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RESEARCH ARTICLE

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Connecting the Belt and Road through sea-rail collaboration

Abstract As part of China's "the Belt and Road" strategy, China Railway Express provides alternative shipping routes and transportation modes from Asia to Europe and creates new opportunities for intermodal transportation in the shipping industry. A time–distance-based cost (time cost) function was proposed to compare China Railway Express with traditional transportation modes. Time cost was related to different types of cargoes, which exhibit distinct sensitivity to time. Using the proposed cost function as basis, we identified the cost indifference area where total costs are equal. Further analysis was performed for selecting the transportation mode and supply area for a specific cargo. This study provides various parties, such as business owners, the government, and the shipping industry, with many valuable insights.

Keywords China Railway Express, the Belt and Road, shipping industry, combined transportation

1 Introduction

In the past few decades, the global container shipping market has developed rapidly since 1960 in terms of direct shipping and transshipment. Sea transportation has been regarded extensively as the primary choice because it is clean, safe, and economical. Container shipping among regional and global major ports plays an important role given the tremendous freight transportation volume in present international trade. Drewry (Drewry Research, 2016) reported that the total volume has achieved 691 million TEUs and is expected to increase to 774 million TEUs by 2020. The development of container shipping in Asia-Pacific region is more intense than that in other regions because it is the center of world manufacturing industry and constitutes practically half of the total traffic (Lee et al., 2006).

The convenience of maritime transportation attracted various kinds of businesses and investments in the coastal region of China, such as Guangdong, Zhejiang, and Fujian. Products, such as toys, clothes and shoes, and electronic devices, can be easily loaded on container vessels and shipped to Europe. Bulk cargoes, such as coals, minerals, and grains, needed to be transferred via trains or barges from inland to sea port before sailing to Europe. With the increasing container vessel size and economic scale, shipping one TEU from Guangzhou to London only costs around 1,500 USD (Yang and Liu, 2015), which is the main attraction of sea transportation. However, the trip from Guangzhou to London lasts roughly 1 month due to the slow steaming of vessels. Another common choice is air transportation, which is completely of maritime transportation: shipment can be completed within a few days but costs around 70,000 USD per TEU (Verny and Grigentin, 2009). Despite the very high volume and very low cost of shipping compared with air transportation, the long shipping time is the major drawback: customers must either wait long or maintain high inventory, which reduces the value of products. Eventually, shippers have to make difficult decisions between timeliness and shipping cost.

In recent years, the environment of manufacturing industry in the coastal region has encountered several challenges due to increasing living and labor cost and difficulty of hiring skilled laborers. Many low-profit labor-intense industries began to relocate their business in central and western regions of China. For example, Foxconn, the largest electronic device assembler, initialized its business in Shenzhen many years ago. With the increasing labor and land costs, Foxconn has moved many operations toward inland cities, such as Chengdu and Wuhan. Similarly, Hewlett-Packard has shifted its production from Shanghai to Chongqing. Table 1 presents the index of manufacturing

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Table 1 Index of Manufacturing Industry Migration from 2003 to 2009

Manufacturing industry	Eastern regions	Central regions	Western regions
Coal processing	– 35.51	12.07	9.7
Food processing	– 28.72	19.81	4.45
Textile industry	– 27.28	6.23	6.56
Feather processing	– 25.24	14.86	9.88
Instrumentation	– 24.76	14.51	8.43
Other industry	– 24.09	11.61	9.79
Condiments & fermentations	– 22.85	– 3.03	21.17
Tea processing	– 22.84	10.91	11.72
Soft drink producing	– 22.4	9.17	8.82

industry migration from the National Bureau of Statistics in China.

With the movement of manufacturing industry, rail-sea combined transportation has become popular: containerized cargos are delivered to container ports via railway system and they are finally loaded to vessels after transshipment at sea terminals. In recent years, Customs has simplified the clearance process to improve the efficiency, which could save about one-day: instead of checking at sea terminals, Customs attempts to complete all necessary procedures before entering the railway system. Therefore, containers can be directly loaded to vessels without long delays after arrival at the sea terminal. However, the rail-sea combined transportation requires considerable cost and time than sea transportation.

In 2011, a new freight transportation mode — Chinese Railway Express (CRE) — started its operation. By connecting railway systems among different countries/regions, including China, Kazakhstan, Pakistan, Russia, and Europe, CRE served as an alternative for container transportation between China and Europe. As part of China's "the Belt and Road" strategy, CRE network has covered 16 cities in China and 12 cities in Europe and the accumulative value of import and export cargo has reached 17 billion USD at the end of June 2016. With the manufacturing industry moving from coastal region to inland, CRE can be a new option for companies in shipping their cargoes from China to Europe by railway instead of rail-sea combined transportation. In addition, shippers had to select between air transportation with high shipping cost or sea transportation with long shipping time in recent years, and a balanced method does not exist until CRE. CRE can provide a balanced alternative as shown in Table 2. Hence, this new freight transportation model will obtain a share of sea shipping market.

Currently, the primary challenge of CRE is its cost. High cost is due to the negotiation of shipping price between individual shippers and local railway bureaus, which makes it far from achieving the economies of scale. As CRE is still under test run, Chinese government provides subsidies, that is, 4,000–8,000 USD per rail car. To reduce the cost, the Chinese government is consolidating all shipping contracts to enable them to negotiate with the railway bureau of other countries for a low shipping price.

Another fact exists that may affect the shipping network significantly: as the manufacturing industry moved to South-east Asia with low labor cost and adequate work force, foreign direct investment (FDI) has increased rapidly in recent years, as shown in Fig. 1. With the increase of investment and manufacturing industry migration, container activities in this region have increased to 95 million TEUs, and are expected to grow to 106 million TEUs by 2020 according to Drewry (Drewry Research, 2016). The major import and export channel in this region is container shipping, and the majority of containers passes through the Strait of Malacca and then sails toward Europe. However, timeliness is still a challenge although the industry can benefit from a low manufacturing cost. CRE operation provides a new channel that can tradeoff between timeliness and cost for South East Asia-Europe shipping: instead of passing through Malacca, cargoes can be shipped to the coastal region of China, get onboard CRE, and then ship to Europe on the ground. For example, sailing from Haiphong (Vietnam), Port Kelang (Malaysia), Bangkok (Thailand) and Manila (Philippines) to Xiamen (China) takes around 3 days, and then CRE will take control, which requires around 12 days to reach Moscow (Russia).

Table 2 Timing and cost comparison between different transportation modes (Source: Port of Xiamen)

From Xiamen to Europe	By air	By CRE	By sea
Time needed (days)	3–7	14–16	35–45
Cost per TEU (USD)	40,000–80,000	9,000–11,000	2,000–3,000

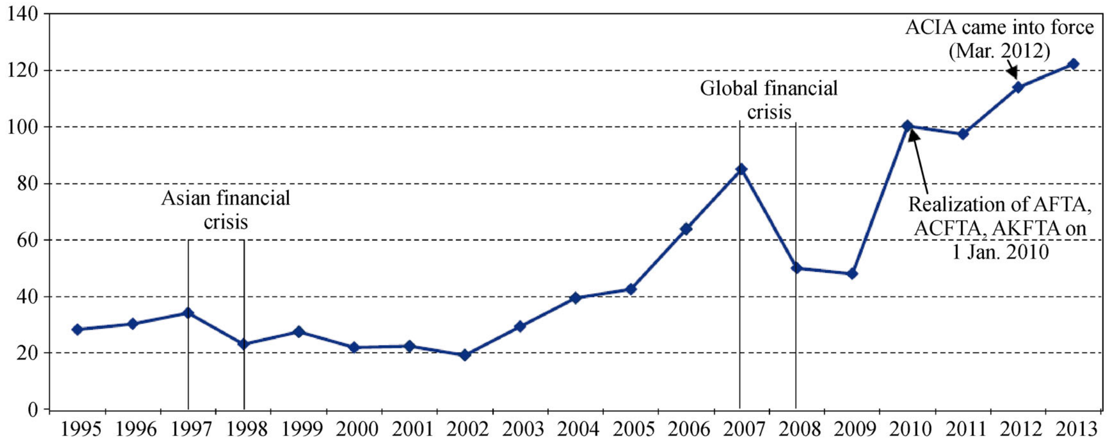

Fig. 1 ASEAN investment on a growth momentum (billions of USD)

In summary, CRE brings new challenges to traditional shipping industry with the movement of manufacturing industry and embarks new opportunities for intermodal transportation between sea and rail. In this study, we intended to compare the cost between new transportation and traditional modes for different types of cargoes and identify the area that will result in the same cost. Using the cost indifference area as basis, further analysis can be made for selecting the transportation mode and supply area for a specific cargo. This study can provide various parties with many valuable insights. For example, a business owner can roughly determine where he should locate his manufacturing facilities, the government can set corresponding strategies to attract new businesses, and the shipping industry can improve its operation to attract considerable customers by choose its shipping mode.

In recent years, the studies of CRE have emerged in China. Based on the national strategy of "the Belt and Road," Wang (2014) proposed a network of six major international channels, four border ports, and two main domestic railway channels. Wang (2015) compared the total transportation cost and shipping time of 12 fixed routes using CRE or other intermodal transportation services. The total transportation cost can be categorized as freight and inventory costs in terms of high and low-time sensitive cargoes. In this study, the key features of several major CRE services are also summarized in terms of market demand, network planning, and operation challenges. Li (2016) introduced the current operation status and existing problems of CRE, proposed the layout optimization problem of rail logistics center, and recommended the acceleration of international transit node construction.

Considerable papers studied CRE based on intermodal transportation perspective. For example, Cai (2015) established a multi-objective model with time and cost in the land-sea intermodal transportation. The heuristic algorithm and simulation method were used to obtain the Pareto optimal solution of shipping route. Gao (2016) proposed a freight model by analyzing the loop formed by CRE and maritime transport and found key nodes (the costs from the node to the destination are equal if traveling on two directions from the node). The nodes are regarded as the demarcation points, and economic transport routes are selected.

In summary, the research gap can be summarized as follows: (1) Many qualitative studies have discussed the advantages and disadvantages of CRE, and the quantitative analysis on CRE operation are compared with other transportation modes. (2) CRE is a new concept to intermodal transportation with special features on timing and cost. Thus, operators and decision makers should conduct new studies on CRE. (3) The special features of CRE also limited the types of cargo suitable for this new shipping mode. Hence, the tradeoff between time and cost with different types of cargo should be studied, which provided a new direction for the research on traditional intermodal transportation.

The remaining sections are organized as follows. Section 2 formulates the cost function, including freight and time costs, for rail transportation and rail-sea combined transportation modes. Section 3 conducts a comparison study among the three types of cargoes using two transportation modes. Section 4 proposes a similar study for two alternative transportation modes (sea transportation and sea-rail combined transportation). Finally, Section 5 presents the conclusions and recommendations for future research.

2 Problem description

As shown in Fig. 2, four areas are defined: origin area of sea and rail transport (O), destination area of sea and rail transport (D), supply area for a specific cargo (S), and the cost indifference area (C). With the operation of CRE, a

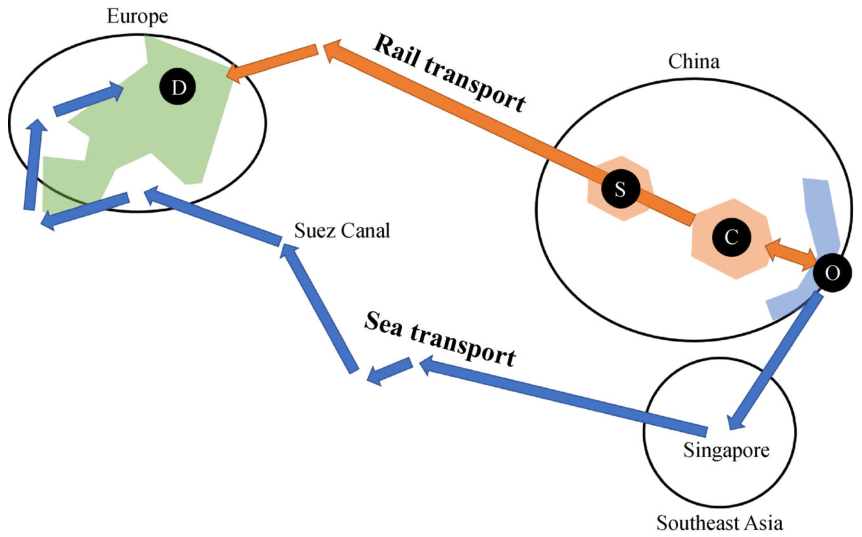

Fig. 2 Illustration of two transportation modes

new transportation mode is introduced in the shipping industry to compete with traditional rail-sea combined transportation. Hence, we define that

• Rail transportation (RT): the cargo will depart from the region where the manufacturer is located and be delivered by CRE to the region where the market is directly located, such as shipping from Region S to Region D with rail transport as shown in Fig. 2;

• Rail-sea combined transportation (RSCT): the cargo will be delivered from the supply region to sea port via railway system and then be shipped to the market region via container shipping, such as shipping from Region S to container terminal at Region O with rail transport, and then shipping from Region D to Region O with sea transport as shown in Fig. 2.

The goals of this study are to (1) identify the area that will result with the same cost between different transportation modes, which is defined as the cost indifference area, and (2) select transportation mode according to the supply area of the specific cargo. We can assume that the selected area is covered by the railway system and the business owner will set up its facilities near the railway system because it is fundamental public service in many counties. Setting up a business at the cost indifference area has no preference on transportation mode. If the business sets the supply area in another place, then the mode preference can be determined based on the relation between supply area and cost indifference area.

2.1 Total transportation cost

In this study, we defined that total transportation cost is composed of three components: the freight cost, which is determined by shipping distance, the time cost, which is mainly obtained from the on-route holding cost, and the setup cost, which includes one-time charges depending on the shipping mode, such as loading and unloading charges and clearance fees. Total transportation cost and its breakdowns can be represented as below:

$$C_m = CF_m + CT_m + CS_m, \tag{1}$$

where C_m is the total transportation cost of shipping mode$m \in \{RT, RSCT\}$. Its breakdown costs are CF_m freight cost, CT_m time cost, and CS_m setup cost. When $C_{RT} = C_{RSCT}$, cost indifference area α_0 can be calculated. For supply areas with $\alpha < \alpha_0$, RT mode should be selected, otherwise, RSCT mode should be selected.

2.2 Freight cost

The freight cost is charged by carrier and is calculated by shipping distance. As a high-level study, we can assume that rail and sea distances between O and D are given, which are represented by d_r and d_s. Considering that the study is focused in the supply area, we defined the rail distance from S to D as d_{SD}^r. To represent the location of supply area, coefficient α is introduced as

$$\alpha = \frac{d_{SD}^r}{d_r}. \tag{2}$$

Small α means that S is close to D, otherwise S is close to O. Then, the freight cost by RT and RSCT can be presented as below:

For RT, cargoes move directly from S to D by rail. Thus, freight cost can be expressed as

$$CF_{RT} = \alpha \times p_r \times d_r. \tag{3}$$

For RSCT, cargoes are moved from S to O by rail, and then from O to D by sea. Thus, freight cost can be expressed as

$$CF_{RSCT} = p_s \times d_s + p_r \times d_r \times (1-\alpha), \tag{4}$$

where p_s is the unit freight cost by sea (USD per TEU per km), and p_r is the unit cost by rail (USD per TEU per km).

2.3 Time cost

For the time value of cargo, Miao (2014) showed that many direct and indirect factors should be considered, such as fuel, oil, emissions, and extra operating costs, in-transit inventory holding costs, and potential lost sales cost. Intuitively, cargo time cost is also strongly related to the type of cargo. Generally, high-tech cargo with high value or perishable goods, such as food with limited expiration date, are sensitive to time. Thus, the longer shipping to the market, the less value of goods will remain. Yang et al. (2015) categorized the products as general and high-tech products with several time related costs.

In this study, we categorized the cargoes into three categories and three cost time factors, including service ρ_1, which includes insurance and taxes, and Transit Inventory Risk ρ_2, which includes damage, pilferage, and Obsolescence ρ_3. Usually, service and risk costs will increase with shipping time, and obsolescence is cargo dependent.

(a) Non-time-sensitive cargo: cargo is not sensitive to time, then obsolescence will not be considered. For example, cargoes, such as plastic box, steel tube, and slippers, will not decay significantly during transportation. Then, time cost is mainly obtained from service and transit inventory risk.

$$\beta(t) = cp \times \left(\rho_1 + \rho_2\right) \times t, \tag{5}$$

where cp is the value of cargo (USD), and t is the total shipping time (day).

(b) High-time-sensitive cargo: cargo is highly sensitive to time, and the obsolescence of cargo is also very sensitive. However, the obsolescence of cargo will not exceed the original value of the cargo. Hence, time cost can be defined as

$$\beta(t) = cp \times \left(\rho_1 + \rho_2\right) \times t + \min(cp \times \rho_3 \times t, cp), \tag{6}$$

(c) Partial-time-sensitive cargo: cargo is sensitive to time, but the market can tolerate a certain level of delay. In this case, we defined that cargo will start obsolescence after time t', and the cost will not exceed the original value of the cargo. Hence, time cost can be defined as

$$\beta(t) = \begin{cases} cp \times (\rho_1 + \rho_2) \times t \\ t \leqslant t' \\ cp \times (\rho_1 + \rho_2) \times t + \min(cp \times \rho_3 \times (t-t'), cp) \\ t > t' \end{cases}, \tag{7}$$

where t' is the market tolerance in terms of time (day).

Then, we defined total transportation time as RT and RSCT:

$$T_{RT} = \alpha \times T_r, \tag{8}$$

$$T_{RSCT} = T_s + (1-\alpha) \times T_r, \tag{9}$$

where T_r, T_s are the shipping time from O to D by rail and sea, respectively.

Finally, we can obtain the time cost of RT:

$$CT_{RT} = \beta(T_{RT}). \tag{10}$$

The time cost of RSCT:

$$CT_{RSCT} = \beta(T_{RSCT}). \tag{11}$$

2.4 Setup cost

Based on Table 3, we concluded that most of the RT setup cost came from the costs of cooling, empty rail car returning, container usage, weighing, and several incidental cost. Meanwhile, for RSCT, the setup cost included RT and terminal related costs, such as loading and unloading costs and terminal usage. Finally, we can have

Table 3 Setup costs by sea and rail

Setup cost by sea	USD per TEU	Setup cost by rail	USD per TEU
Booking charge	40	Weighing fee	4
Warehouse charge	74	Cooling cost	89
Document charge	22	Empty rail returning freight	59
Terminal handling charge	70	Container usage charge	37
Port construction charge	12		
Weight due	3		
Other	59	Other	30
Total cost	280	Total cost	220

Date sources: Port charge rules (foreign trade section) was from The Chinese Ministry of Communications Decree No. 11 of 2001. The table of railway freight miscellaneous fees was promulgated by Chinese Ministry of Railways.

$$CS_{RT} = 220, \quad (12)$$

$$CS_{RSCT} = CS_{RT} + 280, \quad (13)$$

where the unit is in USD per TEU.

3 Numerical experiment

In this section, we will find cost indifference area α_0 when $C_{RT} = C_{RSCT}$.

According to three categories of cargoes, three products are selected, such as plastic box, middle-quality clothing, and branded electronic blender. Plastic box is inexpensive with low additional value. Thus, it is used as non-time-sensitive cargo. Clothing is defined as high-time-sensitive cargo to time because its life cycle is short, for example, seasonal market, in which the total life cycle is around 90 days. The market may incur loss if clothing cannot enter the market immediately. Electronic blender is a popular home appliance, and companies upgrade their product line rapidly with new technology and functions. To be attractive and competitive, these products should enter the market quickly to occupy the market. However, the life cycle of electronic blender is longer and its market tolerance is higher compared with clothing. Therefore, no time cost is required for the time period at the beginning, and time cost will be incurred subsequently. Based on cargo unit price and volume per TEU of Yang et al., we summarized the cargo value and cost factors in Table 4.

As the manufacturing industry move toward inland China as shown in Table 2, we will demonstrate how to identify the cost indifference area for three types of cargoes. Table 5 and Table 6 define the origins, destinations, and related distance and time between O and D.

Based on C_{RT} and C_{RSCT} introduced in Section 2, we can see the α-cost plots for three cargoes as shown in Fig. 3. In Fig. 3(a), plastic box is suggested to use RT if the supply area is located at the place with α<0.79, or by RSCT if the supply area is located at the place with $\alpha > 0.85$. Meanwhile, from geographic point of view, if the supply area of plastic box is located in China and $\alpha > 0.85$, it should consider using RSCT and should be near the sea ports. For clothing and electronic blender, RT is suggested to be their primary selection because time cost will significantly increase the total cost of RSCT. The experiments have demonstrated that the proposed method can be used for obtaining several high-level intuitions for the government on industry migration, that is, the kind of industry that should be relocated to which region of China. Certainly, various products with different characteristics will lead to different results. Similar experiments can be applied to other analysis if data are available.

Table 7 shows the total transportation cost reduction of RSCT by reducing sea shipping time. By reducing the sea shipping time, RSCT cost can be reduced, especially for high-time sensitive cargoes. Table 8 shows the sensitivity

Table 4 Time cost for different cargoes

Cargo	Value of cargo per TEU (,000 $)	Time cost factors
Plastic box	328	$\rho_1 = 0.014\%$, $\rho_2 = 0.014\%$, $\rho_3 = 0$
Clothing	7,296	$\rho_1 = 0.014\%$, $\rho_2 = 0.014\%$, $\rho_3 = 1\%$
Electronic blender	936	$\rho_1 = 0.027\%$, $\rho_2 = 0.027\%$, $\rho_3 = 3\%$, $t' = 35$

Table 5 Shipping distance, time, and price by rail

By rail		Total distance (km)	Total time (day)	Price (USD per TEU per km)	Setup cost (USD per TEU)
Shanghai	Antwerp	9,624	13.19	0.5	220
	Rotterdam	10,406	14.01		
	Hamburg	9,912	13.49		
Shenzhen	Antwerp	10,471	14.07		
	Rotterdam	11,501	15.14		
	Hamburg	10,461	14.06		

Table 6 Shipping distance, time, and price by sea

By sea		Total distance (km)	Total time (day)	Price (per TEU per km)	Setup cost (per TEU)
Shanghai	Antwerp	19,363	33.03	0.05	500
	Rotterdam	19,370	33.04		
	Hamburg	19,836	33.79		
Shenzhen	Antwerp	18,049	30.92	0.06	
	Rotterdam	18,056	30.94		
	Hamburg	18,522	31.68		

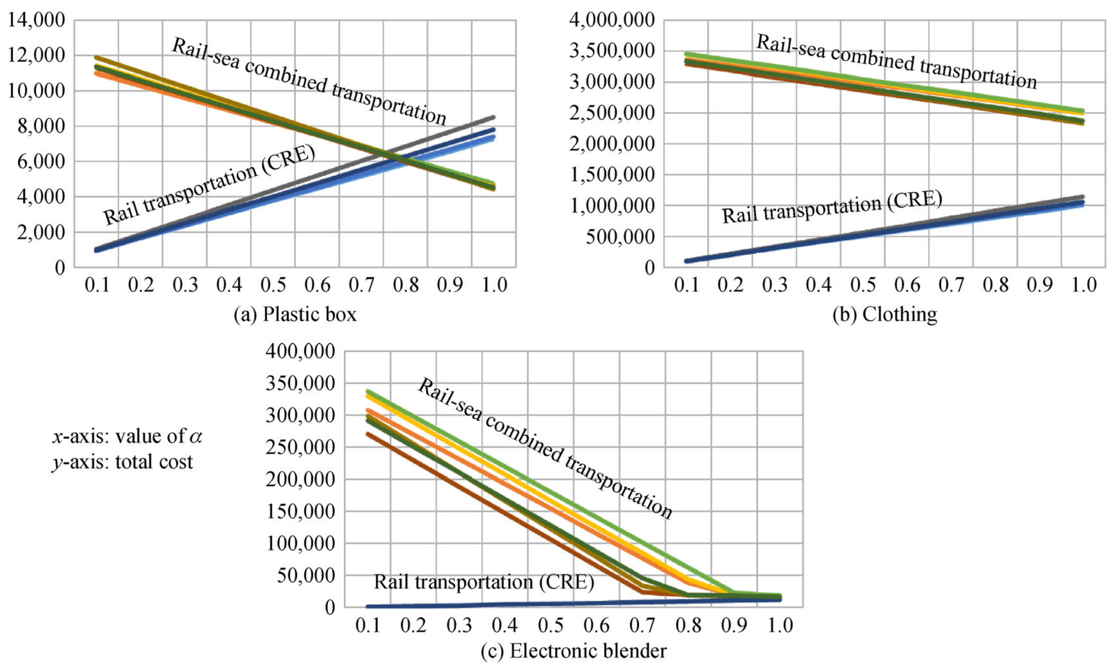

Fig. 3 α-cost plots for three cargoes

Table 7 Total transportation cost reduction of RSCT by reducing the sea shipping time

Reducing sea shipping time (day)	Plastic box (Non-time-sensitive cargo)			Clothing (High-time-sensitive cargo)		
	Antwerp	Rotterdam	Hamburg	Antwerp	Rotterdam	Hamburg
2	2.47%	2.04%	2.43%	5.25%	5.20%	5.14%
4	4.94%	4.80%	4.85%	10.51%	10.39%	10.28%
6	7.41%	7.20%	7.28%	15.76%	15.59%	15.42%

Table 8 Sensitivity of α by reducing sea shipping time

Reducing sea shipping time (day)	Plastic box (Non-time-sensitive cargo)		Clothing (High-time-sensitive cargo)
	Range of α_0	Average difference	
2	0.78–0.84	− 1.6%	α_0 is larger than 1. Thus, CRE is still preferred
4	0.76–0.82	− 3.2%	
6	0.75–0.81	− 5.1%	

of α_0 by reducing the sea shipping time. The results showed that if time (cost) by sea transportation is reduced by 2, 4 and 6 days, the α_0 value of plastic box will decrease. This condition indicated that the cost indifference area moved toward the destination area, and RSCT will have a high attraction to the industries located in the south of China. Although the cost of shipping clothing with RSCT is greatly reduced, α_0 remains larger than 1, indicating that the suitable way for shipping clothing to the market is to use CRE.

4 An extension case study

Considering the movement of manufacturing industry to South-east Asia, the supply area may be relocated to regions along the sea route as shown in Fig. 4. An alternative shipping route is introduced with CRE operation: instead of passing through Malacca, cargoes will be shipped to the coastal region of China, get onboard the CRE, and then move to Europe on the ground. For example, sailing from Bangkok (Thailand) to Xiamen

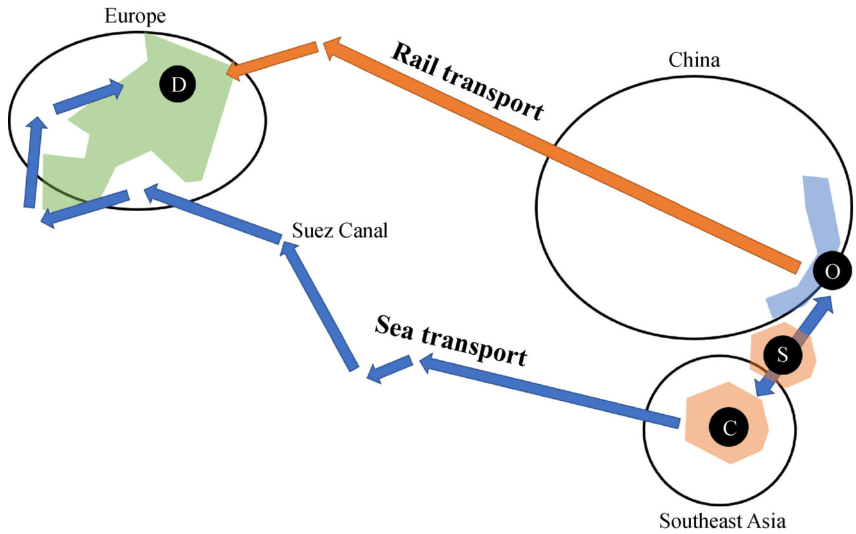

Fig. 4 Illustration of two alternative transportation modes

(China) takes around 3 days, and then CRE will take control, which requires around 12 days to reach Moscow (Russia). For consistency, we named this new transportation mode as sea-rail combined transportation (SRCT), and it will be compared with sea transportation (ST). Under this context, we need to redefine the following formulations:

$$\alpha = \frac{d^s_{SD}}{d_s}, \tag{14}$$

where d^s_{SD} is the sea distance from S to D.

For freight cost of ST, cargoes move directly from S to D by sea. Thus, freight cost can be expressed as

$$CF_{ST} = \alpha \times p_s \times d_s. \tag{15}$$

For freight cost of SRCT, cargoes are moved from S to O by sea, and then from O to D by rail. Thus, freight cost can be expressed as

$$CF_{RSCT} = p_r \times d_r + p_s \times d_s \times (1-\alpha). \tag{16}$$

For time costs of ST and SRCT:

$$CT_{ST} = \beta(\alpha \times T_s), \tag{17}$$

$$CT_{SRCT} = \beta\Big(T_r + (1-\alpha) \times T_s\Big). \tag{18}$$

For ST and SRCT setup:

$$CS_{ST} = 280, \tag{19}$$

$$CS_{SRCT} = CS_{ST} + 220. \tag{20}$$

Similar experiments are conducted based on the above formulations. Figure 5(a) shows that the plastic box constantly has a lower cost using ST than SRCT, which indicates that ST is constantly preferred regardless of where the plastic box is produced along the sea route. For high-time-sensitive cargo, such as clothing, as shown in Fig. 5(b), when α is less than 0.70, ST should be used, whereas if α is greater than 0.74, consolidating in Shanghai and then shipping by rail (SRCT) is much economical. In this situation, the region where α is between 0.70 and 0.74 is the cost indifference area. For partial-time-sensitive cargo, such as electronic blender, ST mode is inexpensive when α is less than 0.83, and SRCT is inexpensive if α is more than 0.91. In addition, the cost indifference area of this product is larger than clothing. This condition indicated that the company producing partial-time-sensitive cargo has considerable options on selecting its facility locations.

Table 9 shows the sensitivity of α by reducing the sea shipping time. The results showed that the cost indifference area moved toward the O area, which indicated that many areas in South-East Asia would prefer to use sea transport for clothing industry because the ground transport cost of CRE remains very high.

5 Conclusions

With the movement of manufacturing industry toward inland China and South-East Asia, CRE provided two new transportation modes in the traditional shipping industry from Asia to Europe: rail and sea-rail combined transportations. A time-distance based cost function was proposed to compare with traditional modes, such as sea transportation and rail-sea combined transportation. Time cost was related to different cargoes considering that they have different sensitivities to time. Based on the proposed cost function, we identified the cost indifference area where the total costs are equal. Then, transportation mode and supply

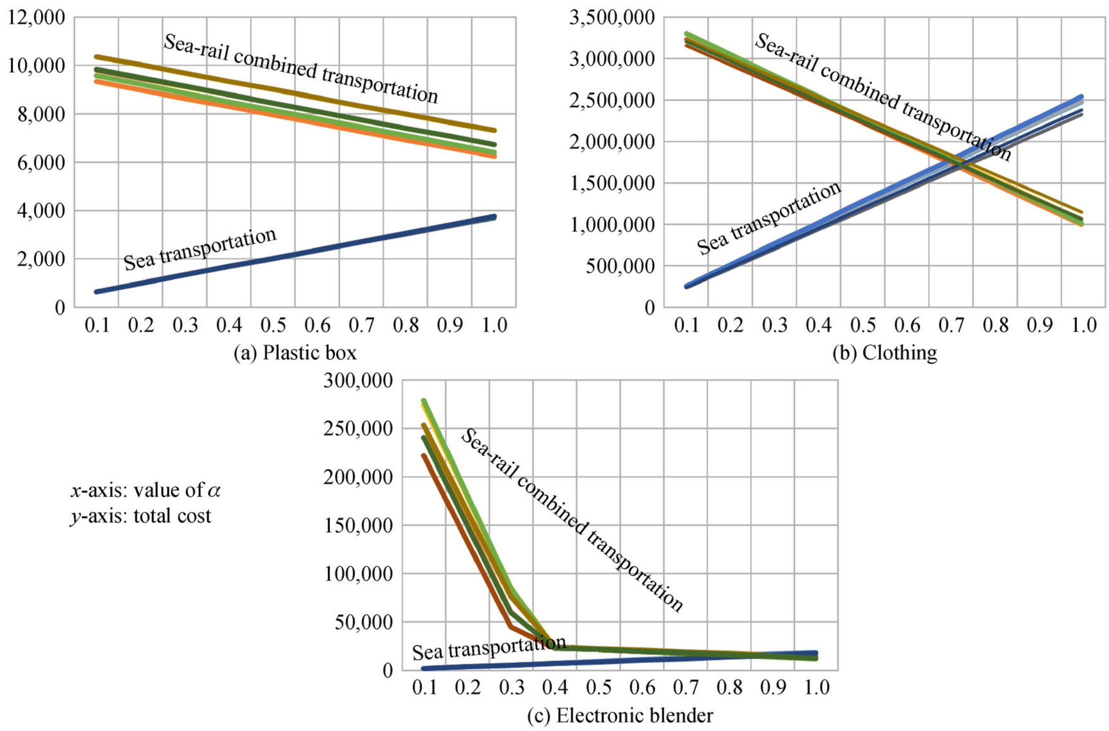

Fig. 5 α-cost plots for three cargoes in ST and SRCT

Table 9 Sensitivity of α by reducing the sea shipping time

Reducing sea shipping time (day)	Plastic box (Non-time-sensitive cargo)	Clothing (High-time-sensitive cargo)	
		Range of α_0	Average difference
2		0.71–0.76	1.8%
4	α_0 is larger than 1. Thus, sea transport is still preferred	0.72–0.79	3.9%
6		0.73–0.80	5.8%

area selection for specific cargo was analyzed. This study can provide many valuable insights to various parties. For example, a business owner can roughly determine where he should locate or select its supply area, the government can set corresponding strategies to attract new businesses, and shipping industries can improve their operation to attract many customers by selecting their shipping mode.

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Appendix: List of abbreviations and notations

ASEAN	Association of South-east Asian Nations
C	Cost indifference area
CRE	Chinese Railway Express
D	Destination area of the sea and rail transport
FDI	Foreign direct investment
O	Origin area of the sea and rail transport
RSCT	Rail-sea combined transportation
RT	Rail transportation
S	Supply area for a specific cargo
SRCT	Sea-rail combined transportation
ST	Sea transportation
TEU	Twenty-foot equivalent unit
C_m	Total transportation cost of shipping mode $m \in \{RT, RSCT, ST, SRCT\}$
T_m	Total transportation time of shipping mode m
CF_m	Freight cost
CT_m	Time cost
CS_m	Setup cost
d_r,d_s	Rail/sea distance between O and D
d^r_{SD},d^s_{SD}	Rail/sea distance from S to D
p_r,p_s	Unit freight cost by rail/sea (USD per TEU per km)
ρ_1,ρ_2,ρ_3	Time cost factors, including the cost of service, transit inventory risk, and obsolescence
cp	Value of cargo (USD)

References

Cai W (2015). Multimodal Transport Path Optimization on Silk Road of Land and Sea. Dissertation for the Master degree. Dalian: Dalian Maritime University

Drewry Research (2016). Container Forecaster & Annual Review 2016/17. London

Gao Y (2016). Economical Route in Transportation Network of the Belt and Road. Dissertation for the Master Degree. Beijing: Beijing Jiaotong University

Lee L H, Chew E P, Lee L S (2006). Multicommodity network flow model for Asia's container ports. Maritime Policy & Management, 33 (4): 387–402

Li J (2016). Study on countermeasures of optimizing China-Europe block trains under "the Belt and Road" strategy. Railway Transport and Economy, (5): 41–45

Miao Q (2014). Measuring the Value of Time in Highway Freight Transportation. Dissertation for the Doctoral Degree. Texas: Texas A&M University

Verny J, Grigentin C (2009). Container shipping on the northern sea route. International Journal of Production Economics, 122(1): 107–117

Wang Y (2015). Status, problems and suggestions on development of Sino-Europe block trains. China Transportation Review (S1), 70–75, 89

Wang Z (2014). Resrarch on corridor development strategy of "The Silk Road Economic Belt" railway. Journal of Railway Engineering Society, 184(1): 24–31

Yang L, Zheng B, Zhang Y (2015). Study on cargo transport time cost. Value Engineering, (22): 189–190

Yang X, Liu L (2015). China-Europe sea-land express passages and the balkans as the pivot of the Belt-and-Road transportation network. Contemporary International Relations, 28–46