A Study on Port Collection and Distribution System Model of Sea-Rail Intermodal Transportation

Mingwei Zheng[1] and Yifeng Cai[2]

[1]Traffic Engineer of Municipal Engineering Design Institute, Tongji Architectural Design (Group) Co. Ltd., Shanghai, China (corresponding author). Email: 309055695@qq.com
[2]Deputy Chief Engineer of Group, Tongji Architectural Design (Group) Co. Ltd., Shanghai, China. Email: 3415965753@qq.com

ABSTRACT

Currently, problems exist in port gathering and transportation modes, such as considering efficiency, neglecting environmental protection, focusing on scale expansion, and neglecting the transportation system coordination. Barriers between modes of transport and lack of communication channels lead to facility layout optimization difficulties. One factor for the construction of a hub port is the support of a collection and distribution network. The advantages of rail-sea intermodal transport are large capacity, high safety, low cost, and low emissions. The development of rail-sea intermodal transport promotes transport structure and facilitates regional export-oriented economic advancements. However, the proportion of port cargo carried by railway in China is low, and the capacity of the railway is insufficient, which restricts port development. By analyzing the freight demand of ports, this paper summarizes transportation mode characteristics. Using the Shanghai system as an example, this paper clarifies the necessity and presents the challenges of sea-rail intermodal transport construction.

CURRENT PROBLEMS IN THE PORT COLLECTION AND DISTRIBUTION SYSTEM

At present, the irrational transportation structure and low development level of multimodal transport are the main reasons for low freight efficiency and high logistics cost in China (Zhao 2018). It is not only related to the distribution capacity and speed of port cargo, but also will lead to the aggravation of the burden of urban roads and highways in the area where the port is located. Overuse of highway transportation will produce negative effects such as large energy consumption, large land occupation and serious emission pollution. The development of China's port collection and distribution system is not only restricted by the technical and economic characteristics of different modes of transportation, but also by the restrictions of system and concept.

The Idea of Development

The inconsistency in the management system and concept of various collection and distribution methods, and the most viewpoint is that railway has comparative advantages

for transport distance over 500 km, which directly make the railway give up a large number of medium and short-haul passenger cargo market (He 2009). The container transportation distance below 200km is the advantage of road transportation in freight rate; more than 500km is the reasonable transportation range and target market of the railway. Therefore, the distance between 200km and 500km become the scope of railway transportation competing with road transportation. The service radius of international container collection and distribution of China's coastal port cargo collection and distribution system is within 500km, such as Shanghai port facing the Yangtze River Delta region and Guangzhou Shenzhen Port facing the Pearl River Delta region. As a result, the collection and distribution system of these major ports in China have fallen into the situation of "one highway is dominant".

Planning and Construction

The road freight industry has the characteristics of low market barriers and high openness, strong adaptability to infrastructure, types of goods, flexible operation and door-to-door direct transportation. There are also some disadvantages such as unexpected weather, potential safety hazards and unfriendly environment. Road freight transportation belongs to the service industry of demand-driven supply. Due to the difference of market demand, its market attribute of resource allocation is very obvious. However, the railway system is relatively closed, which needs the support of transportation scale and is limited by external channels and other conditions.

The reasons for the slow development of sea-rail intermodal transport in some areas are as follows. First, the capacity of railways is limited by the throat passage capacity of railway transportation. Second, infrastructure is imperfect. At present, railway station construction is still a single investment, lack of interaction with other investors, and often unable to meet the requirements of multimodal transport development in site selection and function. Third, there is a lack of standardization of logistics information construction. Railway information system and port management system, shipping management system and highway information system are present not fully connected, and lacking a unified data sharing platform.

THE DIRECTION AND PATH OF THE DEVELOPMENT OF SEA-RAIL INTERMODAL TRANSPORT MODE

Enlightenment from the Development of Sea-Rail Intermodal Transport in Foreign Ports

For a long time, road transportation has had the advantages of flexibility, convenience, easy door-to-door transportation and minimal replacements, so it has become the main mode of port collection and transportation. However, developed countries are currently trying to reduce the market share of road transport and increase the market share of water

transport and rail transport. In this square, the Port of Los Angeles in the United States have done a lot of work.

The port system of the Port of Los Angeles has two major characteristics. First, it is large in scale. The railway line in the port area is 180 kilometers and has direct access to each terminal. The second is seamless integration. The transportation process is “unloading on board → no need to transfer the card directly to the freight train → Alameda Corridor → urban railway freight transfer station → National Railway Network”, as shown in Figures 1 and 2.

Figure 1. The position of Alameda freight corridor line

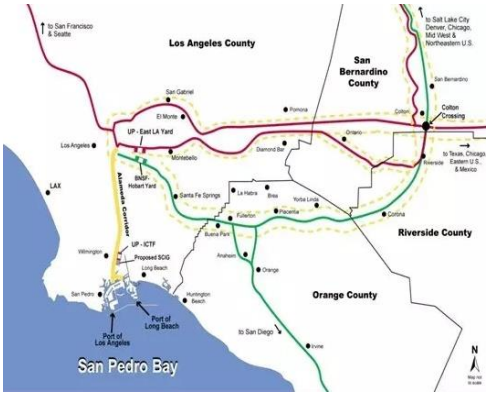

Figure 2. Alameda freight Corridor and port railway

The “Alameda Freight Corridor” is a dedicated freight railway line of about 32km. It solves the problem of “one kilometer in the middle” of multimodal transport, and connects the Los Angeles Port, the Long Beach Port and the inland railway station, and merges four railway feeder lines. By excavating 16 kilometers of underground channels, it eliminates more than 200 parallel intersections, which reduces traffic delay losses by 90%, and makes great contributions to alleviating the contradiction between the port and the city.

For functional aspects, the Alameda Freight Corridor effectively alleviates the increasingly sharp contradiction between port and city and releases the traffic pressure in Los Angeles, as shown in Figure 3. The hinterland of the port will be developed inland through railway lines, so as to solve the problem of "one kilometer in the middle" of land bridge transportation and international maritime transportation, so that the coastal ports and inland stations can be connected efficiently and quickly, and the overall effect of multimodal transport can be brought into full play.

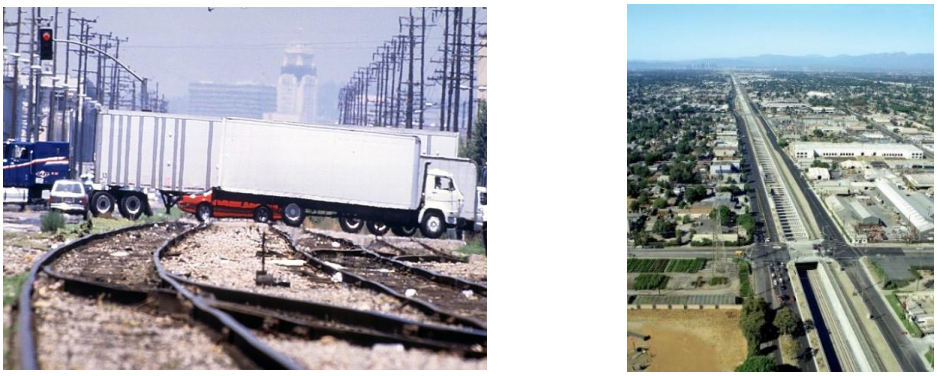

Figure 3. Comparison of the conflicts between the Los Angeles port to city before and after the construction of the Alameda freight corridor

For funding, construction adopts the PPP (Public-Private Partnership) construction mode, issues long-term bonds, and establishes platform organizations to jointly build and operate. It has removed the simple construction model of government funds, which guarantees the smooth construction and long-term stable operation of the Alameda freight corridor, and brings a gradual increase in revenue.

Development Effect of Sea-Rail Intermodal Transport in Domestic Ports

China's sea-rail intermodal transport is participated by railway companies, shipping enterprises and freight forwarding companies. Shipping companies and port groups are responsible for cargo shipping, railway companies are responsible for "port-to-station" railway transport, and highway motor transport companies are responsible for receiving and delivering at both ends. Ship booking, customs declaration and inspection and other operations are generally undertaken by third-party freight forwarding companies or by customers themselves, with more intermediate transportation processes and greater transportation risks (Qi 2019).

China's sea-rail intermodal transport has grown rapidly, but the total amount is still small. The proportion of sea-rail intermodal transport of coastal ports is only about 1.2% of the total (Liu 2019). While the growth rate is generally accelerated, the development speed of various regions is not balanced, such as the Shanghai port sea railway combined transportation at less than 0.02%. There is still a big gap between the 10% and 30% of the large international seaports in Europe and America. The main reasons are the lack of coordination in the service process, the separation of sea-rail intermodal transport stations, the lack of coordination of service standards and specifications, and the lack of flexibility in railway quotation mechanisms.

In recent years, influenced by positive factors such as government attention, policy support, department linkage and model innovation(Cao 2019), Qingdao Port, Ningbo to Zhoushan Port and other container sea-rail intermodal transport projects have made fruitful

progress, leading the development of multi-modal transport of container containers nationwide, as shown in Figures 4 and 5.

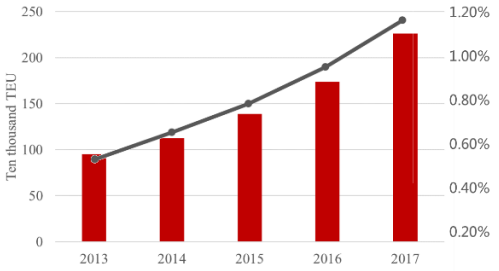

Figure 4. Total container volume and proportion of sea-rail intermodal transport in China's ports

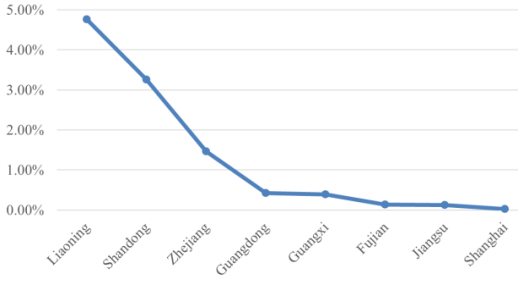

Figure 5. Proportion of sea-rail intermodal transport containers in major provinces in China in 2017

In 2018, Qingdao port sea-rail intermodal transport has completed 1.154 million TEUs (about 5.5% of the total container throughput), an increase of 48.7% over the previous year. It has become the first coastal port in China with a container throughput exceeding 1 million TEUs, and has won the national port Championship for the fourth consecutive year (Jiao 2019). At present, 40 train lines have been opened, forming a network layout of "one city, one port, covering Shandong". At the same time, the radiation is along the yellow and goes directly to Central Asia.

In 2018, the intermodal transport of sea and rail in Ningbo to Zhoushan Port completed 600,000 TEUs (about 2.3% of the total container throughput), ranking third in the country, with an increase of more than 50% year on year, and the growth rate ranking first in the country. Two railway container handling stations have been set up in Beilun Port and Zhenhai Port, with an annual operating capacity of nearly 1 million TEUs. These stations have 12 normal operating lines, which business covers 46 cities in 15 provincial regions. More than 200 enterprises have actually engaged in container sea-rail intermodal transport business, and the cumulative volume of container sea-rail intermodal transport business has reached 1798.5 million TEUs, which further consolidate its role as the largest port of the container sea-rail transport in the South. Ningbo to Zhoushan Port has opened 11 sea-rail intermodal transport lines. Its business scope covers 36 cities in 14 provinces in the country. A sea-rail intermodal transport network covering East China, Central China and Western Region has initially formed (Jiang 2018).

SHANGHAI LINGANG INDUSTRIAL AREA (SHANGHAI SOUTH PORT) SEA-RAIL INTERMODAL TRANSPORT DEVELOPMENT MODEL

Shanghai Lingang area is located in the southeast corner of Shanghai, at the intersection of rivers, bays and coastal corridors. According to the Shanghai General

Regulations 2035, the Hangzhou bay port operation area (Shanghai south port) will create a multimodal transport hub which integrates the transportation system, policy system, trade system and information system. The development of sea-rail intermodal transport faces opportunities and challenges.

Development Requirements

National and Shanghai development requirements

The national "Belt and Road" development strategy and Shanghai's new round of overall planning require vigorous development of sea-rail intermodal transport and improvement of railway services to ports and industrial areas. As an important part of the national coastal railway channel, Shanghai to Nantong Railway and Shanghai to Zhapu to Hangzhou Railway are mainly customer-oriented, both passengers and goods, and serving the passenger and cargo transportation demand between the eastern coastal cities of the country. At present, Shanghai south port in the Shanghai Lingang Industrial Area has no railway line connecting with the main railway channel, and it is urgent to realize the regional service function of the railway to the port and industrial area.

The new round of overall planning requires the optimization of the port transport structure and the construction of a multi-level transport logistics system. The Lingang industrial area plans the Hangzhou bay port area and the Luchao port area promotes the regional radiation capacity of the port and service to the industrial area, as shown in Figures 6 and 7.

Figure 6. Location of the Lingang Industrial Area in the Shanghai Railway System

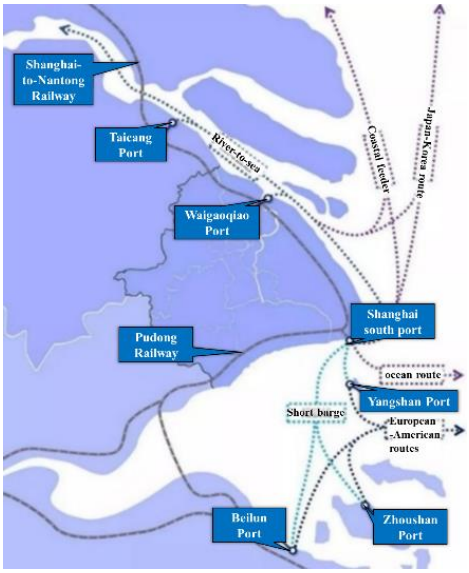

Figure 7. Shanghai south port Multimodal Transport

Regional development needs

Support the development of heavy equipment industrial areas and improve the logistics and transportation system of enterprise logistics. At present, the enterprises in the Lingang heavy equipment industrial area have issued scales. The main collection and transportation methods of enterprise logistics are road and water transport. The transportation cost of highways is high, the transportation of major parts is inconvenient, and the service scope of water transportation is limited. It is urgent to introduce special railway lines to optimize the freight structure of heavy equipment industrial areas.

Promote the development of the Lingang operation area and realize the function of sea-rail intermodal transport. Hangzhou bay port area (Langang operation area) is a multi-purpose and comprehensive port area supporting the Lingang Industrial area. It is also a key construction project of the Shanghai port during the "Twelfth Five-Year Plan" period, and mainly serves the advanced manufacturing and logistics industries in the Lingang heavy equipment industrial area. The introduction of special railway lines will realize the sea-rail intermodal transport function of the port-opening operation area, which effectively improve the radiation range of the port-opening operation area, and improve the comprehensive benefits of Lingang operation area for heavy equipment industrial area.

The Necessity of Developing Sea-rail Intermodal Transport and Railway Function Positioning

Shanghai south port is backed by the Yangtze River and faces the East China Sea. It is surrounded by the S2 Freeway, S32 Freeway, and G1501 Beltway around city as well as Lianggang Avenue. It has obvious advantages in traffic location and good conditions for development hinterland. However, the connection with inland rivers and railways in the industrial area is not smooth, the combination of inland rivers, the Yangtze River, offshore and Zhongyuanyang has not been organically integrated, and the three-dimensional multimodal transport hub of waterway, highway, railway and aviation has not yet been formed, as shown in Figure 8.

Figure 8. Freight transportation facilities in Lingang Industrial Area are not effectively integrated

The development of sea-rail intermodal transport is to implement the medium - and long-term plan for the development of logistics industry (2014-2020) and strengthen the construction of logistics infrastructure network. It is the need of reducing the port industrial park and logistics park transport costs. It is the need of constructing rail and highway combined transportation network to conform to the inevitable trend of future logistics development. It is the need of expanding the port hinterland, improving the port industrial park and logistics park transportation cost advantage. It is the need of taking advantage of Shanghai south port's iron and steeling combined transport to build and improve the comprehensive transportation system of Lingang highway, railway and waterway.

In addition to meeting the freight demand of the Lingang industrial area, it is also significant for Shanghai south port to undertake the transshipment volume of the adjacent Yangshan port area to develop the mode of sea-rail intermodal transport. At present, the throughput of Yangshan port has become saturated and it’s carrying capacity is limited. The Donghai Bridge is a highway bridge which connect Yangshan port and land, so the railway cannot directly serve the port area. In order to achieve the goal of building an international shipping center by 2020, Shanghai port has shifted from scale expansion to intensive operation, focusing on enhancing the port’s soft power. Shanghai south port has excellent geographical advantages and conditions to integrate into the Maritime Silk Road. Part of the container traffic in Yangshan port will likely be transferred to Shanghai south port in the future.

Therefore, the function positioning of dredging port railway in Lingang industrial area should be an organic part of the development strategy of national One Belt and One Road and Yangtze river economic belt, and a strong support for the optimization of urban freight structure proposed by the new round of general regulations of Shanghai and the development of sea-railway combined transportation. It is an important part of the gathering and transportation system of Lingang heavy equipment industrial area. It improves the convenience and reliability of the transportation of major parts and promotes the integrated development of Lingang heavy equipment industrial area along the river and coastal areas. It is an important supplement to the realization of the port function of Hangzhou bay port area (Lingang operation area). Improving the regional radiation range of the port and the service level of the port to the industrial area through the improvement of the sea-rail combined transport function

The Challenge of Developing Sea-rail Intermodal Transport in Lingang Area

Shanghai railway freight volume declined overall

In recent years, Shanghai's railway freight volume has been declining from 12.78 million tons in 2005 to 4.7 million tons in 2017, and the proportion of transportation structure has decreased to less than 0.5%. The reasons are as follows:

1) There is a critical distance between railway transport and road transport. It is better to use railway transport than the critical distance, otherwise it is better to use highway. However, container transport is different from bulk goods. For bulk goods, a special line can be built directly to the owner's factories and mines, but container goods are small batch of goods, which shippers will not be able to reach the economic scale of building dedicated lines. Railway transportation cannot complete the door-to-port operation alone, and the ferries between shippers and railway stations must be transported by road, which increases the loading and unloading costs and road freight, lengthens the critical distance, and reduces the occasions for railway transportation. The increase of a ferry operation also extends the transportation time, also reduces the convenience of use, and reduce the opportunity of railway transportation. Therefore, the division of labor distance between railway transportation and road transportation should be larger than the critical distance calculated according to the cost. The main radiation range of Shanghai port is in the East China region, which is dominated by the Yangtze River Delta region.

2) Rail transport is a highly organized mode of transport, with far less mobility than road transport. Therefore, the use of rail transport is the user to meet the requirements of the transport sector, and the use of road is the transport sector to meet the requirements of the user. However, container cargo is very sensitive to time and has high requirements for convenience of use, which limits the use of railway transportation in multimodal transport. More importantly, railway transportation is a transport mode with more intensive investment, and the fixed cost accounts for a higher proportion in the total cost. Therefore, the use of railway transportation requires a relatively large volume of traffic. Limited by factors such as the layout of the external channel network of railway transportation and transportation cost, the demand of Shanghai port sea-rail intermodal transportation is limited (Xiao 2010).

Figure 9 shows that the development report of Shanghai's transportation industry (2018) shows that in 2017, the volume of goods transported in Shanghai exceeded 970 million tons, up 9.7 percent from the previous year.

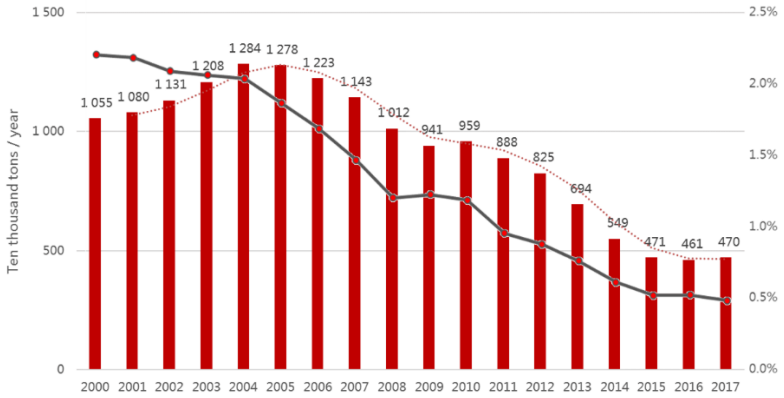

Figure 9. Shanghai Railway Freight Volume and Transportation Ratio from 2000 to 2017 (Shanghai Statistics Yearbook 2017)

The overall increase was from a downward trend, and the growth rate reached a new high in the past five years. From the perspective of freight traffic structure, the volume of highway freight transportation in Shanghai is about 400 million tons, accounting for 40.9% of the total cargo transportation, as shown in Figure 10. Over 4.7 million tons of railway goods were sent, accounting for 0.5% of the total. The volume of waterway cargo transportation is about 570 million tons, accounting for 58.2%. Air cargo and mail handled 4232,000 tons, accounting for 0.4%. Railway freight volume accounted for only 0.5% of the total mode, only 1.2% of the highway.

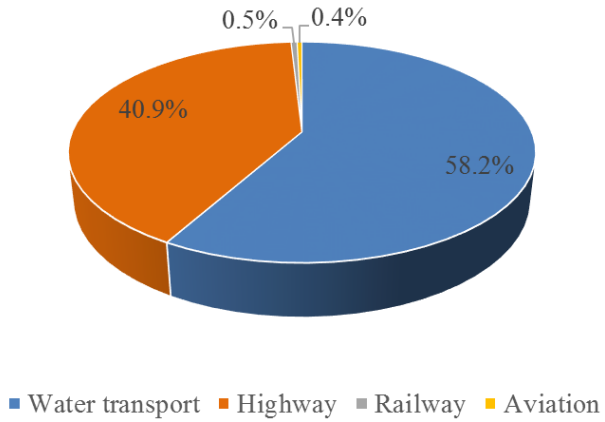

Figure 10. Shanghai's external freight traffic structure in 2017

Fierce competition in coastal ports and limited access to external freight railways

Shanghai port was developed by water transportation. The Shanghai port has taken the Yangtze River delta, which contains Jiangsu province and Zhejiang province, as the direct hinterland of Shanghai port, and other areas of the Yangtze River basin as the indirect

hinterland of Shanghai port. Other areas are not considered as the main hinterland of Shanghai port. The direct connection with the hinterland is mainly inland river transport and road transport, and indirect hinterland is mainly the Yangtze River transport. The link to the railway hinterland is rarely considered. Therefore, although Shanghai port is a super port, its railway facilities are relatively weak, and its marketing work has not paid attention to these areas.

From north to south, there are Dalian Port, Tianjin Port, Qingdao Port, Ningbo-Zhoushan Port, Xiamen Port, Guangzhou Port, Shenzhen Port and other major seaports in China's coastal areas, as shown in Figure 11. They have traditional dominant markets in their direct hinterland. And some of the major ports in Chongqing, Sichuan, Hubei, Hunan, Jiangxi, Anhui and other five provinces and cities form a fierce competitive relationship with Shanghai port.

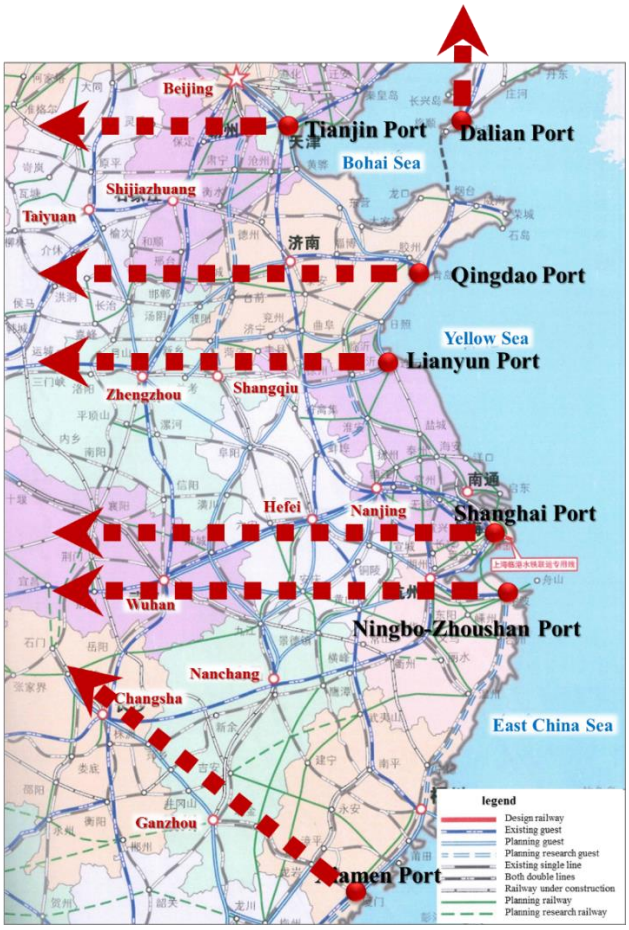

Figure 11. Distribution of major coastal ports in China

Railway gathering and transportation conditions of some seaports are superior to those of Shanghai port. For example, Dalian port and Qinhuangdao port have a port station with

complete facilities and perfect structure. The port owns everything that railway station owns, and even locomotive maintenance is completed by the port itself. After the train is handed over at the front station, from the disintegration, all operations are completed by the port until all operations are completed. The train is organized at the front station and then towed by the railway locomotive to the station. Almost every wharf front, every front warehouse and yard or rear warehouse has railway direct access, such as Qingdao, Lianyungang and other ports. The equipment situation is roughly the same. The difference is that there is no self-contained locomotive in the port, and the pick-up and delivery operation between the station and the port area is completed by the locomotive at the station. Their railway facilities are of large scale and have sufficient capacity to handle railway vehicles. Shanghai Port faces these challenges in developing Rail-sea intermodal transport.

CONCLUSION

By comparing the development modes of different port collection and distribution systems, and summarizing the development changes of port freight in Shanghai (Lingang), it is found that port cargo is facing the transformation from high speed to high quality and from scale expansion to structural optimization. Green and sustainable development has become the goal of port gathering and transportation. Overall planning and facility convergence are important to promote the development of rail-sea intermodal transport. It is an inevitable choice to reverse the excessive dependence on road transport to establish the standard system of rail-sea intermodal transport and increase the infrastructure investment of rail-sea intermodal transport. For the outstanding problems, we should explore comprehensive management methods such as mode and technological innovation, information and platform sharing to promote substantive breakthroughs in port rail-sea intermodal transport.

REFERENCES

Cao Y. (2019). “Review on the development of China's port container hot metal water transport in 2018.” *Continental Bridge Vision*, (04): 66-68.

He J., Sun Y., Liu X., and Chen H. (2009). “Research on Economic Transportation Distance and Reasonable Sharing Rate of Sea-rail intermodal transportation in China—Inspiration from the Case Study of Shanghai yangshan Port Sea-rail intermodal transport.” *Price Theory and Practice*, (06): 67-68.

Jiao L. (2019). “Qingdao Port became the first sea-rail intermodal transport in the country to break through the million TEU port.” *Continental Bridge Vision*, (02): 22.

Jiang H. and Ge H. (2018). “Analysis of the development experience of container sea-rail intermodal transport in China's major ports.” *Modern Trade and Industry*, 39 (34): 24-25.

Liu X. and Ren W. (2019). "Research on the development of container multimodal transport in the Yangtze River Delta region." *Railway Freight*, 37 (02): 6-10.

Qi Y., Lang M., Dong N., He J. and Feng Y. (2019). "A Study on Developing Strategies of the whole Process Logistics Service for Sea-rail Container Intermodal Transport." *Railway Transport and Economy*, 41(05):58-62.

Xiao Z. (2010). "Shanghai Port is not suitable for the development of sea-rail intermodal transport." *China Port*, (12): 18-19.

Zhao J. (2018). "The comparative advantage of the railway freight transport." *China Highway*, (08): 44-46.