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Article

Analysis and Evaluation of Comprehensive Competitiveness of China's Main Coastal Ports

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Abstract: As the center of national resource strategy and global resource allocation, the port is of great significance in economic development and foreign trade. The implementation of "The Belt and Road" initiative makes China's ports play a more prominent role in foreign trade than before. As the dominant node of the maritime route of the Silk Road, China's ports are facing great opportunities and challenges. With the increasing economic pressure in the world, the competition of ports is increasingly fierce, and the ports are facing a severe challenge. This paper analyzes the basic problems and explores how to develop further in China's coastal major ports along "The Belt and Road". The evaluation factors of port comprehensive competitiveness are selected to establish the evaluation index system. The factors of 13 ports are defined by SPSS software to obtain the ranking of comprehensive competitiveness of the ports through the ladder comparison with cluster analysis. Based on the result, the appropriate policy is suggested.

Keywords: Port Economy; Comprehensive Competitiveness; Factor Analysis; Cluster Analysis

1. Introduction

With the adjustment of the world economic and trade pattern, Chinese enterprises have become competitive globally and secured excessive production capacity and foreign exchange assets. Under the globalization of the world economy, China in 2013 proposed the "area" initiative, namely the economic belt of "Silk Road" and "Marine Silk Road" to use the existing platform effectively for regional cooperation and develop the partnership for mutual benefit and win-win progress for economic and social integration in the global society. In 2015, The National Development and Reform Commission, the Ministry of Foreign Affairs, and the Ministry of Commerce jointly issued the "Vision and Actions for Promoting the Joint Construction of the Silk Road Economic Belt and the 21st Century Maritime Silk Road" which aims to expand the cooperation from a single country or community to multiple countries or communities starting from the regional cooperation.

In recent years, China's rapid economic development has promoted the strategy of local development and open economy, which results in the rapid development of the ports in China. Harbor cities have been constructed and developed rapidly and become an important support for China's economy. To promote the construction and development, the optimization of the development pattern of the coastal economy is required for the coordination of the regional economy, the achievement of developing goals, and the accelerating the execution of open economy.

China has many large harbors. Thus, the development of ports has been undergone successfully but not that of the software, which slowed down the development. As port construction is an important prerequisite for promoting maritime strategy, the government has increased capital investment in large-scale facilities of ports along the "The Belt and Road" since 2015, which increases the number of ports. However, rapid development has resulted in excess capacity and homogenization of ports, which induces fierce competition.

Since 2019, the overall performance of the Chinese economy has had downward pressure. However, it is crucial to maintain a steady economic growth of the Chinese economy. China has 7 container ports that is listed in the world's top 10 container ports. The total number of containers in the ports was 261 million TEU that is decreased when compared to that in the previous year.

With the progress and development of China's social and economic construction, the port economy presents multi-level development and the new port logistics reform. The research result on port competitiveness states the strengths and weaknesses of the ports and helps to promote the reasonable allocation of resources and improve the efficiency of strategic policy execution. It also enhances port competitiveness. The research on port competitiveness is therefore a subject of great practical significance as it is closely related to the survival and development of the port and national economy.

In this study, 13 ports along China's coast were selected from the perspective of the competitive edge. Based on the theory of port competitiveness and the result of factor analysis, this paper adopts the parallel theory and practice to investigate the development status and solve existing problems of China's major ports. The analysis of competitiveness is expected to provide a guideline for China's ports and to promote the healthy development of the port.

2. Relevant Theories of Port Competitiveness

2.1. Port Competitiveness

2.1.1. Concept of Port Competitiveness

Port competitiveness refers to the comparative advantages of a port in terms of its natural environment, terminal facilities, and hinterland economic resources. It attracts various production and shipping elements, occupies the transportation market, increases the value of logistics, and maintains the sustainable development of the port through the optimal allocation of various resources. Port competitiveness not only depends on the internal environment but also the external environment such as geographical location, hinterland economic, social and transport capacity, policy measures, transportation facilities, management efficiency, service quality, and so on (Yeo, 2010). Port industry has two characteristics: economic and social. Port industry is for profit-making, which provides the development and employment of related industries for society. It provides great benefits for the national economy, especially the hinterland economy.

2.1.2. Causes of Port Competition

The first reason for competition among ports is that ports need to continue to attract customers to survive and develop. With the gradual improvement of the transportation network, multiple ports have the same target customers. This situation triggers fierce competition among ports. There is competition between container ports, too. The rapid development of international container transportation makes the industry profitable, which intensifies the competition for container transportation between domestic and foreign ports. The imbalance of port supply and demand increases port competition. The overlapping of port functions and services and the lack of sustainable strategic development planning and macro-management systems make the related market imbalanced and compete severely.

(1) "Policy factors" of Port Competition

At present, the competition in ports not only involves the supply of market commodities but also policy measures. As the port is an important infrastructure for economy and trade, it is paid great attention to from government departments, and the investment and support as policy measures are increasing.

(2) "Environmental Factors" of Port Competition

The environment here not only refers to the natural environment but also the location of the port, the port hinterland's infrastructure, economy, service level, traffic environment, and so on. These factors affect the port development.

(3) The "Source Factor" of Port Competition

In terms of economic transportation facilities, port development is often listed as a priority development project. The social nature of ports is different from ordinary enterprises and induces the competition for sources of goods.

2.1.3. Evolution Process of Modern Port Development

The role and function of ports are constantly changing. The United Nations defined the generations of port development at the 1992 Trade and Development Conference. In 1999, United Nations Commission on Trade and Development (UNCTAD) proposed the fourth-generation of ports as a new generation of ports. In 2009, at the Port Logistics and Supply Chain Development Trends Sub-forum of the 8th China Logistics Conference, the then authoritative expert outlined the concept of the fifth-generation port from the perspective of port strategic planning (Xi, 2012). The evolution of the generation of the port is shown in Table 1.

The first-generation ports existed before 1950. Its main functions were transportation, temporary storage, receiving, and delivery of goods, which are the combinations of land and water transportation. The main task is to transfer groceries and bulk cargo. The port is independent of transportation and trade activities. The second-generation port existed from 1950 to 1980. With the recovery of the world economy, the functions of ports gradually increased from those of the first-generation ports. The functions were mainly for serving industry and commerce which were increasing. That is, the value-added processing of goods occurred within the port area. In terms of transportation and trade, it expanded to the vicinity of ports, integrated related logistics businesses, expanded material storage and distribution services, and established a close relationship with local communities.

The third-generation port refers to the port from 1980 to 1990. This generation of ports not only had the basic functions of the previous generations but also strengthened the connection with the region and customers to promote services beyond the boundaries of the past ports. With the addition of comprehensive services such as transportation and trade information content services and cargo distribution, the port became the center of distribution and international logistics. Nowadays, several ports in China still pertained to the third generation. The fourth-generation port refers to the port from 1990 to around 2010. With the rapid economic development, international multimodal transport and integrated world logistics services have emerged. This generation of ports has more functions than the previous generations. It is mainly based on the cooperation between ports and shipping and inter-ports to properly handle networked container cargo to meet the requirements of market flexibility. It also formulates an integrated development model of ports and hinterland cities, and land and marine economies. The ports at Ningbo-Zhoushan and Shanghai are the fourth-generation ones. The fifth-generation port has appeared from 2010 to the present. It mainly carries containerized cargo. Containers are transported at sea ports, dry ports, inland port areas, and branch ports. The development strategy of the fifth-generation port aims to develop inland supply between seaports and inland areas, increase the total volume of goods, ensure the prosperity of the inland, improve service levels and efficiency, and expand the proportion of outbound transportation. According to the strategy, inland port areas and branch dry ports operate cooperatively to provide inland areas with port services.

Table 1. The evolution process of port development.

Development Period		**Development Strategy**	**Organizational Characteristics**
The first-generation port	Before 1950	Combination of land and sea transportation modes	Independent activities in the port
The second-generation port	1950–1980	Transport loading and unloading, Industrial and commercial services	The relationship between the port and the city is close, value-added of port cargo
The third-generation port	1980–1990	International transportation center, Logistics platform	The closer relationship between port and city Strengthening port services
The fourth-generation port	1990–2010	Cooperation between port and shipping and inter-port	Integration of port and city International shipping center
The fifth-generation port	After 2010	Mainly container transportation, Joint venture sub home port	Port resource integration, sustainable development

2.2. Theory of Factor Analysis

2.2.1. Concept of Factor Analysis

Factor analysis provides extended and developed results based on the principal component analysis (Fávero & Belfiore, 2019). The factor analysis was used in this study by using SPSS software. It summarizes related variables into representative factors and helps to understand the relationship between factors. By studying the relationship between correlated factors, it reduces a dimension in multivariate analysis for offering the significant factors.

2.2.2. Mathematical Model of Factor Analysis

For N samples and P indicators, when $X = (X_1, X_2, X_3, \cdots X_p)^T$ is a random vector, and the common factor to find is $F = (F_1, F_2, F_3, \cdots F_m)^T$, then the model is defined as follows.

$$\begin{cases} X_1 = a_{11}F_1 + a_{12}F_2 + \cdots + a_{1m}F_m + e_1 \\ X_2 = a_{21}F_1 + a_{22}F_2 + \cdots + a_{2m}F_m + e_2 \\ \vdots \\ X_p = a_{p1}F_1 + a_{p2}F_2 + \cdots + a_{pm}F_m + e_p \end{cases} \tag{1}$$

where Matrix $A = (\alpha_{ij})$ is the factor loading matrix, α_{ij} is the factor loading, F_i is a common factor, X_j. is the variable, and ε is a special factor.

For calculating common factors, the variables of larger loads are defined and then named as the common factors. If it is difficult to interpret the common factor, actor rotation is required to obtain a reasonable explanation. After calculating the common factors, the mathematical model of factor scores is obtained through regression analysis. Each common factor is expressed as a linear variable, and the factor scores are calculated to comprehensively evaluate the sample as Equation (2).

$$F_i = b_{i1}X_1 + b_{i2}X_2 + \cdots b_{ip}X_p \quad (i = 1,2,\ldots,m) \tag{2}$$

3. Development of Major Coastal Ports in China under the Background of "The Belt and Road"

3.1. Countries along the "The Belt and Road" and Their Regional Division

Since the "The Belt and Road" initiative was proposed, positive progress has been made in trade cooperation between China and "The Belt and Road" countries, which strengthens the trade cooperation, the optimized framework, and the facilitation level of sustainable development. The countries along the "The Belt and Road" include 65 countries in Southeast Asia, South Asia, East Asia, Central Asia, West Asia, North Africa, and Central and Eastern Europe. As shown in Table 2, their total area accounts for more than one-third of the world, and their total population accounts for approximately 60% of the world population.

Table 2. Regional division table of 65 "The Belt and Road" countries.

Area	Countries
East Asia (2 countries)	China, Mongolia
Southeast Asia (11 countries)	Singapore, East Timor, Thailand, Laos, Indonesia, Brunei, Philippines, Myanmar, Vietnam, Cambodia, Malaysia
South Asia (8 countries)	India, Bangladesh, Pakistan, Afghanistan, Sri Lanka, Nepal, Bhutan, Maldives
Central Asia (5 countries)	Kazakhstan, Uzbekistan, Turkmenistan, Tajikistan, Kyrgyzstan
West Asia and North Africa (19 countries)	UAE, Azerbaijan, Saudi Arabia, Jordan, Turkey, Lebanon, Israel, Egypt, Cyprus, Kuwait, Iran, Georgia, Yemen, Cartel, Armenia, Syria, Iraq, Palestine, Oman
Central and Eastern Europe (20 countries)	Russia, Poland, Jack, Macedonia, Albania, Romania, Ukraine, Slovenia, Lithuania, Belarus, Bulgaria, Bosnia and Herzegovina, Croatia, Hungary, Slovakia, Estonia, Latvia, Serbia, Moldova, Montenegro

3.2. Determination of Major Ports along the Routes

The vision and actions of "The Belt and Road" clearly stated the development of "The Belt and Road" which planned to construct 15 harbor cities such as Shanghai and Shenzhen and trade zones to promote cooperation and development among countries along the route. The main ports in China's coastal areas are divided into five parts: Bohai Rim, Yangtze River Delta, Southeast Coast, Pearl River Delta, and Southwest Coast. Table 3 presents that 13 cities in the "Vision and Action" have nearly 80% of the total coastal container throughput. Therefore, they are classified as the main coastal representative harbors in China along the "The Belt and Road".

Table 3. China's 13 major coastal ports along the routes.

China's Main Coastal Ports along the Line		Container Throughput (Ten Thousand TEU)	Proportion in Total Coastal Area（%）
Bohai Bay	Qingdao Port	2,101	9.10
	Yantai Port	310	1.34
	Tianjin Port	1,730	7.49
Southeast coast	Xiamen Port	1,112	4.82
	Fuzhou Port	341	1.48
	Quanzhou Port	258	1.12
Yangtze River Delta	Shanghai Port	4,330	18.75
	Ningbo-Zhoushan Port	2,753	11.92
Pearl River Delta	Shenzhen Port	2,577	11.16
	Guangzhou Port	2,324	10.06
	Shantou Port	135	0.58
Southwest coast	Zhanjiang Port	112	0.49
	Haikou Port	197	0.85
	Total	18,280	79.16

3.3. Development Status of National Ports

The port industry is a large-scale infrastructure industry. Since the 1990s, the biggest change in the global port industry was observed as Asia has emerged as the important market. Its fast growth is still accelerating the development of China to make the country handle the largest amount of containers.

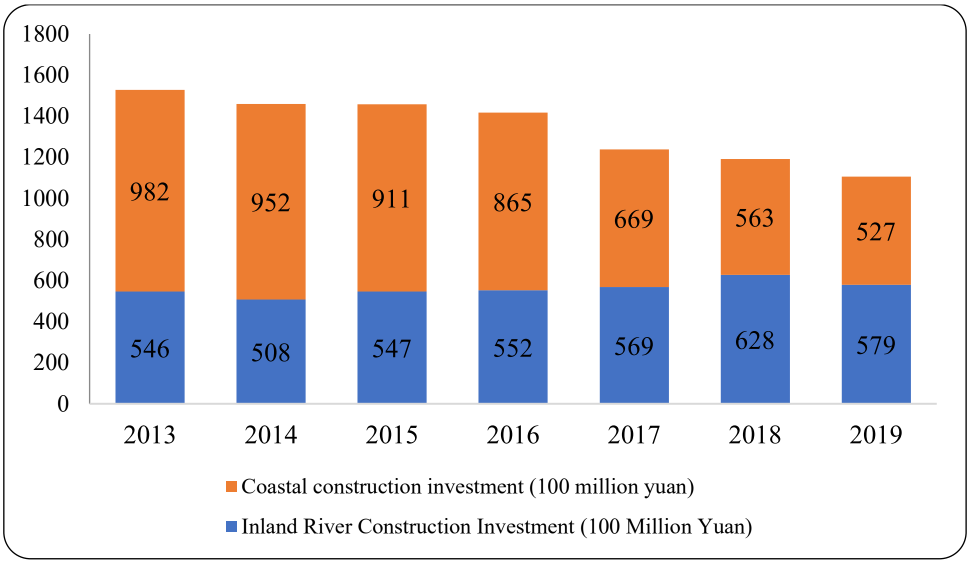

Fig. 1. Investment scale of waterway construction in China from 2013 to 2019.

China's ports are grouped into main hub ports and small and medium ports. In recent years, as the growth of capacity of ports has slowed down, ports are experiencing structure adjustments and utilization imbalances. Ports need to assess their capability for maintaining existing inventory. The port construction has also slowed down with declined investment.

3.3.1. Investment Status of Port Construction

In recent years, the throughput of China's ports has maintained an increasing trend. The imbalance of supply and demand and the development of new port areas have intensified the competition between the areas, which affects the operating efficiency of the ports. The debt of companies related to the port industry surfaced out, which causes market adjustments. Construction investment has experienced negative growth for at least seven consecutive years. However, the balance of supply and demand tends to recover, and resource integration has been promoted.

Fig. 1 shows that China's investment in water transport construction has decreased from 2013 to 2019. Investment in coastal construction also declined, while construction in rivers increased. In 2019, investment in coastal construction reached USD 8 billion that was decreased by 6.4% from that in 2018.

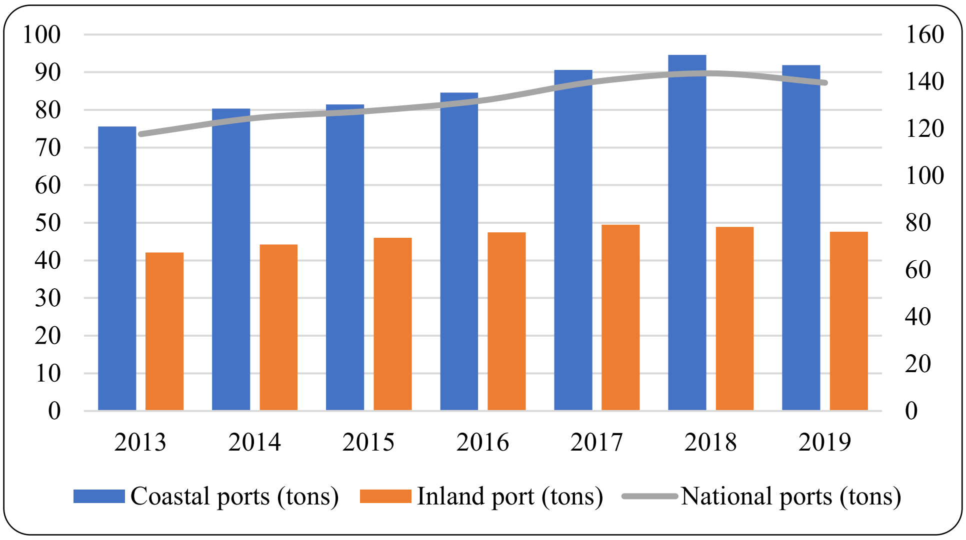

Fig. 2. Cargo throughput of national ports from 2013 to 2019.

3.3.2. Current Port Throughput

Figure 2 shows that China's port throughput has increased as a whole since "The Belt and Road Initiative" was proposed, but the growth has gradually slowed down. In 2019, the annual cargo throughput of China ports was 14 billion tons that were decreased by 3% from that in 2018, while the container throughput was 261 million TEU, an increase of 9%. The increases indicate that China's ports are developing towards the fifth generation of ports.

3.4. Development Status of Major Coastal Ports in China

The ranking of the top ten container ports in the world in 2019 is shown in Table 4. The overall ranking has not changed much from 2018. Seven harbors of China, Shanghai, Ningbo-Zhoushan, Shenzhen, Guangzhou, Qingdao, Hong Kong, and Tianjin were listed in the top ten. Six harbors belong to the cities of "The Belt and Road".

Table 4. 2018 and 2019 global container throughput rankings.

Port Rank	2018	2019
1	Shanghai Port	Shanghai Port
2	Singapore Port	Singapore Port
3	Ningbo-Zhoushan Port	Ningbo Zhoushan Port
4	Shenzhen Port	Shenzhen Port
5	Guangzhou Port	Guangzhou Port
6	Pusan Port	Pusan Port
7	Hong Kong Port	Qingdao Port
8	Qingdao Port	Hong Kong Port
9	Los Angeles/Long Beach Port	Tianjin Port
10	Tianjin Port	Dubai Port

3.4.1. Shanghai Port

Shanghai is located at the intersection of the east-west transportation channel of the Yangtze River and the north-south sea transportation channel. The hinterland city is the country's largest economic, trade, and financial center. As Shanghai has China's largest coastal hub port and is on "The Belt and Road" route, it participates in the international economic circle and foreign trade. In 2019, Shanghai Port had a cargo throughput of 720 million tons with a 1.4 % decrease from that in 2018. The container throughput reached 43,302,600 TEUs that were increased by 3.1% from that in 2018 but the largest throughput in the world for ten consecutive years. The trade volume of countries along "The Belt and Road" reached USD 100 billion which accounts for 22.4% of the city's trade. Since the opening of Shanghai Yangshan Automated Terminal for trial operation in 2018, Yangshan Deepwater Port Phase IV has become the world's largest automated port.

3.4.2. Ningbo Zhoushan Port

Ningbo Zhoushan is located in the Yangtze River Delta region, with a golden location where the river meets the sea. It is the end of China's Grand Canal and the starting point of the Maritime Silk Road. It has been a core port for cultural exchanges between the East and the West since ancient times. In recent years, Ningbo-Zhoushan Port has achieved informatization and intelligence, established trade channels in more than 190 countries and regions, and become an important hub of the Silk Road Economic Zone. In 2019, Ningbo Zhoushan-Port's cargo throughput reached 1.12 billion tons that were increased by 3.3% from that in 2018, and won the global championship for 11 consecutive years. Its container throughput reached 27.535 million TEUs with an increase of 4.5% and was positioned as one of the top ten container ports. It is the first port to realize a "paperless port". In 2019, the real-time dynamic visualization of the information of various logistics was completed. To achieve environmental protection through saving energy and reducing emissions, it has been constantly innovating to be a green port.

3.4.3. Shenzhen Port

Shenzhen is located in the Pearl River Delta region, and the east and west areas are separated by the Kowloon Peninsula. The west area is located on the east bank of Lingdingyang estuary, the estuary of the Pearl River and provides convenient waterway transportation. It reaches the domestic coastal areas and ports around the world through Hong Kong Amston Waterway. The east area is located in Dapeng Bay in the east of Shenzhen, and an excellent natural harbor is located in southern China. In 2019, the cargo throughput of Shenzhen Port was 260 million tons that were increased by 2.6% from that in 2018. The container throughput was 25.7692 million TEUs that were increased by 0.1%. At the end of the year, there were 157 port berths, of which 76 were 10,000-ton berths.

3.4.4. Guangzhou Port

Guangzhou is located in the Pearl River Delta region with developed hinterland cities. It is connected to major coastal ports in China through the North-South channel. It is the largest trading port in South China and the waterway center of the Pearl River Delta. It connects the international routes to North America, southeast Asia, the Red Sea, Africa, and the Mediterranean, and is a key node of the maritime routes on the Silk Road. In 2019, the cargo throughput of Guangzhou Port was 630 million tons that were increased by 12.6% from that in 2018. The container throughput was 23,236,200 TEUs that were increased by 6.0%. Guangzhou Port opened hundreds of water routes covering the entire Pearl River-Xijiang River Basin. 67 cruise lines are operated by Guangzhou Port Group, which is the river-sea combined transport network.

3.4.5. Qingdao Port

Qingdao is located at the intersection of the Bohai Rim port group and the Yangtze River Delta port group. It occupies the center of the Northeast Asian port circle. It is an important port and trade hub in the Western Pacific and one of the world's largest comprehensive ports. In 2019, the port throughput of Qingdao Port was 577 million tons that were increased by 6.6% from that in 2018. The container throughput was 21.01 million TEUs that were increased by 8.8%. The total import and export to countries along the "The Belt and Road" was USD 28 billion that was increased by 30% from those in 2018. After the establishment of Shandong Port Group, many trade companies were newly opened from Weihai, Rizhao, Lanshan to Qingdao as its subsidiaries. A strategic cooperation agreement with domestic shipping companies was signed to promote domestic trade on 38 main and branch routes.

3.4.6. Tianjin Port

Tianjin is located at the intersection of the Beijing-Tianjin-Hebei urban agglomeration and the Bohai Rim Economic Circle. It is one of China's main coastal hub ports and important hubs of the integrated transportation system. It is the largest port in the Bohai

Rim region and has the most complete functions of coastal ports in China. In 2019, the cargo throughput of Guangzhou Port was 492 million tons that were increased by 4.1% from that in 2-18. The container throughput of 17.307 million TEUs that was increased by 8.1%.

3.5. Analysis of China's Port Problems

Overcapacity: In the early stage of port development, too much emphasis was put on the scale of port facilities and construction. However, the rapid development has led to overcapacity that worsens profitability. There is a large gap between the facilities and shipping and services. The return on investment is diminishing, and the investment is no longer plausible in the current economic situation.

Competition: The problems of overlapped construction and functions in the same province have led to fierce and vicious competition between the ports, which has caused a serious conflict of interest. It is necessary to move from competition to competition and cooperation. Even though the operating company of Ningbo Zhoushan Port was merged with those of Tianjin Port and Hebei Port, many companies have not yet completed resource integration and information sharing.

Imperfect system of collection and distribution: The current transportation mechanism is still incomplete, and the resource utilization rate is not high. Sharing the information on various transportations is not implemented. Even though commercial freight occupies traffic roads mainly, the transportation system is not well designed and constructed. The development of multi-mode transport is slow. It is necessary to accelerate the construction of the collection and distribution system, promote the rational integration of various transportation methods, improve the collection and distribution capacity, and enhance the competitiveness of the port.

4. Empirical Analysis based on Factor Analysis

4.1. Research Methods and Procedures

The factor analysis focuses on how to find common factors. The SPSS 25.0 software is used to perform factor analysis on 14 specific indicators in 4 aspects of 13 ports. The calculation steps are as follows.

(1) "Z-score standardization" of the original data
(2) Screening of specific indicators
(3) KMO inspection and Bartlett treatment
(4) Extraction of factors
(5) The rotated component matrix
(6) The score of each common factor and the comprehensive score.

4.2. Establish Evaluation Index System and Data Sources

Yuen *et al*. (2012) combined objective evaluation index data and removed non-quantitative factors to obtain the following aspects: production and operation capacity, economic development capability of hinterland city, the development potential of hinterland city, and development potential. To establish an evaluation index system of competitiveness for China's coastal ports under "The Belt and Road" policy, the specific indicators are defined as shown in Table 5. The relevant indicators are set based on the research results of Yang *et al*. (2018).

The analyzed data included 14 indicators that were collected from13 ports, including Haikou Port, Tianjin Port, Qingdao Port, Yantai Port, Shenzhen Port, Guangzhou Port, Fuzhou Port, Shanghai Port, Ningbo Zhoushan Port, Shantou Port, Xiamen Port, Quanzhou Port, and Zhanjiang Port. The data was obtained from the 2019 National Economic and Social Development Statistical Bulletin of the aforementioned port hinterlands.

Table 5. Evaluation index system.

	First Level Indicators	Secondary Indicators
Comprehensive competitiveness of ports	Port production and operation capacity	Cargo throughput
		Container throughput
	Economic development capacity of port hinterland cities	GDP of hinterland cities
		Consumer price index
		Fixed assets investment in hinterland cities
		Total retail sales of consumer goods
		Total import and export volume of hinterland cities
	Development potential of port hinterland cities	GDP growth rate of hinterland cities
		Proportion of tertiary industry in GDP of hinterland cities
		Growth rate of fixed assets investment in hinterland cities
		Growth rate of total retail sales of social consumer goods
		Growth rate of foreign trade import and export volume of hinterland cities
	Port development potential	Growth rate of cargo throughput
		Growth rate of container throughput

4.3. Data Interpretation

The explanation of the secondary index data in the evaluation index system is as follows (Table 6) (Yang, *et al*., 2018):

(1) Cargo throughput (X1): The cargo throughput of the port in 2019 (unit: 100 million tons)

(2) Container throughput (X2): The container throughput of the port in 2019 (unit: 10,000 TEUs)

(3) Hinterland city GDP (X3): The gross national product of the city where the port is located (unit: 100 million yuan)

(4) Consumer Price Index (X4): The consumer price index of the city where the port is located in 2019.

(5) Fixed asset investment in hinterland cities (X5): Fixed asset investment in cities where the port is located in 2019 (unit: 100 million yuan)

(6) Total retail sales of consumer goods (X6): Total retail sales of consumer goods in the city where the port is located in 2019 (unit: 100 million yuan)

(7) Total foreign trade import and export of hinterland cities (X7): Total foreign trade import and export of cities where the port is located in (unit: 100 million yuan)

(8) GDP growth rate of hinterland cities (X8): The GDP growth rate of the port city in 2019 compared to last year. (unit: %)

(9) The proportion of the tertiary industry in the GDP of hinterland cities (X 9): The proportion of the added value of the tertiary industry in the GDP of the port city in 2019. (unit: %)

(10) Growth rate of fixed asset investment in hinterland cities (X10): The growth rate of fixed asset investment in cities where the port is located in 2019 compared to last year. (unit: %)

(11) Growth rate of total retail sales of consumer goods (X11): The growth rate of total retail sales of consumer goods in the port city in 2019 compared with last year. (unit: %)

(12) Growth rate of total foreign trade import and export of hinterland cities (X12): The growth rate of total foreign trade import and export of cities where the port is located in 2019 compared to last year. (unit: %)

(13) Cargo throughput growth rate (X13): The growth rate of cargo throughput in the city where the port is located in 2019 compared to last year. (unit: %)

(14) Growth rate of container throughput (X14): The growth rate of container throughput of the city where the port is located in 2019 compared to last year (unit: %).

Table 6. Raw data.

	X1	X2	X3	X4	X5	X6	X7
Tianjin	4.92	1,730.07	14,104.28	102.7	12,122.70	5,654.80	7,346.03
Qingdao	5.77	2,101.00	11,741.31	103.3	10,204.10	5,234.70	5,925.60
Yantai	3.86	310.24	7,653.45	103.0	6,232.30	3,306.46	2,906.83
Shanghai	7.20	4,330.26	38,155.32	102.5	8,012.20	13,497.21	84,267.90
Ningbo	11.20	2,753.50	13,356.60	102.7	7,303.50	5,054.30	10,541.40
Guangzhou	6.30	2,323.62	23,628.60	103.0	7,462.20	9,978.20	9,995.81
Shenzhen	2.60	2,576.92	26,927.09	103.4	7,374.70	6,582.85	29,773.86
Shantou	0.32	135.00	2,694.08	103.0	2,701.00	1,894.34	616.88
Fuzhou	1.70	340.82	9,392.30	102.5	7,090.10	4,198.94	2,525.80
Xiamen	2.13	1,112.22	5,995.04	103.0	2,858.00	1,731.85	6,412.89
Quanzhou	1.27	257.93	9,946.66	102.3	5,006.10	3,761.82	2,111.80
Zhanjiang	2.16	111.53	3,064.72	103.4	1,809.01	1,839.50	413.84
Haikou	1.12	197.26	1,671.93	103.3	1,123.20	785.58	331.38

	X8	X9	X10	X11	X12	X13	X14
Tianjin	4.8	63.5	13.9	2.2	−9.1	4.1	8.1
Qingdao	6.5	60.9	21.6	8.1	11.2	6.6	8.8
Yantai	5.5	51.2	5.0	7.4	−4.8	15.7	3.4
Shanghai	6.0	72.7	5.1	6.5	−1.2	−1.4	3.1
Ningbo	7.0	49.6	8.2	7.5	8.5	3.3	4.5
Guangzhou	6.8	71.6	16.5	7.8	1.9	12.6	6.0
Shenzhen	6.7	60.9	18.8	6.7	−0.6	2.6	−0.9
Shantou	6.1	48.0	12.9	7.0	3.4	−10.7	14.4
Fuzhou	7.9	53.6	9.0	9.6	3.2	16.8	5.1
Xiamen	7.9	58.0	9.0	12.2	6.9	−1.7	3.9
Quanzhou	8.0	36.3	6.3	10.2	13.9	−0.8	7.3
Zhanjiang	4.0	46.5	−2.3	8.4	9.7	−1.0	10.3
Haikou	7.5	79.2	−15.4	4.7	−2.9	4.0	6.8

4.4. Empirical Analysis

4.4.1. Data Processing

It is difficult to explain the correlation coefficients between the variables as they have different units. The variables are therefore standardized to avoid the influence of dimensions. All data were standardized by usiong *Z*-score (Table 7).

Table 7. Standardized data.

	X1	X2	X3	X4	X5	X6	X7
Tianjin	.33376	.24108	.10793	−.63047	−.19867	.21530	−.22717
Qingdao	.60877	.51717	−.11275	1.00876	−.22489	.09762	−.28916
Yantai	−.00921	−.81574	−.49451	.18914	−.27916	−.44252	−.42091
Shanghai	1.07145	2.17646	2.35408	−1.17688	−.25484	2.41214	3.12978
Ningbo	2.36566	1.00284	.03811	−.63047	−.26452	.04709	−.08772
Guangzhou	.78026	.68287	.99742	.18914	−.26235	1.42638	−.11153
Shenzhen	−.41688	.87141	1.30546	1.28196	−.26355	.47527	.75160
Shantou	−1.15458	−.94617	−.95767	.18914	3.32518	−.83809	−.52084
Fuzhou	−.70808	−.79297	−.33212	−1.17688	−.26744	−.19252	−.43753
Xiamen	−.56895	−.21880	−.64940	.18914	−.32527	−.88360	−.26790
Quanzhou	−.84721	−.85467	−.28035	−1.72330	−.29592	−.31496	−.45560
Zhanjiang	−.55925	−.96364	−.92306	1.28196	−.33960	−.85345	−.52970
Haikou	−.89574	−.89983	−1.05313	1.00876	−.34897	−1.14867	−.53330

	X8	X9	X10	X11	X12	X13	X14
Tianjin	−1.39685	.46999	.57743	−2.17632	−1.79917	.03201	.49596
Qingdao	−.01253	.25386	1.37911	.21857	1.19831	.35716	.68017
Yantai	−.82683	−.55248	−.34918	−.06557	−1.16424	1.54070	−.74090
Shanghai	−.41968	1.23477	−.33877	−.43089	−.63266	−.68331	−.81985
Ningbo	.39463	−.68549	−.01602	−.02498	.79963	−.07203	−.45142
Guangzhou	.23176	1.14333	.84813	.09679	−.17492	1.13752	−.05668
Shenzhen	.15033	.25386	1.08759	−.34971	−.54407	−.16307	−1.87249
Shantou	−.33825	−.81849	.47332	−.22794	.04657	−1.89286	2.15387
Fuzhou	1.12750	−.35297	.06727	.82744	.01704	1.68377	−.29352
Xiamen	1.12750	.01279	.06727	1.88281	.56338	−.72233	−.60932
Quanzhou	1.20893	−1.79109	−.21383	1.07099	1.59699	−.60528	.28543
Zhanjiang	−2.04830	−.94318	−1.10922	.34034	.97682	−.63129	1.07491
Haikou	.80178	1.77510	−2.47312	−1.16154	−.88368	.01901	.15385

4.4.2. Screening of Specific Indicators

All of 14 indexes of 13 ports cannot be selected to create the definite matrix. Through the common factor extraction quota analysis, the insignificant factors are eliminated to obtain the evaluation indicators for factor analysis. For dimension reduction, it is necessary to calculate the common factor variance as shown in Table 8. Common factor variance is an index to describe the common degree of variables. It measures the explanatory power of the common factors. The larger the common factor variance is, the stronger the explanatory power of the common factor is. Table 8 shows that the common factor variances of X1, X5, X8, X9, X10, and X14 are small with weak explanatory power. Therefore, we deleted them and analyzed the remaining 8 indicators.

Table 8. Common factor variance.

	Initial	Extraction
Z score: X1	1.000	.642
Z score: X2	1.000	.963
Z score: X3	1.000	.941
Z score: X4	1.000	.968
Z score: X5	1.000	.755
Z score: X6	1.000	.918
Z score: X7	1.000	.910
Z score: X8	1.000	.685
Z score: X9	1.000	.770
Z score: X10	1.000	.662
Z score: X11	1.000	.866
Z score: X12	1.000	.853
Z score: X13	1.000	.882
Z score: X14	1.000	.781
Extraction method: principal component analysis		

4.4.3. KMO and Bartlett Sphere Test

When the KMO statistic is close to 1, the correlation is regarded to be significant. When the KMO statistic is greater than 0.5, factor analysis can be carried out. As shown in Table 9, the KMO statistic is 0.634 (greater than 0.5), which indicates that the overlap between the variables is high. The significance level is 0 (less than 0.5), which means the data group is appropriate for factor analysis. Table 10 presents that the degree of variable extraction is close to or greater than 75%. This indicates that the loss degree of data is small. Then, the effect of factor extraction is ideal, and the extracted factors is considered to contain most of the original information.

Table 9. KMO test and Bartlett sphere test.

KMO sampling fitness measure		.634
Bartlett sphere test	Approximate chi-square	64.640
	Degree of freedom	28
	Significance	.000

Table 10. Variable extraction.

	Initial	Extraction
Z score: X2	1.000	.869
Z score: X3	1.000	.950
Z score: X4	1.000	.457
Z score: X6	1.000	.943
Z score: X7	1.000	.885
Z score: X11	1.000	.837
Z score: X12	1.000	.862
Z score: X13	1.000	.860
Extraction method: principal component analysis.		

4.4.4. Factor Extraction

The common factors are extracted when they show a higher cumulative variance percentage than 70%. The eigenvalues of the first, second and third common factors are greater than 1, and the variance percentages are 47.983%, 21.234% and 14.072%, respectively, and the total cumulative variance contribution is 83.289%. Therefore, the first three common factors are extracted as shown in Table 11.

Table 11. Factor extraction.

Total variance interpretation						
Element	Initial eigenvalue			Extract the sum of squares of the load		
	Total	Percentage of Variance	Accumulation %	Total	Percentage of Variance	Accumulation %
1	3.839	47.983	47.983	3.839	47.983	47.983
2	1.699	21.234	69.216	1.699	21.234	69.216
3	1.126	14.072	83.289	1.126	14.072	83.289
4	.814	10.179	93.468			
5	.298	3.723	97.191			
6	.106	1.330	98.521			
7	.089	1.109	99.629			
8	.030	.371	100.000			
Extraction method: principal component analysis.						

4.4.5. Constructing the Component Matrix after Rotation

For the matrix rotation, the maximum tolerance method is used to obtain the result as shown in Table 12. F1 is for container throughput, hinterland city GDP, and social security. F2 is for the growth rate of total retail sales of social consumer goods and the growth rate of total foreign trade import and export of hinterland city. F3 is for the total consumer price and the growth rate of cargo throughput. The higher coefficients of *F*1, *F*2 and *F*3 are related to strong correlation with each other.

Table 12. Composition matrix after rotation.

	Common Factors		
	F1	F2	F3
Z score: X2	.926	−.096	−.043
Z score: X3	.962	−.109	.112
Z score: X4	−.340	−.362	−.459
Z score: X6	.943	−.084	.215
Z score: X7	.930	−.077	−.120
Z score: X11	−.144	.899	.087
Z score: X12	−.143	.889	−.224
Z score: X13	−.081	−0.179	.906
Extraction method: principal component analysis.			
Rotation method: Kaiser normalized maximum variance method.			
a. The rotation has converged after 5 iterations.			

4.4.6. Calculate Each Factor Score and Comprehensive Score

The regression analysis of standardized data is carried out to construct the factor score coefficient matrix. As shown in Table 13, the matrix presents the scores of *F*1, *F*2 and *F*3.

Table 13. Component score coefficient matrix.

	Component		
	F1	**F2**	**F3**
Z score: X2	.258	.006	−.094
Z score: X3	.258	.009	.039
Z score: X4	−.096	−.256	−.402
Z score: X6	.249	.027	.132
Z score: X7	.264	.013	−.161
Z score: X11	.017	.514	.130
Z score: X12	.033	.493	−.143
Z score: X13	−.085	−.063	.790

Extraction method: principal component analysis.
Rotation method: Kaiser normalized maximum variance method.
Component score.

According to Table 13, the equation for calculating the score of each factor is as follows.

$$F1 = 0.258X2 + 0.258X3 - 0.096X4 + 0.249X6 + 0.264X7 + 0.017X11 + 0.033X12 - 0.085X13 \quad (3)$$

$$F2 = 0.006X2 + 0.009X3 - 0.256X4 + 0.027X6 + 0.013X7 + 0.514X11 + 0.493X12 - 0.063X13 \quad (4)$$

$$F3 = -0.094X2 + 0.039X3 - 0.402X4 + 0.132X6 - 0.161X7 + 0.130X11 - 0.143X12 + 0.790X13 \quad (5)$$

Here, X_n is the standardized variable data of each port. The proportion of the initial eigenvalues of each factor to the total initial eigenvalues of the three common factors is calculated as weights by using Equation 6.

$$L_i = \frac{\lambda_i}{\lambda_1+\lambda_2+\lambda_3} \quad (6)$$

where λ_i (i=1, 2, 3) is the eigenvalue of the i^{th} principal component and L_i is the weight of the i^{th} principal component. The comprehensive score F is calculated by

$$F = 0.576F_1 + 0.255F_2 + 0.169F_3. \quad (7)$$

Then, the factor scores and comprehensive scores of 13 ports and their rankings are calculated, as Table 14. Table 14 shows that Shanghai Port has the highest score and Haikou Port has the lowest.

Table 14. Common factor scores and comprehensive scores of ports and their rankings.

	***F1* Score**	***F1* Ranking**	***F2* Score**	***F2* Ranking**	***F3* Score**	***F3* Ranking**	***F* Comprehensive Score**	**Comprehensive Ranking**
Tianjin	.0453	5	−1.8410	13	.2994	4	−1.4964	10
Qingdao	−.0316	6	.4227	5	−.2604	7	0.1308	7
Yantai	−.7488	11	−.7801	11	1.3655	2	−0.1634	8
Shanghai	2.7394	1	−.0463	7	−.3295	8	2.3636	1
Ningbo	.3495	4	.5538	4	.0063	6	0.9096	5

Table 14. *Cont.*

	*F*1 Score	*F*1 Ranking	*F*2 Score	*F*2 Ranking	*F*3 Score	*F*3 Ranking	*F* Comprehensive Score	Comprehensive Ranking
Guangzhou	.6400	3	−.1057	9	1.0412	3	1.5754	4
Shenzhen	.7459	2	−.7260	10	−.7009	11	−0.6810	9
Shantou	−.6963	10	−.0679	8	−1.5826	13	−2.3468	12
Fuzhou	−.4704	9	.6107	3	2.01507	1	2.1552	2
Xiamen	−.4216	8	1.2080	2	−.5603	10	0.2262	6
Quanzhou	−.2038	7	1.7952	1	.2271	5	1.8185	3
Zhanjiang	−.8700	12	.3229	6	−1.0826	12	−1.6296	11
Haikou	−1.0778	13	−1.3462	12	−.4380	9	−2.8620	13

4.5. Analysis of the Comprehensive Competitiveness of China's Coastal Ports

13 ports are divided into four levels according to the comprehensive score of each port. The comprehensive scores of Shanghai Port, Fuzhou Port, Quanzhou Port, Guangzhou Port are greater than 1, so these ports are classified as the first class. The comprehensive scores of Ningbo- Zhoushan Port, Xiamen Port and Qingdao Port are between 0 and 1, so these ports are classified as the second class. The comprehensive scores of Yantai Port and Shenzhen Port are between -0.1 and 0, so these ports are classified as the third class. The comprehensive scores of the remaining Tianjin Port, Zhanjiang Port, Shantou Port and Haikou Port are less than -0.1, so these ports are classified as the fourth class.

Among the first-class ports, Shanghai Port ranks first in terms of competitiveness. This indicates that Shanghai Port is attributed to the port development brought by the strong economic conditions of hinterland cities. Fuzhou Port and Quanzhou Port belong to the southeast coastal area. Although the scores of *F*3 and *F*2 for Fuzhou Port and Quanzhou Port are the highest, Shanghai's powerful economic conditions are incomparable to those of Fuzhou and Quanzhou. Guangzhou Port is not well ranked in *F*3, which means Guangzhou Port is weak in the development potential of hinterland cities, which leads to a low overall ranking.

In the second class, Ningbo-Zhoushan Port ranks first. Although Xiamen Port ranks second in terms of hinterland city development potential, the other two components rank relatively low. Qingdao Port is in the middle of the three rankings, and it is relatively stable. In the third class, Yantai Port and Shenzhen Port are among the top in the *F*3 and *F*1 rankings, respectively. The development of the port and the hinterland is different, resulting in a low overall ranking. In the fourth class, Tianjin Port shows the lowest *F*2 score, while the other two components rank above the middle level. The competitiveness of Tianjin Port is not high, which indicates that the potential of economic development of hinterland cities is lower than that of other port. The last three ports of Shantou Port, Zhanjiang Port, and Haikou Port have the worst strength and need great changes.

Competitiveness not only refers to the existing economic strength, but also the future growth potential, development potential, and innovation capacity. The competitiveness of port development is not balanced in China even for the same port group or in the same provinces, so a plan and strategy for sustainable development are needed.

5. Conclusion

This paper firstly introduces the theory of "The Belt and Road" strategy and port competitiveness. The evaluation system is established by using SPSS software. The competitiveness of 13 ports is analyzed and compared in the list of ranking. With the analysis of the development status and problems of the ports in China, improvement strategies are proposed.

First of all, ports need all-round development. At present, the focus of improving the competitiveness of ports is put on the construction of basic hardware such as berth and the collection and distribution system and the development of software such as logistics services. Improving the software of the port requires the adoption of information technology, sound port drain system, the improvement of loading and unloading method, work efficiency, time reduction of unloading in the destination port, operating costs reduction, quality services according to the different needs of customers, construction of rapid response mechanism, and value-added service. Secondly, in the fifth generation of port development, the establishment of information intelligence is an important method to enhance the competitiveness of the port. China's ports need to implement the process of the fourth generation ports to follow the global trend and move forward to the construction of the fifth generation ports. Thus, information technologies such as the Internet of Things and big data need to be applied to the ports for sustainable development and a green port operation.

In addition, in fierce competition, cooperative operation of the ports is required. A feasible method is to integrate the sources of goods between the ports according to the source of goods transported from the hinterland. The reasonable distribution of cargo reduces the vicious competition and waste of resources. Coordinated development is a long-term and arduous task. Thus, it is necessary to constantly find problems in the process of exploration, solve them with experience and coordinated development. Finally, the rapid development of the port needs high-quality human resources. The ability of information system application, analysis of management and decision-making personnel can be strengthened through training. As a result, the general staff can acquires management knowledge to improve the level of cognition, management, and decision-making.

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References

1. Fávero, L.P., & Belfiore, P. (2019). *Principal Component Factor Analysis.* Data Science for Business and Decision Making, NY: Academic Press.
2. National Development and Reform Commission, the Ministry of Foreign Affairs and the Ministry of Commerce (2015). The Vision and Actions for Joining the Building of the Silk Road Economic Belt and the 21st Century Maritime Silk Road.
3. United Nations Commission on Trade and Development (UNCTAD) (1999). Fourth Generation Ports, Ports Newsletter, 19.
4. Xi, P. (2012). The fifth-generation port - the home port of joint venture. *Water Transportation Management*, 34(1): 22–24.
5. Yang, R., Mou, N.X., Peng, P., Liu, X. L., Zhang, H.C., & Lu, F. (2018). Modelling the competitiveness of the ports along the Maritime Silk Road with Big Data. *Journal of Geo-information Science*, 20(5): 623–631.
6. Yeo, H.J. (2010). Competitiveness of Asian Container Terminals. *The Asian Journal of Shipping and Logistics*, 26(2): 225–246.
7. Yuen, C.L.A., Zhang, A.M., & Cheung, W.M. (2012). Port competitiveness from the users' perspective: An analysis of major container ports in China and its neighboring countries. *Research in Transportation Economics*, 35(1): 34–40.

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