Analysis of Port Competitiveness Based on Multi-level Grey System Evaluation

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Abstract

In order to be able to more accurately evaluate the port competitiveness, the design of port competitiveness evaluation system, establish a multi-level evaluation model of grey system, with domestic coastal ports in Shanghai port, Guangzhou port, Ningbo port and Xiamen as an example, and then establish port competitiveness evaluation index system, calculation of single correlation, multi-layer structure correlation synthesis and the port competitiveness. The final result shows that the port competitiveness is in order of Shanghai port, Ningbo port, Guangzhou port and Xiamen port.

Keywords

Port competitiveness; multi-level grey evaluation model; evaluation index system; correlation.

1. Introduction

The port is not only the central link in the transport network, but also an important link in the economic system. The port competitiveness not only has a huge impact on the overall competitiveness of the region, but also has a certain impact on the competitiveness of the whole country. Therefore, the study of port competitiveness is an inevitable requirement for the development of China's market economy and the change of the world's shipping structure.

Many scholars have studied port competitiveness accordingly. Literature [1] by using the growth rate and DEA analysis numerical respectively as the longitudinal axis and the horizontal axis of the Boston matrix, reveals that the northeast Asia between 2001 and 2007 in The Three Kingdoms (China, Japan, South Korea) twelve important container port competition status changes, and according to the port of growth and development of performance value of the port technology were compared and the sorting efficiency and competition status. Literature [2] adopted UTAGMS method, combined with limit sequencing analysis and monte carlo simulation, to carry out empirical analysis on the competitiveness of 16 core ports in the trunk line of the Yangtze river in China. Literature [3] makes a systematic analysis and research on the comprehensive competitive force of several major ports in China by using data envelopment analysis method. Literature [4] discusses the points, mathematical models and calculation steps of factor analysis for key indicators, and applies it to the analysis of several typical inland ports. Literature [5] determines the index weight through the analytic hierarchy process, and comprehensively evaluates four ports, including Wuhan port, with the integrated TOPSIS model of gray correlation. Literature [6] takes grey relational analysis as the basic method, and combines the analytic hierarchy process to determine the weight, builds the evaluation index system by analyzing the influencing factors of iron ore ports, and evaluates the development of iron ore port logistics in Dalian port and 12 other ports. Literature [7] applied the multi-level grey evaluation method of comprehensive empowerment to the selection of strategic alliance partners of Rizhao port, sorted 16 influential ports in China, and selected suitable partners for Rizhao port.

The above research has not carried out systematic and scientific research on the influence index of port competitiveness. At present, the research on port competitiveness has not been completed. This paper will establish a multi-level evaluation system for the influence factors of port competitiveness, and put forward its research method based on the combination of quantitative and qualitative thinking.

2. Design of Port Competitiveness Evaluation System

In order to objectively and scientifically evaluate the competitiveness of ports and observe the position of ports in the competition, it is necessary to design a set of scientific, complete and comprehensive index system that can reflect the competitiveness of ports from all directions and angles. According to the design principles of scientificity, integrity and rationality of the index system, some indexes that can not only reflect the main aspects of the connotation of port competitiveness, but also obtain data from the existing statistical data are selected as the index system to evaluate the port competitiveness by using the gray theory, as shown in table 1.

The evaluation system is composed of five categories and 18 indicators, which better reflects the basic connotation of port competitiveness. For a port to have strong competitiveness, it must have strong competitiveness of port conditions, port production level, hinterland city, port development potential and convenient distribution and transportation.

Table 1 port competitiveness evaluation index system

Level 1 (target layer A)	Level 2 (criteria layer B)	Level 3 (index layer C)
Port competitiveness A	Port condition competitiveness B1	Number of berths/unit C1
		Number of 10,000-ton berths per unit C2
		Length of berth /m C3
		Number of loading and unloading machines/set C4
		Number of container liner routes / article C5
	Port productivity level competitiveness B2	Cargo throughput/ton C6
		Container throughput / 10,000 TEU C7
		Foreign trade cargo throughput/tons C8
	Hinterland urban competitiveness B3	Fixed assets investment / 100 million yuan C9
		City GDP/ 100 million yuan C10
		The proportion of tertiary industry in GDP /% C11
		Total imports and exports/us $100 million C12
	Port development potential competitiveness B4	Cargo throughput growth rate /% C13
		Container throughput growth rate /% C14
		Foreign trade cargo throughput growth rate /% C15
		Total import and export growth rate /% C16
	Collection and distribution of convenient degree B5	Highway traffic mileage /km C17
		Expressway mileage /km C18

3. Multi-level Grey System Evaluation Model

Grey correlation analysis provides a method for quantitative analysis of the degree of correlation between various factors [8].Here, the basic idea of grey correlation analysis to evaluate competitiveness is as follows: take each index value of the optimal competitive port among ports as

the reference X_0entity x_{0k}, and each index of the evaluated port as the $X_i$entity x_{ik} of the comparison sequence, and calculate the correlation degree r_i.The greater the correlation degree is, the more similar the evaluated port is to the most competitive port, the stronger its competitiveness will be. Conversely, the competitiveness is weaker. Therefore, the order of the degree of correlation is the order of the competitiveness of the evaluated port. The evaluation steps are as follows.

3.1 Select the Reference Sequence

Let: i be the serial number of the ith evaluation unit (port), $\mathrm{i} = 1,2,\cdots,\mathrm{m}$; k is the serial number of the kth evaluation index, $\mathrm{k} = 1,2,\cdots,\mathrm{n}$; v_{ik} is the evaluation value of the kth index of the ith evaluation unit.

Take the optimal value v_{0k} of each indicator and refer to the entity of the sequence V_0, then:

$$V_0 = (v_{01}, v_{02}, \cdots, v_{0n}) \tag{1}$$

In the formula:$v_{0k} = \mathrm{Optimum}(v_{ik}), \mathrm{i} = 1,2,\cdots,\mathrm{m}; \mathrm{k} = 1,2,\cdots,\mathrm{n}.$

For a system with m evaluation units (ports) and n evaluation indexes, the following matrix is obtained:

$$\mathrm{V} = (V_{ik})_{m\times n}\begin{bmatrix} V_{11} & V_{12} & \cdots & V_{1n} \\ V_{21} & V_{22} & \cdots & V_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ V_{m1} & V_{m2} & \cdots & V_{mn} \end{bmatrix} \tag{2}$$

The number of parameters selected is listed as:

$$V_0 = (v_{01}, v_{02}, \cdots, v_{0n}) \tag{3}$$

3.2 Normalized Processing of Index Values

In order to make each index comparable, it is necessary to normalize the value of each index. The normalized formula is as follows:

$$X_{ik} = \frac{V_{ik} - \min\limits_i V_{ik}}{\max\limits_i V_{ik} - \min\limits_i V_{ik}} \tag{4}$$

After normalization,

$$\mathrm{X} = (X_{ik})_{m\times n}\begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix} \tag{5}$$

3.3 Calculation of Correlation Coefficient

Take the normalized sequence $X_0 = (x_{01}, x_{02}, \cdots, x_{0n})$ as the reference sequence, $X_i = (x_{i1}, x_{i2}, \cdots, x_{in})(i = 1,2,\cdots,m)$ is used as the comparison sequence, and the calculation formula of the correlation coefficient is:

$$\xi_{ik} = \frac{\min\limits_i \min\limits_k |X_{0k} - X_{ik}| + \rho \max\limits_i \max\limits_k |X_{0k} - X_{ik}|}{|X_{0k} - X_{ik}| + \rho \max\limits_i \max\limits_k |X_{0k} - X_{ik}|} \tag{6}$$

In equation (6), rho acuity coefficient, $\rho \in [0,1]; \mathrm{i} = 1,2,\cdots,\mathrm{m}; \mathrm{k} = 1,2,\cdots,\mathrm{n}$.

The deflections $\xi_{ik}(\mathrm{i} = 1,2,\cdots,\mathrm{m}; \mathrm{k} = 1,2,\cdots,\mathrm{n})$, and the following correlation coefficient matrix is obtained:

$$\mathrm{E} = (\xi_{ik})_{m\times n}\begin{bmatrix} \xi_{11} & \xi_{12} & \cdots & \xi_{1n} \\ \xi_{21} & \xi_{22} & \cdots & \xi_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \xi_{m1} & \xi_{m2} & \cdots & \xi_{mn} \end{bmatrix} \tag{7}$$

In formula (7): ξ_{ik} is the correlation coefficient of the kth index of the ith evaluation unit (port) with the kth best index.

3.4 Calculation of Single-level Correlation Degree

Considering the importance of each index is not the same, so the calculation method of correlation degree adopts weight multiplied by correlation coefficient. According to the expert method, the priority weight of each index in a certain layer relative to the upper target is:

$$W = (\omega_1, \omega_2, \cdots, \omega_n) \tag{8}$$

Type (8) : $\sum_{k=1}^{t} \omega_k = 1$, t said index number in this layer.Then the calculation formula of correlation degree is:

$$R = (r_i)_{1\times m} = (r_1, r_2, \cdots, r_m) = WE^T \tag{9}$$

3.5 Calculate the Final Correlation Degree of the Multi-level Evaluation System

For a multi-level evaluation system composed of L layers, the calculation method of the final correlation degree is as follows: Then take the correlation degree of this layer as the original data, continue to synthesize the correlation degree of each index of the k-2 layer, and so on, until the correlation degree of the highest level index is calculated.

3.6 Ranking of Port Competitiveness

According to the degree of correlationr_i(i = 1,2,⋯, m), the order of correlation degree is the order of port competitiveness.

4. Application Examples

Here, four major domestic ports, namely Shanghai port, Tianjin port, Ningbo port and Xiamen port (V_1,V_2,V_3,V_4), are taken as examples and compared.

4.1 Establishment of Port Competitiveness Evaluation Index System

The evaluation index system of port competitiveness is shown in figure 1. The system is composed of three layers of indicators, namely, the first layer: target layer, port competitiveness (A);The second layer: factor layer, including port condition competitiveness (B_1), port production level competitiveness (B_2), hinterland city competitiveness (B_3), port development potential competitiveness (B_4) and transport convenience (B_5);The third layer: indicator layer, with a total of 18 indicators (C_1, C_2,... C_{18}).

4.2 Calculation of Single-layer Correlation Degree

Four major domestic ports: Shanghai port, Tianjin port, Ningbo port and Xiamen port (V_1,V_2,V_3,V_4).Data v_{ik}(i = 1,2,3,4; k = 1,2,3,⋯,18) and the optimal value $v_{ik}$of each indicator are listed in table 2.

Table 2 port index values and satisfaction values

Port / Indicator	V_1	V_2	V_3	V_4	Satisfaction
C_1	1.80	1.50	1.70	1.50	2.00
C_2	2.50	2.10	2.30	2.30	3.00
C_3	1.40	1.50	1.70	1.30	2.00
C_4	2.50	2.30	2.60	2.50	2.00
C_5	1.30	1.60	1.60	1.50	1.00
C_6	0.68	0.80	0.75	0.76	0.60
C_7	0.09	0.08	0.09	0.07	0.10
C_8	0.19	0.22	0.20	0.16	0.30
C_9	0.08	0.10	0.13	0.11	0.15
C_{10}	0.08	0.12	0.16	0.13	0.45
C_{11}	0.17	0.11	0.21	0.16	0.30

C_{12}	0.11	0.14	0.21	0.11	0.30
C_{13}	0.65	0.55	0.70	0.55	1.00
C_{14}	0.76	0.82	0.56	0.60	1.00
C_{15}	0.10	0.14	0.20	0.11	0.26
C_{16}	0.21	0.09	0.14	0.12	0.25
C_{17}	0.15	0.14	0.10	0.11	0.20
C_{18}	0.13	0.10	0.12	0.09	0.15

Table 2 shows the reference sequence

V_0=(2.00,3.00,2.00,2.00,1.00,0.60,0.10,0.30,0.15,0.45,0.30,0.30,1.00,1.00,0.26,0.25,0.20,0.15)

The deflective coefficient of association of each index with the best value of the reference series obtained after the deflective values in table 2 were normalized. The values of$\xi_{ik}(\mathrm{i}=1,2,\cdots,\mathrm{m};\mathrm{k}=1,2,\cdots,\mathrm{n})$are listed in table 3.

Table 3 relates to the numerical table

Port / Correlation coefficient	V_1	V_2	V_3	V_4
ξ_{i1}	0.89	0.60	0.78	0.60
ξ_{i2}	0.63	0.45	0.52	0.52
ξ_{i3}	0.49	0.55	0.72	0.45
ξ_{i4}	0.50	0.67	0.45	0.50
ξ_{i5}	0.67	0.45	0.45	0.50
ξ_{i6}	0.74	0.45	0.54	0.52
ξ_{i7}	0.96	0.74	0.96	0.61
ξ_{i8}	0.52	0.63	0.55	0.45
ξ_{i9}	0.85	0.55	0.63	0.45
ξ_{i10}	0.52	0.48	0.48	0.45
ξ_{i11}	0.69	0.45	0.54	0.57
ξ_{i12}	0.69	0.50	0.54	0.45
ξ_{i13}	0.52	0.45	0.57	0.45
ξ_{i14}	0.63	0.72	0.45	0.48
ξ_{i15}	0.45	0.54	0.77	0.47
ξ_{i16}	0.89	0.45	0.56	0.51
ξ_{i17}	0.65	0.61	0.45	0.48
ξ_{i18}	0.78	0.50	0.67	0.45

4.3 Synthesis of Multilayer Structure Correlation Degree

The following weights are obtained by using the expert survey method:

$$W_{AB}=(0.25,0.21,0.20,0.17,0.17)$$
$$W_{B_1C}=(0.22,0.22,0.20,0.18,0.18)$$
$$W_{B_2C}=(0.35,0.35,0.30)$$
$$W_{B_3C}=(0.25,0.25,0.25,0.25)$$
$$W_{B_4C}=(0.30,0.30,0.20,0.20)$$
$$W_{B_5C}=(0.50,0.50)$$

Using the formula $\mathrm{R}=WE^T$ get the index correlation of layer B:

$$R_{B_1}=W_{B_1C}E_{B_1C}^T=(0.643,0.543,0.592,0.516)$$

$$R_{B_2} = W_{B_2C}E_{B_2C}^T = (0.751,0.605,0.690,0.531)$$
$$R_{B_3} = W_{B_3C}E_{B_3C}^T = (0.688,0.495,0.530,0.480)$$
$$R_{B_4} = W_{B_4C}E_{B_4C}^T = (0.613,0.549,0.572,0.479)$$
$$R_{B_5} = W_{B_5C}E_{B_5C}^T = (0.715,0.555,0.560,0.465)$$

In the above formula, $E_{B_1C}, E_{B_2C}, E_{B_3C}, E_{B_4C}, E_{B_5C}$ are matrices composed of corresponding data in table 3, respectively.

The correlation degree of the highest index A can be obtained further.

$$R_A = (r_1, r_2, r_3, r_4) = W_{AB}\left[R_{B_1}, R_{B_2}, R_{B_3}, R_{B_4}, R_{B_5}\right]$$
$$=(0.682,0.549,0.591,0.497)$$

4.4 Ranking of Port Competitiveness

According to the degree of correlation in R_A, the order of competitiveness of ports can be obtained as follows: $V_1>V_3>V_2>V_4$, that is, the competitive advantage of Shanghai port is the largest, followed by Ningbo port, Guangzhou port and Xiamen port.

5. Conclusion

(1) As mentioned above, the port competitiveness system is actually an incomplete and inaccurate system. The grey system theory can be used to evaluate the port competitiveness, and the information source can be expanded and the credibility of the scoring board can be improved under the condition of incomplete and inaccurate information.

(2) When calculating the correlation degree, the weighted average synthesis method is used instead of the arithmetic average synthesis method to consider the difference of the importance degree of each index, which is more reasonable and more accurate.

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