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Research on the Evaluation of Port Group Coupling Coordinated Development based on Coupling Theory

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Abstract

In order to evaluate the interrelation degree of the subsystems within the port group and the overall development and coordination of the port group comprehensively and quantitatively, this paper puts forward an evaluation study on the coupling and coordination development of the port group. Based on the coupling theory in physics and the contribution index of subsystems, a computational model of port group coupling coordination evaluation is established by constructing the evaluation index system of port group coupling coordination. Taking the port group in the middle reaches of the Yangtze River as an example, the evaluation model is tested. The result of case study verifies the validity of the evaluation model, and it is suitable to be applied to other port groups.

Keywords

Port Group; Coupling Theory; Coupling Coordination Model; Subsystem Contribution Index.

1. Introduction

As a product of regional social and economic development to a certain stage, port group is a special group system formed by the interaction of several individual ports whose partial or all functions can be replaced with each other. At present, my country has formed five regional port groups in the long-term historical development of the Yangtze River Delta port group, the Bohai Rim port group, the Pearl River Delta port group, the southeast coastal port group, and the southwest coastal port group. The country's port layout has formed a preliminary structure. However, some problems have gradually been exposed in the development process of the port cluster, such as repeated construction and misallocation of resources. Therefore, studying how to measure the depth of cooperation and development coordination among ports in a port group, as well as how to coordinate the operation of the ports in the port group, undoubtedly plays an important role in the development of the port industry.

For the recent years of research on port clusters, from a domestic perspective, the research content mainly includes the definition of port clusters and qualitative research on institutional models, research on comprehensive evaluation methods for port clusters, and research on cooperation and competition among port clusters. Specifically, Mainly : Wang Liehui et al. [1] compared and studied three different forms of foreign port group system cooperation modes, and then inspected the current cooperation system of the port group in the Yangtze River Delta, and proposed that "government retreats, associations enter, and enterprises are the main body." New ideas for institutional cooperation. Jiang Ganzhi et al. [2] analyzed the strategic planning of ports in major urban agglomerations in the world, summarized the evolution trend of urban ports, provincial and municipal ports, and ports in global urban agglomerations, and analyzed the bottlenecks in the coordinated

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development of the port group in the Yangtze River Delta. Proposed specific strategic measures for the coordinated development of the port group in the Yangtze River Delta. Wei Ling[3] first used AHP and entropy weight method to calculate the index weight, then adopted a comprehensive weighted evaluation method to construct a comprehensive evaluation model, and finally made an evaluation on the current development level of my country's coastal port groups. Xiao Hanbin et al. [4] used variance analysis to analyze the differences in the port logistics capabilities and regional economy of China's five major port clusters along the coast, and clearly demonstrated the status of port logistics and regional economic development in the five major port clusters in China. Luo Fang [5] through the study of the coordinated development and governance mechanism of the port group, scientifically designed the competition mechanism, so that the internal competition environment of the port group can be optimized. Yu Shaoqiang et al. [6] used cluster analysis and game theory to specifically analyze the impact of large ships on the competition and cooperation relations of Liaoning port groups, and proposed a long-term win-win competition and cooperation relationship to achieve the optimal port group. interest. Zhang Qiang et al. [7] summarized relevant and beneficial development experiences through the introduction of the port cluster on the Northwest Coast of the United States and analysis of the cooperation activities and specific development measures carried out by the United States in promoting the coordinated development of the port cluster on the Northwest Coast. From the perspective of foreign research, Lam et al. [8] evaluated the port's supply chain positioning and performance from the perspective of port users, and proposed a unified framework for a port-centric multimodal transport network to provide performance evaluation for port groups. The reference direction. Bai et al. [9] established an institutional framework to help analyze the interaction and coordination of important port group participants in environments, and further determine that policy is the main driving force for the evolution of the cluster.

Generally speaking, whether it is domestic or foreign research, a consensus has been reached on the definition of port clusters and the importance of coordinated development of port clusters, and there is a relatively unified framework for the comprehensive evaluation of port cluster performance, but combined with existing research in view of this, there are few researches on coupling coordination evaluation of port groups and there are some shortcomings. Firstly, the existing research is mostly a qualitative analysis of the coordinated development of a specific port group, which is not universal, and it is difficult to compare different port groups. Secondly, there are two directions for the research on the evaluation of the development of the port group: ① Only evaluate the correlation degree of the internal subsystems of the port group, that is, the evaluation of the coupling degree; ② Only make a qualitative evaluation of the overall development and coordination status of the port group, that is, In the evaluation of coordination degree, the separation of the two cannot fully reflect the interaction between port groups and the comprehensive development level of port groups.

2. Theoretical basis of coupling and coordination evaluation model

2.1 Coupling Theory and Coordination Theory

Coupling is a basic concept of physics. It refers to the phenomenon in which two or more systems influence each other, interact with each other and even unite through various interactions. It is the mutual connection, interdependence, and mutual coordination of various subsystems. The dynamic relationship of [10]. The degree of coupling is an index that describes the degree of interconnection between a system or its internal elements. On the basis of understanding the concept of capacity coupling in physics, using the capacity coupling coefficient model for reference, the coupling degree formula of the system U containing n subsystems is obtained as

$$C_n = n \cdot \{(u_1 + u_2 + \cdots u_n)/(u_1 + u_2 + \cdots u_n)^n\}^{\frac{1}{n}} \quad (1)$$

Where: U_i is the contribution of the i-th subsystem to the order of the total system, which can be solved by the power function. Coordination is a relational structure, it is the reflection of the proportional relationship formed by the various subsystems or elements in the system in the

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coordinated movement. The degree of coordination is a measure of the degree of harmony between the various subsystems or elements in the development process. It reflects the trend of the system from simple to complex, from low to high, and from disorder to order. It is used to describe the evolution of the system. An indicator of the degree of coordination in the process.

2.2 Connotation of Coupling Coordination Degree of Port Group

According to the system coupling theory and system coordination theory, the port group can be regarded as a whole system formed by the mutual influence, and cooperation of several subsystems. Port group coupling refers to the dynamic relationship formed by the influence and interaction of various sub-systems in the port group through certain associations (such as policy orientation and competition, etc.) in the process of development and evolution. Coordination of the port group means that each subsystem in the port group system eliminates the inherent contradictions and conflicts to form a mutually beneficial, orderly and stable state, so as to maximize the overall benefits of the complex system as much as possible.

3. Coupling Coordination Evaluation Model Construction

3.1 Selection of evaluation indicators and calculation of weights

This article draws on the idea of the production process of the enterprise, and the evaluation index system established includes the input layer, the process layer and the output layer, representing three different types of data. Taking into account the availability and completeness of the data, the The evaluation index system in Table 1. The indicators of the input layer are analogous to the production input of enterprises, indicating the socio-economic development level of the main hinterland of each port; the indicators of the process layer indicate the infrastructure construction of each port, which is an index for transforming the logistics demand of the hinterland into products produced by the port; the indicators of the output layer The strength of the analogous enterprise's production capacity reflects the current production capacity of the port and its future development potential.

Table 1. Evaluation index system for coupling and coordination of port groups

Indicators category	Index
Input layer	Regional GDP/ 100 million yuan
	GDP year-on-year growth rate/%
	Tertiary Industry/%
	Year-on-year growth rate of the tertiary industry/%
	Foreign trade import and export volume/100 million U.S. dollars
	Year-on-year growth rate of import and export volume /%
Process layer	Number of berths/one
	Berth length /m
Output layer	Cargo throughput / 10,000 t
	Container throughput / 10,000 TEU
	Cargo throughput growth rate /%
	Container throughput growth rate /%

For the calculation of indicator weights, this paper chooses the entropy weight method to objectively assign weights to the indicators, which avoids the interference of human factors. The entropy weight method is used to calculate the indicator weights. First, the information entropy of each indicator must be calculated, and then Then according to the calculation formula of information entropy and indicator weight, the weight of each indicator is finally calculated. The specific relationship between information entropy and indicator weight as

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{n} (1 - E_j)} \tag{2}$$

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In the formula: E_j is the information entropy of each index, which can be calculated according to the information entropy formula after normalizing and standardizing the data from the original information table; W_j is the weight of each index.

3.2 Calculation of contribution index of port subsystem

The contribution index of the port subsystem is the contribution degree of the port subsystem to the order degree of the port group system, and it is also used as the basis for the subsequent calculation of the coupling coordination degree of the port group. The calculation formula is

$$U_i = \sum_{j=1}^{M} W_j \cdot A_{ij} \tag{3}$$

Where: U_i is the contribution index of the i-th port subsystem; M is the number of sequence parameters contained in each port subsystem; W_j is the internal sequence parameter index of each subsystem; A_j is the weight in the comprehensive evaluation;

A_{ij} is the value of the j-th order parameter in the ith subsystem after the dimension (normalized processing) is removed. The greater the contribution index of the port subsystem, the greater the contribution of this subsystem in the ordering process of the port group system.

3.3 Calculation of Coupling Degree of Port Group Coupling

The coupling coordination degree of port group proposed by system coupling theory and system coordination theory is a comprehensive index of coupling degree and coordination degree. Its purpose is to judge the coordination degree of system coupling, which can reflect the degree of association in the development process of each subsystem, and can also Reflecting the development level of the overall synergy of the system, its algorithm can be expressed as

$$D = (C_n T)^{\frac{1}{2}} \tag{4}$$

$$T = \sum K_i U_i \tag{5}$$

Where, C_n is the coupling degree of the system, which can be obtained by Equation (1). T is the comprehensive synergy index of the system, namely the overall synergistic effect or contribution of the system; K_i is the weight coefficient, namely the importance degree of each port subsystem in the port group. Here, it is determined according to the proportion of the contribution index of each port subsystem to the total contribution index of the port group system. U_i is the contribution index of the port subsystem.

4. Case test of evaluation model

This paper takes the port group in the middle reaches of the Yangtze River as an example, which includes eight major ports: Wuhan Port, Yichang Port, Jingzhou Port, Huangshi Port, Changsha Port, Yueyang Port, Nanchang Port, and Jiujiang Port. The port group in the middle reaches of the Yangtze River is restricted by natural conditions and some objective conditions in the development and construction. Its development exposes some problems such as unbalanced overall development and utilization of port shoreline resources, repeated construction, and insufficient collection and distribution network. Therefore, the middle reaches of the Yangtze River port is chosen. Group as an example, the evaluation model is used to evaluate the coupling and coordinated development of the port group in the middle reaches of the Yangtze River to test the effectiveness of the evaluation model.

4.1 Calculation of Coupling Coordination Degree of the Port Group in the Middle Reaches of the Yangtze River

According to the evaluation index system constructed in Table 1, the data of 12 indicators of the eight major ports in the middle reaches of the Yangtze River from 2008 to 2017 were collected and sorted. After the data was dimensioned out, the calculation formula of information entropy was used to obtain the value of each indicator. The information entropy value Ej can be obtained by formula (2) to obtain

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the weight of the evaluation index over the years, and then the contribution index of each port subsystem can be calculated by formula (3).

After obtaining the contribution index of each port subsystem, the next step can be to calculate the coupling degree and comprehensive synergy index of the port group. For the port group in the middle reaches of the Yangtze River, eight main ports are selected in this study. Therefore, n is taken as 8 when calculating the port coupling degree using formula (1), and then the comprehensive coordination index of the port group is calculated according to formula (5), and finally calculated using formula (4) Coordination degree of outbound port group coupling. The calculation results of the coupling coordination degree of the port group in the middle reaches of the Yangtze River over the years are shown in Table 2.

Table 2. Coupling coordination degree of the port group in the middle reaches of the Yangtze River from 2010 to 2019

Year	The coupling Cn	Synthetic synergy exponent T	Coupling coordination D	State judgment
2010	0.786	0.373	0.541	Barely
2011	0.847	0.363	0.554	Barely
2012	0.834	0.35	0.54	Barely
2013	0.914	0.379	0.588	Barely
2014	0.837	0.348	0.54	Barely
2015	0.91	0.338	0.554	Barely
2016	0.857	0.33	0.532	Barely
2017	0.926	0.33	0.553	Barely
2018	0.817	0.331	0.52	Barely
2019	0.841	0.315	0.515	Barely

It can be seen from Table 3 that the coupling coordination degree of the port group in the middle reaches of the Yangtze River has been in the interval (0.50, 0.59) for the past 10 years, that is, the type of barely coordination. The collaboration is not perfect yet, and there is still much room for improvement in the development level of the port group system.

5. Conclusion

As a special group system gradually formed through cooperation and competition between ports, how to evaluate its development level accurately is very important to the development of the port industry. Based on the coupling theory in physics, this research constructs a port group coupling coordination evaluation model by introducing a contribution index, and uses the port group in the middle reaches of the Yangtze River as an example to test the evaluation model. Through an example analysis, the results show that the coupling and coordination status of the port group in the middle reaches of the Yangtze River during the ten years from 2010 to 2019 has been in a reluctant coordination type. Combining the coupling degree and the comprehensive synergy index, the coupling degree has fluctuated and increased during this period. The comprehensive synergy index has a slight downward trend in small fluctuations, which shows that in the development process of the port group, although the degree of correlation between the ports continues to increase, it is limited by the asynchronous development of the ports, and the coupling and coordinated development level of the port group system is not There will be no significant improvement. It can be seen that the coupled and coordinated development of the port group not only depends on the degree of correlation of the various subsystems, but also the development of avoiding excessive gaps between the ports can not be ignored. Combined with the development status of the port group in the middle reaches of the Yangtze River, the results of the case analysis show that the port group coupling and coordination evaluation model proposed in this study is effective.

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