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Analysis and Evaluation of China's Major Port Logistics Competition

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ABSTRACT

As the connection point of sea and land transportation and the node of international transportation of resources, ports play a pivotal role in the economic systems of countries today, and have become an important part of economic development. In China, most foreign trades are carried out by sea. Recently, many coastal areas have taken the development of the marine economy as the focus of economic structural transformation, and the importance of ports has become increasingly prominent. To accurately find out the factors that influence the competitions of port logistics, make the correct strategic positioning of the respective ports, achieve strengths and avoid weaknesses in the development of ports, and compete effectively, it is particularly important to improve the competitiveness of port logistics.

This paper selects 18 ports in China's coastal areas, such as Shanghai port, Zhoushan port, Tianjin port, Shenzhen port, Guangzhou port, Tianjin port, Qingdao port and Dalian port, and constructs a port competitiveness index system including port logistics scale, infrastructure conditions, hinterland economic conditions and port development potential. According to the principal component analysis of the comprehensive analysis of the port and the cluster analysis of the port classification, we put forward reasonable suggestions to improve the competitiveness of port logistics.

***Keywords**: Port Logistics, Port Competitiveness, Evaluation System, Principal Component Analysis(PCA), Cluster Analysis*

1. INTRODUCTION

As the node connecting the sea and land transportation, the port plays an indispensable role in the world. Currently, ports play an increasingly important role in supporting marine economy, and the scope of port services is also expanding[1]. From simple transportation and handling services to more complex logistics services, the competitions between ports are becoming more and more fierce. Therefore, the concept of port competitiveness is put forward and studied. With the development of China's economy and the enhancement of import and export trade capacity, the development of ports in China's coastal areas has made considerable progress. In the 41 years of reform and opening up, China's coastal ports have reached more than 160. Basically, a port group with reasonable layout and clear division of labor has been formed, and professional cargo, bulk cargo and container transportation systems have been established around many ports.

Coastal ports are important infrastructure for China's modernization, economic development and social progress. They play an important role in promoting the development of international trade, improving China's transportation system and enhancing China's economic strength in international competitions. In today's world, the trend of economic globalization and trade liberalization is becoming more and more important. With the development of China's market economy, port management, infrastructure construction and technology application are gradually expanding. With the rapid development of the international shipping market, the scale of ships and the transport partnership has also changed, which poses new challenges to the development of the ports.

At present, China has formed five major port groups: Bohai Rim port group, Yangtze River Delta port group, Pearl River Delta port group, southeast coastal port group and southwest coastal port group. With the change of regional economic structure, industrial upgrading, transformation and the vigorous development of marine economy, the ports and port groups along the coast of China have new opportunities and challenges. Generally speaking, Chinese ports are facing international logistics competitions, competition among Chinese ports and competitions among port companies1)1)[2].

Port competitiveness analysis is an important part of port research. It is also the objective requirement of sustainable economic development, continuous strengthening of foreign trade and exchange, accelerated economic transformation strategy and industrial upgrading. Research on the competitiveness of ports will be helpful to the decision-making of relevant departments in China, the development and market competition of port companies, the rational investment and construction of port departments, the rational allocation of resources, the sustainable development of China's port industry and the decision-making of port related industries.

Principal Component Analysis(PCA) method and *Cluster Analysis(*CA*)* method are mainly used in this paper, which introduces the competitiveness of ports, analyzes the main factors affecting the competitiveness of Chinese ports, and establishes an index system to evaluate the competitiveness of ports, so as to further explore the key factors affecting the competitiveness of ports, and then cluster and evaluate the ports.

2. THEORY OF PORT COMPETITIVENESS

2.1. Definition of port competitiveness

With the expansion of modern port capacity, the port is no just an area for ships to berth and handle passenger and cargo transport procedures, but also a multifunctional place to provide value-added services for goods. Most ports in China have been commercialized and enterprised, and have participated in the fierce competitions of market economy. Therefore, China's ports have economic characteristics. At the same time, as ports are important facilities for China's social development, China's ports have certain social attributes. As a result, in order to obtain economic and social benefits, port competitiveness can be defined as: more logistics market share and the allocation of various resources by virtue of its own environment, infrastructure and economic level of the region. It has greater advantages over other ports in terms of occupying water transport market share, obtaining logistics value-added chain and realizing port sustainable development.

The main feature of port competition in the industry is oligopoly. As the supplier of port services, the port must first have the necessary natural conditions for the construction of the port; secondly, the port must have the necessary infrastructure to operate the port, and the construction of such infrastructure usually requires a lot of money, so it is difficult for businesses to enter the port logistics industry.

Generally speaking, there are two kinds of port competitions: port-to-port competition and intra-port competition. It usually includes port competitions in the same economic hinterland or the same coastal area, as well as competitions between different countries or regions; intra port competition is mainly competition between companies in the port, such as competition between different loading and unloading companies in the port. This kind of competitions helps to improve the efficiency of port service, so as to improve the competitiveness of the port itself. This paper mainly expounds the competitions between ports.

2.2. Principal Component Analysis

Principal component analysis was proposed by Hotelling in 1933. It uses the idea of dimension reduction to transform multiple indicators into multiple comprehensive indicators, and the obtained comprehensive indicators are called principal components. Each principal component is a combination of original variables, and each principal component is not related[3].

Suppose that the number of samples is r and the number of variables in each sample is m; p_{ij}（i=1,2,…,n；j=1,2，…，m）represents the value of the m-th variable in the i-th sample; p_j（j=1,2，…，m）is the j-th variable. For the convenience of explanation, it is assumed that the mean value of P_j is 0 and the variance is 1. Then, we can get a matrix P about the values of the original variables of the sample.

$$P=\begin{bmatrix} p_{11}\ p_{12}\ \cdots\ p_{1m} \\ p_{21}\ p_{22}\ \cdots p_{2m} \\ \cdots\ \cdots\ \cdots\ \cdots \\ p_{n1}\ p_{n2}\ \cdots p_{nm} \end{bmatrix} \quad (1)$$

Principal component analysis is to transform the M original variables into a new comprehensive variable index. Suppose y1，y2，…，yx（x≤m） is the principal component, which is the new variable index.

$$Namely: P=\begin{bmatrix} p_{11}\ p_{12}\ \cdots\ p_{1m} \\ p_{21}\ p_{22}\ \cdots p_{2m} \\ \cdots\ \cdots\ \cdots\ \cdots \\ p_{n1}\ p_{n2}\ \cdots p_{nm} \end{bmatrix} \quad (2)$$

It is expressed by matrix as:Y=VP, among

$$\sum Y=\begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ y_x \end{bmatrix}, V=\begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1m} \\ v_{21} & v_{22} & \cdots & v_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ v_{x1} & v_{x2} & \cdots & v_{nm} \end{bmatrix}, P=\begin{bmatrix} p_1 \\ p_2 \\ \cdots \\ p_m \end{bmatrix} \tag{3}$$

Meet the requirements：

①y_i and y_j（i≠j；i，j=1,2，…，x）are not related to each other;

②Each line of V is a unit line vector, $v_{i1}^2+v_{i2}^2+\ldots+v_{im}^2=1$，（i=1,2，…，x）；

③y_1 is the largest variance among p_1，p_2，…，p_m all linear combinations；y_2 is the largest variance among all the linear combinations of p_1，p_2，…，p_m which are not related to y_1; ……y_q（q≤x） is the largest variance among all linear combinations of p_1，p_2，…，p_m which are not related to y_1，y_2，…，y_{q-1};

④The sum of variance of p_1，p_2，…，p_m and y_1，y_2，…，y_x is the same.

y_1，y_2，…，y_x is p_1，p_2，…，p_m the first, second , …X principal component.

From the definition and explanation above principal component analysis is to extract the coefficient v_{ij}（i=1，2，…，x；j=1,2，…，m）of y_1，y_2，…，y_x。Through mathematical proof, we can know that V_{ij} is the value in the matrix composed of the eigenvectors corresponding to the first X larger eigenvalues of the p_1，p_2，…，p_m correlation matrix,y_1，y_2，…，y_x is the corresponding characteristic root f_i.

The number of variables is usually large, if the sum of the variances of the previous principal components y_1，y_2，…，and y_x accounts for a large part of the total variance, the new variable index y_1，y_2，…，y_x can be used to replace the original variable p_1，p_2，…，p_m, and most of the information of the original variable can still be saved.

Principal component analysis includes eight steps：

①Specify the variables to be analyzed and collect the original data;

②Standard collection of raw data;

③The covariance matrix of standardized data is obtained ，If the second step is not performed, the correlation matrix of the original data can be obtained; that is

$$C=\begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1m} \\ c_{21} & c_{22} & \cdots & c_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ c_{m1} & c_{m2} & \cdots & c_{mm} \end{bmatrix} \tag{4}$$

c_{ij}（i，j=1,2，…，m）are the original variables p_i and p_j, $c_{ij}=c_{ji}$，the calculation formula is as follows:

$$C_{ij}=\frac{\sum_{k=1}^{n}(p_{ki}-\bar{p}_i)(p_{kj}-\bar{p}_j)}{\sqrt{\sum_{k=1}^{n}(p_{ki}-\bar{p}_i)^2\sum_{k=1}^{n}(p_{kj}-\bar{p}_j)^2}} \tag{5}$$

④The eigenvalues and the corresponding orthonormal eigenvectors are calculated;

⑤The contribution ratio and cumulative contribution ratio of principal components were calculated;

Contribution ratio：

$$\frac{f_i}{\sum_{k=1}^{m} f_k},(i=1,2,\ldots,m) \tag{6}$$

Cumulative contribution ratio：

$$\frac{\sum_{k=1}^{i} f_k}{\sum_{k=1}^{m} f_k},(i=1,2,\ldots,m) \tag{7}$$

⑥Determine several principal components，the general principle of determining several principal components is: the cumulative contribution ratio reaches 85%, the eigenvalue $f_i \geq 1$, and the turning point of the eigenvalue curve.

⑦Calculation of principal components

SPSS software was used to analyze the data. SPSS does not include a special principal component analysis module, but the principal component analysis method is closely related to factor analysis，by selecting "principal component method" and applying the factor analysis module is used to obtain the factor load matrix.

$$A=(\sqrt{f_1T_1},\sqrt{f_2T_2},\ldots,\sqrt{f_mT_m}) \tag{8}$$

Among them，$f1 \geq f2 \geq \ldots \geq fm \geq 0$ is the eigenvalue of the covariance matrix;T1，T2，…，Tm is the eigenvector of the covariance.

The matrix G composed of the coefficients of principal components is the transpose of the unit eigenvector T, i.e.

$$G = T' = (T_1, T_2, \ldots, T_m)' \tag{9}$$

Therefore, the coefficient matrix G of the principal component can be calculated by using the factor load matrix obtained by the "principal component method" in the factor analysis module of SPSS and the above formula.

⑧Conclusion and analysis.

Index system analysis is the main method of industrial competitiveness research. The basic concept of principal component analysis is dimension reduction. According to the specific characteristics of evaluation indicators, fewer new indicators are used to replace more original indicators, and fewer new indicators will reflect the original indicators as much as possible. The new indexes are not related to each other, which avoids the subjectivity of index selection and the deviation of evaluation results.

2.3. Cluster Analysis

Cluster analysis is a quantitative classification method for samples or variables. There are three main methods of cluster analysis: systematic clustering, two-step clustering and K-means clustering. The idea of cluster analysis is based on the different degrees of similarity between the samples or variables. Cluster analysis is to find a quantitative statistic that can express the similarity and classify the samples or variables according to the similarity. Because this article uses the system clustering, now the system clustering method, the K-means clustering method and the two-part clustering method are not introduced here.

Hierarchical clustering is also called hierarchical clustering. In principle, the samples or variables with the highest photographic similarity (i.e. the nearest distance) are grouped. or example, if the number of samples is x, the samples are first grouped into x categories, which means, each sample is a separate category; Secondly, based on the distance or the value calculated by the formula, two highly similar categories are clustered into one category to form an X-1 category; According to the rules above two similar categories in X-1 category are clustered into one, and finally all samples are classified into one category.

In this paper, Ward method in system clustering is used. It is also known as the sum of squares of deviation method. The step is to treat multiple samples as a single type. When merging categories, the variance between the every centers of the categories is calculated, and the two categories that can make the sum of squares of deviations within the category increase the least are selected to merge. One category is reduced each time, and the merging is carried out in turn. With the continuous merging of the categories, the sum of squares of deviations within the category increases continuously until the final synthesis into one category. The specific algorithm is as follows:

M samples are divided into k classes, and each sample is represented by F：F1，F2，F3，…，F_k， the ith sample in Gt is represented by Xi $^{(t)}$,here Xi (t) is a q-dimensional vector, which means, there are a total of q indexes of system clustering. The number of samples in Gt is expressed by mt, $\overline{X^{(t)}}$ is the center of gravity of Gt, which means, the average value of such samples, Then the sum of squares of deviations of samples in Gt is:

$$W_t = \sum_{i=1}^{m_t} (X_t^{(t)} - \overline{X^{(t)}})'(X_i^{(t)} - \overline{X^{(t)}}) \tag{10}$$

Then the sum of squares of within class deviations of class k is:

$$W = \sum_{t=1}^{k} W_t = \sum_{t=1}^{k} \sum_{i=1}^{m_t} (X_t^{(t)} - \overline{X^{(t)}})' (X_i^{(t)} - \overline{X^{(t)}}) \tag{11}$$

3. ANALYSIS ON THE CURRENT SITUATION OF PORT COMPETITION

3.1. The significance of competition among ports

After more than ten years of rapid development, China's port industry has been in the situation of a hundred flowers competing for beauty, and the competition among ports is in full swing. The law of the development of things determines that there must be competition on the road of development. Just as the so-called development cannot do without competition, it will also promote development. In the fierce competition among ports, there are the following positive effects:

Reasonable competition among ports is the driving force to promote the development of ports. There will be pressure in competition, under which every port does not want to be at a disadvantage. The only way is to improve the level of logistics services, expand the scale of the port, improve the reputation of the port, and try to attract more shipping companies, and gradually improve their competitiveness[4].

Reasonable competition among ports can optimize the allocation of port resources. In the competitive environment, in order to be in a favorable position, we need to optimize the allocation of resources to maximize the function of limited resources and maximize the benefits.

Reasonable competition among ports promotes the development of economic hinterland. While vigorously developing ports, port cities will also make full use of port resources, give full play to their coastal geographical advantages, develop foreign economy and expand foreign trade according to their own characteristics. As a logistics transportation node, port provides waterway channel for resource output of port cities, and waterway transportation has the advantages of large transportation volume and low cost. in this way, it not only enlivens the market economy, but also reduces the required logistics cost.

3.2. The manifestation of port competition

The competition among ports is mainly the competition of resources. Due to the shortage of resources, there must be competition. There are two main forms of expressions.

The competition of resources in the hinterland of port economy: at present, China's ports show the trend of large-scale, deep-water and specialization, and form five port groups: Bohai Rim port group, Yangtze River Delta port group, Pearl River Delta port group, southeast coastal port group and southwest coastal port group. With so many ports and overlapping hinterlands, the resources behind them will compete fiercely. In general, cargo owners calculate costs and choose one of the ports to serve, but transportation conditions have improved in recent years. Especially after the development of multimodal transport， logistics transport has become more and more convenient, which makes the competitive relationship increasingly prominent[5].

Competition in the number of routes and liners: route is the carrier of flight, which is also the carrier of logistics. Every port must increase routes and attract flights to maintain its competitive advantage. Routes, flights and cargo sources are closely linked. If the port can have multiple routes and stable flights, it can attract more cargo sources. Therefore, ports with more routes and flights can attract more freight forwarders, buyers, shippers, distributors and other customers.

3.3. Problems in Port Competition

Port competition is a double-edged sword and reasonable competition can enhance the strength of the port itself, which is conducive to the optimal allocation of resources and can promote the development of port logistics, but excessive competition will hinder the progress of the port. Some negative effects on China's port competition are attracting more and more people's attention. These negative effects are mainly manifested in:

Due to the excessive competition of ports, resources cannot be optimized. Excessive competition leads to the lack of cooperation among ports and insufficient understanding of each other, leading to repeated construction and inefficient operation of facilities at various ports, or some idle special facilities and equipment due to lack of supply of goods, resulting in the unreasonable allocation of resources and waste.

Excessive price reduction leads to losses. Price war is a common marketing method in the sales and service industry. In order to attract more business customers, some ports do not hesitate to reduce their profits or even operate below the operating costs. In the long-term competition, it will inevitably lead to the decline of profitability, insufficient income, lack of funds, reduce equipment maintenance and operation efficiency, personnel outflow and other vicious consequences, and then lead to the loss of goods. It seems that the price war is beneficial to the cargo owners, but if the operation of the port continues to deteriorate, the cargo owners will have to give up the near and seek the far, instead of wasting time and financial resources to increase the logistics cost. The driving effect of port on hinterland economy will disappear.

It is difficult to form a scale effect. If there are too many open ports, the density will increase, leading to the direct dispersion of goods, thus reducing the efficiency and revenue of port operation. In addition, the investment funds of the local government to the port will also be allocated, which is not conducive to the cultivation of local port, making enterprises difficult to form a scale.

These negative results can only be attributed to unreasonable port competition. For this purpose, what we must do is to establish an open, ordered, and fair port competition mechanism under national macro regulation to create a good port competition environment and guide ports to develop in a reasonable competitive environment.

4. EVALUATION OF MAJOR PORT COMPETITIVENESS IN CHINA BASED ON PRINCIPAL COMPONENT ANALYSIS

4.1. Construction of an evaluation index system for Port Competition

4.1.1. Factors affecting port competitiveness

In order to gain advantages in competition, ports must make full use of their own conditions, develop advantages, and avoid disadvantages. Before creating an evaluation index system of competitiveness, it is necessary to analyze the factors affecting port competitiveness. There are two main categories: internal factors and external factors[6].

4.1.1.1. Internal factors

①Hardware conditions

The hardware condition of the port has a great influence on the port, which is one of the key indexes for transportation companies and shippers to check when selecting port companies. The hardware conditions mainly include mechanical equipment, yard area and the number and size of berths. Port infrastructure condition is the basis of port operation, which can directly reflect the strength of the port.

First, mechanical equipment. Modern ports are becoming more and more mechanized and automated. Advanced machinery and equipment help to improve operational efficiency. Efficient and accurate loading and unloading service can save the time and money of transportation companies, followed by the yard area. The yard is the distribution place of goods, which will affect the turnover of goods and the residence time of vehicles and ships. The size of the yard is directly related to the throughput and handling efficiency. Reasonable storage of goods can improve the efficiency of port loading and unloading, and the larger the effective area of yard is, the larger the working space will be, which is conducive to the improvement of operation capacity; the third is the number and size of berths. Large ships, especially container ships, need deep water berths. The longer the coastline of the port is, the more berths and deep-water berths are, and the more ships are berthed on the wharf, which reduces the congestion of the port and improves the operation efficiency of the port[7].

②Logistics service capability

As an important logistics node of water transportation, the competitiveness of the port is mainly reflected in the logistics service function. Logistics service function mainly includes port throughput and route quantity.

Port throughput and port container throughput can directly reflect the production and operation level of the port, and the scale of throughput also indirectly reflects the income and scale of the port, which can directly affect the choice of customers port logistics service level. Shipping routes are also part of the logistics service level. With a large number of routes, shipping companies and cargo owners can transport goods to more places through the port, so the more routes, the more business customers will be attracted.

③Operation and management level

As a market economy, the most important index of competition is the operation level of the port. The level of port operation and management will affect the sustainable development of the port. Usually, it mainly analyzes the operation status of port companies, such as revenue, net profit and profit margin. Port revenue, profitability and port operation level can be clearly presented through port revenue, net profit and profit margin. The rapid growth of revenue and net profit shows that the port has good management level and great development potential.

4.1.1.2. External factors

①Geographical location and climatic conditions

Although China has a vast territory, its import and export trade is still concentrated in the coastal areas. If the port is close to the economically developed areas or transportation hubs, the transportation cost of the cargo owners will be greatly reduced, which is conducive to the competition of hinterland goods and transit goods. If it is a transit port, it is more important to be close to international routes than inland hinterland. For example, the hinterland of Singapore port is very limited, but it can still become a famous transit port because of its geographical location close to international routes. In addition, climate conditions will also affect the competitiveness of the port. For example, the northern part of China is cold in winter and vulnerable to the impact of water surface freezing, while the southern part of China is vulnerable to the impact of typhoon weather in summer.

②Hinterland economic conditions

Hinterland economy is an important driving force for port development. A good background economy can provide enough supply for the port, so the competitiveness of the port is closely related to its hinterland economy. The good development of hinterland economy will greatly enhance the competitiveness of the port. The GDP of internal regions is directly proportional to the total amount of import and export, the development of logistics industry and the demand for port services. Shipping is the main form of China's foreign trade. In addition, the proportion and scale of secondary industry and tertiary industry in the city where the port is located also have a significant impact on the performance and revenue capacity of the local port. The index representing the growth rate of hinterland economic indicators is also very important. Different from the current scale index, the growth index is mainly used to reflect the development potential of the port.

③Policy conditions

The competitiveness of the port is also affected by local government policies and the degree of commercialization. For example, bonded zones and free trade zones are more attractive to customers because goods can be freely circulated, sold, processed, packaged and stored in these zones. Customs will not interfere with these activities, thus reducing many complex procedures and speeding up the flow of goods.

4.1.2. Port competitiveness evaluation index system

According to the influencing factors of competitiveness, 12 indicators are summarized and expressed by X_1-X_{12}:

X_1：Throughput of cargo in ports (ten thousand ton);

X_2：Port container throughput（ten thousand TEU）

X_3：Port dock length (m);

X_4：Number of port berths（s）；

X_5：Length of wharf for port production (m);

X_6：Number of berths for port production（s）

X_7: Number of 10,000-ton berths for port production (s);

X_8：GDP of economic hinterland (RMB100 million);

X_9：Total output value of tertiary industry in economic hinterland (RMB 100 million);

X_{10}：Total foreign trade imports and exports in economic and abdominal locations（100 million dollars）;

X_{11}：Actual total amount of foreign investment in economic hinterland（100 million dollars）;

X_{12}：GDP growth rate of economic hinterland（%）。

According to China port network, China statistical information network and forward looking data network, the following data are obtained, as shown in table 1. The original data is the latest data in 2019.

Table 1. original data of port competitiveness index

Port name	X_1	X_2	X_3	X_4	X_5	X_6
Dalian Port	36641	876	45255	248	41378	223
Yingkou Port	23818	548	19849	93	19115	87
Qingdao Port	57736	2101	32205	141	31066	135
Rizhao Port	46377	450	21153	83	20849	82
Yantai Port	38632	310	41709	261	40626	252
Qinhuangdao Port	21880	62	17161	92	15928	72
Tianjin Port	49220	1730	39295	167	36482	139
Shanghai Port	71677	4330	102931	1054	75182	560
Lianyungang Port	23456	478	16876	75	16579	73
Ningbo Port	112009	2753	100986	703	95304	607
Xiamen Port	21344	1112	94273	165	92187	152
Fuzhou Port	21255	354	9443	121	9072	98
Quanzhou port	12726	258	23453	95	21458	87
Shenzhen Port	25785	2577	17127	197	16875	163
Guangzhou Port	60616	2283	55996	556	51011	483
Shantou Port	3155	135	10298	91	10028	86
Zhanjiang Port	21570	112	16924	132	16176	109
Haikou Port	12447	197	12307	75	10564	69
Port name	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
Dalian Port	104	7001.7	3743.3	621.83	26.8	-8.7
Yingkou Port	62	1328.2	618.8	67.61	1.46	-1.37
Qingdao Port	89	11741.31	7148.57	846.2	47.1	7.23
Rizhao Port	70	1949.38	949.73	139.91	1.87	8.17
Yantai Port	104	7653.45	3917.55	43.21	19.41	6.13
Qinhuangdao Port	44	1612.02	875.56	52.05	10.86	-1.46
Tianjin Port	122	14104.28	8949.87	1049.43	210.1	4.8
Shanghai Port	183	38155.32	27752.28	4863.83	190.48	16.75

Lianyungang Port	59	3139.29	1413.44	93.22	6.14	13.26
Ningbo Port	183	11985.1	5879.9	1310.04	23.6	11.54
Xiamen Port	56	5995.04	3474.56	916.13	134.16	25.12
Fuzhou Port	28	9392.3	5034.84	360.83	9.4	19.54
Quanzhou port	23	9946.66	3872.78	301.69	6.3	10.28
Shenzhen Port	47	26927.09	16406.06	2385.71	82.03	9.06
Guangzhou Port	73	23628.6	16923.23	1427.24	71.43	3.37
Shantou Port	19	2694.08	1293.5	85.79	1.87	7.25
Zhanjiang Port	37	3164.72	1524.49	59.11	2.36	5.2
Haikou Port	41	1671.93	1324.75	47.34	6.72	10.69

4.2. Principal component analysis of port competitiveness

4.2.1. Applicability test of factor analysis

First, it is necessary to test whether the selected indicators are suitable for factor analysis. In this paper, we use spss22.0 software to perform KMO test and Bartlett sphericity test for each index, as shown in Table 2.

Table 2. tests of kmo and Bartlett

<table>
<tr><td colspan="2">Kaiser Meyer Olkin measure of sampling adequacy</td><td>.679</td></tr>
<tr><td rowspan="3">Bartlett's sphericity test</td><td>Approximate chi-square values</td><td>369.015</td></tr>
<tr><td>df</td><td>66</td></tr>
<tr><td>Sig.</td><td>.000</td></tr>
</table>

When KMO value is higher than 0.6, factor analysis can be carried out. According to this standard, in the output results of Table 4-2, the KMO value of the sample data is 0.679 > 0.6; different from KMO, Bartlett's spherical test is considered from the perspective of overall correlation, and the null hypothesis is the unit matrix of the correlation coefficient matrix. Hypothesis test can be used to determine whether the correlation coefficient matrix is significantly different from zero.

When the corresponding associated probability value is less than the significance level $\alpha = 0.05$, the zero hypothesis is rejected, which proves that it is suitable for factor analysis. In the results, Sig.=0.000, less than the significance level of 0.05, indicating that the sample data has correlation. In conclusion, it is suitable for factor analysis.

4.2.2. Common factor variance

Through factor analysis, this paper first solves the common factor variance of each factor to get the degree of commonality of each factor, as shown in table 4-3.

Table3. common factor variance

Index	Initial	Extract
X_1	1.000	.870
X_2	1.000	.936
X_3	1.000	.949
X_4	1.000	.902
X_5	1.000	.933
X_6	1.000	.902
X_7	1.000	.870
X_8	1.000	.968
X_9	1.000	.983
X_{10}	1.000	.955
X_{11}	1.000	.662
X_{12}	1.000	.866

The common factor variance table shows the commonness of variables. Commonality indicates how much information the original variable retains when the original variable is replaced by a common variable. The higher the degree of commonality, the higher the degree of variables can be described. It can be seen from table 4-3 that the commonality of each factor is greater than 0.60, indicating that the extracted principal components have a high degree of explanation for the original variables.

4.2.3 Extracting common factors

In spss22.0 software, according to the eigenvalue ≥ 1, the extraction results of common factors are shown in table 4.

Table 4. explained total variance

Component	Initial eigenvalue			Extract sum of squares load		
	total	variance %	accumulate %	total	variance %	accumulate %
1	8.086	67.380	67.380	8.086	67.380	67.380
2	1.553	12.941	80.320	1.553	12.941	80.320
3	1.157	9.640	89.960	1.157	9.640	89.960
4	.579	4.825	94.785			
5	.313	2.610	97.395			
6	.148	1.232	98.628			
7	.105	.871	99.499			
8	.033	.275	99.774			
9	.018	.147	99.921			
10	.007	.056	99.977			
11	.003	.022	99.999			
12	.000	.001	100.000			

Three common factors were extracted. The variance contribution rate of the first common factor was 67.380%, the second common factor 12.941%, and the third common factor 9.640%. The total variance contribution rate of the three common factors is 89.960%, which is more than 85%, indicating that the three common factors extracted can explain the total variance.

4.2.4. Gravel map

The gravel map horizontal coordinate is the number of components, and the vertical coordinate is the eigenvalue. As can be seen from Figure 1, the first three components are more clearer, and the difference between adjacent eigenvalues is larger, while the difference between the eigenvalues of the last nine components is smaller. Therefore, we can see that the first three common factors summarize most of the information, so it is reasonable to extract the three common factors.

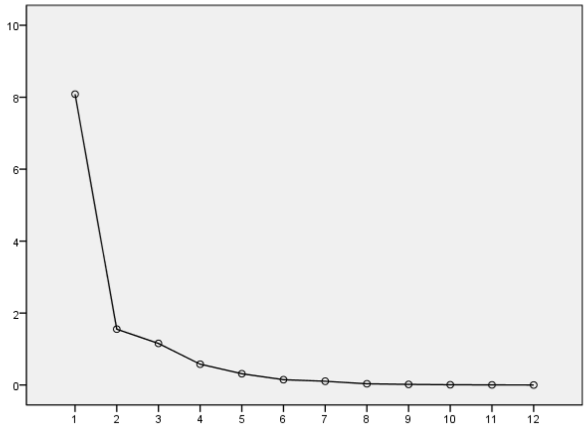

Figure 1. gravel map

4.2.5. Factor meaning

In order to make the meaning of the extracted common factor variables clearer, the orthogonal rotation method is used to rotate the component matrix. The rotated component matrix is shown in table 5.

Table 5. composition matrix

Index	Component		
	F_1	F_2	F_3
X_1	.886	.266	-.114
X_2	.551	.791	.080
X_3	.846	.290	.387
X_4	.728	.609	.033
X_5	.856	.171	.415
X_6	.835	.453	-.029
X_7	.863	.349	-.070
X_8	.266	.945	.059
X_9	.263	.955	.052
X_{10}	.359	.894	.163
X_{11}	.245	.684	.366
X_{12}	.014	.147	.919

It can be seen from table 4-5 that the first principal component indicators with large loading capacity are port cargo throughput, port container throughput, port terminal length, port berth number, port production terminal length, port production berth number, and port production 10000 ton berths, so they can be regarded as the principal components of port development scale and infrastructure construction; In the second principal component, the indicators that account for a large amount of load are GDP of economic hinterland, gross output value of tertiary industry of economic hinterland, total foreign trade import and export of economic hinterland and actual total amount of foreign investment in economic hinterland，which can be regarded as the principal component indicating the economic level of port economic hinterland; in the third principal component, the indicator with a large amount of load is GDP growth rate of economic hinterland, which can be regarded as a reflection of the main component of economic development potential of port hinterland.

4.2.6. Calculation factor score coefficient

Using spss22.0, the three extracted principal components are transformed into the linear expression of the original variables, the scores of each component are calculated, and the factors are used to replace the original variables for the next step of data analysis. The score coefficient matrix of the components is shown in table 6.

Table 6. component score coefficient matrix

Express	Component		
	F_1	F_2	F_3
X_1	.278	-.102	-.176
X_2	.005	.178	-.053
X_3	.228	-.139	.243
X_4	.122	.063	-.082
X_5	.260	-.193	.279
X_6	.206	-.022	-.122
X_7	.245	-.067	-.147
X_8	-.142	.316	-.072
X_9	-.145	.322	-.079
X_{10}	-.099	.260	.015
X_{11}	-.101	.179	.215
X_{12}	-.084	-.046	.751

Component score coefficient matrix is the eigenvector corresponding to the eigenvalue of principal component. According to the score coefficient matrix, we can write the expressions of principal components F1, F2, F3 about x1, X2, X3, x4, X5, X6, X7, X8, x9, X10, X11,X12：

$$F_1=0.278X_1+0.005X_2+0.228X_3+0.112X_4+0.260X_5+0.206X_6+0.245X_7-0.142X_8-0.145X_9-0.099X_{10}-0.101X_{11}-0.084X_{12}$$

$$F_2=-0.102X_1+0.178X_2-0.139X_3+0.063X_4-0.193X_5-0.022X_6-0.067X_7+0.316X_8+0.322X_9+0.260X_{10}+0.179X_{11}-0.046X_{12}$$

$$F_3=-0.176X_1-0.053X_2+0243X_3-0.082X_4+0.279X_5-0.122X_6-0.147X_7-0.072X_8-0.079X_9+0.015X_{10}+0.215X_{11}+0.751X_{12}$$

4.2.7. Factor score and comprehensive score

Through the calculation above, the corresponding principal component scores can be obtained, and F1, F2 and F3 are the principal component scores. Using variance contribution rate divided by variance cumulative contribution rate as weight, the expression of comprehensive score F can be obtained as follows:

$$F=（67.380F_1+12.941F_2+9.640F_3）/89.960$$

According to the calculation above, the ranking of each principal component and comprehensive score is shown in table 7.

Table 7. component score and comprehensive score

Port name	F_1	F_1 ranking	F_2	F_2 ranking	F_3	F_3 ranking	Comprehensive score	Comprehensive ranking
Dalian Port	0.624	3	-0.368	8	-1.596	18	0.24	6
Yingkou Port	-0.205	10	-0.607	14	-0.967	17	-0.34	10
Qingdao Port	0.077	7	0.175	5	-0.340	14	0.05	8
Rizhao Port	-0.036	8	-0.745	17	-0.199	10	-0.16	9
Yantai Port	0.539	5	-0.643	15	-0.269	12	0.28	5
Qinhuangdao Port	-0.407	11	-0.567	13	-0.904	16	-0.48	13
Tianjin Port	-0.038	9	0.699	4	0.000	8	0.07	7
Shanghai Port	1.134	2	2.800	1	0.616	3	1.32	2
Lianyungang Port	-0.501	13	-0.559	12	0.402	4	-0.41	11
Ningbo Port	3.028	1	-0.789	18	0.021	7	2.16	1
Xiamen Port	0.412	6	-0.682	16	3.201	1	0.55	3
Fuzhou Port	-1.008	17	-0.047	6	0.877	2	-0.67	16
Quanzhou port	-0.805	15	-0.176	7	0.319	5	-0.59	14
Shenzhen Port	-1.251	18	1.905	2	-0.223	11	-0.69	17
Guangzhou Port	0.590	4	1.041	3	-0.778	15	0.51	4
Shantou Port	-0.925	16	-0.395	9	-0.042	9	-0.75	18
Zhanjiang Port	-0.476	12	-0.528	11	-0.333	13	-0.47	12
Haikou Port	-0.751	14	-0.513	10	0.215	6	-0.61	15

From the table above, we can preliminarily see that in terms of port infrastructure construction, the scores of Dalian port, Qingdao port, Yantai port, Shanghai port, Ningbo port, Xiamen port and Guangzhou port are positive, while the scores of Yingkou port, Rizhao Port, Qinhuangdao port, Tianjin port, Lianyungang port, Fuzhou Port, Quanzhou port, Shenzhen port, Shantou port, Zhanjiang port and Haikou Port are negative. More than half of the ports still need to strengthen their infrastructure construction.

Both the second and the third principal component belong to the same economic index. In terms of the principal component of port hinterland economic strength, only Qingdao port, Tianjin port, Shanghai port, Shenzhen port and Guangzhou port are positive, while others are negative. In terms of hinterland economic development potential, Tianjin port, Shanghai port, Lianyungang port, Ningbo port, Xiamen port, Fuzhou port, Quanzhou port and Haikou Port are positive while scores of others are negative. It indicates that China's ports also need to actively carry out import and export trade, promote the economic development of the hinterland, and enhance the economic strength and development potential of the hinterland.

In the comprehensive score of competitiveness, according to the score ranking table, basically ports in big cities will be more competitive than ports in small cities. The Dalian port, Qingdao port, Yantai port, Tianjin port, Shanghai port, Ningbo port, Xiamen port and Guangzhou port have positive scores, while the other 10 ports have negative scores, which illustrates that the comprehensive strength of China's ports is still very weak. There is still a lot of room for improvement.

5. PORT CLASSIFICATION AND EVALUATION BASED ON CLUSTER ANALYSIS

5.1. Tree diagram

This paper uses spss22.0 software to classify the ports from the perspective of competitiveness, and uses ward clustering method to cluster the scores of three principal component factors and comprehensive scores (see table 7 component scores and comprehensive score table) extracted by principal component analysis.To begin with, each port is regarded as a class, and then the two classes with the highest similarity are combined to form a new class,and then the new class is combined with the class with high similarity. Furthermore, this process is repeated until all individuals are classified into one class. The following is the tree graph obtained by clustering (Figure 2).

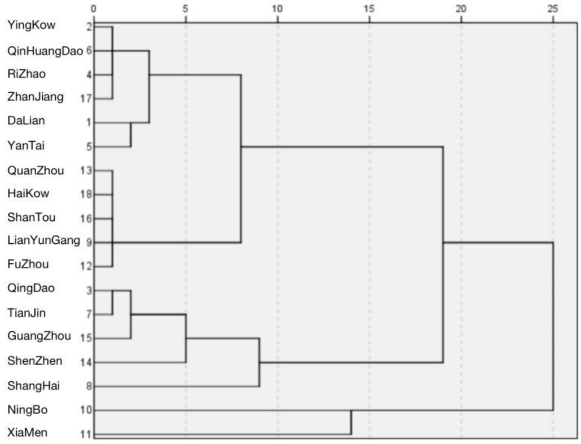

Figure 2. tree diagram

In view of the fact that ports can't be classified too accurately, ports in the category lack commonness, but they can't be too wide, so it's reasonable to divide them into five categories according to the tree diagram. As shown in Table 8, firstly, Ningbo port and Xiamen port are classified into category 1; secondly, Qingdao port, Tianjin port, Guangzhou port, Shenzhen port and Shanghai port are classified into category 2; thirdly, Quanzhou port, Haikou Port, Shantou port, Lianyungang port and Fuzhou port are classified into category 3; then Dalian port and Yantai port are classified into category 4; finally, Yingkou port, Qinhuangdao port, Rizhao Port and Zhanjiang port are classified into category 5.

Table 8. port classification

Classification	Port
The first category	Ningbo Port Xiamen Port
The second category	Qingdao port Tianjin Port Guangzhou port Shenzhen Port Shanghai Port
The third category	Quanzhou port Haikou Port Shantou Port Lianyungang Port Fuzhou Port
The fourth category	Dalian Port Yantai Port
The fifth category	Yingkou Port Qinhuangdao Port Rizhao Port Zhanjiang Port

5.2. Analysis of port classification evaluation

5.2.1. Ningbo port and Xiamen Port

The comprehensive scores of Ningbo port and Xiamen port are the first and the third respectively, especially the score of Ningbo port, which is far ahead of other ports. In terms of the first principal component, the two ports ranked the 1st and 6th respectively, , which indicates that Ningbo port is obviously better than Xiamen port in port infrastructure construction. In the second principal component, the scores rank the 18th and 16th respectively, indicating that the hinterland economic conditions of these two ports are poor. In the third principal component, the score ranking is in the seventh and the first place respectively, which shows that although the hinterland economic conditions of these two ports are poor compared with other ports, the hinterland has a strong potential for economic development and has a lot of room for improvement. Therefore, Ningbo port and Xiamen port need to seize the development opportunity, on the premise of maintaining the original development hardware foundation, focus on joint development with the hinterland, actively expand their own hinterland source of goods, enhance the economic strength of the hinterland, and then better enhance the competitiveness of each port.

5.2.2. Qingdao port, Tianjin port, Guangzhou port, Shenzhen port and Shanghai Port

These ports are in the same category in cluster analysis, so they are analyzed at the same time. The comprehensive competitiveness score of each port is in the 8th, 7th, 4th, 17th and 2nd place respectively, which shows that Shenzhen port is obviously weaker than other ports in the comprehensive competitiveness score, while Qingdao port and Tianjin port are in the middle level. In terms of the first principal component, the scores rank at the 7th, 9th, 4th, 18th and 2nd respectively, which indicates that the infrastructure construction of Shenzhen port is poor. The ranking order of the first principal component score is similar to that of the comprehensive score. It can be basically seen that the impact of infrastructure construction on port competitiveness accounts for the vast majority. On the second principal component, the score ranking is in the fifth, the fourth, the third, the second and the first place respectively. These ports rounded out the top five,which indicates that the hinterland of these five ports has strong economic strength. In the third principal component, the score ranking of port is the 14th, 8th, 15th, 11th and 3rd respectively, which indicates that the hinterland economic development potential of the other three ports is weak except Tianjin port and Shanghai port. According to the data survey, Tianjin port is the 8th because the economic development of Tianjin in recent years is not very good compared with previous years.

Consequently, we can see that the common point of this classification is that the Hinterland's economic strength is very strong. Qingdao port and Tianjin port are located in the Bohai Rim region, so we should make full use of the development opportunities and potential brought by the region, strengthen our foreign trade import and export business, intensify port construction and fully optimize the allocation of resources. The low score of Guangzhou port is only in the third principal component indicates that the economic development of Guangzhou is very stable, and we need to find new growth points for development to further break through the bottleneck. Shenzhen port also needs to strengthen the infrastructure construction, timely update the old equipment, and try to improve the effective area of the port to avoid idleness and waste, and make effective use of existing resources; Shanghai Port's various indicators are ranked in the forefront, but it lags behind Ningbo port in terms of infrastructure construction, which leads to a comprehensive ranking behind one place. Shanghai port needs to continue to consolidate its infrastructure construction and at the same time, make good use of their own advantages in the hinterland, and constantly improve their competitive strength.

5.2.3. Quanzhou port, Haikou Port, Shantou port, Lianyungang port and Fuzhou Port

These five ports are all southern ports, with the comprehensive scores ranking the 14th, 15th, 18th, 11th and 16th respectively, and their comprehensive competitiveness is at a lower level. In terms of the first principal component, the scores rank the 15th, 14th, 16th, 13th and 17th respectively, which indicates that the infrastructure construction of these five ports is relatively poor and needs to be strengthened urgently. In the second principal component, the score ranking is in the 7th, 10th, 9th, 12th and 6th respectively, which indicates that the economic strength of the hinterland of the port is in the middle or lower middle level. In the third principal component, the score ranking is in the fifth, sixth, ninth, fourth and second place respectively, which indicates that although the hinterland economy is not at the top level, its economic development strength is relatively strong, and Shantou is slightly weaker.

Generally speaking, the common characteristics of these five ports are backward basic conditions, limited economic resources in hinterland, but great potential for economic development. We need to actively carry out import and export trade business, in addition to serving the local foreign trade, but also actively expand their own hinterland source of goods, increase the intensity of infrastructure construction, achieve rational allocation of resources, achieve efficient operation, and enhance the service capacity of the port.

5.2.4. Dalian port and Yantai Port

The comprehensive competitiveness scores of Dalian port and Yantai port are the sixth and the fifth respectively, which indicates that the comprehensive competitiveness of Dalian port is in the forefront in China. In the first principal component, the score ranking is in the third place and the fifth place respectively, which indicates that the hardware facilities of these two ports are very good. In the second principal component, the score ranking is in the 8th and 15th respectively, which shows that the economic strength of Dalian port hinterland is in the middle level, while the economic strength of Yantai port hinterland is in the lower level. In the third principal component, the scores rank in the 18th and 12th respectively, indicating that the economic development potential of these two regions is weak. The two ports also belong to the Bohai Rim region, benefiting from the infrastructure construction, with strong comprehensive competitiveness. Although there is a gap between the two ports in terms of hinterland economic ranking, both Dalian Port and Yantai Port should seize the economic development opportunities in the Bohai Rim, continue to maintain their own advantages in port facilities construction, and at the same time actively strive for foreign trade sources of goods.Yantai port should take more active part in the development and construction of Shandong's Marine economy.

5.2.5. Yingkou port, Qinhuangdao port, Rizhao Port and Zhanjiang Port

The comprehensive scores of these ports are ranked the 10th, 13th, 9th and 12th respectively, and the comprehensive competitiveness scores are all in the lower middle level. In the first principal component, the score ranking is in the 10th, 11th, 8th and 12th respectively, which is close to the comprehensive score ranking, and also in the lower middle level.

In the second principal component, these ports scores ranked in the 14th, 13th, 17th and 11th respectively. Except Zhanjiang port in the lower middle level, the rest of these ports are in the lower level. In the third principal component, these ports scores ranked in the 17th, 16th, 10th and 13th respectively. Except Rizhao Port in the lower middle level, other ports are in the lower level.

The strength of this group of ports is low in any aspect. One of the reasons is that the area of this group of ports is too small, so the strength is naturally inferior to Grand Harbour. To improve the competitive strength of ports, we need more support from countries, such as government funding to strengthen the planning and construction of ports, vigorously cultivate professional talents, improve port service capacity, and give full play to their own geographical advantages, develop the industries adjacent to the port well, improve their own import and export trade business capacity.

6. CONCLUSION

This paper selects Xiamen port, Yingkou port, Qingdao port, Zhanjiang port, Tianjin port, Rizhao Port, Fuzhou port, Dalian port, Shanghai port, Lianyungang port, Qinhuangdao port, Zhoushan port, Guangzhou port, Quanzhou port, Shenzhen port, Yantai port, Shantou port and Haikou Port. A total of 18 ports as the research objects of port competitiveness, the following conclusions are obtained:

By reviewing the literature on port competitiveness and the theories related to port and port competitiveness, this paper summarizes these theories, takes the summary and relevant theories as the basis, and follows the principle of establishing index system. Under these conditions, the evaluation system of port competitiveness is established. In the process of establishing the index system, as a part of the index system, the contents of "Actual amount of foreign investment in place" and "Total amount of foreign trade import and export" are added to explain the impact of foreign trade economic development on port competitiveness.

To begin with, this paper analyzes the competitiveness of China's 18 coastal ports by using the method of principal component analysis, scores and ranks the principal components of the 18 ports, and calculates the totality competitiveness of the comprehensive score and ranking based on the score and ranking of the principal components; Furthermore， it uses the method of cluster analysis to cluster the 18 ports, according to the principal component analysis and the comprehensive competitive score obtained from the principal component analysis, obtaining the classification results of five ports. Finally, based on the main component score, comprehensive competitiveness score and ward clustering classification results, this paper evaluates and analyzes the port competitiveness, and provides consequent suggestions for the development and competitiveness improvement of the ports.

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