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Synergistic Development of China Railway Express and Liner Shipping under "the Belt and Road"

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Abstract

Since 2013, when General Secretary Xi proposed the"The Belt and Road" initiative, China railway express has been growing rapidly. In particular, the blockage of the Suez Canal has drawn attention to the need to find alternative solutions for shipping, but also to consider the environmental impact of carbon and sulfur emissions from the transportation industry. In the context of practicing the "The Belt and Road" initiative and starting a new journey of a strong transportation country, this paper analyzes the differences between China railway express and China-Europe maritime liner transportation in different regions by constructing a generalized cost function model and considering the negative impacts of transportation cost, transportation time, time value cost of goods and carbon and sulfur emissions. It is found that regions close to inland will choose China railway express more often, while regions close to ports will choose liner shipping more often. It is also important to be alert to the increase of carbon emissions caused by liner shipping and the increased use of liner shipping under the sulfur restriction.

Keywords

Generalized Transportation Costs, China Railway Express, Liner Shipping, Synergistic Development.

1. Introduction

In September and October 2013, General Secretary Xi Jinping proposed the initiative of building the Silk Road Economic Belt and the 21st-Century Maritime Silk Road during his visits to Central Asia and Southeast Asia[1]. Since then, "the Belt and Road" has developed rapidly and become an important practical platform to promote the building of a community of human destiny. "The Belt and Road" initiative has played a great role in helping developing countries, including China, to seek new economic growth points and promote sustainable economic growth. At the same time, the initiative also clearly proposes to highlight the concept of ecological civilization in investment and trade, strengthen cooperation on ecological environment, biodiversity and climate change, and build a green Silk Road.

In 2017, waterway transportation accounted for the highest share of China's exports to the Belt and Road countries, reaching US$567.93 billion, accounting for 73.4% of China's exports to the Belt and Road countries, followed by air transportation, road transportation, railway transportation, other transportation and mail transportation, accounting for 12.3%, 11.9%, 2.0%, 0.4% and 0.1%, respectively[2]. In the case of China and Europe, the share of rail transport has been on the rise between 2002 and 2017, with the rapid development of China railway express(CR Express) taking credit, but sea transport still occupies half of the China-Europe transport market. According to Chinese customs statistics, China's total trade with Europe reached US$ 907.557 billion in 2020, an increase of 3.5% year-on-year.

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CR Express is an emerging mode of transportation between China and Europe under the initiative of "the Silk Road Economic Belt", and the number of CR Express has exceeded 10,000 trains in 2020. The annual 12,406 trains were operated, an increase of 50% year-on-year. The comprehensive heavy container rate reached 98.4%, an increase of 4.6 percentage points year-on-year[3]. Due to the outbreak of the COVID-19, shipping and air cargo space is scarce, and CR Express have become a new choice for foreign trade enterprises.

80% of China's foreign trade transport relies on sea transport, which has the advantages of large capacity, cheap freight, and more frequent. However, the disadvantages of long distance, slow speed, poor timeliness and geopolitical risks of transport routes cannot be ignored. Compared with the traditional liner transportation, CR Express has the advantages of fast speed, short time, only one-third of the time of sea transportation[4], strong timeliness, high safety factor, green and environmental protection, etc. In addition, coupled with the promotion of "the Belt and Road" policy and government support in recent years, the price has a certain attraction. CR Express has enriched the means and methods of trade transportation between China and Europe, and plays an important role in the trade transportation between China and Europe.

Due to the government's strong support for "the Belt and Road" initiative and the need to build a world-class shipping power, for China-Europe trade transport in consideration of transport costs on the choice of transport methods at the same time to consider the impact of carbon and sulfur emissions, while the implementation of sulfur restrictions and the impact of the epidemic sea freight prices surge, the growing demand for trade in Europe and other places In such a situation, it will be of great significance to study the synergistic development of CR Express and liner transportation, which are subject to the blockage of Suez Canal and the urgency of seeking other transportation solutions.

2. Literature Review

This paper focuses on the generalized transportation costs consisting of transportation costs, time value of goods, fuel consumption costs and environmental costs in the transportation process from Shanghai, Wuhan and Chongqing to Duisburg, and compares them according to the different transportation modes chosen for different regions.

A variety of alternative modes of transportation exist, commonly maritime, road, air, and rail transportation, etc. Lian et al. analyzed the impact of the frequency of CR Express operations and the percentage of increased fuel costs passed on to shippers by liner carriers on the division of different modes of commodity transportation, the profitability of carriers, and total carbon and sulfur emissions under sulfur restrictions[5]. By constructing a utility function considering cost, environmental impact, modal reliability and safety, transport time and infrastructure reliability, demonstrating the significant advantages of CR Express over traditional ocean routes and their heterogeneous impact on different regions of China, emphasizing the importance of considering infrastructure reliability when selecting trade routes[6]. As can be seen, most of the studies by scholars on the choice of transport modes are constructed based on freight rates and transport time, with little consideration of the loss of time value of goods during transport. In this paper, the time value of goods is included in the scope of the study.

In terms of cargo time value, Wang proposed that CR Express is profitable only when it is used to transport the right cargo or in the right regional environment, and that CR Express only plays the role of complementing ocean transportation and can never be replaced[7]. Based on sensitivity analysis, Yiran Zhao et al. studied the impact of changes in the time value of cargo and the frequency of CR Express departures on the sharing rate of sea-rail-air transport modes, revealing the main marketing directions and marketing tools for future CR Express[8]. Most scholars on the study of time value of cargoes target a single cargo, but the time value of different commodities is different and may not be applicable for other commodities.

For the study of environmental costs, Yingxia Xue et al. analyzed the calculation method of carbon emission costs of maritime transport and the optimization of liner shipping routes in a low-carbon context[9]. The uncertainty and dynamism of the development of the CR Express, the New Asia-

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Europe Continental Bridge and traditional maritime transport are discussed in three different scenarios[10]. Regarding the environmental costs, most scholars considered only carbon or sulfur emissions, and few considered the environmental impacts of both emissions. In this paper, we consider the impact of carbon emission cost on the choice of transportation mode based on the context of sulfur restriction.

Larranaga used the Stated Preference (SP) method to determine the parameters of multiple logit models and analyzed the competitive relationship between road, intermodal including rail and intermodal including inland waterway transport in Rio Grande do Sul, Brazil, concluding that the most important factor influencing the choice of transport mode is the reliability of transport, followed by the cost of transport[11].Jiang et al. selected five typical CR Express and analyzed the comparison between CR Express and maritime transport from the perspective of freight cost, and the results showed that government subsidies for CR Express help reduce the cost by 60% and shippers of IT products are more likely to choose CR Express[12]. At present, many studies are about the competitive analysis of CR Express and liner transportation, but there are fewer studies about the synergistic development of the two transportation modes.

Analyzing the current situation and existing problems, it is found that domestic and foreign scholars for generalized transportation costs are generally constructed by the published tariffs of carriers and transportation time, and rarely consider the influence of time value of goods, etc. However, from the practical point of view, it is unreasonable to ignore these factors, because cargo owners consider not only transportation costs but also losses suffered by cargoes due to time delays when choosing transportation modes. In addition, there are fewer studies on the choice of transportation modes considering carbon emissions. With the growing problem of carbon emission, carbon emission is also a key factor to be considered in the study of transportation mode selection. In this paper, we construct a generalized cost function model in the context of "The Belt and Road", and consider the effects of transportation cost, transportation time, time value cost of goods and environmental cost to explore which transportation mode should be chosen by different regions when transporting goods.

3. Model Building

3.1 Problem Description

In recent years, the transport industry has been actively responding to "The Belt and Road" initiative, serving the new development pattern of domestic circulation as the main body and domestic and international circulation promoting each other, seizing the opportunity of national transport structure adjustment and development, strengthening the collaboration between road, port and airline, taking the service of industrial chain and supply chain smoothly as its responsibility, continuously improving the marketing network of logistics services in the hinterland. The outbreak of the new crown epidemic in 2020 had led to a continuous tightening of container supply and an imbalance in capacity, resulting in higher freight rates. This time, due to the blockage of Suez Canal, many shippers turned to CR Express, resulting in higher freight prices for CR Express. How to choose the right transportation method is a question worth considering for shippers.

This study analyzes the impact of freight rates on shippers' transport mode choice in the China-European freight market, taking into account the value of cargo time and environmental costs. We decompose the comprehensive transportation costs into two parts, namely the total transportation time (including in-transit and waiting time) costs and the total transportation costs, in order to determine how shippers should consider when choosing a transportation mode.

3.2 Method

Transportation cost is the most important influencing factor for transportation mode selection. Through comparative analysis, this study aims to compare the changes of transportation costs between CR Express and liner transportation in the China-Europe freight market due to the different origins, in order to select the most suitable transportation mode. The transportation costs are broadly defined, including transportation costs, time value of goods, fuel consumption costs and environmental costs.

3.3 Components of Generalized Transportation Costs

3.3.1 Transportation Costs

The cost of transportation depends on the price of containerized cargo, the distance of transportation and the number of containers. Since there are domestic and foreign sections of CR Express in the transportation process, the prices of different transportation routes are different due to the cooperation issues of countries along the route, and there is no official or authoritative data information on the freight rates of CR Express ever released, and the reference data are extremely scarce. In this paper, we take the price of container transportation of CR Express as 3.2CNY/KM and calculate the formula as follows.

$$C_C = 3.2LN \tag{1}$$

CC is the CR Express transportation cost, L is the CR Express transportation distance, and N is the number of standard containers (TEU).

In the use of sea-rail transport, the rate of containerized cargo of the railroad transport section is determined according to the "Rules of Railway Cargo Tariff" with the formula:

$$C_C = (C_1 + C_2 L)N \tag{2}$$

C_1 is the base price1 in CNY /TEU; C_2 is the base price2 in CNY /TEU-km.

Table 1. Domestic railroad container cargo tariff rates

Box type standard	Base price1 /(CNY /TEU)	Base price2/(CNY /TEU-km)
20ft container	440	3.185
40ft container	532	3.357

Data source: China Railway Corporation

3.3.2 Time Value of Goods

In the market affected by policy adjustments, changes in supply and demand and other factors, the value of the product is constantly changing. Some of the goods depreciate rapidly, presenting time sensitivity and increased timeliness of transportation. In order to put the goods on the market faster, customers are willing to pay additional transportation costs. The time value of goods is used to replace the time of transportation of goods in order to translate into transportation costs, which are calculated as follows.

$$C_{1k} = U_i T_k \tag{3}$$

$$U_i = \frac{M_i r}{24 \times 365} \tag{4}$$

C_{1k} is the time value cost of transporting goods using mode k, U_i is a constant proportional to the value of commodity i, T_k is the total transit time (hour) for transporting the commodity using mode k, M_i is the monetary value of commodity i (USD/TEU), and r is the opportunity cost of the shipper's capital. In practice r is considered to be the annual rate of return on a risk-free investment, usually expressed in terms of long-term government bond rates.

$$T_0 = Tt_0 + T_{0w} \tag{5}$$

$$T_{0w} = \frac{168}{2f_0} \tag{6}$$

T_0 is the time of CR Express transportation and T_{0W} is the waiting time of CR Express transportation. f_0 (frequency/week) is the frequency of CR Express departure, 168 hours a week, then the time interval between adjacent liner is $168/f_0$. We assume that the goods arrive evenly, so the average waiting time for each shipment is $168/2f_0$.

3.3.3 Fuel Consumption Cost

Vessels use low-sulfur fuel oil (MGO) and heavy fuel oil (IFO) as fuel for the main engines when sailing inside and outside the Emission Control Area (ECA), respectively; the main engines do not consume fuel while in port, and the auxiliary engines consume low-sulfur fuel oil for normal operation.

$$T_1 = T_{1in} + T_{1out} + T_{1w} \tag{7}$$

$$T_{1in} = \frac{d_{1in}}{v} \tag{8}$$

$$T_{1out} = \frac{d_1 - d_{1in}}{v} \tag{9}$$

Equation (7) calculates the liner sailing time, including the sailing time T1in and T1out the emission control area and the waiting time T_1w in the port. In equations (8) and (9), d1in and d1out represent the sailing distance and total sailing distance in the emission control area, respectively, and v is the average sailing speed.

In the study of ship speed, following the rule of three for ship speed and design speed [13,14,15] the daily fuel consumption of the liner main engine in the emission control area is defined as:

$$M_1 = F_M \left(\frac{v}{v_d}\right)^3 \tag{10}$$

M_1 is the daily fuel consumption of the main engine and F_M is the daily fuel consumption of the main engine when driving at the design speed V_d.

$$F_M = (SFOC_M EL_M W_M)\frac{24}{10^6} \tag{11}$$

$SFOC_M$ is the fuel consumption per kWh of the mainframe, and EL_M and W_M are the load factor and power of the mainframe, respectively.

Auxiliary engines provide auxiliary power required for ship power generation and fuel consumption is independent of ship speed. The daily fuel consumption of the auxiliary engine is expressed as:

$$M_2 = (SFOC_A EL_A W_A)\frac{24}{10^6} \tag{12}$$

M_2 is the daily fuel consumption of the auxiliary machine. $SFOC_A$ is the fuel consumption per kWh of the auxiliary machine, and EL_A and W_A are the load factor and power of the auxiliary machine, respectively.

The fuel cost is the product of time, daily fuel consumption and fuel price. The fuel costs inside and outside the emission control area are:

$$C_{2in} = P_{MGO}\frac{T_{1in}}{24}(M_1 + M_2) \tag{13}$$

$$C_{2out} = \frac{T_{1out}}{24}(P_{IFO}M_1 + P_{MGO}M_2) \tag{14}$$

Taking into account the cost of fuel while waiting in port to bring the costing closer to reality, the cost of fuel while waiting in port is calculated as follows.

$$C_{2W} = P_{MGO}M_2\frac{T_{1W}}{24} \tag{15}$$

Total cost of fuel for liner shipping:

$$C_2 = C_{2in} + C_{2out} + C_{2W} \tag{16}$$

C_{2in} and C_{2out} are the fuel cost inside and outside the emission control area, respectively, C2W is the fuel cost while waiting in port, C_2 is the total fuel cost, and P_{MGO} and P_{IFO} denote the price of MGO and IFO fuel, respectively.

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3.3.4 Environmental Costs

With the increase in domestic and international transportation demand, traffic pollution is becoming a serious problem. Many countries are developing green transportation development strategies and using carbon taxes to limit carbon emissions from transportation. China's CO_2 emissions are striving to peak by 2030 and become carbon neutral by 2060.

Environmental costs in transportation mainly include carbon and sulfur emissions, and the calculation of CO_2 and SO_2 emissions usually adopts the indirect approach of energy conversion. Railroad transportation mainly relies on electric traction, and electric locomotives do not produce carbon and sulfur emissions during transportation, while electric energy is a secondary energy source, and carbon and sulfur pollution are produced during power generation, and the amount of energy consumed during power generation is counted as energy consumption during transportation of electric locomotives. According to the accounting method given in the "Guidelines for the Preparation of Provincial Greenhouse Gas Inventories" issued by the National Development and Reform Commission, the environmental cost of the shuttle train is calculated as follows.

Carbon Emissions :

$$Q_{c0} = \pi_1 \lambda d (D_1 \kappa_1 + D_2 \kappa_2 + D_3 \kappa_3) \tag{17}$$

Cost of carbon emissions :

$$C_{c0} = Q_{c0} \Omega \tag{18}$$

Sulfur emissions :

$$Q_{s0} = \pi_2 \lambda d (D_1 \kappa_1 + D_2 \kappa_2 + D_3 \kappa_3) \tag{19}$$

Q_{c0}, C_{c0}, Q_{s0} are the unit carbon emission (kg/TEU-km), unit carbon emission cost, and unit sulfur emission respectively; Ω is the carbon emission environmental tax levy price; π_1 is the carbon emission coefficient of electric energy (kg/Kwh), π_2 the sulfur emission coefficient of electric energy (kg/Kwh); λ is the unit energy consumption of electric locomotive (Kwh/TEU-km), D_1、D_2、D_3 are the transportation distance of domestic section, Russian section and European section, d is the number of containers, κ_1、κ_2、κ_3 are the proportion of coal power generation in domestic, Russian and European regions.

The environmental costs of the liner are as follows.

Carbon Emissions :

$$Q_{c1} = \frac{T_{1in}}{24} \theta_1 (M_1 + M_2) + \frac{T_{1out}}{24} \theta_2 (M_1 + M_2) + \frac{T_{1W}}{24} M_2 \theta_1 \tag{20}$$

Cost of carbon emissions :

$$C_{c1} = Q_{c1} \Omega \tag{21}$$

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Sulfur emissions :

$$C_{s1}=(M_1+M_2)\frac{T_{1in}}{24}\delta_1+(M_1+M_2)\frac{T_{1out}}{24}\delta_2+M_2\frac{T_{1W}}{24}\delta_1 \tag{22}$$

Here Q_{c1}、Q_{s1} and C_{c1} are carbon emissions, sulfur emissions and carbon cost, respectively; θ_1、θ_2、δ_1 and δ_2 are the carbon emission factors of the fuel used inside and outside the emission control area and the sulfur content of the fuel, respectively.

4. Empirical Study

4.1 Data Sources

In this paper, Duisburg is the destination, and the starting place is chosen from three cities with large geographical differences, namely Shanghai, Wuhan and Chongqing. For China-Europe cargo transportation, there are two common modes of transportation, one is liner transportation, and the mode of China-Europe sea transportation in this paper refers to the iron-sea transportation formed by relying on the sea route and domestic railroad, and the other is China railway express. The transport paths of Shanghai, Wuhan and Chongqing using different transport modes are shown in Table 2.

Table 2. Transportation path of different transportation modes

Related indexes	Liner Transportation	China railway express Transportation
Shanghai - Duisburg	Shanghai - Rotterdam - Duisburg	Shanghai - Suzhou - Duisburg
Wuhan - Duisburg	Wuhan - Yantian - Rotterdam - Duisburg	Wuhan - Duisburg
Chongqing - Duisburg	Chongqing - Yantian - Duisburg	Chongqing - Duisburg

In the liner transportation, CHINA COSCO SHIPPING GROUP AEU6 route was chosen. According to the route information published on its official website, AEU6 route connects 13 Chinese and foreign ports including Qingdao, Shanghai, Ningbo, Shenzhen, Singapore, Port Klang in Malaysia, Antwerp in Belgium and Rotterdam in the Netherlands, etc. The vessel transported is named APL MERLION container ship. The barge named QUINTO of CONTARGO Group is used to transport the cargo to Duisburg.

The analysis in this paper uses the data of China railway express and liner transportation operation in 2020, whose main sources are the railroad liner container cargo tickets, China Railway Corporation's China railway express operation program, China Railway 95306, China railway express integrated service platform, Europe portal, CHINA COSCO SHIPPING GROUP, portdisance website, Shanghai Shipping Exchange, Clarkson, China Maritime Service Network and CONTARGO Group official website, etc. The prices of bunker fuels are obtained from China Maritime Services website, and the average fuel prices in December 2020 are 420USD/t for low sulfur fuel oil (MGO) and 315USD/t for heavy sulfur oil (IFO380).

4.2 Calculation of Transportation Costs

4.2.1 Transportation Costs

According to formula (1) to calculate the transportation cost of China railway express from Chongqing to Duisburg; Shanghai to Suzhou, Chongqing to Yantian, Wuhan to Yantian railroad section transportation take domestic container tariff, the dollar exchange rate is taken as 1:6.5, according to formula (2) to get its transportation cost. The liner shipping and foreign river transportation costs are obtained according to the tariffs published on the official websites of CHINA COSCO SHIPPING GROUP and CONTARGO Group. The total transportation cost is finally obtained as shown in Table 3.

Table 3. Unit transportation costs of different transportation modes in the three regions

Related indexes	Shanghai - Duisburg	Wuhan - Duisburg	Chongqing - Duisburg
Liner transportation costs(USD/TEU)	4324.88	5216.38	6006.75
China railway express transportation costs(USD/TEU)	5819.62	5267.69	5503.51

Data source: Calculated and compiled by the author

From Table 3, we can see that the transportation cost of Shanghai to Duisburg by liner transportation is less than that of its China railway express, while the opposite is the case for Chongqing and Shanghai. This is due to the fact that Chongqing is landlocked and it is more convenient to transport using the China railway express,and with the strong support from the Chinese government, the cost of rail transport is decreasing. Shanghai has an international port, and even with the increase in ocean freight rates due to the epidemic, its liner shipping costs are still less than those of the China railway express. However, with the increase of sea freight and the government's support to "The Belt and Road", the difference of transportation cost between the two modes of transportation will be reduced. Wuhan is in the central region of China, no matter what kind of transportation method is used, the impact on the transportation cost is small.

4.2.2 Time Value of Goods Costs

As of December 19, 2020, the 10-year Treasury yield is 3.2953%, i.e.r = 3.2953%. The time value cost per unit of cargo transported by China railway express and liner transportation is obtained according to equations (3) and (4) as shown in Table 4.

Table 4. Cost of time value of goods per unit for different modes of transportation in three regions

Related indexes	Shanghai - Duisburg	Wuhan - Duisburg	Chongqing - Duisburg
Liner transportation costs(USD/TEU)	0.0032Mi	0.0030Mi	0.0031Mi
China railway express transportation costs(USD/TEU)	0.0015Mi	0.0012Mi	0.0012Mi

Data source: Calculated and compiled by the author

The time value of cargoes is mainly affected by time. China railway express transport time is short and strong time-efficient, while liner transport time is long and poor time-efficient. For goods with rapid changes in supply and demand may prefer China railway express transportation. Although Shanghai, Wuhan and Chongqing are in different geographical locations, the difference in the cost of time value of goods is not very big. The blockage of the Suez Canal this time caused congestion in

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the shipping lanes, which had an impact on global logistics, resulting in delayed delivery of some commodities, and even if the blockage is resolved quickly, port congestion and further delays in the already constrained supply chain are inevitable. In this case, the use of the China railway express is also a good option.

4.2.3 Fuel Consumption Cost

Considering that rail transport is mainly using electricity, the cost of fuel consumption during rail transport by China railway express and domestic section is not considered for the time being. The calculations are the same as for sea transport when using barges for inland transportation from Rotterdam to Duisburg. Since we could not find the fuel quantity for the main engine and auxiliary engine of QUINTO barge, we chose the same barge with the same deadweight tonnage as in the case and took an approximate value for the fuel consumption to calculate the barge fuel quantity.

The main data for APL MERLION's container ships and QUINTO barges are shown in Table 5.

Table 5. Vessel parameters

Indicators	APL MERLION	QUINTO
Fuel consumption per kWh for mainframe $SFOC_M$ /(g/KW·h)	175	206
Fuel consumption per kWh for auxiliary machines $SFOC_A$/(g/KW·h)	221	221
Design speed v_d /(knots)	23	20
Power of main machine W_M /(KW)	62030	1760
Power of auxiliary machine W_A /(KW)	4000	69
Mainload factor EL_M	0.8	0.8
Auxiliary machine load factor EL_A	0.5	0.5

Data source: Clarkson official website

The fuel consumption and unit fuel cost during liner transportation are calculated according to Equations (10)-(16) as shown in Table 6.

Table 6. Fuel consumption and unit fuel cost

Indicators	Shanghai - Duisburg	Wuhan - Duisburg	Chongqing - Duisburg
Amount of fuel consumed by the main engine per day /(t)	99.90	99.90	2.49
Amount of fuel consumed per day by auxiliary machines /(t)	10.61	10.61	0.18
The amount of fuel consumed in the emission control area /(t)	170.37	105.91	2.01
The amount of fuel consumed outside the emission control area /(t)	2541.73	2417.41	0
Amount of fuel consumed during waiting time at the port /(t)	95.91	80.00	0.13
Unit fuel cost /(USD/TEU)	67.95	62.58	10.94

Data source: Calculated and compiled by the author

The Shanghai to Rotterdam and Yantian to Rotterdam liner shipments are the same vessel on the same route, with the same amount of fuel consumed per day by the main engine and auxiliary engines, but with different ranges of the emission control area, resulting in differences in the amount of fuel within and outside the emission control area. Rotterdam to Duisburg is a cargo transportation via inland waterways and both are within the emission control area.

4.2.4 Environmental Costs

According to the data published by Lanzhou Railway, the unit energy consumption of electric locomotive is 0.14Kwh/TEU-km, and the average emission factor of national power grid in 2015, i.e., the carbon emission factor $\pi 1$ of electric energy in China is 0.6101kg/Kwh, and the sulfur emission factor π_2 of electric energy is 0.28kg/Kwh. The analysis of the electricity structure of the world in 2019 published by China Electricity Network obtains the proportion of coal power generation in China, Russia and Europe as 66.7%, 64% and 22.6%, respectively. The carbon and sulfur emissions of liner transportation are obtained from Equations (17) and (19).

The energy carbon emission factor is the amount of CO_2 generated per unit of energy consumed. The IMO GHG Study of 2009 measured the carbon emission factors of heavy and light fuel oil for ships, which were 3.012 and 3.082 (in CO_2t/bunker oil t), respectively [16], and the low-sulfur oil MGO used in this paper is light oil and IFO380 is heavy oil. According to the sulfur limit order, the sulfur content of marine fuels used inside and outside emission control areas is 0.1% m/m and 0.5% m/m, respectively. shipping sulfur emissions can be measured by fuel oil consumption and SO_2 emission statistics. By reviewing the literature on sulfur emissions, it can be seen that the amount of SO_2 produced by the consumption of 1t of heavy/light fuel oil is 0.06t and 0.02t respectively, which can be regarded as the sulfur emission factors of 0.06 and 0.02 for heavy and light fuel oil respectively (unit:SO_{2t}/ fuel oil t).

In this paper, it is assumed that both the China railway express and the liner are fully loaded and full, i.e. the maximum loading capacity of the liner is 13086 TEU and the maximum loading capacity of the China railway express is 120 TEU.

In the transport mode of rail-sea intermodal transport, carbon and sulfur emissions from domestic rail section cargo are obtained from equations (17) and (19).Carbon and sulfur emissions from maritime transportation are obtained from equations (20) and (22).The final emissions from the China railway express and liner transportation are obtained as shown in Table 7.

Table 7. Emissions of carbon and sulfur from different modes of transport in the three regions

Related indexes		Shanghai - Duisburg	Wuhan - Duisburg	Chongqing - Duisburg
Liner transportation	Carbon emissions/(kg/TEU)	694.23	710.06	801.95
	Sulfur Emission Volume/(kg/TEU)	11.95	39.25	81.42
China railway express transportation	Carbon emissions/(kg/TEU)	581.11	525.06	552.34
	Sulfur Emission Volume/(kg/TEU)	266.69	240.87	253.49

Data source: Calculated and compiled by the author

According to the World Bank report State and Trends of Carbon Pricing2019 published Singapore's carbon tax of 4USD/t. The final cost of carbon emissions for the two modes of transportation is shown in Table 8.

Table 8. Cost of carbon emissions for different modes of transport in the three regions

Related indexes	Shanghai - Duisburg	Wuhan - Duisburg	Chongqing - Duisburg
Liner transportation(USD/TEU)	2.78	2.84	3.21
China railway express transportation(USD/TEU)	2.32	2.10	2.21

Data source: Calculated and compiled by the author

As can be seen from Table 8, the unit carbon and sulfur emissions of liner transportation are higher than those of China railway express transportation, regardless of the location of the origin. The difference in carbon and sulfur emissions between the three locations when using China railway express transportation is mainly due to the difference in transportation distance, with the farther the distance, the higher the emissions. The regions with the highest carbon and sulfur emissions when using liner transportation are Chongqing, Wuhan and Shanghai in descending order. This is due to the fact that the liner transportation in this paper is by rail and sea, and the difference in distance in the domestic rail section leads to the highest emissions from Chongqing to Duisburg.

In this paper, electronic products, a cargo transported by the China railway express since its inception, are used as the goods transported. According to the data of Chinese customs in 2018, the fully loaded value of electronic product containers exported to Europe Mi is about 459,000 USD/TEU. calculated to obtain Table 9.

Table 9. Generalized transport costs and sulfur emissions for different modes of transport in the three regions

Related indexes		Shanghai - Duisburg	Wuhan - Duisburg	Chongqing - Duisburg
Unit generalized transport costs(USD/TEU)	Liner transportation	5889.40	6684.36	7524.31
	China railway express transportation	6531.36	5839.49	6076.40
Sulfur Emission Volume /(kg/TEU)	Liner transportation	11.95	39.25	81.42
	China railway express transportation	266.69	240.87	253.49

Data source: Calculated and compiled by the author

The generalized transportation cost of Shanghai to Duisburg liner transportation is lower than that of China railway express transportation, while the external environment remains unchanged and carbon emission cost is considered. The generalized transportation cost of liner transportation from Wuhan and Chongqing to Duisburg is higher than that of China railway express transportation. Therefore, considering the cost of carbon emission, China-Europe cargo transportation can choose the appropriate transportation mode according to the place of origin. With Wuhan as the critical point, liner shipping can be chosen for areas south of east of central China, and China railway express for areas north of west.

Due to the global implementation of sulfur restrictions, it is assumed that when sulfur restrictions are not considered, i.e., IFO 380 fuel is used throughout the voyage. The data obtained for China railway express and liner shipments are shown in Table 10.

The new sulfur restrictions have increased fuel consumption costs, but as refining technology continues to be optimized and upgraded, the price differential between low and high sulfur oils will narrow and the impact of sulfur restrictions on fuel costs will be reduced. However, we still need to be alert to the strengthening of environmental policies requiring further increases in emission control areas or the use of cleaner fuels, at which point fuel costs will increase.

Table 10. Carbon and sulfur emissions and cost of carbon emissions under different scenarios in the three regions

Related indexes			Shanghai - Duisburg	Wuhan - Duisburg	Chongqing - Duisburg
Consider sulfur restrictions	Liner transportation Liner transportation	Carbon Emissions/(kg/TEU)	694.23	710.06	801.95
		Sulfur emissions/(kg/TEU)	11.95	39.25	81.42
		Cost of carbon emissions/(USD/TEU)	2.78	2.84	3.21
	China railway express transportation	Carbon Emissions/(kg/TEU)	581.11	525.06	552.34
		Sulfur emissions/(kg/TEU)	266.69	240.87	253.49
		Cost of carbon emissions/(USD/TEU)	2.32	2.10	2.21
No consideration of sulfur restrictions	Liner transportation Liner transportation	Carbon Emissions/(kg/TEU)	691.05	707.29	799.18
		Sulfur emissions/(kg/TEU)	13.77	40.83	83.00
		Cost of carbon emissions/(USD/TEU)	2.76	2.83	3.20
	China railway express transportation	Carbon Emissions/(kg/TEU)	581.11	525.06	1214.16
		Sulfur emissions/(kg/TEU)	266.69	240.87	253.49
		Cost of carbon emissions/(USD/TEU)	2.32	2.10	48.57

Data source: Calculated and compiled by the author

As can be seen from Table 11, the carbon and sulfur emissions per unit container for liner shipping are still higher than those for the China railway express when sulfur restrictions are not considered, and the emissions increase with distance. Compared with the case when sulfur restriction is considered, the sulfur emissions from the China railway express, which relies on electric traction, remain unchanged. The implementation of the sulfur restriction has resulted in lower sulfur emissions from liner shipping, but an increase in carbon emissions. If the sulfur restriction is considered, the sulfur emissions of individual containers will be reduced by about 2%. This is because the sulfur content of the fuel used by the ship is reduced from 0.5% to 0.1%, which leads to the reduction of sulfur emissions in liner shipping. However, we should also be alert to the fact that the reduction of sulfur emissions in liner shipping due to sulfur restriction is accompanied by an increase in carbon emissions.

Secondly, the rapid development of cross-border e-commerce, overseas demand for products made in China is getting stronger. Coupled with the impact of the epidemic, Europe and the United States and other places rely heavily on imports due to the lack of production capacity, but the increase in the volume of transport led to a shortage of containers pushed up the transportation costs of sea routes. And due to the epidemic, resulting in container loading and unloading, handling, lifting, picking up, etc. received a serious impact on the terminal storage time increased significantly, and even lead to port congestion, further hindering the efficiency of container handling in the port, causing the ship waiting for berthing time extended. The blockage of the Suez Canal waterway leads to the transfer of cargoes with requirements for transportation timeliness from sea to the China railway express. At this time, the China railway express plays a significant role in supplementing the transport demand and relieving the pressure on logistics and transportation.

5. Conclusion

Despite the very special domestic and international environment has led to a historical imbalance between supply and demand. However, based on the short-term unsolvable container equipment turnover problem and the continued positive demand for container shipping market transportation, the market may continue to maintain such a hot market. At the same time, the government's support for "The Belt and Road" is likely to prompt more shippers to shift to the China railway express. As the most mature industry force to promote "The Belt and Road", the maritime industry should give full play to the backbone role in the construction of "The Belt and Road"; "The Belt and Road" is also the maritime industry it should seize the opportunity to improve the global shipping service network system, promote the formation of a new pattern of comprehensive opening, strengthen the pioneering role of maritime transport, drive the economic and social development along the route, and make positive contributions to the construction of the community of human destiny.

Based on the generalized transportation cost consisting of transportation cost, time value of goods, fuel consumption cost and environmental cost, this paper compares the generalized transportation cost of three different regions, Shanghai, Wuhan and Chongqing, under the two transportation modes of China railway express and liner, and considers the impact of environmental cost on China-Europe trade transportation.

The analysis and research in this paper shows that, taking Central China as the critical point, areas north of Central China to the west may use China railway express transportation when transporting cargoes, while areas south of Central China to the east are more likely to use liner transportation. When in Central China, different modes of transportation can be used depending on the demand for different cargoes. Although the sulfur restriction has a positive impact on reducing sulfur emissions, it will increase the carbon emissions from ships.

At present, due to the blockage of Suez Canal, cargoes with requirements for transportation timeliness are shifting from maritime transport to China railway express, and the railroad transport system of China railway express will effectively ease the tension of international logistics transport. It can be seen that railroad transportation will be increasingly recognized by traders and will probably be included as part of the supply chain in the future, becoming an effective supplement to maritime transport.

To simplify the calculation, for the costs of China railway express and liner shipping, only the difference and comparison of transportation costs are considered in the above cases, while cargo handling costs and labor costs, etc. are assumed to remain unchanged. Affected by the sulfur restriction, shipping companies may adjust their routes, adopt low sulfur fuel or install sulfur reduction towers. However, due to the lack of detailed data, only the cost comparison under the condition of adopting low-sulfur fuel is considered in this paper. In-depth analysis and thoughtful generalization of the choices of different emission reduction strategies can be carried out in the future.

References

[1] Vision and actions for promoting the construction of Silk Road Economic Belt and 21st Century Maritime Silk Road [J]. Transportation Finance and Accounting,2015(4):82-87.

[2] National Information Center "Belt and Road" Data Center. 2018 "Belt and Road" Trade Cooperation Big Data Report [DB/OL].http://www.sic.gov.cn/archiver/ SIC/UpFile/Files/Default/20180509162109827517.pdf.2018.

[3] Xinhua News Agency. China-Europe Classes to run 12,406 trains a year in 2020 [EB/OL]. http://www.gov.cn/xinwen/2021-01/19/content_5581186.htm.2021-01-19/2021-01-25.

[4] SearchNavigator.com. 2019 [2020/12/15]. 2020 Sulfur Restrictions to be implemented soon! Low-sulfur surcharges up sharply, ocean freight rates up 20% [EB/OL]. https://www.sohu.com/a/347624272_99994729.

[5] Lian F, He Y , Yang Z . Competitiveness of the China-Europe Railway Express and liner shipping under the enforced sulfur emission control convention[J]. Transportation Research Part E: Logistics and Transportation Review, 2020, 135.

[6] Wen X, Ma H L , Choi T M , et al. Impacts of the Belt and Road Initiative on the China-Europe trading route selections[J]. Transportation Research Part E Logistics and Transportation Review, 2019, 122:581-604.

[7] Jiaoe W,Jingjuan J,Li M . An organizational model and border port hinterlands for the China-Europe Railway Express[J]. Journal of Geographical Sciences,2018, 28(9):1275-1287.

[8] Zhao Yiran, Yang Zhongzhen, Theo Notteboom. The role of China-Europe railway express in China-Europe trade transportation [J]. Journal of Dalian Maritime University, 2018, 44(3): 33-40.

[9] Xue Yingxia, Shao Jungang. Liner Line Allocation in the Context of Low Carbon Economy [J]. China Navigation, 2014, 37(4): 115-119.

[10] Dong Y, Liping J , Ng A K Y . One Belt one Road, but several routes: A case study of new emerging trade corridors connecting the Far East to Europe[J]. Transportation Research Part A: Policy and Practice, 2018, 117:190-204.

[11] Larranaga A M, Arellana J , Senna L A . Encouraging intermodality: A stated preference analysis of freight mode choice in Rio Grande do Sul[J]. Transportation Research Part A Policy and Practice, 2016,102:202-211.

[12] Jiang Y, Sheu J B , Peng Z , et al. Hinterland patterns of China Railway (CR) express in China under the Belt and Road Initiative: A preliminary analysis[J]. Transportation Research Part E: Logistics and Transportation Review, 2018, 119:189-201.

[13] Corbett J J, Wang H , Winebrake J J,The effectiveness and costs of speed reductions on emissions from international shipping[J]. Transportation Research Part D, 2009, 14(8):593-598.

[14] Doudnikoff M, Lacoste R.Effect of a speed reduction of containerships in response to higher energy costs in Sulphur Emission Control Areas[J]. Transportation Research Part D Transport & Environment, 2014, 28:51-61.

[15] Wang S, Meng Q.Sailing speed optimization for container ships in a liner shipping network[J]. Transportation Research Part E, 2012, 48(3):701-714.

[16] Buhau, O, Corbett, J.J., Endresen, O., et al. Second IMO GHG study 2009.International Maritime Organization (IMO) London, UK, April 2009.