Analysis of urban logistics capability based on fuzzy matter-element quantitative model

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Abstract. An index system of logistics capability analysis in Shenzhen was established, and the fuzzy matter-element quantitative model for urban logistics capability analysis was established based on entropy evaluation method and fuzzy matter-element method. The change process of urban logistics capacity in Shenzhen in 2007–2016 was obtained through the model solution. In result, the overall logistics capacity of Shenzhen had been increasing gradually in 2007–2016, and the logistics capability of all the first level indexes had been increasing and the capacity of the existing logistics scale had increased most rapidly. The results are consistent with the present situation, which provides a scientific basis for the relevant departments to formulate the logistics and economic development strategies.

1. Introduction

In recent years, China's logistics industry has been developing rapidly. Many policies to support the development of logistics have come out in succession. However, there are still many problems in the improvement of urban logistics capability. Therefore, scientific analysis of urban logistics capability is of great significance for improving urban logistics capability and comprehensive competitiveness. Scholars at home and abroad have done some researches on the analysis of urban logistics capability. Luo Xiantie[1] finds that the capacity of urban logistics is closely related to the construction of logistics infrastructure, the development level of logistics and the handling capacity of logistics. Liu Lin[2] considers logistics resources and urban efficiency to build an index system for evaluating logistics capability, and proved that these two dimensions have great impact on urban logistics capability. Zhao Xiuli[3] adopts the fuzzy comprehensive evaluation method based on entropy weight to analyse the logistics capability of the supply chain. Banomyong R[4] uses semi-structured analysis of Vietnam's logistics capability to draw the gap between Vietnam's logistics capability and other countries. Sule Önsel Ekici[5] uses artificial neural network to analyse Turkey's logistics capability. So far, the research on urban logistics capability is not comprehensive. Most of the domestic enterprises only stay in the research of logistics capability of enterprises or supply chain, and build the index system of logistics capability evaluation. There is little scientific way to study how to improve the city's logistics capability. Foreign scholars try to use different methods to study the logistics capability of the country, but the direct research on the logistics capability of the city is relatively rare.

From the research method of logistics capability, the existing research mainly uses cluster analysis, fuzzy comprehensive evaluation, data envelopment analysis, grey relational method, neural network method and so on to evaluate the logistics capability of industry or region. These research methods inevitably have the defects of subjectivity, randomness, and easy to lose information. Fuzzy matter-element is the comprehensive application of fuzzy mathematics and matter element analysis,
combining the quality and quantity of things together, so as to reflect the essence of things more deeply, and to describe the process of the change of objective things more accurately. The fuzzy matter element quantification model is introduced into the field of urban logistics capability analysis. This paper analyses the logistics capacity of Shenzhen, explores the internal rules of logistics development, provides reference for improving the logistics capacity of the city, and verifies the adaptability of the model in the field of logistics capability analysis.

2. Establish fuzzy matter-element quantitative model

2.1. Construct the original matter-element model
Assume that compound matter element is \( R_{\text{mre}} \), write down object \( i(i=1,2,\ldots,m) \) as \( M_i \), write down features \( j(j=1,2,\ldots,n) \) as \( C_j \), \( x_{ij} \) represents object \( i \) and feature \( j \), construct the original matter-element model as follows:

\[
R_{\text{mre}} = \begin{bmatrix}
M_1 & M_2 & \cdots & M_m \\
C_1 & x_{11} & x_{12} & \cdots & x_{1n}
C_2 & x_{21} & x_{22} & \cdots & x_{2n}
\vdots & \vdots & \vdots & \ddots & \vdots
C_m & x_{m1} & x_{m2} & \cdots & x_{mn}
\end{bmatrix}
\]  

(1)

2.2. The optimal subordinate degree
\[
x_{ij}^* = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}}, \quad x_j^* = \frac{\min x_j - x_j}{\max x_j - \min x_j}
\]

(2)

Among them: \( \max x_{ij} \) and \( \min x_{ij} \) represents the maximum and minimum of all \( x_{ij} \) corresponding to feature \( j \) respectively, \( x_{ij}^* \) is the optimal subordinate degree of object \( i \) and feature \( j \).

2.3. Construct the optimal fuzzy matter element
\( R_{\text{mre}}^* \) represents fuzzy matter-element of the optimal subordinate degree. The optimal fuzzy matter-element refers to the optimal subordinate degree of each index in \( R_{\text{mre}}^* \). Assume that \( u_{0i}(i=1,2,\ldots,n) \) is corresponding fuzzy value, then optimal fuzzy matter element are as follows:

\[
R_{\text{mre}}^* = \begin{bmatrix}
M_1 \\
C_1 & u_{01} \\
C_2 & u_{02} \\
\vdots & \vdots \\
C_m & u_{0m}
\end{bmatrix}
\]  

(3)

2.4. Difference square compound fuzzy matter element
\( \Delta_j (j=1,2,\ldots,n) \) is used as the square of the difference \( \Delta_j = (x_{ij}^* - x_j^*)^2 \) between the optimal fuzzy matter element \( R_{0n}^* \) and optimal subordinate degree fuzzy compound matter element \( R_{\text{mre}}^* \), form a difference square fuzzy matter element \( R_{\Delta}^* \):
2.5. Entropy method to determine the weight

2.6. Euclidean close degree compound fuzzy matter element

The degree of closeness between each plan and the optimal plan is called close degree. The greater the value is, the closer it is to the optimal plan. By calculating the close degree, we can get the close degree between each plan and the optimal plan and the relative order of the plans.

\[ dH_i = 1 - \sqrt{\sum_{j=1}^{n} w_j \Delta_y, i = 1, 2, ..., m} \]  

(5)

According to \( dH_i \), construct the compound fuzzy matter element of the Euclidean close degree \( R'_{dH} \):

\[
R'_{dH} = \begin{bmatrix}
    M_1 & M_2 & \ldots & M_n \\
    C_1 & \Delta_{11} & \Delta_{12} & \ldots & \Delta_{1m} \\
    C_2 & \Delta_{21} & \Delta_{22} & \ldots & \Delta_{2m} \\
    \vdots & \vdots & \vdots & \ddots & \vdots \\
    C_n & \Delta_{n1} & \Delta_{n2} & \ldots & \Delta_{nm}
\end{bmatrix}
\]  

(4)

3. Construct index system

3.1. Research objects and data

Shenzhen is a traffic hub city. The transportation network of sea, land and air has developed rapidly. Shenzhen has a market and policy suitable for logistics development. As of 2017, the added value of Shenzhen's logistics industry reached 227 billion 639 million yuan, an increase of 9.8%. The logistics industry plays an important role in supporting and promoting the economy of Shenzhen. During the "13th Five-Year" period, the logistics industry in Shenzhen is facing a major transformation. The traditional extensive mode of development is difficult to survive, and must be developed to modern logistics. The growth rate of the logistics industry will continue to slow. This paper analyses the logistics capability of Shenzhen city with certain representativeness.

The quantitative data are mainly derived from the statistical yearbooks of Guangdong, and the statistical yearbooks of Shenzhen and the prospective database of 2007~2016. Because qualitative data is difficult to quantify, this paper uses questionnaires and interviews with industry related experts. Finally, we use fuzzy comprehensive evaluation to get the conclusion. This paper divides the qualitative index into nine grades, and uses \{1, 2, 3, 4, 5, 6, 7, 8, and 9\} to express \{extreme bad, very bad, bad, a little bad, general, good, a little good, very good, excellent\}, specific data are detailed in the appendix.

3.2. Initial index system

This paper uses the literature analysis\(^{[1-5]}\) method to build a first level index system from six aspects to analyse the urban logistics capability. They are logistics infrastructure, the current situation of logistics development, existing logistics scale, relevant economic indicators, logistics information support and logistics development potential. The study preliminarily determines the second level index. Logistics infrastructure is the basic condition for the development of logistics industry. In this paper, the second level indicators are divided into urban real road area, total number of civil vehicles, total number of civil transport vessels and number of port berths. The current situation of logistics development refers to the general development of logistics industry every year. In this paper, the second level index is considered as the number of employees in the logistics industry, the value added of the logistics industry, the proportion of the added value of the logistics industry, and the proportion of the fixed assets investment of the logistics industry to all the fixed assets investment. The existing logistics scale
refers to the existing scale of the city's logistics industry. This paper considers that the second level indicators are the total amount of post and telecommunications, freight volume, freight turnover, airport cargo handling capacity and port cargo throughput. Relevant economic indicators usually measure the overall economic situation of a city and people's living standards. This paper considers that the second level indicators are the total retail sales of consumer goods, the gross domestic product and the per capita GDP. Logistics information support refers to the communication technology and information means to ensure the normal development of logistics activities in this city. This paper considers that the second level indicators are mobile phone users, fixed telephone subscribers, telephone numbers per hundred people, and internet broadband users. Logistics development potential refers to resources and conditions that can promote the development of logistics industry in the future. This paper considers that the second level indicators are the number of college students, the urban basic environmental conditions and the urban logistics development policy.

3.3. Correlation analysis
According to the literature analysis, there is a certain degree of correlation and overlap between the two indicators. At the same time, considering the adaptability of Shenzhen's logistics capability, we use principal component analysis to analyse the correlation of indicators and screen out appropriate indicators to build an index system. The data of the collected quantitative indicators and the score of the qualitative indicators obtained from the questionnaires were input into SPSS for principal component analysis.

3.3.1. Get the initial eigenvalue and the total variance and extract the number of main components
According to the selection principle of principal components, we select the number of principal components whose eigenvalues are greater than 1. A total of four principal components accorded with this condition, and the variance accumulation reached 94.195%. Basically, the four principal components can reflect the information represented by all indicators.

3.3.2. Get the matrix of components after rotation
In order to make the coefficient in the factor load matrix more significant, the rotation factor load matrix is analysed in this study. The result is easy to understand and more explanatory. This paper selects the index of load factor greater than 0.8 to express the meaning of principal component. According to the results of the principal component analysis, the index system used to analyse the logistics capacity of Shenzhen is obtained. Nineteen second level indexes \( C_1, C_2, \ldots, C_{19} \) are expressed as follows:

| First level indexes | Second level indexes |
|---------------------|----------------------|
| Logistics infrastructure | Urban real road area \( C_1 \), Total number of civil vehicles \( C_2 \), Total number of civil transport vessels \( C_3 \). |
| The current situation of logistics development | The number of employees in the logistics industry \( C_4 \), The value added of the logistics industry \( C_5 \), The proportion of the fixed assets investment of the logistics industry to all the fixed assets investment \( C_6 \). |
| Existing logistics scale | Total amount of post and telecommunications \( C_7 \), Freight volume \( C_8 \), Freight turnover \( C_9 \), Airport cargo handling capacity \( C_{10} \), Port cargo throughput \( C_{11} \). |
| Relevant economic indicators | Total retail sales of consumer goods \( C_{12} \), Gross domestic product \( C_{13} \), Per capita GDP \( C_{14} \). |
| Logistics information support | The number of phones per hundred people \( C_{15} \), Internet broadband users \( C_{16} \). |
| Logistics development potential | Number of college students \( C_{17} \), Urban basic environment conditions \( C_{18} \), Urban logistics development policy \( C_{19} \). |
4. Quantitative process and result analysis

4.1. Quantitative process
The research takes years as objects, indicators as characteristics, and determines all data used to construct complex elements. Among them, \( M_1, M_2, \ldots, M_{10} \) represent 2007~2016 respectively. According to the entropy method, the weights of the nineteen indicators are calculated.

| Index | Weight | Index | Weight | Index | Weight | Index | Weight |
|-------|--------|-------|--------|-------|--------|-------|--------|
| C1    | 0.015  | C6    | 0.041  | C11   | 0.004  | C16   | 0.125  |
| C2    | 0.083  | C7    | 0.168  | C12   | 0.072  | C17   | 0.016  |
| C3    | 0.032  | C8    | 0.034  | C13   | 0.075  | C18   | 0.030  |
| C4    | 0.084  | C9    | 0.068  | C14   | 0.049  | C19   | 0.020  |
| C5    | 0.042  | C10   | 0.030  | C15   | 0.013  |

According to formula (1) ~ (7), the European closeness in 2007-2016 is calculated:

\[
R_{EH}^* = \left[ \begin{array}{cccccccccc}
M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 & M_8 & M_9 & M_{10} \\
0.045 & 0.138 & 0.190 & 0.241 & 0.345 & 0.413 & 0.535 & 0.607 & 0.709 & 0.773
\end{array} \right]
\]

4.2. Result analysis
Shenzhen's logistics capability in 2007~2016 has been increasing gradually. This shows that Shenzhen's logistics capabilities have improved significantly. Among them, the logistics capability of 2007~2010 has been increasing steadily in the trend of slower growth. The annual growth rate of logistics capacity in 2011~2016 fluctuated significantly, but the upward trend was still obvious. The logistics capability of the first level index is basically on the rise. Among them, the existing logistics scale capacity growth is the fastest. Logistics development potential and logistics information support make the greatest contribution to the upgrading of logistics capability in Shenzhen. Among the second level indicators, total amount of post and telecommunications, internet broadband users, total number of civil vehicles, and the number of employees in the logistics industry are relatively large. As can be seen from Figure 1, the indicators with relatively high weight are basically increasing every year. These indicators have great contribution to the improvement of logistics capability.

![Figure 1. The annual percentage increase of the larger weight index (%).](image)

Based on the analysis of the current situation of logistics in Shenzhen and the quantitative results, this paper puts forward some improvement strategies for the logistics and economic development of Shenzhen: Relevant departments should coordinate the construction of water, land and air, pay attention to the compatibility of various transport facilities and the compatibility of various modes of transportation, and improve land use rate and utilization rate of facilities. They should give full play to
the overall role of the government, plan and coordinate the logistics industry, and optimize the resources and structure of the logistics industry. They also should seek the breakthrough of the port development, improve the level of logistics information, and promote the development of traditional logistics to modern logistics.

5. Conclusions
Taking the urban logistics capability as the research object, this paper combines entropy method and fuzzy matter element analysis to establish a fuzzy matter-element quantitative model. Based on the analysis of the logistics capability of Shenzhen, six indexes of the first level and nineteen indexes of second level are set up to analyse the logistics capability analysis index system of Shenzhen. Based on the fuzzy matter-element quantitative model, the quantitative analysis of Shenzhen's urban logistics capability is carried out. The result of the example shows that the overall logistics capability of Shenzhen 2007~2016 has been increasing gradually. At the same time, it validates the adaptability of fuzzy matter-element quantitative model in urban logistics capability analysis.

6. Appendices

Table 3. Quantitative index and value of urban logistics capacity

| C  | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|----|------|------|------|------|------|------|------|------|------|------|
| 1  | 8322 | 8630 | 8864 | 9080 | 10629 | 11496 | 11633 | 11838 | 11920 |
| 2  | 116.008 | 128.757 | 145.264 | 170.546 | 197.616 | 224.922 | 262.287 | 315.390 | 319.350 | 322.588 |
| 3  | 142 | 160 | 173 | 220 | 227 | 245 | 252 | 265 | 269 | 277 |
| 4  | 15.472 | 17.143 | 18.379 | 20.354 | 29.443 | 47.095 | 463.291 | 500.405 | 540.80 | 626.32 |
| 5  | 18.421 | 19.212 | 23.033 | 18.773 | 16.315 | 10.995 | 16.995 | 12.728 | 12.053 | 10.965 |
| 6  | 513.540 | 611.750 | 676.520 | 293.700 | 563.580 | 622.990 | 761.990 | 1040.320 | 1715.020 |
| 7  | 1.368 | 1.957 | 2.237 | 2.618 | 2.890 | 3.034 | 2.751 | 2.938 | 3.097 | 3.116 |
| 8  | 794.100 | 1094.160 | 1136.640 | 1654.160 | 1955.690 | 1988.920 | 2386.370 | 2267.250 | 2246.860 |
| 9  | 62 | 60 | 61 | 81 | 85 | 85 | 91 | 96 | 101 | 113 |
| 10 | 1.999 | 2.113 | 1.937 | 2.210 | 2.233 | 2.281 | 2.340 | 2.232 | 2.171 | 2.141 |
| 11 | 1930.805 | 2276.586 | 2567.844 | 3000.763 | 3520.874 | 4008.779 | 4500.456 | 4918.998 | 5017.838 | 5512.756 |
| 12 | 6801.571 | 7786.792 | 8290.284 | 9773.306 | 11515.860 | 12971.460 | 14572.660 | 16001.820 | 17502.860 | 19492.60 |
| 13 | 7.627 | 8.343 | 8.506 | 9.618 | 11.052 | 12.345 | 13.763 | 14.950 | 15.799 | 16.741 |
| 14 | 244 | 246 | 234 | 243 | 274 | 296 | 286 | 362 | 296 | 264 |
| 15 | 189 | 205 | 247 | 261 | 280 | 304 | 398 | 442 | 674 | 632 |
| 16 | 5.891 | 6.563 | 6.695 | 6.732 | 7.000 | 7.557 | 8.240 | 8.767 | 9.011 | 9.188 |
| 17 | 3 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6 |
| 18 | 4 | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 7 |

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