ICIC Express Letters
Part B: Applications
Volume **8**, Number **2**, February **2017**

 ISSN 2185-2766
pp. 343–349

RESEARCH ON SITE SELECTION OF LOGISTICS PARK BASED ON FUZZY WEIGHTED AVERAGE

Ying Qu, Tiezhu Yang and Wei Song

School of Economics and Management
Hebei University of Science and Technology
No. 26, Yuxiang Street, Shijiazhuang 050018, P. R. China
{ quying1973; yangtiezhu0723; songwei3318 }@126.com

Received July 2016; accepted October 2016

Abstract. *The rationality of site selection of logistics park plays an important role in the service capacity of logistics park in the future. In this paper, on the basis of analyzing the influence factors for site selection of logistics park, we make the ideas of the fuzzy weighted average into blurring the criteria weights and criteria evaluation values. While taking the advantage of KM algorithm to simplify the calculation, we make planning for the site selection of logistics parks in the multi-attribute decision-making problems. This model uses cut sets to make the degree of fuzzy controlled, which can make that the final consequence will reflect much more qualitative information. Simultaneously, using the interval possibility algorithm to rank the schemes can avoid distortion of the single variable, which can provide a new idea for the site selection of logistics parks.*
Keywords: Logistics park, Multi-attribute decision-making, Fuzzy weighted average

1. **Introduction.** As a new industry, the adequacy of logistics park location determines the efficiency of transport logistics network, operating costs and customer service levels. So the studies are also increasingly focused by enterprise logistics executive leaders and research scholars. In view of the site selection of logistics park problem, domestic and foreign scholars have made many related researches. W. Hu et al. [1] presented a location selection model of the logistics distribution center for SDN enterprises and then introduced a coordination factor to improve the accuracy of its algorithm. Later, M. Yi [2] proposed a method which takes the aspects of uncertainty and ambiguity and AHP method into account to erect the index system, and the key process is constructing the mathematical model of fuzzy weights by introducing the concept of triangular fuzzy numbers. To deal the problems of subjectivity and operation in practice, D. Zhang [3] creatively put forward a practical model constructing method with AHP and the platform GIS. In addition, S. Liu et al. [4] considered the weight of the attributes and decision makers' willing, and objective weighting for multiple attributes to calculate the comprehensive evaluation value of each alternative combining with the multi-granularity linguistic comparison matrices and the LWAA operator. In addition to improving methods mentioned above, some researchers also carry on the relative work in other aspects. F. Qian and Y. Zhou [5] constructed a hierarchical model with relational matrix, and quantitatively revealed the influence of various factors that affect the degree of integration between the logistics park location with decision test and evaluation experiment. H. Hui and Q. Ren [6] expanded triangular fuzzy semantic translation into fuzzy areas and applications, which overcomes the DEMATEL method's inaccuracy when dealing with the relationship among system factors.

At present, the research on site selection of logistics park needs to be analyzed from qualitative and quantitative two aspects. If we only consider the qualitative factors, the subjective factors will make the evaluation results deviate from the objective fact and the quantitative analysis alone will make the results become rigid and lack of flexibility and adaptability, even the relative research will be no practical significance. Therefore, in this paper we introduce fuzzy weighted average into multi-attribute decision-making method to solve the problem of site selection of logistics parks. This method, considering influence factors from the qualitative and quantitative aspects, has the advantages which can reflect the rational thinking about the problem from the experts and it was inferred and calculated by mathematics theory strictly, in which way it can give more precise advice. Compared with other methods, the method is introduced fuzzy weighted average to measure index weights and evaluation of each attribute and those are represented by fuzzy numbers. While applying different α cut sets in the calculation, we can get different advices for decision-making based on different blurring degrees, by which we can reduce the impact of individual factors on the objective evaluation. The calculation complexity of the fuzzy weighted average reaches $O(2^n)$ times for general calculation methods about KM algorithm in [7]. However, we improve the operations process of KM algorithm by simplifying the shutdown conditions and using the cycle procedures to make calculation, in which way we can greatly reduce the computational complexity in this paper. This paper is organized as follows. In the first section, we introduce the research status and research background of site selection of logistics park, the novelty and distribution of this paper. And we analyze and design the index system of influence elements in the second section. Otherwise, we make one introduction of the fuzzy weighted average algorithm and model building in the third section. Furthermore, the specific example is introduced to assess the improved test model in the fourth section. Finally, we make a conclusion about all the research and recommendations for future research are also made.

2. **Influence Elements of Site Selection of Logistics Park.** Site selection is a comprehensive decision-making problem, which involves many affecting factors. And each factor has a different degree of influence in the process, in order to make decision-making more reasonable and more scientific by integrating various influence factors. Usually, in the construction of logistics park location decisions we should mainly consider its economic costs of park construction, social factors, facilities and capacity for sustainable development, etc. In this paper, we establish the index system based on [7,8]. On the basis of comprehensive analysis of four aspects, we construct the index system of influencing factors on site selection of logistics park as shown in Figure 1.

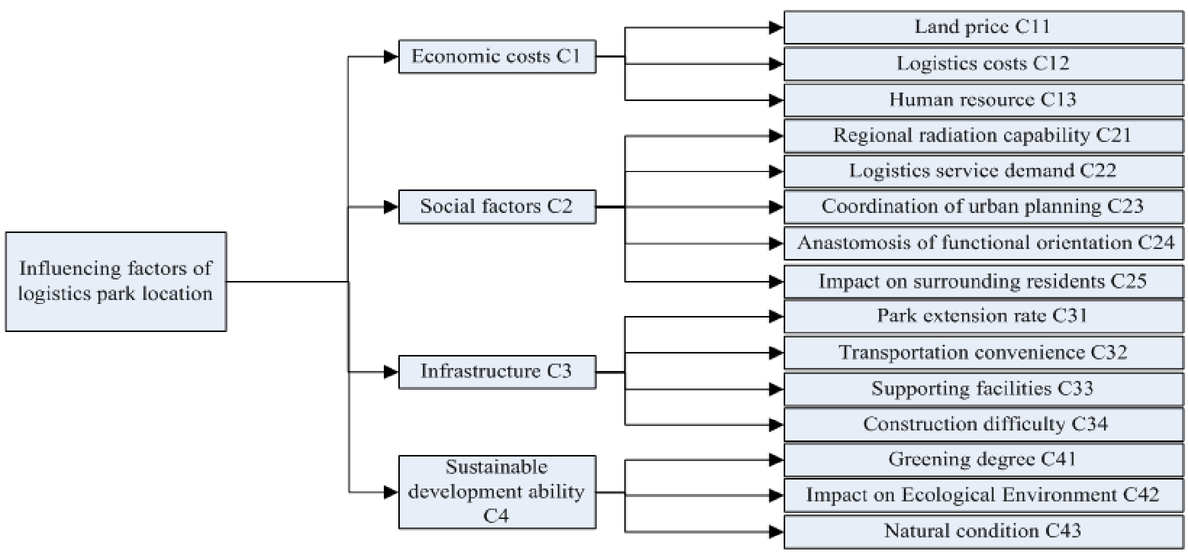

FIGURE 1. The index system of influencing factors on site selection of logistics park

3. Introduction of Fuzzy Weighted Average Algorithm and Model Building.

3.1. **Model building.** Let us assume that there are m plans $(A_1, A_2, \ldots, A_m)$ to a multi-attribute decision-making problem, and to evaluate n attributes $(C1, C2, \ldots, Cn)$ of the options. Several experts grade on them by the n attributes. The weight of the attribute i is W_i, and the grade of the attribute i of the plan j is X_{ji}. Both W_i and X_{ji} are presented by fuzzy numbers. To average the fuzzy weight is to calculate the attribute i's fuzzy weight W_i, and make weighted average with the result of fuzzy grade of the attribute i of plan j, so we can sort all the plans, and pick out the best one.

Fuzzy weighted average Y_j is expressed as the weighted average of fuzzy weight W_i and fuzzy evaluation X_{ji}.

$$\begin{aligned} Y_j &= f(X_{j1}, X_{j2}, \ldots, X_{jn}, W_1, W_2, \ldots, W_n) = \frac{W_1X_{j1} + W_2X_{j2} + \cdots + W_nX_{jn}}{W_1 + W_2 + \cdots + W_n} \\ &= \sum_{i=1}^{n} W_iX_{ji} \Bigg/ \sum_{i=1}^{n} W_i \end{aligned} \tag{1}$$

For each $X_1, X_2, \ldots, X_n$ and $W_1, W_2, \ldots, W_n$, $\alpha \in [0, 1]$, we define the cut sets of fuzzy weight and fuzzy evaluation by α cut set as follows:

$$(W_i)_\alpha = \left[\left(W_i^L\right)_\alpha, \left(W_i^R\right)_\alpha\right], \quad (X_{ji})_\alpha = \left[\left(X_i^L\right)_\alpha, \left(X_i^R\right)_\alpha\right]$$

Type "L" and "R" separately represent the left and right values of the fuzzy weight and fuzzy evaluation's cut sets, so there are the corresponding cut sets.

$$\begin{aligned} (Y_j)_\alpha = \left[\left(y_i^L\right)_\alpha, \left(y_i^R\right)_\alpha\right] &= [f_L(w_1, w_2, \ldots, w_n), f_R(w_1, w_2, \ldots, w_n)] \\ f_L(w_1, w_2, \ldots, w_n) &= f\left(\left(x_{j1}^L\right)_\alpha, \ldots, \left(x_{jn}^L\right)_\alpha, w_1, \ldots, w_2\right) \\ &= \frac{w_1\left(x_{j1}^L\right)_\alpha + w_2\left(x_{j2}^L\right)_\alpha + \cdots + w_n\left(x_{jn}^L\right)_\alpha}{w_1 + w_2 + \cdots + w_n} \\ f_R(w_1, w_2, \ldots, w_n) &= f\left(\left(x_{j1}^R\right)_\alpha, \ldots, \left(x_{jn}^R\right)_\alpha, w_1, \ldots, w_2\right) \\ &= \frac{w_1\left(x_{j1}^R\right)_\alpha + w_2\left(x_{j2}^R\right)_\alpha + \cdots + w_n\left(x_{jn}^R\right)_\alpha}{w_1 + w_2 + \cdots + w_n} \end{aligned} \tag{2}$$

(1) Solving Equation (2) can use KM algorithm to simplify the calculation. First we calculate the left values f_L of $f(w_1, w_2, \ldots, w_n)$, which can be proceeded as follows.

Step one. Let $\left(x_{j1}^L\right)_\alpha$ be in ascending order, and then make the weight values w_i correspond with $\left(x_{j1}^L\right)_\alpha$ re-sorted.

Step two. Set the initial value of $k_0 = \left[\frac{n}{2}\right]$.

Step three. Set $w_i = \begin{cases} \left(w_i^L\right)_\alpha, i \le k \\ \left(w_i^R\right)_\alpha, i > k \end{cases}$, and then calculate the f_{k_0}.

$$f_{k_0} = \frac{\sum_{i=1}^{k_0} \left(w_i^R\right)_\alpha \left(x_{ji}^L\right)_\alpha + \sum_{i=k_0+1}^{n} \left(w_i^L\right)_\alpha \left(x_{ji}^L\right)_\alpha}{\sum_{i=1}^{k_0} \left(w_i^R\right)_\alpha + \sum_{i=k_0+1}^{n} \left(w_i^L\right)_\alpha}$$

Step four. Find the k values that can satisfy the condition of $\left(x_{jk}^L\right)_\alpha \le f_{k_0} \le \left(x_{j(k+1)}^L\right)_\alpha$.

Step five. If $k = k_0$ exists, then stop calculating, and $f_L = f_{k_0}$ is the final result. If $k \neq k_0$ exists, we need to get the new f_k.

$$f_k = \frac{\sum_{i=1}^{k} \left(w_i^R\right)_\alpha \left(x_{ji}^L\right)_\alpha + \sum_{i=k+1}^{n} \left(w_i^L\right)_\alpha \left(x_{ji}^L\right)_\alpha}{\sum_{i=1}^{k} \left(w_i^R\right)_\alpha + \sum_{i=k+1}^{n} \left(w_i^L\right)_\alpha}$$

Then re-order $k_0 = k$, skip to Step four to recalculate it until we get the solutions which can meet shutdown condition. In similar method we can calculate right values f_R.

The shutdown condition is $f_k = f_0$ in original KM algorithm, but we find that when $f_k = f_0$ exists, the condition $k = k_0$ exists. So the algorithm process can be simplified by changing the values of corresponding item without having to make plurality of times of cyclic calculations.

(2) Scheme evaluation results can be expressed as the form of interval numbers by fuzzy weighted average. Application of the following methods can be used to integrate the interval number evaluation results, in order to sort problems of various programs.

Set interval number $a = [a^-, a^+]$, $b = [b^-, b^+]$, order $l(a) = a^+ - a^-$, $l(b) = b^+ - b^-$, so it has the transform.

$$p(a \geq b) = \max\left(1 - \max\left(\frac{b^+ - a^-}{l(a) + l(b)}\right), 0\right) \tag{3}$$

The N interval number $Y_1, Y_2, \ldots, Y_n$ are written in the form of matrix P.

$$P = (p_{ij})_{n\times n} = \begin{matrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{matrix} \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{bmatrix}_{n\times n} \tag{4}$$

Then calculate the rank results.

$$Rank(Y_i) = \frac{2}{n}\sum_{j=1}^{n} p_{ij} \tag{5}$$

Finally, we rank the results Y_i based on the consequence of $Rank(Y_i)$.

3.2. **Key factor weights determined.** The site selection of logistics park is a multi-attribute decision-making problem, which needs experts to evaluate alternative locations. The importance of each attribute is not absolutely clear in reality, so it needs to introduce the relevant theory of fuzzy mathematics into the evaluation, which is expressed by fuzzy numbers. Then, combining with the historical data for alternative address and their subjective experience, all the experts, who have been invited to take participate in judging the importance of each index and scoring for each alternative address with the judging criteria, make a judge for each index. And so each attribute according to the importance of the corresponding is divided into six levels with triangular fuzzy number as Table 1.

Table 1. Fuzzy linguistic variables and the corresponding fuzzy weights

Fuzzy linguistic variables	Fuzzy weights
Very unimportant (VU)	(0.0, 0.1, 0.2)
Unimportant (U)	(0.1, 0.2, 0.3)
Middle unimportant (MU)	(0.2, 0.3, 0.4)
Middle important (MI)	(0.4, 0.5, 0.6)
Important (I)	(0.7, 0.8, 0.9)
Very important (VI)	(0.9, 0.9, 1.0)

Experts $(M_1, M_2, \ldots, M_m)$ based on Table 1 evaluate the importance of attributes, and the final weights of each attribute are the weighted average of the m experts' evaluation results as Table 2 according to the formula $W_i = \frac{1}{m}\sum_{k=1}^{m} \tilde{M}_k$, $k = 1, 2, \ldots, m$.

Notes: M means one expert, and m refers to the m-th expert.

Table 2. Experts' evaluation of the importance of each index and fuzzy weight

Index		Expert group			Fuzzy weighted average weight
		M_1	M_2	M_3	
C1	C11	I	VI	VI	(0.833, 0.867, 0.967)
	C12	MI	I	VI	(0.500, 0.600, 0.700)
	C13	U	MU	VU	(0.100, 0.200, 0.300)
C2	C21	MU	I	VI	(0.600, 0.667, 0.767)
	C22	VI	I	I	(0.767, 0.833, 0.933)
	C23	U	VU	U	(0.067, 0.167, 0.267)
	C24	MI	VI	I	(0.667, 0.733, 0.833)
	C25	VI	U	MI	(0.467, 0.533, 0.633)
C3	C31	MI	I	MU	(0.433, 0.533, 0.567)
	C32	I	VI	I	(0.767, 0.833, 0.933)
	C33	I	U	MI	(0.400, 0.500, 0.600)
	C34	MU	MI	MI	(0.333, 0.433, 0.533)
C4	C41	VU	MU	I	(0.333, 0.400, 0.500)
	C42	VI	MU	VU	(0.367, 0.433, 0.533)
	C43	MI	VI	VI	(0.733, 0.800, 0.809)

Similarly, using triangular fuzzy numbers to describe the corresponding evaluation results, we divide fuzzy weights of each attribute into seven levels in Table 3. According to Table 3, we determine the fuzzy weights of each level.

Table 3. Fuzzy linguistic variables and corresponding fuzzy weights of each index level

Fuzzy linguistic variables	Fuzzy weights
Very poor (VP)	(0.000, 0.000, 0.167)
Poor (P)	(0.000, 0.167, 0.333)
Middle poor (MP)	(0.167, 0.333, 0.500)
Middle (M)	(0.333, 0.500, 0.667)
Middle good (MG)	(0.500, 0.667, 0.833)
Good (G)	(0.667, 0.833, 1.000)
Very good (VG)	(0.833, 1.000, 1.000)

4. **H Group Logistics Park Location Analysis.** Shijiazhuang H Group plans to build one logistics park and there are four alternative addresses for selecting. The first site is nearby Douyu in South Third Ring Road of Shijiazhuang, relying on the railway hub and the highway. The second site is the northeast of Luquan, near Xibaipo region and the third channel of Shijiazhuang-Taiyuan expressway. The third site is the northwest district of Zhengding, which is based on the commercial city and relies on the Beijing-Zhuhai expressway and the 107 National Roads. The fourth is located in Liangcun Development Zone in Shijiazhuang, and it is close to the inland port. For the actual situation of the each location, experts make one score for each alternative address according to Table 3.

TABLE 4. Average of fuzzy weights in different α cut sets

α	Fuzzy weighted average results			
	Location 1	Location 2	Location 3	Location 4
$\alpha = 0.0$	(0.4224, 0.7937)	(0.3652, 0.7379)	(0.5197, 0.8559)	(0.4922, 0.8548)
$\alpha = 0.1$	(0.4408, 0.7752)	(0.3851, 0.7209)	(0.5391, 0.8420)	(0.5112, 0.8377)
$\alpha = 0.2$	(0.4591, 0.7566)	(0.4051, 0.7038)	(0.5585, 0.8281)	(0.5302, 0.8205)
$\alpha = 0.3$	(0.4775, 0.7379)	(0.4251, 0.6867)	(0.5585, 0.8281)	(0.5491, 0.8033)
$\alpha = 0.4$	(0.4959, 0.7192)	(0.4452, 0.6696)	(0.5779, 0.8140)	(0.5681, 0.7861)
$\alpha = 0.5$	(0.5142, 0.7005)	(0.4653, 0.6524)	(0.6167, 0.7857)	(0.5870, 0.7688)
$\alpha = 0.6$	(0.5326, 0.6818)	(0.4854, 0.6352)	(0.6361, 0.7714)	(0.6059, 0.7514)
$\alpha = 0.7$	(0.5510, 0.6629)	(0.5055, 0.6179)	(0.6555, 0.7571)	(0.6248, 0.7340)
$\alpha = 0.8$	(0.5694, 0.6441)	(0.5256, 0.6007)	(0.6749, 0.7427)	(0.6436, 0.7165)
$\alpha = 0.9$	(0.5878, 0.6252)	(0.5458, 0.5834)	(0.6942, 0.7282)	(0.6625, 0.6690)
$\alpha = 1.0$	(0.6063, 0.6063)	(0.5660, 0.5660)	(0.7136, 0.7136)	(0.6814, 0.6184)

4.1. **Fuzzy logic and numerical analysis.** According to the fuzzy weights of indicators in Table 2 and experts' evaluation results in Table 3 scored by experts, based on the application of KM algorithm, we can use MATLAB software programming computing different α cut sets of each option's weighted average values, and then the results are shown in Table 4.

It can be seen that there will be some differences for different values of α when we calculate the fuzzy weighted average results. Since α represents the fuzzy degree of fuzzy numbers, we can see that when α is zero, the fuzzy numbers will show total value, left value and right value are significantly different. When α is equal to one, the fuzzy numbers will show complete accuracy, and then left and right values are equal to the same value. Next there is a choice of two programs which should be evaluated on the degree of blurring.

When α is equal to 0.5, according to Formulae (3), (4) and (5), we can calculate the corresponding consequence of ranked index as follows.

$$Rank(Y_1) = 0.3880, Rank(Y_2) = 0.4350, Rank(Y_3) = 0.4268, Rank(Y_4) = 0.5440$$

Thus, we get a conclusion that location 4 > location 2 > location 3 > location 1.

Similarly, when α is equal to 0.8, we get the other conclusion that location 4 > location 2 > location 3 > location 1.

From the above results, it can be seen that the optimal location is location 4, and location 1 is the worst place when $\alpha = 0.5$ and $\alpha = 0.8$ exist. According to experts' advice and corresponding evaluation index to measure, the fourth site Liangcun Development Zone of Shijiazhuang has strong advantages, while the first location near Douyu in Luancheng city has obvious disadvantages. At the same time, it should also be noted that when we select a different degree of blurring, the results of the evaluation will be different, which is mainly reflected in the alternative locations between location 2 and location 3. However, it also shows that the difference between the second place and the third place is not very obvious. In other words, different experts have different views for the comprehensive advantages. However, what forms this above result? Because the importance of each attribute to the Logistics park is different, the combination of infrastructure and basic conditions of each option having calculated according to the method location of the park, leads to such the above result.

4.2. **Selection of fuzzy degree.** The conclusion suggests that the accuracy of the evaluation criteria of understanding is different, and the results of the evaluation will produce different results. The fuzzy degree can make influence for the final optimal scheme, so in this paper we select the fuzzy degree mainly based on the average values of fuzzy degree made by all the experts who took participation in the process of scoring the attributes weight and the attributes' values about the index system.

5. **Conclusions.** In actual problems, due to the complexity, the uncertainty and the ambiguity of human thinking existing in the objective things, decision-making information is often represented by fuzzy attributes. Each evaluation and criteria evaluation are endowed with fuzzy weights values, and then we effectively deal with attribute weights and attribute values in a variety of fuzzy numbers based on fuzzy weighted average method, α cut sets and KM theory algorithms in the process of fuzzy multi-attribute decision-making. While calculating the interval possibility degree between each two can reduce the risk of evaluations functions' distortion caused by single index. Finally, the model can provide the best location for decision-makers based on the ranking results, which can give a scientific reference for site selection of logistics park. However, the research on multi-attribute decision-making problems based on different degrees of blurring does not completely enter practice process, and it is not sufficient to prove the chosen decision scheme will be the optimal solution. In the future, we will introduce the accurate values of each attribute which can be measured to combine with fuzzy attributes in the process of fuzzy evaluation, and then make the simulation models analyze multi-attribute programs in order to prove the rationality of final decision-making scheme.

Acknowledgments. This paper is supported by the Project of National Natural Science Foundation of China (71301044). It also gets help from the project of Heibei Education Department of China (ZD201449).

REFERENCES

[1] W. Hu, Y. Hou and L. Tian, Selection of logistics distribution center location for SDN enterprises, *Journal of Management Analytics*, vol.2, no.3, pp.1-14, 2015.
[2] M. Yi, Research on site location of logistics park based on triangular fuzzy number comprehensive evaluation, *Highway and Qiyun*, no.1, pp.85-89, 2015.
[3] D. Zhang, *Study on Logistics Park Planning and Site Selection of Urban Area Port*, Master Thesis, Chongqing Jiaotong University, 2014.
[4] S. Liu, F. T. S. Chan and W. Ran, Multi-attribute group decision-making with multi-granularity linguistic assessment information: An improved approach based on deviation and TOPSIS, *Applied Mathematical Modeling*, vol.37, no.24, pp.10129-10140, 2013.
[5] F. Qian and Y. Zhou, The analysis of main factors about the site selection of logistics park on the basis of DEMATEL method, *Logistics Technology*, no.11, pp.212-214, 2014.
[6] H. Hui and Q. Ren, Site selection of low-carbon logistics park based on fuzzy DEMATEL method, *ICIC Express Letters, Part B: Applications*, vol.7, no.7, pp.1543-1550, 2015.
[7] F. Jiang, *Study on Methods of Fuzzy Multi-attribute Decision-making*, Ph.D. Thesis, University of Science and Technology of China, 2013.
[8] L. Huo and T. Lin, An improved method of fuzzy weighted average in fuzzy multi-attribute decision-making, *Operations Research and Management Science*, no.2, pp.92-96, 2010.