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Multimodal Transportation: The Case of Laptop from Chongqing in China to Rotterdam in Europe

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ABSTRACT

Multimodal transportation is a key component of modern logistics systems, especially for long-distance transnational transportation. This paper explores the various alternative routes for laptop exports from Chongqing, China to Rotterdam, the Netherlands. It selects seven available routes for laptop transportation from Chongqing to Rotterdam. The multimodal model was adopted to demonstrate alternative routes using various factors such as transport cost, transfer cost, transit time, transport distance, document charge, port congestion surcharge, customs charge, confidence index and so on. Among possible alternative routes, the results indicate that the route 6 was the fastest routes except for the air transport (route 7), while the route 1 was the cheapest and safest way. Nonetheless, route 1 may be not suitable for the laptop transport due to the importance of timeliness. The logisticians may able to utilize this research's findings to make a balance between transit time and transport cost for effective multimodal transport of laptops from Chongqing to Rotterdam.

1. Introduction

Transportation costs are considered as one of the largest expenses related to logistics activity. The selection of route and transport modes can directly affect transport cost and transit time. In particular, multimodal transport route selection is salient in international trade to minimize cost, risk and provide on-time service (Beresford et al., 2011). The effective multimodal transport activities probably facilitate the global trade and global supply chains.

As a factory of the world and the fastest growing country, China has been attempted to enhance its multimodal transport system for supporting efficient exporting and importing based on 'One Belt, One Road' (OBOR) policy. Especially, the city of Chongqing in China, as a rising manufacturing cluster, is trying to enhance its transport system to handle massive exporting cargo throughput. From the geographical aspect, Chongqing is one of the most important omnibus traffic hub region in China which is a trade-link between China and Europe. It brings together the Yangtze river transportation, international aviation, road transportation and railway transportation, where it is bordered by Shanxi province to the North, Guizhou province to the South, Sichuan province to the Northwest, and Hubei province and Hunan province to the East. Accordingly, it is clear that both manufacturing level and geographical advantage have laid

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the foundation for Chongqing's multimodal transport development. Due to this, IT industry is one of main pillar industries of Chongqing. Statistical data from the Chongqing Foreign Trade & Economic Relations Commission for 2014 showed that laptop production in Chongqing had reached 61,000,000 units (CPCNEWS, 2015). Approximately 11,730 40'HQ (High-Cube container) containers or 3,000 railway carriages are required to export half this production volume to foreign countries assuming a laptop weight of 5 kg. Assuming an average transport price of USD 0.56/40'HQ/km based on China's national railway price regulations, annual transportation expenses are in the hundreds of thousands of USD, an enormous amount.

For the traditional export transportation approach to Europe like 'Chongqing-Yangtze waterway-Shanghai-(sea)-Rotterdam', Southwest cities like Chongqing obviously has no advantage on location, time and distance. However, as the recent development of Chongqing's railway system, airline and the proposal of the OBOR policy, the whole game has been changed. More and more international IT enterprises such as NVidia Corporation, HP, Quanta, Acer and Foxconn etc. were already moved in and put into production in Chongqing. As a biggest laptop manufacturing base in Asia, there are around 20 million laptops transported to foreign countries annually. The company A (interviewed laptop manufacturer in Chongqing) sends 4 million laptops to Europe annually, and their frequency of shipment is every week, while the average volume of shipment is about 75,000 laptops (e.g. equivalent to approximately 144/40'HQ) by using various ways such as rail, air and maritime transport. Due to the fluctuating demand, their shipment volume tends to be not constant. In nowadays transport activities for the laptop are delicate due to characteristics such as high value. The laptops can be damaged and depreciated easily. Therefore, the requirements of laptop transport to transport are not easy, as they need to maintain the quality, transit time and appropriate transport capacity compared to other simple products.

Therefore, this paper aims to explore laptop exports from Chongqing as a research case by adopting a multimodal transportation cost-model to clarify the value of each available route and transport mode (Beresford et al., 2011; Banomyong and Beresford, 2001; Beresford, 1999). This model is flexible enough to be applied to any operational condition and any multimodal transport distance (Banomyong and Beresford, 2001). Using this method, logisticians can lower intermodal transport costs and improve logistical operation efficiencies. From the shippers' perspective, the findings of this paper may lead to higher transportation quality, shorter transportation time, lower transportation costs, and optimised transportation routes by adopting a multimodal transportation mode that effectively reduces logistics costs and improves service quality. Section 2 reviews China's multimodal transport development. Section 3 explains the methodology, and section 4 reports the findings. Section 5 provides the conclusion.

2. Concept of Multimodal Transport and China's Multimodal Transport Development

2.1. *Multimodal Transportation*

The European Conference of Ministers of Transport (1997) defines multimodal transportation as the shipment of cargo in which two or various transportation modes linked end to end, through billing and liability, and combines normally used transportation such as air, barge, rail, truck, and ocean lines. Intermodal freight transportation seems like complicated cargo movement. However, as logistics operations techniques are developing, the tendency has been to ease the operating procedure. In particular, an entire intermodal transportation process requires just one signed document, and insurance can be purchased. Charges are incurred for a single consignment. In other words, for consignors, fragmented transport has already been transferred to an integrated transformational process. Besides, standardization of multimodal transport is mainly reflected in the use of International Standardization Organization (ISO) containers or tanks as transport units to achieve seamless connections during the re-handling process. From the cost aspect, a rational intermodal path can also reduce unnecessary delivery costs at container freight stations or inland container depots, thus lowering total logistics costs.

Regarding multimodal transport, Beresford et al. (2011) examined the multimodal transport options for iron ore from Northwest Australia to Northeast China as a case study, identifying the multimodal option for heavy bulk cargo shipments. Banomyong and Beresford (2001) investigated the alternative multimodal transport routes for garment exports from Laos to Netherland. Notably, they incorporated a confidence index for each route, transport modes and nodal links. Beresford (1999) explored the multimodal freight cost from the UK to Greece with the case of Scotch whisky. Despite the various previous studies' existence, none of the extant research has examined the case of multimodal transport for the laptop which motivates the current study.

2.2. *Current Situation of China's International Intermodal Transport Development*

In 1970, China introduced the concept of international container transportation and logistics, which remained until the enactment of international container multimodal transport management regulations in 1997. China entered a relatively backwards all-around development stage of intermodal transportation. However, during the past four decades, China's international intermodal transportation has made a series of achievements, especially in improving the infrastructure and internationalising standardised construction. China's intermodal transportation industry continues to be in the development stage and has the following characteristics.

Rapid expansion of industry scale

China's intermodal transportation is rapidly growing, and the country has two main seaports. The first is the largest, the port of Shanghai. Its intermodal transportation mode is mainly combined transportation on inland waterways (Yangtze River) and the ocean. Moreover, the opening of the five-set scheduled train gives Shanghai more options for transporting cargo to and from other cities, such as Chongqing, Ningbo, and Hefei. By 2006, China's total throughput was 310,000,000 TEU, with its combined river–sea intermodal transportation accounting for 10% or 30,00,000 TEU, and its combined rail–sea intermodal transportation accounting for 5%, or approximately 130,000 TEU (AAPA, 2010). Secondly, the port of Shenzhen was established in the same year, and the city became a special economic zone of China given its development during the last two decades. Currently, nine port districts exist, including Shekou, Chiwan, Marwan, Yantian, Dongjiaotou, Fuyong, Xiadong, and Shayuyong. The ports of Yantian, Chiwan, and Shekou represent three specialised container terminals. By 2007, the total container handling capability reached 18,470,200 TEU, with year-on-year growth of more than 14%. Similarly, the port of Shenzhen opened several five-set scheduled trains (rail–ocean intermodal transport) to other cities, including the Yushen rail–ocean joint transport channel. This line was run in 2010 from Chongqing's railway central station for container transport to Yantian port. Indeed, the Yushen line is a low-cost, highly efficient export channel and promotes the internationalisation and standardisation of China's container transportation, achieving seamless connections and rapid development of rail–ocean intermodal transportation.

Road–ocean intermodal transportation as a main transportation method in China

The intermodal transportation modes can be divided into road–rail and land–ocean intermodal transportation. However, China suffered from lower railway network coverage and train service shortages. For most developed countries, such as the United States and Germany, the ocean–rail mode normally takes 20–40% of total port container throughput. In contrast, in China, ocean–rail accounts for only 1.5%, indicating that the rail–ocean approach has not fully unleashed its potential. Thus, road–ocean is still the main transportation method in China.

Land bridge transport as a new initiative in China

The current construction of the land bridge was born in 2013 under the One Belt One Road strategy (the Silk Road Economic Belt and the 21st Century Maritime Silk Road) of the Chinese government. This project aims to link China with Asia, Europe, and Africa using five different transportation channels. Land carriage channels include (1) starting from China, going through Central Asia and Russia to countries in Europe; (2) starting from China, going through Central and West Asia to the Middle East and the Mediterranean; and (3) starting from China, going to Southeast Asia, South Asia, and the Indian Ocean. Through the first channel, China has worked with other countries to establish the new Eurasian Continental Bridge (NECB), also known as the Second Eurasian Continental Bridge after SLB (NDRC, 2015). Recently, China relied on the NECB to open the international Yuxinou (YXO) rail line, which starts from Chongqing in China via the Yulan and Yuan railways and exits through the Sinkiang Alataw Pass to Kazakhstan, Russia, the Republic of Belarus, Poland, Duisburg, and finally the port of Rotterdam. Because this route involves multiple countries and has a short transportation distance, it provides an excellent opportunity for China to develop its export trade and domestic economy and to internationalise the logistics framework in its southwest regions (Bochra, 2015).

Improvements to the transport infrastructure

Currently, the transport infrastructure and the logistics facilities' standards need to be improved. Since the beginning of the opening-up policy, China's transport infrastructure has improved significantly to reach international levels. For instance, the establishment of the Three Vertical and Four Horizontal railway network system and the Five Longitudes and Seven Latitudes national main trunk express line both help China break through the domestic intermodal transportation bottlenecks. Additionally, the traditional 1-ton/5-ton/10-ton containers were displaced by 20'GP (general purpose)/40'GP/40'HQ (high cube) containers. Furthermore, new transfer and information technics have been applied to the international transport of containers (e.g., double stack-trains and electronic customs clearance).

3. Methodology

3.1. *Multimodal Transport Cost-Model*

An intermodal freight transport system combines multiple transport modes that are linked end to end. Given more frequent increases in international trade volume and applications of intermodal transport (Min, 1991), many multimodal choices have been developed. Some studies show that the transport mode choice or a combination of transport modes directly affects the efficiency of a multimodal transport system. If one of the segments is inefficient, the intermodal transport system's overall performance is affected (Liberatore and Miller, 1995). In other words, choosing the most effective transport mode or a combination of transport modes assists transport decision makers in minimising costs and risks and improving customer satisfaction (Banomyong and Beresford, 2001; Beresford et al., 2011; Beresford, 1999).

The cost multimodal transport model was developed by Beresford and Dubey (1990) and improved by Beresford (1999). The model includes both transport (road, rail, inland waterway, and sea) and intermodal transfer (e.g., port handling, inland clearance depots) as cost components (Banomyong, 2001). The model also includes factors, such as distance and transit time, to explore similarities and differences between alternatives routings.

According to recent average prices of different transport modes in the logistics industry, the model assumes that the unit costs of transport vary by transport modes. Sea transport is set as the cheapest mode, road as expensive per tonne-km, and inland waterway and rail costs as intermediate (Banomyong, 2001). This model uses curve steepness to reflect the cost changes of each mode, the slopes indicate transport cost per distance, and vertical surges show the cost steps of multimodal transfer (Beresford et al., 2011). The cost of the different combination of modes may vary depending on the chosen route. Therefore, the model provides an intuitive and accessible graphical comparison between routings and finds the best cost-wise and time-wise route using costs, transit time, and distance. Also, the model and other similar methods have been tested by many eminent scholars (Banomyong, 2001; Beresford et al., 2011; Beresford and Dubey, 1990; Beresford, 1999) and were adopted as the UN's standard approach (United Nations, 2003; UNESCAP, 2006).

The model can be divided into four developmental stages: a basic comparison between two transport modes, two intermediate stages, and its final form including various modes and nodes.

3.2. *Risk and Consignor Satisfaction Analysis: The Confidence Index*

The efficiency of an intermodal transport mode is based on multiple factors that are directly related to transportation costs, transit time, and distance. Some factors such as the nature of the freight, cargo value density, risk of damage and pilferage, security, ease of freight, packing requirements, are not included in the multimodal transport cost-model. The main goal of intermodal transport activities is to provide consignors with convenience, rapidity, safety, and economic efficiency in international transport. Highly efficient choices of intermodal transport combinations can lead to high consignor satisfaction. The risks are the uncertainty caused by a lack of predictability during the overall planning stage and the uncertainty of the outcomes or consequences given the previous decision (Hertz and Thomas, 1983). Banomyoung (2001) highlighted most of the decision-makers responsibilities and the decisions made. Banomyoung and Beresford (2001) indicated four elements of the intermodal transport risk associated with the consignor's satisfaction related to laptop exports from Chongqing to Europe, as follows:

The decision-maker

Decisions made by the decision-maker can directly affect transport outcome quality. In this case, the shippers, freight forwarders, and logistics providers in Chongqing, Shanghai, and Shenzhen are the decision makers.

Routing selection

This task is critical when a decision maker makes a decision regarding intermodal transport. Except for route selection, the transport mode selected can determine the quality of the result. For laptop exports, the main transport modes are rail, road, inland waterways, and air. Because each mode has technological and economic limitations, the decision maker should fully consider each segment's transport mode on the basis of each segment's traffic conditions, a laptop's transporting characteristics, and the consignor's requirements.

Transport quality (unpredictable event) and convenience

A "fully covered" transport plan does not imply the absolute security of goods during carriage. Certain events may cause a loss of goods, such as weather, fire, piracy, and others, making it necessary to estimate the probability of a harmful event's occurrence. However, most logistics enterprises lack a standardized evaluation system and have only insurance to cover losses caused by uncertainty events. For this problem, a confidence index is used to quantify the uncertainty for each transport mode, intermodal transfer, and other nodal activities based on a scale from one to five that reflects realistic circumstances: (1) almost no confidence; (2) not very confident; (3) fairly confident; (4) confident; and (5) very confident. In addition to a risk evaluation, other characteristics such as transport convenience can be quantified as similar indexes.

Consequences

The previous discussion indicates that the selection and the uncertainties of the intermodal transport corridor affect the outcomes. Further, quantification of both transport quality and convenience, combined with the basic intermodal transport cost-model, reveals the most competitive multimodal transport route after a comprehensive comparison.

3.3. *Explanation of Index Quantification and Data Sources*

The data presented in this paper are mostly real. The data collection approach includes field interviews and receiving real data such as a bill of lading, airway bill and cargo arrival notice from employees of Chinese laptop manufacturer, third logistics service providers, freight forwarders, air freight forwarder, port terminal operators, railway companies, inland transport companies, and shipping companies.

A total of 21 interviews were conducted at 12 companies with senior and middle managers based on on-site interviews between April and September 2016. The companies were chosen using purposive sampling. The purposive sampling provides researchers with a level of control rather than being at the mercy of any selection bias inherent in pre-existing groups (Mays and Pope, 1995). A summary of the 12 companies can be found in Table 1.Various data such as a bill of lading, airway bill and cargo arrival notice were obtained from above companies to estimate the transport cost and transport duration objectively. For the road, rail, inland waterway, and sea transportation mode, part of the data, such as transit time and cost, are obtained from freight forwarders and the YXO railway company. Transport distances are from journals and newspapers, and measurements are from Google Maps.

Further, this study uses the expert grading method during the data collection process to quantify the confidence index. All confidence indexes are the mean values of export grading of cargo integrity, transport security, ease of customs clearance, and ease of information exchange. All these constructs were derived from existing studies (See Banomyong et al., 2001). Each confidence index was reported from relevant companies (e.g. Route 1's confidence index was reported from companies B, D, F and J as shown in the bottom of Table 3, so refer to each table's source). However, as some data are related to the confidentiality of the logistics companies, some parts of the routes lack all transfer process costs and times.

Moreover, based on different transport modes, differences exist in container type selection between each mode. Currently, containers used in container transportation in China can be divided into three types for different proposes, such as 20'GP (General Purpose) (5.69M x 2.13M x 2.18M; Quantity Limit 21.5 Tons), 40'GP (11.8M x 2.13M x 2.18M; Quantity Limit 25.5 Tons), and 40'HQ (High Cube) (11.8M x 2.13M x 2.72M; Quantity Limit 26 Tons). The 40'GP is the most commonly used container type in China. Further, for traditional 20'GP and 40'GP containers, typically, the 20'GP is suitable for light cargo and the 40'GP is suitable for heavy cargo. However, the popularisation of container transport is resulting in an increasing number of consignors selecting containers to transport cargo. To fulfil such a demand, shipping companies designed the 40'HQ container, which is specialised for light cargo (e.g., such as laptop and textile) exports to Europe. A shipping company in Chongqing noted that 40'GP containers are not used for inland waterway transport on the Yangtze River; instead, the 40'HQ is used for waterway–sea intermodal transport from Chongqing to Rotterdam, which is inconvenient for a cost comparison between each path because of the different container types were chosen. To compare such incompatible cost information, this paper makes all of the cost units' uniform by assuming that both 40'GP and 40'HQ containers can hold 22 tons of laptops (including the outer packing).

Table 1
Profile of the interview respondents

Firm	Type	Managers interviewed
A	Laptop manufacturer	General manager; administration manager
B	Shipping company	Operation manager; regional manager
C	Air freight forwarder	Managing director
D	Barge company	Logistics manager; operations manager
E	Rail company	Managing director
F	Freight forwarder	Managing director; vice president
G	Freight forwarder	Vice president; administration manager
H	3PL service provider	Operations manager; warehouse manager
I	3PL service provider	Assistant manager; IT manager
J	Port operator in Shanghai port	Regional manager; general manager
K	Port operator in Shenzhen port	Operations manager; quality manager
L	Inland transport provider	Sales manager

Source: Authors

4. Multimodal Laptop Transport–China to Europe

4.1 *Overview of Laptop Export Routes from Chongqing to Europe*

For laptop exports, various alternative routes exist. However, from the carrier's side, selecting the routings from the choices is one of the most important tasks. Additionally, given the particularity of the laptop product and fierce market competition, the consignor's requirements for intermodal transport incorporate not only a lower transport cost but also a higher security level and shorter transit time. As such, this paper compares the seven most representative intermodal transport routes for laptop transport from Chongqing to Rotterdam (see Table 2). The routes were selected for the railway, inland waterway, road, and sea transport modes.

Table 2
Laptop routing alternatives, Chongqing, China–Rotterdam

Routes	Intermodal Transportation Path
1	Chongqing–Inland waterway (Through Yangtze River)–Shanghai Port–sea–Rotterdam Port
2	Chongqing–road–Shanghai Port–sea–Rotterdam Port
3	Chongqing–railway–Shanghai Port–sea–Rotterdam Port
4	Chongqing–road–Yantian Port (Shenzhen)–sea–Rotterdam Port
5	Chongqing–railway–Yantian Port (Shenzhen)–sea–Rotterdam Port
6	Chongqing–railway–Urumqi–railway–Duisburg (Germany)–railway–Rotterdam Port
7	Chongqing-Air-The Rotterdam

Source: Authors

Fig. 1. Map of routing alternatives for laptop exports from Chongqing to Rotterdam

Source: Authors

4.2 Routing through Shanghai (Inland Waterway–Maritime Transport) (Route 1)

It is well known that the economic centres in China are in the Yangtze River Delta and Pearl River Delta. However, because Chongqing is in the southwest region of China, its economic development lags. Before the implementation of the Western Region Development in China project, the main domestic trade transport mode was inland waterways through the Yangtze River to the port of Shanghai and back. Therefore, Route 1 has been chosen because it represents the traditional route for Chongqing's domestic and export transports. Recently, the Three Gorges Project II Stage construction and the first stage of the Jiulong and Cuntan Ports were completed, which propelled the development of the upper reaches of the Yangtze River's container transportation. Through this route, ships depart from Chongqing, go through Yichang and Wuhan, and finally arrive at the Port of Shanghai. The efficiency of the container terminal normally depends on two factors. The first factor includes port operation time, the cargo clearance process, and handling time for documents. Applying to customs takes 15 minutes per shipment at Chongqing Port, which is in a leading level of the upper reaches of the Yangtze River region. Customs inspections include opening the box, which takes half a working day. During the loading process, the average handling time for the express liner is six hours at Cuntan Port and eight hours at Jiulong Port, and the handling time for a regular liner are 12 and 16 hours, respectively. This information indicates that the express liner has double the handling efficiency of the regular liner. Secondly, this study searched for actual transit times from Chongqing to Shanghai. For different shipping companies, the total transit time for a regular liner is typically fifteen days. The five-set scheduled express liner (settled Port, Routes, Sail Schedule, Transit Time, and Ship) in 2007 reduced the total transit time to five days. Total costs are comprised of transit fees and other document charges. Transit fees can be divided into transportation costs and port transfer costs, such as container handling charges and container storage charges. Unfortunately, given the early development stage and for other political reasons, these two costs are relatively higher than those for other ports through the route, such as the ports of Shanghai, Wuhan, and Yichang, among others. Once the containers are unloaded, they are loaded on the maritime vessel after the laptops are transported to the Port of Shanghai and the second stage of the journey from Shanghai to Rotterdam is ready to begin. It is worth mentioning that most Shanghai ports are equipped with H986 container inspection systems, which do not require sealed containers to be opened during the inspection process, resulting in higher efficiency than the Port of Chongqing. The confidence index of this route is a fairly low 1.9, primarily because of unpredictable risk during the inland waterway transport and the low efficiency of Chongqing Port. In summary, given the distance between Chongqing and Shanghai, and the lower efficiency of the inland waterway transport through the Yangtze River, this route has the longest transit time of all routes (47/48 days) but with a relatively lower cost (USD2,354.10/40'HQ). Fig. 2 shows the movement graphically.

Table 3
Chongqing–(inland waterway)–Shanghai–(sea)–Rotterdam

Day	Leg	Mode	Transit Time	Distance (km)	Cost (USD)	Confidence Index
1	Chongqing–Shanghai	Inland waterway	15 days	2,529	359/40'HQ	
	Port Construction				7.18/40'HQ	
	Document Transfer				4.4/40'HQ	
16	Shanghai Port		8 days	0		
	1. Document Charge (DOC)				67.2/Shipment	
	2. Port Congestion Surcharge (PCS)				4.4/40'HQ	
	3. Terminal Handling Charges (THC)				180.9/40'HQ	
	4. Container Loading Charge				224.2/40'HQ	
	5. Seal Charge				6.73/ Container	
	6: Equipment Management Fee				1.49/ Container	
	7. Port Construction				14.3/40'HQ	
	8. Customs				14.9/Shipment	
	9. B/L Charge				15	
48	Shanghai–Rotterdam	Sea	24 days	19,378.67	1,100/40'HQ	
	Other handling charges				354.4	
	Total		47/48 days	21,907.6	2354.1	1.9

Source: Authors' elaboration based on interviews with firm B, D, F and J

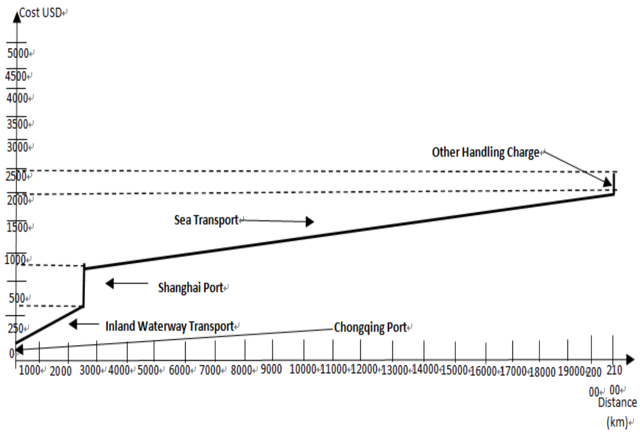

Fig. 2. Analysis of cost and distance of the route through Shanghai (inland waterway–sea intermodal transport)
Source: Authors' elaboration based on interviews with firm B, D, F and J

4.3 Routing through Shanghai (Road–Maritime Intermodal Transport) (Route 2)

Instead of using inland waterways, Route 2 uses the road from Chongqing to Shanghai. The route chosen by this paper is the G50 Yuhu Highway through the cities of Yichang, Wuhan, and Suzhou, for a total distance of 1,693 km—only 60% of the distance of the inland waterways. According to CMT (2008) and CPGPRC (1997), the total road transportation cost is constituted of transportation fees, highway tolls, and intra-urban transportation fees. The fixed transportation cost typically includes depreciation charges for the vehicle, insurance expenses, labour costs, and fuel charges, among others. Based on interviews with inland transport firms, the average road container transport price was approximately USD1.00/40'HQ/km. In fact, fixed transport costs only comprise 20–30% of total costs, and the remaining 70–80% is known as viable costs, especially the relatively higher viable cost of trunk transportation because the road maintenance and construction funds are primarily from road levy taxes. The road toll is a key reason for a high total cost. In this case, approximately 20 toll highway sections exist from Chongqing to Shanghai, accounting for a 168/40'HQ total road toll. Based on the regulation pointed out by CMT (2008), the distance between two toll stations should be no less than 50 km, even though the distance between two toll stations is only 2–3 km in some areas. Another problem caused by this issue is traffic congestion, especially during holidays, and traffic moves very slowly on the highway. Therefore, both issues delay transit time and result in high charges. However, the road toll is the only visible cost. Chongqing's road toll policy was adopted in 2004, which caused a series of problems such as irregular charge and arbitrary fines. As a result, some vehicle owners usually pay illegal "passage money" to law enforcement officers to pay less or even skip the road toll. Therefore, this route's confidence index is not very high. As shown in Fig. 3, whereas the inland road transport fee (not including other costs, such as handling charges, for Shanghai Port) comprises approximately 45% of the total cost, the distance of the road transport mode is only 8%. Therefore, this route has a relatively shorter transit time but the highest cost relative to other intermodal transport combinations.

Table 4
Chongqing–(road)–Shanghai–(sea)–Rotterdam

Day	Leg	Mode	Transit time	Distance (km)	Cost (USD)	Confidence index
1	Chongqing–Shanghai	Road	4 days	1,728	1,486/40'HQ	
	Road Toll				168/40'HQ	
5	Shanghai Port		7.5 days	0		
	1. Document Charge (DOC)				67.2/shipment	
	2. Port Congestion Surcharge (PCS)				4.4/40'HQ	
	3. Terminal Handling Charges (THC)				180.9/40'HQ	
	4. Container Loading Charge				224.2/40'HQ	
	5. Seal Charge				6.73/container	
	6: Equipment Management Fee				1.49/container	
	7. Port Construction				14.3/40'HQ	
	8. Customs				14.9/shipment	
	9. B/L charge				15	
36.5	Shanghai–Rotterdam	Sea	24 days	19,378.67	1,100/40'HQ	
	Other handling charges				354.4	
	Total		36/37 days	21,106.6	3,637.5	2

Source: Authors' elaboration based on interviews with firm B, G, J and L

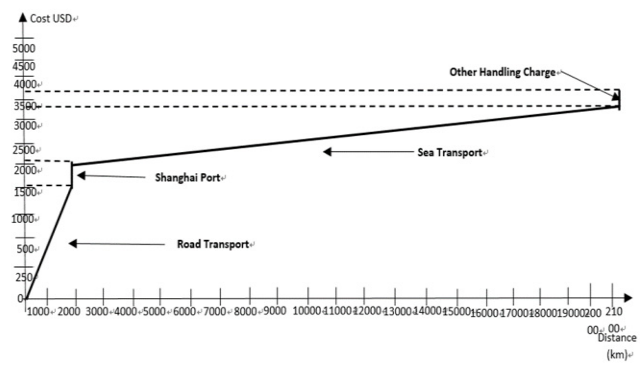

Fig. 3. Analysis of cost and distance of the route through Shanghai (road–sea intermodal transport)
Source: Authors' elaboration based on interviews with firm B, G, J and L

4.4 Routing through Shanghai (Rail–Maritime Intermodal Transport) (Route 3)

This route is through the Port of Shanghai but uses rail as the inland transportation mode. Recently, two aspects highly promote the efficiency of the rail transport mode between Chongqing and Shanghai. One is the establishment of the Yuli railway, and the other is the opening of the YuHu five-set scheduled train. The five-set scheduled train is a point-to-point express railway with an explicitly stipulated departure arrival time, transit time, and total transportation cost for the entire journey. Because only a few train terminals exist that provide non-stop service in China, the five-set railways have recently operated primarily between marshalling stations. The newly opened Yuli railway starts at Chongqing (Tuanjiecun) and goes through Fulin, Enshi, Yichang, Wuhan, Macheng, Hefei, Nanjing, and Wuxi, and finally Shanghai (Yangpu), for a total distance of approximately 1,900 km. The transit time for this approach has been shortened from six to four days. Also, for transport services provided by many freight forwarders, the route was covered by a bill of freight, indicating that processes such as customs clearances and customs transfers can be handled in Chongqing, allowing for quicker, more efficient, and more accurate transportation. However, the proposed YuHu five-set scheduled train project was to meet the demand for laptop transportation, but the train operates only once a week. Therefore, the transported cargo's variety and flexibility during transportation are both relatively low. NDRC (2015) stated that the recent price that was uniformly set by the state is USD0.56/40'HQ/km for a similar transit time for road transportation, which obviously has a greater advantage. Two main factors contribute to this advantage. First, no formal toll is charged by the government. Second, fuel is well known as one of the largest expenses for any transport mode and a train consumes 10 kg/ton/km of energy, which is only 60% of that for road transportation. Further, regarding transportation sustainability aspects, lower energy consumption means a lower CO_2 discharge. This route's confidence index is 2.5 and it provides more efficient services. The five-set scheduled train also provides a higher security level during transportation. Both these factors have contributed to improving customer satisfaction. Fig. 4 shows this movement graphically.

Table 5
Chongqing–(rail)–Shanghai–(sea)–Rotterdam

Day	Leg	Mode	Transit Time	Distance (km)	Cost (USD)	Confidence Index
1	Chongqing–Shanghai	Rail	4.5 days	1,919	1,106/40'HQ	
	Handling Charge				43.7/40'HQ	
	Other Handling Charge				14/40'HQ	
	DOC				14.9/40'HQ	
6	Shanghai Port		8 days	0		
	1. Document Charge (DOC)				67.2/BL	
	2. Terminal Handling Charges (THC)				180.9/40'HQ	
	3. Port Congestion Surcharge (PCS)				4.4/40'HQ	
	4. Container Loading Charge				224.2/40'HQ	
	5. Seal Charge				6.73/container	
	6. Equipment Management Fee				1.49/container	
	7. Port Construction				14.3/40'HQ	
	8. Customs				14.9/BL	
	9. B/L charge				15	
38	Shanghai–Rotterdam	Sea	24 days	19,378.67	1,100/40'HQ	
	Other handling charges				354.4	
	Total		37/38 days	21,297.67	3,162.1	2.5

Source: Authors' elaboration based on interviews with firm A, B, E, F and J

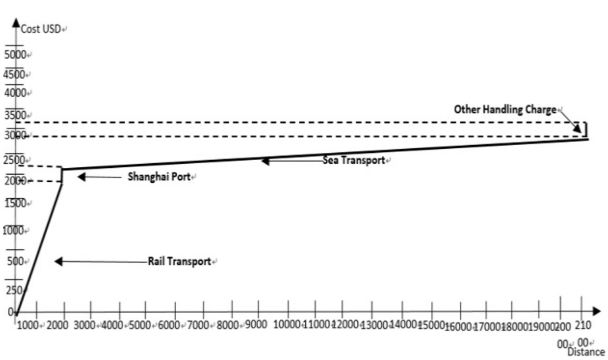

Fig. 4. Analysis of cost and distance of the route through Shanghai (rail–sea intermodal transport)
Source: Authors' elaboration based on interviews with firm A, B, E, F and J

4.5 Routing through Shenzhen (Road–Sea Intermodal Transport) (Route 4)

Similar to the city of Shanghai, Shenzhen as a coastal city is also one of the largest export cities in the southern region of China. From a geographical aspect, routing through Shenzhen is more advantageous than routing through Shanghai for transporting laptops from Chongqing to Europe. Route 4 (Table 6) is preferred by Chongqing exporters. The main reason is the shorter transport distance, at only 1,587 km between Chongqing and Shenzhen. Given this discussion, a toll is a significant expense for road transportation in China, especially because it is typically higher when entering or exiting a province. From the national map, this route connects Chongqing, Qianjiang, Huaihua, Shaoyang, Foshan, and Guangzhou, and the city of Shenzhen. Hunan is the only province passed during the entire inland transportation route, whereas others cross two or three provinces. Further, the shipping distance from Shenzhen to Rotterdam is 19,378 km, shorter than the routes through Shanghai. Therefore, both transit time and cost have been reduced. It is worth mentioning that the telex releases a surcharge in the Port of Shenzhen. Normally, the shipper sends a bill of lading (B/L) through the bank or by mail after or during the cargo shipment. The B/L represents the cargo property rights of certification. Therefore, the consignee can only pick up the goods after receiving the original B/L. However, because shipping time on this route has shortened, the possibility exists that the consignee cannot receive the bill of lading sent by the bank or by mail before the shipment arrives. To ensure receipt of the B/L, the consignee needs to ask the shipper to send the electronic bill through fax or email. Given different shipping companies' regulations, charges may vary. Normally, this value-added service costs USD30/BL, but the Port of Shenzhen costs USD50/BL, which is quite expensive. In summary, this route costs USD3,387, which is 93% of the cost on the road–sea intermodal transport through Shanghai (see Fig. 5). Although this route has many advantages, one drawback is the significant road transportation cost. Interestingly, the Chinese government has recognised this issue. Thus, under the OBOR subsidy policy, the consignor can receive a subsidy from the government to cover the road transport cost for road transportation between most prominent port cities, such as Chongqing (inland port), Xian (inland port), Shenzhen, and Shanghai, to encourage the development of China's foreign trade. This route's confidence index is 2.2 because of lower costs and shorter transit time and distance, which have improved customer satisfaction and security during transport.

Table 6
Chongqing–(road)–Shenzhen–(sea)–Rotterdam

Day	Leg	Mode	Transit Time	Distance (km)	Cost (USD)	Confidence Index
1	Chongqing–Shenzhen (Yantian)	Road	3 days	1,587	1,392/40'HQ	
	Road Toll				108.5/40'HQ	
4	Yantian Port		7.5 days	0		
	1. Document Charge (DOC)				74.7/BL	
	2. Original Receipt Charge (ORC)				283.9/40'HQ	
	3. Seal Charge				3.7/BL	
	4. Port Security Charge				4.48/ Container	
	5. Port Construction				22.4/40'HQ	
	6. Customs				14.9/BL	
	7. Telex Release Surcharge				50/BL	
34.5	Yantian Port–Rotterdam	Sea	22 days	18,064.6	1,100/40'HQ	
	Other handling charges				332.5	
	Total		34/35 days	19,651.6	3,387	2.2

Source: Authors' elaboration based on interviews with firm A, B, H, K and L

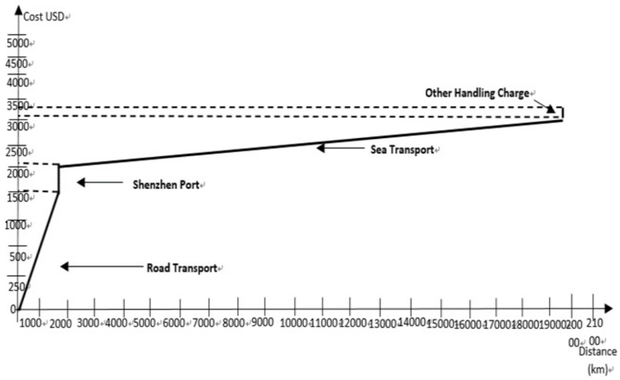

Fig. 5. Analysis of cost and distance of the route through Shenzhen (road–sea intermodal transport)

Source: Authors' elaboration based on interviews with firm A, B, H, K and L

4.6 Routing through Shenzhen (Rail–Sea Intermodal Transport) (Route 5)

Route 5 has been chosen because it is one of the most representative intermodal transport routes in Chongqing during the age of modern logistics. The route starts at Tuanjiecun marshalling station, goes through cities such as Wuhan, Changsha, Hengyang, and Guangzhou, and finally arrives the Port of Yantian, for a total transport distance of 2,002 km. As mentioned, the ports of Chongqing and Shenzhen (Yantian) engage in close cooperation. Similar to YuHu railway, in 2010, Chongqing opened a five-set scheduled train (YuShen railway) to Yantian Port, which was one year earlier than YuHu. Statistics on the Yantian (Shenzhen) international container hub show that, by the second quarter of 2014, this route had operated 770 trains for total container transport volume of 73,000 40'GP and ranked at the top in inland province transportation (WHJTCX, 2014). Unlike YuHu railway, which the government is focusing more on to establish new infrastructure, YuShen railway is an enhanced version of the original infrastructure through a strengthened transportation arrangement. The implementation can be summarised into the following four aspects. (1) Safe railway management was strengthened. According to the Ministry of Railway's requirements and regulations, the railway bureaus of Chongqing, Guangdong, and even Chengdu focused more on the technical servicing of vehicles and dynamically monitoring the safety system during transportation. (2) Organizing the daily schedule was strengthened. Every railway bureau on this route strengthened its contact with one another and focused on operation time to ensure on-time departures and avoid driver fatigue. (3) Information tracking and feedback were strengthened. The customer service centre of China Railway Container Transport Corp sends tracking information every day to COSCO Logistics through text messages at 9:30 and 16:30, allowing customers to notice the operational state of the train easily. (4) Cooperation with customs, the commodity inspection department, and ports, among others, were strengthened. Because the characteristics of container railway transportation fit with a long transport distance and large transport volume, this route has fully adopted the concept of a One Bill Process, which means that processes such as custom clearance and stuffing are conducted in the Tunjiecun marshaling station in Chongqing to allow for seamless rail–sea transfers at Yantian Port. These four aspects have contributed to improving cargo integrity, transport security, information flow, and customs clearance efficiency. This route receives the highest confidence index (3.1) among all routes. It is worth mentioning that both route expenses and transfer costs are relatively low and the intermodal transport process is easy. The transit and transfer times are also being shortened. Therefore, this route is considered one of the most competitive intermodal transport combinations (see Fig. 6).

Table 7
Chongqing–(rail)–Shenzhen–(sea)–Rotterdam

Day	Leg	Mode	Transit Time	Distance (km)	Cost (USD)	Confidence Index
1	Chongqing–Shenzhen (Yantian)	Rail	3.5 days	2,002	1,121.1/40'HQ	
	Handling Charge				43.7/40'HQ	
	Document Charge (DOC)				89.6/40'HQ	
	Customs				14.9/BL	
	Seal Charge				3.7/container	
4.5	Yantian Port		5 days	0		
	1. Original Receipt Charge (ORC)				283.9/40'HQ	
	2. Port Security Charge				4.48/container	
	3. Port Construction				22.4/40'HQ	
	4. Telex Release Surcharge				50/BL	
31.5	Yantian Port–Rotterdam	Sea	22 days	1,8064.6	1,100/40'HQ	
	Other handling charges				332.5	
	Total		31/32 days	20,066.6	3,066.2/40'HQ	3.1

Source: Authors' elaboration based on interviews with firm A, B, E, I and K

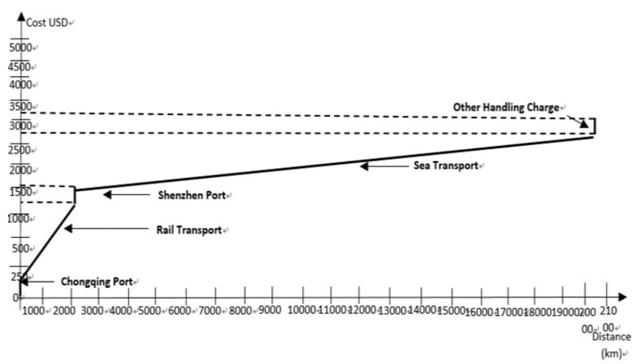

Fig. 6. Analysis of cost and distance of the route through Shenzhen (rail–sea intermodal transport)

Source: Authors' elaboration based on interviews with firm A, B, E, I and K

4.7 Routing through Yuxingou (YXO) (Land bridge transport) (Route 6)

Route 6, which opened in 2011, starts at Chongqing, goes through Urumchi (Xinjiang), Kazakhstan, Russia, the Republic of Belarus, and Poland, and finally ends in Duisburg (Germany)—and is considered the most innovative rail transport approach. As shown in Table 8, the route has advantages given its total distance of 11,179 km and only 13 days of transit time. However, during the project's early development stage, the transit process was inefficient. First, seven countries are on this route. Therefore, each time the train enters a country, it must repeat the customs declaration and inspection process, which is a waste of time and money, especially for high value-added cargo. Therefore, the route was previously unused. To solve this issue, with the support of the Chinese government, the Chongqing government and the governments of six other countries developed the One Bill agreement in 2010. Each country agreed to use a Free Pass Card after the customs clearance process in Chongqing, and allow for law enforcement cooperation and information sharing. Second, every rail company in the different countries has its running schedule. In this case, a YXO train is considered to be on only a side schedule, indicating that significant time is wasted by pulling over to let other “on schedule” trains pass. Before 2011, this route’s total transit time was typically 25 days. Therefore, Chongqing cooperated with rail companies in other countries along the route and developed the YXO five-set scheduled train, a concept similar to other existing five-set scheduled trains in China. It is well known that trains can be classified as express, fast, and slow. The re-arranged running schedule gave the train the highest priority, and the route has only 12 stops and a maximum train speed of approximately 75 mph. Finally, each country has a different transport cost. For example, in Kazakhstan, the price is USD0.60/40’GP, whereas in Russia the price is USD1.00/40’GP. Thus, prices must be coordinated. Interestingly, during coordination, the Chongqing government found that every country has the psychology of seeking sameness, implying that countries with low transport prices support those with high prices. In this case, the price in Russia, which was the highest, was reduced to USD0.55/40’GP after coordinating with it on numerous occasions. Given this price reduction, this route’s total transit cost was also reduced. Research shows that transport cost is highly related to transport volume. If the volume is high enough, significant price reduction potential exists from the rail enterprise. Compared to other modes of inland–ocean intermodal transportation, the advantage of a non-stop YXO operating model is incomparable. In particular, all of the following problems are difficult to overcome: the labour cost and inventory related to the re-handling process, the cost of time, and the uncertainty of maritime transport. After the cargo arrives at the marshalling station in Duisburg, the rest of the journey from Germany to Rotterdam passes through road or rail transportation. For reasons of confidentiality, the cost shown in Table 8 is based on the average transport price in China collected from a local company’s real data. However, as previously mentioned, Germany is one of the most important hubs in Europe, especially for cargo such as electronic products from China. Recently, however, Rotterdam, Germany has become the European distribution centre for imported laptops. The route’s confidence index is 3.5.

Table 8

Chongqing–(rail)–Urumchi–(rail)–Duisburg

Day	Leg	Mode	Transit Time	Distance (km)	Cost (USD)	Confidence Index
1	Chongqing Port		2 days	0		
	Container Loading Charge				61.5/40’H Q	
	Seal Charge				3.7/ Container	
	Customs				71.4/BL	
3	Chongqing–Urumchi	Rail	2 days	2,923		
5	Urumchi		0.5 days			
17	Urumchi–Duisburg (Germany)	Rail	11.5 days	8,256		
					Total transit cost 4,300/40’HQ	
17	Duisburg Marshalling Station					
	Charges		1 day		100/40’HQ	
18	Duisburg (Germany)–Rotterdam (Netherlands)	Road	2 hrs	200 km	180/40’HQ	
18	Duisburg(Germany)-Rotterdam (Netherland)	Rail	2.5 hrs	362 km	271.2/40’HQ	
	Total		15–18 days	11,179	4,436.6/40’ HQ	3.5

Source: Authors’ elaboration based on interviews with firm A, E, F and G

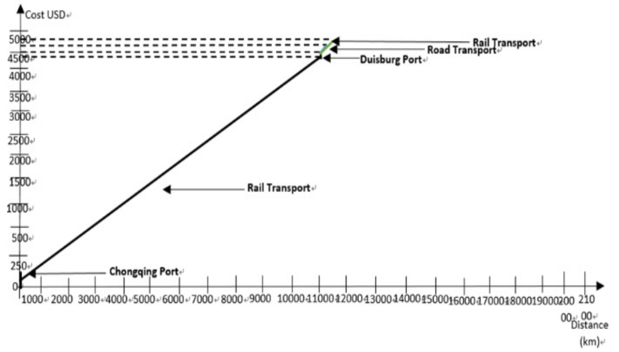

Fig. 7. Analysis of cost and distance of the route through YXO (land bridge transport)

Source: Authors’ elaboration based on interviews with firm A, E, F and G

4.8 Routing via Air (Air transport) (Route7)

Route 7 was normally adopted when the cargo value is more than USD 10 million. The confidence index of this route is 3.7, which is fairly high. As the nature of laptop transportation, carriage by air shows its advantage on both cargo integrity, transport security, information flow and transit time. Further, there are a large number of laptop factories have moved in Chongqing, with the rapid increase in air transport demand. Thus, Chongqing airport has been busy owing to laptop transport to Europe since 2010. Recently, the freight volume through air takes 30% of the total. However, air transport has a fatal defect which is the high freight rate (see Table 9). According to EIWCCQ. (2012), the laptop export volume in Chongqing has exceeded 10 million by the end of 2012. If the weight of one laptop is 4.5kg, it costs approximately USD 1.5 billion as transportation cost, adding other transfer incidentals. The total expenses can be huge. Fig. 8 shows the movement graphically.

Table 9

Chongqing–(AIR)–Rotterdam

Day	Leg	Mode	Transit Time	Distance (km)	Cost (USD)	Confidence Index
1	Chongqing Air Port		1 days	0		
	Handling Charge				15/40’HQ	
	Customs				40.5/BL	
3.5	Chongqing-Rotterdam	Rail	1.5 days	8,171	8875/40’HQ	
	Total		3-4 days	8,171	8930.5/40’HQ	3.7

Source: Authors’ elaboration based on interviews with firm A, C and H

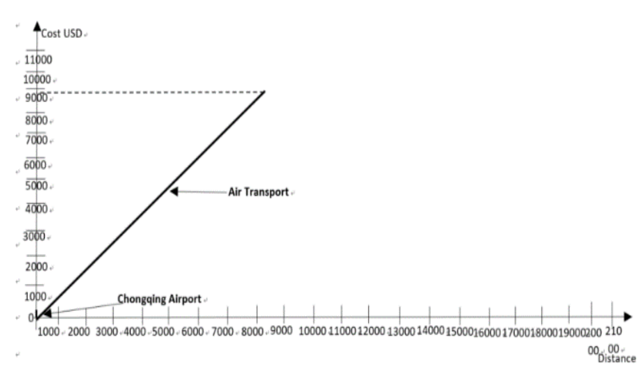

Fig. 8. Analysis of cost and distance of the route via air (Air transport)

Source: Authors’ elaboration based on interviews with firm A, C and H

5. Conclusion

This paper compares seven laptop transport routes from Chongqing, China to Rotterdam, Europe using the multimodal transport cost-model. Among possible alternative routes, a comprehensive evaluation shows that the routing through YXO (Route 6) achieves 2nd fastest route except for the air transport. The YXO railway as the epitome of the OBOR policy appears successful. However, because the Chongqing government has invested significant capital in its development, and the cost of One Bill customs clearance is also higher than the average customs charge, some logisticians raise questions about the government's claim that the YXO railway can save transit costs and improve transport efficiency.

The inland–ocean transport approaches of Chongqing's laptop exports can be summarized in five routes with three combinations: inland waterway–sea intermodal transport: (a) Chongqing–inland waterway–Shanghai–sea–Rotterdam; rail–sea intermodal transport: (a) Chongqing–rail–Shanghai–sea–Rotterdam; (b) Chongqing–rail–Shenzhen (Yantian Port)–Rotterdam; road–sea intermodal transport: (a) Chongqing–road–Shanghai–sea–Rotterdam; (b) Chongqing–road–Shenzhen (Yantian Port)–sea–Rotterdam. A factor that these routes have in common is waterway transport. It is well known that the most severe shortcoming is a long transit time. However, the laptop has the characteristic of being a quickly renewed product. Therefore, inland waterway or sea routes do not meet the significant timeliness needed for laptop transportation and the time costs are also relatively higher than that of the YXO railway. Relative to road and rail transport, Yangtze River transport has the advantages of lower investment and transport costs for inland waterway–sea intermodal transport. By combining these two modes, this route has the lowest total transport cost among all routes but also the worst transport timeliness. Therefore, this route might be not suitable for laptop transportation. Rail–sea intermodal transport has the characteristics of low transport cost and relatively low transit time. In addition, the safety level during the entire transport process is also higher than the other two modes. Nevertheless, this mode still has a re-handling process that leads to a higher time cost relative to the YXO railway's non-stop transit. Finally, the comprehensive score for the road–sea intermodal transport is between two other modes; the strongest advantage is high flexibility, which easily assists in achieving door-to-door transport. However, the transport cost of Routes 2 and 4 are the highest of other inland–sea intermodal transports, and transit time is still higher than that of the route using the YXO railway.

For the route through air, the actual transit time is only 12 hours which is the biggest advantage of air transport. However, for routine laptop transportation, especially for those cargo value between USD 2 million to 10 million per bill, the transit cost of air transport is obviously too high for consignors. Based on the above discussion, the transit time of YXO slower than the route via air, but with the price of USD 4,436/40'HQ which is only half of the cost through the air. As the optimisation of train schedule and the improvement of rail infrastructure, the comprehensive scoring of YXO is decent. Recently, based on the data public by Chongqing Finance Affairs Committee, the laptop export volume through air takes 30% of the total, 20% through Rail-Sea intermodal transport, and the transport volume via YXO already reaches 50%. Therefore, for cargoes which do not require 1-2 days transit time, by transporting laptop through YXO is obviously a better choice. To be more specific, every 10% of transport volume transferred from Air to YXO can save around USD 21 million logistics cost, which significantly lowered the comprehensive cost by transport laptop from Chongqing to Europe. This can make 'made in Chongqing' laptops have more price advantage in Europe IT market.

This study's finding can assist Chinese laptop producers to reduce production costs, which are significantly affected if transport costs are controlled. Furthermore, adopting reliable multimodal transport and developing various alternative routes may give producers more supply chain routes, enabling them to minimise disruptions when an existing route is unavailable because of unexpected natural disasters, and facilitating new trade routes. Moreover, this model might be used as part of the transport policy formulation process, as well as for OBOR policy.

To improve the accuracy of scientific evidence, future research should emphasise collecting more real data during the information collection period, such as the transport delay occurrence rate or the accident rate, among others, and minimise or avoid subjective assessments and estimations. Further, this study only discusses transport from Chongqing to Europe. However, it is well known that the return trip is one of the most important logistical factors to consider, especially for the YXO rail line. For the first four years of YXO's formal operations, it suffered from a lack of return trip cargo resources. Recently, given the rapid development of cross-border e-commerce, the cargo transport value of the return trip has begun to increase gradually. Therefore, if the Chongqing government can take full advantage of this increase, doing so might further reduce costs and even improve performance.

Table 10
Total transport costs, transit times and confidence indexes

Route	Mode	Total Transport Cost (USD)	Total Transit Time (days)	Confidence Index
(1) CQ–SH–Rotterdam	Inland water–Maritime transportation	2,354.1/40'HQ	47/48	1.9
(2) CQ–SH–Rotterdam	Road–Maritime transportation	3,637.5/40'HQ	36/37	2
(3) CQ–SH–Rotterdam	Rail–Maritime transportation	3,162.1/40'HQ	37/38	2.5
(4) CQ–SZ–Rotterdam	Road–Maritime transportation	3,387/40'HQ	34/35	2.2
(5) CQ–SZ–Rotterdam	Railway–Maritime transportation	3,066.2/40'HQ	31/32	3.1
(6) Via YXO Railway	Railway transportation	4,436.6/40'HQ	15-17	3.5
(7) Via Air	Air transportation	8,930.5/40'HQ	3/4	3.7

Source: Authors' elaboration based on the combination of Table 3-8.

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