Proceedings of ICEMGD 2025 Symposium: Digital Transformation in Global Human Resource Management
DOI: 10.54254/2754-1169/2025.LD24895

The Role of Multimodal Transport Strategies in Optimizing the Efficiency of Maritime Supply Chains—A Case Study of Rail-Sea Intermodal Transport

Haoming Ma

College of Transport & Communication, Shanghai Maritime University, Shanghai, China
202310621121@stu.shmtu.edu.cn

Abstract. Against the backdrop of global supply chain optimization, rail-sea intermodal transport holds a relatively dominant position among multimodal transport methods. Its 'port-railway-inland hinterland' model significantly contributes to advancing economic globalization. This study systematically analyzes its role through the comparison between traditional and modern models and cases such as the Port of Antwerp. The analysis shows that the rail-sea intermodal transport model significantly improves the overall efficiency of the supply chain by integrating sea and land transport resources, refining process integration and information flow, reducing the overall transportation cost, and improving the point-to-point transportation timeliness. However, as an emerging transport model, it still has the problem of insufficient adaptability to diversified cargo types, which may make it lack momentum under the trend of gradual expansion of international trade. Nevertheless, this problem can be gradually solved by promoting standardized operations, improving the intelligent level, and setting up a scientific freight rate system.

Keywords: rail-sea intermodal transport, port-station integration, one-bill system, efficiency-driven, congestion relief.

1. Introduction

In the era of economic globalization, the volume and dynamism of international trade are steadily increasing. At the same time, the structure, system, and mode of the global supply chain, which connects the economic exchanges and trade contacts among countries, are also continuously improving.

The three major international transportation networks in the world, namely the air transportation network, the port shipping network, and the inland railway network, which are formed relying on the three major long-distance transportation tools of aircraft, ships, and trains, are the indispensable and important foundation for forming the global supply chain and maintaining global trade.

Against the background of the rapid development of science and technology and the intelligence of infrastructure, the improvement of the global infrastructure level has promoted the linkage and integration of the three organization methods, and a systematic and collaborative multimodal transport model has gradually become the mainstream trend. This model forms a composite and

© 2025 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2754-1169/2025.LD24895

efficient transport model with unbroken whole chain, information sharing, and unobstructed communication channels by connecting two or more transport methods at a common node (such as a port, station, or airport) or by short-distance transport connecting two adjacent nodes. It can be roughly divided into air-rail intermodal transport, sea-air intermodal transport, and rail-sea intermodal transport (according to the provisions of China's Maritime Law, one of the multimodal transport methods must include a sea transport method, so air-rail intermodal transport does not belong to this model category), so it is called collaborative multimodal transport or connected multimodal transport.

Since the concept of this model was put forward, the main import and export node countries in the global supply chain have been widely promoting and piloting it. In this process, the role of this model in optimizing the supply chain has gradually become prominent, including but not limited to: integrating and strengthening the advantages of various transport methods to improve transport efficiency; connecting various transport networks to expand the breadth and depth of transport business; and intelligently integrating and sharing various information in the process to simplify the point-to-point and line-to-line processes.

Among these various combined and linked transport methods, rail-sea intermodal transport is the main and relatively mature intermodal transport method. This is not only because it has unified the container as the most basic transport unit, which is convenient for information statistics and sharing in the transport process, but also because it effectively combines the low cost and large transport volume of water transport with the advantages of railway transport, which is less affected by climate and can go deep into the inland and traverse the inland for long-distance and punctual transport. Compared with the traditional single transport method, rail-sea intermodal transport has obvious advantages in cost control and operation stability.

Based on the above research background, this paper will mainly use research methods such as the present situation analysis method, comparative analysis method, and case analysis method to analyze the role of rail-sea intermodal transport in optimizing the efficiency of the maritime supply chain from multiple angles and dimensions such as transport volume, transport speed, and transport cost.

2. Analysis of domestic and foreign current situations

As a vital part of the multimodal transport system, rail-sea intermodal transport is becoming a key breakthrough in reconstructing the efficiency of the global supply chain. This model simplifies operations through the process of "one declaration, one inspection, one release" by integrating the global accessibility of the maritime transport network and the scale advantages of railway transport and shows significant efficiency in reducing coordination costs and optimizing resource allocation [1].

The rail-sea intermodal transport has promoted the collaborative and standardized process of planning management at the theoretical level and verified the effectiveness of the systematic integration of multiple transport methods. Its digital transformation practices such as the container intelligent dispatching system and the transport service platform provide empirical support for the supply chain resilience theory and expand the research boundaries of organization economics through the scale economy and low-carbon cost model [2].

In China, since 2018, with the goal of adjusting the transport structure, actions such as the railway transport capacity improvement action, water transport system upgrading action, and multimodal transport speed-up action have been implemented nationwide to adjust the transport structure. As an important part of them, rail-sea intermodal transport has achieved remarkable

DOI: 10.54254/2754-1169/2025.LD24895

development. For example, as of May 9, 2025, the Yangtze River Delta Railway has completed more than 1 million TEUs of rail-sea intermodal transport, 9 days ahead of 2024. In recent years, the China Railway Shanghai Bureau Group has strengthened cooperation with the Shanghai Port and the Ningbo-Zhoushan Port in rail-sea intermodal transport projects, optimized transport organization, accurately arranged train departures in stages according to customer needs, and seamlessly connected loading/unloading and ship schedules, significantly reducing the stay time of vehicle flows at stations and ports. As of May 9, the Shanghai Port and the Ningbo-Zhoushan Port have cumulatively completed 1,004,000 TEUs of rail-sea intermodal transport in the current year, an increase of 8% year-on-year [3].

The foreign shipping industry started earlier than that in China, and the exploration and research on this model are relatively more mature. The European Commission's "2010 European Transport Policy: It is Time to Decide" proposed to set up multimodal transport freight corridors to promote the transfer of road transport to railway and water transport, thereby promoting the development of rail-sea intermodal transport. For example, as the largest port in Germany, the Port of Hamburg is an important maritime transfer hub in the EU and has built relatively mature port-railway docking infrastructure. The railway transportation volume of the Port of Hamburg accounts for one-third of the port's throughput, and a relatively mature rail-sea intermodal transport model has been explored. (As shown in Figure 1).

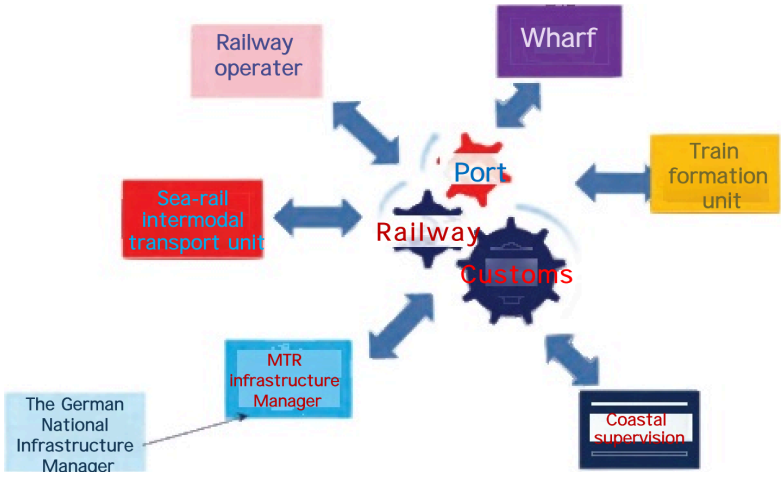


Figure 1: The main participation of Port Railway

The port mainly focuses on direct transfer transport and adopts the direct loading operation of rail-sea cargo at the terminal, directly building the railway to the front of the terminal and loading the containers from the ship directly onto the train, avoiding the short handling of containers from the ship to the ground and then loading them onto the train [4].

3. Role analysis

3.1. Resource integration

Rail-sea intermodal transport breaks the traditional segmented transport barriers through the deep integration of the maritime transport and railway transport networks and can achieve transport ability sharing and collaborative dispatching. For example, the "port-station integration" design of ports and inland railway hubs can efficiently distribute container resources, reduce empty container allocation, and transport ability idling, and maximize the use of infrastructure ability [5].

DOI: 10.54254/2754-1169/2025.LD24895

For example, the Port of Antwerp, the second largest port in Europe, has nearly 1,000 km of intra-port railways and 26 on-site port stations. As soon as the goods are unloaded from the cargo ship, they can be shortly hauled within the port and loaded onto the freight train, and the freight train can also synchronously transfer the international transport goods to the cargo ship.

The close connection between the maritime transport chain and the railway transport chain realizes the deep integration of the two transport networks, which not only integrates the transport capacity resources but also promotes the improvement of the overall efficiency of the supply chain.

3.2. Process collaboration

The connected and collaborative intermodal transport method of rail-sea intermodal transport promotes the whole-process collaboration of the maritime supply chain in the long-distance transport operation process. The "one-bill system" is the core system to realize this process collaboration.

It refers to a unified transport document (bill of lading) covering all links and costs of the whole transport process in the multimodal transport process and can realize the deep seamless connection and efficient information sharing between different transport methods through the information sharing platform in the rail-sea intermodal transport process [6].

The promotion of this system can unify the multimodal transport rules and operation standards, greatly simplify the repetitive processes of customs declaration, insurance, settlement, and other links, and effectively avoid the cargo detention caused by the non-unification of documents in the traditional model [6]. And through the rail-sea intermodal transport data of Ningbo Port from 2009 to 2024 (see Table 1), this process collaboration can increase the rail-sea intermodal transport volume to a certain extent and achieve efficiency improvement on the whole supply chain to a certain extent [7].

DOI: 10.54254/2754-1169/2025.LD24895

Table 1: Growth of rail-sea intermodal transport in Ningbo-Zhoushan port from 2009 to 2024 (unit: 10,000 TEUs)

Year	Rail-Sea Intermodal Transport TEU Volume	Growth Rate of Rail-Sea Intermodal Transport TEU Volume	Port Container Throughput	Proportion of Rail-Sea Intermodal Transport in Container Collection and Distribution
2009	0.2	/	1050	0.02%
2010	2.8	1547.1%	1315	0.2%
2011	4.7	67.9%	1472	0.3%
2012	5.2	10.6%	1617	0.3%
2013	10.5	101.9%	1733	0.6%
2014	13.5	28.6%	1945	0.7%
2015	17.0	25.9%	2063	0.8%
2016	25.0	32.0%	2156	1.2%
2017	40.1	60.2%	2461	1.6%
2018	60.2	50.3%	2635	2.3%
2019	80.9	34.4%	2753	2.9%
2020	100.5	24.2%	2872	3.5%
2021	120.4	19.8%	3108	3.9%
2022	145.2	20.6%	3335	4.4%
2023	165.2	13.8%	3530	4.7%
2024	181.1	9.6%	3930	4.6%

3.3. Cost optimization

Rail-sea intermodal transport can reduce the comprehensive cost of the whole coordination supply chain to a certain extent through the unification of the basic transport carriers and the continuity of the processes.

In the traditional international container transport chain in the past, the transport method following water transport was basically mainly road transport. For example, in 2007, China's port container throughput exceeded 100 million TEUs, reaching 112.70 million TEUs. But in the national

DOI: 10.54254/2754-1169/2025.LD24895

port container collection and distribution volume, road transport accounted for about 85%, water transport about 14%, and railway transport only about 1% [8].

Short-distance transportation of containers after unloading may be more efficient in the form of road short haul, but its radiation range is too small. For most containers that need to be transported to the inland for long-distance transport, multiple transfers are needed, making the cost continuously consumed in the layer-by-layer transfers and difficult to reduce.

In the rail-sea intermodal transport model, replacing road short haul with railway mainline transport can not only reduce fuel and labor costs but also compress transfer losses through centralized loading and unloading and the "one-container-to-the-end" model and simultaneously promote large-scale operations to further spread the unit transport cost. This not only provides enterprises with a more competitive organizational solution but also saves the cost of the supply chain transport chain to a certain extent.

3.4. Timeliness improvement

In the traditional maritime transport chain, the difficulty in improving the transport timeliness has been a major pain point for a long time. The transport method of road short haul (such as truck transport) inevitably causes large-scale goods to be continuously dispersed due to its miscellaneous and scattered transport units, and the conversion from water to land and from land to water is difficult to effectively and stably connect and manage, resulting in a large amount of time being consumed in handling cargo detention and port traffic management.

However, with the continuous promotion of the rail-sea intermodal transport method, its role in accurately and effectively improving timeliness has become prominent. On the one hand, it can rely on the railway liner operation to accurately match the ship schedule, effectively reducing the cargo detention rate, which not only saves the time cost in cargo docking but also further ensures the stability of the transport plan [9]. On the other hand, because the railway transport route is basically fixed, the risk of delaying the ship schedule due to congestion or temporary dispatching is greatly reduced, making the management of port traffic convenient and fast.

4. Problem analysis and suggestions

4.1. Insufficient adaptability of diversified cargoes to the rail-sea intermodal transport model

In the operation of the international supply chain, driven by increasing globalization or as international trade globalizes, the types and forms of goods have also become more and more diversified, which has led to the fact that although the container is a relatively standardized basic transport unit, its proportion in all transport types is still only a small part, and other cargo types such as dry bulk cargo and general cargo still occupy the main position in the composition of the freight volume.

However, container transport accounts for the main position in the rail-sea intermodal transport process. Although this makes the standardization degree of the rail-sea intermodal transport process relatively high, making the transfer process indeed more convenient, fast, and conducive to statistics, it also makes it difficult for diversified goods in the rail-sea intermodal transport model to be effectively adapted and integrated. This is not only because the rail-sea transport is to a certain extent limited by the railway line layout and equipment conditions and cannot achieve standardized adaptation to diversified goods but also because compared with high-value-added container transport, the transport of other cargo types is difficult to form a stable industrial chain.

DOI: 10.54254/2754-1169/2025.LD24895

These two main reasons that make it impossible for the rail-sea intermodal transport to universally benefit diversified cargo types, losing the transport market of diversified cargo types such as dry bulk cargo and general cargo that occupy the main position in the supply chain operation [10].

4.2. Suggestions

4.2.1. Policy promotion of standardization

Through promoting cooperative research between the government and relevant industry associations, formulate unified and effective standards for diversified goods in the four main links of loading and unloading, packaging, transportation, and storage, and issue corresponding feasible policy restrictions to promote the standardized and professional adaptation of diversified cargo types in the rail-sea intermodal transport model.

4.2.2. Technology promotion of intelligence

While initially promoting the standardization of diversified cargo types through policies, it is also necessary to simultaneously promote the whole-process intelligence of the rail-sea intermodal transport process with technology. Relying on the data advantage that the data in the process can be more easily statistically mastered due to this standardization, it is possible to more conveniently build an intelligent platform with the current developed electronic information technology. The construction of this platform also allows other cargo types to be classified more carefully, and the feedback can promote standardization. And it can further play to the process collaboration advantages of rail-sea intermodal transport.

4.2.3. Scientific formulation of a dynamic freight rate system

The promotion of standardization and the promotion of intelligence have solved the pain points of diversified goods being limited by hard conditions to a certain extent, but due to the low added value of diversified cargo types, this structural disadvantage is still difficult to solve only by standardization and intelligence means. Therefore, a reasonable, transparent, and dynamic freight rate pricing mechanism should be formulated based on the data experience accumulated by the above two methods for statistical analysis.

5. Conclusion

In this paper, the role of rail-sea intermodal transport in perfecting the efficiency of the maritime supply chain and the current existing shortcomings are studied and analyzed mainly through direct current situation analysis and data analysis, supplemented by indirect comparative analysis and case analysis.

The rail-sea intermodal transport strategy mainly plays four major roles in the whole-chain efficiency optimization of the maritime supply chain: integrating water transport and railway transport resources and networks; promoting the whole-process collaboration and information sharing of the transport process; optimizing the transport cost and reducing unnecessary expenses; saving the time of secondary links and improving the transport timeliness.

At present, rail-sea intermodal transport is faced with the problem of being difficult to closely follow the trend of cargo diversification, which can be effectively solved to a certain extent through

DOI: 10.54254/2754-1169/2025.LD24895

three main measures: standardization, intelligence, and dynamic freight rates.

This study aims to supplement the development of relevant theories and provide a reference path and direction for the optimization of the model in the future by analyzing the role of the rail-sea intermodal transport model in the supply chain. The problem analysis in this study has limitations, and more comprehensive and perfect research can be conducted in this aspect in the future.

References

[1] Zhuang, R.L., Zhang, J.J., Zhi, M.L., et al. (2025) A Review of Rail-Sea Intermodal Transport Research Based on CNKI and WOS Journal Literature from 2000 to 2023. Railway Transport and Economy, 47(03), 66-83.
[2] Li, C. (2021) Analysis of Development Countermeasures for Rail-Sea Intermodal Transport. China Shipping Weekly, 11, 48-49.
[3] Li, X.P. (2025) The Yangtze River Delta Railway Has Completed More Than One Million TEUs of Rail-Sea Intermodal Transport This Year. People's Daily, 1.
[4] Wu, Z.X., Zhao, H.S., Liu, Q.Y. (2019) Development Experience and Enlightenment of Rail-Sea Intermodal Transport in Foreign Ports. Railway Freight Transport, 37(03), 49-53.
[5] Ambrosino, D., Asta, V., Crainic, T.G. (2021) Optimization Challenges and Literature Overview in the Intermodal Rail-Sea Terminal, Transportation Research Procedia, 52, 163-170.
[6] Sun, S.P., Li, Y. (2025) Analysis of the Role of the One-Bill System Transport of Railway Multimodal Transport in Reducing Logistics Costs, Improving Quality and Efficiency. Railway Procurement and Logistics, 20(03), 36-38.
[7] Chao, Y.G., Zhang, Y., Dai, D.S. (2025) Research on Countermeasures for the High-Quality Development of Ningbo Container Rail-Sea Intermodal Transport. Ningbo Economy (Sanjiang Forum), 04, 3-5.
[8] Wang, P. (2011) Strengthening Rail-Sea Intermodal Transport to Enhance Port Competitiveness. China Ports, 10, 32+34.
[9] Yan, B.C., Jin, J.G., Zhu, X.N., Lee, D.H., Wang, L., Wang, H. (2020) Integrated Planning of Train Schedule Template and Container Transshipment Operation in Seaport Railway Terminals, Transportation Research Part E: Logistics and Transportation Review, 142, 102061, ISSN 1366-5545.
[10] Zhuang, R.L., Yang, J., Zhi, M.L. (2025) The Course, Challenges, and Optimization Path of Zhejiang Rail-Sea Intermodal Transport for the Modern Logistics System. Journal of Ocean University of China (Social Sciences Edition), 01, 42-51.