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Abstract: As a hot topic in supply chain management, fuzzy method has been widely used in logistics center location selection to improve the reliability and suitability of the logistics center location selection with respect to the impacts of both qualitative and quantitative factors. However, it does not consider the credibility of experts in pre-decisions. So this paper proposes a multi-criteria decision making model based on credibility of decision makers by introducing credibility mechanism into fuzzy multi-criteria decision making approach. In this way, only the decision makers who pass the credibility evaluation are qualified to assess. Finally, a practical example is analyzed to illustrate how to use the model. The result shows that the fuzzy multi-criteria decision making model based on credibility of decision makers can improve the reliability and suitability of site selection for the logistics center.

Keywords: multi-criteria decision making approach, fuzzy theory, logistic center location, credibility

1. INTRODUCTION

In modern society, logistics systems has become essential in ensuring economic development and the normal function of the society, and the suitability of site selection for the logistics center have direct impact on the efficiency of logistics systems, therefore, a reasonable approach of site selection must be adopted. When selecting the location for the logistics center, not only quantitative factors like costs and distances, but also qualitative factors such as environmental impacts and governmental regulations should be taken into consideration, unlike traditional approaches' ignorance of qualitative factors, multi-criteria decision making approach based on fuzzy theory takes both groups of factors into consideration. Hence, it is of great importance to conduct researches on multi-criteria decision making approach based on fuzzy theory.

Fuzzy theory was firstly introduced to measure the impacts of qualitative factors on results in real life, which cannot be measured by traditional algorithms. An analytical network process tool was used to select suitable facility locations [1]. Masood Badri offered a method which combined AHP and goal program modeling approach for international facility location problem[2] . A combination of Genetic Algorithm and AHP model was developed to solve distribution network problems in supply chain management[3]. But these methods mentioned above could only deal with facility location problem under certain environment. To solve distribution network problems under uncertain environment, new methods were proposed, for instance, an algorithm for facility site selection based on fuzzy theory and hierarchical structure analysis was proposed to deal with facility site selection problem under uncertain environment[4]. In order to resolve the ambiguity of concepts that are associated with human being's judgments, a fuzzy TOPSIS model under group decision making to solve the facility location selection problem was built for evaluating facility locations[5] [6]. Cengiz Kahraman used four fuzzy multi-attribute group decision making approaches for alternative locations, with witch uncertainty and vagueness from subjective perception can be effectively represented and reached to a more effective decision[7] .

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Kuo-Liang Lee and Shu-Chen Lin introduced a fuzzy simple additive weighting approach with objective and subjective criteria under group decision making for location selection[8]. In order to calculate criteria values under uncertain environment to evaluate and select the suitable location for building logistic center, a fuzzy TOPSIS model was built by L.A. Zadeh[9]. However, the literature listed above neglects the impacts of credibility of decision makers on the results, thus, cannot ensure the accuracy of site selection.

In response to the above problem, this paper introduces credibility mechanism into multi-criteria decision making approach, and only decision makers with high level of credibility in the criterion are invited to provide assessment, ultimately improve the reliability of the result for site selection.

2. DEFINING AND SELECTING LOCATION CRITERIA

Since the criteria will be used to evaluate the potential location for the logistics center, it is of great importance to select a justified set of criteria in order to ensure the rationality of final result. In this paper, six criteria are chosen to find out the best location for constructing a logistics center, as illustrated in Table 1.

Table 1. Criteria for location selection.

Criterion	Unit of Measurement
Costs (C_1) [10]	Quantitative
Distance to Suppliers (C_2)	Quantitative
Distance to Customers (C_3)	Quantitative
Conformance to Governmental Regulations and Laws (C_4)	Qualitative
Quality of Service (C_5)	Qualitative
Environmental Impact (C_6)	Qualitative

3. MODEL BUILDING

3.1 Defining the linguistic variables and membership functions

3.1.1 Linguistic variables

In this paper, linguistic variables ranging from a scale of 1 to 9 for rating the criteria and the potential locations for the logistics center will be used, as illustrated in table 2 and table 3.

Table 2. Linguistic terms for objective ratings.

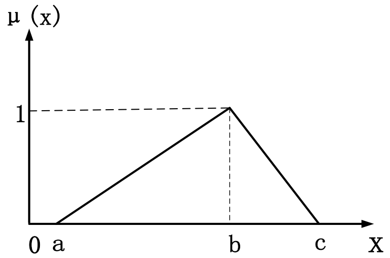
Linguistic Term	Membership function
Very poor（VP）	（1,1,3）
Poor（P）	（1,3,5）
Fair（F）	（3,5,7）
Good（G）	（5,7,9）
Very good（VG）	（7,9,9）

Table 3. Linguistic terms for criteria ratings.

Linguistic term	Membership function
Very low(VL)	（1,1,3）
Low(L)	（1,3,5）
Medium(M)	（3,5,7）
High(H)	（5,7,9）
Very high(VH)	（7,9,9）

3.1.2 Membership function

Triangular membership function, trapezoidal membership function, Gaussian membership function, and bell-shaped membership function are commonly used [11], in this paper, the triangular membership function will be used, and the membership function of triangular fuzzy number x is defined as illustrated in Figure 1.



$$\mu_x = \begin{cases} 0, x \le a \\ \dfrac{x-a}{b-a}, a \le x \le b \\ \dfrac{c-x}{c-b}, b \le x \le c \\ 0, x \ge c \end{cases}$$

Figure 1. Triangular membership function

3.2 Fuzzy multi-criteria decision model establishing

3.2.1 Defining the parameters in fuzzy multi-criteria decision model

Defining the potential location for the logistics center as $L = (L_1, L_2 .....L_n)$.

Criteria: $C = (C_1, C_2 .....C_m)$.

Aggregated fuzzy weights for each criterion: $W_i (i = 1, 2.....m)$.

Experts participating in the evaluation: $d_k (k = 1, 2.....k)$.

P_{ki} is the credibility of expert k with respect to criterion i, it is based on the mutual history of expert k and criterion i.

$N_t(k,i)$ denotes the number of times expert k provided right performance rating for criterion i in the past.

$N_f(k,i)$ denotes the number of times expert k provided wrong performance rating for criterion i in the past.

When assessing a certain criterion, only experts with leading level of credibility are invited to participate in the performace rating of that criterion.

The performance rating of expert k for criterion i is X_{ik}.

The performance ratings of expert k for location j with respect to criterion i are denoted by X_{ijk} $(i = 1, 2.....m; j = 1, 2....n; k = 1, 2....k)$ with membership function μ_x.

The aggregated fuzzy rating for criterion i of all the experts are defined as $R_i = (a_i, b_i, c_i)$.

The aggregated fuzzy rating for potential location j with respect to criterion i of all the experts are defined as $R_{ij} = (a_{ij}, b_{ij}, c_{ij})$.

In order to bring the various criteria scales into a comparable one, define $\overline{R_{ij}}$ as the fuzzy rating for R_{ij} after being normalized.

p_i is the final fuzzy evaluation value for potential location i.

3.2.2 Determining the parameters

$$P_{ki} = \frac{N_t(k,i)}{N_t(k,i) + N_f(k,i)} ; \quad 0 \le P_{ki} \le 1 \tag{1}$$

$$R_i = (a_i, b_i, c_i) \qquad a_i = \min\{a_{ik}\} \qquad b_i = \frac{1}{k}\sum_{k=1}^{k}\{b_{ik}\} \qquad c_i = \max\{c_{ik}\} \tag{2}$$

$$R_{ij} = (a_{ij}, b_{ij}, c_{ij}) \qquad a_{ij} = \min\{a_{ijk}\} \qquad b_{ij} = \frac{1}{k}\sum_{k=1}^{k}\{b_{ijk}\} \qquad c_{ij} = \max\{c_{ijk}\} \tag{3}$$

$$\overline{R_{ij}}=\left(\frac{a_{ij}}{c_{ij}},\frac{b_{ij}}{c_{ij}},\frac{c_{ij}}{c_{ij}}\right), f_i \in B, B: criteria\ having\ positive\ effects\ on\ location\ selection$$
$$\overline{R_{ij}}=\left(\frac{a_{ij}}{c_{ij}},\frac{a_{ij}}{b_{ij}},\frac{a_{ij}}{a_{ij}}\right), f_i \in C, C: criteria\ having\ negative\ effects\ on\ location\ selection \quad (4)$$

$$p_i=\sum_{j=1}^{n}\overline{R_{ij}}()\times R_i, i=1,2.....m \quad (5)$$

3.2.3 Comparisons of potential locations

P_i is triangular fuzzy number, so it is very difficult for experts to determine which location is the best directly. This paper conduct a pairwise comparison of P_i and P_j to show what is the preferable over two potential locations L_i and L_j. Define the difference between L_i and L_j as Z_{ij},

$$Z_{ij}=p_i-p_j \quad (6)$$

E= [e_{ij}] is the fuzzy preference matrix, e_{ij} represents the degree of preference of location L_i over location L_j (i,j=1,2,,,m), and the fuzzy preference relation between L_i and L_j is defined as:

$$e_{ij}=\frac{S_1}{S}, S>0, with S_1=\int_{x>0}u_{z_{ij}}(x)dx, s=\int_{x>0}u_{z_{ij}}(x)dx+\int_{x<0}u_{z_{ij}}(x)dx \quad (7)$$

According to the computing results, the preference relation between L_i and L_j is :

$$\begin{cases} L_i > L_j, e_{ij} > 0.5 \\ L_i = L_j, e_{ij} = 0.5 \\ L_i < L_j, e_{ij} < 0.5 \end{cases} \quad (8)$$

4. APPLICATION

A new logistics center is needed in a city. There are three potential locations L_1, L_2, L_3, and five experts, K_1, K_2, K_3, K_4, K_5, intended to select the best location in respect to 6 criteria shown in table1. The mutual history of the experts with respect to each criterion is shown in table 4.

Table 4. Mutual history of the experts with respect to each criterion

Criterion	Experts									
	K_1		K_2		K_3		K_4		K_5	
	$N_t(k,i)$	$N_f(k,i)$	$N_t(k,i)$	$N_f(k,i)$	$N_t(k,i)$	$N_f(k,i)$	$N_t(k,i)$	$N_f(k,i)$	$N_t(k,i)$	$N_f(k,i)$
C_1	3	3	4	3	6	2	5	0	4	1
C_2	4	1	3	0	4	1	2	3	4	3
C_3	3	2	6	0	5	1	4	0	1	1
C_4	4	0	2	2	8	1	6	3	5	0
C_5	4	1	3	2	6	3	9	0	8	1
C_6	2	2	6	0	3	3	8	0	9	1

Calculate the credibility of the experts with respect to each criterion using equation (1), see table 5.

Table 5. Credibility of experts with respect to each criterion

Criterion	Experts				
	K_1	K_2	K_3	K_4	K_5
C_1	0.5	0.57	0.75	1	0.8
C_2	0.8	1	0.8	0.4	0.57
C_3	0.6	1	0.83	1	0.5
C_4	1	0.5	0.89	0.67	1
C_5	0.8	0.6	0.67	1	0.89
C_6	0.5	1	0.5	1	0.9

For each criterion, choose the top three experts of the reliability ranking to perform the assessments. The performance rating of the 6 criteria and the potential locations are shown as table 6 and table7.

Table 6. The performance rating of the 6 criteria

Criterion	Experts assessments				
	K_1	K_2	K_3	K_4	K_5
C_1			VH	VH	VH
C_2	H	VH	VH		
C_3		H	VH	VH	
C_4	VH		H		VH
C_5	H			M	H
C_6		VH		VH	H

Table 7. The performance rating of the potential locations

Criterion	Potential locations	Experts assessments				
		K_1	K_2	K_3	K_4	K_5
C_1	L_1			G	VG	G
	L_2			G	G	VG
	L_3			G	G	G
C_2	L_1	G	VG	VG		
	L_2	F	G	G		
	L_3	P	F	P		
C_3	L_1		F	G	G	
	L_2		F	F	F	
	L_3		F	F	G	
C_4	L_1	G		G		G
	L_2	F		G		F
	L_3	F		G		G
C_5	L_1	G			G	G
	L_2	G			G	F
	L_3	F			G	P
C_6	L_1		F		F	F
	L_2		F		P	P
	L_3		P		VP	VP

Compute the aggregate fuzzy weights of each criterion using equation (2). Then evaluate the aggregate fuzzy rating of potential locations with respect to each criterion using equation (3). Calculate the final fuzzy evaluation values for potential locations using equation (4) and (5), the final fuzzy evaluation values are:

$P_1 =$（8.1,25.76,55.3）

$P_2 =$（11,26.68,54）

$P_3 =$（13.02,26.56,51.73）

Compare the potential locations using equation (6) and (7), results as following:

$P_1 - P_2 = (-2.90,-0.92, 1.30)$

$P_1 - P_3 = (-2.80,-0.80, 1.45)$

$P_2 - P_3 = (-2.02, 0.12, 2.27)$

The fuzzy preference matrix $E=\begin{pmatrix} 0.5 & 0.18 & 0.2 \\ 0.82 & 0.5 & 0.5 \\ 0.78 & 0.42 & 0.5 \end{pmatrix}$.

According to the computing result, compare the three potential locations using equation (8), $P_2 > P_3$, and $P_3 > P_1$, therefore, $P_2$is the best location to establish the logistics center.

5. CONCLUSIONS

The multiple-criteria decision making approach based on fuzzy theory and credibility mechanism proposed in this paper have taken both quantitative criteria and qualitative criteria under uncertain environment into consideration. Moreover, it solved the inaccuracy caused by the different credibility of experts, improved the reliability of the logistic center location selection. The method proposed in this paper is a better one in logistic center location than traditional algorithms.

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