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Optimization of the dedicated corridor system connecting Bohai Rim gateways

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Optimization of the Dedicated Corridor System Connecting Bohai Rim Gateways

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DECLARATIOM

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

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

(Signature): .....

(Date): .....

Supervised by

Prof. Zheng Shiyuan

Shanghai Maritime University

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ABSTRACT

Title of Research paper: **Optimization of the Dedicated Corridor System Connecting Bohai Rim Gateways**

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In recent years, with the development of the Chinese economy, our country has entered a new developing stage, how to effectively plan a region by local government departments becomes a new trend. The Bohai Rim region is one of the most important developing regions in China. If a dedicated corridor system connecting the hinterlands and seaports can be built in the Bohai Rim region, the development of the Bohai Rim region will be better. Therefore, according to the four basic components of a corridor, which are nodes, link, flow and hub, this dissertation aims to discuss the multimodal transports related to the Bohai Rim region and give some suggestions for the development of Bohai Rim region. And in the dissertation, the methods we use are mainly the shortest path model and some forecast models. Forecast models are used to forecast the possible amount of freight traffic in the future, and the shortest path model is used to select the best routes as a corridor system for Bohai Rim gateways. The assessment framework includes general transport modes and their performance for different corridor systems due to their different advantages. In conclusion, the optimal routes will be selected, which is possibly useful for the development of the Bohai Rim region. The more cost-effective transport plan of the multimodal transport network is helpful to strengthen the connection between hinterlands and seaports.

KEYWORDS: Multimodal transport network, Bohai Rim gateway, Shortest path model, Corridor development

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1 Introduction

1.1 Background

Before specifically discussing the optimization of the dedicated corridor system connecting Bohai Rim gateways, I want to expound some reasons why it is meaningful to optimize a dedicated corridor system for the Bohai Rim region.

Firstly, it is affected by global demands. With the acceleration of the process of economic globalization, the demand for freight transportation is all over the world, the activities of domestic and cross-border freight transportation are increasing, and it also affects the demand for freight transportation of our country-China. Therefore, in order to deal with the increasing demand for freight transportation, China has developed rapidly for many years and always focused on establishing international, fast and high efficient transport network systems in recent years. Maybe someone thought that the trend of trade was not good, but actually, some recent data shows that although the growth of demand is slow, it is still increasing and keep a huge amount. China is the second one of the top 5 partners in exports, and Chinese merchandise trade and transport services both have an increase. (Figure 1)

Figure 1 International Merchandise Trade

Source: UNCTADstat, from the web: http://unctadestat.unctad.org

Secondly, it is affected by national policy. Based on the launching of Cooperation Initiatives 'One Belt, One Road'(OBOR), which aims to reduce impediment to trade among the Eurasian landmass under common rules and transport regulations, a series of large-scale transport infrastructures have been built in China and the mileage of railways, highways and inland waterways have been greatly improved for vigorously developing its six economic corridors, China-Mongolia- Russia, New Asia-Europe Continental Bridge, China-Central Asia-West Asia, China-Central South Peninsula, China-Pakistan, Bangladesh-China-India-Myanmar. Although OBOR focuses more on overland projects and few on maritime projects, it still has a major impact on the role of sea power in geopolitics and increases the speed and efficiency of land transport, which directly or indirectly provides convenience for the development of multimodal transport, so that the efficiency of cargo transportation can be further improved, and the cargo from inland area can be transported to seaports more easily, and then the economic development in inland areas can be developed.[1]

Thirdly, it is stuck in its own conditions. Nowadays, throughout the development of ports in China, three regions are famous. They are the Yangtze River Delta region, the Pearl River Delta region and the Bohai Rim region, all of them are the important gateways of China. The ports in these areas are undertaking China's import and export trade. However, at present, China's multimodal transport of freight activities accounts for a relatively low proportion of the total freight volume, which is far less than the developed countries in Europe and the United States. Compared to the

[1] The Maritime Dimension of "One Belt, One Road" in Strategic Pectivetive-Remarks to a Center for Naval Analysis Workshop with the Rajaratnam School of International Studies, Retrieved 16 June 2019 from the web: http://www.mepc.org/speeches/maritime-dimension-one-belt-one-road-strategic-perspective

Yangtze River Delta region and the Pearl River Delta region, the Bohai Rim region has more ports, and the competition between these ports is more fierce. At the same time, because of the geographical position, the radiation range of the Bohai Rim region covers half of China, and the Bohai Rim region is the main gateways of some parts of Northeast, North, Northwest and East regions in China. Therefore, current unbalanced developments and fierce competition among different provinces and cities connecting Bohai Rim gateways result in wasting resources such as the utilization of transportation and slowing down the growth of the economy.

Thus, based on these reasons, on the one hand, because of the impact of the outside environment, on the other hand, because of its inadequacy, for active development, it is somewhat meant to discuss a topic of optimization of the dedicated corridor system connecting Bohai Rim gateways.

1.2 Research questions

Then how to analyze the issue of optimization of the dedicated corridor system connecting Bohai Rim gateways is the following steps.

Firstly, we need to ensure the concepts of the corridor. Corridors are a fundamental structure-shaping economic development. The function of a corridor is to promote both internal and external trade by providing more efficient transport and logistics services. And for transport corridor, it can be understood as the multimodal transport network. The more effective multimodal transport network is applied to the Bohai Rim region, the stronger connection with the development of inland areas such as Northwest, Midwest and Northeast regions, and even the countries bordering on

these areas will be.

Secondly, three ports will be chosen as empirical studies for us to directly have practical research and get a better and useful solution. And the ports I choose are Dalian port, Tianjin port, and Yantai port because these three ports are comprehensive or regional hub port and they are serviced for calling of the liner. The multimodal transport network is more useful for containers.

Thirdly, the data will be collected and analyzed by some model methods. The main methods I use are forecast models and the shortest path model. Forecast models are used to forecast the possible amount of freight traffic in the future, and the shortest path model is used to select the best routes as a corridor system for Bohai Rim gateways.

Finally, we will get a conclusion about how to optimize the corridors connecting Bohai Rim gateways and give some suggestions.

1.3 Literature review

Firstly, about the Bohai Rim gateway. Researchers have done some analyses on the development of Bohai Rim gateway.

In Wang Xiqian (2017), we can know about the current development of the Bohai Rim region. China is focusing on the launching of Cooperation Initiatives ‘One Belt, One Road’. And with a superior geographical location and a wide range of natural resources, Bohai Rim gateways play an important role to connect with the inland

areas. Therefore, optimizing the dedicated corridor system connecting Bohai Rim gateways is a good way to develop the economy and respond to the Cooperation Initiatives ‘One Belt, One Road’.

In Zhang Yuqin(2011), we can find that in recent years, with the continuous expansion of China's opening to the outside world and the rapid growth of foreign trade, the demand for the import and export of foreign cargoes from the coastal port to the inland hinterland has also increased. Therefore, we need to consider the problem of path optimization. Its purpose is to make a reasonable distribution of flow between source and consumer.

In Huang Xiaomin(2008), in order to cope with the efficiency and environmental problems of a single and simple corridor system, many foreign countries had made changes. They increased the proportion of railway and waterway transportation and developed combined sea, rail and river transportation. It is the same with Bohai Rim gateways.

In Chen Yuanyue(2018), it shows that the port system in the Bohai Rim has experienced four stages: (a) balanced development of ports with high rank order, (b)breakthrough of small and medium ports, (c) differential development of large, medium and small ports, (d) port integration under the competition and cooperation of hub ports. The changing tracking of the rank-size distribution of the port container throughput has also experienced four stages: (a) external segmentation development, (b) formation of the hub port and the integration of emerging ports,(c) large scale of feeder port, (d) integration of the container network. So now it is time to develop the container network.

Secondly, it is about specific ports in the multimodal network around the Bohai Rim gateway. The introduction and analysis of the Tianjin port, Dalian port and Yantai port can be founded in Yan Mengjun(2017), Quan Bo et al.'s article(2014), Liu Tianshou (2014) and Zhang Dezhi(2018).

For Tianjin port, it is deemed to the Northern international shipping center, which mainly serves the import and export of goods in North China and Northwest China. Its target is to develop into the main port of bulk cargo and containers and to shape modern logistics in Northern China. Therefore, the paper suggests optimizing the corridor system from three levels-national, regional and urban. The main point is to enhance the connection between seaports and inland areas. And now the Tianjin port has opened many businesses for container transport. For example, it has opened container liner transport, which realizes the seamless connection between port and hinterland and also extends the whole logistics industry chain of the Tianjin port. Tianjin port is committed to the construction of container hub center for sea-rail intermodal transport, which will provide basic support for further promoting the development of intermodal container transport in Tianjin Port.

For Dalian port, it has many natural advantages such as its good depth of the harbor and it is ice-free all year round. What's more, it has a complete transportation system as well. Therefore, it is convenient to transport ore, crude oil and liquid chemical products. Also by relying on more than 100 trade routes at domestic and abroad, more than 30 domestic airports and stations in Northeast China and well-developed railway hubs in port-vicinity areas, Dalian port will further speed up the construction of the multimodal transport system. In addition, Dalian Port will be built as a customs supervision center for the multimodal transport in Northeast China. It can integrate container cargo transshipment, transit, warehousing and distribution, which

is conducive to the operation and cost reduction.

For Yantai port, as the main hub of waterway transportation in China and one of the important ports along the coast, it plays an important role in the national transportation network. Its natural and geographical conditions are superior, and it is an essential node of the coastal north-south channel from Tongjiang to Sanya, which has a long history. The hinterland of Yantai Port is vast and its coastline is 702.5 kilometers, and its economic hinterland includes Shandong province and Shanxi province. Major minerals such as gold, copper and graphite are transported from Yantai port into hinterlands. What's more, Yantai has also developed agriculture, mainly including wheat and maize.

Thirdly, it is about the optimization of the multimodal transport network.

In Xu Xiaoyan(2018), Martine Mostert(2017), it shows the difference between multimodal transport and intermodal transport. Usually, container transportation is the typical form of transportation in intermodal transport, in which goods are required to be only one in the whole transportation process. In other words, any operation of the goods in transit is carried out in the form of the container transportation unit. For example, in container transportation, the loading and unloading are carried out directly. Many facilities and equipment are designed and utilized according to standard container standards. Therefore, intermodal transport emphasizes the requirements of loading and unloading of cargo, which is a form of transport restriction. Usually, it is easy to operate and has unified standards. However, multimodal transport, which has a broader form of transport, does not have any restrictions on cargo transport. In other words, it can be directly transported, or it can be transported after being assembled by ordinary boxes or containers. Therefore, it is

a more flexible form. In conclusion, from these differences between multimodal transport and intermodal transport, intermodal transport is a special case of multimodal transport.

And for multimodal transport, the algorithms of optimizing multimodal transport are showed in Yan Mengjun(2017). Through comparing transport distance, cost, time and quality among different routes, it can get the best route of Tianjin port, Dalian port and Yingkou port. And the method is TOPSIS decision-making model. Specifically, considering the influence factors of transportation distance, cost, time and quality, this paper analyses the multimodal transport routes from three ports to Northeast China, and finally chooses the optimal multimodal transport scheme through comparative analysis, and puts forward countermeasures and suggestions to promote the development of multimodal transport according to the research results.

In the process of finding the data, we need to make a prediction of the volume of freight traffic. In Liu Yiqun, Zeng Ming(2018), it studied the real case about Dalian port. Dalian port is vital for the import and export of goods in the three Northeast provinces of China and nearby regions. In this paper, quadratic exponential smoothing modal, multiple linear regression analysis and grey prediction method, etc. are used to forecast the future freight traffic and compared it with actual data to analyze the validity of different methods.

Fourthly, it is about some existing problems in the development in the Bohai Rim region.

1. The proportion of three main modes of transport-road, railway and waterway is not good enough. It should be more efficient.

In Zhang Y.Q.(2011), although inland collection and distribution network has initially taken shape, it mainly relies on highway transport and lacks special railway lines. Moreover, most ports and trunk highways do not have a dedicated channel to connect, which makes it difficult to operate smoothly. Therefore, the collection and distribution network has not yet played its function, which restricts the future development of ports. Besides that, the better the proportion of transport modes are, the more green the corridors are. In Aditjandra P.T., Zunder T.H., Islam D.M.Z., Palacin R. (2016), Green corridors, as a strategic freight transport policy, can only really be implemented alongside improvements to the long-distance transportation sector, where rail becomes the backbone network of land surface transportation.

2. The integration of the corridor system of Bohai Rim gateways still has some problems.

In Quan B., Li X., Li K.(2014), the existing railway corridors from the Tianjin port to the west has problems like "circuitous route" and "unobstructed route" and lack of high-capacity railway to the West.

In Zhang Y.Q.(2011), port logistics has problems such as small scale and narrow radiation range. In addition, various transport departments have artificially separated the links and unification of various modes of transport. Therefore, there are some actual difficulties of linking up with the rear transport network, which results in low-effectively launching inland multimodal transport and low-efficiently promoting the modern logistics network in the hinterland.

In Lv X.H., Wang Z.H, Chang Z.(2010), due to the shortage of container dedicated flat vehicles, the shortage of special container handling stations and the low level of

technical equipment, the large gap between technical management and the development requirements of modern logistics has become major obstacles to the rapid growth of container traffic. In addition, the information support the technology of the railway system is still very backward. The port, the shipping company and the inspection sections can not achieve data information sharing so that the information transfer on all links is lagging, and the container can not be effectively managed and tracked in real-time.

Finally, it is about possible contributions of the dissertation to the existing literature.

In accordance with the existing problems we have talked above, I would like to make the following amendments.

1. Enhance an economical, efficient and green corridor system

In Zhang Y.Q.(2011), it suggests that China's ports should pay more attention to the reasonable allocation of the proportion of highway, railway and waterway transport modes. For example, China can give full play to the advantages of waterway transport to actively support and develop waterway feeder routes of cargo in integrated port areas. China can also actively develop inland railway transit stations or container transit stations, and build a network mode of the railway as the mainline, at the same time, supplemented by short-distance highway transportation as branch line, to complete the main multimodal transport network of inland container transportation. In addition, in order to enhance the market competitiveness of railway transport, double-deck container railway transportation can be developed, which can not only alleviate the tension of railway transport but improve both transportation efficiency and economic benefits. In short, the continuous increase of the reasonable

proportion of inland and coastal transport can accelerate the development of multimodal transport in port areas.

2. Choose the optimal routes

Combining the concept of the corridor system and multi-mode transportation, to optimize the transportation route and mode. The different choices of these two points will directly lead to the difference in transportation costs and total time.

In Xu X.Y.(2018), Li S.W.(2015), Wang T., Wang G.(2005), Chen G.L.(2019), all of them show a similar method according to the different research conditions, and it is a multimodal transport network(Figure 2).

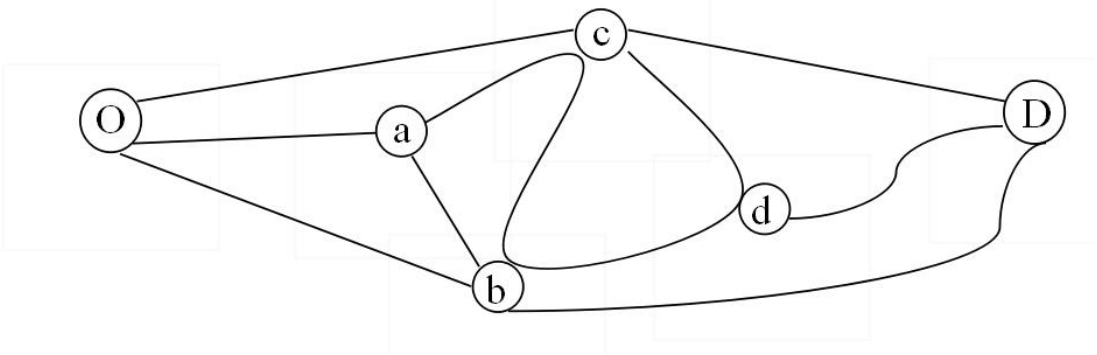

Figure 2 Schematic Figure of a multimodal transport network

Nodes（hub）----OD(origin and destination),a,b,c,d

Link----Highways, railways, waterways(transport modes)

Flow---the demand of cargo can be transported

And in Sirasak Tepjit and Thanyawan Chanpanit (2015), Teodor Gabriel Crainic,

Nicoletta Ricciardi, Giovanni Storchi(2009), Cathy Macharis & An Caris & Bart Jourquin &Ethem Pekin(2011), all of them show the methods how to deal with the shortest routes problem. Firstly, find sets, parameters, and decision variables (X_{ijk} - node i to node j by transportation mode k). Secondly, use objective functions and constraints. Finally, get the optimal solution.

1.4 Dissertation Structure

The structure of the dissertation is very simple. Firstly, the background of the research will be introduced to explain why it is meaningful to optimize the corridors system of the Bohai Rim region. Secondly, the brief introduction of the Bohai Rim region such as current development, advantages and some specific ports will be discussed and then find out the existing problems. Thirdly, the methods on how to optimize the multimodal network of the Bohai Rim region will be introduced, the basic way is to analysis the basic components of corridors, which are flow, nodes and links. Finally, empirical studies will be discussed as examples and get the final results.(See Figure 3)

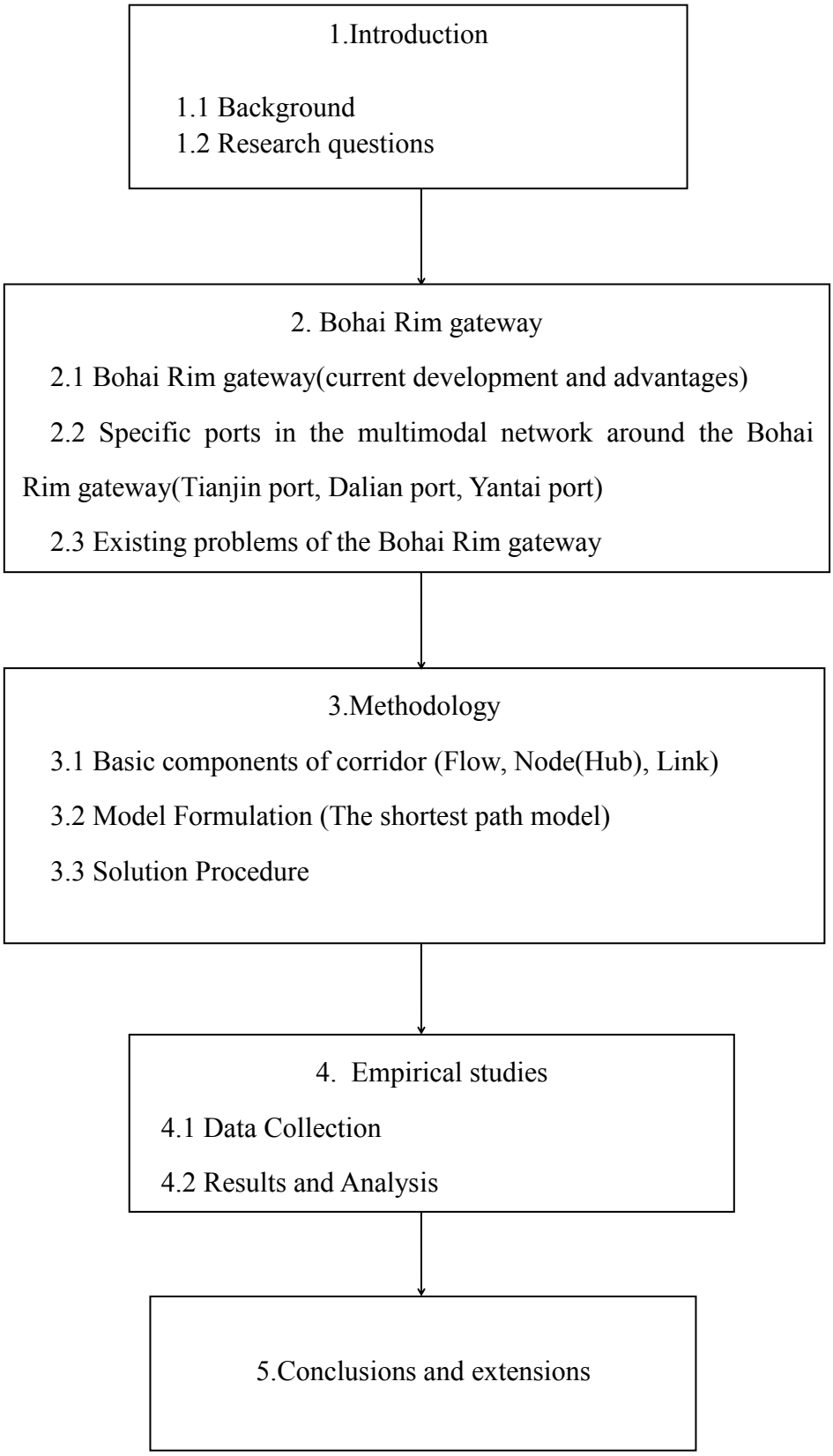

Figure 3 Dissertation Structure

2 The multimodal network around the Bohai Rim gateway

2.1 Bohai Rim gateway

2.1.1 The current development of Bohai Rim region

The Bohai Rim region, as one of three major regional port groups in China with the Yangtze river delta and Pearl river delta port group, is one of the three poles of economic growth along the coast of China. There are more than 5,000 kilometers of coastline around the Bohai Sea, including more than 60 ports in Dalian, Yantai, Tianjin, Yingkou, Qinhuangdao, Qingdao, Rizhao and other regions, and about 20 large and medium-sized cities. Thousands of large and medium-sized enterprises have been developed in these cities.

Therefore, the competence in the Bohai Rim region is rather fierce. Six-tenths of a billion tons of ports in China are concentrated here. The hub ports like Dalian port, Tianjin port are committed to becoming the shipping center. And the regional ports like Yingkou Port and Yantai port are pursuing the hub ports and committed to becoming the regional boss. The strong competence between these ports brings opportunity to the Bohai Rim region at the same time creates the obstacle in future development. Therefore, the way to integrate these port resources is very important. To optimize the dedicated corridor system connecting Bohai Rim gateways is a good way to connect the hinterland with the seaports and promote economic development.

2.1.2 The advantages of Bohai Rim gateway

Bohai Rim gateway occupies a lot of advantages, and its development relays on the following points.

First, it is about geography. The Bohai Bay area around Beijing and Tianjin form a "C" shaped development area. It has a superior geographical location and a wide range of natural resources. The total area accounts for about 12 % of China's land area and the total population accounts for about 20 % of China's population. It is based on the Shandong Peninsula, Liaodong Peninsula, and Beijing-Tianjin-Hebei. The coastal economic belt around the Bohai Sea has developed. It extends inland to the Black Dragon River, Jilin, Liaoning, Shanxi, Hebei, Shandong, and Inner Mongolia Central and Eastern League cities. The Bohai port group is not only of great significance to the development of cities and ports around China but also to the development of Northeast Asia and the Pacific. It is at the center of the East and North Asia Economic Zone and is one of the important bridgeheads at the eastern end of the Eurasian Continental Bridge in China. It plays an important role in international economic cooperation and development in the Asia-Pacific region and is a driving force for the development of Western China. It is of great significance to revitalize the old industrial base in Northeast China.[2]

Second, it is about economy. The economy of the Bohai Rim regions is rather strong and active. The Bohai Rim gateway covers more than half of China and is the main seaport in parts of Northeast China, North China, Northwest China and East China. The food, animal products, and oil of the three Northeastern provinces and the Inner Mongolia East Fourth League, coal and fur in the Northwest region, oil and textile

[2] Wang X.Q. Analysis of logistics development of Bohai port group under the "belt and road" strategy. China business theory, 2017 (18): 44-45.

products in North China, seafood from the Bohai Sea, and even goods from Qinghai and Xinjiang thousands of miles away are transported from here to the world.[3]

At the same time, it is a channel for trade with more than 160 countries and regions in the world. From here, equipment, funds, and commodities imported from abroad must also enter China's Northern market. These inland areas, involving more than a dozen provinces and autonomous regions, account for about 60 % of the country's land area and about 40 % of the country's gross national product. It is also rare in other coastal regions of China.[4]

Third, it is about polity. The development of the Cooperation Initiatives ‘One Belt One Road’ promotes the development of the Bohai Rim region. China will vigorously develop its six economic corridors, China-Mongolia- Russia, New Asia-Europe Continental Bridge, China-Central Asia-West Asia, China-Central South Peninsula, China-Pakistan, Bangladesh-China-India-Myanmar. And Corridors are a fundamental structure-shaping economic development.[5] The function of a corridor is to promote both internal and external trade by providing more efficient transports and logistics services. For the Bohai Rim gateways, many ports like Dalian port, Tianjin port and Yantai port are building a network of sea lanes to enhance connectivity with global ports at the same time building a network of land bridge transport for the opening of economic corridors on land.

[3] The baike baidu gives further information on courses (https://baike.baidu.com/item/%E7%8E%AF%E6%B8%A4%E6%B5%B7%E5%9C%B0%E5%8C%BA/1779752?fr=aladdin)
[4] The baike baidu gives further information on courses (https://baike.baidu.com/item/%E7%8E%AF%E6%B8%A4%E6%B5%B7%E5%9C%B0%E5%8C%BA/1779752?fr=aladdin)
[5] Wang X.Q. Analysis of logistics development of Bohai port group under the "belt and road" strategy. China business theory, 2017 (18): 44-45.

2.2 Specific ports in the multimodal network around the Bohai Rim gateway

Based on the above introduction, we have known that Bohai Rim region is surrounded by the "C" shape of the Liaodong Peninsula, Shandong Peninsula and North China Plain. It covers most of China and is the main sea outlet in Northeast, North, Northwest and East China. Food, livestock products, petroleum, coal and fur in Northwest China, petroleum and textile products in North China, seafood in the Bohai Sea, and even goods from Qinghai and Xinjiang thousands of miles away are transported to all parts of the world. It has more than 5,000 kilometers of coastline around the Bohai Sea, including more than sixty large and small ports in Dalian, Yantai, Tianjin, Yingkou, Qinhuangdao, Qingdao, Rizhao and other regions.

And in the dissertation, the main ports I want to discuss are Dalian port, Tianjin port, and Yantai port because these three ports are comprehensive or regional hub port and they are located in the upper, middle and lower parts of Bohai Rim gateways respectively, forming a stable triangular structure.（See Figure 4）And all three ports are serviced for the calling of the liner.

It is obvious from Figure 4 that Dalian port, Tianjin port, and Yantai port are separately pointing to the three areas - Liaodong Peninsula, Shandong Peninsula and North China Plain (See Figure 5). Therefore, when discussing the dedicated corridor system connecting Bohai Rim gateways, I think it is more helpful to choose each port in three areas to avoid the duplicate analysis and improve the effectiveness of analysis and to make the analysis more convenient and easier to understand.

Figure 4 The locations of Dalian port ,Tianjin port, and Yantai port

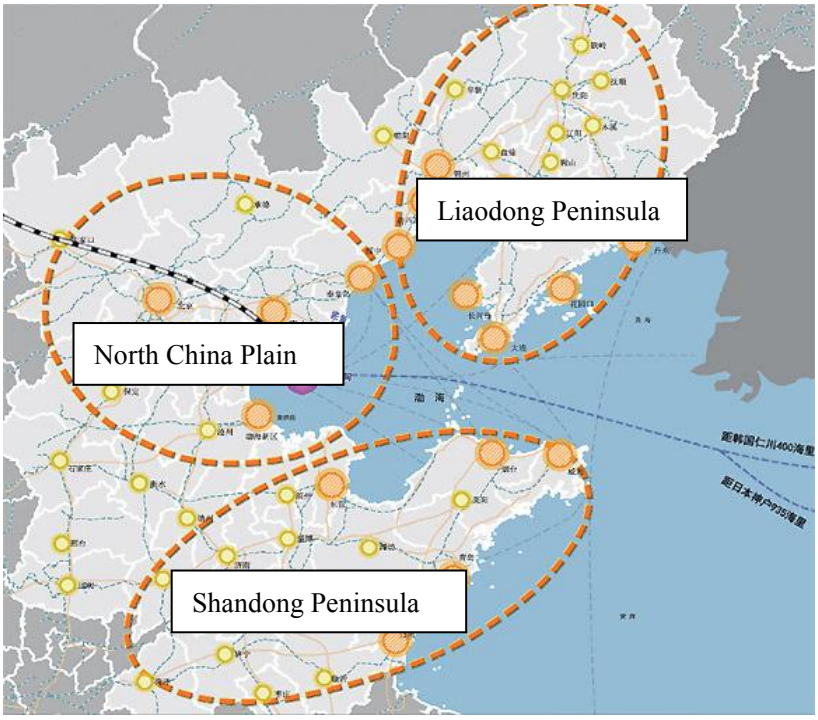

Figure 5 The three areas surrounding the Bohai Rim region

Before the empirical studies, I want to simply introduce the basic circumstances of Dalian port, Tianjin port, and Yantai port.

2.2.1 Tianjin port

For Tianjin port, it is positioned in Northern China, and is deemed to the northern international shipping center, which mainly serves the import and export of goods in North China and Northwest China. Its target is to develop into the main port of both bulk cargo and container, which is equipped with the modern logistics at the same time.[6] Tianjin port has very convenient and modern transport, therefore, the connection between Tianjin port and its hinterland is rather strong. Tianjin port has enough railway and highway transport, which helps to realize the seamless connection between port and hinterland. And Tianjin port has improved the whole logistics industry chain.[7] Therefore, it can provide comprehensive services such as transportation organization, loading and unloading, storage, transshipment, distribution and other functions.

2.2.2 Dalian port

For Dalian port, it is also an important port in Northern China. Due to its location, it has some natural advantages as a port, such as its good depth of the harbor and its ice-free condition all year round. At the same time, it also has a complete transportation system.[8] By relying on more than 100 trade routes at domestic and

[6] Liu T.S., Li H.N., Zhu M.F. Functional positioning analysis of major ports around the Bohai Sea in China. Productivity study, 2014 (06): 112-116+129.
[7] Quan B., Li X., Li K. Construction of Multi-level Collection and Distribution System of Tianjin Port, North International Shipping Center. Urban Transportation, 2014, 12 (04): 55-64.
[8] Liu T.S., Li H.N., Zhu M.F. Functional positioning analysis of major ports around the Bohai Sea in China. Productivity study, 2014 (06): 112-116+129.

abroad and full stations in Northeast China, it can transport ore, crude oil, liquid chemical products all over the world. Nowadays, Dalian port is focusing on accelerating the construction of the multimodal transport network system, which can integrate cargo transshipment, transit, warehousing and distribution. In addition, Dalian Port will be built as a customs supervision center for multimodal transport in Northeast China.[9]

2.2.3 Yantai port

For Yantai port, as the main hub of waterway transportation in China and one of the important ports in Northeast China. Due to it is near to Korea and Japan, it has been playing an important role in the international transportation network. Its natural and geographical conditions are superior, and it is also an important node of the coastal north-south channel from Tongjiang to Sanya, which has a long history. The hinterland of Yantai Port is vast and its coastline is 702.5 kilometers, and it connects the economic hinterland includes Shandong and Shanxi provinces. Usually, it transports major minerals such as gold, copper and graphite from Yantai port to the hinterland for supporting the industry development. Besides that, Yantai has also developed agriculture, including wheat and maize. [10]

2.3 Existing problems of the Bohai Rim gateway

Although the development of Bohai Rim gateway has improved a lot, it still has

[9] Yan M.J. Study on Container Multimodal Transport Scheme from Northern Ports to Northeast China. Dalian Maritime University, 2017.
[10] Zhang D.Z. Qualitative and Quantitative Analysis of Yantai Port Development Research. Market Weekly, 2018 (11): 40-42.

some problems.

Firstly, the proportion of three main modes of transport-highway, railway and waterway is not good enough. Although inland collection and distribution network has initially taken shape, it mainly relies on highways, lacks special railway lines, and does not take supporting measures. In addition, most ports do not have direct railways to the port areas, usually, the trucks are used to complete the transportation from the railway container center station to the port area, which increases the number of loading and unloading of containers, resulting in increased costs. Moreover, most ports and trunk highways do not have a dedicated channel to connect, which makes it difficult to operate smoothly. The collection and distribution network has not yet played its role to restrict the future development of ports. Therefore, although mature water transportation services are basically distributed in coastal cities, the services in inland cities are not yet sound enough, which increases the difficulty of successfully completing the "door to door" service for rail transport.[11]

Secondly, the imperfection of rail and sea combined transport mechanism. In many foreign ports where the multimodal transport network has been well developed, combined maritime and rail transport has the ability to achieve a "seamless connection", which means, goods can be loaded directly by cargo ships to trains. However, in China, due to a sector-divided traffic management system, it is difficult to have a perfect combined maritime and rail transport system. The connection between maritime and rail transport is not smooth and faces many problems. For example, the existing railway corridors from the Tianjin Port to the west has problems like "circuitous route" and "unobstructed route" and lack of high-capacity

[11] Zhang Y.Q. Development status and optimization analysis of port collection and distribution system in China.Logistics Engineering and Management, 2011,33(06): 9-10+19.

railways passage to the West. [12]In addition, container transport also involves customs, inspection and quarantine and other regulatory agencies and financial institutions. There are many differences in the management of these aspects, the unsound mechanism of the management leads to many links, large obstacles and high costs, which ultimately affects the normal development of the combined transport work. And Port logistics has a small scale, narrow radiation range, and various transport departments have artificially separated the links and unification of various modes of transport. Therefore, there are problems of linking up with the rear transport network, not effectively launching inland multimodal transport, and the modern logistics network has not been fully promoted in the hinterland, with low operational efficiency.[13]

Thirdly, the contradiction of high container vacancy and intense rail transportation capacity both exist. On the one hand, compared to foreign multimodal transport, our multimodal transport has many shortcomings. Our technical equipment is backward, though the railway has taken many measures in recent years to raise funds to accelerate development, the railway container station operation capacity is still low, non-specialized and low efficiency. In addition, the high container vacancy and low standardization level restrict the railway and other modes of transportation to carry out multimodal transport, especially international multimodal transport. However, on the other hand, railway transportation capacity is generally insufficient. Due to the limitation of the ship's time, it is important to ensure the speed and timeliness of transportation, so it is necessary to ensure the enough railway transportation capacity is available, but the reality is that there is an imbalance in the volume of container

[12] Quan B., Li X., Li K. Construction of Multi-level Collection and Distribution System of Tianjin Port, North International Shipping Center. Urban Transportation, 2014, 12 (04): 55-64.
[13] Lv X.H., Wang Z.H, Chang Z. China Container Sea-rail Transport Development Research[J] . China Port, 2010(03): 18-19.

transport in terms of time and geography, the transportation of the mainline and some areas is tight and the seasonal transportation capacity is uneven. In addition, because of the huge Chinese population, in the busy seasons and periods, the utilization rate of the major railway lines keeps high level, even as high as 100 %, and in order to ensure passenger transport, the railway department has to stop freight trains or allow trucks to bypass, which has greatly affected the convenience of railway container transportation, and directly affected the development of rail and rail transport. Thus, the shortage of technical equipment and the development requirements of modern logistics capacity have become important obstacles to the rapid growth of the multimodal transport network.[14]

Finally, the insufficient share of multimodal transport. At present, the information on cargo transportation can be basically exchanged with banks, customs, commodity inspections, traders and insurance companies, etc. However, for railway transport, the information support system is still very backward. The port, the shipping company, and the inspections can not realize the sharing of data and information with railway transportation. Therefore, the information transmission on each node is lagging, and the container can not be effectively managed and tracked in real-time, which leads to a reduction in the efficiency of multimodal transport.[15]

3 Methodology

[14] Lv X.H, Wang Z.H., Chang Z. China Container Sea-rail Transport Development Research[J] .. China Port, 2010(03): 18-19.
[15] Zhang Y.Q. Development status and optimization analysis of port collection and distribution system in China.Logistics Engineering and Management, 2011,33(06): 9-10+19.

Based on the above introduction, now we know that there are many shortcomings of the Bohai Rim gateway. For a long time, due to the limitation of railway lines and the obvious seasonal influence on rivers and other reasons, China's freight transport is mainly highway. However, due to various shortcomings of highway transportation, China's logistics costs are always high. With the increasing demand for delivery level, not only transport time should be reduced, response speed should be improved, but also cost savings should be achieved. Therefore, following the guidance of national policy and the actual situation of transportation, the multimodal transport network is a better choice to solve the current problems. The core of the multimodal transport network in this dissertation is to optimize the transportation route and mode. The different choices of these two points will directly lead to the difference in transportation costs and total time.

And we know that corridors are a fundamental structure-shaping economic development. The function of a corridor is to promote both internal and external trade by providing more efficient transport and logistics services. Therefore, if we apply the corridor system, we can get the essential elements that we need. Basically, there are four components of a transport corridor that consisted of nodes, a link, flow, and a hub. A node is a position of access to the transport network. A link is physical infrastructure that connected to nodes. There are at least two nodes and a link within a corridor. A link could contain one or more than one mode of transport and multi-mode connection as well. Flow means traffic circulate between nodes. A hub could be defined as a major node that covered several logistics activities such as distribution centers, warehouses, and business centers.[16]

[16] Tepjit S., Chanpanit T. (2015) Combining Simulation with Optimization to Evaluate Freight Logistics Performances for Developing a Corridor. In: Kachitvichyanukul V., Sethanan K., Golinska- Dawson P. (eds) Toward Sustainable Operations of Supply Chain and Logistics Systems. EcoProduction (Environmental Issues in Logistics and Manufacturing). Springer, Cham, pp310-311.

Specifically speaking, firstly, we need to find the origin and destination, and all other nodes can be replaced, and the alternative modes of transportation between nodes are different. (See Figure 6)

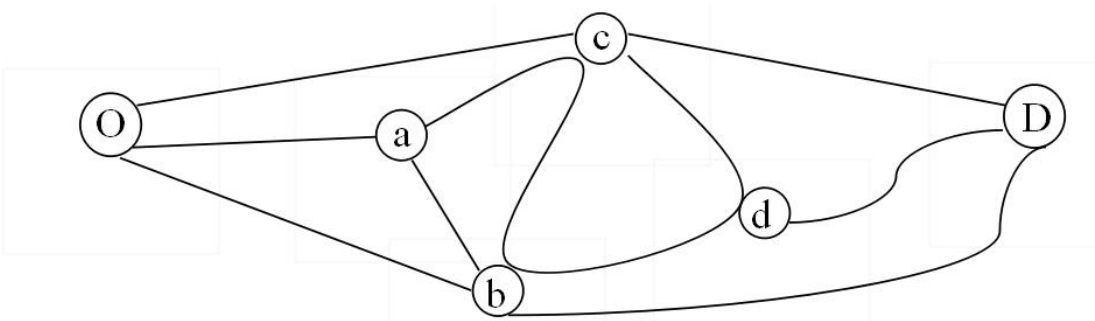

Figure 6 Schematic Figure of a multimodal transport network

Source: Xu X.Y. Multi-commodity flow multi-mode path combination optimization under uncertain conditions. Beijing Jiaotong University, 2018.

Nodes（hub）----OD(origin and destination), a, b, c, d

Link----Highways, railways, waterways (transport modes)

Flow---the demand of cargo can be transported

And then we can compare the transportation distance, cost and time under the different combinations of different transport modes. And then select the optimal solution. Usually, different transport modes have different advantages.

Finally, by using some decision-making techniques, we can get the optimal solution. And get a conclusion about the optimization of the dedicated corridor system connecting Bohai Rim gateways.

And in order to finish the analysis, we need to apply some decision making

techniques. The main methods are forecast models and the shortest path model. Forecast models are used to forecast the possible amount of freight traffic, and the shortest path model is used to select the best routes as a corridor for Bohai Rim gateways.

Firstly, the forecast models used are including moving average models and simple exponential smoothing models. and specifically,

Moving average models include First Order Moving Average and Second Order Moving Average, and its forecast model is,

First Order MA $$M_t^{(1)} = \frac{y_t + y_{t-1} + \ldots + y_{t-N+1}}{N} \quad (1)$$

Second Order MA $$M_t^{(2)} = \frac{M_t^{(1)} + M_{t-1}^{(1)} + \ldots + M_{t-N+1}^{(1)}}{N} \quad (2)$$

MA Forecast Model $$\hat{y}_{t+T} = a_t + b_t T \quad (3)$$

$$\begin{cases} a_t = 2M_t^{(1)} - M_t^{(2)} \\ b_t = \frac{2}{N-1}(M_t^{(1)} - M_t^{(2)}) \end{cases} \quad (4)$$

$y_t, y_{t-1}, \cdots$ represents the observations of $t, t-1, \ldots$ period respectively; N is the average number of items

Simple Exponential Smoothing models also include First Order Exponential Smoothing and Second Order Exponential Smoothing, and its forecast Model is,

First Order Exponential Smoothing $$S_t^{(1)} = \alpha y_t + (1-\alpha) S_{t-1}^{(1)} \quad (5)$$

Second Order Exponential Smoothing $$S_t^{(2)} = \alpha S_t^{(1)} + (1-\alpha) S_{t-1}^{(2)} \quad (6)$$

Exponential Smoothing Forecast Model $$\widehat{y}_{t+T} = a_t + b_t T \quad (7)$$

$$\begin{cases} a_t = 2S_t^{(1)} - S_t^{(2)} \\ b_t = \dfrac{\alpha}{1-\alpha}(S_t^{(1)} - S_t^{(2)}) \end{cases} \quad (8)$$

S_t, the primary exponential smooth value of phase t

S_{t-1}, the quadratic exponential smooth value of phase t-1

α, smooth coefficient

b， selected trend smoothing coefficient

$\hat{y}_t$, smoothing prediction of simple exponents in phase t

$\hat{y}_{t+T}$, smoothing prediction of simple prior period exponents for phase T.

The shortest path model is to solve the shortest path problem, which is a classical algorithm problem in graph theory research. It aims to find the shortest path between the two nodes in the graph (composed of nodes and paths). So it is a model is suitable to be applied to analyze the transport corridor because nodes, links are also the components of the transport corridor.[17]

So in the dissertation, the shortest path model is applied to optimize the dedicated corridor system connecting Bohai Rim gateways, in other words, to make the multimodal transport network of the Bohai Rim region the most effective from the perspective of the balance of cost and time.

3.1 Multimodal network around the Bohai Rim gateway

[17] Li S.W. Transport Route Recommendation and Express Network Structure Optimization under Multimodal Transport Network [D]. Beijing University of Posts and Telecommunications, 2018, PP28

As described above, in order to analyze how to optimize the multimodal transport network, we need the information of four components of a transport corridor. The origin and destination are visible. It is the gateways of the Bohai Rim region, in other words, it is the ports where to manage imports and exports. And in the paper, the ports I choose are Dalian Port, Tianjin port and Yantai port, which are separately pointing to the three areas - Liaodong Peninsula, Shandong Peninsula and North China Plain. Therefore, the following analysis of nodes, flow and links are related to Dalian Port, Tianjin port and Yantai port.

3.1.1 Nodes

In order to improve the transportation system of the multimodal transport network, China has done a lot. The ministry transport of China has carried out demonstration projects of multimodal transport network and the layout of the related nodes, which are largely helpful to accelerate the development of Cooperation Initiative “One Belt, One Road” and the strategy of “coordinated development of Beijing, Tianjin and Hebei provinces” and “Yangtze River Economic Belt”etc.

And now the ministry transport of China has published three batches of the list of demonstration projects of multimodal transport network early or late. And according to the list of demonstration projects, the projects that are beneficial for the Bohai Rim region are including the provinces where the Tianjin port, Dalian port and Yantai port are located, which are Tianjin province, Liaoning province and Shandong province. Especially, Tianjin port and Dalian port are the key development objects because they have their own development projects for ports. Besides that, the provinces

around them and even the provinces where they can radiate and connect are also on the list. And the nodes that are possibly connected to Bohai Rim gateways are Taiyuan, Beijing, Tianjin, Qingdao, Lanzhou, Zhengzhou, Shizuishan, Yinchuan, Xi'an，Shijiazhuang, etc.(See Table 1)

Table 1 Some key city nodes and the provinces where they are located

Nodes	**Provinces**
Taiyuan	Shanxi Province
Lanzhou	Gansu Province
Zhengzhou	Henan Province
Shizuishan/ Yinchuan	Ningxia Province
Xi'an	Shannxi Province
Qingdao	Shandong Province
Shijiazhuang	Hebei Province

Source: The list of demonstration projects of the multimodal transport network

At the same time, *The National Intergovernmental Land and Port Agreement* is also signed for enhancing the connectivity and seamless connection of international transport, promote the efficiency of transport and logistics and reduce their costs, while expanding the coverage of transport and logistics to the vast hinterland and remote hinterland because of the necessary to promote the development of an internationally integrated multimodal transport and logistics system in Asia and its surrounding regions with the increasing of the volume of international trade. For China, there are 24 key node cities that have been divided to be developed nationwide. And the nodes that are possibly connected to Bohai Rim gateways are Changchun, Erlianhot, Harbin, Horgos, Wulumuqi, Hunchun, Kashgar, Manzhouli, Suifenhe, etc.(See Table 2)

Table 2 The key city nodes and the provinces where they are located

Nodes	**Provinces**
Changchun/ Hunchun	Jilin Province
Erlianhot/ Manzhouli	Inner Mongolia Province
Harbin/ Suifenhe	Heilongjiang Province
Horgos/ Kashgar	Xinjiang Province

Source: *The National Intergovernmental Land and Port Agreement*

And if we put the nodes on the map, it will be shown in the following Figure 7. And to connect them with each other one by one, we will find the transport routes easily. And we can see in Figure 7 that compared with the Liaodong Peninsula and its radiation areas, the Shandong Peninsula and North China Plain and their radiation areas are nearer and have a stronger connection. Of course, the nodes in Liaoning province, Jilin province and Heilongjiang province can be connected to other nodes and other two ports---Tianjin port and Yantai port, but based on the fixed nodes I choose, it is obvious that the distance is farther and detoured, so I didn't connect them together.

As a whole, I divide the multimodal network transportation of the Rohai Rim region into two parts. One is the Northeast area, and the other is the Midwest area. According to the different gateways and the actual needs, the choice of routes are different. Of course, the routes can be extended to the cities in the west such as Xinjiang province, Qinghai province. All of the cargoes of these cities can be transported to the Bohai Rim gateways through train or road. The reason why I didn't choose them is that relatively speaking, the way to transport in these areas is simpler

due to the limitation of economy and nature conditions, and I think that to discuss the areas nearby the Bohai Rim region are more meaningful and useful due to the rapid traffic construction and development of the economy.

Based on the ports I choose, the following routes and nodes are my choices. (See Table 3) The Northeast area is very simple, but the Midwest area is more difficult. And for Northeast area, it is connected to Dalian port, and the other is connected to both Tianjin port and Yantai port. And when analyzing the Midwest area, I choose the Lanzhou as my origin because it is the westernmost point. And I choose the cities such as Hohhot, Xi'an, Yinchuan, Shijiazhuang, Zhengzhou, Taiyuan, Beijing and Ji'nan as my middle nodes. The reason is based on enhancing the connection between hinterland and seaports. These middle modes are logistics centers to connect the west of China and the east of China. Of course, the other choices are also feasible, here are just some examples. The aim is to explain how to plan the multimodal transport network, in other words, to create and optimize a dedicated corridor system.

Figure 7 The possible transport routes that I choose

Table 3 The transport nodes and their connection

Areas	Northeast area	Midwest area
Routes	Harbin—Changchun/Shenyang---Dalian port	Lanzhou-Hohhot/Xi'an/Yinchuan/Shijiazhuang/Zhengzhou/Taiyuan/Beijing/Ji'nan---Tianjin port/Yantai port

3.1.2 Transport modes

As we all know, there are usually three kinds of transport modes, which are highways, railways and waterways. Of course, there are also maritime transport, air transport and pipeline transport. But for general multimodal transport, highways, railways and waterways are the normal ways, and they have some advantages and disadvantages. (See Table 4) Generally speaking, the speed of highways and railways are faster than the speed of waterways, but the volume of waterways are more than the volume of highways and railways. At the same time, as being limited by the natural conditions, the waterways only can be developed in the regions with canals, relatively, highways and railways can be constructed in many places because based on the development of construction technology, even the remote places such as Xinjiang province where is full of harsh, chilly and unpredictable weather and the insurmountable mountain can access to have the highways and railways.

Besides that, the cost of these three transport modes is also a key point that needs to know because the cost is one of the most important key performance indicators. For the transport industry, the profit per cargo is very low, but because of the huge volume, the profit can be higher, therefore, as long as the cost is lower, the profit margin can be bigger so that the transport can be more economic. Generally speaking, the farther the distance is, the higher the cost is. For three transport modes, their

relationship between cost and distance are different. (See Figure 8) Usually, highways transport is more suitable for the shorter distance and waterways transport is more suitable for the farther distance. As for railway transport, it is also suitable for the far distance, especially when waterways transport cannot be accessed.

And for my study of multimodal transport, highway and railway transport are my considering key modes because the natural conditions of inland rivers in the Northwest and Midwest of China is not very good. On the one hand, the inland river in these regions is meeting a fragile ecological environment and at the same time, the degradation of the inland river is more and more serious because of the unreasonable and unbridled development and pollution. On the other hand, the inland river is stuck in itself. For example, the Yellow River, which is the most important inland river in the north of China, has its special difficulties and limitations. One is that the Sanmenxia Water Control Project is an important obstacle to the navigation dam in the Yellow River, and another major obstacle is Hukou Waterfall due to the cost and the protection of the natural landscape. Therefore, the Yellow River Midstream Coastal Area such as Inner Mongolia, Shanxi province and Shannxi province cannot enjoy the convenience of the waterways transport.[18]

Totally, considering the actual conditions, to choose highway transport and railway transport as our discussing objects is a better choice.

Table 4 Comparison of advantages and disadvantages of different modes of transport

modes	advantages	disadvantages
Highways	Fast, flexible, door to door	Limited volume, pollution,

[18] The baike baidu gives further information on course (https://baike.so.com/doc/320477-339361.html)

		high risk
Railways	Cheap price, big volume, low risk	The possibility of delay
Waterways	Cheap price,big volume,environmental,safety	Long time, weather influence

Source: Xu Xiaoyan. Multi-commodity flow multi-mode path combination optimization under uncertain conditions. Beijing Jiaotong University, 2018.

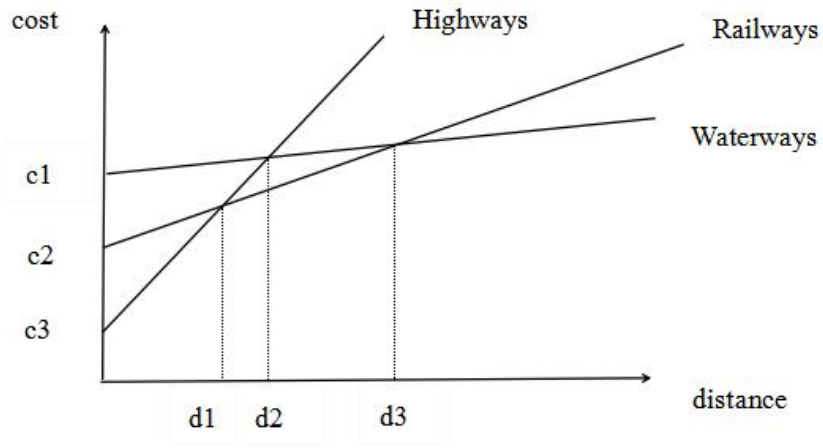

Figure 8 Relationship between cost and distance of each mode of transport

Source: Xu Xiaoyan. Multi-commodity flow multi-mode path combination optimization under uncertain conditions. Beijing Jiaotong University, 2018.

3.1.3 Flow

Flow means traffic circulate between nodes, for multimodal transport, which shows the demand for the container transport. To know about the volume of freight traffic is vital because it is useful for us to forecast the possible traffic demand in the future

and its trend, so to collect the past data is necessary. And I collect the data from the website 'National Data', according to the ports and nodes cities I choose, I collect their information about Freight Traffic (See Table 5, 6), Freight Traffic of Railways(See Table 7, 8) and Freight Traffic of Highways(See Table 9, 10).

Table 5 Freight Traffic(10000 tons) of Northeast Area

Freight Traffic(10000 tons)					
Northeast Area	2018	2017	2016	2015	2014
Jilin Province	52,156	49,903	45,060	43,333	48,311
Liaoning Province	223,346	216,135	207,064	202,021	222,138
Heilongjiang Province	55,190	56,398	53,569	54,478	60,213
Summation	330,692	322,436	305,693	299,832	330,662

Source: National Data, from the web: http://data.stats.gov.cn/

Table 6 Freight Traffic(10000 tons) of Midwest Area

Freight Traffic(10000 tons)					
Midwest Area	2018	2017	2016	2015	2014
Gansu Province	70,386	66,204	60,661	58,251	57,240
Inner Mongolia	232,525	213,318	186,726	175,112	191,869
Shaanxi Province	173,245	163,079	149,046	140,900	157,012
Ningxia	38,916	38,187	43,260	42,626	41,308
Hebei Province	249,265	228,854	210,586	198,024	209,946
Henan Province	259,884	230,114	206,087	192,859	200,801
Shanxi Province	211,497	189,516	167,076	161,765	164,918
Beijing	20,873	20,110	20,734	20,078	26,551
Tianjin	52,221	51,800	50,506	48,779	49,753

Shandong Province	354,019	327,006	285,386	261,849	264,459
Summation	1,662,831	1,528,188	1,380,068	1,300,243	1,363,857

Source: National Data, from the web: http://data.stats.gov.cn/

Table 7 Freight Traffic of Railways (10000 tons) of Northeast Area

Freight Traffic of Railways(10000 tons)					
Northeast Area	2018	2017	2016	2015	2014
Jilin Province	5,615	5,097	3,944	4,432	6,074
Liaoning Province	19,691	17,740	16,230	16,442	19,154
Heilongjiang Province	11,357	11,161	9,542	9,033	11,777
Summation	36663	33998	29716	29907	37005

Source: National Data, from the web: http://data.stats.gov.cn/

Table 8 Freight Traffic of Railways (10000 tons) of Midwest Area

Freight Traffic of Railways(10000 tons)					
Midwest Area	2018	2017	2016	2015	2014
Gansu Province	6,087	6,052	5,866	5,936	6,448
Inner Mongolia	72,506	65,835	56,113	55,612	65,165
Shaanxi Province	42,245	39,162	35,459	32,951	37,483
Ningxia	7,159	6,528	5,839	5,631	6,990
Hebie Province	19,580	17,100	16,313	17,843	20,619
Henan Province	10,461	10,087	10,287	9,969	11,770
Shanxi Province	85,260	74,616	64,861	70,509	76,411
Beijing	596	736	762	1,034	1,135
Tianjin	9,249	8,736	8,150	8,378	8,874
Shandong Province	23,247	22,295	20,574	19,191	20,268

Summation	276390	251147	224224	227054	255163

Source: National Data, from the web: http://data.stats.gov.cn/

Table 9 Freight Traffic of Highways (10000 tons) of Northeast Area

Freight Traffic of Highways(10000 tons)					
Northeast Area	2018	2017	2016	2015	2014
Jilin Province	46,520	44,728	40,777	38,708	41,830
Liaoning Province	189,737	184,273	177,371	172,140	189,174
Heilongjiang Province	42,943	44,127	42,897	44,200	47,173
Summation	279200	273128	261045	255048	278177

Source: National Data, from the web: http://data.stats.gov.cn/

Table 10 Freight Traffic of Highways (10000 tons) of Midwest Area

Freight Traffic of Highways(10000 tons)					
Midwest Area	2018	2017	2016	2015	2014
Gansu Province	64,271	60,117	54,761	52,281	50,781
Inner Mongolia	160,018	147,483	130,613	119,500	126,704
Shaanxi Province	130,823	123,721	113,363	107,731	119,343
Ningxia	31,757	31,659	37,421	36,995	34,318
Hebie Province	226,334	207,340	189,822	175,637	185,286
Henan Province	235,183	207,066	184,255	172,431	179,680
Shanxi Province	126,214	114,880	102,200	91,240	88,491
Beijing	20,278	19,374	19,972	19,044	25,416
Tianjin	34,711	34,720	32,841	30,551	31,130
Shandong Province	312,807	288,052	249,752	227,934	230,018
Summation	1342396	1234412	1115000	1033344	1071167

Source: National Data, from the web: http://data.stats.gov.cn/

Based on the above data, we can find an increasing trend both in the Northeast area and Midwest Area(See Figure 9,10). So in the future, it is possible to keep increasing. And we can see from Figure 9, 10, the freight traffic of the Midwest Area increases faster than the freight traffic of the Northeast Area, which can indirectly prove the fact that the Chinese government is committed to developing the Midwest Area in recent years. And the increasing of freight traffic of highways is faster than the increasing of freight traffic of railways, which is the result of the more difficult construction of railways. As a result, It can be believed that with the increasing demand for freight traffic, it is essential to improve our transport level, so the optimization of multimodal transport is a predictable operation for better development.

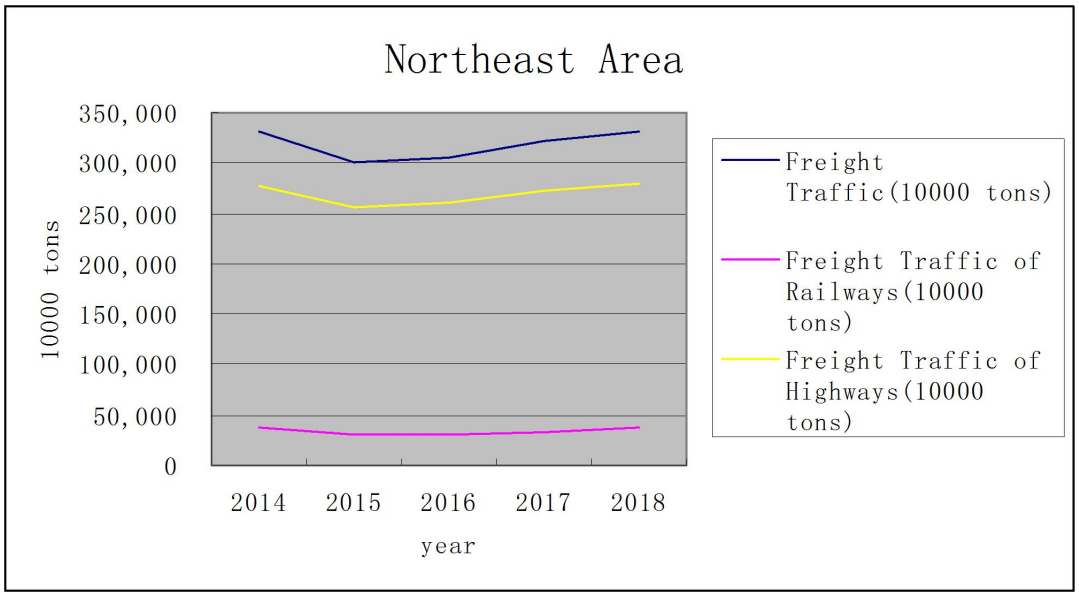

Figure 9 The trend of Northeast Area

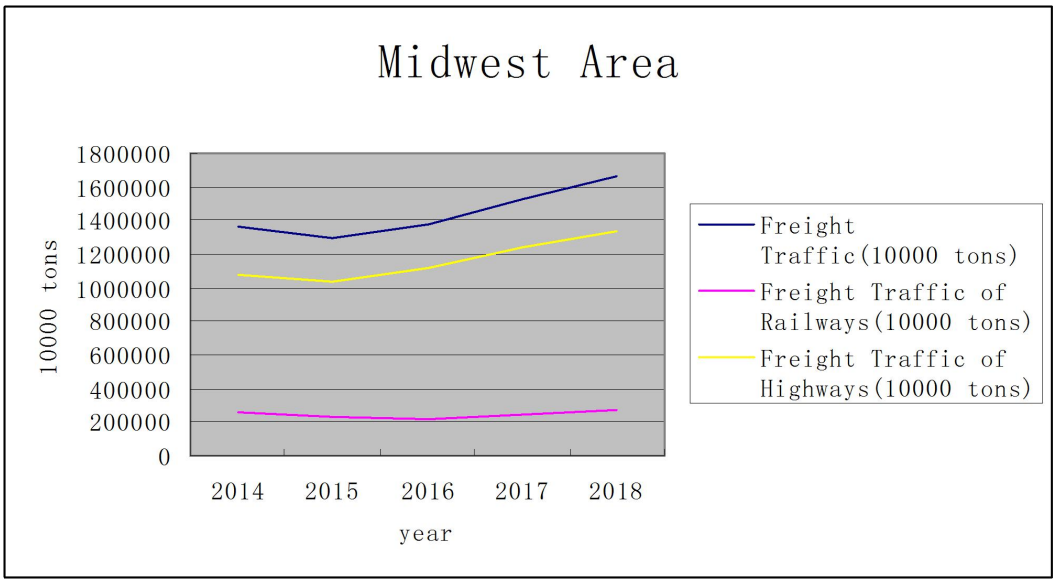

Figure 10 The trend of Midwest Area

So now thinking back the forecast models we have talked before, moving average models and simple exponential smoothing models will be used to do a prediction of freight demand. And the result is shown by the following Figures. Figure 11 and Figure 12 show the prediction of freight traffic in the Northeast Area based on moving average models and simple exponential smoothing models separately. The blue line represents the raw data, the yellow line represents the fitting line based on the First Order(First Order MA or First Order exponential smoothing) and the pink line represents the fitting line based on the Second Order(Second Order MA or Second Order exponential smoothing). From Figure 11 and Figure 12, for the prediction of the Northeast Area, it is clear that the yellow line is more fitting the blue line, namely, the First Order MA or First Order exponential smoothing is more suitable. At the same time, the same result can be got from Figure 13 and Figure 14, for the prediction of the Midwest Area, the First Order MA or First Order exponential smoothing is more suitable.

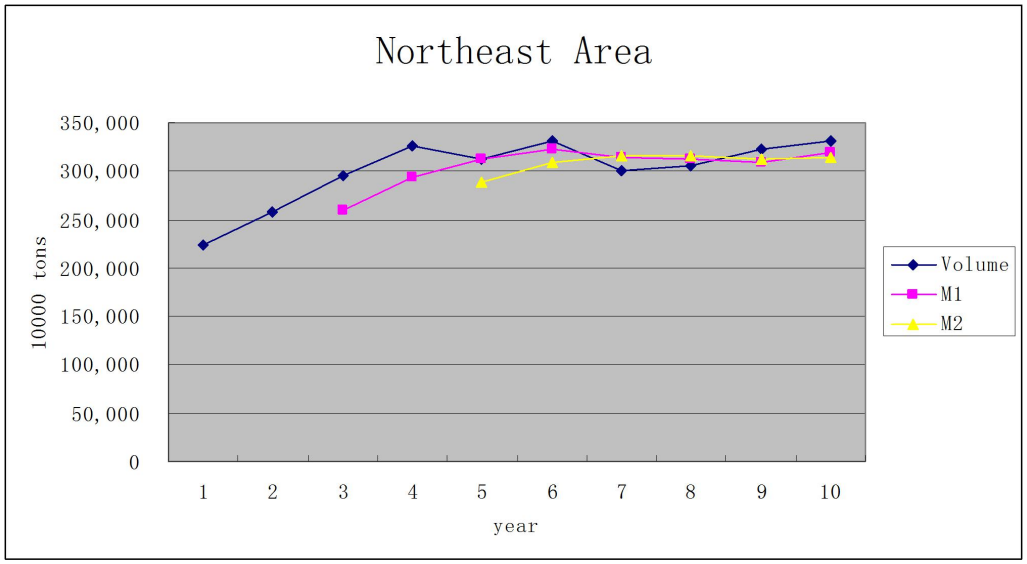

Figure 11 The prediction of freight traffic in Northeast Area based on moving average models

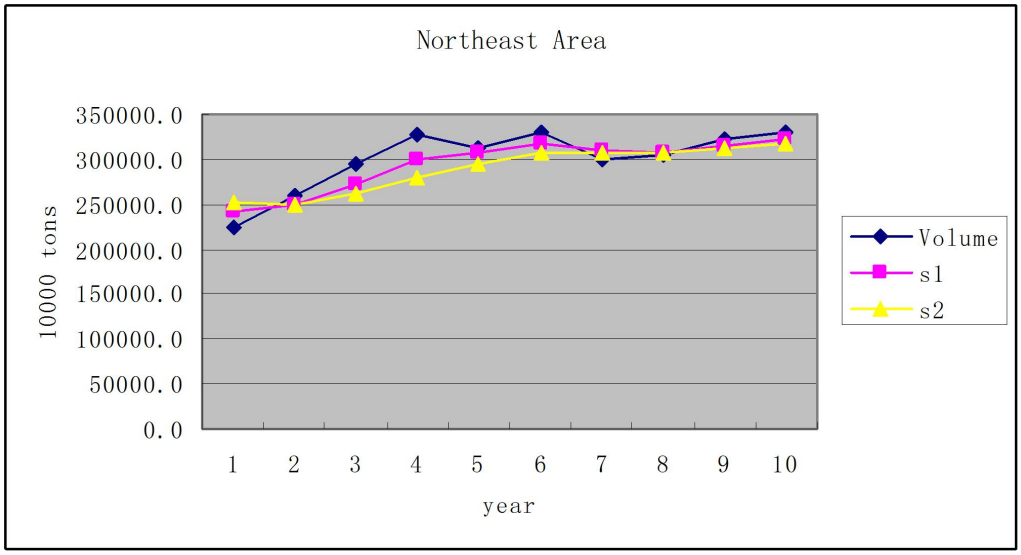

Figure 12 The prediction of freight traffic in Northeast Area based on simple exponential smoothing models

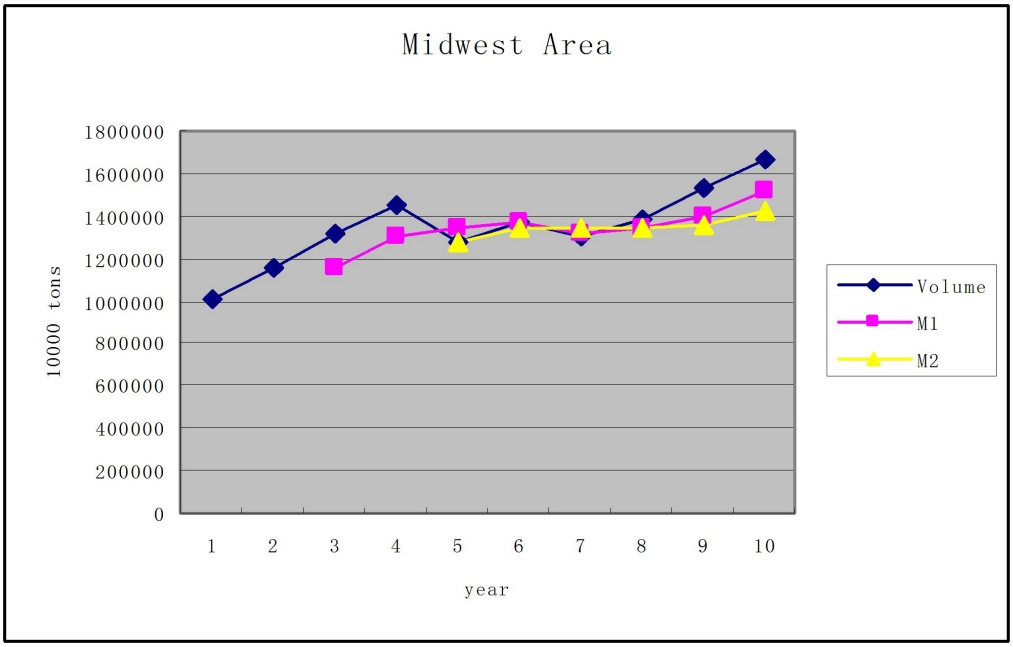

Figure 13 The prediction of freight traffic in Midwest Area based on moving average models

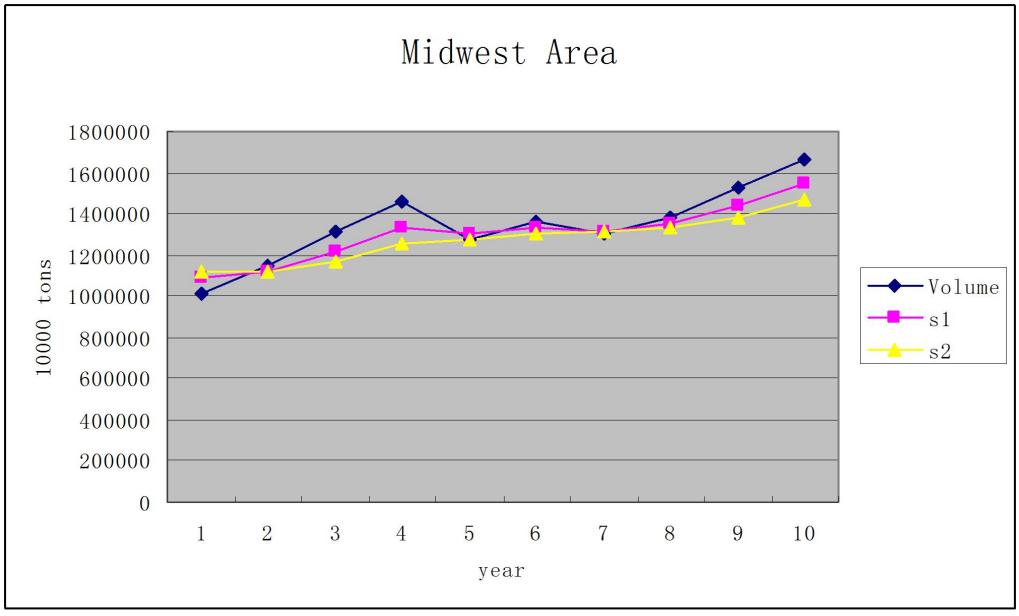

Figure 14 The prediction of freight traffic in Midwest Area based on simple exponential smoothing models

Besides the above Figures, I also have done some calculations to help to distinguish which kind of forecast models is better. Table 11 shows specific data. Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) are the measures of forecast error. The smaller the MAE and MAPE are, the better the model is. Therefore, from Table 11, it is clear that the First Order exponential smoothing is the best choice for the prediction of freight traffic of both the Northeast Area and Midwest Area because the data of MAE and MAPE are the smallest, and at this time, the Smoothing constant is 0.5. And the reason why the Smoothing constant is 0.5 is that the interval of Smoothing constant is 0-1 when Smoothing constant is 0, it is a straight line, and when Smoothing constant is 1, it is the original data. Generally, If the time series has a stable tendency, then it should be given a larger value(0.1-0.3). If the time series has a relatively obvious tendency to increase or decrease, then it should be given a larger value(0.3-0.6). If the time series has a rapid and obvious tendency to increase or decrease, then it should be given a larger value(0.6-0.8). [19]And in this study, the trend of freight traffic is a little increase, so the Smoothing constant is 0.5.

Then, we can get the forecast figures. (See Table 12) It shows an increasing trend, which indirectly stresses the importance to promote the transport construction and give us a possible data as a basis to make a plan for the development of these regions.

Table 11 Mean Absolute Error (MAE) and Mean Absolute Percentage Error

Areas	moving average models(First Order)	simple exponential smoothing

[19] Wang C.J. Selection of smoothing coefficients in exponential smoothing method [J]. Journal of Zhongbei University (Natural Science Edition), 2006 (06): 558-561.

			models(First Order)	
	MAE	MAPE	MAE	MAPE
Northeast Area	16433.537	0.052	7009.462	0.023
Midwest Area	71253.148	0.053	30269.301	0.022

Table 12 The Forecast Figures of freight traffic (10000 tons)

	2020	2021	2022	2023	2024	2025
Northeast Area	340202	345999	351795	357592	363389	369185
Midwest Area	1800223	1883429	1966636	2049842	2133049	2216255

3.2 Model Formulation

According to the previous analysis of multimodal transport, the paper collates the data between the relevant nodes on the transportation distance and transportation time. Because the indicators of the decision model are to get the minimum cost and the reasonable time, so as we know that cost is related to the transportation distance, the shorter the distance is, the less the cost is. And when keeping the low cost, the less time is better. And I will use the Shortest path model to find the shortest distance.

3.2.1 Sets, Parameters, and Decision Variables

i, j : Node

s : starting node

t: Terminal node

(i, j): The arc from i to j

X_{ij} : if the arc from i to j is used in the optimal route, X_{ij}=1. X_{ij}=0

b_{ij} : The transport cost from i to j

3.2.2 Objective Functions and Constraints

$$\min_{X_{ij}} \sum_{(i,j)} b_{ij} X_{ij} \tag{9}$$

$$s.t. \sum_{j} X_{ij} - \sum_{j} X_{ji} = \begin{cases} 1 & i = s \\ 0 & i \neq s,t \\ -1 & i = t \end{cases}$$

3.3 Solution Procedure

According to the Shortest path model, it is clear to know the data we need, which is the transport distance and nodes. The nodes have been chosen by the previous analysis. So the next step is to collect the data on transport distance. Based on the two transport modes we choose as the connection of hinterlands, one is highway transport, the other is railway transport, the application of the shortest path model becomes more complex because we need to distinguish which way is the best for the cost. Therefore, before the application of the shortest path model, the first thing is to know the key point to distinguish the best economical distance between railway transport and highway transport. General speaking, the economic mileage of railway transportation is generally more than 300 kilometers, while the economic mileage of

highway transportation is generally less than 300 kilometers,[20] without considering other factors such as the speed of highway transportation, 'door to door' service of highway transportation or the freight density and volume of railway transportation, etc. But for the simplification of analysis, we will put 300 kilometers as a key point of demarcation to choose the transport modes.

At the same time, single highway transport and single railway transport will also be calculated because the transport time of single highway transport is the shortest and the transport time of single railway transport is more. If the transport time of the path we get is between the transport time of single highway transport and the transport time of single railway transport, it could be considered reasonable.

And transport time is the time that the container goods are transported from the place of origin to the destination, such as the time of transport, the time of loading and unloading of the goods, the time of transit of the goods, and the time of transport are closely related to the distance of transport and the speed of transport. However, for the simplification of analysis, the transportation time is only the result of the distance of highway or railway transportation divided by the speed of highway or railway transportation. The average speed of domestic highway transportation is 90 km/h, and the average speed of domestic railway transportation is 80 km/h.[21]

4 Empirical studies

[20] The baike baidu gives further information on course (https://wenda.so.com/q/1556067859218536)
[21] Yan M.J. Study on Container Multimodal Transport Scheme from Northern Ports to Northeast China. Dalian Maritime University, 2017.

4.1 Data Collection

According to the above analysis, the empirical studies will be divided by two parts. One is the Northeast Area, the other is the Midwest Area. The Northeast Area is a simple example, and the Midwest Area is a more complex one. And the data that need to be collected is the distance of highway transport and the distance of railway transport among each node.

For Northeast Area, its transport routes are shown in Figure 15. The starting node is Harbin and the terminal node is Dalian port. Changchun and Shenyang are the middle nodes. And in this study, the transport routes are all single arrow, so it is easier to calculate and find the shortest routes.

And the distance of highway transport and the distance of railway transport among each node are shown in Table 13. According to 300 kilometers as a key point of demarcation, the more economical transport mode is chosen, which are the bold and underlined figures. The distance of highway transport which are a little more than 300 kilometers are still selected because the figures are close and the transport time of highway transport is less.

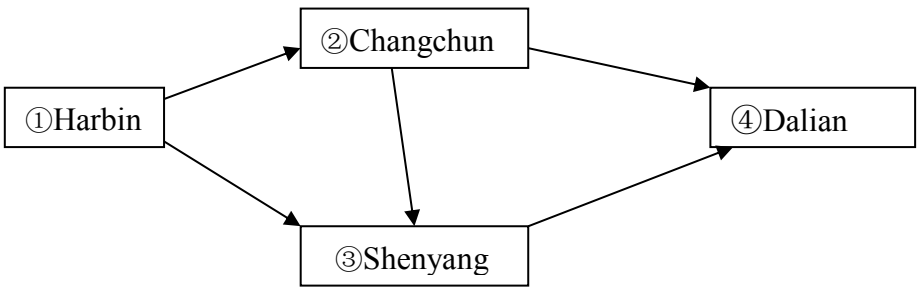

Figure 15 Transport route from Harbin to Dalian in Northeast China

Table 13 the distance of highway transport and the distance of railway transport among each node (km)

Dalian port	①-②	①-③	②-③	②-④	③-④
	Harbin -Changchun	Harbin -Shenyang	Changchun -Shenyang	Changchun -Dalian	Shenyang -Dalian
Highway transport	**273.1**	570	**307.6**	677.1	380
Railway transport	246	**549**	303	**693**	**516**

Source: Railway transport distance among each node, from the web: http://www.huochepiao.com; Highway transport distance among each node, from the web: http://www.changtu8.com

For Midwest Area, it is the same as the Northeast Area. The special thing is that the terminal node has two. One is the Tianjin port, and the other is the Yantai port. So we need to do the calculations twice for two different terminal nodes. The lucky thing is that the starting node and middle nodes can be the same. The starting node is Lanzhou and the middle nodes are Hohhot, Xi'an, Yinchuan, Shijiazhuang, Zhengzhou, Taiyuan, Beijing and Ji'nan, And in this study, some of the transport routes are the two-way arrow, so it is more complex to calculate and find the shortest routes. The transport routes from Lanzhou to Tianjin port is shown in Figure 16, and the transport routes from Lanzhou to Yantai port is shown in Figure 17.

And the distance of highway transport and the distance of railway transport among each node are showed in Table 14(from Lanzhou to Tianjin port) and Table 15 (from Lanzhou to Yantai port). The more economical transport mode is also chosen by putting 300 kilometers as a key point of demarcation, and these figures are bold and

underlined as well. The special figure(**1219.4km**) of the distance of highway transport from Hohhot to Yantai is chosen because there is no railway transport from Hohhot to Yantai.

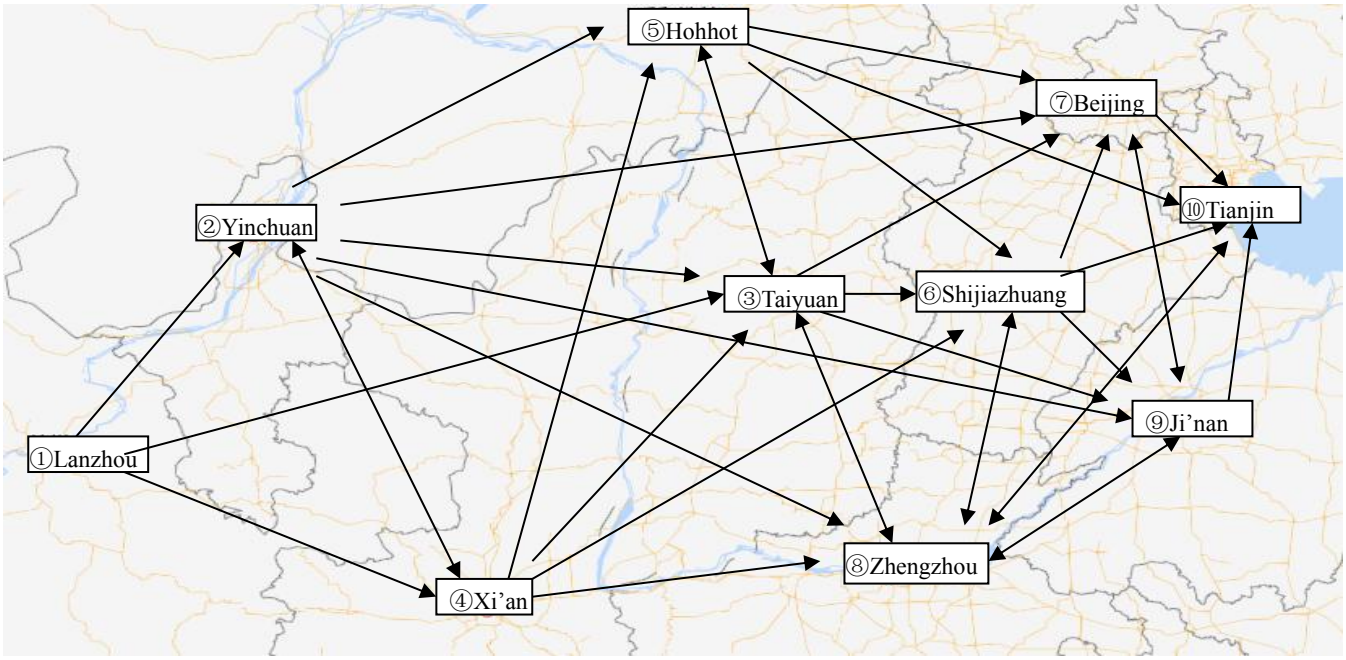

Figure 16 The transport routes from Lanzhou to Tianjin port in Midwest China

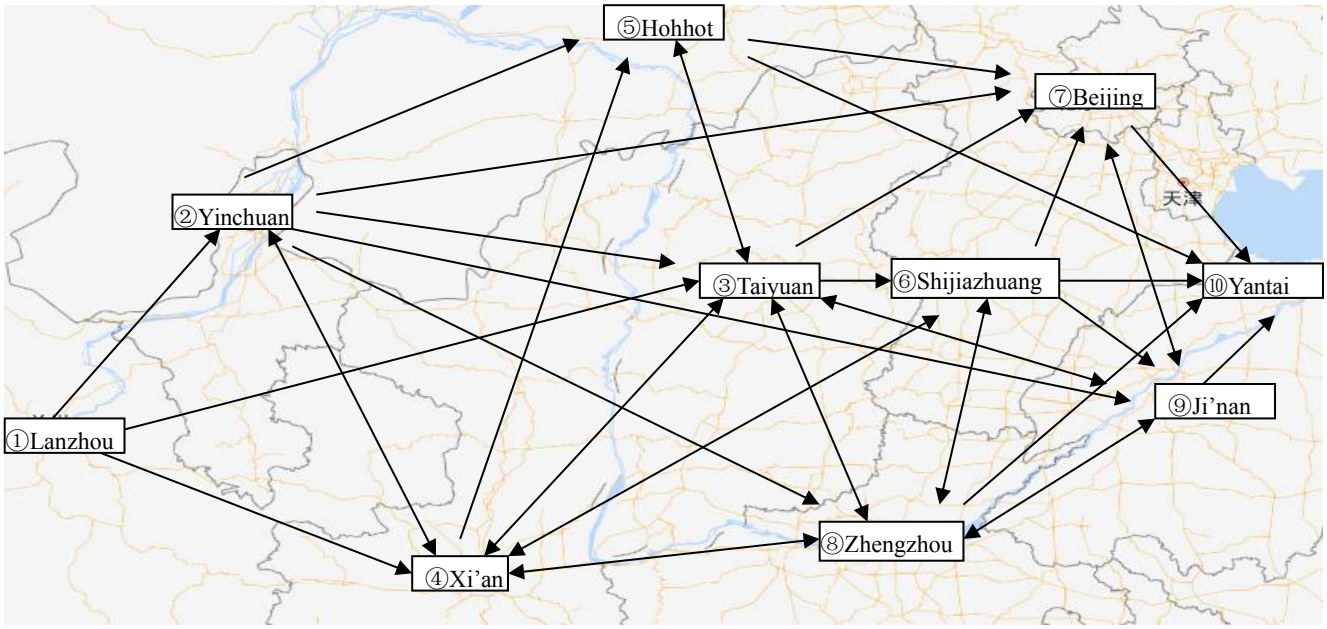

Figure 17 The transport routes from Lanzhou to Yantai port in Midwest China

Table 14 The distance of highway transport and the distance of railway transport among each node from Lanzhou to Tianjin (km)

Tianjin port					
	①-②	①-③	①-④	②-③	②-⑤
	Lanzhou -Yinchuan	Lanzhou -Taiyuan	Lanzhou -Xi'an	Yinchuan -Taiyuan	Yinchuan -Hohhot
Highways transport	447.2	1014.4	625.6	702.5	678.4
Railways transport	**478**	**1147**	**676**	**710**	**1208**
	②-⑦	②-⑧	②-⑨	②-④	③-④
	Yinchuan -Beijing	Yinchuan -Zhengzhou	Yinchuan -Ji'nan	Yinchuan -Xi'an	Taiyuan -Xi'an
Highways transport	1150	1032	1123	715.5	598.2
Railways transport	**1208**	**1294**	**1251**	**933**	**654**
	③-⑤	③-⑦	③-⑥	③-⑨	③-⑧
	Taiyuan -Hohhot	Taiyuan -Beijing	Taiyuan -Shijiazhuang	Taiyuan -Ji'nan	Taiyuan -Zhengzhou
Highways transport	437.8	498.9	**223.8**	520.3	435.1
Railways transport	**632**	**513**	255	**539**	**577**
	④-⑤	④-⑥	④-⑧	⑤-⑥	⑤-⑦

	Xi'an -Hohhot	Xi'an -Shijiazhuang	Xi'an -Zhengzhou	Hohhot -Shijiazhuang	Hohhot -Beijing
Highways transport	964.8	791.9	483.9	593.7	483.6
Railways transport	**1107**	**935**	**511**	**926**	**653**
	⑤-⑩	⑥-⑦	⑥-⑧	⑥-⑨	⑥-⑩
	Hohhot -Tianjin	Shijiazhuang -Beijing	Shijiazhuang -Zhengzhou	Shijiazhuang -Ji'nan	Shijiazhuang -Tianjin
Highways transport	615.8	**293.6**	417.8	**311.7**	**313.9**
Railways transport	**646**	241	**412**	307	443
	⑦–⑨	⑦–⑩	⑧–⑨	⑧–⑩	⑨–⑩
	Beijing -Ji'nan	Beijing -Tianjin	Zhengzhou -Ji'nan	Zhengzhou -Tianjin	Ji'nan -Tianjin
Highways transport	410.1	**137.2**	446.5	698.8	**329.7**
Railways transport	**406**	137	**719**	**851**	304

Source: Railway transport distance among each node, from the web: http://www.huochepiao.com; Highway transport distance among each node, from the web: http://www.changtu8.com

Table 15 The distance of highway transport and the distance of railway transport among each node from Lanzhou to Yantai (km)

Yantai port					
	①–②	①–③	①–④	②–③	②–⑤
	Lanzhou -Yinchuan	Lanzhou -Taiyuan	Lanzhou -Xi'an	Yinchuan -Taiyuan	Yinchuan -Hohhot
Highways transport	447.2	1014.4	625.6	702.5	678.4
Railways transport	**478**	**1147**	**676**	**710**	**1208**
	②–⑦	②–⑧	②–⑨	②–④	③–④
	Yinchuan -Beijing	Yinchuan -Zhengzhou	Yinchuan -Ji'nan	Yinchuan -Xi'an	Taiyuan -Xi'an
Highways transport	1150	1032	1123	715.5	598.2
Railways transport	**1208**	**1294**	**1251**	**933**	**654**
	③–⑤	③–⑦	③–⑥	③–⑨	③–⑧
	Taiyuan -Hohhot	Taiyuan -Beijing	Taiyuan -Shijiazhuang	Taiyuan -Ji'nan	Taiyuan -Zhengzhou
Highways transport	437.8	498.9	**223.8**	520.3	435.1
Railways transport	**632**	**513**	255	**539**	**577**
	④–⑤	④–⑥	④–⑧	⑤–⑥	⑤–⑦
	Xi'an -Hohhot	Xi'an -Shijiazhuang	Xi'an -Zhengzhou	Hohhot -Shijiazhuang	Hohhot -Beijing

Highways transport	964.8	791.9	483.9	593.7	483.6
Railways transport	**1107**	**935**	**511**	**926**	**653**
	⑤–⑩	⑥–⑦	⑥–⑧	⑥–⑨	⑥–⑩
	Hohhot -Yantai	Shijiazhuang -Beijing	Shijiazhuang -Zhengzhou	Shijiazhuang -Ji'nan	Shijiazhuang -Yantai
Highways transport	**1219.4**	**293.6**	417.8	**311.7**	736.8
Railways transport	/	241	**412**	307	**793**
	⑦–⑨	⑦–⑩	⑧–⑨	⑧–⑩	⑨–⑩
	Beijing -Ji'nan	Beijing -Yantai	Zhengzhou -Ji'nan	Zhengzhou -Yantai	Ji'nan -Yantai
Highways transport	410.1	741	446.5	910.9	453.2
Railways transport	**406**	**949**	**719**	**969**	**539**

Source: Railway transport distance among each node, from the web: http://www.huochepiao.com; Highway transport distance among each node, from the web: http://www.changtu8.com

4.2 Analysis and Results

Firstly, talking about the transport routes from Harbin to Dalian port. According to the above data, finally, I can get the distance among each node, just as shown in Table 16. And then by calculation, the result is shown in the Table 17, the shortest route is ①–②–④, and its total distance is 966.1 km, and its transport mode is firstly highway transport and then railway transport.

Table 16 The final distance among each node (km)

Routes	①–②	①–③	②–③	②–④	③–④
	Harbin-Changchun	Harbin-Shenyang	Changchun-Shenyang	Changchun-Dalian	Shenyang-Dalian
Distance	**273.1**	**549**	**307.6**	**693**	**516**
Transport mode	Highways	Railways	Highways	Railways	Railways

Source: Railway transport distance among each node, from the web: http://www.huochepiao.com; Highway transport distance among each node, from the web: http://www.changtu8.com

Table 17 The calculation and result (km)

Routes	Process	Total Distance
①–②–④	273.1+693	966.1
①–②–③–④	273.1+307.6+516	1273.7
①–③–④	549+516	1065

Secondly, talking about the transport routes from Lanzhou to Tianjin port and Yantai port. According to the above data, finally, I can get the distance among each node, just as shown in Table 18 and Table 20. Table 18 shows the distance from Lanzhou to

Tianjin among each node and their transport modes among each node, while Table 20 shows the distance from Lanzhou to Yantai among each node and their transport modes among each node.

And then by the calculation of the shortest path model, the result is showed in Table 19 and Table 21. Table 19 shows the calculation and results from Lanzhou to Tianjin, while Table 21 shows the calculation and results from Lanzhou to Yantai. And their the shortest routes are both ①–③–⑥–⑩, except the terminal nodes are different, the middle nodes are the same. And the shortest total distance from Lanzhou to Tianjin is 1684.7 km, and its transport mode is firstly railway transport and then highway transport and finally highway transport. And the shortest total distance from Lanzhou to Yantai is 2163.8 km, and its transport mode is firstly railway transport and then highway transport and finally railway transport.

Table 18 The final distance from Lanzhou to Tianjin among each node (km)

Tianjin port					
	①–②	①–③	①–④	②–③	②–⑤
	Lanzhou -Yinchuan	Lanzhou -Taiyuan	Lanzhou -Xi'an	Yinchuan -Taiyuan	Yinchuan -Hohhot
Distance	**478**	**1147**	**676**	**710**	**1208**
Transport mode	Railways	Railways	Railways	Railways	Railways
	②–⑦	②–⑧	②–⑨	②–④	③–④
	Yinchuan -Beijing	Yinchuan -Zhengzhou	Yinchuan -Ji'nan	Yinchuan -Xi'an	Taiyuan -Xi'an
Distance	**1208**	**1294**	**1251**	**933**	**654**

Transport mode	Railways	Railways	Railways	Railways	Railways
	③–⑤	③–⑦	③–⑥	③–⑨	③–⑧
	Taiyuan -Hohhot	Taiyuan -Beijing	Taiyuan -Shijiazhuang	Taiyuan -Ji'nan	Taiyuan -Zhengzhou
Distance	**632**	**513**	**223.8**	**539**	**577**
Transport mode	Railways	Railways	Highways	Railways	Railways
	④–⑤	④–⑥	④–⑧	⑤–⑥	⑤–⑦
	Xi'an -Hohhot	Xi'an -Shijiazhuang	Xi'an -Zhengzhou	Hohhot -Shijiazhuang	Hohhot -Beijing
Distance	**1107**	**935**	**511**	**926**	**653**
Transport mode	Railways	Railways	Railways	Railways	Railways
	⑤–⑩	⑥–⑦	⑥–⑧	⑥–⑨	⑥–⑩
	Hohhot -Tianjin	Shijiazhuang -Beijing	Shijiazhuang -Zhengzhou	Shijiazhuang -Ji'nan	Shijiazhuang -Tianjin
Distance	**646**	**293.6**	**412**	**311.7**	**313.9**
Transport mode	Railways	Highways	Railways	Highways	Highways
	⑦–⑨	⑦–⑩	⑧–⑨	⑧–⑩	⑨–⑩
	Beijing -Ji'nan	Beijing -Tianjin	Zhengzhou -Ji'nan	Zhengzhou -Tianjin	Ji'nan -Tianjin
Distance	**406**	**137.2**	**719**	**851**	**329.7**
Transport mode	Railways	Highways	Railways	Railways	Highways

Table 19 The result of shortest routes from Lanzhou to Tianjin

Total distance	1684.7 km
Routes	①–③–⑥–⑩
Transport modes	Railways-Highways-Highways

Table 20 The final distance from Lanzhou to Yantai among each node (km)

Yantai port					
	①–②	①–③	①–④	②–③	②–⑤
	Lanzhou -Yinchuan	Lanzhou -Taiyuan	Lanzhou -Xi'an	Yinchuan -Taiyuan	Yinchuan -Hohhot
Distance	**478**	**1147**	**676**	**710**	**1208**
Transport mode	Railways	Railways	Railways	Railways	Railways
	②–⑦	②–⑧	②–⑨	②–④	③–④
	Yinchuan -Beijing	Yinchuan -Zhengzhou	Yinchuan -Ji'nan	Yinchuan -Xi'an	Taiyuan -Xi'an
Distance	**1208**	**1294**	**1251**	**933**	**654**
Transport mode	Railways	Railways	Railways	Railways	Railways
	③–⑤	③–⑦	③–⑥	③–⑨	③–⑧
	Taiyuan -Hohhot	Taiyuan -Beijing	Taiyuan -Shijiazhuang	Taiyuan -Ji'nan	Taiyuan -Zhengzhou
Distance	**632**	**513**	**223.8**	**539**	**577**
Transport	Railways	Railways	Highways	Railways	Railways

mode					
	④–⑤	④–⑥	④–⑧	⑤–⑥	⑤–⑦
	Xi'an -Hohhot	Xi'an -Shijiazhuang	Xi'an -Zhengzhou	Hohhot -Shijiazhuang	Hohhot -Beijing
Distance	**1107**	**935**	**511**	**926**	**653**
Transport mode	Railways	Railways	Railways	Railways	Railways
	⑤–⑩	⑥–⑦	⑥–⑧	⑥–⑨	⑥–⑩
	Hohhot -Yantai	Shijiazhuang -Beijing	Shijiazhuang -Zhengzhou	Shijiazhuang -Ji'nan	Shijiazhuang -Yantai
Distance	**1219.4**	**293.6**	**412**	**311.7**	**793**
Transport mode	Highways	Highways	Railways	Highways	Railways
	⑦–⑨	⑦–⑩	⑧–⑨	⑧–⑩	⑨–⑩
	Beijing -Ji'nan	Beijing -Yantai	Zhengzhou -Ji'nan	Zhengzhou -Yantai	Ji'nan -Yantai
Distance	**406**	**949**	**719**	**969**	**539**
Transport mode	Railways	Railways	Railways	Railways	Railways

Table 21 The result of shortest routes from Lanzhou to Yantai

Total distance	2163.8 km
Routes	①–③–⑥–⑩
Transport modes	Railways-Highways-Railways

Since we have done the calculation of the shortest routes(See Table 22), we can now

get the transport time of each study according to their distance and transport modes.

As we know, T=S/V(T=time, S=Distance, V=Speed), and the average speed of domestic highway transportation is 90 km/h, and the average speed of domestic railway transportation is 80 km/h.

Therefore, we can get the results,

The transport time from Harbin to Dalian,

$$T=273.1/90+693/80=11.69 \text{ hours}$$

The transport time from Lanzhou to Tianjin,

$$T=1147/80+(223.8+313.9)/90=20.31 \text{ hours}$$

The transport time from Lanzhou to Tianjin,

$$T=(1147+793)/80+223.8/90=26.74 \text{ hours}$$

Table 22 The shortest routes and the transport modes (km)

	Harbin-Dalian	Lanzhou-Tianjin	Lanzhou-Yantai
Total distance	966.1	1684.7	2163.8
Transport mode	Highway(273.1)+ Railway(693)	Railway (1147)+ Highway(223.8)+ Highway(313.9)	Railway (1147)+ Highway(223.8)+ Railway (793)

In order to determine whether the transport time is reasonable and acceptable, I will compare the transport time of the single highway transport and the transport time of the single railway transport. Because the average speed of domestic highway transportation is higher than the average speed of domestic railway transportation, therefore under the same distance, the transport time of highway transport is less than

the transport time of railway transport. As long as the transport time of multimodal transport is between the transport time of highway transport and the transport time of railway transport, the transport time of multimodal transport could be looked as reasonable and acceptable because it means that the multimodal transport controls the lowest cost and relatively less time.

For getting the transport time of single highway transport and single railway transport from Harbin to Dalian port, the same way is used to calculate. The first is to calculate the shortest distance. From Table 23 and Table 24, we can know that the shortest distance of single highway transport is 950.2 km and the shortest distance of single railway transport is 939 km, and their transport time is,

The transport time of single highway transport,

$$T=950/90=10.56 \text{ hours}$$

The transport time of single railway transport,

$$T=939/80=11.74 \text{ hours}$$

Table 23 The Total Distance of single highway transport in different routes (km)

Routes	Process	Total Distance
①–②–④	273.1+677.1	950.2
①–②–③–④	273.1+307.6+380	960.7
①–③–④	570+380	**950**

Table 24 The Total Distance of single railway transport in different routes (km)

Routes	Process	Total Distance
①–②–④	246+693	**939**

①–②–③–④	246+303+516	1065
①–③–④	549+516	1065

Therefore, we can know that the transport time of multimodal transport is acceptable because the 11.69 hours are between 10.56 hours and 11.74 hours. In this study, although the transport distance of single highway transport is longer than the transport distance of single railway transport, the transport time of single highway transport is still less than the transport time of single railway transport because the speed of highway transport is higher.

For getting the transport time of single highway transport and single railway transport from Lanzhou to Tianjin port and from Lanzhou to Yantai port, it is the same way. The first is to calculate the shortest distance. From Table 25 and Table 26, we can know that the shortest distance from Lanzhou to Tianjin port of single highway transport is 1552.1 km and the shortest distance from Lanzhou to Tianjin port of single railway transport is 1845 km, and their transport time is,

The transport time of single highway transport,

$$T=1552.1/90=17.25 \text{ hours}$$

The transport time of single railway transport,

$$T=1845/80=23.06 \text{ hours}$$

Therefore, we can know that the transport time of multimodal transport is acceptable because the 20.31 hours are between 17.25 hours and 23.06 hours.

Table 25 The result of shortest distance from Lanzhou to Tianjin port of single highway transport (km)

Total distance	1552.1 km
Routes	①–③–⑥–⑩
Transport modes	Single Highways

Table 26 The result of shortest distance from Lanzhou to Tianjin port of single railway transport (km)

Total distance	1845 km
Routes	①–③–⑥–⑩
Transport modes	Single Railways

From Table 27 and Table 28, we can know that the shortest distance from Lanzhou to Yantai port of single highway transport is 1975 km and the shortest distance from Lanzhou to Yantai port of single railway transport is 2195 km, and their transport time is,

The transport time of single highway transport,

$$T=1975/90=21.94 \text{ hours}$$

The transport time of single railway transport,

$$T=2195/80=27.44 \text{ hours}$$

Therefore, we can know that the transport time of multimodal transport is acceptable because the 26.74 hours are between 21.94 hours and 27.44 hours.

Table 27 The result of shortest distance from Lanzhou to Yantai port of single highway transport (km)

Total distance	1975 km

Routes	①–③–⑥–⑩
Transport modes	Single Highways

Table 28 The result of shortest distance from Lanzhou to Yantai port of single railway transport (km)

Total distance	2195 km
Routes	①–③–⑥–⑩
Transport modes	Single Railways

In these two case studies, the most of transport distances of highway transport are less than the most of transport distances of railway transport, therefore, the transport time of highway transport must be less than the transport time of railway transport. And even some of transport distances of highway transport are more than some of transport distances of railway transport, it doesn't make a problem because they are not in the shortest routes.

In short, according to the different choice of transport modes and nodes, the result is different. If the transport mode is highway transport, the distance may be the shortest and the time is the least, but the cost may be the highest. And if the transport mode is railway transport, the cost may be the lowest but the distance is higher and the time is more. And for nodes, if the nodes are too much and don't have hub nodes, the routes may go around and waste time. The result shows that the shortest routes won't go through too many nodes, so make sure the main nodes is very important, it is helpful to short the transport distance so that the time and the cost will be saved.

Therefore, for the optimization of the multimodal transport network of the Bohai

Rim region, there are two key points. First, make sure the suitable number and geographical location of nodes. The center of a province is a good choice. Second, arrange a suitable transport mode plan. For long distance, the railway transport is better. And for a short distance, highway transport is better.

5 Conclusions and extensions

According to the above analysis, we have the ideas on how to optimize the dedicated corridor system connecting Bohai Rim gateways. Let us review the concept of the corridor. The corridor has four elements, which are nodes, link, flow and hub. For the development of the corridor system of the Bohai Rim region, our country has done a lot. The nodes in the case study are mainly hubs, which are developing very fast under the demonstration projects of multimodal network transportation. And we have analyzed the advantages and disadvantages of different transport modes so that we can choose the suitable transport modes as a link to connect each node or hub. And we also forecast the possible freight traffic in the future in the Bohai Rim region so that we can have a plan for the transport construction and have a better distribution of freight traffic in advance.

In the dissertation, I only analyze three simple cases, but it can be suitable for all other conditions. By using the shortest path model, we can find the most economical corridor. We can use it in any nodes to find the best corridor including the low cost, transport mode and the acceptable time. As long as we find all corridors connecting the hinterland and seaports, the corridor system can be made.

However, my study of the optimization of the corridor system connecting Bohai Rim dateways is not perfect and still has many problems to be solved. For example, the transport time should still contain the transit time and loading and unloading time, but these parts are not considering in the dissertation. And in the transportation process, the transport quality is also important, which are also not considered in the dissertation. General, railway transport and waterway transport is safer than highway transport. Or from the perspective of environmental protection, railway transport and water transport are the better choices. Or from the perspective of service, highway transport is more convenient and faster. But in the dissertation, the main key point is to control the cost, therefore, I focus more on transport distance because the shorter transport distance is the direct way to cut the cost. Of course, the weight of cargo is also a key factor affecting the transport cost. But this factor is not easy to analysis because the data is more complex. And the aim of the dissertation is for the government to make a transport plan for the Bohai Rim region, so making the distance of corridors shorter and costing less time is enough. As long as the connection between hinterland and seaports becomes shorter, it is natural that the hinterland will be developed because the communication between hinterland and seaports becomes convenient, which indirectly helps the transport companies cut down their cost and promote the flow between hinterland and seaports.

Finally, for the optimization of the dedicated corridor system connecting Bohai Rim gateways, I have three suggestions. The first is to strengthen the construction of basic transportation. Those short routes can be the main corridors. The second is to develop the waterways in the middle reaches of the Yellow River, which is really helpful to improve the transport from the hinterland to seaports. The final is to strengthen the facility construction of nodes so that the transit time can be less.

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Appendix Shortest Path Model Computing Process

Table A1 The calculation and result from Lanzhou to Tianjin (km)

Shortest path model								
Network structure and flows					**Flow balance constraints**			
Origin	Destination	Distance	Flow		Node	Net outflow		Required net outflow
1	2	478	0		1	1		1
1	3	1147	**1**		2	0		0
1	4	676	0		3	0		0
2	3	710	0		4	0		0
2	4	933	0		5	0		0
2	5	1208	0		6	0		0
2	7	1208	0		7	0		0
2	8	1294	0		8	0		0
2	9	1251	0		9	0		0
3	5	632	0		10	-1		-1
3	6	223.8	**1**					
3	7	513	0					
3	8	577	0					
3	9	539	0					
4	2	933	0					
4	3	654	0					
4	5	1107	0					
4	6	935	0					

4	8	511	0					
5	3	632	0					
5	6	923	0					
5	7	653	0					
5	10	646	0					
6	7	293.6	0					
6	8	412	0					
6	9	311.7	0					
6	10	313.9	**1**					
7	9	406	0					
7	10	137.2	0					
8	6	412	0					
8	9	719	0					
8	10	851	0					
9	7	406	0					
9	8	719	0					
9	10	329.7	0					
Objective to minimize								
Total distance	1684.7							

Table A2 The calculation and result from Lanzhou to Yantai (km)

Shortest path model						

Network structure and flows					**Flow balance constraints**			
Origin	Destination	Distance	Flow		Node	Net outflow		Required net outflow
1	2	478	0		1	1		1
1	3	1147	**1**		2	0		0
1	4	676	0		3	0		0
2	3	710	0		4	0		0
2	4	933	0		5	0		0
2	5	1208	0		6	0		0
2	7	1208	0		7	0		0
2	8	1294	0		8	0		0
2	9	1251	0		9	0		0
3	5	632	0		10	-1		-1
3	6	223.8	**1**					
3	7	513	0					
3	8	577	0					
3	9	539	0					
4	2	933	0					
4	3	654	0					
4	5	1107	0					
4	6	935	0					
4	8	511	0					
5	3	632	0					
5	6	923	0					
5	7	653	0					
5	10	1219.4	0					

6	7	293.6	0					
6	8	412	0					
6	9	311.7	0					
6	10	793	**1**					
7	9	406	0					
7	10	949	0					
8	6	412	0					
8	9	719	0					
8	10	969	0					
9	7	406	0					
9	8	719	0					
9	10	539	0					
Objective to minimize								
Total distance	2163.8							

Table A3 The shortest distance from Lanzhou to Tianjin port of single highway transport (km)

Shortest path model							
Network structure and flows				**Flow balance constraints**			
Origin	Destination	Distance	Flow	Node	Net outflow		Required net outflow
1	2	447.2	0	1	1		1

1	3	1014.4	1		2	0		0
1	4	625.6	0		3	0		0
2	3	702.5	0		4	0		0
2	4	715.5	0		5	0		0
2	5	678.4	0		6	0		0
2	7	1150	0		7	0		0
2	8	1032	0		8	0		0
2	9	1123	0		9	0		0
3	5	437.8	0		10	-1		-1
3	6	223.8	1					
3	7	498.9	0					
3	8	435.1	0					
3	9	520.3	0					
4	2	715.5	0					
4	3	598.2	0					
4	5	964.8	0					
4	6	791.9	0					
4	8	483.9	0					
5	3	437.8	0					
5	6	593.7	0					
5	7	483.6	0					
5	10	615.8	0					
6	7	293.6	0					
6	8	417.8	0					
6	9	311.7	0					
6	10	313.9	1					

7	9	410.1	0					
7	10	137.2	0					
8	6	417.8	0					
8	9	446.5	0					
8	10	698.8	0					
9	7	410.1	0					
9	8	446.5	0					
9	10	329.7	0					
Objective to minimize								
Total distance	1552.1							

Table A4 The shortest distance from Lanzhou to Tianjin port of single railway transport (km)

Shortest path model							
Network structure and flows					**Flow balance constraints**		
Origin	Destination	Distance	Flow		Node	Net outflow	
1	2	478	0		1	1	
1	3	1147	1		2	0	
1	4	676	0		3	0	
2	3	710	0		4	0	

2	4	933	0		5	0	
2	5	1208	0		6	0	
2	7	1208	0		7	0	
2	8	1294	0		8	0	
2	9	1251	0		9	0	
3	5	632	0		10	-1	
3	6	255	1				
3	7	513	0				
3	8	577	0				
3	9	539	0				
4	2	933	0				
4	3	654	0				
4	5	1107	0				
4	6	935	0				
4	8	511	0				
5	3	632	0				
5	6	926	0				
5	7	653	0				
5	10	646	0				
6	7	241	0				
6	8	412	0				
6	9	307	0				
6	10	443	1				
7	9	406	0				
7	10	137	0				
8	6	412	0				

8	9	719	0				
8	10	851	0				
9	7	406	0				
9	8	719	0				
9	10	304	0				
Objective to minimize							
Total distance	1845						

Table A5 The shortest distance from Lanzhou to Yantai port of single highway transport (km)

Shortest path model								
Network structure and flows					**Flow balance constraints**			
Origin	Destination	Distance	Flow		Node	Net outflow		Required net outflow
1	2	447.2	0		1	1		1
1	3	1014.4	1		2	0		0
1	4	625.6	0		3	0		0
2	3	702.5	0		4	0		0
2	4	715.5	0		5	0		0
2	5	678.4	0		6	0		0
2	7	1150	0		7	0		0
2	8	1032	0		8	0		0

2	9	1123	0		9	0		0
3	5	437.8	0		10	-1		-1
3	6	223.8	1					
3	7	498.9	0					
3	8	435.1	0					
3	9	520.3	0					
4	2	715.5	0					
4	3	598.2	0					
4	5	964.8	0					
4	6	791.9	0					
4	8	483.9	0					
5	3	437.8	0					
5	6	593.7	0					
5	7	483.6	0					
5	10	1219.4	0					
6	7	293.6	0					
6	8	417.8	0					
6	9	311.7	0					
6	10	736.8	1					
7	9	410.1	0					
7	10	741	0					
8	6	417.8	0					
8	9	446.5	0					
8	10	910.9	0					
9	7	410.1	0					

9	8	446.5	0					
9	10	453.2	0					
Objective to minimize								
Total distance	1975							

Table A6 The shortest distance from Lanzhou to Yantai port of single railway transport (km)

Shortest path model								
Network structure and flows					**Flow balance constraints**			
Origin	Destination	Distance	Flow		Node	Net outflow		Required net outflow
1	2	478	0		1	1		1
1	3	1147	1		2	0		0
1	4	676	0		3	0		0
2	3	710	0		4	0		0
2	4	933	0		5	0		0
2	5	1208	0		6	0		0
2	7	1208	0		7	0		0
2	8	1294	0		8	0		0
2	9	1251	0		9	0		0
3	5	632	0		10	-1		-1
3	6	255	1					

3	7	513	0					
3	8	577	0					
3	9	539	0					
4	2	933	0					
4	3	654	0					
4	5	1107	0					
4	6	935	0					
4	8	511	0					
5	3	632	0					
5	6	926	0					
5	7	653	0					
6	7	241	0					
6	8	412	0					
6	9	307	0					
6	10	793	1					
7	9	406	0					
7	10	949	0					
8	6	412	0					
8	9	719	0					
8	10	969	0					
9	7	406	0					
9	8	719	0					
9	10	539	0					

Objective to minimize								
Total distance	2195							