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Factor Cluster Analysis of Qingdao Port Logistics Competitiveness

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Abstract: In order to make clear the positioning of the port logistics competitiveness of Qingdao Port among the major coastal ports in China, recognize the development level and shortcomings of its own port, and promote the enhancement of its own port logistics competitiveness, this paper uses the factor analysis method and fuzzy equivalence relationship clustering method to select 17 evaluation indicators from the two dimensions at the port hardware level and software level, respectively. Based on the relevant index data of nine major coastal ports in China including Qingdao Port from 2019, this paper makes a comparative analysis on the competitiveness of Qingdao Port in major coastal port groups in China. The results reflect the differences in the competitiveness of port logistics, and find the weaknesses of Qingdao Port in the strength of the port logistics industry, port transport conditions, etc., so as to improve and enhance the competitiveness of port logistics, such as increasing the proportion of port fixed investment, and speeding up the adjustment of transport structure.

Keywords: port logistics; competitiveness; factor analysis; fuzzy clustering

1. Introduction

As important infrastructures of regional economic development, ports play a decisive role. To develop modern port logistics and improve the competitiveness of port logistics has become an important issue concerning the modernization of ports and sustainable development of regional economy. At present, Qingdao is solidly advancing the construction of a free trade pilot zone, and port logistics is essential for the construction of free trade ports. In order to improve the logistics competitiveness of Qingdao Port and maintain its sustainable competitive advantage, it is necessary to understand the factors that affect the competitiveness of Qingdao Port and compare it with other ports horizontally. The scientific evaluation and analysis of port logistics competitiveness is conducive to the common development of coastal cities and ports [1].

In order to clarify the status and level of Qingdao Port logistics competitiveness in China's main coastal port groups, this paper first uses factor analysis to compare and analyze the competitiveness of Qingdao Port in China's major coastal port groups. The results show that the various strength and comprehensive strength of Qingdao Port are in the middle level, and there is a big gap between Qingdao Port and the leading port in China. However, Qingdao Port has developed rapidly in recent years and has great development potential. On the basis of factor analysis, fuzzy equivalence relation clustering with higher accuracy for small data clustering is further adopted to classify and analyze the port group, and finally the main coastal ports in China are divided into three echelons according to their comprehensive strength, and Qingdao Port is temporarily listed in the middle of the second echelon. Finally, according to the result of factor clustering, relevant suggestions are put forward to improve the comprehensive competitiveness of Qingdao Port, such as increasing the proportion of fixed port investment, promoting multimodal transport of roads, railways, sea transport and rivers, and accelerating the integration of port resources in the province.

2. Literature Review

In recent years, the evaluation and research of logistics competitiveness have attracted extensive attention from scholars at home and abroad, and have achieved certain results. Reviewing the research of domestic scholars, the early stage mainly analyzed and studied the logistics competition from the perspective of the factors affecting logistics competition. Wang Bo [2] and others analyzed that the key factors of regional logistics development are logistics rationality, logistics subsystem efficiency and service level, and external environment, and built an evaluation index system of the regional logistics development level in the Tianjin area around these three key factors. With further research, the evaluation index system of logistics competitiveness is constantly improved. Lu Pu [3] and others believed that the relationship between an urban logistics development level index system and economic development of logistics radiation area should be considered in the construction of an urban logistics development level index system, and it should be evaluated from three aspects: urban logistics development capacity, urban logistics development environment, and urban energy consumption and environmental pollution. In terms of the theoretical methods of studying logistics efficiency or logistics competitiveness, Li Taoying [4] and others have adopted fuzzy equivalence relation clustering, the K-means clustering algorithm, and the fuzzy FCM algorithm to conduct clustering analysis on the logistics efficiency index data of eight major ports in China, and concluded that the clustering accuracy of fuzzy equivalence relation is higher and conforms to the status quo of each port. Wang Jingmin [5] used factor analysis to analyze five of the southwest coastal port groups in China. A comprehensive evaluation of the logistics competitiveness of each port is provided to provide a decision-making reference for the competitive development of the port group. Li Nan [6] and others used a deep autoencoder momentum update algorithm (DEA-WMA) to analyze a cluster analysis of logistics competitiveness, and compared it with the DAE-ESA and DAE-CSA algorithms, and it was concluded that the research results of the DAE-WMA method are more reasonable. Tae Won Chung [7] used the Porter diamond theory model to analyze an evaluation of the competitiveness of logistics clusters in major countries, showing that the competitiveness of logistics clusters in six countries is very different.

Through a review of the relevant literature at home and abroad, it is found that with the continuous deepening of research, the logistics competitiveness evaluation index system is continuously improved, and the research methods gradually mature, but there is less relevant research on a Qingdao Port competitiveness evaluation, and in the selection of clustering analysis methods, there is a lack of consideration based on data sets.

3. Construction of the Evaluation Index System and Research Methods

3.1. Construction of the Indicator System

In recent years, with the intensification of port competition, on the basis of factor analysis, fuzzy equivalence relation clustering with higher accuracy for small data clustering is further adopted to classify and analyze the port group, and finally the main coastal ports in China are divided into three echelons according to their comprehensive strength, with Qingdao Port temporarily listed in the middle of the second echelon. Factors affecting port competitiveness have become more diverse and complicated. The competition in modern ports has evolved into a competition of comprehensive strength, and the soft and hard power of a port is both crucial to its own development [8]. Therefore, when constructing the rating index system, this paper takes into account both the hardware level and the software level of port logistics development, and based on the research on the model and method of port competitiveness evaluation by domestic and foreign scholars [9–13] and the principles of representativeness, objectivity, and comprehensiveness, relevant indicators that are difficult to quantify are excluded, such as the relevant government policy and legal environment, the degree of port hinterland city opening, and the degree of port informationization. Finally, 17 evaluations were finally selected for the correlation analysis. The evaluation index system is shown in Table 1.

Table 1. Evaluation index system of port logistics competitiveness.

First-Level Indicators	Secondary Indicators
Port hardware level	Density of highway network adjacent to port X_1 (km/km^2) Density of railway network adjacent to port X_2 (km/km^2) Terminal berth X_3 Terminal container berth X_4 Terminal yard area X_5 (10^4 m^2) Port cargo throughput X_6 (10^4 t) Port cargo turnover X_7 (10^4 t) Total number of port routes X_8 Total number of international container liner routes X_9 Port clearance capacity X_{10} (10^4 TEU) Port fixed assets profit margin X_{11} (%)
Port software level	Port hinterland economic aggregate X_{12} (100 million yuan) Total import and export trade X_{13} (100 million yuan) Output value of port logistics industry X_{14} (100 million yuan) Port logistics industry output value accounts for GDP proportion X_{15} (%) Output growth rate of port logistics industry X_{16} (%) Port new fixed assets ratio X_{17} (%)

3.2. Research Methods

3.2.1. Factor Analysis

Factor analysis is a multivariate statistical method, which from the dependency of an internal research matrix, and according to the correlation between the variable packet size, makes the correlation between variables within the same group low; thus, a low correlation between different variables within the group, in this way—on the premise of trying to reduce the loss of information—extracted from many indexes is not associated with a small number of indicators. Weights are determined according to the variance contribution rate, and then there is a method to calculate the comprehensive score. The biggest advantage of factor analysis is that you can get the final comparable score result without subjectively weighting the indicators. Therefore, it has been widely used in the field of comprehensive evaluation [14].

Theoretical analysis of the factor model. The common factor in factor analysis is a common influence factor that cannot be directly observed but objectively exists. Each variable can be expressed as the sum of the linear function of the common factor and the special factor, namely

$$X_i = a_{i1}F_1 + a_{i2}F_2 + \cdots + a_{im}F_m + \varepsilon_i, (i = 1, 2, \cdots, p)$$

where $F_1, F_2, \cdots, F_m$ is the common factor, and ε_i is the special factor of X_i.The model can be expressed as

$$X = AF + \varepsilon$$

Among them:

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_p \end{bmatrix}, A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ a_{p1} & a_{p2} & \cdots & a_{pm} \end{bmatrix}, F = \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_m \end{bmatrix}, \varepsilon = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_p \end{bmatrix}$$

The matrix A in the model is called the factor loading matrix, and a_{ij} is called the factor loading, which is the load of the i-th variable on the j-th factor. If the variable X_i is regarded as a point in the m-dimensional space, a_{ij} represents its projection on the coordinate axis F_j.

The basic steps of factor analysis are as follows:

1. Dimensionless processing of original data;
2. KMO inspection and Bartlett inspection.

The KMO test is performed on the index. The KMO (Kaiser-Meyer-Olkin) test statistic is an indicator used to compare the simple correlation coefficient and partial correlation coefficient between variables. The closer the KMO value is to 1, the stronger the correlation of the index. Usually, when the KMO value is greater than 0.6, factor analysis can be performed. When the commonality of the variables is close to or greater than 90%, it means that the data loss is small and the effect of factor extraction is better [15];

3. Extraction of factors.

Calculate the factor root and variance contribution rate, and select the cumulative variance contribution rate greater than 90% as the common factor to determine the number of common factors;

4. Naming of factors.

Construct the rotated factor load matrix and complete the factor naming based on the rotated common factor load matrix;

5. Calculate the score of each factor and the comprehensive factor score.

According to the rotated factor loading matrix, the formulas for each factor score are obtained. The proportion of the variance contribution rate of each factor to the total variance contribution rate of all factors is used as a weighted summary to obtain a formula for calculating the comprehensive score F.

3.2.2. Fuzzy Equivalence Relation Clustering

According to the characteristics and degree of similarity between objective things, the mathematical method of classifying objective things by establishing a fuzzy similarity relationship is called fuzzy cluster analysis. The calculation steps are as follows:

1. Dimensionless processing of original data;
2. Establish a fuzzy similarity relationship.

Establishing the fuzzy equivalent relationship is to calculate the similarity statistics [16] between the classification objects. First, establish the fuzzy similarity relationship on the classification object set. $R= [r_{ij}]_{nn}$, r_{ij} classification object x_i versus x_j degree of similarity, and $0 \le r_{ij} \le 1$. This paper uses the angle cosine method to calculate r_{ij}:

$$r_{ij} = \frac{\sum\limits_{k=1}^{s} x_{ik}x_{jk}}{\sqrt{\sum\limits_{k=1}^{s} x_{ik}^2 \sum\limits_{k=1}^{s} x_{jk}^2}} \tag{1}$$

Among them, $i, j= 0, 1, \ldots, n; x_{ik}$ is the K-th dimension of x_i [17];

1. Establishing fuzzy equivalence relations.

The method of transforming the fuzzy similarity matrix into a fuzzy equivalent matrix is to construct a similarity relationship transitive closure and do a composite operation [18]:

$R \bigcirc R = \left(c_{ij}\right)_{nn} = R^2$ is the second-order fuzzy matrix, where $c_{ij}=$ maxmin{a_{ik}, a_{kj}}, and $1 \le k \le n$. In this recursion, there must be a natural number k such that $R^k = R^k \bigcirc R^k$, then R^k is a fuzzy equivalent relationship. On this basis, we can get clusters at different levels.

In clustering analysis, the distance is usually not directly used to measure, but rather the similarity measurement method is used. The formulas of various similarity measurements are widely different, and the similarity measurement Formula (2) is used in this paper.

$$r(x_i, x_j) = \frac{d(x_i, x_j)}{\max\limits_{x_u, x_v \in X} d(x_u, x_v)} \tag{2}$$

In Equation (2):

$$d(x_i, x_j) = \sum_{p=1}^{m} \omega_p (x_{ip}, x_{jp}) \tag{3}$$

In Equation (2), $r(x_i, x_j)$ represents the correlation degree between object x_i and object x_j to be clustered, which is abbreviated as r_{ij}, representing the similarity degree between them, $d(x_i, x_j)$ represents the weight distance between cluster object x_i and x_j, ω_p represents the weight of the p-th index, and $\max\limits_{x_u, x_v \in X} d(x_u, x_v)$ represents the maximum distance among all cluster objects. Thus, the correlation matrix R among the objects to be clustered can be obtained, and $R = (r_{ij})_{n \times n}$ is the fuzzy similarity matrix.

Proof.

(1) Reflexivity

For the same object, the geometric distance must be 0, that is, $d(x_i, x_i) = 0$. According to Formula (2), $d(x_i, x_i) = 0$.

(2) Symmetry

The distance between any two objects, $d(x_i, x_j) = d(x_j, x_i)$, and at the same time, when the cluster objects remain unchanged, $\max d(x_u, x_v)$ is also constant. According to the similarity relation adopted in (2), $r_{ij} = r_{ji}$. □

In practical clustering analysis, closure is usually used to find the fuzzy equivalent matrix of the fuzzy similarity matrix R. After the fuzzy equivalence relation is obtained, the threshold α is set for clustering.

4. Empirical Analysis

In order to study the positioning of Qingdao Port in the main coastal port group of the country's port logistics competitiveness, this paper intends to select Tianjin Port, and includes Qingdao Port, Dalian Port, Qinhuangdao Port, Ningbo Zhoushan Port, Shanghai Port, Guangzhou Port, Shenzhen Port, and Xiamen Port, which are used as the research object. The original data are derived from the China Port Yearbook (2019) and the 2019 National Economic and Social Development Statistical Bulletin of the city where the port is located. SPSS software and MATLAB software were used to process and analyze the original data.

4.1. Factor Analysis

According to the steps of the factor analysis method, the original data are standardized (the data after the standardization process are omitted). First, the KMO and Bartlett tests (applicability tests of factor analysis) are performed on the constructed evaluation index system. The results are shown in Table 2. After testing, the KMO value is 0.648, which is greater than 0.6; the significance is 0.003, which is less than 0.5, so factor analysis can be performed. The commonality of the variables is close to or greater than 90%, as shown in Table 3, which indicates that the degree of data loss is small and the factor effect of the extraction is ideal, and the extracted factors already contain most of the information of the original data variables.

Table 2. KMO and Bartlett test.

KMO Sampling Suitability		0.648
Bartlett Spherical Test	**Approximate Chi-Square**	794.274
	Significance (*p*-Value)	0.003

Table 3. Variable commonness.

Index	**Initial Value**	**Variable Commonality**
X_1	1.000	0.964
X_2	1.000	0.941
X_3	1.000	0.974
X_4	1.000	0.976
X_5	1.000	0.936
X_6	1.000	0.972
X_7	1.000	0.848
X_8	1.000	0.934
X_9	1.000	0.764
X_{10}	1.000	0.976
X_{11}	1.000	0.897
X_{12}	1.000	0.970
X_{13}	1.000	0.872
X_{14}	1.000	0.798
X_{15}	1.000	0.783
X_{16}	1.000	0.989
X_{17}	1.000	0.993

Main factor extraction. The orthogonal rotation method is used to maximize the variance of 17 evaluation indicators to extract the main factors, and then the number of main factors can be determined based on the principle that the eigenvalue is greater than 1 and combined with the gravel chart. The results are shown in Figure 1 and Table 4. Among them, the eigenvalues of the common factors 1, 2, 3, and 4 are all greater than 1, and the variance contribution rates are 54.798%, 16.865%, 13.274%, and 6.368%, respectively, and the total cumulative variance contribution rate is 91.305%. The first four factors are used as the main factors, which are denoted as F_1, F_2, F_3, and F_4.

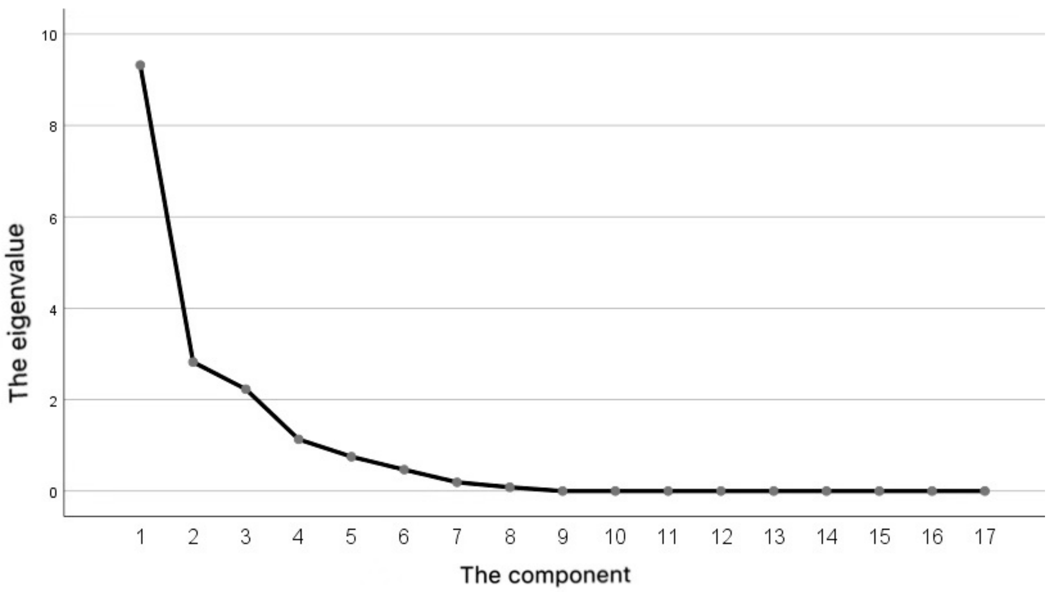

Figure 1. Crushed stone.

Table 4. Eigenvalue and variance contribution rate.

Common Factor	Characteristic Root	Variance Contribution Rate (%)	Cumulative Variance Contribution Rate (%)
1	9.324	54.798	54.798
2	2.832	16.865	71.663
3	2.229	13.274	84.937
4	1.134	6.368	91.305

Set up the factor loading matrix after rotation. Construct the factor loading matrix after rotation for the four common factors extracted, select the index with a load value greater than 0.7 or 0.8 as the naming basis of the common factor, and complete the naming of the factors. The results are shown in Table 5. The results show that the common factor F_1 has large load values on X_6, X_7, X_{10}, X_{11}, and X_{17}, reflecting the strength of the port logistics industry, so F_1 is named "port logistics industry strength factor" and the higher the score on this factor, the stronger the port logistics industry's strength and the stronger its competitiveness; the common factor F_2 has a large load value on X_{12}, X_{13}, X_{14}, X_{15}, and X_{16}, reflecting the macroenvironment of the port, so F_2 is named "macro observing environmental factors"; the common factor F_3 has a large load value on X_1, X_2, X_8, and X_9, which reflects the transportation conditions of the port, so F_3 is named "port transportation condition factor"; the common factor F_4 has a large load value on X_3, X_4, and X_5, which reflects the situation of port infrastructure construction, so F_4 is named "port infrastructure factor". The final naming of each main factor is shown in Table 6.

Table 5. Factor loading matrix after rotation.

Index	F_1	F_2	F_3	F_4
X_1	−0.132	−0.032	0.971	0.136
X_2	0.182	0.085	0.831	0.672
X_3	0.314	0.782	0.203	0.843
X_4	0.761	−0.076	−0.046	0.766
X_5	0.122	0.032	0.235	0.937
X_6	0.786	0.567	0.016	0.289
X_7	0.832	0.799	0.108	0.034
X_8	0.314	0.287	0.783	0.366
X_9	0.642	0.179	0.789	0.132
X_{10}	0.876	0.673	0.079	0.201
X_{11}	0.765	0.641	0.653	−0.015
X_{12}	−0.112	0.901	0.613	0.512
X_{13}	−0.032	0.986	0.512	0.062
X_{14}	0.246	0.881	0.644	0.275
X_{15}	0.690	0.838	0.086	−0.179
X_{16}	0.338	0.815	0.675	0.341
X_{17}	0.834	0.432	0.678	0.436

Table 6. Factor naming.

Main Factor	High Load Index	Factor Naming
F_1	X_6 (port cargo throughput), X_7 (port cargo turnover), X_{10} (port clearance capacity), X_{11} (port fixed asset profit margin), X_{17} (port (New fixed assets ratio)	Port logistics industry strength factor
F_2	X_{12} (total port hinterland economy), X_{13} (total import and export trade), X_{14} (port logistics industry output value), X_{15} (port logistics industry output value to GDP proportion), X_{16} (port logistics industry output value growth rate)	Macroenvironmental factors

Table 6. *Cont.*

Main Factor	High Load Index	Factor Naming
F_3	X_1 (density of highway network adjacent to port), X_2 (density of railway network adjacent to port), X_8 (total port lines), X_9 (total international container liner lines)	Port transportation condition factor
F_4	X_3 (number of dock berths), X_4 (number of dock container berths), X_5 (area of dock yard)	Port infrastructure factor

Calculate the score of each factor and the comprehensive score. Calculate the score of each factor according to Table 4, taking F_1 as an example:

$$F_1 = -0.132X_1 + 0.182X_2 + 0.314X_3 + 0.761X_4 + 0.122X_5 + 0.786X_6 + 0.832X_7 + 0.314X_8 + 0.742X_9 + 0.876X_{10} + 0.765X_{11} - 0.112X_{12} - 0.032X_{13} + 0.246X_{14} + 0.716X_{15} + 0.338X_{16} + 0.834X_{17}$$

The calculations of F_2, F_3, and F_4 are the same, and are omitted here. Finally, the proportion of the contribution of the variance of each factor to the total contribution of the four factors is used as a weighted summary. The calculation formula for the comprehensive score F:

$$F = 0.6002F_1 + 0.1847F_2 + 0.1454F_3 + 0.0697F_4$$

Finally, according to the above formula, the factor scores of nine ports such as Qingdao Port can be calculated separately, namely the comprehensive score and ranking, as shown in Table 7.

Table 7. Factor score table of each port.

Port	F_1	Rank	F_2	Rank	F_3	Rank	F_4	Rank	F	Total Ranking
Qingdao	1.142839	7	0.823769	6	1.059694	6	1.251137	6	0.988	7
Tianjin	1.428534	4	0.81885	7	1.873723	4	3.319311	2	1.287	5
Qinhuangdao	−1.00006	9	−1.00005	9	−1.00012	9	−0.99971	9	−0.663	9
Dalian	1.292435	6	0.836126	5	0.433152	7	0.918751	7	1.018	6
Shanghai	3.645418	2	3.986523	1	3.968112	1	3.958856	1	3.265	1
NBZS	3.969478	1	2.336751	2	2.514898	3	3.310097	3	3.133	2
Guangzhou	1.883439	3	1.687294	3	1.637451	5	2.381660	5	1.643	3
Shenzhen	1.350946	5	1.545988	4	3.234765	2	2.475655	4	1.332	4
Xiamen	−0.07153	8	−0.32401	8	0.183713	8	0.286325	8	−0.032	8

4.2. Cluster Analysis of Fuzzy Equivalence Relations

Cluster analysis is an important multivariate statistical method, which simplifies the data [19] through data modeling. Specific cluster analysis methods are various. In this paper, we choose Li Taoying [4] and others (2014) on the related research of logistics efficiency evaluation of major ports in China, and this paper uses the fuzzy equivalence relation clustering method and compares and analyzes the clustering results with the common K-means clustering algorithm and fuzzy FCM algorithm. The results show that, common clustering algorithms have a large deviation when processing clusters of small data sets, and fuzzy equivalent relationship clustering has a higher time complexity, which is more suitable for the clustering of small data sets, and the accuracy of clustering is higher, so the results are more in line with the development status of each port. Therefore, considering that the original data set selected in this paper is a small data set, the clustering analysis is performed using a fuzzy equivalent relationship clustering method with higher clustering accuracy. Using MATLAB software to perform cluster analysis on the standardized index data, the initial fuzzy similarity matrix *R* can be obtained, as shown in Table 8, and then the similarity relationship transfer closure is constructed, and the synthesis operation is performed to finally obtain the fuzzy equivalent matrix (Table 9). Its port name sequence is Qingdao Port, Tianjin Port, Qinhuangdao Port, Dalian, Shanghai, Ningbo, Zhoushan Port, Guangzhou, Shenzhen, Hong Kong, Xiamen, and Hong Kong, with 1, 2, . . . , 9 to represent.

Table 8. Fuzzy similarity matrix.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	1.00	0.84	0.45	0.80	0.44	0.50	0.75	0.72	0.58
2	0.84	1.00	0.37	0.73	0.52	0.58	0.76	0.74	0.50
3	0.45	0.37	1.00	0.45	0.19	0.22	0.35	0.37	0.72
4	0.80	0.73	0.45	1.00	0.43	0.49	0.71	0.60	0.58
5	0.45	0.52	0.19	0.43	1.00	0.84	0.55	0.52	0.26
6	0.50	0.58	0.22	0.49	0.84	1.00	0.61	0.56	0.29
7	0.75	0.76	0.35	0.71	0.55	0.61	1.00	0.73	0.47
8	0.72	0.74	0.37	0.60	0.52	0.56	0.73	1.00	0.49
9	0.58	0.50	0.72	0.58	0.26	0.29	0.47	0.49	1.00

Table 9. Fuzzy equivalence matrix.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	1.00	0.83	0.58	0.80	0.61	0.61	0.76	0.74	0.58
2	0.83	1.00	0.58	0.80	0.61	0.61	0.76	0.74	0.58
3	0.58	0.58	1.00	0.58	0.58	0.58	0.58	0.58	0.72
4	0.80	0.80	0.58	1.00	0.61	0.61	0.76	0.74	0.58
5	0.61	0.61	0.58	0.61	1.00	0.84	0.61	0.61	0.58
6	0.61	0.61	0.58	0.61	0.84	1.00	0.61	0.61	0.58
7	0.76	0.76	0.58	0.76	0.61	0.61	1.00	0.74	0.58
8	0.74	0.74	0.58	0.74	0.61	0.61	0.74	1.00	0.58
9	0.58	0.58	0.72	0.58	0.58	0.58	0.58	0.58	1.00

According to the values in the fuzzy equivalent matrix {0.57, 0.61,0.72, 0.74, 0.76, 0.80, 0.83, 0.84, 1}, nine value ranges and corresponding clustering results can be obtained, as shown in Table 10. Figure 2 is a visual tree representation of the clustering results.

Table 10. Clustering results.

Range	Number of Categories	Clustering Results
(0, 0.57]	1	{1, 2, 3, 4, 5, 6, 7, 8, 9}
(0.57, 0.61]	2	{3, 9}, {1, 2, 4, 5, 6, 7, 8}
(0.61, 0.72]	3	{3, 9}, {1, 2, 4, 7, 8}, {5, 6}
(0.72, 0.74]	4	{3}, {9}, {1, 2, 4, 7, 8}, {5, 6}
(0.74, 0.76]	5	{3}, {9}, {1, 2, 4, 7, 8}, {5, 6}, {8}
(0.76, 0.80]	6	{3}, {9}, {1, 2, 4}, {5, 6}, {7}, {8}
(0.80, 0.83]	7	{3}, {9}, {1, 2}, {4}, {5, 6}, {7}, {8}
(0.83, 0.84]	8	{3}, {9}, {1}, {2}, {4}, {5, 6}, {7}, {8}
(0.84, 1]	9	{3}, {9}, {1}, {2}, {4}, {5}, {6}, {7}, {8}

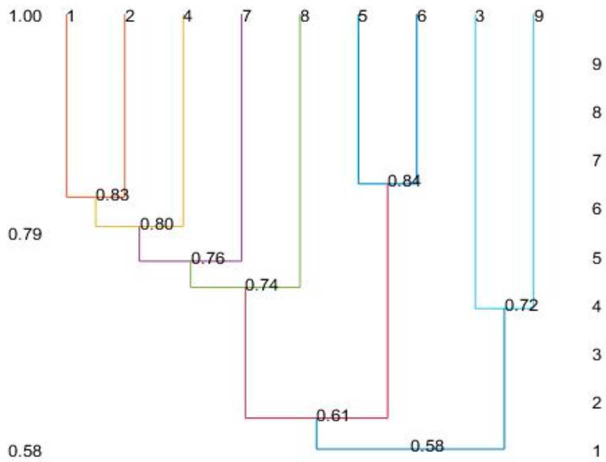

Figure 2. Cluster analysis diagram.

5. Discussion

It can be seen from the contribution ratio of the four major factors in Table 5 that the results of the port competitiveness are mainly composed of the first principal component strength to explain the port logistics industry, with the variance contribution rate of the highest up to 54.798%. It shows that the factors reflecting the basic strength of the port, such as the throughput and turnover of the port, the customs clearance capacity of the port, and the profit margin of the port fixed assets, are the decisive factors of the comprehensive competitiveness of the port. The contribution rate of the first two main factors is as high as 71.663%, accounting for more than half of the information to be explained. At the same time, port transport conditions and port infrastructure represented by the third and fourth major factors are also important indicators to measure port production capacity, operation capacity, and development level, which determine the development level of port logistics competitiveness to a certain extent [20].

From the scores and comprehensive scores and rankings of the factors in Table 6, it can be seen that the comprehensive scores of Shanghai Port (3.265) and Ningbo Zhoushan Port (3.133) are very close. The ranking of each factor is in the forefront of the port group, indicating the logistics competition between the two ports. It has strong strength and has a leading position among the major port groups in the country; the comprehensive scores of Guangzhou Port (1.643), Shenzhen Port (1.332), Tianjin Port (1.287), Dalian Port (1.018), and Qingdao Port (0.988) are relatively close. It also has a certain competitive strength, but there is still a certain gap between Shanghai Port and Ningbo Zhoushan Port. Although the comprehensive ranking of Tianjin Port is not prominent, it is more competitive in terms of port infrastructure (F_4 main factor). Tianjin Port, Dalian Port, and Qingdao Port are similar in terms of software and hardware, their comprehensive factor scores are very close, and their port logistics competitiveness is also close. They are the three strong ports in the Bohai Bay Port Area. Logistics maintains a rapid development momentum, but looking at coastal ports across the country, its competitiveness is still slightly behind. Qingdao Port ranks slightly behind in its echelon port group, and its port logistics competitiveness still has a lot of room for improvement; the overall score of Xiamen Port (−0.032) and Qinhuangdao Port (−0.663) is low, and their port logistics competitiveness is weak, mainly due to their port logistics industry strength factors, macroenvironmental factors, and other gaps from other ports.

According to Figure 2, the port logistics competitiveness level of the nine ports can be divided into three categories, that is, three echelons. The first echelon includes Shanghai Port and Ningbo Zhoushan Port, the second echelon includes Guangzhou Port, Shenzhen Port, Tianjin Port, Dalian Port, and Qingdao Port, and the third echelon includes Xiamen Port and Qinhuangdao Port.

6. Countermeasures and Suggestions

Learning from the successful experience of advanced and strong ports is an important way to promote the development of Qingdao Port itself. Shanghai Port and Ningbo Zhoushan Port, as the two ports with the most comprehensive competitiveness in the port group, have their internal and external advantages for development. The hinterland of Shanghai Port itself is very rich in resources. At the same time, it is highly valued and supported by the national and local governments, as well as the favorable geographical environment and natural conditions of Shanghai Port, which makes the development of Shanghai Port have the excellent advantage of "right time, right place and harmonious" [21]. In recent years, the integration of port resources and the combined transport of sea and rail have also made Zhoushan Port of Ningbo more and more powerful in its development momentum. It has not only achieved the "ten successive championships" in the port cargo throughput of the whole year, but is also striding toward the world-class "strong port" with the amazing "speed of Ningbo Port". In recent years, Guangdong Province has focused on integrating the province's port resources and formed the "dual-core" of Shenzhen Port and Guangzhou Port. The two main bodies vigorously promoted the adjustment of the Haihe River transportation structure of the railway, and developed an international multimodal transport network [22], which has led to the rapid development of its port logistics. On the basis of analyzing the successful experience of strong ports and combining with the results of factor cluster analysis, the following suggestions are put forward for Qingdao port to improve its logistics competitiveness:

1. From the results of the factor analysis, it can be seen that the port logistics industry strength of Qingdao Port has yet to be improved, it needs to draw lessons from the successful experience of the two big strong ports, it needs further expansion of the Qingdao economic hinterland, and relevant departments should enhance the proportion of port fixed investment, establish and improve financial policy of financial support, and provide a powerful guarantee for the development of port logistics. At the same time, it also needs to pay attention to the integration of peripheral port resources to form a joint development force.

2. As can be seen from the clustering results, the competitiveness of Qingdao Port in the second tier is also in a weak position. Therefore, Qingdao Port should first focus on narrowing the development gap with the second-tier ports and strive to occupy the forefront of the development of the second-tier port group. Therefore, it is necessary to fully learn and draw lessons from the development experience of other ports. Firstly, we can learn from the successful experience of Tianjin Port in infrastructure construction, increase investment in port infrastructure construction, and strengthen channel dredging, with facilities supporting construction and road construction and repair, etc., so as to lay a solid foundation for the development of port logistics. In addition, we must continue to accelerate the pace of "learning Shenzhen and catching up to Shenzhen" and learn its advanced development model and development experience in port construction, focusing on learning the port resources that effectively integrate the experience in the province. Qingdao should speed up the formation of the "Qingdao Port as the hub port, Rizhao Port, Yantai Port and Bohai Bay Port around their hinterlands" maritime spur line layout. Qingdao Port should take the enhancement global shipping resource allocation ability as the main line to accelerate the building of an international logistics center in Northeast Asia.

3. Attach importance to the linkage of the port and city as a powerful weapon to create an evolutionary symbiosis mode between port industry and hinterland industry. Focus on supporting the leading enterprises or multinational companies that can form the growth pole of industrial clusters, strengthen the advantage of local companies such as Haier and Hisense, and give some preferential policies to foreign companies, such as Japanese, Korean and American enterprises in Qingdao. Vigorously introduce small- and medium-sized supporting enterprises to form a complete equipment manufacturing industry chain. Make full use of the free trade area advantages, vigorously foster and develop the strategic emerging industry of Qingdao, build an industrial cluster adjacent to the port, focus on improving the industrial structure and transforming the pattern of economic

development for emerging industries such as marine biomedicine, marine instruments and equipment, seawater desalination equipment, and new marine energy, and further expand business clusters for the development of emerging industries.

4. In order to further enhance the competitiveness of port logistics, Qingdao Port also needs to speed up the adjustment of transport structure, improve the construction of the traffic network, vigorously promote the development of "four-port linkage" multimodal international logistics corridors for land, sea, air, and rail, form a system centered on Qingdao Port and integrated multimodal transport, warehousing and distribution, and tax declaration trade. At the same time, Qingdao Port should also give full play to its own development advantages and rely on the geographical location to seize the resources of large ships. Multi-party linkage promotes transformation and upgrading from "single loading and unloading port" to "composite value-added port", from logistics port to hub port trading port, and from "automation" to "smart", and comprehensively enhance the competitiveness of Qingdao Port logistics and move towards a world-class ocean port.

5. The covid-19 epidemic earlier this year has had a significant impact on port economy. Although public health emergencies are not inherent production factors in the economy, the prevention and control of diseases and the fear caused by diseases will change people's behavior towards consumption, investment, and production, which is equivalent to an external impact on the economic system. During the epidemic, it is all the more important to optimize the business environment at ports, introduce preferential policies and safeguard measures, and ensure the smooth transportation of important materials that affect the national economy and people's livelihoods. After the epidemic, the port should become the external merchant bureau of the government, and the government should become the booster of resource input. In other words, enterprises should help local governments to develop innovative industries, accelerate the improvement of industrial chain and industrial ecological construction, and the government should help enterprises to realize the policy support, financial support, and land support needed for development.

7. Conclusions

From the results of the empirical analysis, the results of the factor analysis and fuzzy equivalence relation cluster analysis are basically in line with the actual situation of China's coastal port development. It is reasonable to evaluate the development level of Qingdao Port competitiveness in national coastal ports by factor analysis and cluster analysis. Factor analysis makes factor variables more interpretable through rotation, can effectively name factors, and can accurately calculate the scores of each factor and the comprehensive scores. Cluster analysis can classify the research objects directly. The combination of the two analysis methods can complement each other and analyze and solve problems more comprehensively and efficiently, which is a good research method in the field of comprehensive evaluation research.

This paper selects 17 indicators from two dimensions to establish a port logistics competitiveness evaluation index system and uses factor analysis to extract four main factors such as port logistics industry strength and macroenvironment. The results show that the port logistics industry strength factor is the main influence factor, and the comprehensive score calculation and ranking of each port can determine the port logistics competitiveness positioning of Qingdao Port in the main coastal port groups in the country. Further, when selecting the clustering method, this paper considers the original data as a small data set and selects fuzzy equivalence relation clustering with higher clustering accuracy than the general clustering method to classify and analyze the port group. The results reflect the gap in the level of logistics competitiveness of each port, and provide an objective and proper understanding and evaluation for Qingdao Port. The competitiveness level of its own port logistics provides a reference for, and is conducive to, Qingdao Port finding its own weak links, which is convenient for targeted improvement and general improvement.

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