Study on the Sustainable Development Strategy of Container Rail-Water Intermodal Transport in Chinese Ports

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Abstract. The sustainable development of container rail-water intermodal transport in China faces a series of deep-seated constraints. In this paper, we quantitatively summarize the development status of container rail-water intermodal transportation in China's ports. Next, the typical problems faced by the sustainable development of rail-water intermodal transport are analyzed from the bottom constraints and direct constraints. Finally, this paper proposes strategic ideas to promote sustainable development of rail-water intermodal transport, taking into account network layout, technical equipment, data exchange rules, and policy environment.

1. Introduction

It is a widespread belief that multi-modal cargo transportation is beneficial to society because of its lower demands on scarce resources such as space, clean air, silence, etc.[1-2]. Port container rail-water intermodal transportation has gained significant attention in China. Recent studies suggest that the development of rail-water intermodal transportation in Chinese ports faces significant challenges in achieving sustainability. These challenges include insufficient infrastructure connectivity, transportation equipment mismatch, lack of harmonization of rules and standards, insufficient application of information technology, etc.[3-5]. Several responses to development have also been put forward. Most of the previous published studies are limited to the problems of transportation itself. In this paper, based on quantitative analysis of the current situation of the development of containerized rail-water intermodal transport in Chinese ports, the typical problems faced by the sustainable development of rail-water intermodal transport are analyzed from the bottom constraints and direct constraints. And strategic ideas to promote the sustainable development of rail-water intermodal transport are put forward based on China's latest policy.

2. Status and characteristics of container rail-water intermodal transport in China

2.1. Volume of freight

China's container rail-water intermodal transport volume experienced a high growth rate, but low proportion from 2011 to 2022. The average annual growth rate of containerized iron and water intermodal transportation is 17.09%. Especially in the past five years, the average annual growth rate reached 20.58%, and the national containerized rail-water intermodal transport volume reached 8.75 million TEU in 2022, as shown in Figure 1. In terms of proportion, the port containerized iron and water intermodal transportation volume accounted for from 1.01% in 2011 to 2.96% in 2022.

Fig.1. Volume and growth rate of container rail-water intermodal transport in Chinese ports, 2011-2022

2.2. Infrastructure networks

At present, China's container rail-water intermodal transport service network has basically realized national coverage. As of 2022, national ports opened a total of 526 routes of container block trains. It has established a network for rail-water intermodal transport service that connects four major ports including the Bohai Rim, Yangtze River Delta, Guangdong-Hong Kong-Macao Greater Bay Area, and Beibu Gulf Port. Out of the total 526 liner routes operated, Bohai Sea port group had the largest share of 295 routes accounting for 56.1 percent. Additionally, China has formed 9 major corridors for rail-water intermodal transport. There are 29 routes for...
China-European Union (CEU) trains, which start from coastal ports, and 6 routes for CEU and Western Land-Sea New Corridor trains, which start from inland ports.

2.3. Main ports for rail-water intermodal transport

In 2022, there are 47 ports and 95 port areas that specialize in container operations. Additionally, there are 44 port areas with access to railway lines, which account for 46.3% [6]. Coastal ports have become the primary hubs for container rail-water intermodal transport, as shown in Table 1. Taking 2022 as an example, coastal ports contributed 95.31% of container rail-water intermodal traffic. Among them, Qingdao Port, Ningbo Zhoushan Port and Tianjin Port rank the top 3 in container rail-water intermodal transport volume, accounting for 53% of container rail-water intermodal transport volume in coastal ports, as shown in Figure 2. In terms of river ports, the majority of rail-water intermodal transport river ports are located along the Yangtze River. The ports with the highest volume of rail-water intermodal transport are Nanjing Port, Chongqing Port, and Jiujiang Port. These three ports account for 60% of the volume of container rail-water intermodal transport in inland river ports, as illustrated in Figure 3.

<table>
<thead>
<tr>
<th>Ports</th>
<th>Coastal Ports</th>
<th>River Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail-water Intermodal Transport Volume (Million TEU)</td>
<td>8.34</td>
<td>0.41</td>
</tr>
<tr>
<td>Container Ports</td>
<td>31</td>
<td>16</td>
</tr>
<tr>
<td>Container Port Areas</td>
<td>61</td>
<td>34</td>
</tr>
<tr>
<td>Port Areas Accessed By Railroad Lines</td>
<td>31</td>
<td>13</td>
</tr>
<tr>
<td>Percentage Of Railroad Line Access (%)</td>
<td>50.8</td>
<td>38.2</td>
</tr>
</tbody>
</table>

Table 1. Ports and inbound railroads for container rail-water intermodal transport in China, 2022

Fig.2. Major container rail-water intermodal transport port capacity along China’s coast in 2022

3 Development needs of China's port container rail-water intermodal transport

3.1. Transport restructuring creates huge transport demand

Whether for reducing social logistics costs or achieving carbon peaking and carbon neutrality goals, rail and waterway transportation will be the primary modes of transportation for bulk goods over medium to long distances in China's future. It has been estimated that if the proportion of multimodal transportation in the total freight volume of society increases by 1 percentage point, the total cost of social logistics can be reduced by approximately 0.9 percentage points, resulting in cost savings of about 100 billion yuan. In the next five years, China's container rail-water intermodal transport volume will grow at an average annual rate of more than 15%.

3.2. Industrial upgrading leads to higher added value in cargo transportation

Currently, there is a new wave of industrial transfer taking place in China. Heavy industries and labor-intensive manufacturing industries are being relocated from the economically developed areas on the eastern coast, such as the Yangtze River Delta and the Pearl River Delta, to the central-western and northeastern parts of the country. This has resulted in a strong demand for trans-regional logistics and transportation between the east and the west. In addition, there is an increasing proportion of goods with high value-added and high timeliness characteristics in the category structure of goods transportation throughout the country. This means that the transportation of goods is transitioning from a quantity-growth type to a value-growth type.

3.3. Technological revolution brings the possibility of breaking through the bottleneck of rail-water intermodal transport

Modern information technologies such as 5G and new intelligent equipment are being widely used across various industries. These applications are also

Fig.3. Major container rail-water intermodal transport port capacity on China's inland waterways in 2022
transforming the way transport is organized, the mode of full-service, and the mode of logistics supply, ultimately leading to innovative changes in the rail-water intermodal transport. Society expects logistics and transportation to be more efficient, safer, and more convenient, and for the time and cost loss caused by transportation mode changes to be reduced. These problems need to be addressed by leveraging new technologies.

4. Factors restricting the sustainable development of China's port container rail-water intermodal transport

4.1. Fundamental constraints

4.1.1 Imbalanced spatial distribution of productivity

China's manufacturing industry is mainly located in the eastern coastal regions, such as Beijing-Tianjin-Hebei, Yangtze River Delta, and Guangdong-Hong Kong-Macao Greater Bay Area, among others. In 2021, the industrial-added value of these three strategic regions accounted for 44.94% of the country's share[7]. Due to the strong spatial agglomeration in most industries, port cargo transportation distance overland is typically short. Based on a survey, it was found that most of the dredging destinations for Tianjin and Hebei ports are located within a radius of 150km[8]. Additionally, in the Yangtze River Delta and Pearl River Delta, 77.5% of land transportation distances are less than 300km, and a high proportion of 93.4% are less than 500km. It is worth noting that short-distance transportation costs for railroads are higher than for roads in distances less than 500km, which means that railroads do not dominate port evacuation.

4.1.2 Slow industrial upgrading

China has reached the middle and late stages of industrialization, but the majority of its industries are still situated in the middle and lower end of the industrial chain. Cargo transportation is largely dominated by low-value-added products, which results in a low rate of containerization. China's railway transportation is primarily used for transporting bulk goods such as coal, iron, steel, ore, grain, and other similar items. In the year 2022, the amount of cargo transported by railway container amounted to 682 million tons, which accounted for 17.47% of the total amount of goods transported by railway. However, this amount is only 1.34% of the total volume of freight transported throughout the whole society.

4.1.3 Uncoordinated integrated transport systems

China has been developing its modes of transport independently for a long time. They have their own system for traffic planning, infrastructure construction, operation and management, and transport organization. However, the level of intensive resource utilization and sharing is not high, and there are many barriers between modes of transport.

4.2. Direct constraints

4.2.1 Inadequate infrastructure

As of the end of 2022, 55% of the national ports' container port area remains disconnected from the rail line. This means that sea-rail containers need to be transferred to the terminal via short barge operations. Out of 29 rail container port stations, only 7 can be seamlessly connected to the terminal. For the other port stations, rail-water intermodal transport requires the use of the highway barge. Although some ports have built railroad lines, they are often far away from the terminal, leading to high highway connection costs.

4.2.2 Inadaptable transport equipment

When it comes to transportation vehicles, regular railway vehicles are inadequate to meet the new requirements of high-value, small-batch, and rapid container transportation. Moreover, the current railway container is mainly a 20ft 35t container, which is around 10cm wider than the standard international container used in water transportation and does not match the container position in the cabin. This necessitates changing the container at the port and then transferring it to the sea, which increases logistics costs and time. In addition, the rated load of coastal cranes in China's coastal ports is primarily 65t, and it is impossible to double-hang 35t railway boxes at one time, resulting in inadequate utilization of operating capacity.

4.2.3 Barriers to information and standards

Railways, ports, highways, freight forwarders, shipping companies, and customs have their own management information systems that are not interconnected with each other. The laws and regulations governing railway and waterway transportation have different provisions on liability boundary, insurance, and claims between the carrier and the shipper. Additionally, the caliber of railway and waterway transportation services is not uniform, and the requirements and rules of bill document format, tariff billing rules, cargo name code, loading, and reinforcement standards are inconsistent.

5. Countermeasures

5.1. Improving the infrastructure layout to cope with industry shifts

When implementing the national comprehensive three-dimensional transportation network, logistics hubs and other related planning, reserve good access space for the
development of rail-water intermodal transport. Control the function of land use and make arrangements for the development of the time sequence. Port enterprises should construct "waterless ports" in significant nodal cities and inland ports. Railroads should have direct links to large industrial parks and logistics parks. Priority should be given to promoting the construction of railroad lines in container hub ports such as Shanghai Waigaoqiao, Tianjin Xingang, Ningbo Beicang, Jiangsu Taicang, etc.

5.2. Upgrading intermodal technical equipment to tap the potential of transport capacity

The research, development, and application of multimodal fast-loading and transshipment equipment should be accelerated such as container trucks, fast container trucks, double-deck container trucks, special flatcars for railroad backpack transportation, and special cars for express transportation. The railway system should actively encourage the use of 20- and 40-foot international standard containers. Special containers such as reefers, tanks, and dry bulk cargo boxes should also be promoted. Additionally, pallets, container bags, packing boxes, and other unitized loading modes of transportation should be encouraged.

5.3. Achieving commonality of data and rules across modes of transport

It is important to promote coordination and mutual recognition of rules between railroads and waterways regarding container transport, cargo codes, loading requirements, safety supervision, and billing rules. A platform for sharing information related to multimodal transportation hubs should be built at both the central and local levels. The government should collaborate with relevant departments to develop smart ports, railroads, highways, and digital ports. The sharing of digital infrastructure between government and enterprises, as well as among different modes of transportation and port supervisory departments, should be promoted. Platform accounts should be used commonly, and data should be shared appropriately to ensure smooth circulation of resources for rail-water intermodal transport.

5.4. Ensuring the development elements of multimodal transport

The Government needs to work together with all stakeholders to overcome the challenges related to urban planning, land acquisition, relocation, and environmental protection in the construction of multimodal transportation infrastructure. Additionally, the Government should encourage private sector participation and provide more financial support for infrastructure projects such as rail-water intermodal transport liner operations and inbound rail lines. To improve the efficiency of rail-water intermodal transportation, it is recommended that government ministries and commissions establish a coordination mechanism for making major policy and engineering decisions. Railroads should adopt differentiated pricing strategies based on different regions, volumes, and distances, which should form a reasonable price relationship with highways. Additionally, the approval process for new types of cargo should be streamlined, and a policy of tilting capacity should be implemented by railroads.

6. Conclusion

The paper provides an overview of the development of container rail-water intermodal transport in China, covering three aspects: transport volume, infrastructure network, and port pattern. It also examines the demand and trends of rail-water intermodal transportation. Furthermore, the main constraints to the development of container rail-water intermodal transport in Chinese ports are analyzed in contrast to the development needs. To solve these problems, Chinese government departments and enterprises need to take measures in terms of infrastructure, transportation equipment, rules and standards, and policies. The analysis in the paper is mainly carried out from a macro perspective. And in the future, the research will focus more on specific issues at the practical operation level.

Acknowledgments

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Reference


