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Analysis on the adjustment of transportation structure and the logistics transformation of railway freight

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Abstract

Purpose – This paper aims to provide a comprehensive analysis of the strategic adjustments in China's transportation structure, with a particular focus on the pivotal role of railway freight and its integration into the modern logistics system. It seeks to address the need for a more nuanced understanding of the "road to rail" policy, emphasizing the importance of intermodal collaboration and service of fragmented market demands.
Design/methodology/approach – The study employs a transport economics perspective to evaluate the achievements and shortcomings of China's transportation structure optimization. It bases its assessment of the current state of railway freight logistics, multi-modal transportation and the broader implications for the transportation service market on data analysis. The methodology includes a review of existing policies, an examination of industry practices and a comparative analysis with global trends in railway logistics.
Findings – The research underscores the importance of focusing on the development of non-bulk materials, noting the insufficiency in the development of China's rail multi-modal transportation and highlighting the instructive value of successful cases in open-top container road-rail intermodal transportation. The study posits that the railway sector must enhance cooperation with other market entities, aligning with the lead enterprises in the logistics chain that are characterized by speed, high value and strong coordination capabilities, in order to better serve the transportation market. This approach moves away from a reliance on the railway's own capabilities alone.
Originality/value – This paper offers original insights into the transformation of railway freight in China, contributing to the body of knowledge on transportation economics and logistics. It provides valuable recommendations for policymakers and industry practitioners, emphasizing the strategic importance of railway logistics in the context of China's economic development and intense competition in the supply chain. The value of the article lies in its comprehensive understanding of the complexities involved in the adjustment of transportation structures, providing direction for the market-oriented reform of China's railway freight sector.

Keywords Transportation structure optimization, Railway freight, Logistics transformation, Multi-modal transport

Paper type Research paper

1. Introduction

Since 2018, the optimization of the transportation structure has emerged as a critical task within China's transportation sector. Regulatory bodies have emphasized the enhanced

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utilization of railways for the transportation of bulk commodities and long-distance shipments. A clear directive has been issued to promote the "road to rail, road to water" initiative for bulk freight, aiming to increase the proportion of large-scale industrial and mining enterprises and logistics parks connected by dedicated railway lines and to improve the railway connectivity rate in major port areas. The goal is to establish a development paradigm by 2025 where medium- and long-distance transportation of bulk goods and containers is predominantly led by railways and waterways. According to the data from the "2023 Statistical Bulletin of Transportation Industry" published by the Ministry of Transport, by the end of 2023, the national railway freight volume had increased by 134.6 million tons compared to 2017, representing a share of 9.2% in the total freight volume, up from 7.8% in 2017. The waterway freight volume had surged by 268.9 million tons compared to 2017, accounting for 17.1% of the total freight volume, up from 14.1% in 2017. The container rail-water intermodal volume reached 10.1836 million twenty-foot equivalent units (TEUs), marking a significant increase from 2017. Concurrently, the proportion of road freight volume in the total freight volume decreased from 78% in 2017 to 73.7%. The China-Europe Railway Express operated a total of 17,500 trains in 2023, transporting 1.9 million TEUs, with the number of trains operated increasing by 377% compared to 2017.

Despite the positive outcomes of the transportation structure optimization, there remain several gaps and deficiencies. These include the average annual growth rate of container rail-water intermodal volume and the proportion of medium- and long-distance railway transportation in major coal-producing regions such as Shanxi, Shaanxi and Inner Mongolia, which still fall short of the targeted goals. The construction of intermodal facilities like dedicated railway lines is lagging, and there is a scarcity of multi-modal freight hubs. The intermodal hubs often suffer from issues of being "adjacent but not connected" and "connected but not smooth." The level of coordination in transportation organization remains suboptimal, with a dearth of multi-modal operators capable of cross-modal operations and comprehensive cargo organization. Furthermore, the mechanisms for information interconnectivity and sharing among departments, modes, enterprises and regions are yet to be fully established (Li, 2023; Wei, 2024). Consequently, the central government has intensified its focus on this domain, with recent high-profile meetings underscoring the need to reduce logistics costs across society and to further refine the cargo transportation structure. There is a particular emphasis on deepening reforms in railway freight and commercial circulation, with a special mandate to advance the "independent operation of naturally monopolistic segments and the market-oriented reform of competitive segments" within the railway industry and other sectors.

Researchers have pointed out that the railroad and other modes of freight transport cooperation can improve the efficiency of transport and revenue. Ohnell and Woxenius (2003) in Sweden and other European countries of the railroad transport enterprises and express enterprises after the analysis of the cooperation pointed out that the transportation supply chain can be divided into a number of links. The interdependence of resources between the subjects of different links makes the cooperation between railroad transportation enterprises and express delivery enterprises possible in theory, and the essence of the cooperation between the two sides is to enhance the overall transportation efficiency by matching the supply and demand of each other's capacity resources. Troche (2005) defines the concept of high-speed rail freight transport and provides case studies of high-speed rail freight transport systems in France, Germany, the United Kingdom, Sweden and Denmark. Hilmola (2007) points out that after analyzing the reasons for the decline of rail freight transportation in Europe, it becomes evident that rail transportation enterprises rely solely on their own network resources and have been difficult to adapt to the market's requirements for transportation in terms of timeliness, and therefore, it is urgent to carry out. Virum (2007) pointed out the analysis of the transportation efficiency of the railroad freight supply chain that, although there is a certain degree of competition between railroad transport enterprises and express enterprises in the field of fast transportation, railroad transport enterprises can be based on the principle of "resource sharing, risk sharing" to enhance the railway network by strategic alliance. Liang,

Tan, Whiteing, Nash, and Johnson (2016) analyzed the cooperation modes in France, Germany and China and pointed out that due to the public nature of the railroad network and public welfare, it is difficult for express enterprises to fully integrate with railroad enterprises to reduce transaction costs, but they will choose to adopt contractual cooperation, industrial alliance cooperation or quasi-integration cooperation modes according to the number of subjects participating in the transaction and the investment needs of specialized assets. However, according to the number of subjects involved in the transaction and the investment needs of specialized assets, they will choose to adopt contractual cooperation, industrial alliance cooperation or quasi-integrated cooperation mode to minimize transaction costs.

There are also studies focusing on specific models of cooperation between railroads and other modes of transport or the development of logistics chains by railroads. Lomotko (2016) suggests that a multi-criteria approach can be used to solve the problems of management tasks and rationalization of logistics systems for cargo transport in cooperation between railroads and other modes of transport to increase the qualitative characteristics of the transport process and the efficiency of the cargo service. Shramenko (2018) develops a mathematical model for the operation of the production and transport chain of railroad routes for the transport of bulk cargoes, measures the costs of the links and proposes directions for optimization of a number of segments of delivery, loading, intermodal transport, etc. Lytvynenko (2022) empirically demonstrates the possibility of the development of freight transport by the urban light railroads, specifies the space of cooperation between the urban light freight railroads and other modes of transport and analyzes the examples of effective public–private partnerships in this process.

We posit that the ultimate objective of optimizing and adjusting the transportation structure is not merely to bolster the market share of railways in freight transportation but also to pay close attention to the commodity category structure. It is essential to enhance the market-oriented service capabilities of railways within the context of a robust transportation nation, thereby charting a course for the long-term development of the railway sector. This necessitates that railways draw extensively on domestic and international experiences and make corresponding adjustments in transportation modes and business models.

2. Economic analysis of railway transportation in response to fragmented demand

2.1 Modular supply and fragmented demand in transportation economics

Economies of scale and scope are fundamental principles in economic activities. Given the network characteristics and the complexity of transportation production and product measurement methods, the principles of economies of scale and scope translate into transportation density economies and network span economies. The transportation density economy encompasses line throughput density, port station (hub) capacity economy, vehicle carrying capacity economy, fleet size economy and operational/interconnection and transfer speed economy. The network span economy manifests through two primary means: line extension and an increase in service nodes, which include transportation distance economy and the multi-product economy that arises from network expansion. The large-scale nature of transportation infrastructure and equipment necessitates a high load factor, meaning that in many instances, transportation infrastructure and vehicles will simultaneously transport a variety of different products that are not interchangeable (Rong, 2001).

In the realm of transportation, we observe a pronounced trend towards large-scale and high-speed operations, with ultra-large cargo ships of 400,000–500,000 deadweight tonnage, container ships exceeding 20,000 TEUs, heavy-haul trains weighing tens of thousands of tons, large passenger aircraft with a capacity of over 500 seats and high-density high-speed trains continually being integrated into the transportation system. Conversely, the market still hosts a multitude of small carriers that play a significant role. Demand within the transportation market can be categorized into centralized and fragmented demands. The former is well suited to large-scale supply; for instance, a single coal mine might be the shipper for a ten-thousand-

ton coal train, with a single power plant as the consignee. However, addressing fragmented transportation demands is more complex, such as the myriad e-commerce businesses and consumers who act as shippers and consignees for a dedicated express package train. Balancing the scale economy of the transportation industry with the fragmented demands of the market presents a considerable challenge.

Transportation services involve the movement of goods and are not tangible products; they are specific to time and space and cannot be stored or reallocated. Unlike the marginal unit of "single goods" discussed in general economics, the production decisions of transportation providers are based on the transportation vehicle as the marginal unit, determining whether to provide a certain mode of transport. In other words, there exists a threshold for the minimum load factor or the density economy of the transport vehicle, and transportation providers are only willing to offer services above this economic density (Rong, Li, Wang, & Yan, 2020).

Different modes of transportation each have their own economic efficiencies to achieve, but this does not imply that they should abandon the fragmented demands present in the market. Fragmented demands constitute a significant portion of the transportation market, and the transportation prices and profits for fragmented freight are relatively high, with their proportion continuously increasing as the level of economic development rises. Abandoning fragmented demands equates to forfeiting a substantial market share. However, it must be emphasized that transportation services for fragmented demands require the extensive involvement of intermediary organizations. By collaborating with freight forwarders, multi-modal transport companies or logistics enterprises, these fragmented demands can be efficiently consolidated into cargo batches and loading tools that meet the efficiency requirements of various modes of transportation.

2.2 The shift towards fragmented demand in road freight and maritime transport

In a comparative analysis, the road freight market inherently possesses the characteristics of small-scale transportation and has become even more pronounced in recent years. Traditional maritime transport, known for its large-scale operations, has also made commendable progress in catering to fragmented demands.

The road freight market is highly segmented, divided into three major categories: full truckload, less-than-truckload (LTL), which can be further divided into large and small LTL, and parcel express. It is also differentiated based on service recipients into "2B" (including "large B" and "small B") and "2C" markets. Road freight adopts the piece as the unit of carriage. With improving road conditions and increasing vehicle load capacities, road freight has not only retained its LTL services but also strives to cater to all levels of fragmented freight demands effectively, an experience worthy of attention for railways. The "dedicated line" model prevalent in LTL freight plays a crucial role in balancing the scale economy of road freight with fragmented demands. Dedicated line transport companies are typically small in scale but, through years of operation and market penetration, have gradually formed a road freight service market system with fixed routes and operating vehicles. There are hundreds of thousands of small and medium-sized enterprises nationwide, acting as intermediaries, managing millions of road freight dedicated lines. The dedicated line network covers virtually all cities in the country and connects with nearly ten million long-haul trucks and drivers. Dedicated lines have often been targeted for governance in the transformation and upgrading of road transport, yet they possess remarkable vitality and adaptability to policies. The pattern of road LTL freight dominated by dedicated lines has taken shape, contrasting sharply with the demise of railway LTL.

Looking at the maritime industry, which exhibits a more pronounced scale effect, we observe how it adjusts its carrying units. Unlike dry bulk and oil and gas transportation, which primarily use the entire vessel or, at most, an entire hold as the carrying unit, containerized maritime transport uses the container as the unit of carriage, operating in a liner mode. Container liners carrying more than 10,000–20,000 TEUs are not necessarily fully loaded on

each voyage. Cooperative freight forwarding companies are responsible for the lending and return of containers on the vessel, determining whether the goods within the containers are consolidated and handling the initial and final collection and distribution services of the containers. In other words, container liners rent out the container slots on the vessel to provide port-to-port transportation, achieving efficient matching between large-scale container ships and the fragmented demands of numerous cargo owners through the cooperation of freight forwarding companies.

In 2022, the total scale of China's road transport market was 5.09 trillion yuan, with the revenue from full truckload business accounting for approximately 49.5%, LTL business for about 31.83% and express business for about 18.67%. This indicates that the two types of fragmented demands, LTL and express, have already captured half of the market and continue to maintain a growth trend (iDigital Consulting, 2024). In 2022, the global seaborne trade volume exceeded 12 billion tons, with dry bulk accounting for about 44.04%, oil and gas for about 29.7% and containers for about 15.4% (Huatai Futures, 2023), the latter mainly transporting the fragmented, high-value, miscellaneous goods consolidated by freight forwarders and logistics companies. In contrast, the proportion of China Railway Group's container (excluding open-top containers) volume in the total freight volume in 2023 was only 6.6% (Yang, 2024), suggesting that the transportation of non-full-truckload miscellaneous goods by railways still requires further development.

Railways have phased out the inefficient LTL transportation category in traditional freight, retaining transportation in the form of full truckload and containers. Even when operating block trains, railways prefer to contract in groups. However, this does not imply that railways cannot serve fragmented demands.

2.3 The capacity of railways to meet fragmented demands needs enhancement

The capacity of railway transportation is reflected by the line-passing capacity of fixed facilities and the carrying capacity of the number and configuration of mobile equipment, represented by the maximum number of trains that meet standard weight and length that can be operated daily. Traditional transportation organization mainly categorizes by destination, distance, locomotive capability and the equipment of the station, compiling and operating trains based on the train assembly plan and train operation diagram. In addition to the technical requirements for punctuality and coordination of all operations, the most critical factor for maintaining traffic efficiency is to achieve as much direct proportion as possible in the train assembly plan and to utilize the full traction quota during operation (Yang, 2015). From the railway's perspective, it is ideal for all goods on a freight train to be loaded at the same station and unloaded at the same station, allowing direct trains to save a significant amount of transshipment costs. Therefore, railways prefer to organize direct transportation of bulk goods, but organizing sources is challenging.

The larger the train traction quota, the higher the probability that the train will be underloaded, which requires more time spent waiting for assembly. The requirements for direct trains and full axles make traditional railway freight place special emphasis on planning. Shippers need to comply with the railway production plan, thus necessitating the submission of a transportation plan application several weeks in advance. Even so, the delivery time limit under the traditional railway transportation organization remains difficult to improve. According to the freight regulations, the minimum number of days for the delivery time limit of railway goods is three days, and the LTL goods that are overweight, oversized or overlength need to add another two days. For goods with a transportation distance of about 1,500 kilometers, road freight can be delivered within three days (many dedicated trucking lanes can deliver within two days), while the railway full truckload requires at least six days, and LTL requires more than nine days (Shi, 2013). Faced with the continuously improving capacity of expressways, the obviously delayed delivery time limit naturally diminishes the competitiveness of railways in the transportation market. Not only has the category of

railway LTL freight disappeared, but the volume of many full truckload transports is also inevitably lost.

In 1997, China's railways began to pilot the operation of "five-fixed" fast freight trains between some cities, characterized by fixed stations, fixed lines, fixed train numbers, fixed times and fixed prices, implementing strict diagram-based operation and ensuring the transportation deadline of direct fast freight trains (Zhang *et al*., 2006). This is a type of freight train that operated like a passenger train, breaking the aforementioned traditional freight organization model, also known as a "block train." However, the most important feature of the block train is actually allowing for operation with fewer than full loads, which reduces its own load-bearing efficiency to ensure relatively fast and timely online services. Unlike LTL income, which entirely depends on the volume of goods transported, the income from block trains comes from contract fees. In the absence of sufficient freight sources, the risk of operating block trains at a loss is significant. Therefore, most are contracted by external fast transport companies or logistics organizations, which are responsible for the entire train or several carriages and are responsible for sourcing cargo. Block train transportation represents an important direction for the development of railway freight, which is to use the railway's own fast and reliable station-to-station services to help others build a high-quality service chain from door to door.

3. Shift in transportation modes

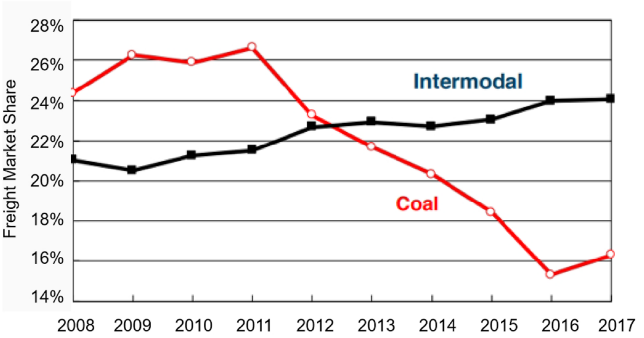
3.1 Vigorously develop multi-modal transportation by railway

With the advancement of the transportation structure adjustment strategy, all parties have reached a consensus on the "road to rail" for bulk materials. "Road to rail" is not a zero-sum game understood in a narrow sense. In fact, the relationship between railways and highways is not absolutely irreconcilable. Generally, it is difficult for railways to achieve door-to-door transportation, but there can be intermodal cooperation, complementary advantages and shared interests between highways and railways, making the cooperative chain services more quality. This situation obviously cannot be summarized as "increasing rail and reducing road," but it should be a win-win cooperation.

Railways do have advantages in transporting bulk goods, but it does not mean that railways need to belittle or give up the market for other goods. The proportion of bulk goods in railway freight is also constantly changing. For example, the proportion of coal in China's railway freight volume has been above 60%. According to the data from the "2023 Railway Statistics Bulletin," this proportion has now dropped to around 50%. Future "dual carbon" will also continue to affect the production, consumption and transportation of coal. The railway department should prepare in advance to cope with changes in the transportation structure.

Compared with the United States of America, coal has also been the largest proportion of the transportation category in American railways in the past. However, as can be seen from Figure 1, the multi-modal transportation revenue of American railways has been stable above the originally largest coal transportation since 2013, and the difference is now more than 10% points. In 2016, the railway coal transportation volume decreased by nearly 40% compared with 2008, and in recent years, the proportion of coal transportation revenue in American railways may even be below 10%, while the railway multi-modal transportation volume has basically remained stable (Hatch, 2021).

The national level attaches great importance to multi-modal transportation work. The recent policy clearly demands accelerating the opening of multi-modal transportation data, supporting the development of integrated multi-modal transportation information services and vigorously cultivating multi-modal transport operators who are responsible for the entire journey to achieve the goal of "one box to the end" for container transportation, without changing containers midway or opening boxes for repeated inspections. It can be seen that the object of transportation structure optimization adjustment is becoming clearer, and the direction is gradually becoming clear. China Railway Group also formulated the "Opinions on



Source(s): BNSF, CSX, KCS, NS, and UP combined company annul reports

Figure 1. Changes in the proportion of USA railway coal and multimodal transportation revenues

Accelerating the Construction of Modern Railway Logistics System" in 2023, requiring the affiliated system to adhere to the market-oriented direction: deeply implement six improvement or innovation projects including railway freight product brand, logistics equipment, freight station, transportation organization, logistics operation and logistics information; promote the transformation and development of railway freight to modern logistics; accelerate the construction of a multi-modal transportation and fast logistics system that deeply integrates with other modes of transportation and integrate into the industrial chain and supply chain with high-quality product supply (Yang, 2024). It can be seen that Chinese railways are jumping out of traditional bulk material transportation and carrying out logistics transformation.

3.2 Focus on container multi-modal transportation

After the Second World War, American railways accepted the container invented by shipping companies, and starting in the 1990s, they began operating more efficient double-decker container trains. In order to effectively control the intermodal chain, several American railway companies once pursued vertical integration by acquiring trucking and shipping companies but later abandoned this approach and eventually gave up this vertical integration and turned to form a close intermodal chain with various intermodal enterprises, including freight forwarding companies, assembly companies, brokerage companies, third-party logistics companies, cargo owner associations, etc. through market contracts. At present, American railway companies focus on improving their own online transportation efficiency and use various box types, pallets and vehicles that are convenient for intermodal transportation and carry out in-depth cooperation with the leaders of the transportation/logistics chain through information technology (Levinson, 2008). The double-decker container train operated by American BNSF company, pulled by 5 + 3+2 diesel locomotives, is 278 cars long, with a total box number of more than 1,000 TEUs (BNSF, 2024), and its transportation efficiency is very high.

Since the 1980s, the container throughput of the Ports of Los Angeles and Long Beach in the United States of America has ranked the top two in the country, and in 2021, it has exceeded 20 million TEUs. In order to strengthen the collection and distribution capacity and adapt to the development of the port, the two ports have actively invested in the acquisition of the existing railway line of the Alameda Corridor and transformed it into a typical container sea-rail intermodal project. This elevated corridor has reduced the travel time of container trains between the port area and the railway station from 2 hours to 45 minutes, and the number of trains running every day has reached more than 50, and the box loading of each train has

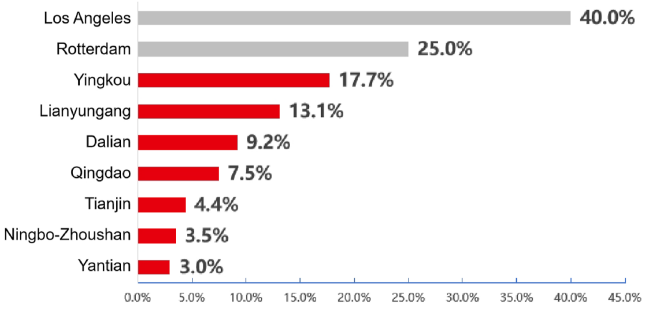
increased from less than 200 TEUs to about 450 TEUs (Rong, 2017). Since 2006, the railway container transportation volume of this port channel has been above 4 million TEUs, and the proportion of the total box volume of the port's container collection and distribution has been basically stable at about 30% (ACTA, 2024).

The development of container multi-modal transportation gives both sea transportation and railways the opportunity to achieve an efficient combination of their own scale characteristics and fragmented demand. China's railway has also been hoping to accelerate the pace of container multi-modal transportation. For example, the China-Europe Railway Express has now connected 217 cities in 25 countries between China and Europe, and from 2016 to 2023, the annual transportation value of the China-Europe Railway Express has increased from 8 bn US dollars to 56.7 bn US dollars (China Railway Group Freight Department, 2024). However, there are still many obstacles in the container sea-rail intermodal transportation. According to the research report of the China Railway Group Freight Department, in 2023, the container sea-rail intermodal transportation only accounted for 4% of the container throughput of the main coastal ports in the country. As can be seen from Figure 2, there is still a certain gap compared with the ports with a high proportion of international container sea-rail intermodal transportation. In addition, double-decker container trains have not been fully developed, and the volume of transportation is relatively small.

3.3 Promote the experience of open-top container road-rail intermodal transportation

In the process of railway transformation, the intermodal transportation of open-top containers has emerged rapidly. China Railway has developed a 20-foot, 35-ton, open-top dry bulk container, which has brought good economic and social benefits. This open-top container has a load capacity of 32 tons, which is basically a standard of "inland box," making full use of the railway and highway limits, and on the premise of increasing the loading capacity by 14.7% compared with the general box, it can be more convenient and efficient for highway intermodal transportation, especially increasing the operation mode of loading from the top of the box and allowing the container truck to unload from one end by gravity. The promotion of open-top containers has increased transportation efficiency including vehicle and train turnover by promoting the "bulk to container" of goods and has achieved valuable experience.

In China's "road to rail" transportation structure adjustment policy, the construction of railway-dedicated lines by mining and storage enterprises with an annual transportation volume of more than 1.5 million tons is encouraged. Large coal mines have the ability to organize a full train through the loading tower, but most coal-using units do not reach the transportation volume level of constructing a dedicated line. For example, there are 200–300 various enterprises near a certain station that need to use coal from a coal mine about 350 kilometers away, with a total annual consumption of tens of millions of tons. Under the traditional railway



Source(s): China Railway Group (2024)

Figure 2. Proportion of rail-water intermodal transport in container throughput at major ports

open car transportation mode, it is impossible to enjoy "door-to-door" service, and flexible and convenient full-process highway transportation has become the first choice for many coal users. After the railway bureau implemented the open-top container road-rail intermodal transportation mode for coal, it has achieved a win-win situation for stakeholders, including railways, customers, logistics enterprises, truck fleets, highway overload control, environmental protection control and transportation structure adjustment. Due to the advantages of open-top container road-rail intermodal transportation in both time and freight rate compared to full-process highway transportation, a large amount of original full-process highway coal transportation volume has turned to road-rail intermodal transportation, and even coal users with dedicated lines have also changed to open-top container road-rail intermodal transportation. In 2017, the coal railway transportation volume of the mine was 18.015 million tons, of which the volume of open-top containers was only 11.2%; by 2020, the coal railway transportation volume increased to 46.443 million tons, and the proportion of open-top containers reached 90.4%. This has greatly increased the proportion of container transportation of the railway bureau, and in 2020, the cargo transported by containers of the bureau accounted for 40.3% of the total cargo transportation volume (Rong *et al.*, 2021).

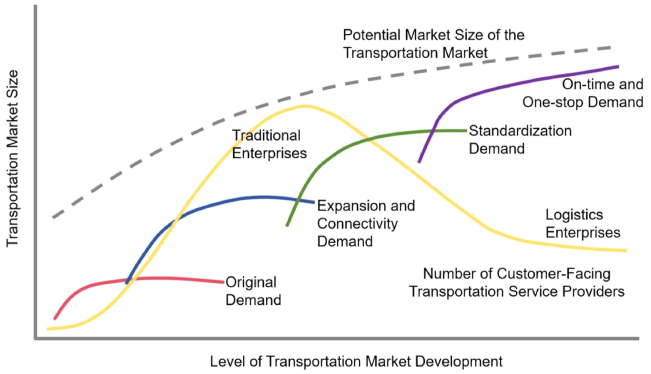
The growth of China's railway container transportation volume was slow from 2005 to 2014. The proportion of container transportation volume in the total freight volume increased slightly from 2.41 to 2.95%. After that, the growth entered a fast lane, especially from 2016 to 2023. The container transportation volume completed by the entire railway network increased from 125 million tons to 732 million tons, i.e. 33.23 million TEUs, and the proportion of container freight volume in the total transportation volume increased to 18.72%, among which the volume of open-top containers accounted for 65% of the railway container transportation volume (Yang, 2024). That is, aside from the increased volume of services like the China-Europe Railway Express, the significant reason for the rapid growth in railway container transportation volume and proportion in recent years is the use of open-top containers for bulk goods such as coal, ore and construction materials.

It should be affirmed that open-top container road-rail intermodal transportation provides specific customers with green and convenient door-to-door services for bulk goods. However, there is still a difference between open-top container transportation and the distributed transportation of "white goods," and railways still need to work hard. Building on the success of open-top containers, China's railways need to explore how to better serve small and medium-sized enterprises, which is also a necessary step for railways to further integrate into the 2C market from the 2B market.

4. Shift in business models

4.1 Evolution of the freight service market and the spectrum of entities

In mature freight markets, transportation companies directly facing customers are increasingly rare (ELA, 2003). Logistics enterprises have become the core intermediary organizations linking diverse spatiotemporal demands with standardized and large-scale transportation operations. Figure 3 illustrates the changing relationship between freight market demand and suppliers. The horizontal axis represents the level of transportation market development, and the vertical axis represents indicators of transportation market size. It can be seen that the potential scale of the transportation market is represented by a curve that continues to rise over time, but the rate of increase varies at different stages. The several short solid lines represent the increases in transportation demand and improvements in transportation service quality at different stages of development. The thick yellow solid line represents the number of transportation service providers facing customers. The shape of this curve indicates that the number of transportation service providers facing customers initially increases from the early to the middle stage and then begins to decrease from the middle stage onwards. Initially, transportation service providers were mainly traditional transportation enterprises in industries such as water transport, railways and highways. However, in the later period, the carriers



Source(s): ELA. Study on Freight Integrators (2003)

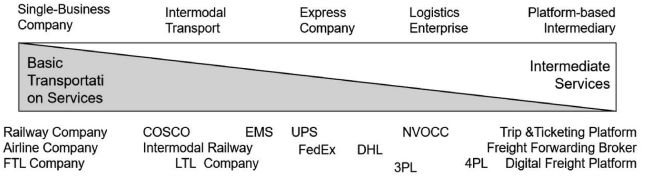
Figure 3. Changes in freight market demand and suppliers

directly facing customers in the transportation market have gradually become logistics service providers, especially those large logistics enterprises with qualifications and integration capabilities, while transportation enterprises providing basic transportation services and numerous small logistics enterprises have largely been integrated into efficient supply chains.

On the supply side of transportation, it can be broadly divided into two main categories: transportation enterprises of different modes and transportation intermediaries. The former can be referred to as basic transportation operators. Transportation intermediaries – depending on whether they own transportation facilities or vehicles and whether they own the main transportation vehicles – can also be further divided into different formats. For example, some transportation intermediaries do not act as carriers but only play an intermediary role or provide necessary information between the demander and the basic transportation operator. Some transportation intermediaries act as contracting carriers, integrate the capabilities of transportation enterprises through business organization and then provide services. This type in the classification of transportation agency is known as a non-vessel operating common carrier. There is a spectrum from providing services directly to providing services entirely through platform-type intermediaries (see Figure 4), and any transportation enterprise or related service operator can find its position on this spectrum (Rong, 2006).

4.2 Exploration of railway logistics models worldwide

The transformation models of railway freight transportation in various countries can inspire the market cooperation of Chinese railways. Schenker, a global international freight forwarding company with a history of over 140 years, is a leading global logistics enterprise. Deutsche Bahn (DB) has a deep origin with freight forwarding and logistics business. In 1931, DB



Source(s): Authors' own work

Figure 4. Schematic diagram of the spectrum of transportation service providers

acquired Schenker as a subsidiary to help achieve door-to-door service. Schenker gradually developed from assisting DB's domestic services to forming a pan-European land service and then to providing global land, sea and air door-to-door multi-modal transportation services. The development of the two complements each other, and DB has also become a model for multi-modal transportation among European railways. In 1991, due to financial pressure from losses, DB was forced to sell Schenker, but the railway freight business between the two did not stop (Fan & Lin, 2006). After the reform of DB in 1994, it continued to focus on providing door-to-door multi-modal transportation services and continuously expanded its service network. In 2003, DB reacquired Schenker and successively merged with several important logistics enterprises, such as the British English logistics group under the name of DB Schenker, and continued to set up branches on all continents. In 2006, DB Schenker acquired the North American BAX Global Company, with more than 1,500 branches in 150 countries and nearly 76,000 employees. Its business volume ranks first in European railways and European land transportation, second in global air transportation, third in global sea transportation and sixth in global contract logistics. DB has become the world's second-largest freight logistics group (Wang, Huang, & Hou, 2016). In 2006, DB established its logistics department, DB Logistics, which included all logistics businesses of DB's own freight department, DB Cargo, and Schenker and Burlington Global under DB Logistics. In 2008, the German Railway Group restructured again, and DB has integrated its own railway freight business into Schenker's global logistics system, with DB acting as the carrier to contract freight business. In September 2024, Danish logistics giant DSV successfully acquired DB Schenker for 14.3bn euros, making DSV the world's largest freight forwarding company (Fortune, 2024). DB focuses more on its domestic railway business and continues to cooperate with Schenker in logistics.

The interdependence between railway freight and logistics is a trend, but it is challenging for railway enterprises to secure sufficient funds for comprehensive acquisitions. Therefore, it is difficult to achieve vertical integration. After the reform of Japanese National Railways, more than 40% of JR Freight's business serves the largest logistics enterprise in Japan, Nippon Express. However, the cooperation remains primarily at the business level.

American railway companies and express delivery companies also pay more attention to achieving close docking in the business field. American railway freight multi-modal transportation is divided into two parts: roll-on/roll-off piggyback transportation and container transportation. Road- and semi-trailers have been successfully integrated into the transportation network of large express companies. The Chicago Area Consolidated Hub (CACH) sorting center was built by UPS in Chicago in 1995. The center has a construction area of 320,000 square meters, 126 unloading doors for express box trailers and 1,054 sorting and loading doors, handling 4,000 trailers and 1.5 million express packages every day. The location of the sorting center is close to Chicago's Midway Airport, but it is adjacent to several loading lines of BNSF Railway's express box trailers, and some tractors directly drag the trailers from the sorting center to the loading platform and are quickly loaded onto the train. In 2005, BNSF arranged 14 express train arrival and departure plans for the sorting center every day. BNSF has established long-term cooperative relations with two major express giants, UPS and FedEx (Fan, 2017; Han, 2024).

Whether an enterprise is classified as logistics or transportation enterprise depends on two things: one is what kind of main assets the enterprise have and the other is what the main source of income for the enterprise is (Xiao, 2020). According to relevant information (Han, 2024), in 2021, the railway freight input of the American BNSF Railway Group accounted for more than 90% of the total income, while the business income of the BNSF Logistics subsidiary established in 2002 was only 789 mn US dollars. It is clear that BNSF is still a railway company overall. In 2022, the business income of DB Cargo, the railway freight department of DB, was 5.24 bn euros, accounting for only 9.3% of the total business income of DB, while the business income of the logistics company DB Schenker accounted for 46.6% of the total business income of DB. If it were not for the determination to sell DB Schenker, DB would almost have become a logistics company.

4.3 Analysis of the exploration of railway freight logistics in China

China's railway freight has made several attempts to transform towards logistics, with varying results. In the early marketization period of the 1980s and 1990s, some railway enterprises provided so-called "extended services," which were essentially traditional railway freight operations centered on transportation plans. After 1993, China Railway Express, which used passenger train luggage cars for door-to-door railway express parcel business, was developed. After more than ten years of development, China Railway Express has become an express enterprise with more than 2,000 express vehicles and more than 5,000 employees, providing domestic and international express and logistics services for more than 300 cities, with an annual turnover of nearly 2 bn yuan. However, after 2003, China Railway Baggage Company, focusing more on managing traditional transportation resources, took over the "China Railway Express" business, leading to the withdrawal of railway express from the express market (Rong, 2006). In 2013, the state railway system's freight implemented a "one-price" reform, attempting to expand extended services again, but mainly hoping to lead the entire chain by itself and keep the benefits within the railway system (Bi, 2019). Due to the railway's limited ability to engage directly with the end customers of "white goods," many logistics enterprises that originally cooperated with the railway transferred their volumes to the highway, and the railway's LTL business faced difficulties once again.

China Railway Corporation and SF Holding jointly established China Railway-SF Express (CR SF) Co., Ltd. in 2018, whose business scope mainly includes high-speed rail express, fast cargo train and other specialized logistics services and the design and construction of railway cross-border e-commerce cargo platforms. Although there is close cooperation between the two parties in the equity of China Railway SF (China Railway Corporation holds 55% and SF holds 45%), due to the ineffective connection in business philosophy and cultural integration, business chain and information system docking, etc., the cooperation has yet to achieve the desired level of success. A few years ago, the State Energy Group also tried to carry out a piggyback transportation project for highway semi-trailers on the railway lines it operated and even designed special railway vehicles for this purpose but encountered a series of thorny problems in the implementation process, such as logistics collection, short transfer connection, small batch of white goods and vehicle sharing difficulties (State Energy Railway Equipment Company, 2023). Whether the railway can become a qualified cooperative entity, an inescapable issue is to adapt freight to small carriers.

At present, there is a high demand for the logistics transformation of railway freight, and various bureaus have also successively established their own logistics centers. However, the transformation of freight into logistics services does not mean that all freight enterprises, including railways, should become logistics enterprises. The key is to integrate the transportation link into an efficient, comprehensive logistics chain. The interdependence between freight and logistics enterprises is increasingly close, forming a typical freight-logistics business ecosystem. Transportation enterprises mainly achieve efficiency by offering standardized services like full truckload, full ship and full container loads, but they struggle to meet the fragmented door-to-door transportation needs of numerous customers. In the traditional station-to-station, port-to-port transportation products, it is increasingly inadequate for meeting the growing demand for door-to-door, hand-to-hand and highly punctual transportation services. However, logistics enterprises can respond quickly to customers and consolidate various sources of goods for loading, making full use of the capacity of transportation tools in both load and volume, helping the transportation industry to achieve market matching. Therefore, the typical division of labor model in the freight and logistics field has become transportation enterprises managing their own professional transportation from station to station, port to port and handing over the work facing customers to corresponding logistics enterprises, with both parties excelling in their respective roles and fulfilling their responsibilities.

Explorations by railways in this field in various countries seem to have shown that it is extremely difficult for railway enterprises to be strong in both freight and logistics fields at the same time. This ultra-large-scale transportation mode undoubtedly needs to form an alliance with qualified intermodal logistics integrators to develop better together.

5. Conclusions

From the perspective of transportation economics, combining the history and current situation of railway freight development, as well as domestic and international experiences and lessons. The main conclusions are:

(1) To achieve the goal of further reducing the social logistics cost and optimizing the cargo transportation structure, it is necessary to deepen the reform of railway freight, commercial circulation, etc. It is necessary to deepen the understanding of the traditional management system of railways, the traditional freight organization model, the traditional business philosophy and the traditional industry monopoly structure to achieve the central policy goals of reducing social logistics costs and optimizing the transportation structure and to continuously explore reform directions and breakthroughs.

(2) As a traditional model of large-scale transportation, railway freight is experiencing a significant period of transformation. While continuing to leverage the original economic advantages of heavy load and high density, it is essential to better align with market demands that have undergone significant changes and continue to evolve. Adjusting the transportation structure must also take into account that with the changes in economic structure, the volume and proportion of bulk materials will gradually decrease, while fragmented and diversified logistics "white cargo" will be the fastest-growing demand in the current and future periods, and railway freight should not lose this important market. It should not be assumed that railways can only serve bulk goods or that the task is completed as long as the transportation of bulk goods is improved. Compared with the simple "road to rail" of zero-sum games, encouraging road-rail combined transportation should be more in line with the policy orientation of collaborative win-win. Other concepts such as "bulk to container," "LTL to block train" and "highway specialized line + railway specialized train" should also be given attention.

(3) While striving to transport bulk goods effectively, railways must significantly enhance their capacity for container multi-modal transportation. Container multi-modal transportation has transformed the relationship between different modes of transportation, shifting the dynamic from competition to cooperation and has also reshaped the competitive-cooperative model of the transportation industry. It is necessary not only to continue to significantly increase the volume and proportion of container rail-water combined transportation but also to encourage the combined transportation of containers or highway trailers by rail. Open-top container road-rail intermodal transportation is a beneficial innovation to help railways achieve "door-to-door" services for small and medium-sized enterprises.

(4) While emphasizing and achieving economies of density in industry transportation, railways must also focus on maximizing the expansion of their ecosystem, integrating into the supply chain and value chain of other modes of transportation and logistics entities and jointly building a high-level, efficient service network. In the process where enterprise competition and industry competition are rapidly replaced by chain competition or network competition, railways must humble themselves to make their short and slow chains subordinate to the long, comprehensive and fast chains of the cooperative logistics chain leaders.

References

Alameda Corridor Transportation Authority (ACTA) (2024). Connecting the ports to the nation, Available from: https://www.acta.org/ (accessed 22 June 2024).

Bi, D. (2019). Strategies for high-quality development of the road freight industry. *China Road Transport*, 6.

BNSF (2024). Container freight train video, Available from: https://www.bilibili.com/video/BV1Dm411X7ni/ (accessed 1 February 2024).

China Railway Group Freight Department (2024). Report on deeply understanding and promoting the transformation and upgrading of freight to railway logistics. Unpublished confidential document.

European Logistics Association (ELA) (2003). Study on freight integrators – the 2003 final report, Available from: http://europa.eu.int/comm/transport/intermodality

Fan, Z. (2017). Research on the cooperation model between American railway companies and FedEx. *China Railways*, 1.

Fan, Z., & Lin, B. (2006). Enlightenment of Deutsche Bahn's experience on China's direct freight logistics. *Logistics Technology, 7*.

Fortune (2024). Denmark's DSV wins biggest bid to date—acquires Deutsche Bahn unit for €14.3 billion, Available from: https://fortune.com/europe/2024/09/13/denmark-dsv-germany-deutsche-bahn-14-3-billion-acquisition/

Han, B. (2024). Research on the construction and implementation path of the modern railway logistics system architecture. *Railway Transport and Economy*, 3.

Hatch, A. B. (2021). Rails 2021: CP+KSU, CNI-TCI, the STB. . ..plus REAL-RR bidness. Available from: https://transportation.northwestern.edu/news-events/sandhouse-rail-group/

Hilmola, O. (2007). European railway freight transportation and adaptation to demand decline: Efficiency and partial productivity analysis from period of 1980-2003. *International Journal of Productivity and Performance Management*, *56*(3), 205–225. doi: 10.1108/17410400710731428.

Huatai Futures (2023). Global seaborne trade overview. Shipping thematic report, Available from: http://www.cfachina.org/servicesupport/analygarden/zsl/jyzsoxqh/202311/P020231119751149110515.pdf (accessed 2 August 2023).

iDigital Consulting (2024). 2023 China LTL industry research report, Available from: https://k.sina.com.cn/article_1796217437_6b101a5d0190177b6.html

Levinson, M. (2008). The box: How the shipping container made the world smaller and the world economy bigger. (J. Jiang, Trans.). Beijing: China Machine Press.

Li, M. (2023). Analysis of the effectiveness of the adjustment of the railway transportation structure. *China Logistics and Purchasing, 14*.

Liang, X., Tan, K., Whiteing, A., Nash, C., & Johnson, D. (2016). Parcels and mail by high speed rail–comparative analysis of Germany, France and China. *Journal of Rail Transport Planning and Management*, *6*(2), 77–88. doi: 10.1016/j.jrtpm.2016.04.003.

Lomotko, D. V., Alyoshinsky, E. S., & Zambrybor, G. G. (2016). Methodological aspect of the logistics technologies formation in reforming processes on the railways. *Transportation Research Procedia*, *14*, 2762–2766. doi: 10.1016/j.trpro.2016.05.482.

Lytvynenko, L., Kalmanbetova, G., Shevket, O., Kara, I., Gerlitz, L., & Popova, Y. (2022). Prospects of using the urban railway for logistics support of urban areas. *Transportation Research Procedia*, *63*, 1199–1204. doi: 10.1016/j.trpro.2022.06.125.

Ohnell, S., & Woxenius, J. (2003). An industry analysis of express freight from a European railway perspective. *International Journal of Physical Distribution and Logistics Management*, *33*(8), 735–751. doi: 10.1108/09600030310502902.

Rong, C. (2001). Discussion on scale economy and scope economy issues in the transportation industry. *China Railway Science*, 4.

Rong, C. (2006). The micro-structure change in the transportation market and the role of intermediate organizations from the perspective of China Railway Express. *Industrial Economic Review, 5* (2), 15–35.

Rong, C. (2017). Enlightenment from the Alameda Corridor's container sea-rail intermodal transport. *Railway Transport and Economy*, 11, 92–97.

Rong, C., Li, X., Wang, X., & Yan, F. (2020). On the transformation trend of distributed transport supply. *Journal of Beijing Jiaotong University*, 3.

Rong, C., Lin, X., & Li, H. (2021). *General theory of transportation economics*. Economic Science Press.

Shi, Z. (2013). Thoughts on the transit time limit of railway freight. *Railway Freight*, 6.

Shramenko N. Y. (2018). Mathematical model of the logistics chain for the delivery of bulk cargo by rail transport. *Engineering, Mathematics*. *5*(5), 136-141. doi: 10.29202/nvngu/2018-5/15.

State Energy Railway Equipment Company (2023). The railway equipment company of China energy investment corporation has opened up the "veins" for high-quality transportation. Available from: https://cpnn.com.cn/dianli/fadian/fadianyw/202301/t20230129_1580210.html (accessed 29 January 2023).

Troche, G. (2005). *High-speed rail freight: Sub-report in efficient train system for freight transport*. Stockholm: Swedish National Road and Transport Research Institute.

Virum, H. (2007). Third party logistics development in Europe. *Logistics and Transportation Review, 6*, 66–67.

Wang, D., Huang, F., & Hou, J. (2016). Research on the development of logistics of Deutsche Bahn AG. *Railway Transport and Economy, 8*.

Wei, H. (2024). Making new achievements in the in-depth promotion of the adjustment of the transportation structure. *China Transport News*. Available from: https://www.chnrailway.com/index/shows?catid=10&id=15615 (accessed 17 May 2024).

Xiao, X. (2020). Xiao Xing's casual talk on logistics. *Ximalaya Applied March, 1*, Available from: https://www.ximalaya.com/album/35153602

Yang, H. (2015). *Railway transportation organization* (4th ed.). China Railway Publishing House.

Yang, Y. (2024). Accelerating the transformation of railway freight to modern logistics. *China Logistics and Purchasing*, 6.

Zhang, T., Lin, B., & Zhang, L. (2006). Research on organizing fixed-schedule trains on direct train lines. *Railway Transport and Economy*, (7).

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