plants Performance Using Fuzzy Multi-Criteria Decision Making," *WSEAS Transactions on Systems*, Vol.9, No.4, 2010, pp. 422-431.
[10] X. Jiang, B. Zheng and L. Wang, "The Coupled Method Fuzzy-AHP Applies to Solve Multi-criteria Decision Making Problems," *WSEAS Transactions on Mathematics*, Vol.8, No.11, 2009, pp. 657-666.
[11] L. A. Zadeh, "Fuzzy Sets," *Information and Control*, Vol.8, No.3, 1965, pp. 338-353.
[12] C. C. Chou, "An Integrated Quantitative and Qualitative FMCDM Model for Location Choices," *Soft Computing*, Vol.14, No.7, 2010a, pp. 757-771.
[13] C. C. Chou, "Application of FMCDM Model to Selecting the Hub Location in the Marine Transportation: A Case Study in Southeastern Asia," *Mathematical and Computer Modelling*, Vol.51, No.5/6, 2010b, pp. 791-801.
[14] J. F. Ding, "Fuzzy MCDM Approach to Evaluate Service Strategies of Customer Value for Global Shipping Carrier-based Logistics Service Providers," *African Journal of Business Management*, Vol.5, No.14, 2011, pp. 5460-5467.
[15] D. Dubois and H. Prade, "Operations on Fuzzy Numbers," *The International Journal of Systems Science*, Vol.9, No.6, 1978, pp. 613-626.
[16] L. A. Zadeh, "The Concept of a Linguistic Variable and Its Application to Approximate Reasoning, Part 1, 2 and 3," *Information Sciences*, Vol.8, No.3, 1975, pp. 199-249; Vol.8, No.4, 1975, pp. 301-357; Vol.9, No.1, 1976, pp. 43-80.
[17] S. H. Ghyym, "A Semi-linguistic Fuzzy Approach to Multi-actor Decision-making: Application to Aggregation of Experts' Judgments," *Annals of Nuclear Energy*, Vol.26, No.12, 1999, pp. 1097-1112.
[18] T. S. Liou and M. J. J. Wang, "Ranking Fuzzy Numbers with Integral Value," *Fuzzy Sets and Systems*, Vol.50, No.3, 1992, pp. 247-255.
[19] K. Kim and K. S. Park, "Ranking Fuzzy Numbers with Index of Optimism," *Fuzzy Sets and Systems*, Vol.35, No.2, 1990, pp. 143-150.
[20] P. L. Chang and Y. C. Chen, "A Fuzzy Multi-criteria Decision Making Method for Technology Transfer Strategy Selection in Biotechnology," *Fuzzy Sets and Systems*, Vol.63, No.2, 1994, pp. 131-139.
[21] I. Becerra-Fernandez, S. H. Zanakis and S. Walczak, "Knowledge Discovery Techniques for Predicting Country Investment Risk," *Computers and Industrial Engineering*, Vol.43, No.4, 2002, pp. 787-800.
[22] A. Bevan, S. Estrin and K. Meyer, "Foreign Investment Location and Institutional Development in Transition Economies," *International Business Review*, Vol.13, No.1, 2004, pp. 43-64.
[23] C. C. Chou, "A Fuzzy MCDM Method for Solving marine transhipment container port selection problems," *Applied Mathematics and Computation*, Vol.186, No.1, 2007, pp. 435-444.
[24] J. F. Ding and G. S. Liang, "Application of Fuzzy MCDM to the Site Selection for Free Port Zone," *Journal of Marine Sciences*, Vol.12, 2003, pp. 251-268.
[25] S. Globerman and D. M. Shapiro, "The Impact of Government Policies on Foreign Direct Investment: The Canadian Experiences," *Journal of International Business Studies*, Vol.30, No.3, 1999, pp. 513-532.
[26] Y. Jinjarak, "Foreign Direct Investment and Macroeconomic Risk," *Journal of Comparative Economics*, Vol.35, No.3, 2007, pp. 509-519.
[27] M. Ojala and J. Hallikas, "Investment Decision-making in Supplier Networks: Management of Risk," *Internal Journal of Production Economics*, Vol.104, 2006, pp. 201-213.
[28] E. R. Rrenes, V. Ruddy and R. Castro, "Free Zones in E1 Salvador," *Journal of Business Research*, Vol.38, No.1, 1997, pp. 57-65.
[29] G. A. Spohrer and T. R. Kmak, "Qualitative analysis used in evaluating alternative plant location scenarios," *Industrial Engineering*, Vol.16, 1984, pp. 52-56.
[30] Q. Sun, W. Tong and Q. Yu, "Determinants of Foreign Direct Investment across China," *Journal of International Money and Finance*, Vol.21, 2002, pp. 79-113.
[31] E. W. K. Tsang, "Influences on Foreign Ownership Level and Entry Mode Choice in Vietnam," *International Business Review*, Vol.14, No.4, 2005, pp. 441-463.

[32] X. Wu and R. Strange, “The Location of Foreign Insurance Companies in China,” *International Business Review*, Vol.9, No.3, 2000, pp. 119-249.
[33] X. Xin and J. Ni, *A Discussion of the East and West: China on the Scale*, Beijing: China Social Press, 1995.