ICIC Express Letters
Part B: Applications
Volume **7**, Number **7**, July **2016**

ICIC International ©2016 ISSN 2185-2766
pp. 1543–1550

SITE SELECTION OF LOW-CARBON LOGISTICS PARK BASED ON FUZZY DEMATEL METHOD

Hongqi Hui and Qiao Ren

School of Economics and Management
Hebei University of Science and Technology
No. 26, Yuxiang Street, Shijiazhuang 050018, P. R. China
huihongqi@126.com; 373053987@qq.com

Received December 2015; accepted March 2016

Abstract. *The low-carbon logistics park location is related to the development of logistics industry. The location research on low-carbon logistics park has some practical significances. From the angle of economic factors, social factors, facility construction and low-carbon layout, we analyze 20 impact indexes on low-carbon logistics park location, and construct the index system. The decision making trial and evaluation laboratory (DEMATEL) method can expand by triangular fuzzy semantic translation into fuzzy areas and applications, which overcomes the DEMATEL method's inaccuracy when dealing with the relationship among system factors. Case study shows that the key impact indexes on site selection of the low-carbon logistics park are consumer market distance, traffic convenience, natural conditions, urban traffic remission and impact on ecological environment. The research shows that fuzzy DEMATEL method is suitable for low-carbon logistics park location; and it has reference value to the future development.*
Keywords: Low-carbon, Logistics park location, Fuzzy DEMATEL method

1. **Introduction.** Modern logistics industry, as a new industry, has been developing rapidly in recent years; and its development degree is becoming a key role in measuring the comprehensive economic strength of country and region scales. The site selection is important for logistics park, which determines the park's operation in the future. Researchers have concentrated in quality, quantity and combination of both analytical perspectives on the site selection method. Quantitative analysis method mainly involves mathematical models and corresponding algorithms. For example, L. Yang et al. established the logistics center location model based on different quantitative algorithms respectively to determine the optimal location [1-3]. When qualitative methods are applied in the selection process, the relationship among the various factors is considered. The qualitative methods mainly include the analytic hierarchy process (AHP), fuzzy comprehensive evaluation, Delphi method, artificial neural network and data envelopment analysis, etc. [4]. Some scholars combined AHP and fuzzy comprehensive evaluation to study logistics park location [5,6]. They set up the evaluation index system of influencing factors on site selection of logistics park, which realized the advantages of two methods effectively. S. Liu and T. S. Felix used a hybrid heuristic algorithm to solve the problem of the distribution center's location [7]. They integrated multiple algorithms based on the original algorithm to compensate for the limitations of using a single method to solve the problem.

On global scale, carbon emission of the logistics industry is up to twenty percent of the total carbon emissions. As a result, it is a trend to achieve a low-carbon development for the modern logistics industry. The logistics park as a gathering area of the comprehensive logistics service should be low-carbon layout and operation to protect the environment. Therefore, low-carbon factors considered in the logistics park site selection can increase the rationality of the optimal location. Most studies consider the factors influencing the location of the logistics park for the model need; and less analyze the influence on the relationship among various factors and low-carbon factors. In this paper, we use fuzzy set theory to analyze the relationship of comprehensive influence among various factors and the influence degree of the low-carbon logistics park location based on the decision making trial and evaluation laboratory (DEMATEL) method, so as to provide references to the location of low-carbon logistics park. The DEMATEL can analyze the relationship among the system elements through graph theory and matrix tools. We study innovatively the problem of low-carbon logistics park location by DEMATEL to make the results more accurate, which is proved by the case study.

The rest of the paper is organized as follows. Section 2 constructs main influential factors on site selection of low-carbon logistics park. In Section 3, the methods are reviewed and analyzed. In Section 4, the case studies are demonstrated. Finally, the conclusions are presented in Section 5.

2. The Determination of Low-Carbon Logistics Park's Location Influential Factors.

The low-carbon logistics park's location should not only consider the economic and social benefits that logistics enterprises in the park bring, but also needs to consider the factors of infrastructure conditions and relevant low-carbon factors.

2.1. Economic factors.

Firstly, it is necessary to consider the land conditions, such as the reasonability of land price. Next, we should consider the cost and the investment level in the logistics park. Then, the consideration is whether there are enough human resources conditions, and whether the development of the logistics park can promote the development of regional economy. Finally, the logistics park should be constructed in the concentrated area of target customers in order to achieve more logistics service requirements.

2.2. Social factors.

First, the improper location will seriously affect the urban traffic. Second, we should take the impact on the surrounding residents into account. In addition, the logistics park's location should be consistent with urban planning and the government logistics planning, which is one of the important factors to the development of the logistics park. Finally, the convenience of traffic can promote the development of the park orderly and it attributes to reduce logistics costs appropriately when the distance to the consumer market is comprehensively considered.

2.3. Facility construction.

As a specific area of logistics park, its development must consider the comprehensive utilization avoiding idle space. Transportation conditions play an important role in the process of logistics distribution. Therefore, the choice of the transportation mode should be considered appropriately. Perfect infrastructures are important supports for logistics park construction and operation, so the logistics park should have good supporting facility.

2.4. Low-carbon layout.

The logistics park location requires superior natural conditions for the foundation. Its development must also consider environmental factors. Therefore, it is very important for the park to greening design. In terms of water treatment, the proper use of water resources should be considered. Low-carbon logistics park location needs to take the elements of sustainable development and the impacts on the ecological environment into account, which is the environmental protection requirement.

According to the comprehensive analysis of the four factors, low-carbon logistics park index system of the main influential factors on site selection is shown in Figure 1.

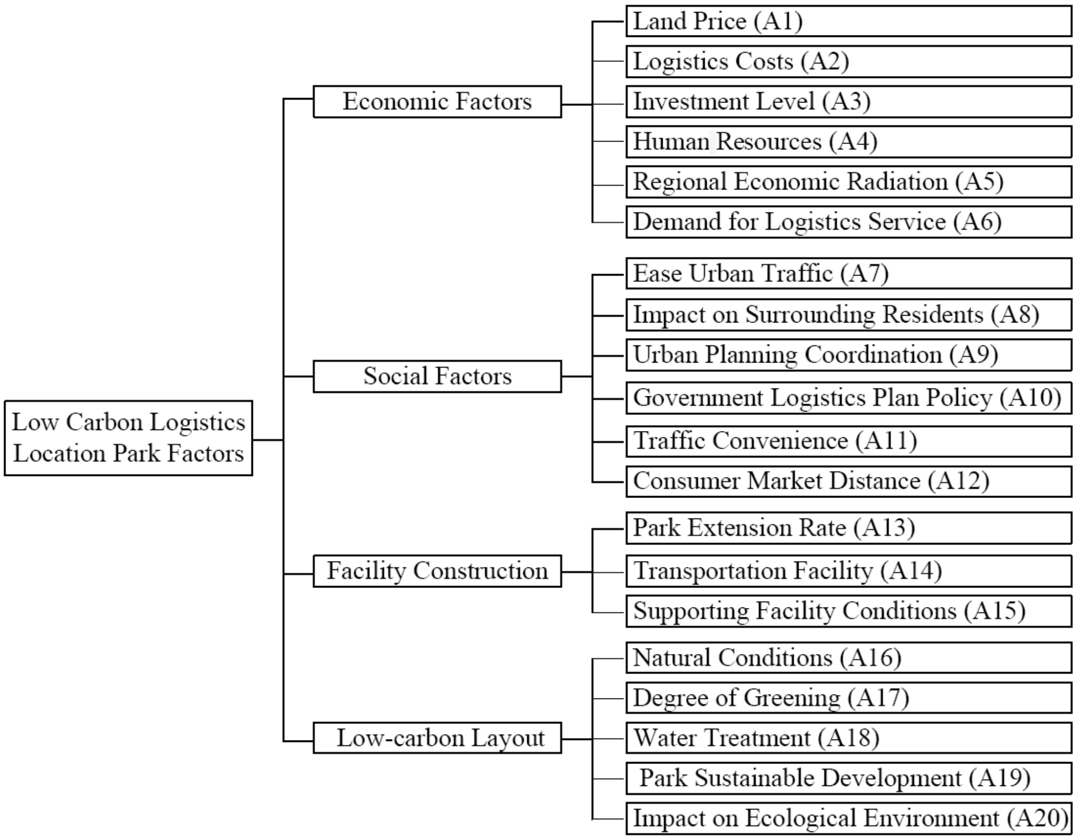

Figure 1. Main influential factors on site selection of low-carbon logistics park

3. Fuzzy DEMATEL Method.

DEMATEL is a kind analysis method of system factors. It establishes a direct impact matrix among various factors through the logical relationship to obtain the degree of each factor influence, center and reasons for degrees. Nevertheless, the effects of each factor are often ambiguity. Therefore, we need to calculate and analyze the influence matrix which is transformed by triangular fuzzy number to strive for the accuracy of the results.

3.1. Establishing expert rating scales.

We assess each expert's comprehension of the influence degree among various factors by the factors comparison. The influence degree of factor i to factor j is showed by using 0, 1, 2, 3, 4, which represent the affecting relationship of no, very low, low, high and very high. Then we establish the direct influence matrix of various factors.

3.2. Semantic conversion by triangular fuzzy number.

The effect among system factors is often ambiguity; therefore, we convert the influence degree which is set by experts to corresponding triangular fuzzy number, as shown in Table 1. And the direct influence matrix is converted to the fuzzy number matrix.

Table 1. The semantic conversion

Semantic term	Influence score	Triangular fuzzy number
No influence	0	(0,0,0.2)
Very low influence	1	(0,0.2,0.4)
Low influence	2	(0.2,0.4,0.6)
High influence	3	(0.4,0.6,0.8)
Very high influence	4	(0.6,0.8,1.0)

3.3. **Dealing with the blur.** The evaluation result of each expert is converted into triangular fuzzy numbers according to the semantic transformation relationship. $x_{ij}^k = \left(l_{ij}^k, m_{ij}^k, r_{ij}^k\right)$ denotes the influence value of factor i to factor j by expert k. l_{ij}^k is the left value of triangular fuzzy numbers; while m_{ij}^k and r_{ij}^k are middle value and right value respectively. The defuzzification steps are as follows.

Step 1: standardize the triangular fuzzy number matrix.

$$xl_{ij}^k = \frac{l_{ij}^k - \min\limits_{1\le k\le K} l_{ij}^k}{\Delta_{\min}^{\max}}. \tag{1}$$

$$xm_{ij}^k = \frac{m_{ij}^k - \min\limits_{1\le k\le K} l_{ij}^k}{\Delta_{\min}^{\max}}. \tag{2}$$

$$xr_{ij}^k = \frac{r_{ij}^k - \min\limits_{1\le k\le K} l_{ij}^k}{\Delta_{\min}^{\max}}. \tag{3}$$

where $\Delta_{\min}^{\max} = \max\limits_{1\le k\le K} r_{ij}^k - \min\limits_{1\le k\le K} l_{ij}^k$, and K denotes the experts number.

Step 2: calculate the left (ls) and right (rs) standard values.

$$xls_{ij}^k = \frac{xm_{ij}^k}{1 + xm_{ij}^k - xl_{ij}^k}. \tag{4}$$

$$xrs_{ij}^k = \frac{xr_{ij}^k}{1 + xr_{ij}^k - xm_{ij}^k}. \tag{5}$$

Step 3: calculate the total standard values.

$$x_{ij}^k = \frac{xls_{ij}^k\left(1 - xls_{ij}^k\right) + xrs_{ij}^k xrs_{ij}^k}{1 - xls_{ij}^k + xrs_{ij}^k}. \tag{6}$$

Step 4: calculate the influence value of factor i to factor j by expert k.

$$w_{ij}^k = \min\limits_{1\le k\le K} l_{ij}^k + x_{ij}^k \Delta_{\min}^{\max}. \tag{7}$$

Step 5: calculate the average influence value of the factor i to factor j by all experts.

$$w_{ij} = \frac{1}{K}\sum_{k=1}^{K} w_{ij}^k. \tag{8}$$

3.4. **Calculation of the mutual relationships based on DEMATEL method.** The relationship matrix $A = [w_{ij}]_{n\times n}$ is standardized; and the comprehensive influence matrix $T = [t_{ij}]_{n\times n}$ is obtained. Finally, calculate the effect degree f_i, affected degree e_i, center degree m_i, and reason degree n_i.

$$D = A/\max_{1\le i\le n}\sum_{j=1}^{n} w_{ij}. \tag{9}$$

$$T = D^1 + D^2 + \cdots + D^n. \tag{10}$$

4. Empirical Analyses.

4.1. **Case analysis based on fuzzy DEMATEL method.** Shijiazhuang H Group plans to build a low-carbon logistics park in order to analyze the main influential factors on site selection. The main influential factors, such as the economic factors, social factors, infrastructure construction and low-carbon layout, should be analyzed synthetically. There are four levels and a total of 20 factors. Through expert scoring evaluation, direct influence matrix A and semantic transformation are shown in Table 2 and Table 3.

Table 2. Direct influence matrix A

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20
A1	0	0	2	0	2	0	0	2	0	0	0	0	4	0	0	0	3	0	2	0
A2	0	0	0	0	0	2	0	0	0	1	0	0	0	3	2	0	0	0	1	0
A3	0	3	0	3	2	0	0	2	0	0	0	0	4	4	4	0	3	3	3	0
A4	0	2	1	0	3	2	0	2	0	0	0	0	1	0	1	0	2	2	2	0
A5	3	1	1	3	0	4	0	4	3	3	1	0	3	2	2	0	0	1	3	1
A6	1	3	0	4	3	0	0	3	0	1	0	0	4	1	3	0	0	0	2	0
A7	0	2	0	0	2	3	0	4	4	4	3	0	0	3	0	1	0	0	0	3
A8	2	0	0	3	3	4	0	0	0	1	0	1	3	2	0	0	0	0	3	0
A9	3	0	1	0	4	0	4	3	0	4	4	3	2	1	0	0	3	3	2	3
A10	3	2	1	3	4	3	2	3	3	0	2	3	3	3	4	0	2	3	4	2
A11	4	3	3	2	4	2	2	4	2	2	0	4	3	3	0	0	0	0	0	0
A12	3	4	0	1	3	3	3	3	2	1	3	0	1	4	2	0	0	0	2	0
A13	1	0	2	3	4	1	0	4	2	3	0	0	0	2	4	0	2	2	1	2
A14	0	4	3	1	2	2	4	3	0	2	4	2	2	0	2	1	0	0	2	3
A15	0	2	3	3	1	3	0	1	0	2	0	0	2	0	0	0	1	1	3	1
A16	3	2	1	0	2	0	0	4	3	1	0	0	3	1	1	0	2	2	3	2
A17	0	0	3	1	1	0	0	4	4	1	0	0	2	0	1	3	0	0	2	4
A18	1	0	2	0	0	0	0	4	3	2	0	0	2	0	1	2	1	0	3	4
A19	2	1	2	2	2	2	0	3	2	3	0	0	3	1	2	2	1	3	0	3
A20	2	2	2	1	3	2	1	4	3	4	0	0	2	3	2	3	3	2	3	0

Comprehensive influence matrix is calculated according to Equations (1)-(10); and each row and each column of the matrix are summed to obtain the comprehensive effects of relational tables, as shown in Table 4.

4.2. **Result analysis.** According to the reason degree value, the influence factors on low-carbon logistics park site selection of H Group are divided into two categories. The first category is the cause factors. The sequence is consumer market distance, traffic convenience, natural conditions, easy urban traffic, impact on ecological environment, government logistics plan policy, urban planning coordination, water treatment, transportation facility, investment level and degree of greening. These factors have direct influences on the location of low-carbon logistics park. The second category is the result factors. The order is impact on the surrounding residents, logistics costs, human resources, regional economic radiation, demand for logistics service, park extension rate, land price, supporting facility conditions, and park sustainable development. These factors are severely affected by other factors.

According to the center degree, the order is government logistics plan policy, regional economic radiation, impact on the surrounding residents, park expansion rate, park sustainable development, urban planning coordination, transportation facility, impact on ecological environment demand for logistics service, investment level, supporting facility conditions, traffic convenience, water treatment, degree of greening, human resources,

Table 3. Semantic conversion matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20
A1	0	0.033	0.4	0.034	0.4	0.034	0.034	0.413	0.034	0.034	0.034	0.034	0.8	0.034	0.034	0.034	0.6	0.028	0.39	0.034
A2	0.034	0	0.034	0.033	0.034	0.4	0.034	0.034	0.034	0.21	0.034	0.034	0.028	0.6	0.41	0.034	0.034	0.034	0.2	0.028
A3	0.034	0.499	0	0.601	0.413	0.034	0.034	0.4	0.034	0.034	0.034	0.034	0.8	0.8	0.8	0.034	0.6	0.59	0.6	0.034
A4	0.034	0.2	0.2	0	0.704	0.41	0.034	0.4	0.034	0.033	0.034	0.033	0.2	0.033	0.2	0.034	0.391	0.4	0.4	0.034
A5	0.524	0.21	0.209	0.601	0	0.888	0.034	0.8	0.610	0.6	0.213	0.034	0.587	0.39	0.4	0.034	0.034	0.2	0.59	0.2
A6	0.21	0.6	0.03	0.787	0.59	0	0.03	0.524	0.034	0.21	0.034	0.028	0.733	0.2	0.59	0.034	0.034	0.034	0.4	0.034
A7	0.033	0.243	0.03	0.03	0.39	0.6	0	0.79	0.8	0.8	0.61	0.028	0.034	0.59	0.034	0.2	0.034	0.034	0.034	0.59
A8	0.401	0.034	0.033	0.499	0.61	0.8	0.03	0	0.03	0.28	0.034	0.2	0.6	0.39	0.028	0.034	0.034	0.034	0.587	0.034
A9	0.6	0.033	0.21	0.03	0.888	0.03	0.888	0.6	0	0.72	0.8	0.6	0.413	0.2	0.033	0.034	0.6	0.59	0.41	0.59
A10	0.7	0.4	0.21	0.5	0.888	0.61	0.39	0.6	0.6	0	0.4	0.61	0.6	0.6	0.79	0.034	0.4	0.6	0.79	0.41
A11	0.84	0.701	0.59	0.243	0.8	0.4	0.4	0.79	0.4	0.39	0	0.8	0.57	0.597	0.033	0.034	0.034	0.034	0.034	0.028
A12	0.601	0.79	0.03	0.2	0.6	0.61	0.6	0.6	0.4	0.21	0.6	0	0.213	0.79	0.391	0.034	0.034	0.034	0.587	0.034
A13	0.209	0.034	0.35	0.5	0.888	0.21	0.034	0.79	0.41	0.6	0.034	0.034	0	0.41	0.8	0.034	0.41	0.413	0.021	0.4
A14	0.034	0.84	0.595	0.4	0.4	0.41	0.888	0.59	0.034	0.4	0.79	0.41	0.41	0	0.39	0.2	0.034	0.034	0.4	0.61
A15	0.034	0.402	0.595	0.499	0.2	0.59	0.034	0.2	0.034	0.39	0.034	0.034	0.4	0.028	0	0.034	0.2	0.21	0.59	0.2
A16	0.7	0.4	0.21	0.034	0.39	0.034	0.034	0.79	0.6	0.213	0.034	0.034	0.6	0.213	0.20	0	0.41	0.41	0.61	0.41
A17	0.03	0.034	0.59	0.2	0.033	0.034	0.034	0.79	0.72	0.213	0.034	0.034	0.41	0.034	0.2	0.6	0	0.034	0.41	0.8
A18	0.2	0.034	0.39	0.16	0.4	0.034	0.034	0.8	0.6	0.4	0.034	0.034	0.39	0.034	0.21	0.41	0.21	0	0.6	0.8
A19	0.243	0.21	0.39	0.39	0.41	0.39	0.033	0.6	0.4	0.6	0.03	0.028	0.6	0.213	0.413	0.391	0.21	0.6	0	0.6
A20	0.243	0.4	0.39	0.2	0.6	0.39	0.2	0.8	0.6	0.79	0.034	0.034	0.4	0.667	0.391	0.597	0.6	0.4	0.61	0

Table 4. Comprehensive relationship

	f_i	e_i	m_i	n_i		f_i	e_i	m_i	n_i
A1	0.895	1.457	2.352	−0.562	A11	1.951	0.954	2.905	0.997
A2	0.611	1.493	2.104	−0.882	A12	1.848	0.794	2.642	1.055
A3	1.586	1.415	3.001	0.171	A13	1.729	2.329	4.058	−0.601
A4	0.957	1.706	2.663	−0.749	A14	2.020	1.731	3.751	0.289
A5	1.834	2.528	4.362	−0.695	A15	1.190	1.728	2.918	−0.539
A6	1.229	1.901	3.130	−0.672	A16	1.629	0.715	2.344	0.914
A7	1.673	0.937	2.610	0.736	A17	1.434	1.263	2.697	0.170
A8	1.209	2.852	4.061	−1.643	A18	1.582	1.274	2.856	0.309
A9	2.258	1.580	3.838	0.678	A19	1.780	2.161	3.941	−0.382
A10	2.586	1.888	4.473	0.698	A20	2.203	1.497	3.701	0.706

consumer market distance, easy urban traffic, land price, natural condition and logistics costs. The higher the factor's center degree is, the higher we can choose and optimize.

4.3. **Determination of the location.** There are four alternative addresses for low-carbon logistics park construction of the H Group. The first is located in Liangcun development zone close to the inland port. The second is nearby Douyu, near the railway hub. The third is in the northwest of Luquan, near Shijiazhuang-Taiyuan expressway. The fourth is in the northwest district of Zhengding, near Beijing-Zhuhai expressway. According to reason degree and center degree sequence, we can analyze each site character. We choose the first site as the best low-carbon logistics park location for the H Group by comparison.

5. Conclusions.

Based on triangular fuzzy number, we put forth the DEMATEL evaluation model. The empirical analysis generates good results with strong operability in actual application. Related studies show that the sensitivity of the DEMATEL method is low, which is suitable for the decision problem. The fuzzy DEMATEL method provides a support for the decision-making and the development of logistics park. Compared to other multi-objective decision-making methods, fuzzy DEMATEL method takes into account the impact of the relationship among various factors. It is convinced in the relation calculation by using fuzzy set theory. However, the applicability of the method remains to be enhanced for the larger complex systems, such as social, economic, and ecological system. At present, the development of low-carbon logistics park is not yet mature and the related research is less. Therefore, it needs scientific practice test in the future study; and it still needs to optimize the low-carbon logistics park location model and the evaluation indexes in order to make the results scientific and rational.

Acknowledgment. This research was supported by the Natural Science Foundation of Hebei University of Science and Technology (QD201502) and Shijiazhuang low-carbon city project (Grant No. 2012011).

REFERENCES

[1] L. X. Yang and X. Y. Ji, Logistics distribution centers location problem and algorithm under fuzzy environment, *Journal of Computational and Applied Mathematics*, vol.208, no.2, pp.303-315, 2007.
[2] X. M. Zhu and Z. Q. Zhang, Based on gravity method and through put prediction, *Journal of Site Selection of Logistics Park Logistics Technology*, vol.30, no.5, pp.88-92, 2011.
[3] X. H. Liu and X. H. Guo, Study on logistics center site selection of Jilin province, *Journal of Software*, vol.7, no.8, pp.1799-1806, 2012.
[4] H. J. Sun and Z. Y. Gao, A bi-level programming model and solution algorithm for the location of logistics distribution centers, *Applied Mathematical Modelling*, vol.32, no.4, pp.610-616, 2008.

[5] H. Dai and P. L. Zhang, Location research based on AHP and fuzzy comprehensive evaluation method of logistics park, *Logistics Technology*, vol.33, no.4, pp.98-100, 2014.
[6] S. S. Sun and B. H. Luo, Location based CCRMP/AHP model of agricultural logistics park, *Logistics Technology*, vol.35, no.6, pp.90-93, 2013.
[7] S. Liu and T. S. Felix, A study of distribution center location based on the rough sets and interactive multi-objective fuzzy decision theory, *Robotics and Computer-Integrated Manufacturing*, vol.27, no.2, pp.426-433, 2011.