Research on the Size and Layout of Iron Ore Wharf in Bohai Rim Region Based on Freight Demand

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Abstract— Reasonable size and layout of ports should be based on its hinterland cargo demand. In this paper, the Huff model is used to segment the hinterland of the 10 main iron ore discharging and loading ports in Bohai Rim port cluster; demand for imported iron ore of each port is calculated based on the hinterlands' iron and steel industry production capacity; the size and layout of the iron ore wharf are evaluated by the coupling analysis between the demand for imported iron ore and the iron ore capacity. The result shows that the current iron ore through capacity of Bohai Rim port cluster cannot meet the demand of large cargo transportation. Each port should step up the development of infrastructure construction for the professional and larger wharfs suitably, which is based on the condition of supply and demand.

Keywords-freight demand; iron ore wharf; size and layout; supply and demand balance ; hinterland

I. INTRODUCTION

Resent years the iron and steel industry has witnessed a rapid growth in China. Crude steel output has increased from 127 million tons in 2000 to 823 million tons in 2014, of which the average annual growth rate was 14.2%; the share of China in global crude steel production rapidly grew from 15.2% in 2000 to 49.5% in 2014. Cast iron has also maintained an average annual growth of 12.9% in the recent 14 years. Thus the demand for iron ore is growing. Although China's iron ore resource is rich, which accounted for about 10% of the world's total reserve, the average grade of iron ore is low. The domestic iron ore production cannot meet the current needs of production of iron and steel industry in China, which makes raw materials supply to be the main limiting factor to develop iron and steel industry. Thus to fill in the domestic demand gap, importing iron ore has become an inevitable choice. Due to the competitive advantage-high grade, good smelting condition and good comprehensive benefit of imported iron ore, although its price continues to rise, most of the iron and steel enterprises in China still choose to import a large number of iron ore from the international market. To use the hybrid of the domestic iron ore and the imported one has become the inevitable choice in the process of China's steel production expansion. About 70% of the iron and steel enterprises in China are located in the coastal or along the Yangtze River, which can conveniently obtain the high grade of imported iron ore through water. The quantity of imported iron ore is increasing year by year, reached 9.325 hundred million tons in 2014.

As one of the most important iron ore consumption and import areas, Bohai Rim region is the most important iron and steel production base in China. In 2012, the main business income of the steel industry in Bohai Rim region accounted for 48.41% of the whole country, the proportion of the crude steel production and pig iron production accounted for 54.03% and 56.27% of the whole country. Although the region's own iron ore resources are abundant, the growing demand growth still requires a large amount of imported iron ore. The importing of iron ore in this region mainly transports through the Bohai Rim port cluster. Because of the close relationship between port's reasonable size, layout and cargo demand of the hinterland, it's necessary to study the demand of imported iron ore and reasonable division of hinterland about iron ore wharfs in the region, which has important guiding significance for the scale control and layout optimization of the iron ore wharfs in Bohai Rim port cluster.

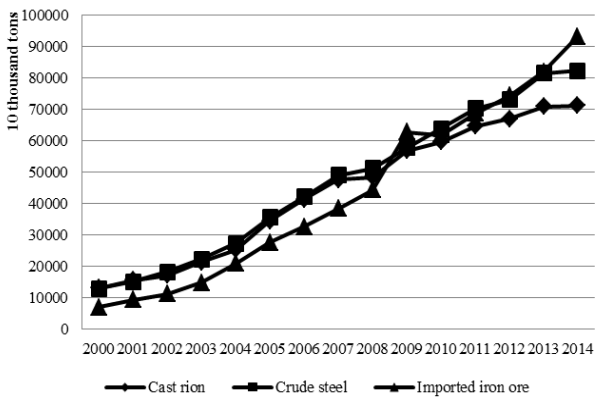

Figure 1. The situation of China's iron and steel industry and imported iron ore

II. DIVIDE THE HINTERLAND OF IRON ORE WHARFS IN BOHAI RIM PORT CLUSTER BY THE HUFF MODEL

A. Model description

Huff model is a type of gravity model, which is simple, easy to use and applicable in solving problems. The theoretical basis of Huff model is similar to the logistic model of multi-objective choice. When dividing the hinterland for each port, the probability that a certain area chooses a port to transport is proportional to the utility of this choice in all the optional ports. That is to say,

$$P_{ij} = U_j / \sum_{k=1}^{n} U_k \qquad (1)$$

Where P_{ij} represents the profit for area i choosing port j, U_j and U_k represent the utility of choosing port j and k, k are all possible choices（k=1，2，…，n）.

In Huff model, the probability of a certain area to choose a port is positively correlated with the comprehensive influence of the port, and negatively correlated with the port distance. That is to say the probability of a certain area to choose a port can be expressed as:

$$P_{ij} = S_j d_{ij}^{-\beta} / \sum_{k=1}^{n} (S_k d_{ik}^{-\beta}) \qquad (2)$$

Where S represents the port's comprehensive influence, d represents the distance between the area and port, β represents the coefficient of distance friction, the meaning of other variables is same to Formula (1). In general studies, $S_j d_{ij}^{-\beta}$ is usually called "potential energy", which is the influence degree of port j to area i.

It can be seen from Equation (2) that the probability of choosing a port to transport cargo for a certain area is different. For area i, the denominator in the equation is same, thus bigger numerator means the probability of choosing post j is bigger. That is to define the port hinterland area according to the biggest port "potential energy" set.

B. Research object and data sources

This article selects 10 ports which are the major iron ore discharging pots in Bohai Rim port cluster as the research object –Tianjin Port, Tangshan Port, Huanghua Port, Qinhuangdao Port, Yantai Port, Qingdao Port, Rizhao Port, Dalian Port, Yingkou Port and Dandong Port. The research of hinterland division covers all prefecture-level cities of 9 provinces in Bohai Rim region, including Beijing, Tianjin, Hebei, Shandong, Liaoning, Shanxi, Jilin, Heilongjiang and Inner Mongolia. The prefecture-level cities could be divided into the port hinterland of 10 ports using Huff model.

The data are all gathered from the yearbook of 2013, which means that all statistics are from 2012. To explain specifically, the steel industry data of 90 prefecture-level cities are mainly acquired from China Steel Yearbook (2013) and statistical yearbooks (2013) of Beijing, Tianjin, Hebei, Shandong, Liaoning, Shanxi, Jilin, Heilongjiang and Inner Mongolia. Some data are acquired from the statistical bulletin for national economic and social development of each city and instant information published by the news, etc. The port data are acquired from China Port Statistical Yearbook (2013) and some internet information.

C. Calculation of comprehensive influence

The comprehensive influence is the embodiment of the port comprehensive strength. There are many indicators and factors in evaluating the port comprehensive influence. Referring to existing research results and combining with the particularity of iron ore wharf, the paper selects 6 indicators-the total number of berth, the length of coastline, the number of loading and unloading equipment, the GDP of port city, the annual throughput capacity of ore and the metal ore throughput-to establish evaluation index system of port comprehensive influence, which mainly measures both port overall strength and turn-over capacity of iron ore.

The comprehensive influence is calculated by Principal Component Analysis (PCA). In order to compare the development situation between the 10 ports of Bohai Rim port cluster and other domestic iron ore ports, meanwhile to make PCA more likely to get reliable results, this paper adds Lianyungang, Shanghai, Ningbo, Zhoushan, Fuzhou, Guangzhou, Qinzhou and Fangchenggang in the research object when using PCA to analyze the comprehensive influence of the port. The results of PCA are shown in Tab.1.

TABLE I. TOTAL VARIANCE EXPLAINED

component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	*Variance(%)*	*Cumulative (%)*	*Total*	*Variance(%)*	*Cumulative (%)*
1	3.326	55.441	55.441	3.326	55.441	55.441
2	1.794	29.898	85.339	1.794	29.898	85.339
3	0.333	5.548	90.888			
4	0.280	4.660	95.547			
5	0.148	2.459	98.007			
6	0.120	1.993	100.000			

Extraction Method: Principal Component Analysis.

TABLE II. FINAL SCORE OF EACH PORT

Port	Dandong	Yingkou	Dalian	Qinhuangdao	Tangshan
Score	-0.842	-0.447	-0.011	-0.732	1.032
Port	Huanghua	Tianjin	Yantai	Qingdao	Rizhao
Score	-0.659	0.628	-0.363	0.528	0.035

TABLE III. THE INFLUENCE VALUE OF EACH PORT IN BOHAI RIM PORT CLUSTER

Port	Dandong	Yingkou	Dalian	Qinhuangdao	Tangshan
Value	179.7	308.6	523.8	216.5	814.7
Port	Huanghua	Tianjin	Yantai	Qingdao	Rizhao
Value	236	755.5	357	685.9	469.4

The final scores of each port concluded by PCA are shown in Tab. 2. The influence value should be positive in Huff model, so it should modify the final scores. This paper adopts logarithmic Logistic data standardization method to deal with the original results, the formula is as follows:

$$y_i = \frac{1000}{1+e^{-x_i}} \qquad (3)$$

Where y_i is the influence value of port i in Huff model, x_i is the final score of port i in PCA. Finally the influence value of each port in Bohai Rim port cluster is calculated and recorded in Tab. 3.

D. Determination of the port hinterland range

In Huff model, d represents the shortest distance between the city center and the target port, which can be required by ArcGIS software, the coefficient of distance friction β is the prefecture-level city scale-3 based on the existing research. Put the parameters of the above calculation into Equation (3) and get the results of the "potential energy" of each port. The maximum set of one port's potential energy is the hinterland range of this port. The hinterland range of 10 ports in Bohai Rim ports cluster is shown in Fig. 2.

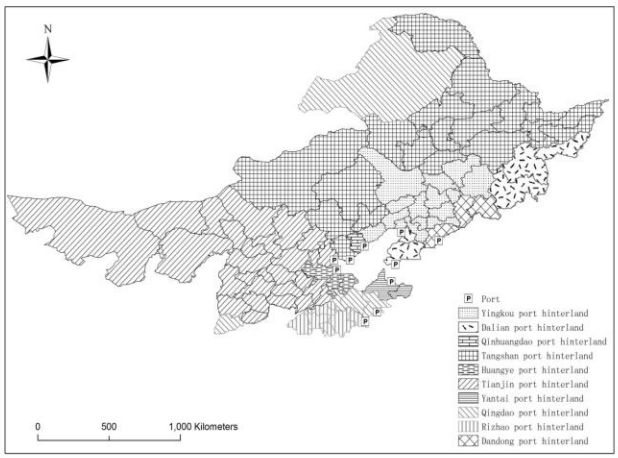

Figure 2. Hinterland range of 10 ports in Bohai Rim region

III. SUPPLY AND DEMAND ANALYSIS OF IRON ORE WHARF IN BOHAI RIM REGION

A. Supply analysis

Iron ore discharge capacity in China is mainly concentrated in Bohai Rim port cluster and Yangtze River Delta port cluster, especially Bohai Rim port cluster, which undertakes most of iron ore discharge volume. Bohai Rim port cluster has formed the iron ore discharging port layout, which is predominated by Tianjin Port, Qingdao Port, Rizhao Port, Tangshan Port and Dalian Port, and supplemented by Dandong Port, Yingkou Port, Qinghuangdao Port Huanghua Port and Yantai Port.

Bohai Rim port cluster has occupied for about 60% of the country's total iron ore specialized wharf, where large–scale iron ore wharfs of 200000 tons and above are mostly concentrated. Qingdao, Rizhao, Tangshan and Dalian port have large–scale professional wharfs as well as good water conditions; other ports use universal berths to discharge the iron ore, where the specialized level is low, the berth tonnage is small, the channel navigation conditions are poor and ore transportation needs multi-pass transshipment or large lightening of the ship.

B. Demand analysis

Bohai Rim region is the most important steel production base in China, which has occupied an important place during the development process of China's steel industry. Many national key steel enterprises are distributed in this region, e.g., Capital Iron and Steel Company, Anshan Iron and Steel Group Corporation, Tangshan Iron and Steel Group Company, Baogang Group. In 2012, the main business income of the steel industry in Bohai Rim region accounted for 48.41% of the whole country, the proportion of the crude steel production and pig iron production accounted for 54.03% and 56.27% of the whole country, the capacity and production of Hebei province has reached about a quarter of the whole country, as shown in Tab. 4.

Bohai Rim region is the most important iron ore production region in China, of which Hebei and Liaoning province are the first and second iron ore production provinces. Domestic iron ore cannot meet the growing demand of raw materials of the steel industry in this region as a result of its low grade and high mining cost, which leads to the amount of imported iron ore to increase year by year. In 2012, the imported iron ore of Bohai Rim region has reached 424 million tons, up to 57.04% of the whole country, which mainly imports from Australia, Argentina, Brazil, India, etc. In the past two years, owing to the increasingly serious problems of the steel industry such as overcapacity prominent and serious environmental pollution in Beijing-Tianjin-Hebei Metropolitan Region, some relevant policies rolled out to compress steel production capacity, but it will not reduce the dependence on imported iron ore in Bohai Rim region and the demand of imported iron ore will maintain steady growth.

TABLE IV. THE DEVELOPMENT SITUATION OF STEEL INDUSTRY IN THE BOHAI RIM REGION

Province	Main business income (one hundred million yuan)	Crude steel production (ten thousand tons)	Pig iron production (ten thousand tons)	Iron ore imports (ten thousand tons)
Beijing	686.52	2.61	--	--
Tianjin	4010.92	2124.20	1974.6	4282.9
Hebei	13974.29	18048.40	16358.54	17012.4
Shandong	6501.59	6579.02	6860.17	14521.58
Liaoning	6934.91	5188.50	5390.79	2825.5
Jilin	957.82	1174.19	1112.60	192.3
Heilongjiang	362.98	697.59	673.68	572
Inner Mongolia	2096.95	1734.1	1326.40	641.86
Shanxi	3356.48	3950.18	4009.63	2366.3
Total	38882.46	39498.79	37706.41	42414.84
Accounts for the proportion（%）	48.41	54.03	56.27	57.04

Due to the limit of the prefecture level statistics, the iron ore imports of 90 prefecture-level cities in Bohai Rim region cannot be all accessed directly. Through referring to relevant research and analyzing of existing data, it can be found that iron ore imports and crude steel production together with iron production are highly correlated. So this paper estimated the iron ore imports of 90 prefecture-level cities based on the crude steel production and the cast iron production (see Table 5).

C. Supply and demand balance analysis

Seeing from the total volume perspective, iron ore imports and discharge volume are 42414.84 and 63415.1 million tons in Bohai Rim region in 2012. The difference is about 21000.26 million tons, accounting for 49.16% of iron ore imports. The total through capacity of ten ports is 34345 million tons, which is 80.97% and 54.16% of the iron ore demand and the iron ore discharge volume. This suggests that the current iron ore through capacity of Bohai Rim port cluster cannot meet the demand of large cargo transportation and the gap is bigger.

The imported iron ore demand and iron ore discharge volume of Dalian port, Qingdao port and Rizhao Port varies a lot. Because the 3 ports are located in Huang Sea, having large–scale professional wharfs and good water conditions, where larger ships transfer to small ones, so the discharging volume is large. Meanwhile the hinterland of Qingdao Port and Rizhao Port extends to East China region and Central China region, the iron ore demand is increasing.

From the analysis on the overall region: the imported iron ore demand, the iron ore discharging volume and through capacity of the 3 ports in Liaoning Province are 2718.22, 7147.1 and 4595 million tons respectively, so the supply and demand balance generally; the imported iron ore demand, the iron ore discharge volume and through capacity of the 3 ports in Hebei Province are 4308.66, 1761 and 16450 million tons respectively, so the supply and demand balance generally; the imported iron ore demand, the iron ore discharge volume and through capacity of the 3 ports in Liaoning Province are 10835.16, 28825 and 10300 million tons, so the demand is less than the supply and there exists certain capacity gap; the imported iron ore demand, the iron ore discharge volume and through capacity of the 3 ports in Liaoning Province are 14552.79, 9833 and 3000 million tons, so the demand is significantly greater than the supply and there exists a very large capacity gap.

TABLE V. IRON ORE SUPPLY AND DEMAND BALANCE ANALYSIS TABLE OF PORTS IN BOHAI RIM PORT CLUSTER IN 2012

UNIT: MILLION TONS

Port	Imported iron ore demand	Iron ore discharge volume	Through capacity
Dandong	81.83	1195.8	500
Yingkou	2090.09	3716.3	1795
Dalian	546.30	2235	2300
Qinhuangdao	473.60	655	2000
Tangshan	12851.88	15159	13700
Huanghua	983.18	1796	750
Tianjin	14552.79	9833	3000
Yantai	683.68	1781.6	700
Qingdao	2754.65	13250	5600
Rizhao	7396.83	13793.4	4000
Total	42414.84	63415.1	34345

IV. SUGGESTIONS ABOUT THE SCALE AND LAYOUT OF IRON ORE WHARFS IN BOHAI RIM PORT CLUSTER

In the respect of wharf scale: in order to ensure the imported iron ore demand of steel enterprises of Tianjin Port, Qingdao Port and Rizhao Port, it should step up the development of infrastructure construction for the professional and larger iron ore wharfs, improve the discharging efficiency and berth level of iron ore wharfs; it should reasonably plan the specialized construction for Dandong Port, Yingkou Port, Huanghua Port and Yantai Port, increase iron ore through capacity appropriately based on the demand of those hinterland; it should keep the iron ore wharfs' scale of Dalian Port, Tangshan Port and Qinghuangdao Port to its original scale, and improve the specialization level of operation and efficiency.

In the respect of wharf layout: Tianjin Port, Tangshan Port, Qingdao Port and Rizhao Port should be classified as the core ports and Dalian Port, Dandong Port, Yingkou Port, Qinghuangdao Port, Huanghua Port and Yantai Port as complementary ports. Each port has to play a role in its own respective. They should strengthen the cooperation between the each other, improve the collaborative efficiency, ensure the high distributing efficiency for imported iron ore, reduce the residence time of the import iron ore ships in port and speed up the logistics for importing iron ore logistics in Bohai Rim region.

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