

Effect Evaluation of Arctic Route Navigation on Port Logistics Competitiveness in China

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Abstract—Arctic route navigation will have different effects on the competitiveness of port logistics. This paper selects 5 Arctic Route ports in China, using entropy weight - double base point method, to evaluate the impact of Arctic route navigation on the competitiveness of port logistics from three aspects: agglomeration level, transport capacity and development potential. The evaluation results show that the competitiveness of port logistics in Shanghai is superior to other ports in terms of agglomeration level and development potential, but slightly less in transport capacity. Dalian Port is the most competitive in transport capacity. From the results of comprehensive evaluation, port logistics in Shanghai has the biggest competitive advantage under the background of Arctic route navigation. Finally, according to the evaluation results, the Arctic route ports are divided into three different development levels, and the suitable development orientation of port logistics for various levels is put forward.

Keywords—Arctic route; port logistics competitiveness; effect evaluation; gravity model; entropy weight—double base point method

I. INTRODUCTION

With the accelerated melting of Arctic sea ice, a brand-new route connecting the Atlantic Ocean and the Pacific Ocean, i.e. the Arctic route appears, this new route has immeasurable economic value. The realization of ice-free navigation on Arctic route will have a significant impact on the strategy, economy and resources of all countries in the world, especially for the countries along the Arctic route and the countries near the Arctic. On January 26, 2018, Chinese government published the White Paper on Arctic Policy for the first time, China's Arctic Policy, which reflects the positive attitude of China towards participating in Arctic activities and cooperation.

So the Arctic route navigation will inevitably change the global maritime transport pattern among Asia, Europe and North America, and will also have a far-reaching impact on

port logistics. Therefore, the analysis of impact of Arctic route navigation on port logistics competitiveness will help to define the development direction of port logistics in the context of Arctic route navigation, and to provide a theoretical basis for the full use of port logistics resources.

II. SELECTION BASIS AND DATA SOURCE OF SAMPLE PORTS

Zhenfu Li (2016) defined the Arctic route ports in China, taking the total amount of import and export trade of the city where the port is located as the basic definition index, taking the voyage reduction, route density, foreign trade throughput and oil and gas throughput capacity as the competitive definition index for comprehensive evaluation, and selected 26 Arctic route ports in China that meet the standard (See "Table I"). Among them, there are five ports that meet the four competitive indexes, namely Dalian, Tianjin, Qingdao, Shanghai and Ningbo Zhoushan. Therefore, this paper chooses these five ports as sample ports to analyze the impact of Arctic route navigation on port logistics.

TABLE I. SELECTION OF ARCTIC ROUTE PORTS IN CHINA

Index	Dalian	Qinhuangdao	Tangshan
Voyage reduction	✓	✓	✓
Route density	✓		
Foreign trade throughput	✓	✓	✓
Oil and gas throughput throughput	✓	✓	✓
Index	Tianjin	Yantai	Weihai
Voyage reduction	✓	✓	✓
Route density	✓		
Index	Tianjin	Yantai	Weihai
Foreign trade throughput	✓	✓	✓
Oil and gas throughput throughput	✓		
Index	Qingdao	Rizhao	Lianyungang
Voyage reduction	✓	✓	✓
Route density	✓		
Foreign trade throughput	✓		✓
Oil and gas throughput throughput	✓	✓	
Index	Shanghai	Zhapu	Zhoushan
Voyage reduction	✓	✓	✓
Route density	✓		✓
Foreign trade throughput	✓	✓	✓
Oil and gas throughput throughput	✓		✓
Index	Fuzhou	Quanzhou	Taibei
Voyage reduction	✓	✓	
Route density			✓
Foreign trade throughput	✓		✓
Oil and gas throughput throughput		✓	
Index	Xiamen	Shantou	Shenzhen
Voyage reduction	✓	✓	✓
Route density	✓		✓
Foreign trade throughput	✓	✓	✓
Oil and gas throughput throughput			
Index	Guangzhou	Zhoushan	Zhuhai
Voyage reduction		✓	✓
Route density	✓		
Foreign trade throughput	✓	✓	✓
Oil and gas throughput throughput	✓		
Index	Jiangmen	Gaoxiong	Zhanjiang
Voyage reduction	✓		✓
Route density		✓	
Foreign trade throughput	✓	✓	✓
Oil and gas throughput throughput			✓
Index	Xianggang	Wenzhou	
Voyage reduction		✓	
Route density	✓		
Foreign trade throughput	✓	✓	
Oil and gas throughput throughput			

^a Reference: Zhenfu Li, etc., Definition of the Arctic Route Ports of China, Area Research and Development [J], Vol. 35, No. 6, Dec. 2016.

The data of this paper comes from the statistical bulletin of national economic and social development of each city, China Aviation weekly, China port guide, China port container statistical yearbook and related data websites.

III. RESEARCH METHODS AND EVALUATION STEPS

In this paper, entropy weight - double base point method is used to evaluate and analyze the impact of Arctic route navigation on port logistics, entropy weight method is used to determine the weight of each index, and double base point method is used to comprehensively evaluate each index.

Entropy weight method is mainly used to solve the weight problem of evaluation indexes. It takes the amount of decision-making information as the standard to determine the weight of indexes and measure the relative importance of the selected indexes. It can strengthen the scientific nature of the weight and reduce the subjectivity. First, the evaluation judgment matrix is determined, and the index zero dimension is processed, then the entropy value of each index is calculated, and finally the weight of each index is determined.

In essence, the double base point method is a sort method approaching to the ideal solution, which takes the index value of the evaluation object and the closeness degree of the ideal solution as the evaluation standard to determine the

degree of superior membership, so as to achieve the evaluation purpose. Firstly, the normalized attribute matrix is established, and then the distance between the evaluation index and ideal point or negative ideal point is determined. Finally, the index is sorted by calculating the superior degree of each port evaluation value.

The combination of entropy weight method and double base point method can make the best use of their advantages, and make the weight assignment more reliable and the evaluation results more applicable.

A. Determination of Index Weight Based on Entropy Weight Method

1) Determining the evaluation judgment matrix

$$(1) \quad R = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \quad m=1,2,3\dots i, n=1,2,3\dots j$$

2) Index zero dimension processing

Due to the differences in the nature and order of magnitude of various indicators, it is necessary to standardize the original data before statistical analysis.

$$(2) \quad r'_{ij} = \frac{r_{ij} - \min(r_i)}{\max(r_i) - \min(r_i)} \quad (i \in I_1) \quad \text{Positive indicators}$$

$$(3) \quad r'_{ij} = \frac{\max(r_i) - r_{ij}}{\max(r_i) - \min(r_i)} \quad (i \in I_2) \quad \text{Negative index}$$

Among them, I_1 indicates the benefit index, i.e. the larger the index value, the better; I_2 indicates the loss index, i.e. the smaller the index value, the better. According to the different properties of indicators, the standardization methods of data processing are also different.

After zero dimension processing, matrix R is obtained. $R' = (r'_{ij})_{m \times n}$. It represents the zero dimension value of port i under the evaluation index j, and the value range is [0, 1].

3) Calculating the entropy value of each index

First, calculate the proportion of index j of the port i

$$(4) \quad y_{ij} = \frac{r'_{ij}}{\sum_{i=1}^m r'_{ij}}$$

Then, calculate the entropy of the index j

$$(5) \quad e_j = -k \sum_{i=1}^m (y_{ij} \times \ln y_{ij})$$

Among them, $k = 1/\ln m$, when n is a fixed value, k is also a fixed constant.

When $y_{ij} = 0$, then $y_{ij} \times \ln y_{ij} = 0$.

4) Determining the index weight

Calculate the weight of index j.

$$(6) \quad W_j = d_j / \sum_{j=1}^n d_j$$

Among them, $d_j = 1 - e_j$.

B. Sorting Based on Double Base Point Method

1) Establishing normalized attribute matrix

$$(7) \quad A = \begin{bmatrix} a_{11} & \dots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \dots & a_{mn} \end{bmatrix} = \begin{bmatrix} w_1 r'_{11} & \dots & w_n r'_{1n} \\ \vdots & \ddots & \vdots \\ w_1 r'_{m1} & \dots & w_n r'_{mn} \end{bmatrix}$$

2) Defining ideal point and negative ideal point of index

$$(8) \quad \text{Ideal point: } P^+ = (P_1^+, P_2^+, \dots, P_n^+)$$

Among them, $P_i^+ = \max_j \{a_{ij} \mid j = 1, 2, \dots, n; i = 1, 2, \dots, m\}$

$$(9) \quad \text{Negative ideal point: } P^- = (P_1^-, P_2^-, \dots, P_n^-)$$

Among them, $P_i^- = \min_j \{a_{ij} \mid j = 1, 2, \dots, n; i = 1, 2, \dots, m\}$

3) Determining the distance between the evaluated object and the ideal point and the negative ideal point

$$(10) \quad \text{Distance from ideal point: } d_i^+ = \sqrt{\sum_{j=1}^n (a_{ij} - p_i^+)^2} \quad i=1, 2, \dots, m$$

$$(11) \quad \text{Distance from negative ideal point: } d_i^- = \sqrt{\sum_{j=1}^n (a_{ij} - p_i^-)^2} \quad i=1, 2, \dots, m$$

4) Determining the degree of preference of each port evaluation value

According to the idea of double base point method, the optimal solution should be the value that is farthest from the negative ideal point and closest to the ideal point. However, in the actual operation and evaluation process, the scheme that meets the two conditions at the same time may not exist. Therefore, the concept of superior degree is used, that is, the ratio of the distance from the negative ideal point to the sum of the distance from the ideal point and the negative ideal point is used to measure, and represented by u_i .

$$(12) \quad u_i = \frac{d_i^-}{d_i^- + d_i^+}$$

IV. ANALYSIS OF INFLUENCING FACTORS OF PORT LOGISTICS COMPETITIVENESS AGAINST THE BACKGROUND OF ARCTIC ROUTE NAVIGATION

After the Arctic route navigation, China's maritime transport pattern will also change, which makes the influencing factors of port logistics competitiveness more complex. This paper analyzes the influencing factors of port logistics competitiveness from three aspects: agglomeration level, transportation capacity and development potential.

A. Agglomeration Level

Agglomeration level refers to the willingness of cargo owners or enterprises to choose the port as the departure port or destination port for cargo transportation. This paper selects three indicators: operation level, trade level and support policy for port development to measure the level of port agglomeration.

1) *Operation level*: From the perspective of operation level, cargo transportation by Arctic route can effectively shorten the route length and reduce the shipping cost. The speed of port cargo turnover will increase, and the level of port agglomeration can be improved. In this paper, route efficiency and route density are selected as indicators to evaluate the operation level. Route efficiency refers to the maximum proportion of route length shorter than that of traditional routes; Route density refers to the number of ports in Europe and the United States after Arctic route navigation.

2) *Trade level*: From the perspective of the total amount of foreign trade, if the total amount of trade of the port keeps rising over the years, and the demand for oil and gas resources accounts for a high proportion, it indicates that the port will occupy a dominant position in port competition after Arctic route navigation. This paper selects oil and gas throughput of the port and import and export trade volume of the city where the port is located as indicators to evaluate the level of trade.

3) *Supporting policy for port development*: The coordination and support of port policies mainly focus on whether the port has preferential policies such as free trade area or bonded area, or cooperative relations with large shipping companies, etc. If so, it means that after Arctic route navigation, the concentration level of port cargo sources will be greatly improved. This paper chooses the policy environment as the index to evaluate the port policy, including all the preferential policies to support the port development.

B. Transportation Capacity

Transportation capacity refers to the capacity of the port to use the Arctic route for cargo transportation under the background of the increase of port business volume and transit cargo volume brought by the Arctic route navigation. The level of port transportation capacity also plays an important role in port competitiveness. If the port has high-level infrastructure and technical personnel, a virtuous cycle of transportation system, and more competitive service capacity than other ports, then the cargo throughput of the port will increase dramatically and the transportation capacity will be stronger after the Arctic route navigation. There are many indicators that affect the port transportation capacity. This paper mainly selects three indicators that can best reflect the impact of the Arctic route on port transportation capacity, namely: port conditions, carrying capacity and port service level.

1) *Port conditions*: The depth of berths and the capacity of container berths are important factors to determine whether a port is competitive. The higher these two indexes are, the greater the port attraction to goods and large ships will be, and the virtuous circulation level of logistics facilities and storage will also be improved, so as to improve the economic benefits of port logistics.

2) *Carrying capacity*: The length of the railway line and the handling capacity determine the operation capacity of the port. If these two indicators are highly satisfied, it means that more cargo flows can still be shared in port competitions, and the carrying capacity of the port logistics will be more advantageous after Arctic route navigation.

3) *Port service level*: The number of port transit boxes and the number of dock loading and unloading machinery can best reflect the service level of a port. At present, the number of port transit boxes has been included in the evaluation index system of each port's transportation capacity. Through these two indicators, we can examine whether the port has the ability to attract cargo after the Arctic route navigation, and then reflect the service level of the port.

C. Development Potential

To evaluate the competitiveness of port logistics in the context of Arctic route navigation, we should not only consider the current development status of port logistics, but also examine the development potential of port logistics. Development potential is an important index to evaluate the future development trend of port logistics. This paper selects three indicators to evaluate the development potential of port logistics, namely, port development, economic development and human development.

1) *Port development*: The annual growth rate of cargo throughput and container throughput can directly reflect whether the port is in a sound development in the operation. Only with a sound development, can the port logistics have greater development potential.

2) *Economic development*: The amount of foreign investment and fixed asset investment fully reflects the capital advantage of the port in the competition. The greater the capital advantage, the more attractive the port will be in the future development, the port logistics will have more development potential.

3) *Human development*: The international popularity of the port is constantly improved in the process of trade increase and port construction, which will attract more tourists to visit. Therefore, the human development should not be ignored when evaluating the development potential of port logistics. In this paper, the city's annual passenger throughput and the number of inbound tourists are selected to evaluate the human development potential of the port.

V. EVALUATION OF INFLUENCE OF ARCTIC ROUTE NAVIGATION ON PORT LOGISTICS COMPETITIVENESS

A. Construction of Evaluation Index System

Based on the analysis of influencing factors of port logistics competitiveness under the background of Arctic

route navigation, and referring to the achievements of other scholars on port logistics competitiveness, this paper constructs an evaluation index system including three first level indexes, nine second level indexes and 17 third level indexes. The index system and detailed description are shown in "Table II".

TABLE II. EVALUATION INDEX SYSTEM

First level	Second level	Third level
Agglomeration level B ₁	Operation level B ₁₁	route efficiency B ₁₁₁
		route density B ₁₁₂
	Trade level B ₁₂	trade volume B ₁₂₁
		oil and gas throughput B ₁₂₂
Coordination and support B ₁₃	policy environment B ₁₃₁	
Transportation capacity B ₂	Port conditions B ₂₁	berth depth B ₂₁₁
		container berth capacity B ₂₁₂
	Carrying capacity B ₂₂	railway line length B ₂₂₁
		handling capacity B ₂₂₂
	Port service level B ₂₃	transit boxes B ₂₃₁
		loading and unloading machinery B ₂₃₂
Development potential B ₃	Port development B ₃₁	growth rate of cargo throughput B ₃₁₁
		growth rate of container throughput B ₃₁₂
	Economic development B ₃₂	foreign investment B ₃₂₁
		fixed asset investment B ₃₂₂
	Human development B ₃₃	passenger throughput B ₃₃₁
		inbound tourists B ₃₃₂

B. Determination of Index Weight

All indicators in the evaluation index system constructed in this paper are positive indicators. The evaluation matrix is established according to formula (1) and (2), the evaluation

matrix is standardized and the zero dimension index standard value is obtained. The entropy value of the index is determined according to formula (4) and (5). The weights of all levels of indicators are calculated according to formula (6). See "Table III" for details.

TABLE III. WEIGHT DISTRIBUTION OF EVALUATION INDEX SYSTEM

First	Weight	Second	Weight	Third	Weight
B ₁	0.3031	B ₁₁	0.1136	B ₁₁₁	0.0483
				B ₁₁₂	0.0653
		B ₁₂	0.1192	B ₁₂₁	0.066
				B ₁₂₂	0.0532
		B ₁₃	0.0703	B ₁₃₁	0.0703
B ₂	0.3424	B ₂₁	0.1081	B ₂₁₁	0.0538
				B ₂₁₂	0.0543
		B ₂₂	0.1162	B ₂₂₁	0.0585
				B ₂₂₂	0.0577
		B ₂₃	0.1181	B ₂₃₁	0.0567
				B ₂₃₂	0.0614
B ₃	0.3545	B ₃₁	0.1128	B ₃₁₁	0.0493
				B ₃₁₂	0.0635
		B ₃₂	0.1222	B ₃₂₁	0.0714
				B ₃₂₂	0.0508
		B ₃₃	0.1195	B ₃₃₁	0.056
				B ₃₃₂	0.0635

C. Determination of the Rank of Superior Degree

Ideal point and negative ideal point are calculated according to formula (7) and (8).

Positive ideal point:
 $P^+ = (0.0483, 0.0653, 0.066, 0.0532, 0.0703, 0.0583, 0.0543, 0.0585, 0.0577, 0.0567, 0.0614, 0.0493, 0.0635, 0.0714, 0.0508, 0.056, 0.0635)^T$

Negative ideal point: $P^- = (0, 0, \dots, 0)^T$

According to the formula (10) - (12), the distance between each index of each port and the positive ideal point, the distance between each index of each port and the negative ideal point, and the ranking of superior degree are determined. See "Table IV", "Table V", "Table VI", "Table VII" for details.

TABLE IV. EVALUATION RESULTS AND RANKING OF PORT AGGLOMERATION LEVEL

Port	Positive ideal point	Negative ideal point	superior degree	Rank
Dalian	0.094132	0.091011	0.491572	2
Tianjin	0.101317	0.055675	0.354638	5
Qingdao	0.108956	0.071566	0.396440	3
Shanghai	0.065182	0.096051	0.595727	1
Zhoushan	0.101695	0.060566	0.373265	4

From the perspective of port agglomeration level, the Arctic route has the greatest impact on the improvement of Shanghai port agglomeration level. Shanghai port is the first in the national container throughput rankings, the volume of foreign trade is the largest in these ports, plus the various preferential policies such as Free Trade Area of Shanghai port, all these factors have contributed to greater advantages of Shanghai port in terms of agglomeration level. The second are Dalian port, Qingdao port, Ningbo Zhoushan port, and the last is Tianjin port.

TABLE V. EVALUATION RESULTS AND RANKING OF PORT TRANSPORTATION CAPACITY

Port	Positive ideal point	Negative ideal point	superior degree	Rank
Dalian	0.070704	0.102602	0.592030	1
Tianjin	0.088962	0.093243	0.511747	3
Qingdao	0.113874	0.035670	0.238525	5
Shanghai	0.092408	0.100241	0.520330	2
Zhoushan	0.097089	0.052970	0.352996	4

From the perspective of port transport capacity, the Arctic route has the greatest impact on the improvement of Dalian port transport capacity. Dalian port is not only the main transit port in China, but also an important port for crude oil import and unloading. After the Arctic route navigation, not only the trade of oil and gas resources but also the number of goods transit will increase significantly, all of these factors will enhance the transport capacity of Dalian port. The second are Shanghai port, Tianjin port, Ningbo Zhoushan port, and the last is Qingdao port.

TABLE VI. EVALUATION RESULTS AND RANKING OF PORT DEVELOPMENT POTENTIAL

Port	Positive ideal point	Negative ideal point	superior degree	Rank
Dalian	0.127590	0.054912	0.300883	5
Tianjin	0.101453	0.070859	0.411226	3
Qingdao	0.113834	0.069262	0.378283	4
Shanghai	0.043292	0.119811	0.734571	1
Zhoushan	0.110709	0.078326	0.414346	2

From the perspective of port development potential, Shanghai Port still has the greatest development potential. No matter the container throughput, or the investment and the number of tourists, Shanghai port has far more competitive advantages than other ports. After the Arctic route navigation, it also has the greatest impact on the development potential of Shanghai port, the second are Ningbo Zhoushan port, Tianjin port and Qingdao port, and the last is Dalian port.

TABLE VII. COMPREHENSIVE EVALUATION RESULTS AND RANKING

Port	Positive ideal point	Negative ideal point	superior degree	Rank
Dalian	0.173606	0.147735	0.459745	2
Tianjin	0.168737	0.129673	0.434547	3
Qingdao	0.194414	0.105789	0.352391	5
Shanghai	0.121087	0.183381	0.602300	1
Zhoushan	0.178954	0.112290	0.385553	4

According to the three indicators of agglomeration level, transportation capacity and development potential, Shanghai port logistics still has the greatest competitiveness in the final evaluation result. Dalian port will have a more favorable location advantage after Arctic route navigation, and its port logistics competitiveness ranks the second in the comprehensive ranking. Then Tianjin port, Ningbo Zhoushan port and Qingdao port are in proper sequence.

D. Analysis of Evaluation Results

According to the results of agglomeration level, transportation capacity, development potential, comprehensive evaluation and superior degree ranking, the five ports selected in this paper can be divided into three different development levels under the background of Arctic route navigation.

Shanghai Port belongs to the first level. Its basic environment and financial environment are the most advantageous, and its economic ties with hinterland are also the most close. Compared with other four ports, Shanghai port is the most competitive, so it can also meet the needs of port logistics best after the Arctic route navigation.

The second level ports include Dalian port, Tianjin port and Qingdao port. Compared with Shanghai port, these three ports have a certain degree of differences in basic environment and their connection with the Arctic route. On the basis of enhancing infrastructure and collecting and distributing level, and giving full play to their advantages in oil and gas handling capacity, they are possible to better meet the cargo diversion brought about by the Arctic route. At the same time, these three ports also have the location advantage for common development, the geographical location is close, the development level is equivalent, so the overall competitiveness can be improved by forming the port strategic alliance.

Ningbo Zhoushan port belongs to the third level port under the background of Arctic route navigation. Compared with the other four ports, its geographical location and port nature have the weakest connection with the Arctic route. It can focus on relevant manufacturing industries, and take the Arctic route regional hub port as its port logistics development direction.

VI. CONCLUSION

The logistics competition between different ports is becoming increasingly fierce. The Arctic route navigation will not have a favorable impact on all ports' logistics, and

the competitive position of each port will inevitably change under the opening of the new route. In order to give full play to the competitive advantage of port logistics, it is necessary to accurately evaluate the possible impact on port logistics after the Arctic route navigation. In this paper, the influencing factors of port logistics under the background of Arctic route navigation are divided into three categories: agglomeration level, transportation capacity and development potential. By constructing the evaluation index system and using the entropy weight - double base point method, the impact of Arctic route navigation on port logistics competitiveness is evaluated, in order to provide theoretical reference for the development orientation of China's port logistics after the comprehensive navigation of Arctic route.

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