Research on Competitiveness Evaluation of Major Inland Ports in China

Siyuan Tang1*, Jianbao Zhang1 and Linan Du1

1China Waterborne Transport Research Institute, Beijing, 10088, China
*Corresponding author’s e-mail: tangsy@wti.ac.cn

Abstract. This paper constructs the competitiveness evaluation model and indicator system of inland port from three aspects of infrastructure, production capacity and development environment. The competitiveness of 31 major ports in the four river systems is measured by analytic hierarchy process and correlation coefficient method. According to the competitiveness evaluation results, K-means clustering analysis is carried out for inland ports by SPSS software. The results show that the competitiveness of inland ports in China is relatively low, and there is a significant gap between the competitiveness of ports in the same river system and different river systems. Each port has its own competitive sources. Highlighting the development advantages of each port and making up for the shortcomings will help to improve the efficiency of port resource allocation. At the same time, suggestions are put forward to improve the competitiveness of inland ports.

1. Introduction

In recent years, remarkable achievements have been made in the construction of inland waterways and inland port facilities. The inland shipping system, with the main framework of the Yangtze River system, the Pearl River system, the Beijing Hangzhou Canal system, the Huaihe River system, the Heilongjiang River system and the Songliao River system, has initially formed. The inland ports have played an increasingly important role in promoting the economic development of the hinterland and promoting the regional economic integration.

Inland shipping has the advantages of low cost, less land occupation, low energy consumption, small pollution and large transportation capacity. However, compared with coastal ports, inland port construction is still lagging behind and port service function needs to be improved. The competitiveness of inland ports is low. To speed up the development of inland shipping can effectively alleviate the land resource shortage and the pressure of land transportation of bulk materials in the river basin, and play a positive role in improving the comprehensive transportation system and promoting the cost reduction and efficiency increase of transportation. In this paper, 31 inland ports are taken as the research objects to build the competitiveness evaluation model of inland ports. From the three dimensions of infrastructure, production capacity and development environment, the competitiveness level of each port is measured. According to the results of competitiveness evaluation, K-means clustering is carried out to analyze the spatial distribution characteristics of the competitiveness of inland ports. Finally, suggestions are put forward to improve the competitiveness of inland ports.
2. Research methods and data processing

2.1. Construction of indicator system

Port competitiveness is a concept of sustainability, potentiality and comprehensiveness. It emphasizes the comprehensive ability based on the current situation of port development and relevant supporting environment, relying on the existing infrastructure, technical equipment, resource investment and operation management, and aiming at the future development of the port. Based on the influencing factors and industrial characteristics of port economy, this paper constructs the evaluation model and indicator system. The competitiveness of inland ports is mainly affected by three factors: firstly, port infrastructure, reflecting the hardware facilities and equipment conditions of the port for production and operation, involving port coastline, wharf berth, storage yard, loading and unloading equipment, etc; secondly, the port production capacity, involving the port cargo throughput and container throughput, which is a comprehensive indicator of port production and operation; thirdly, the port development environment, including the economic and trade situation of the city where the port is located, which is an important factor affecting the development of the port. On this basis, the evaluation model suitable for this study is as follows:

\[ PC = f(C_1, C_2, C_3) = \sum_{i=1}^{3} w_i C_i \]

\[ C_i = \sum_{j=1}^{n} w_{ij} x_{ij} \]

In the formula, \( PC \) is the port competitiveness; \( C_i \) is the evaluation indicator; \( C_1 \) is the infrastructure; \( C_2 \) is the production capacity; \( C_3 \) is the development environment; \( w_i \) is the weight of \( C_i \); \( x_{ij} \) is the standardized value of the evaluation indicator; \( w_{ij} \) is the weight of each specific indicator.

According to the above model, this paper divides the competitiveness evaluation indicator system of inland port into three layers. Namely, the total target layer (\( PC \)) is the port competitiveness. The second layer is the criterion layer, which adopts three kinds of indicators: infrastructure, production capacity and development environment. The third layer is the indicator layer, represented by 8 indicators, following the principles of scientific rationality, comprehensiveness and data availability. (Table 2).

2.2. Research scope, data sources and evaluation methods

2.2.1. Research scope and data sources

In view of the availability and integrity of the data, this paper selects 31 major inland ports of the Yangtze River system, the Pearl River system, the Beijing Hangzhou Canal and the Songliao River system as samples (Table 1). The statistical data selected in this paper are from Compilation of National Transportation Statistics in 2016 and 2017 and National Economic and Social Development Statistical Bulletin of each port city.

| Inland river system          | Major inland port                                                                 |
|------------------------------|-----------------------------------------------------------------------------------|
| Yangtze River system         | Upstream——Yichang, Chongqing, Luzhou and Yibin                                   |
|                              | Midstream——Wuhan, Huangshi, Jingzhou and Jiujiang                                 |
|                              | Downstream——Nanjing, Zhenjiang, Suzhou, Nantong, Jiangyin, Yangzhou, Taizhou,     |
|                              | Maanshan, Wuhu, Tongling, Chizhou and Anqing                                     |
| Pearl River system           | Nanning, Laibin, Guigang, Wuzhou, Zhaoping and Foshan                             |
| Beijing Hangzhou Canal       | Xuzhou, Wuxi, and Hangzhou                                                        |
| Songliao River system        | Harbin and Jiamusi                                                                |

2.2.2. Indicator weight determination

In this paper, correlation coefficient method is used for indicator layer weighting, and analytic hierarchy process is used for criterion layer weighting. This is
mainly based on the following considerations: analytic hierarchy process is more suitable for the evaluation of abstract concepts such as criterion layer; correlation coefficient method is to use the degree of closeness (correlation) between indicators reflected by correlation coefficient to measure the possibility of indicators being replaced, so as to obtain the importance of indicators. The greater is the degree of correlation, the stronger substitutability is the indicator and the smaller the weight, and vice versa. In this paper, the subjective and objective combination weighting method is selected to make the evaluation result more credible (Table 2).

Table 2. Inland Port Competitiveness Evaluation Indicator System and Weighting Results in China

| Target layer | Criterion layer (AHP weighting results) | Indicator layer | Weighting results |
|--------------|----------------------------------------|-----------------|------------------|
| Ports        | $C_1$ infrastructure (0.26)             | $x_1$ berth length for production (m) | 0.28 |
|              |                                        | $x_2$ number of berths                 | 0.20 |
|              |                                        | $x_3$ storage area (m$^2$)              | 0.28 |
|              |                                        | $x_4$ number of handling machinery     | 0.24 |
|              | $C_2$ production capacity (0.41)        | $x_5$ cargo throughput (ten thousand tons) | 0.52 |
|              |                                        | $x_6$ container throughput (TEU)       | 0.48 |
|              | $C_3$ development environment (0.33)    | $x_7$ local GDP (billion yuan)          | 0.51 |
|              |                                        | $x_8$ foreign trade volume (billion dollars) | 0.49 |

2.2.3. Data standardization processing. Considering that there are many indicators variables in the evaluation indicator system, and their properties are different, they have different dimensions and orders of magnitude. In order to avoid the attribute difference and incompatibility of each indicator brought by dimension and ensure the reliability of the result, this paper selects standardization method to deal with the original indicator dimensionless. The formula is as follows:

$$x'_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j}$$  \hspace{1cm} (3)

$x'_{ij}$ is the dimensionless value of indicator $j$ in region $i$; $x_{ij}$ is the original value of indicator; $\bar{x}_j$ is the mean value of indicator $j$ in each region; $s_j$ is the standard deviation of indicator $j$, which is a parameter used to measure the degree of variation of the indicator.

3. Port competitiveness evaluation

3.1. Measurement of criterion layer competitiveness
First of all, based on the competitiveness evaluation indicator system of inland ports, the original values of each indicator variable (Table 3) of 31 major inland ports in China are standardized according to formula (3). Then, the standardized value of each indicator variable value and the corresponding weight in Table 2 are substituted into the formula (1) of the evaluation model, and the evaluation value of each criterion layer of the inland river port can be calculated (Figure 1).
According to the competitiveness measurement results of inland ports in China, from the perspective of port infrastructure, Suzhou Port, Chongqing port and Wuxi port are all rated above 2, which are in the first echelon; followed by Nanjing port, Wuhan port, Xuzhou port and Hangzhou port, which are rated above 1.5, which are in the second echelon. From the perspective of port operation capacity, Suzhou Port, Nanjing port and Foshan port are in the top three. Especially, Suzhou Port's operation capacity score is 5.23, and its cargo throughput and container throughput are far higher than other ports. From the perspective of port development environment, Suzhou, Wuhan, Chongqing, Hangzhou, Nanjing have advantages in economic and foreign trade development level, so the score of their port development environment is relatively high.

| Inland river system | Port      | $x_1$  | $x_2$  | $x_3$  | $x_4$  | $x_5$  | $x_6$  | $x_7$  | $x_8$  |
|---------------------|-----------|--------|--------|--------|--------|--------|--------|--------|--------|
| Yangtze River system| Nanjing   | 28672  | 221    | 2315354| 1211   | 23637  | 316741 | 11715.1| 611.9  |
|                     | Zhenjiang | 22482  | 209    | 2300113| 760    | 14203  | 405288 | 4105.4 | 105.4  |
|                     | Suzhou    | 44977  | 290    | 8838113| 1753   | 60456  | 587519 | 17300.0| 3160.8 |
|                     | Nantong   | 18652  | 105    | 2516035| 972    | 23572  | 1007150| 7734.6 | 349.7  |
|                     | Jiaxing   | 14191  | 96     | 3472728| 641    | 15971  | 540718 | 3488.3 | 211.0  |
|                     | Yangzhou  | 7603   | 44     | 1266040| 371    | 9424   | 489111 | 5064.9 | 108.0  |
|                     | Taizhou   | 19721  | 154    | 651237 | 201    | 19942  | 330284 | 4744.5 | 129.5  |
|                     | Ma’anshan | 9376   | 122    | 853028 | 1920   | 11014  | 44003  | 1163.9 | 55.5   |
|                     | Wuhan     | 14186  | 138    | 1240000| 460    | 12806  | 703975 | 3065.5 | 63.8   |
|                     | Tongling  | 7889   | 82     | 720550 | 236    | 11095  | 44003  | 1163.9 | 55.5   |
|                     | Chizhou   | 8395   | 90     | 326200 | 174    | 4783   | 15380  | 654.1  | 7.7    |
|                     | Anqin     | 6553   | 75     | -      | 338    | 2401   | 82839  | 1708.6 | 13.9   |
|                     | Jiujian   | 14466  | 137    | 797263 | 734    | 11171  | 334731 | 2413.6 | 345.3  |
|                     | Wuhan     | 19436  | 83     | 2122559| 2001   | 10018  | 1357393| 13410.3| 1936.2 |
|                     | Huangshi  | 7462   | 83     | 227328 | 114    | 4039   | 30021  | 1479.4 | 33.7   |
|                     | Jingzhou  | 4957   | 58     | 150860 | 81     | 1043   | 109429 | 1922.2 | 14.2   |
|                     | Yichang   | 22799  | 227    | 376569 | 198    | 1010   | 170180 | 3857.2 | 27.3   |
|                     | Chongqing | 67078  | 742    | 5204135| 730    | 19722  | 1288521| 19500.3| 667.9  |
|                     | Luzhou    | 5402   | 83     | 724361 | 114    | 3493   | 550240 | 1596.2 | 20.6   |
|                     | Yibin     | 3139   | 80     | 92260  | 62     | 1392   | 31139  | 1847.2 | 8.5    |
| Pearl River system  | Nanning   | 5796   | 91     | 412337 | 84     | 1380   | 5333   | 4118.8 | 89.9   |
|                     | Laibin    | 3191   | 55     | 241414 | 53     | 1152   | 31139  | 663.7  | 1.1    |
|                     | Guigang   | 8529   | 113    | 731326 | 349    | 6322   | 222188 | 1082.2 | 3.5    |
|                     | Wuzhou    | 4832   | 78     | 331502 | 89     | 3634   | 647332 | 1338.1 | 8.9    |
|                     | Zhaoqing  | 4095   | 61     | 491345 | 227    | 3973   | 803844 | 2200.6 | 357.9  |
|                     | Foshan    | 19497  | 290    | 2165470| 685    | 7967   | 3901227| 9549.6 | 645.5  |
| Beijing Hangzhou canal| Xuzhou    | 19820  | 297    | 4631435| 1185   | 7420   | 15185  | 6606.0 | 78.1   |
|                     | Wuxi      | 40874  | 802    | 889285 | 1010   | 5396   | 30181  | 10511.8| 812.5  |
|                     | Hangzhou  | 24802  | 730    | 1501550| 775    | 10714  | 51382  | 12556.0| 753.3  |
| Songhua River system| Harbin    | 4086   | -      | 388600 | 66     | 122    | -      | 6355.0 | 33.6   |
|                     | Jiamusi   | 4640   | -      | 318386 | 64     | 198    | -      | 895.6  | 7.8    |

Note: limited by statistical data, $x_3$ and $x_4$ in the table are the data for 2016 and the rest are the data for 2017.
3.2. Measurement of port comprehensive competitiveness

The comprehensive evaluation value of the competitiveness of each inland port can be calculated by substituting the evaluation value of infrastructure, operation capacity and development environment of 31 inland ports and the weight of the criteria layer in Table 2 into formula (1) (Figure 2). It can be seen that the comprehensive competitiveness score of Suzhou Port is 4.44, ranking first, which shows that Suzhou Port has obvious advantages in infrastructure, operation ability and development environment. The comprehensive competitiveness scores of Chongqing Port, Nanjing Port, Wuhan Port and Foshan Port are more than 1.5 points. Compared with other inland ports, the competitive advantage is obvious. From the perspective of the four major water systems, the average comprehensive competitiveness of the three ports of the Beijing Hangzhou canal is the highest, which is 1.31. Secondly, there are 20 ports in the Yangtze River system, with the average comprehensive competitiveness of 1.11. There are many ports in the Yangtze River system, and the competitiveness gap of each port is obvious. The average comprehensive competitiveness of six ports in the Pearl River system is 0.68. However, the comprehensive competitiveness scores of Harbin Port and Jiamusi Port in Songliao water system are lower, which are 0.46 and 0.27 respectively.

3.3. Spatial structure analysis of port competitiveness

According to the evaluation results of port competitiveness, 31 ports are divided into four echelons by K-means clustering analysis of SPSS software. The first echelon is Suzhou Port; the second echelon includes Nanjing Port, Wuhan Port, Chongqing Port and Foshan Port; the third echelon includes 11 ports, including Zhenjiang port, Nantong Port and Jiangyin Port; the fourth echelon includes 15 ports, including Yangzhou Port, Wuhu port and Anqing Port. The classification also passed the significance test (Table 4, table 5)
Table 4. Echelon Division of Competitiveness of 31 Inland Ports

| Classification   | Evaluation Value | Port                                |
|------------------|------------------|-------------------------------------|
| The first echelon| 4.44             | Suzhou                              |
| The second echelon| 1.76-2.40       | Nanjing, Wuhan, Chongqing, Foshan   |
| The third echelon| 0.78-1.46       | Zhenjiang, Nantong, Jiangyin, Yangzhou, Taizhou, Ma’anshan, Wuhu, Jiujiang, Xuzhou, Wuxi, Hangzhou |
| The fourth echelon| 0.27-0.63       | Tongling, Chizhou, Anqing, Huangshi, Jingzhou, Yichang, Luzhou, Yibin, Nanning, Laibin, Guigang, Wuzhou, Zhaoqing, Harbin, Jiamusi |

Table 5. the results of ANOVA

| Indicator            | Mean Squares | df | F     | Sig. |
|----------------------|--------------|----|-------|------|
| Infrastructure        | 5.782        | 3  | 40.793| .000 |
| production capacity   | 7.799        | 3  | 51.282| .000 |
| Development environment| 7.723       | 3  | 50.582| .000 |
| Comprehensive         | 6.879        | 3  | 134.554| .000 |

From the cluster analysis results of the competitiveness of inland ports, the competitiveness gap of inland ports in China is obvious. Suzhou Port ranks first with a comprehensive evaluation value of 4.44, ranking first in infrastructure, operational capacity and development environment. The competitive advantage of Nanjing Port and Foshan Port in the second echelon mainly comes from the high evaluation value of production capacity. The competitive advantages of Chongqing Port mainly lie in the infrastructure and development environment. Chongqing Port has relatively complete wharf, storage yard and loading and unloading facilities. Its infrastructure rating is slightly lower than that of Suzhou Port, ranking second and the development environment rating third. The competitive advantage of Wuhan Port benefits from the economic and foreign trade development of Wuhan, and its development environment is second only to Suzhou Port. There are 26 ports in the third and fourth echelon, accounting for more than 80% of the total sample, which indicates that the overall competitiveness level of China's inland ports is still low. In terms of infrastructure, it still faces the problems of insufficient input of resource elements and low output level. The level of economic development and foreign trade vitality of the city where the port is located also need to be improved. We need to further improve the efficiency of resource allocation, improve the environment for economic development, promote industrial agglomeration with ports, and promote high-quality economic and social development.

4. Conclusions and suggestions

This paper constructs the competitiveness evaluation model of inland port in China. 31 major inland ports of Yangtze River system, Pearl River system, Beijing Hangzhou canal and Songliao River system are selected as samples. The competitiveness of inland port is measured from three aspects of infrastructure, operation ability and development environment. The spatial structure of competitiveness of inland port is analyzed by K-means cluster analysis of SPSS software. The results show that there is a big gap in the competitiveness of inland ports in China, and the differences between the same water system and different water systems are obvious. Infrastructure, production capacity and development environment are the key factors affecting port competitiveness. It is necessary to improve the port hardware and software environment, enhance the port competitiveness and promote the development of regional economy and trade by improving the port infrastructure and
factor investment, according to the actual situation of port development and local conditions. Based on this, this paper proposes:

4.1. Optimize port resource allocation and strengthen interregional port cooperation.
Strengthen division of work and cooperation among inland ports and between inland ports and coastal ports. Expand the economic influence of hinterland, strengthen the cooperation between port and hinterland enterprises, extend the port industrial chain and promote the scale-economy development.

4.2. Strengthen the construction of port informatization and build a smart port ecosystem.
Overall planning of port production management, business, logistics, E-port and other information platform construction, promote the integration of information resources among ports, upstream and downstream enterprises, customs and other departments. Build a market-oriented, digital and international port service system.

4.3. Vigorously promote the development of multimodal transport.
Speed up creating a new pattern for the development of multimodal transport in Yangtze River basin, featuring “internal and external expansion, hub radiation and first-class service”. Through the construction of three-dimensional, network integrated transport corridors and several integrated transport hubs, the logistics cost can be effectively reduced. Make multimodal transport become the development carrier of industrial transfer and industrial innovation, and promote the high-quality development of regional economy and society.

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