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Evaluation of China shipping hub-and-spoke network based on Herfindahl-Hirschmann Index (HHI)

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EVALUATION OF CHINA SHIPPING HUB-AND-SPOKE NETWORK BASED ON HERFINDAHL-HIRSCHMANN INDEX (HHI)

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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Abstract

With the ‘Belt and Road’ initiative, China's port industry has met new opportunities and challenges for development, till now many changes and construction have been made to meet the new demands. It is important to measure the current level of China shipping network. This dissertation decides to analyze the transportation efficiency of China's container transshipment port and calculate the demanded number of effective hubs for 11 provinces and cities with costal hubs and 16 of them with inland hubs. This thesis adopts Herfindahl-Hirschmann Index (HHI) to assess the transport efficiency of Chinese port network and calculate the demanded effective hubs. The result shows that the efficiency for Chinese container port network falls to only 0.7021% which is far less than the suitable range and should be caused by three reasons. The HHI model illustrates that the concentration of containerized trade occurs more in inland hubs, which is more susceptible to the seasonal or sudden changes in the volume of container trade compared with costal hubs. The HHI calculates that two hubs as two world-class international shipping centers and one hub as regional international shipping center are to be constructed, this is mostly being built according to the national development plan except that three hubs as regional international shipping centers are being proposed. The potential of Inland port development and the multimodal transport in China should be further discussed.

Keywords: transportation efficiency, Herfindahl-Hirschmann Index (HHI)

Tabel of Content

List of Tables

List of Figures

List of Abbreviations

HHI	Herfindahl-Hirschmann Index

1 Introduction

1.1 Background of this dissertation

In 1949, at the beginning of the founding of New China, the cargo throughput of Chinese ports was only 10 million tons. In 1978, China's cargo throughput was only 280 million tons, and container transportation has just started. By 2018, China's ports have completed cargo throughput of 14.351 billion tons, and the seven largest ports have been ranked among the top ten cargo throughput ports in the world. After years of construction and development, Chinese ports have shown a trend towards specialization, large-scale and deep-water development.

Chinese ports have 23,919 production berths. Deep-water berths above 10,000 tons have grown from scratch to 2,444 as of 2018. The development of China's coastal ports has also formed five major port clusters including the Bohai Rim, the Yangtze River Delta, the southeast coast, the Pearl River Delta, and the southwest coast. The layout of 8 transportation systems including coal, oil, iron ore, containers, grain, commercial vehicles, ro-ro and passenger transportation. The inland river has formed the layout of the Yangtze River trunk line, the Xijiang shipping trunk line, the Beijing-Hangzhou Canal, the Yangtze River Delta channel network, the Pearl River Delta channel network, 18 main trunk and tributary channels and 28 major ports. In addition, the construction of specialized docks for ro-ro, bulk grain and cruise ships has accelerated, contributing to the adaptation to economic and social development.

With the gradual development of the shipping market and the acceleration of the construction of the free trade zone, China's port development has become a hot spot and different directions of development have emerged. In 2017, the development direction of port terminal construction with innovation as the main content appeared.

In terms of the development strategy of free trade ports, the direction of development is to replace the extensive expansion of competition between ports with integrated resources. In the application of science and technology, effective attempts have been made on green port construction and equipment automation development, and significant progress has been made.

1.2 The purpose of the dissertation

Different development directions have emerged in port construction, such as environmentally friendly ports, technologically intelligent ports, and resource-integrated ports. Each development direction determines that the construction focus would be different at least in the next five years. So, during the transition period, this dissertation decides to analyze the current strength of the port as well as the transportation efficiency and guide the future construction of port scale. Since the national development plan has proposed the strengthen of port construction and planned to build two world-class international shipping centers, three regional international shipping centers, two domestic transshipment centers, and a shipping center of the Yangtze River Basin, this issue can be used to detect whether the current port construction is developing in this direction, and if not, which other ports have developed better. At the same time, based on the strong emphasis on the development of coastal ports and inland ports, the existing coastal port and inland port container trade performance, and the situation of port concentration should be analyzed for better understand the port power and whether it is suitable for the planned development direction.

1.3 Research methodology of the dissertation

This dissertation would adopt the Herfindahl-Hirschmann Index (HHI) method to calculate the number of efficient hubs based on the port container throughput, and analyze whether these efficient hubs are correctly following the guidance of national development plan, especially for the costal hubs that undertake most of the transportation function. Moreover, HHI method is helpful for assessing the concentration of ports and will indicate specific provinces and cities where the port is located have a relatively high port concentration situation, and these higher concentration phenomena is led by trade imbalance. Moreover, the transportation efficiency would be calculated to evaluate whether the Chinese port network is in the efficient situation, and if not, the reason for the inefficiency or the inapplicable method would be given.

2 Literature review

2.1 The hub-and-spoke shipping network design and hub location problems

In last two decades, problems associated with hubs arouse dramatically, when Goldman first pointed out the idea of hub-and-spoke network design (Goldman, 1969). O'Kelly (1986a, 1986b) soon started to study the hub location problems (HLPs) as the most well-known problem in the location theory, he purposed mathematical formulation and the corresponding solution. Also, O'Kelly (1987) purposed the first quadratic integer program for HLP problem which helped him achieve a dominant position in HLP area. In the traditional hub-and-spoke network, the great emphasis is put on the hub due to the economies of scales it brings to the shipping industry when cargoes allocated at hub nodes for further transshipment. Alumur et al. (2008) illustrated that economies of scales were carried out by the reduced transportation cost between hubs. Recently, new transshipment hubs emerged accompanied with several companies' collaboration with alliances to avoid improper used vessels or ship size in long routes to achieve better economies of scales. Therefore, it is always economies of scales which needs to be achieved in the hub-and-spoke network design.

Till now, many scholars have done researches related to HLPs in many aspects under various models by using different algorithm in order to find the most suitable and beneficial shipping network.

Some researchers utilize the hub-and-spoke network in different areas. Toh and Higgins (1985) first attempted to apply the hub location theory in the air transport. Campbell (1994) dealt with the discrete hub location problems and presented several integer programming formulations. Campbell (1996) subsequently paid attention to the facility location problems and also considered the hub-and-spoke network design for motor carriers in 2005 (Campbell, 2005). Jeong et al. (2007) extended the hub-and-spoke network design to the railway transportation field. Moreover, Cunha and Silva (2007) applied the hub-and-spoke network to a Brazil LTL trucking company. Hub network concept has already been used in airline industry, public transport, marine transport, freight transport, postal companies and other areas.

2.2 Mathematical models and existing problem

2.2.1 Mathematical models

1） Shipping hub-and-spoke network

There are many researches on shipping hub-and-spoke network design. A discrete and competitive model proposed by Marianov et al. (1999) was under the assumption that one and only one transshipment hub was adopted in the overall flow, which was certainly infeasible and ignored the probability of using more stopovers or feeders. The adoption of feeders was the idea of controlling unit cost/distance which benefitted from economies of scale in ship size. However, Marianov et al. (1999) illustrated even if the unit cost was optimized, the solution obtained might still be unrealistic considering whether the port of call was economically attractive to upload more cargoes.

Imai et al. (2009) addressed the container liner shipping network design by comparing two kinds of network using two ship sizes between two regions: the hub-and-spoke network with mega-ship and multi-port-calling (MPC) with traditional ship in Asia and Europe, Europe and North America. They supposed that only one hub port was accessible in each region for the hub-and-spoke network which was the same assumption as Marianov et al. (1999), while multiple hubs were available under the MPC assumption. The results showed that multi-port-calling was advanced in reducing costs than hub-and-spoke network in most cases, while shipping company with high costs would benefit from European trade than MPC which was more applicable in practical situation.

Shahin et al. (2010) proposed a mixed integer liner programming model under the assumption that several stops in the overall flow were allowed during the O-D path for both hub-and-spoke network and spoke-and-spoke network. Although great probability lied in the spoke-and-spoke network, especially for the small or medium volume of economy network, most of the existing models still paid attention to the development of hub-and-spoke network. Shahin et al. (2010) demonstrated that the extension of spoke-and-spoke network gave more flexibility in service time, which reconstructed the competitive liner shipping network when newcomer liner shipping company could compete with existing company in service time and transportation cost to earn market share. However, the discussion was operated on the hub-and-spoke network, even though the assumption was based on spoke-and-spoke network.

Eiselt and Marianov (2009) applied the hub-and-spoke network theory to the airline industry, they formulated a nonlinear model that certain airline service would be selected under the consideration of both flying time and ticket price. Therefore, the aviation giant would be the one offering the optimal utility function of time and price. The hub was thus set in the utility function concentrated location. The experiment was conducted using the Australian data which showed robust results concerning the leader hub location. However, the assessment was only suitable for the design of airline hub-and-spoke network service, which was not general for wide usage in worldwide industrial hub-and-spoke network design when utility function was unclear in certain industry.

2） Airport hub-and-spoke network

Airport hub-spoke network help avoid delay and improve efficiency, concentrate passengers, reduce air-travelling cost and offer more travel options (Sugiyanto, 2016). The performance of hub-spoke network is evaluated by the airport transportation efficiency calculated by Herfindahl-Hirschmann Index (HHI). Airport transportation efficiency illustrated the level how On Demand Air Service (ODAS) network satisfies the demand network. Generally, airport transportation efficiency floats up and down between 49% and 52%.

Sugiyanto measured the efficiency of airports in Indonesia and Sumatra Island in 2016 and 2018 respectively, the results came out that both Indonesia and Sumatra Island failed to reach the target of achieving hub-spoke network development in the existing condition scheme.

Sugiyanto (2016) listed 34 airports and 19 airports that offer internal and international routes separately in Indonesia to calculate the HHI, which answered the number of needed hub airports for internal and international routes. Therefore, according to the size of cargo production, 2 domestic hub airports and 1 international hub airports are confirmed. Specifically, 2 domestic hub airports were needed rather than 7 hub airports which was the actual case. Based on the 7 hub airports, the transportation efficiency was calculated to be 68.21% which is above the range of 49% to 52% and thus illustrated the inefficiency of the existing condition scheme.

Similarly, Sugiyanto (2018) tested the Sumatra Island airport efficiency through HHI. The analytical results revealed that based on the 10 domestic airports and 6 international airports, 2 hubs and only 1 hub were required for local and international flights, and the two local hub airports were just in line with the actual situation. According to the actual situation, the air transport efficiency with 2 hubs and 8 spoke airports was calculated to be 68.37% which is inefficient due to the over range.

2.2.2 Existing problem

1） Researches on the hub-and-spoke network has been focused on a single point.

Traces back to Marianov et al. (1999) who purposed the one single hub model in O-D path operated on the hub-and-spoke network, many scholars subsequently made some innovations on the basis of his research. Imai et al. (2009) classified the trade routes into two situations: hub-and-spoke network and multi-port-calling (MPC). Moreover, they also discussed the different ship size as innovation point. Shahin et al. (2010) discussed the spoke-and-spoke network that had received less attention though the experiments were not conducted based on spoke-and-spoke network. Eiselt and Marianov (2009) as an example expanded the hub-and-spoke network to other industries, which was a good attempt. However, shipping hub-and-spoke network might not benefit from that.

Though many researches developed the shipping hub-and-spoke network design, they all put emphasis on one aspect which seemed not suitable for long-term development.

2） Few researches focused on the comprehensive hub-and-spoke network performance of specific country or area, most assessments were only applicable under their models.

In most cases, numerical experiments or computational experiments would be carried out to assess the effectiveness of their models. In these cases, few put emphasis on assessing the hub-and-spoke network performance, though the assessment would be conducted under various assumptions which restricted the general-purpose usage.

3 The analysis of China shipping hub-and-spoke network

3.1 Current situation of China shipping industry

After the founding of New China, the port construction and layout gained new kinetic energy and rebirth. The port construction has a considerable scale of port system, and has made great achievements.

(1) The first stage from 1949 to 1973:

The construction and layout of the port began to recover and adjust. When New China was founded in 1949, the ports were extremely backward. There are more than 100 berths in the country, and only five ports in Dalian, Qinhuangdao, Qingdao, Shanghai, and Basuo have 10,000-ton deep-water berths (Xuan, 2012). The length of the port shoreline is only more than 20,000 meters, and the total cargo throughput is less than 10 million tons (Xuan, 2012). Many terminals have been severely damaged due to disrepair and the siltation of the waterway is visibly serious. Most of the docks loaded and unloaded parts and groceries with simple operation method and poor equipment. The loading and unloading machinery and equipment are only more than 200 sets. In order to change this backward situation as soon as possible, the state began to carry out restoration, reconstruction and layout adjustment of the port.

Firstly, to repair the original dilapidated seaport, and renovate the major coastal ports such as Dalian, Tianjin, Shanghai and Qinhuangdao. On this basis, Shanghai Port implemented professional zoning in 1953: (1) ocean-going land and water transport terminal area; (2) coastal passenger and cargo terminal area; (3) sea-going, river-going and barge water-air transport area; (4) ocean-going, Coastal freighter barge terminal area.

Secondly, a few coastal ports including Zhangjiagang Port, Zhanjiang Port, and Fangcheng Port were newly built. Among them, Zhanjiang Port, which was built in 1956, was the first comprehensive seaport designed and constructed by ourselves.

Thirdly, a number of mechanized coal and mining docks have been built in ports such as Wuhan and Nanjing on the Inland River. In short, through this stage of reconstruction, expansion and new construction, the number of port berths increased to more than 600, of which 10,000-ton deep-water berths increased to more than 90, and the number of ports with 10,000-ton deep-water berths increased to 9. The length of the port shoreline increased to more than 50,000 meters, and the total cargo throughput reached more than 100 million tons (Shi, 2019).

(2) The second phase from 1973 to 1980:

The initial development and layout of the port construction gradually became more reasonable. However, China's economic development and foreign trade have both got promoted, and the lack of port capacity has resulted in the emergence of pressure on ships, cargo, and ports. In order to change this situation, prime minister Zhou Enlai issued a ‘change the appearance of the port within three years’ call in February 1973 (China National Radio [CNR], 2005). This call triggered the following construction actions.

Firstly, oil unloading terminals have been built in ports such as Shanghai, Nanjing and Guangzhou, which can basically meet the needs of crude oil transportation in oil fields such as Daqing, Panjin and Shengli.

Secondly, several new port areas have been built in Qinhuangdao, Tianjin, Yantai, Lianyungang, Shanghai, Ningbo, Fuzhou, Zhanjiang and Fangchenggang, thus alleviating the urgent need for bulk cargo transportation. Although this stage is short, it has achieved good results. By 1980, the number of berths in coastal ports increased to more than 700, of which 10,000-ton deep-water berths increased to more than 140, and the number of ports with 10,000-ton deep-water berths increased to 11. The total cargo throughput reached more than 300 million tons, and the handling equipment increased to more than 10,000 sets (CNR, 2005).

At this stage, the port construction has not only improved its production capacity, but also its layout has become more and more reasonable, and the port groups are gradually taking shape. The Bohai Rim is centered on Dalian and Tianjin, and ports such as Qinhuangdao and Yantai have been constructed accordingly. The east China coast is centered on Shanghai and the construction of ports such as Lianyungang and Ningbo have been strengthened. Ports along the southern China coast like Zhanjiang have been built with Huangpu as the center. While the upper, middle and lower reaches of the Yangtze River Basin have built several port clusters centered on Chongqing, Wuhan and Nanjing respectively.

(3) The third stage from 1980 to 2000:

The rapid development of port construction while the layout began to be layered and systematic. After the reform and opening up, facing the new situation of nationwide production construction and the vigorous development of foreign trade, the port lag problem has increasingly become one of the important factors restricting and affecting economic and trade development. Under such circumstances, port construction and layout have been listed as national strategic priorities, which means port construction has entered a rapid development track. At this stage, coastal and inland ports have developed in a coordinated manner and the port layout has been layered and systematic. Firstly, new batch of new port areas and new ports were built. On the coast, Dalian, Qinhuangdao, Tianjin, Qingdao, Shanghai, Ningbo, Guangzhou and other ports have opened a few new port areas, while a number of new ports have been built, such as Rizhao, Lanshan, Shekou, Chiwan, Yantian, and Beihai. In particular, the 200,000-ton unloading berth in Ningbo Beilun Port, built in 1994 was the largest iron ore transit base in China at that time, with the most advanced equipment and the most complete functions (Ma, 2013). In the Inland River, new batch of small and medium-sized ports and new port areas were constructed at Yangtze River, Pearl River and Heilongjiang river basins.

Secondly, taking the construction of special coal berths as a breakthrough, a batch of modern large-scale coal berths have been built in coastal Qinhuangdao, Qingdao, Rizhao and Lianyungang, and a group of special inland coal berths have been built in the ports of Yangtze River Wuhu, Nanjing and Beijing-Hangzhou Grand Canal. At the same time, a large number of large-scale coal unloading berths were built in Shanghai, Ningbo, Fuzhou, Guangzhou and other ports in East and South China, as well as power plants along the coast of the river, which basically solved the difficult situation of the north-to-south and west-to-east coal transportation (Ma, 2013).

Thirdly, the large-scale layout of container terminals was launched. The first full container berth of New China was built in Tianjin New Port in 1981, and Zhangjiagang Port became the first inland port of New China engaged in international container handling business in 1983 (Chen, 2002). In 1993, several container-specific terminals have been built in the major coastal ports, the main line of the Yangtze River, and the middle and lower reaches of the Pearl River. Besides, a container transport system has been established at core port and feeder port.

Fourthly, relevant parties started to put emphasis on the construction of ro-ro passenger ship dock. The establishment of ro-ro transport system in Liaodong Peninsula and Shandong Peninsula, Hainan and Guangdong, Guangxi Northwest Bay and Hangzhou Bay has greatly facilitated the transportation of passengers and vehicles, which promoted the regional economic exchanges and coordinated development of society (Xu, 2003).

In short, the investment in port construction over the past 20 years has exceeded the sum of the first 30 years after the founding of New China, and the port's production capacity has been greatly enhanced. By 2000, there were more than 1,400 ports and more than 30,000 berths in the country. Among them, 10,000-ton deep-water berths were increased to more than 780, which increased the number of ports with 10,000-ton berths to 45. The length of the port shoreline increased to more than 500,000 meters, the loading and unloading machinery equipment increased to more than 26,000 sets. The total cargo throughput of the port reached more than 500 million tons (Ji &Hu, 2007). At the same time, the port layout was becoming more and more reasonable, basically forming a hierarchical transportation system framework with more than 20 main hub ports in Dalian, Qinhuangdao, Tianjin, Qingdao, Shanghai and Shenzhen as the backbone which supplemented by regional ports and the appropriate development of small and medium-sized ports. The port group of the Bohai Rim, Yangtze River

Delta and Pearl River Delta were gradually taking shape, coal, containers and land island ro-ro transport systems were developed in a coordinated manner.

(4) The fourth phase from 2000 to 2019:

During this period, the port construction realized a leaping development and launched a comprehensive scientific planning layout. In the new century, with China's entry into the WTO in 2001 and the development of a well-off society in an all-round way, China's economic and social development has entered a new historical period. The world economy has also entered a stage of recovery from the 1997 Asian financial crisis. Under this circumstances, China's import and export trade has increased rapidly, and port construction has achieved leaping development, showing a trend of large-scale, deep-water, specialization and modernization. The port layout began to be scientifically arranged in accordance with the national development plan.

After 70 years of rapid development, China's port construction and layout has formed a good situation of which the ports along river and sea got well developed with complete system, clear level, structural optimization, function matching, and complete support.

3.2 Analysis of China hub-and-spoke network

As President Xi proposed that the port is the important part of transportation, and plays an irreplaceable role in China's development. Since 2003, China has become the largest port country in the world and it is believed that first-class ports can lead to strong transportation power. Thus, the port is a significant infrastructure for both national economic and social development.

3.2.1 Hierarchy of ports

The hierarchy of ports in China can be classified into four levels, which are world-class international port, regional international port, domestic transshipment port and the Yangtze River Basin port. According to the layout and development status, two world-class international shipping centers, three regional international shipping centers, two domestic transshipment centers, and a shipping center of the Yangtze River Basin will be formed in the future (Report of the Nineteenth National Congress, 2017).

According to the Nineteenth National Congress, the two world-class shipping centers are the pearl river delta international shipping center with Hong Kong as the center, Shenzhen and Guangzhou as the sub-centers, and Shanghai international shipping center with Shanghai as the center and Jiangsu and Zhejiang as the sub-centers. The three regional international shipping centers include Bohai Bay regional international port centered by Tianjin, with Liaoning and Shandong as the sub centers, the southeast coastal port centered by Xiamen, and the southwest coastal port centered by Beibu Gulf. Two domestic transshipment centers are Zhoushan river-ocean combined transportation center, Ningbo-Zhoushan coastal transportation center. The Yangtze River Basin port is centered by Wuhan, with Chongqing as its sub center.

3.2.2 Analysis of costal ports

In 2015, the 'Visions and Actions to Promote the Joint Construction of the Silk Road Economic Belt and the 21st Century Maritime Silk Road' issued by the three ministries and commissions mentioned that strengthening port construction in coastal cities such as Shanghai, Tianjin, Ningbo—Zhoushan, Guangzhou, Shenzhen, Zhanjiang, Shantou, Qingdao, Yantai, Dalian, Fuzhou, Xiamen, Quanzhou, Haikou and Sanya. All along, China's coastal ports have been working hard to strengthen port construction to meet the ‘Belt and Road’ initiative. As of the end of 2017, China's coastal ports have exceeded 200, and all kinds of production berths have exceeded 6,800. The throughput of all kinds of goods reached 9.07 billion tons, up 7.0% year-on-year (Chen & Zhang, 2019). In 2018, coastal ports still achieved steady growth. Under the influence of the ‘Belt and Road’ initiative, China's port industry has ushered in new opportunities and challenges.

Based on the provinces and cities mentioned in ‘Visions and Actions’ and construction of the four levels of ports in China, these following 11 provinces and municipalities with costal ports show significant importance in realizing a powerful transportation country, which are Liaoning, Hebei, Shandong, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi, Hainan and Tianjin. Furthermore, these 11 provinces and municipalities form two world-class international shipping centers, three regional international shipping centers, and two domestic transshipment centers, which could be said that it occupies most of China's maritime transportation. These 11 key provinces and cities include 18 key ports, which are Shanghai Port, Shenzhen Port, Ningbo-Zhoushan Port, Qingdao Port, Tianjin Port, Guangzhou Port, Yingkou Port, Dalian Port, Yantai Port, Fuzhou Port, Xiamen Port, Quanzhou Port, Qinzhou Port, Lianyun Port, Zhuhai Port, Shantou Port, Zhanjiang Port and Qinhuangdao Port.

There are many ways to evaluate the port competency and transportation capacity. From the perspective of shipping line organization capabilities, the top three are Shanghai Port, Shenzhen Port, and Ningbo Port. These three ports have a very important position in the ‘21st Century Maritime Silk Road’ shipping network. In terms of route control capabilities, Shanghai Port and Ningbo-Zhoushan Port in the Yangtze River Delta Port Group have relatively strong capabilities. From the perspective of route accessibility, the port capabilities are not much different, indicating that China's coastal ports have relatively high route accessibility in the ‘21st

Century Maritime Silk Road' route network. From the perspective of port route attraction, the top six are Shenzhen Port, Shanghai Port, Ningbo-Zhoushan Port, Qingdao Port, Guangzhou Port, and Tianjin Port. To comprehensively evaluate the competitiveness of ports, the Shanghai Port in the Yangtze River Delta Port Group ranks first, and Ningbo-Zhoushan Port ranks second. Besides, the comprehensive competitiveness of Qingdao Port and Tianjin Port around the Bohai Bay is on the upper stream.

3.2.3 Analysis of inland ports

Compared with coastal ports, inland ports play a vital role in promoting the economic continuity between inland and coastal areas, promoting international container multimodal transport, building up bridges for international trade, providing third-party logistics services, international freight forwarding, customs clearance services and supply chain value-added services.

Inland ports help alleviate regional economic gap. From a domestic perspective, China's economic development is uneven, and the economic gap between regions is obvious. One of the reasons is that the inland areas in the central and western regions lack the geographical advantages of coastal areas and cannot directly use marine resources. Thus, inland ports provide a good operating platform for this. Inland ports are generally located in economic central cities and are usually the confluence of railways and highways. If the inland ports are constructed in the central and western regions, a complete logistics network would be formed and scientific transportation routes would be arranged, which not only reduces logistics costs, but also drive economic development in backward areas. Regional economic development can narrow the economic gap, which will definitely have a positive effect on the construction of a maritime power.

Inland ports are an important part of multimodal transport. In the international container multimodal transport, the use of different transportation methods such as road, railway, and sea transportation will organize and arrange the container cargo throughout the whole country and across borders to ensure the timely delivery of the cargo to the destination. The non-coastal geographical conditions of the inland port allow goods to be transported from the inland to the destination by a large amount of sea-rail combined transportation. Sea-rail combined transport is importing and exporting transported goods from inland ports to coastal ports by rail, and then by ship. In the whole process of cargo transportation, the customs clearance service of the inland port can meet the requirements of ‘one declaration, one inspection and one release’, which greatly simplifies the tedious process of cargo clearance. The formation of a sea-rail combined train between the inland port and the sea port will be extremely advantageous.

Inland ports help build international trade bridges. The inland port has the functions of customs declaration, customs clearance, as well as logistics functions such as cargo handling, distribution, unpacking, warehousing, transportation, sorting, and financial functions such as insurance, settlement, credit, and information services, which can help serve ocean import and export. The development of inland ports can break the bottleneck that restricts the development of international trade in inland areas, open international logistics channels, and use inland ports as transshipment port to export directly from inland to foreign countries, while also reducing overall logistics costs. For example, the inland port of Yiwu, Zhejiang, which developed with the small commodity market as its core business, has been driven by the development of logistics and international trade. The establishment of the inland port of Yiwu improves the transportation and customs clearance efficiency and achieves economies of scale. The inland port has built a bridge between inland cities and international trade, which has not only promoted the import and export trade of inland cities, but also brought the supply of goods to the seaports.

With the strong support of the country, China's domestic inland ports have developed rapidly. Among them, the Xi'an International Port Area has developed rapidly in trade volume with a wide range of radiation, strongly promotes economic development in the central and western regions, narrows the gap in economic levels, and is committed to build China's largest international inland port. Xi'an, Shaanxi Province is located at the center of the Asia-Europe Continental Bridge, connecting China's eastern, central and western economic belts. It has a relatively high economic level and a large development advantage. At present, many enterprise investment projects have been launched in Xi'an, and not only seek their own development, but also fully radiate the surrounding areas and promote the common development of the central and western regions.

4 HHI model

4.1 Construction of the HHI model for shipping industry

The method used to assess the transport efficiency of Chinese port network is based on the Herfindahl-Hirschmann Index (HHI), which helps evaluate the performance of hub service by comparing the current occupancy rate with the on-demand hub service. This method derives from the network theory parameters, which is not explained here in detail but can be referred by Fry and DeLaurentis (2008).

Many scholars believe that the effectiveness and accuracy of the HHI method is relatively low, because most port systems are currently at a low level, and the container throughput of a port is small, or because there is no guarantee that there is no missing port throughput data in the calculation process. Therefore, the performance of individual ports will no longer be evaluated in this paper, but the province or city where the port is located will be used as a statistical unit, which is believed to better reflect the port performance.

Sugiyanto (2018) assess the transport efficiency of air service which contains different routes within various airports. In order to evaluate the hub service transport efficiency, the first step is to modify the assessment method as follow:

$$l_w^i = \frac{\sum_j l_{ij} w_{ij}}{\sum_j w_{ij}}$$

Equation 1 Average weighted number of voyages between province i and other provinces j

Where l_{ij} stands for the number of voyages applied to the route connecting ports in province i and j, and w_{ij} is the shipping transportation amount within province i and j in the related route. The calculation gives the result of average weighted number of voyages between province i and other provinces j as l_w^i. Therefore, by using Equation 1, the demanded voyage number is computed for a given province i. The weighted number of voyages appears large when the inter-provincial voyage goes through many ports of call with large amount of transport volume. The value range of l_w^i is equal to or greater than 1. The weighted number of voyages l_w^i is further transferred as Equation 2 to calculate the transport efficiency:

$$E_t = \frac{1}{n} \sum_i \frac{1}{l_w^i}$$

Equation 2 Traffic efficiency for the Chinese shipping network

In the Equation 2, E_t represents the traffic efficiency for the Chinese shipping network, and n stands for the number of provinces participating in the containerized trade. Therefore, the value range of E_t is between zero and one. It is only when the ports in the two provinces i and j have nonstop shipment, and there is only one way of sailing between the two provinces that the E_t is equals to one. However, if the shortest path between the two provinces i and j would go through many transshipment ports and there are several kinds of navigation routes, then the E_t would fall close to zero. According to Sugiyanto (2018), the transporting efficiency of hub and spoke networks is usually around 49% to 52%. E_t falls in this range shows that the on-demand network service generally meets the service demand, which enables the large amount of shipping transportation to be proceed efficiently (Fry and DeLaurentis, 2008).

The HHI was developed by Hirschman (1964) to assess the concentration of port system, which was based on the strict assumption that all ports were involved in the full competition of the same market (Lijesen, 2004). In order to assess the concentration of port system, the HHI is defined as the sum of the squared values of each port's market share that is obtained by comparing the throughput committed by each port against the total throughput of the defined ports in the market. In order to simplify the model, the container throughput of each port is no longer calculated here, but counted in a province or municipality as a unit. Therefore, the size of i in x_i depends on the number of provinces or municipalities participating in the container shipping trade.

Therefore, for a country with i number of provinces or cities participating in containerized trade, the value of HHI would be in the range of $\frac{1}{i}$ and 1. The minimum value will appear when the container throughput of each province or city is equal, which means that the container trade volume of each province or city is balanced and would be seem as the lowest concentration. The HHI reaches the maximum value when the containerized trade in the market is unbalanced, and one province or city occupies the total container trade volume of the country, which means the hub system is fully concentrated in this situation.

Moreover, the number of effective hubs (n_e), the number of hubs (h) can be further calculated, the calculation method is as follows:

$$P_i = \frac{x_i}{\sum x_i}$$

Equation 3 Proportion of container throughout volume of province i

$$\mathrm{HHI} = \sum {P_i}^2$$

Equation 4 HHI

In the Equation 3, x_i stands for the container throughput volume of one specific province or city i. Moreover, the specific value of HHI can be obtained by simple calculation of freight volume. Using the calculated HHI, the number of effective hubs (n_e) and the number of hubs (h) can be obtained as follows:

$$n_e = 1/\mathrm{HHI}$$

Equation 5 Number of effective ports

$$\mathrm{h} = 0.5\left\{n - \left(n^2 - (n * n_e)^{\frac{1}{2}}\right)\right\}$$

Equation 6 Demanded number of effective ports

In the Equation 4, n_e represents the number of effective ports, while n stands for the number of provinces participating in the containerized trade which is the same factor as the one in Equation 2. The result of h is the demanded number of effective ports.

4.2 Data Collection

In order to calculate the transport efficiency E_t and decide the number of hubs (h), the following data are needed: the number of voyages applied to the route connecting ports in province i and j (l_{ij}), and the shipping transport volume on this route (w_{ij}). The number of provinces and cities participating in the seaborne trade (n), including the provinces that have inter-provincial maritime trade and those that export to foreign countries and the container throughput volume of province or city i (x_i). All these data would be collected from China ports organization.

The number of provinces and cities participating in the seaborne trade (n) in 2019 and 2018 is 21, which includes Liaoning, Hebei, Shandong, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi, Hainan, Tianjin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Chongqing, Sichuan, Guizhou and Yunan. The geographical locations of these provinces and municipalities are within the scope of the construction of two world-class international shipping centers, three regional international shipping centers, two domestic transshipment centers and the Yangtze River Basin port shipping center. The data of other variables can be seen below.

In order to analyze the detailed changes of HHI in 2019, the monthly container throughput of coastal hubs and inland hubs (x_i) in 2019 is recorded according to the division of provinces and municipalities for future research on HHI. The detailed data can be referred as follow:

Monthly Container Throughput units: 1,000,000 TEU												
	2019.12	2019.11	2019.10	2019.09	2019.08	2019.07	2019.06	2019.05	2019.04	2019.03	2019.02	2019.01
overall	21.57	22.21	22.11	22.79	22.62	22.77	22.32	22.40	21.94	21.53	16.63	22.16
Costal hub	18.83	19.52	19.58	20.21	20.04	20.16	19.71	19.84	19.24	19.10	14.95	19.73
Liaoning	1.36	1.35	1.36	1.48	1.44	1.40	1.35	1.44	1.45	1.39	1.32	1.55
Hebei	0.40	0.48	0.44	0.43	0.33	0.35	0.35	0.35	0.27	0.27	0.20	0.27
Shandong	2.58	2.59	2.55	2.57	2.55	2.57	2.59	2.58	2.52	2.45	2.06	2.48
Shanghai	3.27	3.55	3.63	3.71	3.76	3.85	3.76	3.76	3.61	3.81	2.86	3.75
Jiangsu	0.37	0.43	0.43	0.43	0.43	0.42	0.43	0.43	0.43	0.43	0.40	0.42
Zhejiang	2.22	2.40	2.51	2.65	2.70	2.79	2.67	2.82	2.49	2.42	2.11	2.85
Fujian	1.50	1.46	1.45	1.48	1.41	1.48	1.47	1.45	1.53	1.49	1.10	1.45
Guangdong	5.25	5.17	5.02	5.27	5.30	5.18	4.99	4.97	4.93	4.96	3.51	5.20
Guangxi	0.40	0.44	0.37	0.35	0.33	0.33	0.32	0.30	0.27	0.27	0.16	0.27
Hainan	0.30	0.22	0.21	0.20	0.22	0.23	0.24	0.23	0.26	0.22	0.14	0.22
Tianjin	1.18	1.42	1.61	1.64	1.56	1.56	1.55	1.52	1.48	1.41	1.10	1.27
Inland hub	2.74	2.69	2.53	2.58	2.59	2.61	2.61	2.56	2.70	2.42	1.68	2.43
Heilongjiang	0	0	0	0	0	0	0	0	0	0	0	0
Shandong	0	0	0	0	0	0	0	0	0	0	0	0
Shanghai	0	0	0	0	0	0	0	0	0	0	0.01	0
Jiangsu	1.19	1.20	1.17	1.17	1.15	1.20	1.18	1.14	1.14	1.15	0.89	1.14
Zhejiang	0.10	0.10	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.05	0.13
Anhui	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.16	0.14	0.09	0.05
Jiangxi	0.06	0.07	0.07	0.06	0.06	0.07	.0.06	0.06	0.05	0.05	0.04	0.05
Henan	0	0	0	0	0	0	0	0	0	0	0	0
Hubei	0.23	0.19	0.16	0.17	0.17	0.17	0.17	0.17	0.30	0.11	0.10	0.14
Hunan	0.06	0.06	0.05	0.06	0.07	0.06	0.06	0.07	0.06	0.06	0.03	0.06
Guangdong	0.70	0.64	0.59	0.62	0.63	0.64	0.64	0.64	0.66	0.64	0.31	0.62
Guangxi	0.11	0.12	0.10	0.11	0.12	0.09	0.10	0.10	0.09	0.07	0.04	0.08
Chongqing	0.11	0.11	0.11	0.11	0.10	0.10	0.11	0.11	0.11	0.10	0.08	0.10
Sichuan	0.03	0.03	0.03	0.04	0.04	0.05	0.04	0.04	0.04	0.03	0.03	0.04
Guizhou	0	0	0	0	0	0	0	0	0	0	0	0
Yunnan	0	0	0	0	0	0	0	0	0	0	0	0

Table 1 Monthly Container Throughput in 2019

(source: http://www.chineseport.cn/)

The schematic diagram below is made based on the raw data for better understanding the geographic distribution of hubs in China and intuitively understanding which provinces and cities have greater monthly container throughput.

In overall, the container throughput of coastal hubs was much larger than that of inland hubs. For coastal hubs, Guangdong and Shanghai ranked first and second respectively in monthly container throughput at around 500,000 TEUs and 370,000 TEUs in 2019. As the third and fourth, Zhejiang and Shandong province had little difference in monthly container throughput, and Zhejiang's monthly container throughput volume was slightly larger than that of Shandong at around 250,000 TEUs. For inland hubs, it can be seen from the chart that the monthly container throughput of Jiangsu was around 120,000 TEUs, which was much larger than that of other provinces and cities and was more than 1.5 times the monthly container throughput of Guangdong province that ranked second. The container throughput of the remaining provinces and cities did not differ much, and most of them fluctuated around 15,000 TEUs per month.

Compared with costal hubs, more provinces and cities have inland hubs. However, subject to the channel conditions, draft limit and other factors, the container throughput of most inland ports is far less than that of coastal ports. However, among the 21 provinces and cities involved in containerized trade, four provinces and one municipalities, Jiangsu, Zhejiang, Guangdong, Guangxi and Shanghai have both inland hubs and coastal hubs. Among them, the container throughput of Jiangsu is nearly three times the volume of the its inland hub.

Moreover, there was a declining trend for both costal hubs and inland hubs occurred in February, provinces and cities with greater monthly container throughput received greater negative impact. While other provinces and cities maintained a stable situation, Hubei saw an increase in throughput in April with an increase of 19,000 TEUs, but this upward trend disappeared in May and fell back to the previous volume.

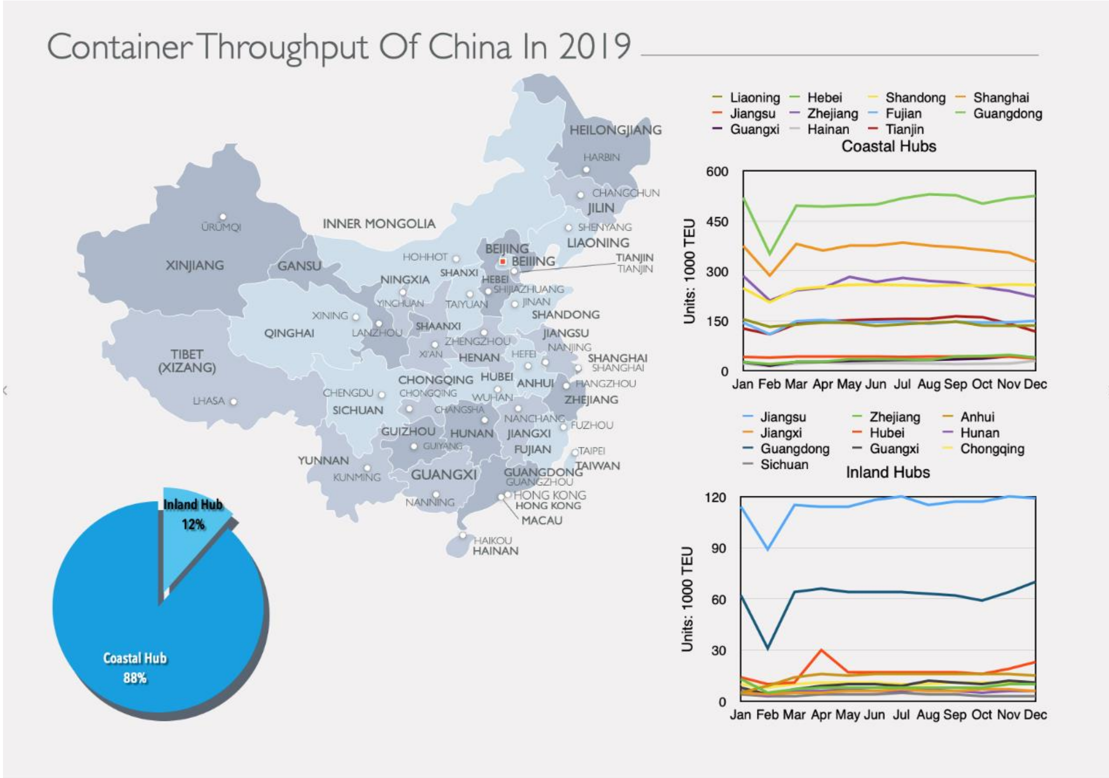

Figure 1 Container Throughput of China in 2019

Besides, the container throughput in 2019 and 2018 would be compared to see how HHI changes through month and how it differentiates between costal hubs and inland hubs.

Container Throughput		units: 1,000,000 TEU
	2019	**2018**
Overall	261.07	249.82
Costal hub	230.92	221.18
Liaoning	16.89	18.78
Hebei	4.13	4.25
Shandong	30.10	27.28
Shanghai	43.30	42.01
Jiangsu	5.05	4.94
Zhejiang	30.63	28.98
Fujian	17.26	16.47
Guangdong	59.76	57.14
Guangxi	3.82	2.90
Hainan	2.68	2.40
Tianjin	17.30	16.00
Inland hub	30.15	28.64
Heilongjiang	0.01	0
Shandong	0	0
Shanghai	0.01	0
Jiangsu	13.73	13.05
Zhejiang	0.95	0.74
Anhui	1.79	1.46
Jiangxi	0.71	0.62
Henan	0	0
Hubei	2.09	1.90
Hunan	0.69	0.66
Guangdong	7.34	6.98
Guangxi	1.13	1.05
Chongqing	1.25	1.16
Sichuan	0.44	0.97
Guizhou	0	0
Yunnan	1	0

Table 2 Container Throughput in 2019 and 2018

(source: http://www.chineseport.cn/)

5 Results of HHI model

5.1 Shipping transportation efficiency

The transportation efficiency of Chinese port network is calculated by the modified method that Sugiyanto (2018) adopted to assess the transport efficiency of air service which contains different routes within various airports. So, the assessment method considers the number of voyages applied to the route connecting ports in province i and other provinces j, and the shipping transportation amount (w_{ij}) within province i and j in the related route. According to the data from port organization, there are seven provinces and two municipalities involved in the container transshipment, and each province and city has different levels of transshipment with its surrounding provinces. These seven provinces and two municipalities are Guangdong, Zhejiang, Anhui, Hubei, Fujian, Shandong, Sichuan, Shanghai and Chongqing.

Most container transshipment centers are in the coastal ports, but Sichuan, Chongqing, Anhui, and Hubei, as inland ports, also undertake non-negligible container transshipment functions. This is partly because there are also containerized trades in provinces and cities in the hinterland of China, and the geographical location of these provinces and cities are in the Yangtze River Basin, which can facilitate the participation in container transshipment. Another reason for the involvement of inland ports is that the construction of the Yangtze River Basin shipping center mentioned in the national development plan, which would put emphasis on Wuhan as the center and Chongqing as the secondary center.

Therefore, based on the data, it is easily calculated that the E_t for Chinese port network only falls to 0.7021% which is far less than the optimal range between 49% and 52%. And this would be interpreted by Sugiyanto as the on-demand network service does not meet the service demand.

There are several reasons for this situation.

Firstly, Sugiyanto adopted the model to evaluate the air transport efficiency which contains different routes within various airports, and this is not exactly suitable for assessing the marine transport efficiency,

Secondly, this method is optimized to count the container transshipment volume of each province and city, rather than each port's own transshipment volume. This may cause some differences in calculation results. However, due to the lack of the volume and routes of various ports involved in container transshipment trade, such research cannot be carried out here. Therefore, this model is not that suitable for assessing container transshipment trade

Thirdly, research data may be missing. This is due to the different statistical method of port data changing in recent years, so some port data may not be counted.

	Shanghai	Guangdon	Zhejiang	Anhui	Hubei	Fujian	Shandong	Sichuan	Chongqing
l_w^i	1.451613	1.783784	1.555556	1.857143	1.363636	1.607843	2.428571429	1.491803	2.285714
E_t	0.7021%								

Figure 2 Traffic Efficiency for the Chinese Shipping Network

5.2 HHI for costal hubs and inland hubs

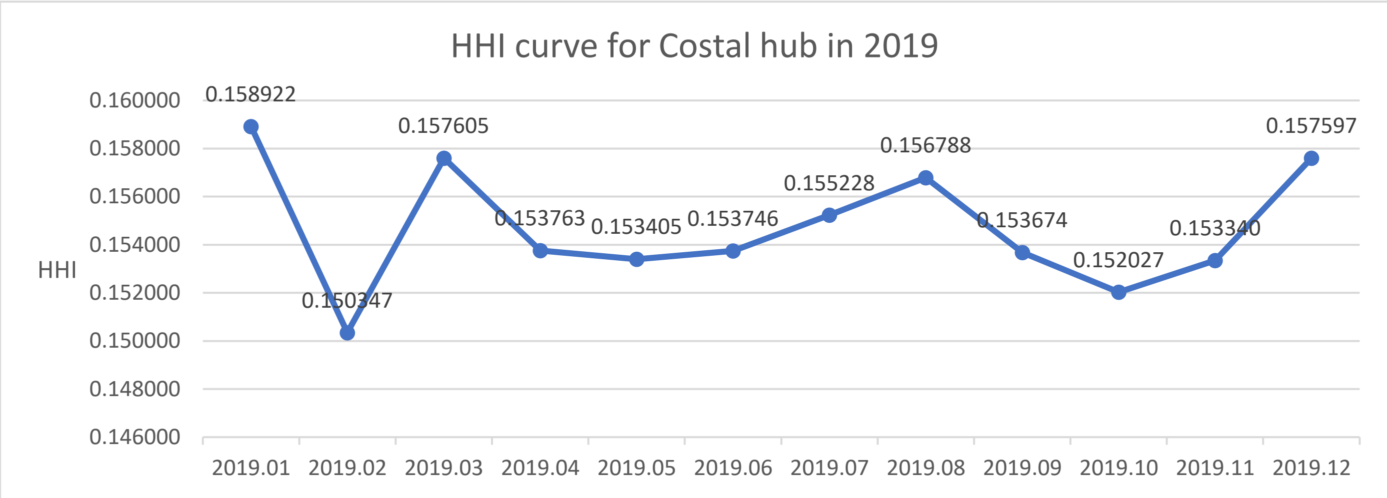

Figure 3 HHI curve for Costal hub in 2019

There are 21 provinces and municipalities participating in the marine transportation, in which 11 provinces and cities have costal hubs and 16 of them have inland hubs, which would be the emphasis of this part.

Based on the Herfindahl-Hirschmann Index (HHI) method, the monthly HHI in 2019 can be calculated, which is shown as curve in Figure 3. It can be seen that the highest and lowest points of HHI in 2019 were 0.158922 and 0.150347 in January and February respectively. After experiencing a decline from the highest point to the lowest point, HHI rose again in March, followed by two small-scale of falling to rising that formed two small U-shape during March to August and August to December. Overall, HHI's floating range in 2019 was between 0.150347 and 0.158922, and HHI's biggest decline in 2019 was 5.40% happened in February.

Since HHI can be used as a tool to assess the concentration of port system, which in this paper can be referred as the concentration of containerized trade among 11 provinces and cities that have costal hubs. It can be concluded that the concentration of container throughput experienced a 5.40% decrease in February of 2019, and fluctuated in the following ten months. By looking back to the monthly container throughput can see that the highest concentration happened in the mature hubs, for example, the ports in Guangdong and Shanghai. The container throughput of these provinces and cities is much larger than some smaller ports, which leads to the high concentration. And this situation confirms to the national development plan, based on the construction of world-class international port and regional international port.

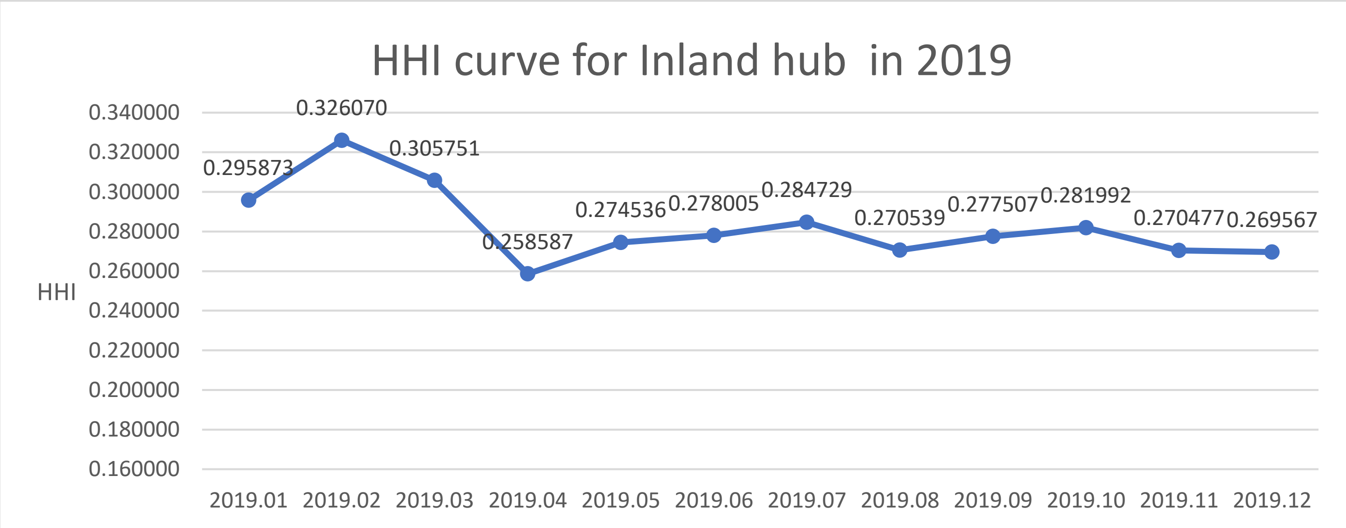

Figure 4 HHI curve for Inland hub in 2019

As have said before, 16 provinces and cities have inland hubs, though the container throughput is far less than the costal hubs.

The HHI curve of the inland port shows that the HHI curve fluctuates more compared to the HHI trend of the coastal hubs. From January to April of 2019, there was an increase and then followed by the decline which stopped in April and continuously fluctuated in a small range from April to the end of the year. The maximum HHI was achieved at 0.326070 in February, which was perfectly opposite to the minimum HHI obtained by costal hubs at 0.150347. This maximum HHI represented the highest concentration for the inland hubs when Jiangsu accounted for 58,000 TEUs more than Guangdong, which ranked second in container throughput.

The inland hub HHI floated between 0.258587 and 0.326070, and the minimum value of the inland port HHI is 0.099648 greater than the maximum HHI of the coastal hub. This could be interpreted as the containerize trade market was more balanced in costal hubs compared to the inland hubs. The reason for this situation is that most inland hubs are currently at a developing status, so the large amount of container would be transferred through few regional international hubs, like Nanjin, Lianyungang and Wuhan. However, most costal hubs have more advanced loading and unloading machinery and equipment, the draft is generally deeper, and the layout is more reasonable. Therefore, the problem of concentration in a certain hub derives from the uneven development steps is relatively rare among various coastal ports. When some accumulation problems occurred in the coastal hubs, it might be caused by some special loading and unloading requirements like mechanized coal and mining terminal.

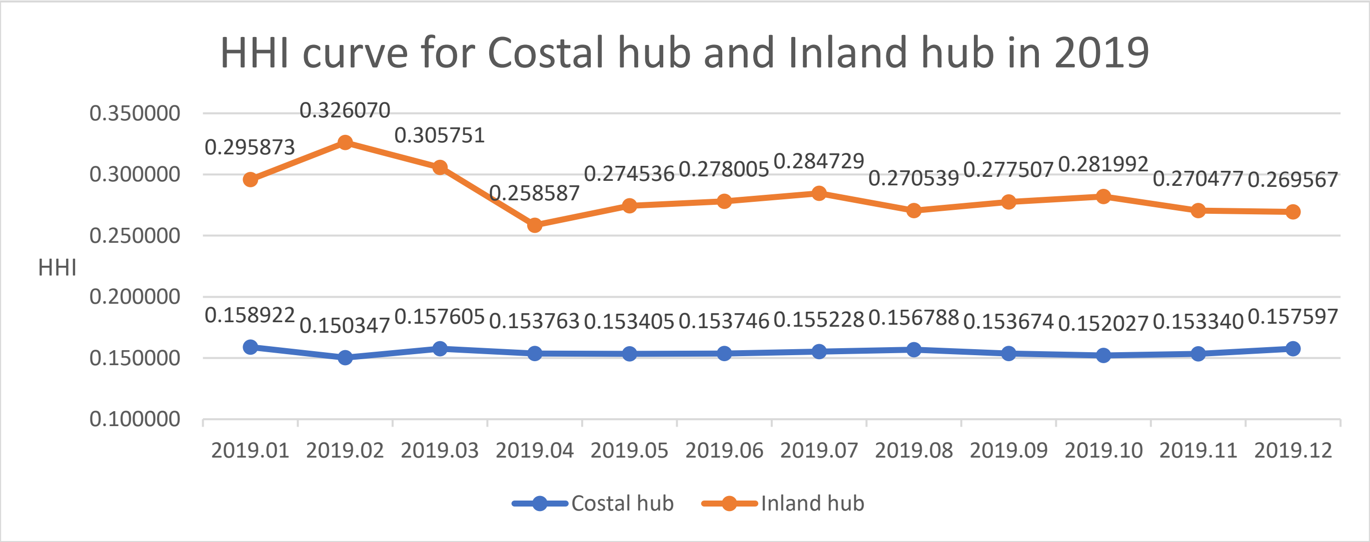

Figure 5 HHI curve for Costal hub and Inland hub in 2019

5.3 HHI analysis of 2018 and 2019

The HHI is calculated based on the strict rule that all ports were involved in the full competition of the same market (Lijesen, 2004). However, the container throughput data was integrated on the different method which caused missing data, thus could not be used under full competition assumption. Therefore, the comparison of HHI would be carried out for 2018 and 2019, which focus on the number of hubs (h) for the costal hub and inland hub. The HHI method calculated that the number of hubs for costal hub is two, and the number of hubs for inland hub is one in both 2018 and 2019.

As Xi Jinping proposed in the report of the '19th National Congress of the Communist Party of China' to build a powerful transportation country. Ports are an important part of a powerful transportation country and have an irreplaceable special status and role. The blueprint for national development plan in 2017 can be summarized as two world-class international shipping centers, three regional international shipping centers, two domestic transshipment centers, and a shipping center of the Yangtze River Basin.

Therefore, the two hubs of costal hubs can be referred as the two world-class international shipping centers. According to the container throughput, the two largest costal hubs locate in Guangdong and Shanghai. These two provinces and cities are in the development plan as the pearl river delta international shipping center with Hong Kong as the center, Shenzhen and Guangzhou as the sub-centers, and Shanghai international shipping center with Shanghai as the center and Jiangsu and Zhejiang as the sub-centers. The gradual development of the ports in these two provinces and cities is fully in line with the national development plan.

For the inland hubs, which is calculated to be one using HHI method, it is more likely to become the regional international shipping centers considering the geographic location and container throughput. The container throughput in both 2018 and 2019 indicates that Jiangsu as an inland port has undertaken most of the container loading and unloading functions and accounts for 45% of the overall container throughputs, which shows that Jiangsu's inland ports are playing an irreplaceable leadership role among the existing inland ports. This situation verifies that the effective number of ports calculated by HHI model as one is correct. The result of this HHI model is somewhat different from the development plan for the regional international shipping center in China, since China plan to construct three regional international ports and only one of them has been greatly used. According to the existing container throughput ranking, then the three regional international shipping centers that China plans to construct would be located in Jiangsu, Guangdong and Hubei.

1,000,000 TEU	2019			2018		
	container throughput	Pi	Pi^2	container throughput	Pi	Pi^2
Costal hub						
Liaoning	16.89	0.073142	0.005350	18.78	0.084908	0.007209
Hebei	4.13	0.017885	0.000320	4.25	0.019215	0.000369
Shandong	30.1	0.130348	0.016991	27.28	0.123338	0.015212
Shanghai	43.3	0.187511	0.035160	42.01	0.189936	0.036076
Jiangsu	5.05	0.021869	0.000478	4.94	0.022335	0.000499
Zhejiang	30.63	0.132643	0.017594	28.98	0.131025	0.017167
Fujian	17.26	0.074745	0.005587	16.47	0.074464	0.005545
Guangdong	59.76	0.258791	0.066973	57.14	0.258342	0.066740
Guangxi	3.82	0.016543	0.000274	2.9	0.013111	0.000172
Hainan	2.68	0.011606	0.000135	2.4	0.010851	0.000118
Tianjin	17.3	0.074918	0.005613	16	0.072339	0.005233
HHI			0.154473618			0.15434081
n_e			6.473597303			6.47916772
n			11			11
h			2			2
Inland hub						
Heilongjiang	0.01	0.000332	0.000000	0	0.000000	0.000000
Shandong	0	0.000000	0.000000	0	0.000000	0.000000
Shanghai	0.01	0.000332	0.000000	0	0.000000	0.000000
Jiangsu	13.73	0.455390	0.207380	13.05	1305.000000	0.207623
Zhejiang	0.95	0.031509	0.000993	0.74	74.000000	0.000668
Anhui	1.79	0.059370	0.003525	1.46	146.000000	0.002599
Jiangxi	0.71	0.023549	0.000555	0.62	62.000000	0.000469
Henan	0	0.000000	0.000000	0	0.000000	0.000000
Hubei	2.09	0.069320	0.004805	1.9	190.000000	0.004401
Hunan	0.69	0.022886	0.000524	0.66	66.000000	0.000531
Guangdong	7.34	0.243449	0.059268	6.98	698.000000	0.059397
Guangxi	1.13	0.037479	0.001405	1.05	105.000000	0.001344
Chongqing	1.25	0.041459	0.001719	1.16	116.000000	0.001640
Sichuan	0.44	0.014594	0.000213	0.97	97.000000	0.001147
Guizhou	0	0.000000	0.000000	0	0.000000	0.000000
Yunnan	0.01	0.000332	0.000000	0	0.000000	0.000000
HHI			0.280385469			0.27981861
n_e			3.566518634			3.57374376
n			13			13
h			1			1

Table 3 Demanded number of effective ports

5.4 Conclusion

The analysis in this dissertation can be divided into two aspects, which are the calculation of transportation efficiency of China's container transshipment port and the adoption of HHI model to calculate the number of effective inland hubs and coastal hubs.

Based on the modified model that Sugiyanto (2018) adopted to assess the transport efficiency of air service, seven provinces and two municipalities mainly in coastal area are involved in the calculation of China's container transshipment transportation efficiency. The efficiency for Chinese container port network falls to only 0.7021% far less than the optimal range among 49% to 52%, which is interpreted by Sugiyanto as can not fully meet the demand for network service. The reason for this insufficiency can be summarized as follows. Firstly, the method is modified from the calculation of satisfaction of aviation service demand, which is not perfectly suitable for the shipping service. Secondly, this model only calculates the throughput of container transshipment ports, not the throughput of each port. Therefore, the result of the transportation efficiency might be different. Thirdly, data like the volume and the number of routes connecting various ports in some years are not available, thus research on China port transportation efficiency can not be fully carried out.

The HHI model is used to calculate the number of demanded effective hubs for both inland hubs and coastal hubs respectively, and reflect the concentration of containerized trade. According to the HHI curve for inland hub and costal hub, it can be seen that the fluctuation occurred more in Inland hubs and the overall HHI data for inland hubs were larger than that for coastal hubs in 2019. This represents that the concentration of container throughput is a more serious problem in inland hubs than in costal hubs, also inland hubs are more vulnerable to seasonal or sudden changes in the volume of container trade. The reason for the vulnerability is that the container trade in inland hubs is dominated by a few mature ports, which is a few regional international hubs, like Nanjin, Lianyungang and Wuhan. Also, compared to the costal hubs, inland hubs are mostly in the developing stage considering the deeper draft, more reasonable layout and advanced loading and unloading machinery for costal hubs.

Based on the container throughput data of 2018 and 2019, the number of hubs for inland hub and costal hub is calculated. The figure did not change in 2018 and 2019 as

2 hubs for costal hub and 1 hub for inland hub. This result indicates that two hubs as two world-class international shipping centers and one hub as regional international shipping center are to be constructed following the national development blueprint. The two hubs for costal hubs locate in Guangdong and Shanghai, the one hub locates in Jiangsu. The result of the HHI model is different from the development plan for the regional international shipping center in China, since China plan to build three regional shipping centers in Jiangsu, Guangdong and Hubei.

6 Suggestion for China hub-and-spoke network design

6.1 Author's recommendation

The pace of port development has gradually accelerated in recent years for the following two reasons.

Firstly, the port is an important node and carrier of the Maritime Silk Road and an important strategic resource. Since the introduction of the 'Belt and Road' initiative, Chinese companies have increased investment to construct ports and logistics facilities along the route, and increase opportunities for international joint ventures and cooperation in the Maritime Silk Road ports, which have achieved fruitful results. Besides, Chinese enterprises have strengthened their investment in overseas ports through mergers and acquisitions, franchise operations, joint ventures and other forms of cooperation, and contributed to the promotion of the connectivity of the 'Belt and Road' facilities.

Secondly, since the establishment of the first pilot free trade zone ‘China (Shanghai) Pilot Free Trade Zone’, pilot free trade zones have been established throughout the country. Based on the construction of a pilot free trade zone, the State Council first proposed the establishment of a "free trade port" in April 2017. Shanghai was the first to report on the free trade port plan, which was designed for the free movement of goods, funds and people, with the direction of developing offshore trade and offshore finance. With the report of the Shanghai Free Trade Port Plan, Zhejiang, Fujian, and Tianjin have also started or are planning to explore free trade ports. The declaration plan for the Dalian Free Trade Port was initially completed and in-depth discussions were conducted, the Guangdong Pilot Free Trade Zone also studied and formed a proposal to build a free trade port. Most of the regions that have proposed the idea of a free trade port plan are areas that are already free trade zones. After a period of exploration, these areas have achieved some results and accumulated experience in opening up and innovation. The construction of the free trade port will start from the coastal and inland ports, and this is one of the reasons for the accelerated port construction.

Therefore, under such a development environment, the number of our existing coastal ports and inland ports has in fact fully conformed to the most effective number of ports analyzed by the HHI model. In addition, the construction of world first-class ports and regional international ports in our national development plan can already be seen in the existing ports and future development plan. Thus, there is no need for many more suggestions on the scale construction of the port. However, there are still some aspects worth noting about the development of inland ports at this stage.

First of all, inland port trade is very unbalanced. For example, the container throughput of Jiangsu ’s inland port is close to twice that of the second largest inland port in Guangdong. Although there are sixteen provinces and cities participating in the container trade, the container throughput of Jiangsu is almost the same as that of the remaining 15 regions. Therefore, it is necessary to reduce the throughput gap between inland ports, and develop container trade in inland areas more effectively according to the geographical location and specialized division of each port.

Secondly, the trade volume of inland ports is much lower than that of coastal ports. The root cause of this problem lies in the geographical location and trade opportunities. Inland ports locate far into the hinterland of China than coastal ports, and the navigation conditions are poor. Besides, vessels passing through inland ports are often relatively small. Therefore, the transportation cost of vessels passing through inland ports is usually higher, which will inevitably affect the trade of inland ports. In addition, inland ports have fewer trade opportunities than coastal ports. Coastal ports will naturally have more trade volume because of the exchange of foreign ships and the better economic development of coastal areas. Also, many pilot free trade zones are set up in coastal port areas. For inland ports where only exists circulation of goods, the trade volume is naturally inferior.

For the development of inland ports, there are two suggestions.

The attempty of reducing throughput gap could be overall planning to clarify the construction purpose of inland ports accompanied by the coordination and regulation, which can finally help avoid the useless construction of inland ports. At the same time, government can provide some financial support to lead the development of inland ports towards modernization. Policy support will greatly promote the development of inland ports, cultivate emerging economic growth to meet the needs of social production, and promote the upgrading of industrial structure to create a better environment for the development of inland ports.

The inland port can enhance the trade volume by building the bridge for international trade. For example, the rapid development of China-Europe trains has opened the import and export channels in western China, enabling western provinces to become the frontier of open policy. The construction of the southbound passage will connect the Belt and Road in the western provinces. These initiates not only provide the inland port with more opportunity of getting in touch with international trade, but also push the development of inland ports toward modernization, informatization, professionalization. Moreover, the international trade in international trade will rely on multimodal transport in the inland of China, and marine transportation will be an important part of it, which means inland ports are indispensable and would face more maritime trade.

6.2 Possible research orientations

1） Inland port development potential and existing problems

The development of inland ports is largely dependent on the international trade, and a representative of international trade is the ‘Belt and Road’. However, there is current viewpoint that the ‘Belt and Road’ international cooperation has achieved more results on land than on the sea. This viewpoint stems from the understanding of the achievements of the ‘Belt and Road’ international cooperation, which seems to be limited to the ‘road construction and port construction’. However, the achievements of the ‘Belt and Road’ international cooperation should not be restricted to road and port construction. The final purpose should be promoting economic, facilitating and developing trade. The Maritime Silk Road is currently the main channel for Asia-Europe trade, and has undertaken more than 85% of China's international trade and transportation tasks. Due to transportation capacity and cost constraints, the land corridor can only be a useful supplement to the sea corridor to meet the demand of different logistics transportation market between Asia and Europe. Thus, how to assess the potential and problems of the inland port of China's Maritime Silk Road at this stage is a key problem. For example, improving the safety, reliability, and convenience of sea lanes, strengthening the network layout of inland ports, promoting policy communication, and realizing information interconnection between inland ports. These should be the target of future promotion. Moreover, the reason for the misunderstanding of the ‘Belt and Road’ achievement should be analyzed. If there is only the reality of port construction, but no substantive results, such as increasing the speed of customs clearance, strengthening the port information exchange degree, and the increase in international trade on the Maritime Silk Road.

2） The potential of multimodal transport in China

Compared with developed countries, China's multimodal transport development is still in its infancy. At present, China's multimodal transport volume accounts for only 2.9% of the total freight volume, while the United States is about 10%. The cost of goods transshipment accounts for about 30% of the entire logistics cost. The current situation of multimodal transport in China is that the efficiency of transportation organization is low, while the operating costs of enterprises are relatively high. The lag in the development of multimodal transport has become a shortcoming in the construction of the ports’ transportation system. In 2018, China's sea-rail combined transportation volume was only 2.366 million TEU. The proportion of China’s sea-rail combined transportation volume to the total container throughput is still too low, which was only 1.13% in 2018, and the proportion of developed country like European and American was about 10% to 20%. The comprehensive advantages of multimodal transport have not been fully utilized. Therefore, how China's port network, especially inland ports, can fully realize the potential of multimodal transport will be a major issue in the future.

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